Fiber Optics

Light switching · Light transportation· Light distribution

The Quality Connection

LEONI

Dear research and business partners, dear customers,

“To stand still is to fall behind”; this classic motto is as true as it ever was.
Driven by the ambition to understand our customers’ needs and wishes and to respond to them, we look back on an eventful year 2012.

You can find the results of these efforts in the current issue of our catalogue:
“Fiber Optics – worldwide and beyond”.

The fourth edition offers you more possibilities than ever to apply products customized to your individual requirements. With maximum influence at every stage of the product manufacturing due to our high vertical integration, we can consult and then act according to our customer’s needs.

We are happy to welcome the j-fiber group, which is now 100 % part of the Business Unit Fiber Optics, as well as the recently integrated US American Richard Losch Inc., which has gained worldwide reputation in laser cable manufacturing with its unique production technique. They now operate under our American subsidiary, LEONI Fiber Optics Inc. Therefore the current catalogue shows new entries in the areas of preforms and raw materials, an expanded range of standard and special optical fibers plus LEONI laser cables featuring the proven quality of Losch high power technology for industry and medicine. In addition, you can look forward to a widened portfolio in medical products as well as in polymer optical fibers and polymer cladded fibers (POF/PCF).

A completely revised and extended edition of the chapter on the principles of fiber optics provides you with a deepened complementary insight into the scientific context of fiber optic technology.

It would exceed the scope of this catalogue to depict every available product. As before, this is only supposed to give you a first impression of our skills. We would be pleased if you contact us for requests, so we can offer you professional consulting as a provider or development partner.

Our products operate even under the toughest environmental conditions such as harsh industrial environments or in outer space. Convince yourself of the variety of applications of fiber optic technology.

We wish you a pleasant time exploring our expanded portfolio with
“Fiber Optics – worldwide and beyond”.

Dipl. Phys. Andreas Weinert Dipl. Ing. Torsten Sefzig
Managing Directors LEONI Fiber Optics GmbH

Fiber**Connect**® Light Guide Fiber & Cable Solutions

We offer you fibers and cables in compliance with international industrial standards
(e. g. ITU-T G.651 – G.657, IEC 60793-2-10, IEC 60793-2-30, IEC 60793-2-40, IEC 60793-2-50) with optical fibers:

- made from glass (singlemode and multimode)
- with polymer cladded glass (PCF ➔ Polymer Cladded Fiber)
- with polymer core (POF ➔ Polymer Optical Fiber).

Many fiber types are also available as radiation-hard versions. We manufacture different cable designs from central core cables to breakout cables with all buffered fiber types and specific inner and outer jacketing materials as well as customized versions according to your needs. We use all fiber types to produce hybrid cables with optical fibers and electrical conductors, pneumatic lines etc. in almost any conceivable configuration. In addition we provide accessories and peripheral equipment such as splice and patch boxes, tools and measuring devices.

Fiber**Tech**® Special Optical Fiber Technologies

We produce singlemode and multimode optical fibers with different core sizes, shapes and profiles, numerical apertures, coatings and claddings as well as fiber bundles and arrays for a wavelength range from 200 nm to 4 µm. All fibers can be produced and assembled according to the customer's specific needs for industrial and medical applications, high-power laser transmission or optical metrology and sensor technology. We will be pleased to develop individual solutions for your particular application fields in collaboration with you.

Fiber**Switch**® Light Switching for Optical Systems

Our fiber optical switches are based on a patented micromechanical/micro-optical design. This guarantees excellent properties, considerable flexibility and maximum long-term stability for many applications. The switches are available for wide wavelength ranges from the ultraviolet to the infrared and for a wide variety of fiber types. Our switches are designed for applications with the highest requirements in the telecommunications area, in measurement and testing and in the biomedical area. Examples of these complex applications include spectroscopy, laser scan microscopy, multi-channel optical performance monitoring, fiber bragg sensors, testing of fiber optical cables and environmental trace analysis.

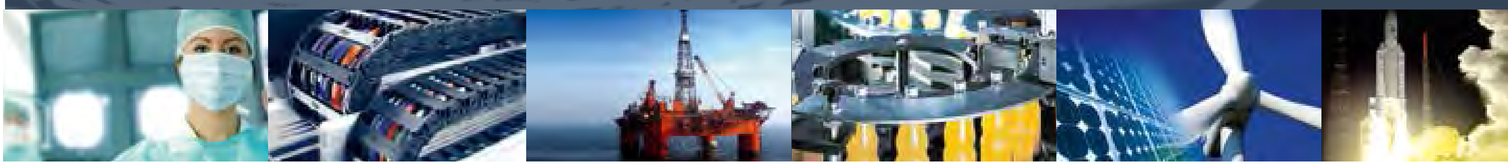
Fiber**Split**® Light Distribution for Optical Systems

Based on optical chip technology, the FiberSplit® product portfolio includes standard components such as 1xN or 2xN splitters as well as modules with integrated complex functionality for fiber optical singlemode and multimode systems. FiberSplit® products guarantee expandability with wide optical bandwidth and maximum bit rates thanks to extremely low PDL/PMD. Our products meet TELCORDIA standards and have been failure-free in the field for the past 17 years. We also produce customer-specific chips, components and modules, for example optical waveguide structures for wavelength ranges from 600 nm to 1700 nm for singlemode components and 450 nm to 2000 nm for multimode components with various waveguide properties and functions including optical chips and fiber arrays.

Business Unit Fiber Optics –
Product solutions for every application

Our fields of competence

- **Communications** (wiring systems for buildings and industry)
- **Energy** (mining, wind, solar, nuclear, petroleum, utilities)
- **Mechanical and Plant Engineering** (drag chains and switches)
- **Automation and Robotics** (Industrial Ethernet, bus systems, high-performance lasers for materials processing)
- **Transportation Engineering** (air and space travel, transport)
- **Defense** (system components and tactical field cables)
- **Laser Technology** (active and passive fiber optic cables for laser welding/laser processing)
- **Audio / Video / Multimedia**
- **Medicine & Life Sciences** (laser probes, endoscopic equipment)
- **Sensor Technology / Analytics** (colour, opacity and gas sensor technology, environmental engineering)
- **Lighting Technology**
- **Naval & Maritime Engineering** (steering control cables)
- **Spectroscopy** (chemical and food industries, astrophysics)
- **Scientific Institutions** (universities, research centres)
- **Optical Engineering** (synthetic fused silica)



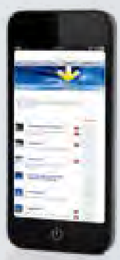
Always worth a visit ➔ **LEONI's media world**

Fiber Optics Website

➔ News
➔ Product range
➔ Developments & research projects
➔ Trade fairs & events

www.leoni-fiber-optics.com

Fiber Optics Smart



Fiber Optics –
worldwide and beyond

Your system partner throughout the entire value chain

The Business Unit Fiber Optics is one of the leading suppliers of highly pure fused silica, preforms, tubes and rods as well as optical waveguides for special applications.

But not only our portfolio is unique. As a system partner we can support you along the entire value chain and offer you the capabilities to optimize the product design at every stage of the production process according to your requirements.

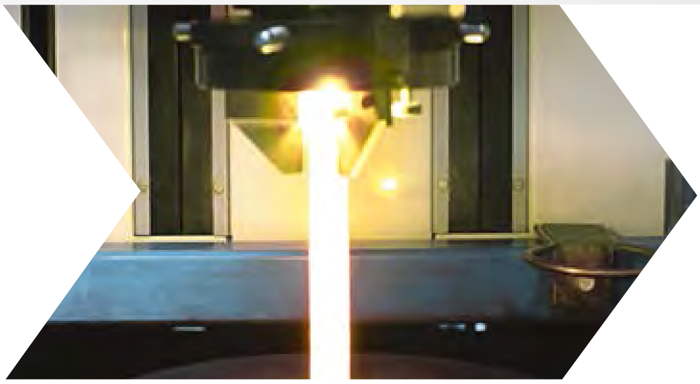
Worldwide and even beyond – into outer space. More than any other European competitor can offer.

Development & design

- Development of customer-specific overall solutions and prototypes
- Industrial research projects in materials science and technology development

Fused silica, preform & fiber production

- Production of fused silica
- Production of customer-specific graded-index and step-index preforms
- Production of multimode fibers with core diameters from 10 to 2700 µm



The product design can be influenced at every stage of the production process according to customer specifications.

No other European competitor has these capabilities.

Special fiber & cable production

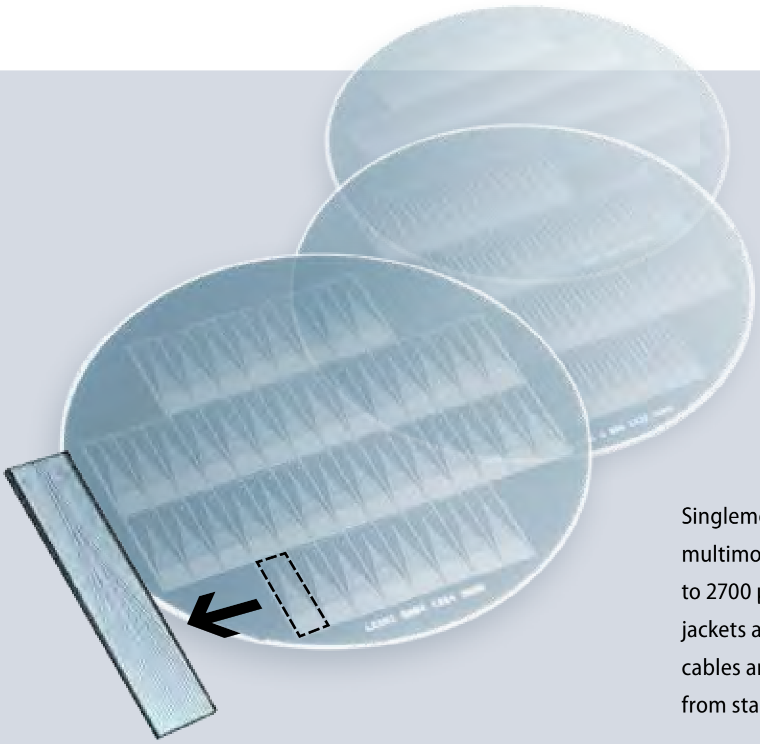
- In-house production of standard and special fibers (glass, silica, POF, PCF)
- Hybrid cables with electrical and optical conductors

Special assembly & components

- Assembly of fiber optic systems for applications in industry, medicine and science
- Production of planar waveguides as optical splitters
- Production of fiber optical switches

Innovations

It all starts with the development of solutions.



Up to 520 glass chips are cut from a 6-inch wafer with a special saw.

The splitter structure that can be seen on the chip serves for the distribution of an input signal into several output channels

LEONI develops and designs overall solutions and prototypes with regard to the customer and the intended application.

In the course of product research we have been working on industrial research projects in materials science and technology development in close collaboration with scientific institutions for years. Basic research and practical relevance are hardly ever so closely linked.

The preform from ultrapure optical glass or fused silica with different core and cladding material is the basis for the production of glass and silica fibers for optical waveguides. We produce customer-specific graded-index or step-index preforms for fiber production.

Singlemode fibers with core diameters from 3 µm to 10 µm and multimode fibers (glass/silica) with core diameters from 10 µm to 2700 µm with different numerical apertures, coatings and jackets are produced by us. We manufacture customer-specific cables and hybrid cables with electrical and optical conductors from standard and special fibers (glass, silica, POF, PCF).

Fiber optic cables, laser probes and special optical components for applications in industry, medicine and science are assembled to fiber optic systems by LEONI. Cable assembly using different fibers from glass, silica and polymers with different lengths, bundles, connectors and special connector systems through to optical switches and splitters

– this results in a unique portfolio of several ten thousand products

INSTITUT für PHOTONISCHE TECHNOLOGIEN
ipht jena

BAM
Bundesanstalt für Materialforschung und -prüfung

Institut für Hochfrequenztechnik
Technische Universität Braunschweig

ISC
Fraunhofer Institut Silicatforschung

The LEONI Group

Cable competence for different industrial markets.

LEONI is a leading supplier of cable systems and related services for the automotive industry and various other industrial sectors.

Our group of companies employs more than 59.000 people in 32 countries. Corporate vision, highest quality and innovative power have made us one of the leading cable manufacturers in Europe. LEONI develops and produces technically sophisticated products ranging from wire and optical fibers to cables through to complete cable systems and also offers the related services. Moreover, the product portfolio comprises strands, standardised cables, hybrid cables, glass fiber as well as special cables, cable harnesses, wiring systems components and fully assembled systems for applications in various industrial markets and achieved a group turnover of EUR 3.81 bn in 2012.

Your markets – our strength.
As diverse as our product and service range are the markets and sectors LEONI is supplying. We focus our activities on customers in the fields of Automotive & Commercial Vehicles, Industry & Healthcare, Communication & Infrastructure, Electrical Appliances and Conductors & Copper Solutions.

We are among the leading European suppliers in the Industry & Healthcare market to which at LEONI as a cable manufacturer also belong activities in the fields of telecommunication systems, fiber optics, industrial solutions and healthcare. Our customers benefit worldwide from innovative as well as reliable and long-lasting products of high quality.

LEONI – we create the best connection for your future.

For further information ***www.leoni.com***

Products and services portfolio at a glance

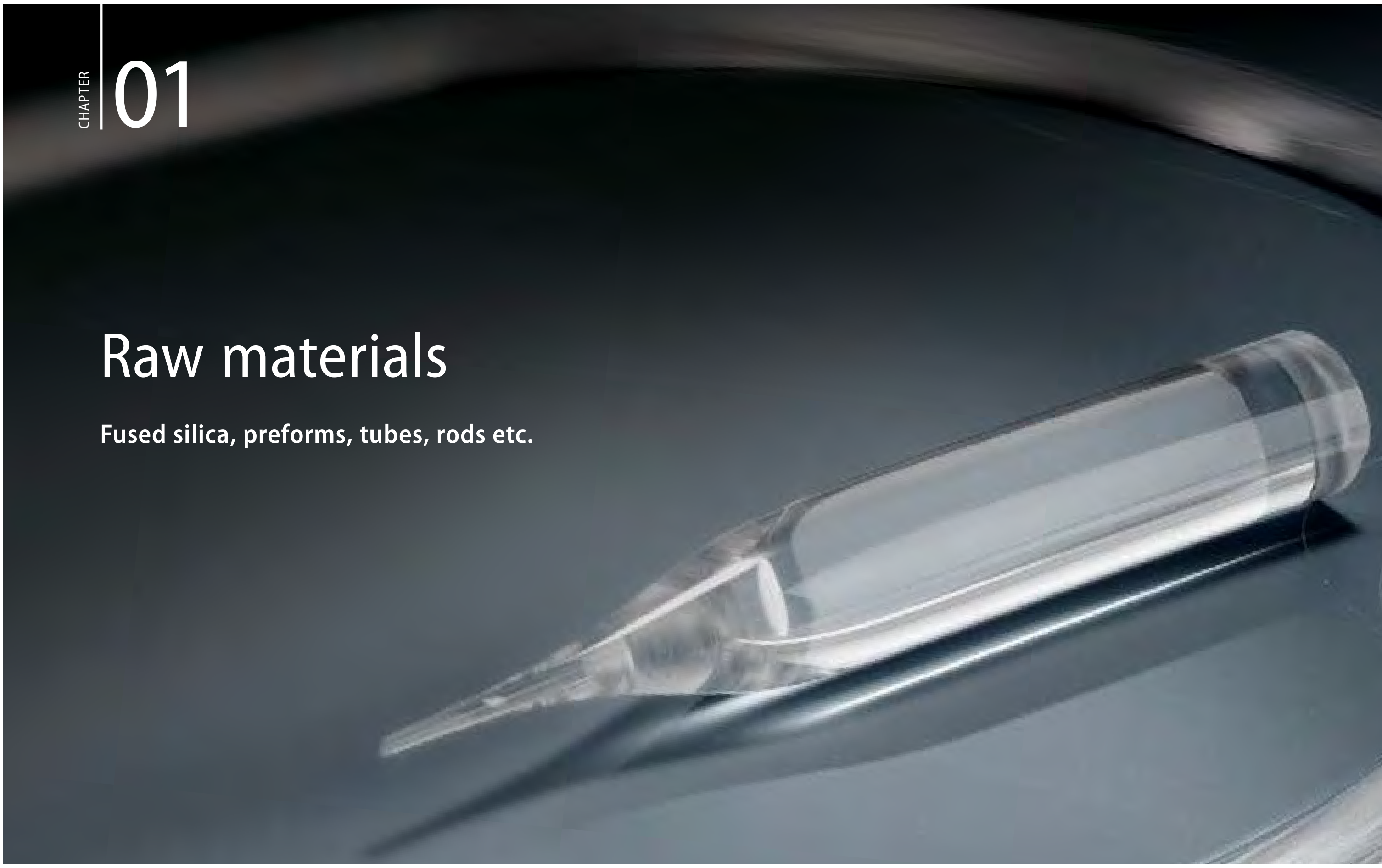
Service
Cable systems / Wiring systems
Cable harnesses | **Power distributors and Connector systems**
Copper cables | **Hybrid cables** | **Optical cables**
Wires & strands | **Optical fibers** | **Connectors**

Development / Engineering

LEONI's core markets

LEONI

Automotive & Commercial Vehicles	Industry & Healthcare	Communication & Infrastructure	Electrical Appliances	Conductors & Copper Solutions



Ultrapure fused silica materials for high-demand optical products and the manufacturing of high-performance optical fibers.

The performance of optical components and optical fibers is above all determined by the quality of the material used. You benefit from a unique value chain and our experience in customer oriented design implementation: in the production of highly pure fused silica materials, the composition of the optical waveguide preforms, the subsequent drawing of the fiber, its cabling and assembly or in the manufacturing of optical components.

By understanding the required performance properties of the final product and with the possibility to influence the production process at every stage, we manufacture the perfect product to meet your individual requirements. Our fused silica materials and fused silica products are the basis for innovative technologies and products of highest quality and performance. To achieve this we use three optimized, highly efficient manufacturing technologies: plasma based vapor deposition (PBVD), modified chemical vapor deposition (MCVD) as well as flame hydrolysis for synthetical fused silica. Ultrapure fused silica materials with excellent optical and physical properties are the result of combining these methods.

Application areas:

- Fused silica in optical applications in laser and lithography systems
- Tubes and rods as a basis for the production of OEM preforms (as fused silica rods and tubes)
- Tubes and rods for the manufacturing of capillaries and fibers
- Preforms for OEM fiber production

Product portfolio:

- Ready-to-order products in standard configurations
- Specified solutions – according to customer specifications
- Solutions depending on individual requirements for performance parameters for the whole wavelength range from UV to VIS, NIR and IR

Therefore LEONI offers the suitable product with special material compositions, various doping options and doping levels as well as individual shapes and geometries for next to every type of requested data or power transmission.

- Thus, we assure that our materials and products meet the demands concerning the functionality of the product designed in collaboration with you.

01. Raw materials

SQ Fused Silica – ultrapure fused silica

In 5 quality grades

Description

SQ Fused Silica – Especially for the production of optical and photonic devices in the fiber optic, semiconductor and display technology markets, as well as for optical applications and laser applications. The particularly inclusion- and bubble-free material features excellent optical and physical properties:

- Laser durability
- Refractive index homogeneity
- Thermal stability and temperature shock resistance
- Low stress birefringence
- Small thermal expansion coefficients.

Due to the high OH and H_2 content our fused silica SQ shows extremely low fluorescence and high stability under high-energy UV and laser radiation.

Application

- Excimer laser optics and beam guiding systems
- DUV and UV optics components
- Standard optics (VIS and NIR)
- UV rods, preforms and optical fibers
- Laser fusion
- Technical applications ➔ Fused silica vessels, windows
- Lithography and microlithography applications ➔ stepper lenses, photo mask blanks, wafers and lithography optics

Design / quality

LEONI offers SQ Fused Silica as ingot or semifinished product (round disc, rod, plate, block etc.) in five quality grades concerning homogeneity, absence of striae and application type. The quality grades are adjusted to individual customer needs in proven measuring and selection procedures. Thus, the fused silica can be used in the optical application range from DUV to NIR.

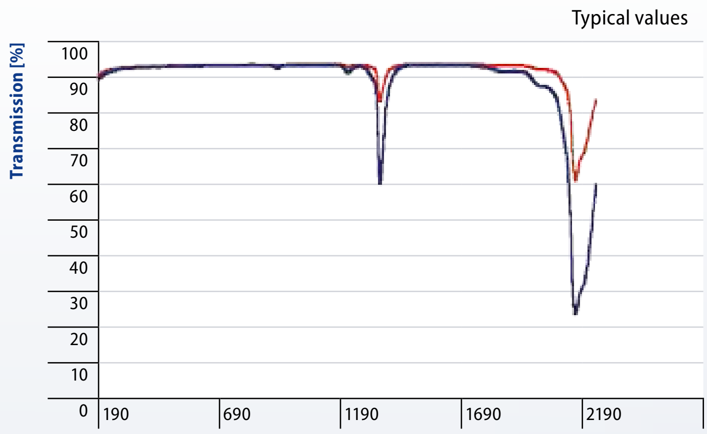
Quality grades *

- **SQ0:** is a 3D material free of striae and striations in any funcional direction. It is recommended for requirements in optical elements with several light directions such as prisms and lenses.
- **SQ1:** With high homogeneity and free of striae and striations in the functional direction. Typical applications are optical elements such as lenses, discs, wafers and rods / fibers.
- **SQT:** not specified concerning homogeneity, striations and striae. This quality level is recommended for technical applications.
  Excimergrade Fused Silica – available as SQ1 or SQ0: Excellent transmission at 193 nm / 248 nm. Lowest level of laser-induced fluorescence (LIF).
- **SQ0-E193 / SQ1-E193** (ArF excimer grade)
- **SQ0-E248 / SQ1-E248** (KrF excimer grade)

* acc. to customer-specific needs / applications

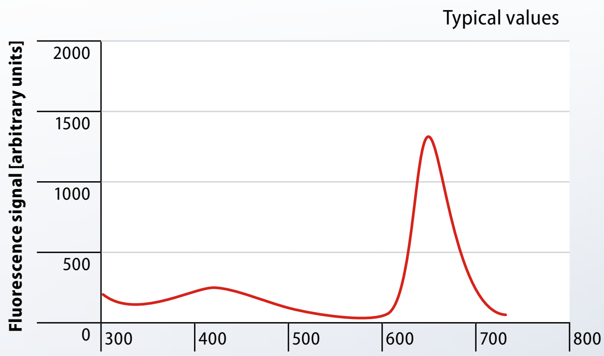
Spectral transmission

(typical transmission [T_g] including Fresnel reflection losses)



■ typ. transmission of 10 mm path length 10 mm
■ typ. transmission of 10 mm path length 40 mm

Example of an LIF spectrum (IPHT Jena)



■ SQ1 excimer grade

Red fluorescence: sensitive criterion for NBOHC (Non Bridging Oxygen Hole Center). Very low level is characteristic for a high Hydrogen content.
Blue fluorescence: sensitive criterion for ODC (Oxygen Deficiency Centers)

Fluorescence
The quality levels for excimer laser wavelengths (ArF, KrF) are selected by measuring the LIF factor (laser induced fluorescence). The standardised method with reference samples has been established at the IPHT in Jena for over 10 years now.
Irradiation parameters per LIF standard:
➔ laser wavelength 193 nm
➔ energy density 210 mJ / cm²
➔ repetition rate 10 Hz

	Optical properties				
Quality grade	Bubbles and inclusions [4]		Homogeneity data		Stress birefringence
	according to ISO 10110-3	max. diameter	local inhomogeneities striations and striae [1] as per ISO 10110-4	refractive index change Δn [2,3] in functional directions	standard [4]
		[mm]		[ppm = $1 * 10^{-6}$]	[nm/cm]
SQ0	1 / 1 × 0.063	0.07	2 /– ; 5 in all directions	standard: PV ≤ 40 ppm	≤ 5
SQ1	1 / 1 × 0.063	0.07	2 /– ; 5 in functional directions		≤ 5
SQT	not defined	0.5	not specified	on request	≤ 10

[1] Shadow method, polarizer and interferometer are used for striae and striation detection.
[2] Homogeneity Δn is tested interferometrically (5% outer edge exclusion)
[3] Lower values with respect to size and processing available on request.
[4] Bubbles and inclusions < 0.05 mm in diameter are not considered in these cases.

Quality grade	Internal transmittance [%] for 10 mm sample thickness			OH content	Other Contaminants
	λ=193 nm	λ=248 nm	λ=300 nm	[ppm]	[ppm]
SQ0	≥ 98.0	≥ 99.5		approx. 1200	≤ 0.05
SQ1	≥ 98.0	≥ 99.5		approx. 1200	≤ 0.05
SQT	—	≥ 95.0	≥ 99.9	800 – 1400	≤ 0.6
SQ-E193	≥ 99.3	≥ 99.8		approx. 1200	≤ 0.05
SQ-E248	≥ 99.0	≥ 99.8		approx. 1200	≤ 0.05

All grades show internal transmittance ≥ 99,9 % in the wavelength range from 300 nm to 900 nm.
All grades show hydrogen content of $1 * 10^{18}$ Mol./cm³ approx.

Preforms

Designs for step-index and graded-index

Description

Using highly pure fused silica materials, the LEONI subsidiary j-fiber develops and produces high-quality preforms according to customer specifications. They are the basis for the manufacturing and application of high-performance special fibers and standard fibers.

Whether your goal is the transmission of high data rates or high-power laser transmission: We can adjust the required waveguide design to your demands, from prototype to series production.

We thereby specify the preform design and configuration in core profile (step or graded index) and dopant option (Germanium, Fluorine, Boron, or Rare-earth elements) in order to achieve the needed numerical aperture. In addition we can provide the required geometry of the preform and determine the shape of core and cladding for application-specific assembly according to your needs.

Process technology

Each preform is produced with the suited technology:
Step 1 ➔ choice of the appropriate core material, either from our raw material production of undoped fused silica with high or low OH content or by direct coating of doped fused silica.

Step 2 ➔ Production of the final waveguide preform, either our own MCVD process (inner coating) for graded-index and step-index fibers or a PBVD process (outer coating) for large core step-index fibers.

Quality

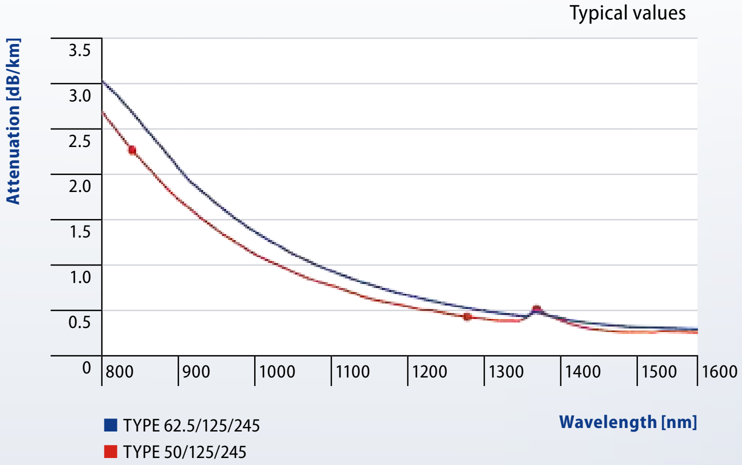
Every preform is subject to a strict quality monitoring that also includes the testing of the goal parameters.

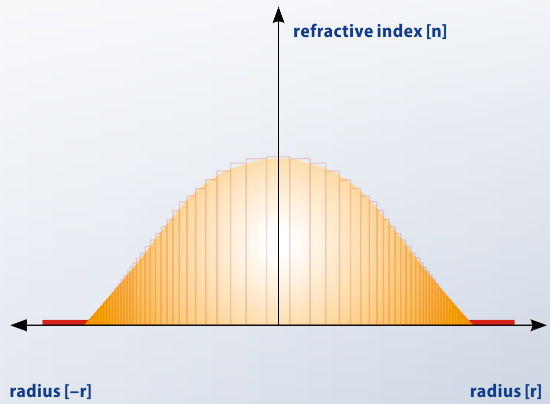
The result is a preform with best performance properties during the drawing of fibers for demanding applications.

Multimode preforms 50/125 and 62.5/125

Graded-index
Preforms

Typical spectral attenuation of a multimode fiber





LEONI offers graded-index preforms for high-performance multimode fibers in the 50/125 and 62.5/125 designs.

The innovative MCVD production technique for preforms ensures that the specified fiber performance properties are fulfilled. On request graded-index preforms are delivered with a handle, which allows the fixing of the preform in the drawing tower.

Performance properties	Preform design 50/125	Preform design 62.5/125
Core composition	SiO_2 / GeO_2	SiO_2 / GeO_2
Refractive index profile	nearly parabolic	
Refractive index delta	13.7×10^{-3}	25.9×10^{-3}
Tolerance of Delta within a rod	2.0×10^{-3}	3.0×10^{-3}
Numerical aperture	0.200 ±0.015	0.275 ±0.015
Preform Ø (O.D.) [mm]	39.0	26.0
O.D. tolerance from rod to rod [mm]	±2.0	
O.D. tolerance within a rod [mm]	±0.5	
Preform length [mm]	600 – 1200	
Preform bow [mm/m]	≤ 0.7	
Preform non-circularity [%]	≤ 1.0	
Clad concentricity error of O.D. [%]	≤ 1.2	

Bubble size s/mm

	acceptable number per preform
in the core	not allowed
in the cladding	
s ≤ 0.3	no count
0.3 < s ≤ 0.8	5
0.8 < s ≤ 2.0	2
s > 2.0	0

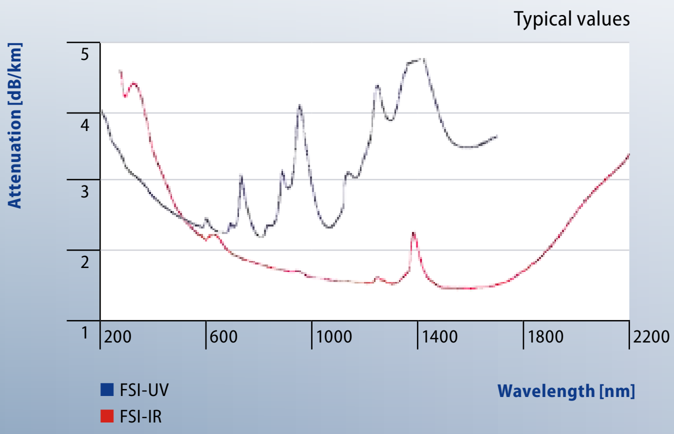
Target fiber specifications		50/125	62.5/125
Core diameter [µm] (± 2.5)		50	62.5
Core non-circularity [%]		≤ 5.0	
Core / clad concentricity error [µm]		≤ 1.5	
Cladding Ø [µm] (± 2.0)		125	
Cladding non-circularity [%]		≤ 1.0	
Attenuation* [dB/km]	850 nm	≤ 2.4	≤ 2.9
	1300 nm	≤ 0.6	≤ 0.8
	1383 nm	≤ 2.0	≤ 2.0
Bandwidth** [MHz · km]	850 nm	≥ 500	≥ 160
	1300 nm	≥ 500	≥ 500

* Highly dependent on optimised drawing conditions.
** Min. 70% of the fiber output meets the specified target fiber values.
Further bandwidth combinations available on request.

Fluorine-doped step-index preforms (FSI)

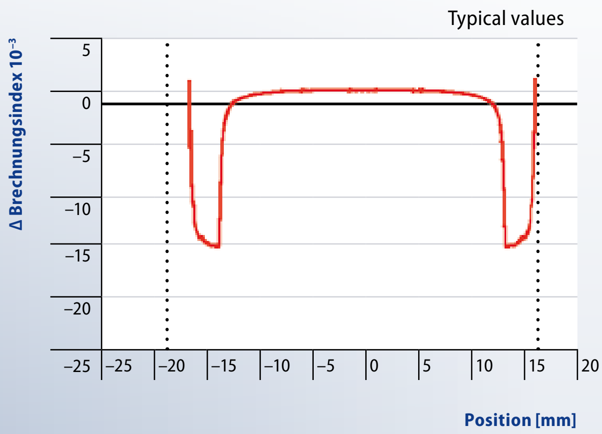
Step-index
Preforms

Spectral attenuation



Refractive index profile

example of CCDR 1.4



FSI preforms are used for the manufacturing of special fibers with undoped core and doped cladding. These fibers are applied in diverse industrial and medical sectors as well as in research and development.

FSI preforms can be fitted to the customer's demands concerning UV or IR laser transmission, spectroscopy and high-power laser transmission. In addition, LEONI offers individual solutions, that can be specified regarding the characteristic parameters such as the type of core and cladding material, cladding thickness and composition (single or multiple cladding) and numerical aperture (NA).

Applications

Highly suitable as basic material for drawing high-performance special fibers for:

- UV–VIS to IR laser transmission
- High-power lasers
- Spectroscopy

Standard properties		Specific values
Core composition		SiO_2
Cladding composition		SiO_2 /F
Refractive index profile		step-index
Refractive index delta		max. (17 ±3) × 10^{-3}
Numerical aperture (NA)*		0.12 ± 0.02 0.15 ± 0.02 0.22 ± 0.02 0.26 ± 0.02
Preform Ø (O.D.) [mm]		20 – 70
O.D. tolerance within the preform [%]	20 – 29 mm 30 – 39 mm 40 – 70 mm	± 4.0 ± 3.0 ± 2.0
Preform length [mm]		400 – 1200
Preform non-circularity [%]		≤ 2.0
O.D. concentricity error		< 10
Cladding to core diameter ratio (CCDR)		1.040 – 1.400
Tolerance of CCDR value**:	1.04 – 1.09 1.10 – 1.39 > 1.4 ***	+0.010/–0.005 ± 0.015 ± 2.5

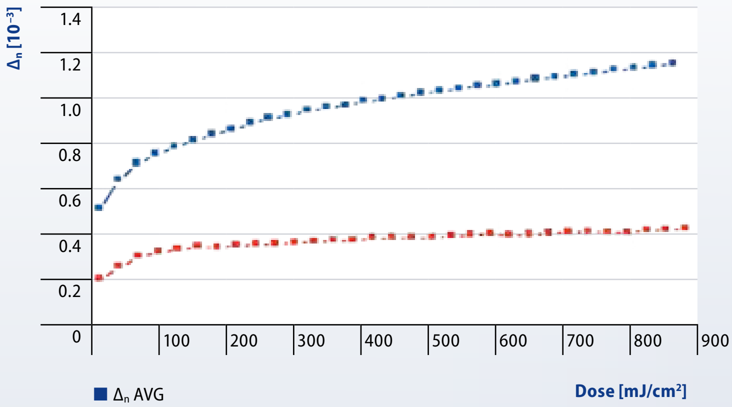
* Further NA values and tolerances available on request
** Further tolerances available on request
*** Multiple cladding

Germanium-doped step-index preforms

Step-index
Preforms

Example of a highly photosensitive fiber
with high Germanium doping (irradiation wavelength 248 nm)

Typical values



Source: IPHT e.V. Jena, Germany

The j-fiber group offers preforms with Germanium-doped core for the manufacturing of special step-index fibers. In order to ensure the specified fiber transmission properties, the preforms are produced using j-fiber's own MCVD technique.

The highly photosensitive singlemode preforms were developed for the efficient production of fibers for FBG inscribing.

On request, the step-index preforms are available with a handle for fixing the preform during the drawing process.

Properties		Singlemode	Singlemode (photosensitive)	Multimode
Core composition		SiO_2 / GeO_2		
Cladding composition		SiO_2		
Refractive index profile		step		
Refractive index delta		$(3.5 – 7.8) * 10^{-3}$	$(8.8 – 31.0) * 10^{-3}$	$(3.5 – 20.0) * 10^{-3}$
Numerical aperture (±0.02)		0.10 – 0.15	0.16 – 0.30	0.10 – 0.24
Core / cladding diameter ratio		1:14 – 1:18*	1:18 – 1:26**	1:1.1 – 1:6
Preform outer Ø [mm]		10 – 40	15 – 25	10 – 40
Outer Ø	Tolerance from rod to rod [%]	±10.0		
	Tolerance within a rod [%]	±4.0		
Preform length [mm]		400 – 1200	400 – 1200	600 – 1200
Preform deflection [mm/m]		≤ 1		
Preform ovality [%]		≤ 2.0		
Core / cladding concentricity error regarding outer Ø [%]		≤ 1.2		

* The preforms can be optimised for the desired operating wavelength or mode field.
** Cut-off wavelengths of 800 nm up to 1500 nm (±50 nm) and mode field diameters between 4 µm and 12 µm approx. are available.

Rods

Fused silica

Description

Rods made from fused silica for the manufacturing of special fibers and optical components.

A distinction is made between three types of fused silica

- **SQ ➔** Fused silica rods made of udoped silica with high OH content
- **j-plasil ➔** Fused silica rods made of undoped silica with low OH content
- Special dopings e.g.
  BDSR ➔ Boron-doped fused silica rods

SQ ➔ High OH fused silica rods from undoped glass

Undoped silica for application in the UV / VIS range. It is used for efficient manufacuring of optical components such as lenses mirrors and plates, as well as for the production of special preforms. The higly pure material offers best optical and physical properties and highest homogeneity in the refractive index. SQ is being produced using a special melting technology, by which highest concentrations of OH and H_2 can be brought into the material.

The result is a material with optimum transmission properties in the UV / VIS range and highest laser durability.

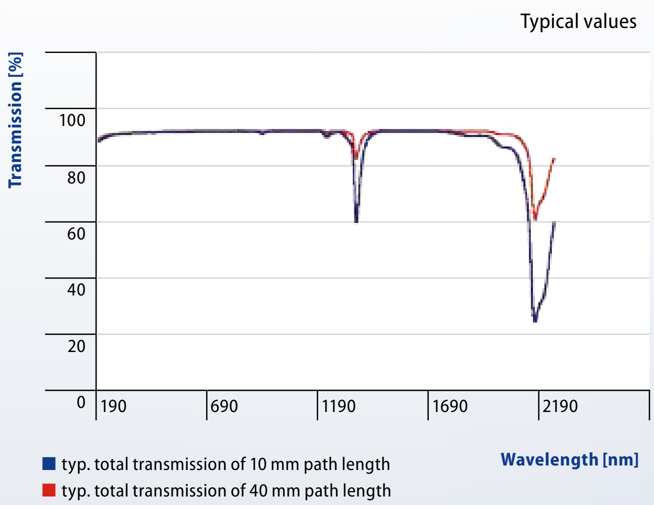
Properties (for fiber optics)

- Absence of inclusions and bubbles
- High OH / H_2 content
- Excellent UV transmittance
- Very low fluorescence
- High laser durability
- Low residual stress
- Very low thermal expansion coefficient
- High thermal stability

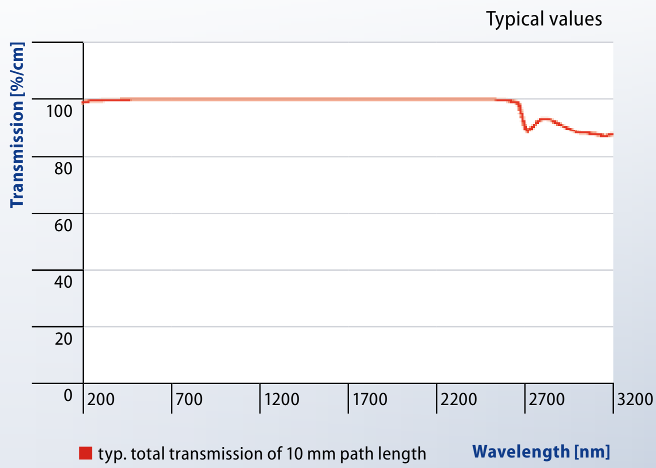
Application

- Design and production of preforms
- Process-controlled manufacturing of optical high-power fibers

Transmission SQ fused silica



Transmission j-plasil fused silica



j-plasil ➔ Fused silica rods from undoped glass

For the VIS, NIR and IR range. The low OH high-performance fused silica material was developed particularly for the transmission in the VIS to IR wavelength range and offers a further optimizing for the application in the IR range. It is produced using a plasma based deposition technique, which creates the chemical coating conditions for fused silica with low OH content.

Undoped fused silica rods are the basis for the production of preforms for the manufacturing of special fibers such as PCF.

Properties (for rods and optical elements)

- Undoped fused silica with high homogeneity
- Low OH content
- Diameter 25 to 80 mm
- Rod length 200 to 800 mm
- Cylinder faces: fire polished or lapped

Application

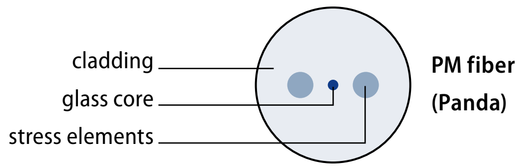
- Appilcation range covers UV, VIS, NIR and IR, optimised for near infrared.

Special dopings

In order to support your specific applications we offer various doping materials such as Germanium, Fluorine and Boron.

BDSR ➔ Boron-doped fused silica rods

are used for the production of polarization maintaining (PM) fibers in the so-called Panda design.



Properties

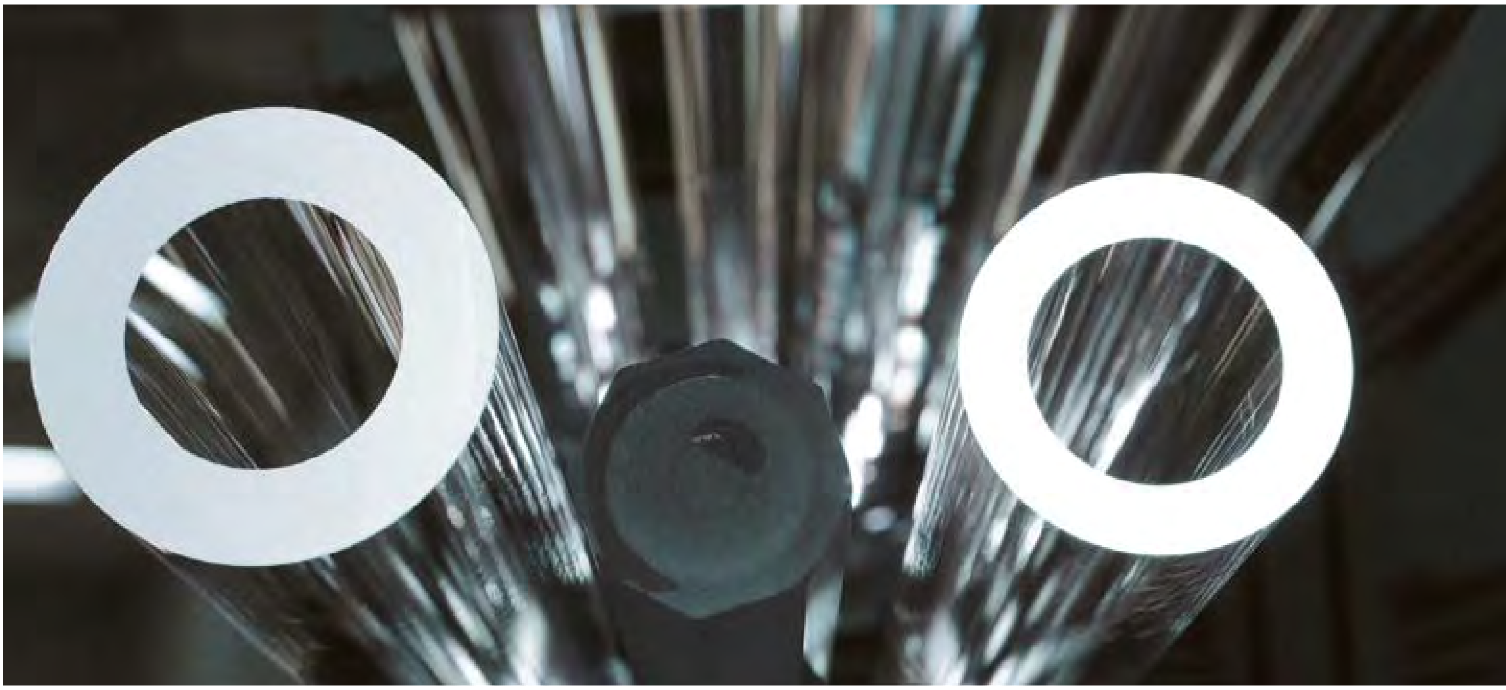
- Tight geometrical tolerances
- Customer-determined geometry stress elements for easy insertion in Panda design preforms
- High yield in PM fiber manufacturing
- Core Ø 3 to 13 mm
- Boron content up to 20 wt. %
- Length of rod 200 to 600 mm

Application

- Production of Panda fibers

Tubes

Fused silica tubes for the production of special fibers and optical preforms



Description

Tubes made of ultrapure fused silica for the production of special fibers, preforms and optical components.

Application

A multitude of applications is possible:

- Drawn as capillary ➔ for industrial and medical applications
- Special doped versions support the manufacturing of combiners in high-power laser transmission
- Ideal tube material for manufacturing photonic crystal fibers

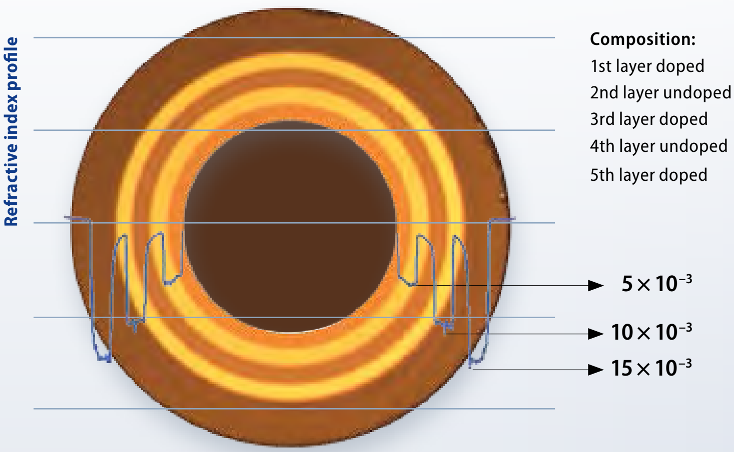
Designs

Fused silica tubes are available with different sizes and dopings:

- Customer-specific undoped fused silica tubes with low OH content in the material composition
- Fluorine-doped fused silica tubes with very high concentration, optionally with uniform doping or with refractive index profiles of two or more levels as required by customer
- As ideal basis for individual preform designs and the manufacturing of innovative special fibers.

Fluorine-doped fused silica tubes (FST)

Example of a customer-specific tube design



Description

FST fused silica tubes were developed to provide special fiber manufacturers with a reliable source for Fluorine-doped high performance tubes.

FST is the perfect basis for preform design, as it meets the particular requirements of special fiber manufacturers. FST tubes contain highest Fluorine concentrations of 4wt. % and resulting in a negative refraction index delta of (17 ±3) × 10^{-3}. We offer FST with numerical apertures (NA) of up to 0.22 (compared to pure fused silica) and with low OH content (<20 ppm) as uniformly doped tubes as well as customer-specific variations. These allow easy finishing and processing in preforms or capillaries.

Customer-specific preforms can be produced with single-level or multi-level refractive index profiles.

Application

- Developed for the production of special fiber designs as substrate or jacketing tubes
- As substrate materials in CVD processes
- For overcladding processes in preform production
- As Fluorine-doped capillary for special fiber designs

Properties

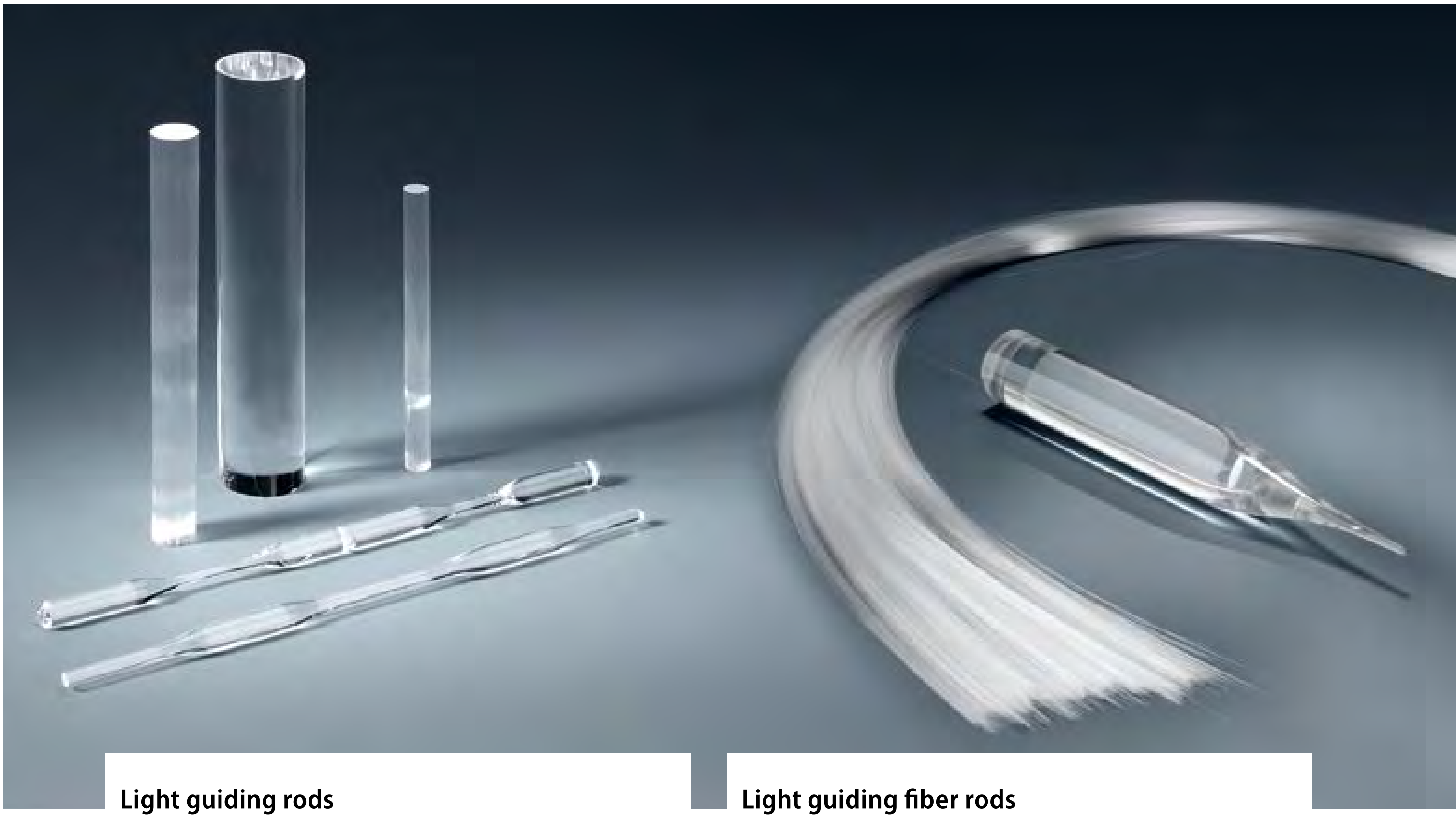
- Concentration of Fluorine doping by customer request
- Customer-specific combination of doped and undoped layers
- Optional inner or outer coatings of pure fused silica
- Customer-specific wall thickness dimensions

Properties (uniform doping of tube)		Specific values
Material composition		SiO_2 / F
Fluorine content [wt %]		max. 4
Refractive index delta (negative compared to undoped fused silica)		up to (17 ±3) × 10^{-3}
Refractive index*	at 633 nm	1.440
	at 1064 nm	1.433
Thermal expansion coefficient (20° – 400° C)		2.5×10^{7} K^{1}
Density [g/cm³]		2.180
Inner tube Ø (I.D.) [mm]		20 – 40
Fluorine doped wall thickness [mm]		1.5 – 15
Tube length [mm]		max. 1000
Non-circularity [%]		≤ 3
Deflection [mm/m]		≤ 1.5

* for a Fluorine content of 4 wt %

Light guiding rods / light guiding fiber rods

Fused silica, optical glass or plastic



Light guiding rods

Description

Optical waveguide made of fused silica, optical glass or plastic with large cross-section featuring a core and a cladding.

Application

For applications with high transmission or if the optical guide does not need to be flexible. Light guiding rods are often used at the end of optical guides consisting of fiber bundles in order to homogenise the emitted light.

Design

Diameter 0.1 mm to ≥ 10 mm

Versions

Customer specific: available as tapers if required (tapered cross-section of certain sections of the rod).

Light guiding fiber rods

Description

Optical waveguides made of fused silica, optical glass or plastic with large cross-section consisting of several hundred individual fibers.

Application

For applications in which, next to the light itself, an image or impression is to be transmitted and the waveguide / image guide does not need to be flexible. The resolution is determined by the number and diameter of the individual fibers.

Design

Diameter 0.1 mm to ≥ 10 mm

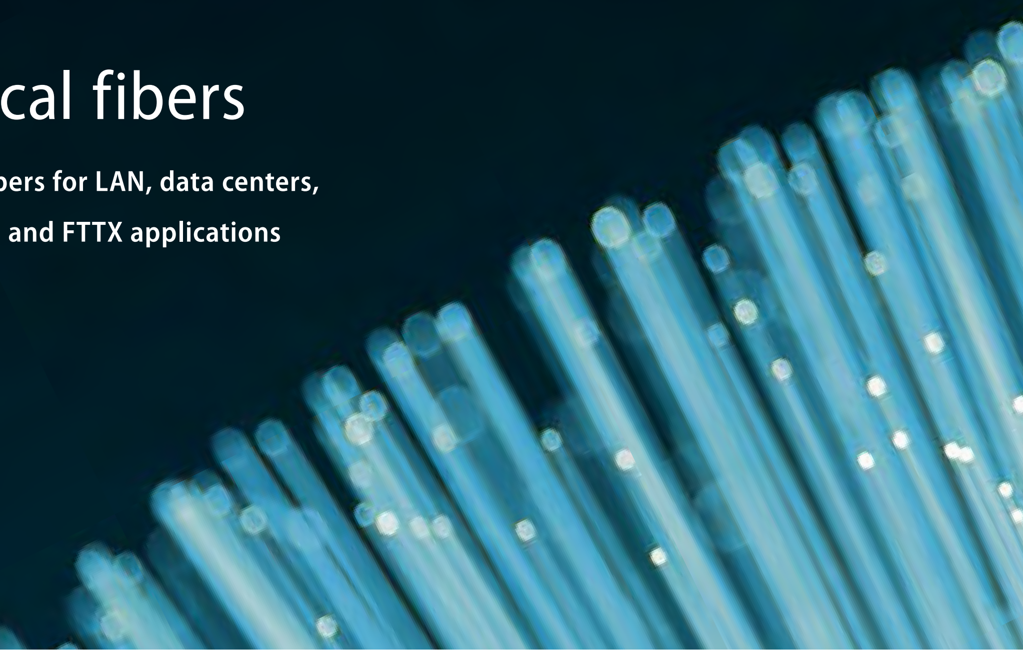
Versions

Customer specific: available as tapers if required (tapered cross-section of certain sections of the fiber rod).

CHAPTER 02

Standard optical fibers

Multimode and singlemode fibers for LAN, data centers, long distance network cabling and FTTX applications



We offer standard multimode and singlemode high-performance fibers for the transmission of high data rates in future proof networks as well as a number of services for cable manufacturers and network providers.

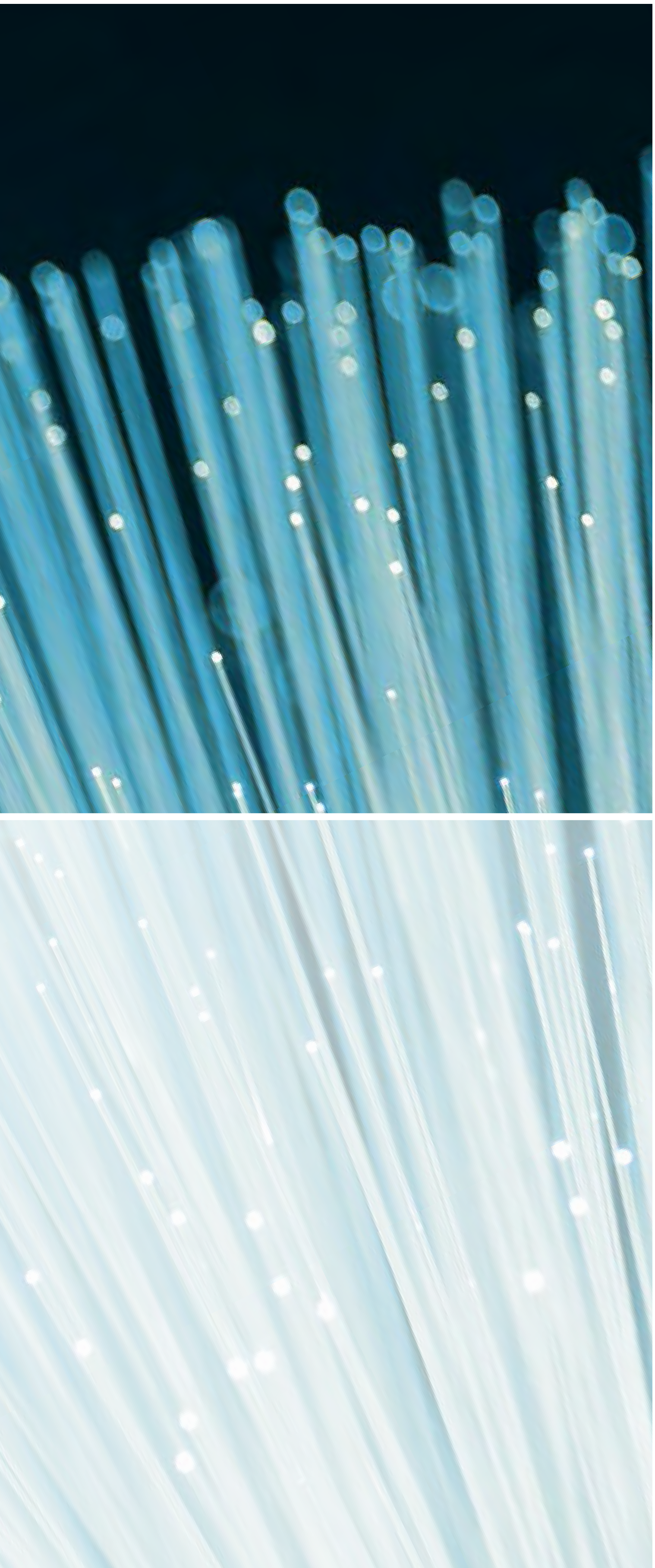
- With the j-fiber group as a leading provider of multimode fibers we ensure that our fibers support the challenging concepts of structured cabling in LAN and data centers – for the demands of today's 10 Gb/s data transmission as well as for parallel data transmission rates of up to 100 Gb/s. We offer a complete portfolio of 50/125 OM4/OM3/OM2+ multimode fibers as standard or as bend-insensitive fibers; plus our 62.5/125 OM1 fibers in the standard version.

- All fibers meet toughest demands concerning losses and laser bandwidth and are DMD characterized for the proof of performance properties beyond today's application standards.

- Our tried and tested singlemode fibers are cost-efficient, reliable fiber solutions in local networks and for the covering of larger distances as well as for FTTX applications and long distance network cabling. They are compatible with the existing network basis and offer superior bending performance for the robust, flexible application with lowest attenuation and perfect fiber geometry with lowest diameter tolerances at the same time.

- As approved MIL STD 790 supplier for the U.S. Defense Logistics Agency we also offer our single and multimode fibers as per MIL PRF specification for use under radiation threatened environmental conditions.

- For the support of cables with high packing density and a productivity-oriented cable manufacturing we offer customer-specific FiberUnit bundles. Up to 12 multimode or singlemode fibers of choice can be bundled to one unit and configured as an outsourcing service for cable manufacturers.



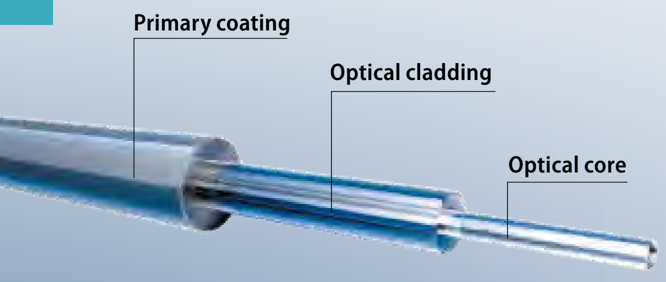
Further basic information on fiber types:
Chapter 12 | Principles
→ page 365 ff

02. Standard optical fibers

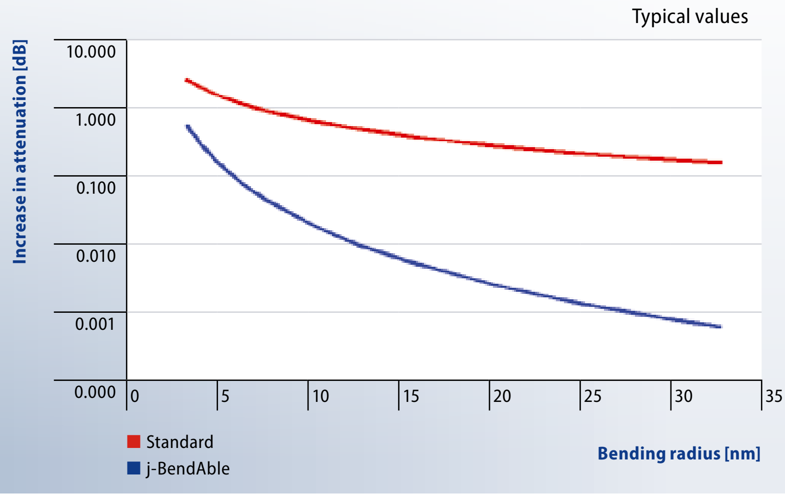
LEONI

j-BendAble OMx fibers

(bend-insensitive 50/125 multimode fibers)



Superiour bending performance of the j-BendAble OMx fiber (typical values)



Description

With the j-BendAble OMx brand, we offer bend-insensitive 50 µm multimode fibers, which have been optimized particularly for 850 nm laser transmission.

They are in compliance with the valid OM2, OM3 and OM4 standards and are also available with OM2+-bandwidth. j-Bendable OMx fibers support compact space management and high fiber count cabling due to their excellent bending performance. They allow frequent modification, addition and changes for maximum flexibility in data center cabling.

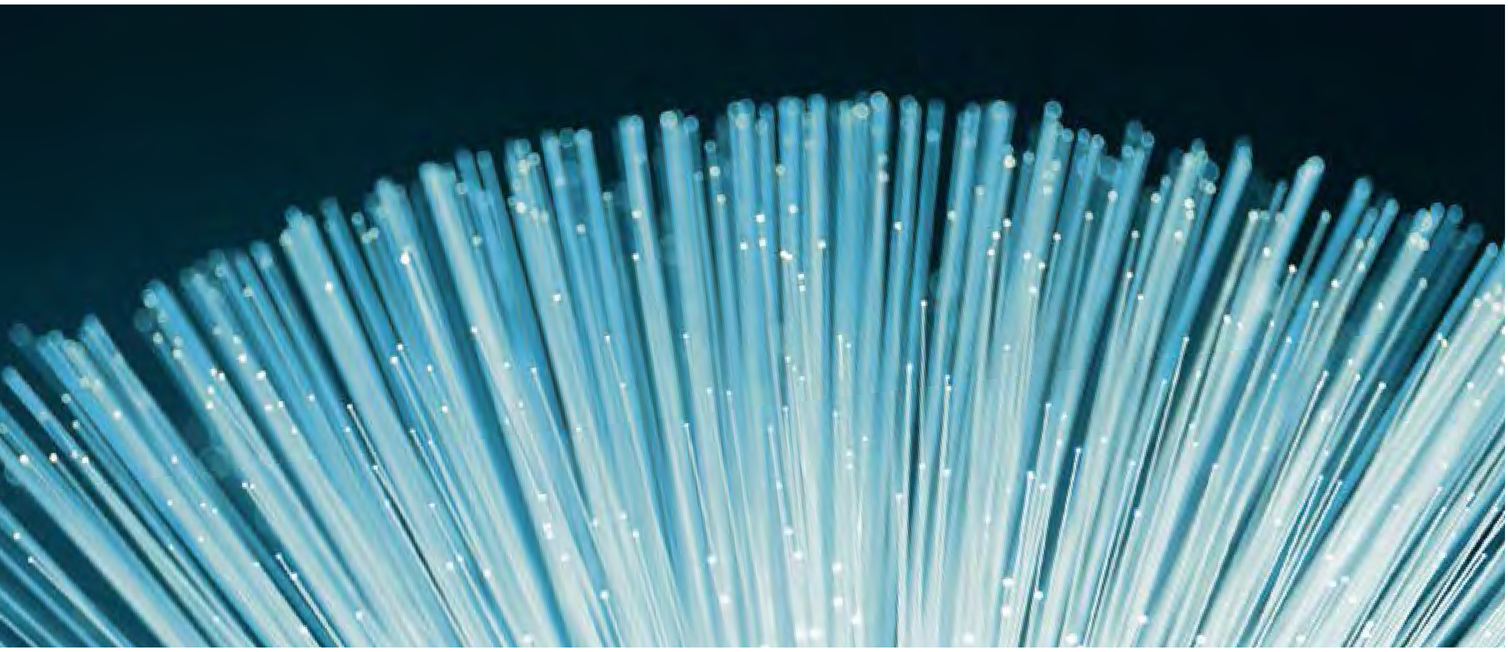
With j-BendAble OMx fibers a serial transmission rate of 10 Gb/s Ethernet over a link length of up to 550 m is achieved, the link length for parallel data transmission of 40 Gb/s or 100 Gb/s is 150m.

j-BendAble OMx fibers provide maximum compatibility with all currently commercially available bend-insensitive standard multimode fiber brands and thereby contribute to high flexibility, independence and cost-effectiveness in the design and installation of complex cabling systems for LAN and data centers.

	Optimized data rates for distances per j-BendAble fiber type at 850 nm			
Data rate	j-BendAble OM4	j-BendAble OM3	j-BendAble OM2+	j-BendAble OM2
40 / 100 Gb/s	170 m	140 m	not defined by the standard	not defined by the standard
10 Gb/s	550 m	300 m	150 m	not defined by the standard
1 Gb/s	1100 m	1000 m	750 m	500 m

Bending properties		Specified value
Macrobending loss / bend induced attenuation [dB]		
100 turns	850 nm	≤ 0.05
Radius 37.5 mm	1300 nm	≤ 0.15
2 turns	850 nm	≤ 0.1
Radius 15 mm	1300 nm	≤ 0.3
2 turns	850 nm	≤ 0.2
Radius 7.5 mm	1300 nm	≤ 0.5

Mechanical properties	Specified value
Proof test [kpsi]	≥ 200
Dynamic tensile strength [N]	≥ 17.6



Fiber characterization

Prior to delivery, every fiber is DMD characterized according to TIA/EIA 455 220 or IEC 60793-1-49 in order to guarantee the specified effective modal bandwidth at 850 nm. The fiber is supposed to meet the requirements of both methods:

- the "use of templates according to the values of the differential mode delay (DMD)" and
- the "calculated effective modal bandwidth (EMBc)"

Standards compliance

Optical, geometrical and mechanical properties as well as properties under certain environmental conditions can be found on pages 26/27.

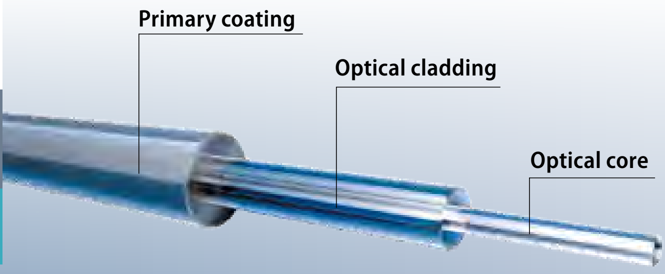
Coating option

The j-BendAble Robust fiber with a special 500 µm coating for optimum protection against mechanical influences is available on request.

		j-BendAble fiber			
Performance properties		OM2	OM2+	OM3	OM4
Bandwidth [MHz×km] (overfilled launch, LED light source)	850 nm 1300 nm	≥ 500 ≥ 500	≥ 750 ≥ 500	≥ 1500 ≥ 500	≥ 3500 ≥ 500
Effective modal bandwidth (EMB) [MHz×km]	850 nm	–	≥ 1000	≥ 2000	≥ 4700
Transmission link length at 10 Gb/s [m]	850 nm (LX4) 1300 nm	– –	150 300	300 300	550 300

OptiGrade

Graded-index 50/125 multimode fibers for 10 Gb/s applications



Description

OptiGrade is an enhanced 50/125 multimode fiber series, specially suited for high-speed network protocols and high data transmission rates.

To achieve this the standard compliant OM3 and OM4 as well as the improved OM2+ fibers were optimized for a 10 Gb/s ethernet data transmission with 850 nm VCSEL over link lengths of 150 to 550 m. OptiGrade fibers offer highest performance regarding the bandwidth for complete building complexes, LAN and SAN systems for low system costs.

This series allows reliable transmission with data rates of 10 Gb/s ethernet over scalable link lengths within the OM2 and OM3 classes. They support low-cost high-speed connections for short distances in IT networks with a serial transmission rate of 10 Gb/s over distances of up to 200 m in the OM2 and up to 500 m in the OM3 class. OptiGrade fibers of the OM4 class support the standard-compliant link length of 550 m for serial transmission of 10 Gb/s.

Note

All OptiGrade fibers are also available as bend-insensitive j-BendAble OMx versions (see page 22).

Fiber characterization

Prior to delivery, every fiber is DMD characterized according to TIA/EIA 455 220 or IEC 60793-1-49 in order guarantee the specified effective modal bandwidth at 850 nm. The fiber is supposed to meet the requirements of both methods:

- the "use of templates according to the values of the differential mode delay (DMD)" and
- the "calculated effective modal bandwidth (EMBc)"

Standards compliance

Optical, geometrical and mechanical properties as well as properties under certain environmental conditions can be found on pages 26/27.

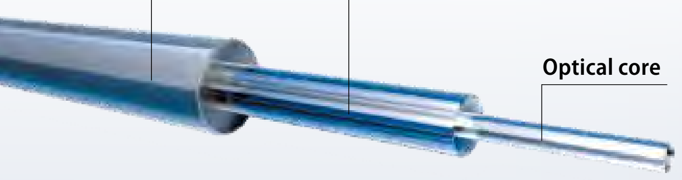
Coating option

The OptiGrade Robust fiber with a special 500 µm coating for optimum protection against mechanical influences is available on request.

Performance properties		OptiGrade class 150	200	300	400	500	550
Bandwidth [MHz×km] (overfilled launch, LED light source)	850 nm 1300 nm	≥ 750 ≥ 500	≥ 1000 ≥ 500	≥ 1500 ≥ 500	≥ 2000 ≥ 500	≥ 2500 ≥ 500	≥ 3500 ≥ 500
Effective modal bandwidth (EMB) [MHz×km]	850 nm	≥ 1000	≥ 1500	≥ 2000	≥ 2700	≥ 4000	≥ 4700
Transmission link length at 10 Gb/s [m]	850 nm (LX4) 1300 nm	150 300	200 300	300 300	400 300	500 300	550 300

GigaGrade multimode fibers 50/125 and 62.5/125

Laser optimized multimode fiber solutions



Description

GigaGrade laser optimized multimode fiber solutions with a broad performance range for the flexible transmission of large amounts of data over short and medium distances in local area networks (LAN).

GigaGrade multimode fibers are specified for the application in laser base high-speed network protocols. They support fiber optic network protocols such as Gigabit Ethernet, ATM, Fast Ethernet as well as networks with lower bit rates in LAN, SAN and parallel high-speed connections. They are equally ideal for the application in riser and horizontal cabling and in local access networks.

Fiber design

- Available in 50/125 or 62.5/125 fiber design
- Optimized for 850 nm and 1300 nm applications with lowest attenuation and large bandwidths
- Available with standard OM1 or OM2 performance or with customer-specific combinations of bandwidths and link lengths for special applications
- Guaranteed link lengths of up to 2000 m for 1 Gb/s transmission
- The fiber exceeds the current industrial standards for Gigabit Ethernet, FiberChannel, FDDI, ATM and more
- Highly flexible and cost-efficient solution for migration of LED to laser as light source, such as VCSEL
- Excellent splicing performance and compatibility with the installed fiber basis and photonic components
- Maximum product consistency and reliability due to patented manufacturing procedure

	50/125	62.5/125
Geometrical properties	**Specified values**	
Core Ø [µm] (± 2.5 µm)	50	62.5
Core non-circularity [%]	≤ 5.0	≤ 5.0
Core/cladding concentricity error [µm]	≤ 1	≤ 1
Cladding diameter [µm] (±1.0 µm)	125	125
Cladding non-circularity [%]	≤ 1.0	≤ 1.0
Coating Ø [µm] (± 7)	242	242
Coating/cladding concentricity error [µm]	≤ 10.0	≤ 10.0
Standard length [km]	2.2/4.4/6.6/8.8/13.2/17.6	2.2/4.4/6.6/8.8/17.6

Performance properties		Specified value range	
Attenuation coefficient* [dB/km] (overfilled launch, LED light source)	850 nm 1300 nm	≤ 2.2 to ≤ 2.4 ≤ 0.6 to ≤ 0.7	≤ 2.7 to ≤ 2.9 ≤ 0.6 to ≤ 0.7
Bandwidth** [MHz×km] (LED, overfilled launch)	850 nm 1300 nm	≥ 400 to ≥ 750 ≥ 500 to ≥ 1200	≥ 160 to ≥ 250 ≥ 500 to ≥ 800
Transmission link length** at 1 Gb/s [m] Light source: laser, restricted mode launch	850 nm 1300 nm	≥ 500 to ≥ 750 ≥ 550 to ≥ 2000	≥ 300 to ≥ 500 ≥ 550 to ≥ 1000

* Special attenuation values on request.
** Available in special combinations and values for both bandwidth and link length.

50/125 µm
j-BendAble / OptiGrade / GigaGrade

50/125 µm j-BendAble / OptiGrade / GigaGrade		Multimode fiber specifications	Test methods	Industrial standards: IEC 60793-2-10	ISO/IEC 11801	ITU G651.1	TIA/EIA 492AAD OM4	TIA/EIA 492AAAC-B OM3	TIA/EIA 492AAAB-A OM2
Performance properties									
Attenuation [dB/KM]	at 850 nm	≤ 2.2 to ≤ 2.4	FOTP 78 IEC 60793-1-40	2.4 to 3.5 (A1a.1) 2.5 (A1a.2)	≤ 3.5 (cabled)	≤ 3.5 (cabled)	≤ 2.5	≤ 2.5	≤ 3.0
	at 1300 nm	≤ 0.6 to 0.7		0.7 to 1.5 (A1a.1) 0.8 (A1a.2)	≤ 1.5 (cabled)	≤ 1 (cabled)	≤ 0.8	≤ 0.8	≤ 1.0
	at 1385 nm (OH peak)	< 2.0		—	—	—	≤ 3.0	≤ 3.0	≤ 3.0
Discontinuity [dB]	at 850 nm	≤ 0.1	FOTP 78 IEC 60793-1-40	—	—	—	≤ 0.2	≤ 0.2	≤ 0.2
	at 1300 nm	≤ 0.1		—	—	—	≤ 0.2	≤ 0.2	≤ 0.2
Bend-induced attenuation [dB] for OptiGrade / GigaGrade									
100 turns Radius 37.5 mm	at 850 / 1300 nm	≤ 0.5	FOTP 62 IEC 60793-1-47	≤ 0.5	—	—	—	—	—
Bend-induced attenuation [dB] for j-Bendable									
100 turns Radius 37.5 mm	at 850 nm	≤ 0.05	FOTP 62 IEC 60793-1-47	≤ 0.5	—	—	—	—	—
	at 1300 nm	≤ 0.15		≤ 0.5	—	—	—	—	—
2 turns Radius 15 mm	at 850 nm	≤ 0.1		—	—	< 1	—	—	—
	at 1300 nm	≤ 0.3		—	—	< 1	—	—	—
2 turns Radius 7.5 mm	at 850 nm	≤ 0.2		—	—	—	—	—	—
	at 1300 nm	≤ 0.5		—	—	—	—	—	—

Modal bandwidth [MHz×km]		OM2 (GigaGrade)	OM2+ (OptiGrade / j-Bendable)	OM3 (OptiGrade / j-Bendable)	OM4 (OptiGrade / j-Bendable)	Test methods	IEC 60793-2-10	ISO/IEC 11801	ITU G651.1	TIA/EIA 492AAD OM4	TIA/EIA 492AAAC-B OM3	TIA/EIA 492AAAB-A OM2
OFL	at 850 nm	≥ 500 to 600	≥ 750	≥ 1500	≥ 3500	FOTP 204 IEC 60793-1-41	200 to 800 (A1a.1) 1500 (A1a.2)	≥ 200 (OM1) ≥ 500 (OM2) ≥ 1500 (OM3) ≥ 3500 (OM4)	≥ 500	≥ 3500	≥ 1500	≥ 500
OFL	at 1300 nm	≥ 500 to 1200	≥ 500	≥ 500	≥ 500		500	≥ 500 (OM1/2/3/4)	≥ 500	≥ 500	≥ 500	≥ 500
EMB	at 850 nm	–	≥ 1000	≥ 2000	≥ 4700	FOTP 220 IEC 60793-1-49	≥ 2000 (A1a.2)	≥ 2000 (OM3)		≥ 4700	≥ 2000	
Transmission link length 1 Gb/s [m]	at 850 nm	550 to 750	750	1000	1100	—	—	—	—	—	—	—
	at 1300 nm	550 to 2000	550	550	550	—	—	—	—	—	—	—
Transmission link length 10 Gb/s [m]	at 850 nm	n.a.	150	300	550	—	—	—	—	—	—	—
	at 1300 nm	n.a.	300	300	300	—	—	—	—	—	—	—

		Multimode fiber specifications	Test methods	IEC 60793-2-10	ISO/IEC 11801	ITU G651.1	TIA/EIA 492AAD OM4	TIA/EIA 492AAAC-B OM3	TIA/EIA 492AAAB-A OM2
Chromatic dispersion Slope at zero crossing of dispersion – λ_0 [nm]		1295≤ λ_0 ≤ 1340	FOTP 175 IEC 60793-1-32	1295≤ λ_0 ≤ 1340	—	1295≤ λ_0 ≤ 1340	1295≤ λ_0 ≤ 1340	1295≤ λ_0 ≤ 1340	1295≤ λ_0 ≤ 1340
Slope at zero crossing of dispersion – S_0 [ps/(nm²×km)] from 1295 ≤ λ_0 ≤ 1310 from 1310 ≤ λ_0 ≤ 1340		≤ 1.105 ≤ 0.000375×(1590-λ_0)		≤ 1.105 ≤ 0.000375×(1590-λ_0)	—	≤ 0.105 ≤ 0.000375 × (1590-λ_0)			
Geometrical properties									
Core Ø [µm]		50 ±2.5	FOTP 176 IEC 60793-1-20	50 ±2.5	50 ±2.5	50 ±3.0	50 ±2.5	50 ±2.5	50 ±3.0
Cladding Ø [µm]		125 ±1.0		125 ±2.0	125 ±2.0	125 ±2.0	125 ±2.0	125 ±2.0	125 ±2.0
Cladding non-circularity [%]		≤ 1.0		≤ 2.0	≤ 2.0	≤ 2.0	≤ 2.0	≤ 2.0	≤ 2.0
Core non-circularity [%]		≤ 5		≤ 6	≤ 6	≤ 6	≤ 6	≤ 6	≤ 6
Core/cladding concentricity error [µm]		≤ 1.5		≤ 3.0	≤ 3.0	≤ 3.0	≤ 3.0	≤ 3.0	≤ 3.0
Coating Ø [µm]		242 ±7	FOTP 176 IEC 60793-1-20	245 ±10	245 ±10	245 ±10	245 ±10	245 ±10	245 ±10
Numerical aperture		0.200 ±0.015	FOTP 177 IEC 60793-1-43	0.200 ±0.015	0.200 ±0.015	0.200 ±0.015	0.200 ±0.015	0.200 ±0.015	0.200 ±0.015
Length [km]	j-BendAble/ OptiGrade	1.1 to 8.8	Calibrated Winder IEC 60793-1-22	—	—	—	min. 1.1	min. 1.1	min. 1.1
	GigaGrade 50/125	1.1 to 17.6							
Proof test [GPa]	j-BendAble	≥ 200 (kpsi) ≥ 1.38 (GPa)	FOTP 31 IEC 60793-1-30	≥ 0.69	—	≥ 0.69	≥ 0.69	≥ 0.69	≥ 0.69
	OptiGrade/ GigaGrade	≥ 100 (kpsi) ≥ 0.69 (GPa)							
Coating strip force [N]	peak value	1.0 ≤ x ≤ 8.9	FOTP 178 IEC 60793-1-32	1.0 ≤ x ≤ 8.9	—	—	1.0 ≤ x ≤ 9.0	1.0 ≤ x ≤ 9.0	1.0 ≤ x ≤ 9.0
	average value	1.0 ≤ x ≤ 5.0		1.0 ≤ x ≤ 5.0	—	—	—	—	—

62.5/125 µm GigaGrade		Multimode fiber specifications	Test methods	IEC 60793-2-10 A1b	ISO/IEC 11801	TIA/EIA 492AAAA-A (OM1)
Performance properties						
Attenuation [dB/KM]	at 850 nm	≤ 2.7 to ≤ 2.9	FOTP 78 IEC 60793-1-40	2.8 to 3.5	≤ 3.5 (cabled)	—
	at 1300 nm	≤ 0.6 to 0.7		0.7 to 1.5	≤ 1.5 (cabled)	—
	at 1385 nm (OH peak)	< 2.0		—	—	—
Discontinuity [dB]	at 850 nm	≤ 0.1	FOTP 78 IEC 60793-1-40	—	—	≤ 0.2
	at 1300 nm	≤ 0.1		—	—	≤ 0.2
Modal bandwidth [MHz×km]						
OFL	at 850 nm	≥ 200 to 300	FOTP 78 IEC 60793-1-41	100 to 800	≥ 200 (OM1)	≥ 200
OFL	at 1300 nm	≥ 500 to 1000		200 to 1000	≥ 500	≥ 500
Transmission link length 1 Gb/s [m]	at 850 nm	300	—	—	—	—
	at 1300 nm	500		—	—	—
Chromatic dispersion Zero crossing of dispersion –λ_0 [nm]		$1320 \leq \lambda_0 \leq 1365$	FOTP 175 IEC 60793-1-32	$1320 \leq \lambda_0 \leq 1365$	—	$1320 \leq \lambda_0 \leq 1365$
Slope at zero crossing of dispersion – S_0 [ps/(nm²×km)] from $1320 \leq \lambda_0 \leq 1345$ from $1345 \leq \lambda_0 \leq 1365$		≤ 0.11 ≤ 0.001×(1458-λ_0)		≤ 0.11 ≤ 0.001×(1458-λ_0)	—	≤ 0.11 ≤ 0.001×(1458-λ_0)
Geometrical properties						
Core Ø [µm]		62.5 ±2.5	FOTP 176 IEC 60793-1-20	62.5 ±3.0	62.5 ±3.0	62.5 ±3.0
Cladding Ø [µm]		125 ±1.0		125 ±2.0	125 ±2.0	125 ±2.0
Cladding non-circularity [%]		≤ 1.0		≤ 2.0	≤ 2.0	≤ 2.0
Core non-circularity [%]		≤ 5		≤ 6	≤ 6	≤ 6
Core/cladding concentricity error [µm]		≤ 1.5		≤ 3.0	≤ 3.0	≤ 3.0
Numerical aperture		0.275 ±0.015	FOTP 177 IEC 60793-1-43	0.275 ±0.015	0.275 ±0.015	0.275 ±0.015
Length [km]	GigaGrade 62.5/125	1.1 to 17.6	Calibrated Winder IEC 60793-1-22	—	—	min. 1.1
Proof test [GPa]	GigaGrade 62.5/125	≥ 100 (kpsi) ≥ 0.69 (GPa)	FOTP 31 IEC 60793-1-30	≥ 0.69	—	≥ 0.69
Coating strip force [N]	peak value	1.0 ≤ x ≤ 8.9	FOTP 178 IEC 60793-1-32	1.0 ≤ x ≤ 8.9	—	1.0 ≤ x ≤ 9.0
	average value	1.0 ≤ x ≤ 5.0		1.0 ≤ x ≤ 5.0	—	—

50/125 | 62.5/125 µm j-BendAble / OptiGrade / GigaGrade 50 / GigaGrade 62.5	Multimode fiber specifications	Test methods	Industrial standards					
			IEC 60793-2-10	ISO/IEC 11801	TIA/EIA 492AAD OM4	TIA/EIA 492AAAC–B OM3	TIA/EIA 492AAAB–A OM3	TIA/EIA 492AAAA–A OM1
Change of attenuation in environmental test [dB/km] at 850 nm and 1300 nm								
Damp heat attenuation increase 30 days at 85 °C / 85 % R.H.	≤ 0.10	FOTP 72 IEC 60793-1-50	≤ 0.20	—	≤ 0.20	≤ 0.20	≤ 0.20	≤ 0.20
Dry heat attenuation increase 30 days at 85 °C		FOTP 72 IEC 60793-1-51						
Change of temperature attenuation increase from –60 °C to +85 °C		FOTP 72 IEC 60793-1-52						
Water immersion attenuation increase, 30 days, 23 °C		FOTP 72 IEC 60793-1-53						

Radiation-hard fibers

Multimode fiber G50/125, G62.5/125

Description

Radiation-hard MIL-Spec multimode and singlemode fibers were specially developed for applications in for example aerospace industries in order to withstand the hazards in radiation-threatened areas or under demanding environmental conditions.

All listed radiation-hard MIL-Spec fibers were tested and approved by the U.S. Defense Supply Center, Columbia (DSCC) according to MIL-PRF 49291. In addition these fibers meet and exceed the quality standards of the ITU G.651 and G.652 or IEC 60793-2-10 and IEC 60793-2-50.

Fiber quality assurance

- MIL-PRF-49291 U.S. Military Specification
- ITU Recommendation G.651 and G.652
- IEC 60793-2-10 and IEC 60793-2-50 (Optical Fiber Specifications)

Every fiber is subject to a 100 percent quality test according to the IEC 60793 standard. In addition, their resistance to radiation is tested according to TIA/EIA 455-64 (Procedure for Measuring Radiation-Induced Attenuation in Optical Fibers).

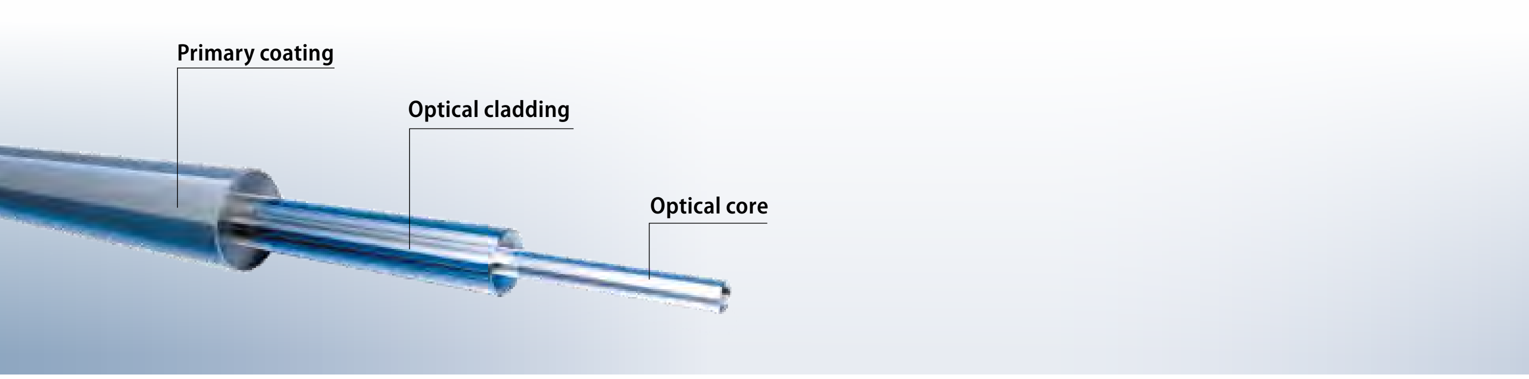
MIL specifications radiation-resistant multimode fibers

	50/125/245 µm	50/125/500 µm	62.5/125/245 µm	62.5/125/500 µm
	MIL-PRF-49291/1-01	MIL-PRF-49291/1-02	MIL-PRF-49291/6-03	MIL-PRF-49291/6-05
Optical properties				
Core Ø (±3) [µm]	50	50	62.5	62.5
Core ovality	≤ 6.0	≤ 6.0	≤ 6.0	≤ 6.0
Core/cladding concentricity error	≤ 1.5	≤ 1.5	≤ 4	≤ 4
Cladding Ø (±1) [µm]	125	125	125	125
Cladding ovality [µm]	≤ 2.0	≤ 2.0	≤ 2.0	≤ 4
Attenuation at 850 nm/1300 nm [dB/km]	3.5 / 1.0	3.5 / 1.0	3.5 / 1.0	3.5 / 1.0
Uniform attenuation at 1310 nm [dB]	≤ 0.2	≤ 0.2	≤ 0.2	0.2
Transient attenuation at 1310 nm [dB]	≤ 1.5	≤ 1.5	–	–
OFL bandwidth at 850 nm/1300 nm [MHz×km]	500/500	500/500	300/600	300/600
RML bandwidth at 850 nm/1300 nm [MHz×km]	N.A.	N.A.	385/700	385/700
Numerical aperture at 850 nm	0.200 ±0.015	0.200 ±0.015	0.275 ±0.015	0.275 ±0.015
Zero crossing of dispersion λ_0 [nm]	$1295 \leq \lambda_0 \leq 1340$	$1295 \leq \lambda_0 \leq 1340$	$1320 \leq \lambda_0 \leq 1365$	$1320 \leq \lambda_0 \leq 1365$
Slope at zero crossing of dispersion S_0 [ps/nm²×km]	≤ 0.11	≤ 0.11	≤ 0.11	≤ 0.11
Macrobending loss at 1300nm* [dB]	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5
	Coating - Acrylate temperature range –55 °C to +85 °C			
Coating Ø [µm]	245 ± 10.0	500 ± 25	250 ± 15	500 ± 25
Core/cladding concentricity error [µm]	≤ 12.5	≤ 15.0	≤ 10.5	≤ 15.0
Overall coating concentricity ratio (OCCR)	≥ 0.70	≥ 0.84	≥ 0.70	≥ 0.84
Mechanical properties				
Length** [km]	≥ 1.1	≥ 1.1	≥ 1.1	≥ 1.1
Fiber weight [kg/km]	≤ 0.1	≤ 0.25	≤ 0.1	≤ 0.25
Proof test [MPa]	≥ 690	≥ 690	690	690
Dynamic tensile strength [GPa] unaged	≥ 3.2	≥ 3.2	≥ 3.2	≥ 3.2
Dynamic tensile strength [GPa] aged	≥ 1.75	≥ 1.75	≥ 1.75	≥ 1.7
Operating temperature [°C]	–55 to +85	–55 to +85	–46 to +85	–46 to +85
Storage temperature [°C]	–62 to +85	–62 to +85	–62 to +85	–62 to +85
Coating strip force [N]	1.8 ≤ F ≤ 13.2	1.8 ≤ F ≤ 20.0	1.8 ≤ F ≤ 13.2	1.8 ≤ F ≤ 20.0

* Radius 3.8 ±0.05 cm, 100 turns
** Max. lengths of up to 17.6 km are available on request.

Radiation-hard fibers

Singlemode fiber 09/125



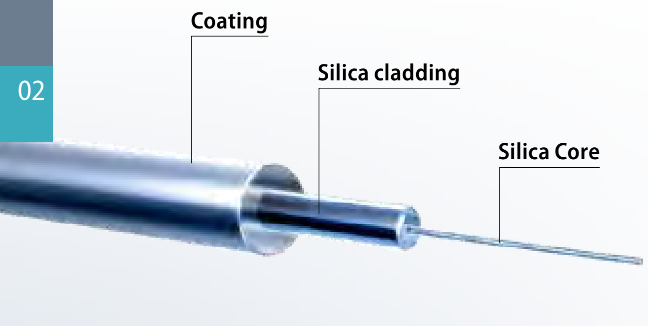
MIL specifications for radiation-resistant singlemode fiber SMF

	09/125/245µm	09/125/245µm
	MIIL-PRF-49291/7-01	MIIL-PRF-49291/7-02
Optical properties	**Specified values**	
Core/cladding concentricity error	≤ 1.0	≤ 1.0
Cladding Ø (±1) [µm]	125	125
Cladding ovality [µm]	≤ 2.0	≤ 2.0
Attenuation at 1310 nm/1550 nm [dB/km]	0.4/0.3	0.4 / 0.3
Uniform attenuation at 1310 nm [dB]	≤ 0.1	≤ 0.1
Mode field Ø [µm]	8.5 ≤ MFD ≤ 10.0	8.5 ≤ MFD ≤ 10.0
Chromatic dispersion at 1310 nm/1550 nm [ps/nm²×km]	≤ 3.2/22	≤ 3.2/22
Macrobending loss at 1300nm* [dB]	≤ 0.5	≤ 0.5
Coating Ø [µm]	250 ± 15	500 ± 25
Coating/cladding concentricity error [µm]	≤ 10.5	≤ 15.0
Overall coating concentricity ratio (OCCR)	≥ 0.70	≥ 0.84
Mechanical properties		
Length [km]	≥ 1.1	≥ 1.1
Fiber weight [kg/km]	≤ 0.1	≤ 0.25
Proof test [MPa]	≥ 690	≥ 690
Dynamic tensile strength [GPa] unaged	≥ 3.2	≥ 3.2
aged	≥ 1.75	≥ 1.75
Operating temperature [°C]	−46 to +85	−46 to +85
Storage temperature [°C]	−55 to +85	−55 to +85
Coating strip force [N]	1.8 ≤ F ≤ 13.2	1.8 ≤ F ≤ 20.0

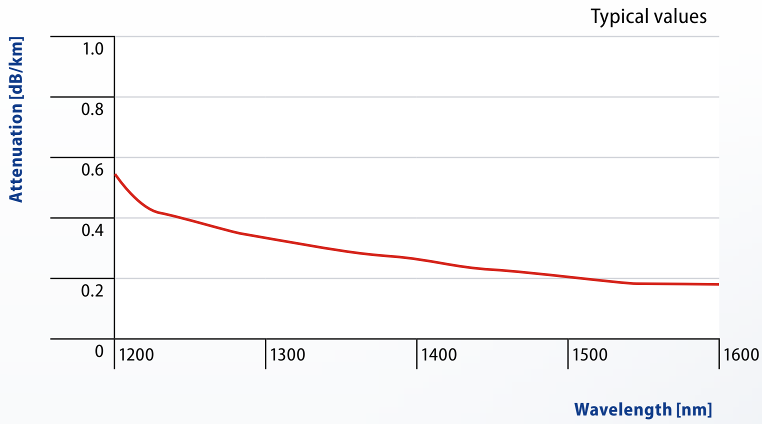
* Radius 3.8 ±0.05 cm, 100 turns

Standard singlemode fiber

Reliable tried and tested singlemode fiber for LAN, FTTX and long distance applications



Typical spectral attenuation for LWP SMF+



Description

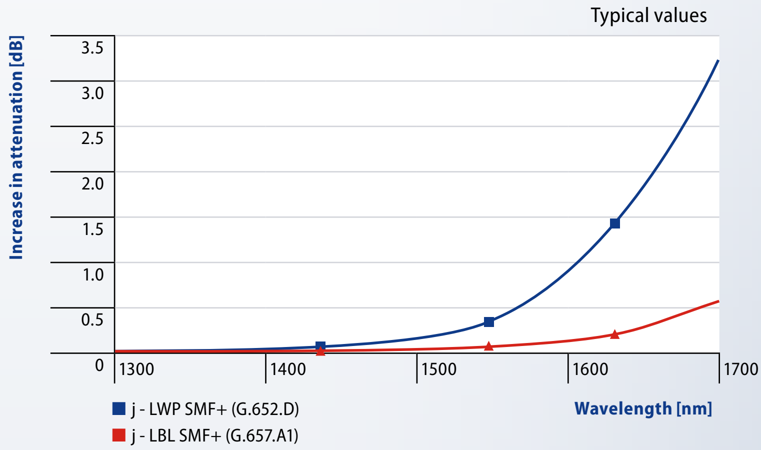
For the bridging of larger distances in LAN cabling as well as for FTTX applications we offer reliable high-performance singlemode fibers.

The G.657.A1 compliant fibers are compatible with installed networks and offer optimized bending properties. With lowest attenuation, perfect fiber geometry and tight fiber diameter tolerances, they are perfectly suited for the system demands in LAN networks.

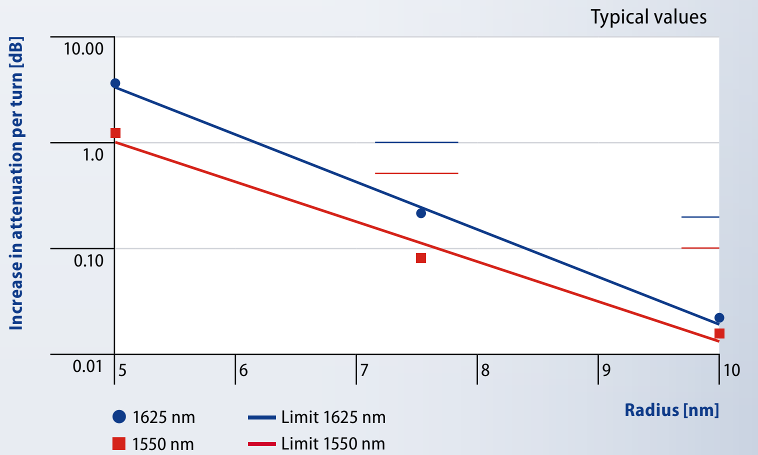
In FTTX applications they meet the requirements for robust and cost-efficient fiber solutions with a future-proof perspective.

In long-distance applications our G.652.D singlemode fibers guarantee cost advantages and performance consistency as required for the transmission of high data rates over long distances.

Comparison of bend-performance of the LBL singlemode fiber to other G.652.D SMF (10 mm radius, 1 turn)



Typical bend-performance of ULBL SMF (G.657.B2)



		LWP SMF+ (ITU-T G.652.D)	LBL SMF (ITU-T G.657 A.1)	ULBL SMF (ITU-T G.657.B2)
Optical properties		Specific values		
Attenuation coefficient [1] [dB/km]	1310 nm	≤ 0.33 to ≤ 0.35	≤ 0.33 to ≤ 0.36	≤ 0.38
	1383 nm [2]	≤ 0.31 to ≤ 0.35	≤ 0.31 to ≤ 0.36	–
	1550 nm	≤ 0.19 to ≤ 0.21	≤ 0.19 to ≤ 0.21	≤ 0.25
	1625 nm	≤ 0.20 to ≤ 0.23	≤ 0.20 to ≤ 0.23	≤ 0.25
Attenuation variance range [3] [dB/km]	1285–1330 nm	≤ 0.03	≤ 0.03	–
	1530–1570 nm	≤ 0.02	≤ 0.02	
	1460–1625 nm	≤ 0.04	≤ 0.04	
Mode field Ø [µm]	1310 nm	9,2 ± 0.4	8,6 ± 0.4	7.5 ± 0.4
	1550 nm	10.4 ± 0.5	9.8 ± 0.5	
Discontinuity (tp = 1 µs) [dB]	1310 nm	≤ 0.05	≤ 0.05	–
	1550 nm	≤ 0.05	≤ 0.05	–
Attenuation uniformity [dB]		≤ 0.05	≤ 0.05	–
Macrobending loss				
Bend-induced attenuation [dB]				
100 turns	1310 nm	≤ 0.05	–	–
Radius 50 mm	1550 nm	≤ 0.05	–	–
1 turn Radius 32 mm	1550 nm	≤ 0.05	– –	– –
10 turns	1550 nm	–	≤ 0.03	≤ 0.03
Radius 15 mm	1625 nm	–	≤ 0.2	≤ 0.1
1 turn	1550 nm	–	≤ 0.3	≤ 0.1
Radius 10 mm	1625 nm	–	≤ 1.0	≤ 0.2
1 turn	1550 nm	–	–	≤ 0.5
Radius 7.5 mm	1625 nm	–	–	≤ 1.0
Fiber cut-off wavelength λ_c [nm]		1200–1330	≤ 1340	–
Cable cut-off wavelength λ_{cc} [nm]		≤ 1260	≤ 1260	–
Zero crossing of dispersion λ_0 [nm]		$1300 \leq \lambda_0 \leq 1324$	$1300 \leq \lambda_0 \leq 1324$	–
Slope at zero crossing of dispersion S_0 [ps/nm²×km]		≤ 0.092	≤ 0.092	–
Chromatic dispersion [ps/nm×km]	1270–1340 nm	≤ 5.00	≤ 5.00	–
	1285–1330 nm	≤ 3.00	≤ 3.00	–
	1550 nm	≤ 18.00	≤ 18.00	–
Effective group index	1310 nm	1.467	1.467	–
	1383 nm	1.467	1.467	–
	1550 nm	1.467	1.467	–
Value of polarization mode dispersion link [4] [ps/√km]		≤ 0.06	≤ 0.06	–
Individual fiber [5] [ps/√km]		≤ 0.10	≤ 0.10	–

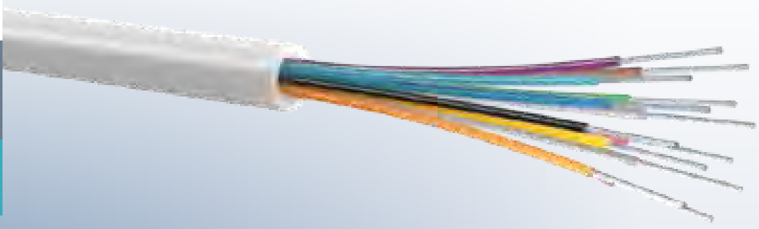
Mechanical properties		Specified values
Proof test	[kpsi]	≥ 100
	[N]	≥ 8.8
	[GPa]	≥ 0.7
Dynamic tensile strength in an unaged fiber (0.5 m) [GPa]	Median tensile strength	≥ 3.8
	Tensile strength 15 %	≥ 3.3
Dynamic tensile strength in an aged fiber (0.5 m) [GPa]	Median tensile strength	≥ 3.03
	Tensile strength 15 %	≥ 2.76
Dynamic fatigue	Stress-corrosion parameter n_d	≥ 20
Operating temperature [°C]		−60 to +85
Average coating strip force (typ.) [N]		1.9

[1] Special attenuation cells on request.
[2] Attenuation values for 1383 nm represent values after hydrogen charging and are always lower or equal to the attenuation value for 1310 nm.
[3] Fiber attenuation in specified areas exceeds the nominal values at 1310/1550 nm no more than the declared value.
[4] M = 20, Q = 0.01 %
[5] Individual values can change during the cabling.

FiberUnit series

Customer-specific MMF or SMF multi-fiber units

Multi-fiber units
combine high-performance fibers
for highly efficient cabling solutions



Description

The FiberUnit series is a new product line with unique advantages – paricularly interesting concerning cost-optimized cable manufacturing

Optical multimode and/or singlemode high performance fibers are available packaged and bundled in units with optional 2, 4, 6, 8 or 12 fibers. The FiberUnits are delivered with a protective acrylate coating which can be easily removed. Next to the insertion of the individual fiber within the unit the finished FiberUnits can receive a ring marking for better identification in high-power cables.

Take advantage of the benefits of the FiberUnit series with bundling service ➔ with this product series you can outsource a complicated production step and thus focus on the efficient manufacturing of optical high-performance cables.

Services & advantages

- Possibility for the manufacturer to outsource the FiberUnit packaging manufacturing stage
- FiberUnits contain optical multimode and / or singlemode high-performance fibers
- Customer-specific fiber design
- Delivery with protective, easily removable acrylate coating on demand
- Various fiber designs in standard colour code or with individualised colours

Number of fibers per unit

Specification FiberUnit		4	6	8	12
		specified values			
Fiber colours		according to IEC 60304 ● red, ● green, ● blue, ● yellow, ○ white, ● grey, ● brown, ● violet, ● turquoise, ● black, ● orange, ● pink (ring marking of unit fibers available on request)			
Coating unit material		UV-cured acrylate			
Colour of unit material coating		transparent			
Filling compound		easily removable gel			
Operating temperature [°C]	at MMF 50	–20 to +80			
	at MMF 62.5 / SMF (G.657.A1)	–40 to +80			
Outer Ø [µm]		850 ± 50	1000 ± 50	1100 ± 50	1350 ± 50

CHAPTER 03

Special optical fibers

Optical fibers with customer-specific design

Optical fibers as a transmission medium for light can be fitted to every desired customer application. The fiber's composition offers different parameters that can be individually adjusted:

Core · Jacket · Coating · Cable design · Assembly

- For the transmission of high data rates singlemode fibers or graded-index mulitmode fibers are used. With graded-index multimode fibers, the profile must be manufactured as perfectly as possible in order to achieve the transmission of very large bandwiths through low modal dispersion.
- For high-power transmission step-index multimode fibers are used. For most of them, undoped fused silica is chosen as core material, as it is suitable for high-power transmission such as laser transmission due to its low attenuation level. Doped fused silica is used if a particularly high numerical aperture for improved launching of light into the fiber or special fiber profiles are needed.
- Shape and size of the fiber core can be adjusted to the application's demands.
- The use of an appropriate coating material and / or an additional layer helps to protect the fiber under different mechanical, thermal or chemical environmental conditions.
- All fibers can be customer-specifically assembled according to your application fields.

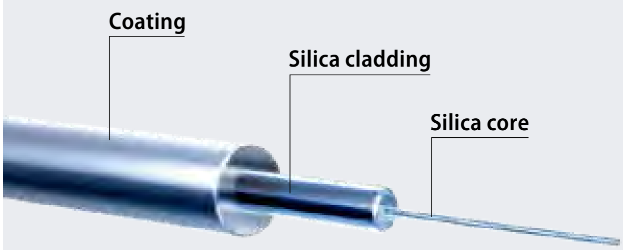
Benefit from our competence in influencing the fiber properties and creating customer-specific fiber solutions. We can rely on an entire value chain – from ultrapure fused silica to the assembly of the finished fiber.


Further additional information on fiber types:
Chapter 12 | Principles
→ page 365 ff

03. Special optical fibers

FiberTech® singlemode special fibers

Bend-insensitive, Select-Cut-Off and polarization-maintaining fibers (PM)



We offer a wide portfolio of Select-Cut-Off and polarization-maintaining singlemode fibers for a wide wavelength range from UV to IR.

Singlemode special fibers are the correct choice for current and future applications in data transmission, optical communications, sensorics and high-power laser transmission. They offer excellent geometrical specifications, high stability and best tolerances in fiber geometry.

Apart from our Singlemode standard fibers, we offer a variety of options and possibilities for adjusting the fiber's design to the customer's application. This covers specific cut-off wavelengths from UV to IR as well as mode field diameters at the desired operating wavelength. Customer-specific demands concerning the numerical aperture can be met by the use of appropriate doping concentrations or special refractive index profiles. Reduced jacket-geometry or adjusted dispersion support the challenging application fields of our customers.

Our singlemode fibers can be coated with acrylate or dual acrylate, high-temperature acrylate or polyimide coatings. Additional jacketing with Nylon or Tefzel buffer materials protects the fibers during the operation in different temperature ranges or under chemical influences.

All fibers can be customer-specifically assembled according to your respective application fields.

FiberTech® Select-Cut-Off singlemode fibers

	Select-Cut-Off singlemode fibers: VIS-IR							
Mode field Ø [µm]	3.5 at 460 nm	3.3 at 488 nm	3.5 at 515 nm	4.4 at 630 nm	4.0 at 630 nm	5.0 at 850 nm	5.6 at 830 nm	4.2 at 830 nm
Jacket Ø [µm]	125	125	125	125	125	125	125	80
Transmision properties								
Wavelength range [nm]	400–550	450–515	450–580	600–700	600–760	760–980	800–920	800–840
Cut-Off wavelength [nm]	370	400	430	550	570	730	730	700
Attenuation [dB/km]	35 at 460 nm	12 at 630 nm	12 at 630 nm	15 at 630 nm	12 at 630 nm	3.5 at 850 nm	5 at 830 nm	5 at 830 nm
Numerical aperture	0.12	0.10–0.14	0.13	0.10–0.14	0.13	0.13	0.10–0.14	0.14–0.18
	Coating – acrylate							
Coating Ø [µm]	245	245	245	245	245	245	245	165
Order no.:	84820001F	84820002F	84820003F	84820004F	84820005F	84820006F	84820007F	84820008F

Further jacket diameters, cut-off wavelengths, coatings and assemblies on request.

	Select-Cut-Off singlemode fibers: VIS-IR						
Mode field Ø [µm]	2.6 at 1100 nm	5.8 at 980 nm	4.2 at 980 nm	5.9 at 980 nm	3.3 at 1100 nm	2.6 at 1100 nm	9 at 1310 nm
Jacket Ø [µm]	125	125	125	125	125	125	80
Transmision properties							
Wavelength range [nm]	960–1600	970–1210	980–1600	980–1600	1100–1600	1100–1600	1250–1610
Cut-Off wavelength [nm]	900	920	920	920	1000	1000	1200
Attenuation [dB/km]	20 at 1550 nm	3 at 980 nm	3.5 at 980 nm	2.1 at 980 nm	20 at 1550 nm	20 at 1550 nm	2 at 1310 nm
Numerical aperture	0.35	0.14	0.2	0.14	0.28	0.35	0.11–0.13
	Coating – acrylate						
Coating Ø [µm]	245	245	245	245	245	245	165
Order no.:	84820009F	84820010F	84820011F	84820013F	84820014F	84820015F	84820016F

Further jacket diameters, cut-off wavelengths, coatings and assemblies on request

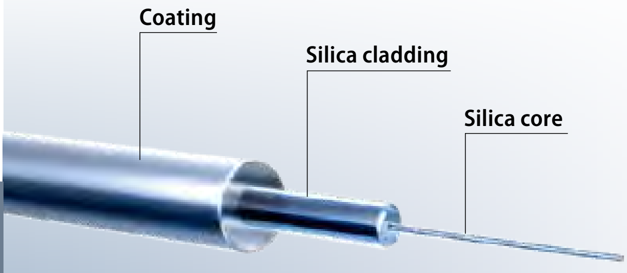
	Select-Cut-Off singlemode fibers : VIS-IR							
Mode field Ø [µm]	5.4 at 1310 nm	9.3 at 1310 nm	6.7 at 1310 nm	9.5 at 1550 nm	9.5 at 1550 nm	4.2 at 1550 nm	8.8 at 1550 nm	8.8 at 1550 nm
Jacket Ø [µm]	80	80	80	125	80	125	125	125
Transmision properties								
Wavelength range [nm]	1250–1610	1310–1620	1310–1620	1460–1620	1460–1620	1460–1620	1330–1620	1330–1620
Cut-Off wavelength [nm]	1200	1250	1250	1400	1400	1430	1200	1200
Attenuation [dB/km]	2 at 1310 nm	0.75 at 1310 nm	0.75 at 1310 nm	0.5 at 1550nm	0.5 at 1550 nm	3 at 1550 nm	3 at 1550 nm	3 at 1550 nm
Numerical aperture	0.19–0.21	0.11	0.16	0.13	0.13	0.29–0.31	0.14	0.14
	Coating – acrylate							
Coating Ø [µm]	165	165	165	245	165	245	245	245
Order no.:	84820017F	84820018F	84820019F	84820020F	84820021F	84820022F	84820023F	84820024F

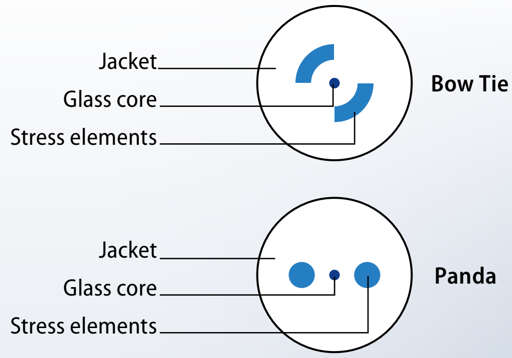
Further jacket diameters, cut-off wavelengths, coatings and assemblies on request

FiberTech® Polarization-maintaining fibers (PM)

Fiber specifications

Polarization maintaining fibers
VIS-IR





Polarization-maintaining fibers are special singlemode fibers that maintain the polarization of the light in the fiber. Stress elementsembedded in the cladding exert mechanical stresses on the fiber core, which leads to birefringence in the fiber core.

The stress elements embedded can have different designs. These fibers are used in networks with optical fibers, for pump lasers and for microscopic applications.

	Polarization maintaining fibers: VIS-IR					
Mode field Ø [µm]	3.2 at 405 nm	3.3 at 515 nm	4.0 at 515 nm	3.6 at 488 nm	4.0 at 515 nm	3.2 at 630 nm
Jacket Ø [µm]	125	125	125	125	125	125
Transmision properties						
Wavelength range [nm]	400–500	460–630	480–540	480–540	480–540	600–675
Cut-Off wavelength [nm]	365	410	435	410	435	550
Attenuation [dB/km]	50 at 405 nm	30 at 460 nm	30 at 480 nm	100 at 488 nm	30 at 480 nm	15 at 630 nm
Fiber type	Panda	Panda	Panda	Bow tie	Panda	Bow tie
Numerical aperture	0.12	0.12	0.1	0.11	0.1	0.16
	Coating – acrylate					
Coating Ø [µm]	245	245	245	245	400	245
Order no.:	84821045G	84821001G	84821003H	84821004E	84821005H	84821006E

Jacketings and assemblies available on request.

	Polarization maintaining fibers: VIS-IR						
Mode field Ø [µm]	4.0 at 630 nm	4.0 at 630 nm	4.0 at 850 nm	5.3 at 780 nm	5.5 at 850 nm	4.2 at 830 nm	5.5 at 850 nm
Jacket Ø [µm]	125	125	125	125	125	125	125
Transmision properties							
Wavelength range [nm]	620–675	630–780	750–820	780–980	800–880	800–880	800–880
Cut-Off wavelength [nm]	560	560	680	710	725	700	725
Attenuation [dB/km]	12 at 630 nm	12 at 630 nm	8 at 780 nm	4 at 780 nm	3 at 850 nm	5 at 830 nm	3 at 850 nm
Fiber type	Panda	Panda	Bow tie	Panda	Panda	Bow tie	Panda
Numerical aperture	0.13	0.13	0.16	0.12	0.11	0.16	0.11
	Coating – acrylate						
Coating Ø [µm]	165	245	245	245	245	245	400
Order no.:	84821008H	84821009G	84821010E	84821011G	84821012H	84821013E	84821014H

Jacketings and assemblies available on request.

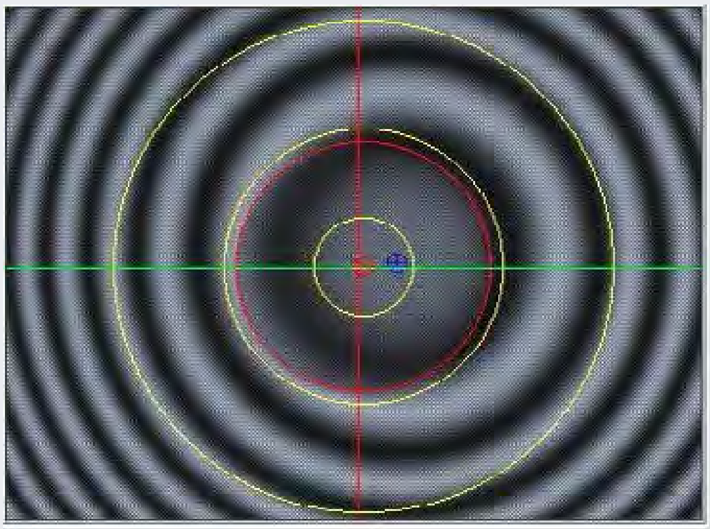
	Polarization maintaining fibers: VIS-IR				
Mode field Ø [µm]	6.6 at 980 nm	6.6 at 980 nm	6.0 at 980 nm	5.4 at 980 nm	6.6 at 1300 nm
Jacket Ø [µm]	125	125	125	125	125
Transmision properties					
Wavelength range [nm]	950–1080	950–1080	970–1170	1020–1130	1270–1390
Cut-Off wavelength [nm]	875	875	920	930	1150
Attenuation [dB/km]	2.5 at 980 nm	2.5 at 980 nm	3 at 980 nm	3 at 1064 nm	2 at 1300 nm
Fiber type	Panda	Panda	Bow tie	Bow tie	Bow tie
Numerical aperture	0.12	0.12	0.14	0.16	0.16
	Coating – acrylate				
Coating Ø [µm]	245	400	245	245	245
Order no.:	84821016H	84821017H	84821018E	84821019E	84821020E

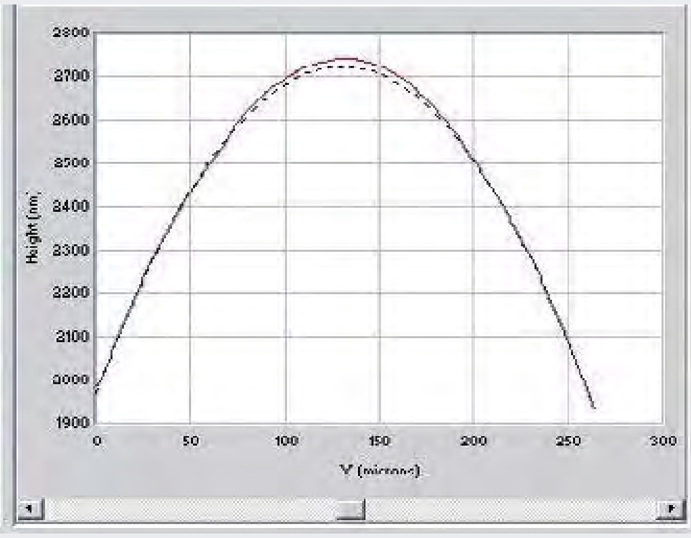
Jacketings and assemblies available on request.

	Polarization maintaining fibers: VIS-IR					
Mode field Ø [µm]	9.5 at 1300 nm	9.5 at 1300 nm	9.8 at 1400 nm	9.8 at 1400 nm	10.5 at 1550 nm	10.5 at 1550 nm
Jacket Ø [µm]	125	125	125	125	125	125
Transmision properties						
Wavelength range [nm]	1290–1485	1290–1485	1380–1560	1380–1560	1450–1620	1450–1620
Cut-Off wavelength [nm]	1195	1195	1290	1290	1370	1370
Attenuation [dB/km]	1 at 1300 nm	1 at 1300 nm	1 at 1400 nm	1 at 1400 nm	0.5 at 1550 nm	0.5 at 1550 nm
Fiber type	Panda	Panda	Panda	Panda	Panda	Panda
Numerical aperture	0.11	0.11	0.11	0.11	0.12	0.12
	Coating – acrylate					
Coating Ø [µm]	245	400	245	400	245	400
Order no.:	84821023H	84821024H	84821025H	84821026H	84821027H	84821028H

Jacketings and assemblies available on request.

Measurements on singlemode special fibers





Insertion loss

The measurement is carried out in accordance with IEC 61300-3-4 method C, alternatively DIN EN. This attenuation is determined by the wavelength and depends greatly on the launch conditions. Typical attenuation values for standard singlemode fibers 9/125 µm are 0.36 dB/km at 1310 nm and 0.21 dB/km at 1550 nm.

Return loss

The return loss enables characterisation of individual connectors. The return loss describes the ratio of launched light energy to reflected light energy and is dependent on the wavelength. The minimum return loss for singlemode is –35 dB. The measurement is carried out in accordance with IEC 61300-3-6, method 1.

Interferometric measurement

In addition to the usual parameters and checks such as insertion loss, optical checking of the end face for scratches or imperfections, the following measurements are important, although not prescribed, to ensure on the one hand that the assembly process is working correctly and on the other that optimum connector geometries are achieved:

Ferrule radius

Too small	➔	Ferrule and fiber end face pointed
Too large	➔	Ferrule and fiber end face flat
Possible consequence	➔	Glass-air-glass transitions in individual areas
	➔	Incomplete contact between the end faces and fibers and thereby possibly mechanical overload of the fibers when connecting them (they could then be deformed too much)
Result	➔	Increase of insertion loss, reduction of return loss, polarization shift or damage

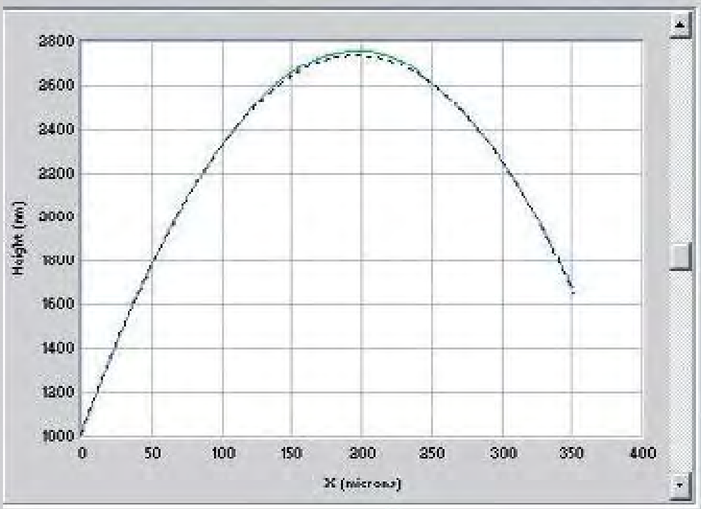
Highest point of the ferrule to center point of the fiber – eccentricity of the polish

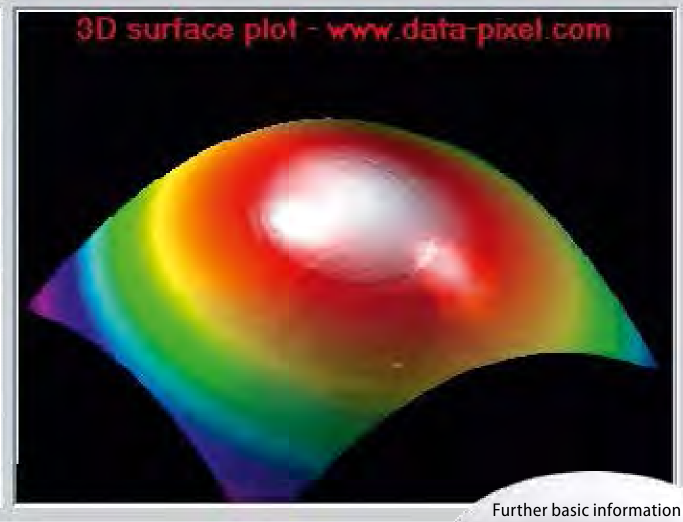
The eccentricity of the polish is the distance between the highest point of the ferrule and the center of the fiber. This offset is also called the apex offset and is measured from the fiber axis to the center. A perfectly polished connector has an apex offset of only a few µm – maximum permitted is 50 µm.

Consequence when apex is too large:

➔ Fiber cores have no physical contact

➔ Increase of insertion loss and decrease of return loss





Further basic information on signal transmission in optical fibers
Chapter 12 | Principles
→ page 367 ff

Fiber cavity – fiber sitting above or below the ferrule

Fiber sitting above ferrule:

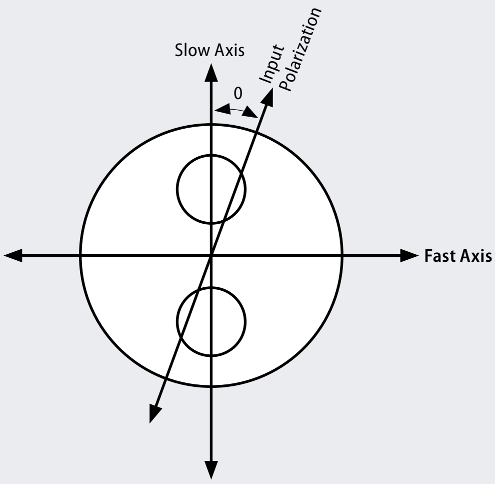
- → Damage to the fiber end faces
- → Stress on the fiber – impairment of the long-term behaviour

Fiber sitting below ferrule:

- → No physical contact (PC) between the fibers
- → Glass-air-glass transition

ER (extinction ratio) measurement

Measuring the quality of the polarized light beam is only important for polarization-maintaining fibers (PM). This value is specified in the form of the extinction ratio (ER). The ER-value describes the ratio of the attenuation in the fiber axis into which the energy is launched (usually slow axis), to the attenuation in the other axis (fast axis). The coupling into the fiber is always done in one of the both axes, and ideally there should be no crosstalk between polarization directions. The more crosstalk into the other axis occurs, the lower is the ER-value. This crosstalk can result from inexact alignment of the fiber to the light source or from mechanical or thermal stress.



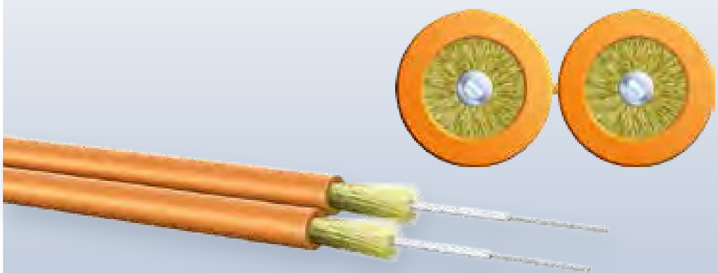
Cables with singlemode special fibers

for indoor installation

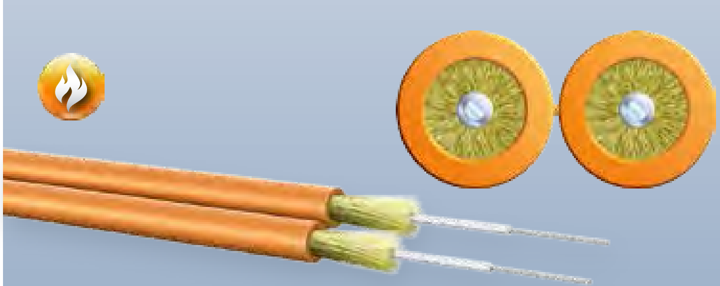
I-V(ZN)H	
Order no.	depending on fiber, on request
Application	for indoor installation
Length	500 m and above

I-V(ZN)Y	
Order no.	depending on fiber, on request
Application	for indoor installation
Length	500 m and above

A-V(ZN)11Y	
Order no.	depending on fiber, on request
Application	for outdoor installation
Length	500 m and above



I-V(ZN)Y 2×1	
Order no.	depending on fiber, on request
Application	for indoor installation
Length	500 m and above

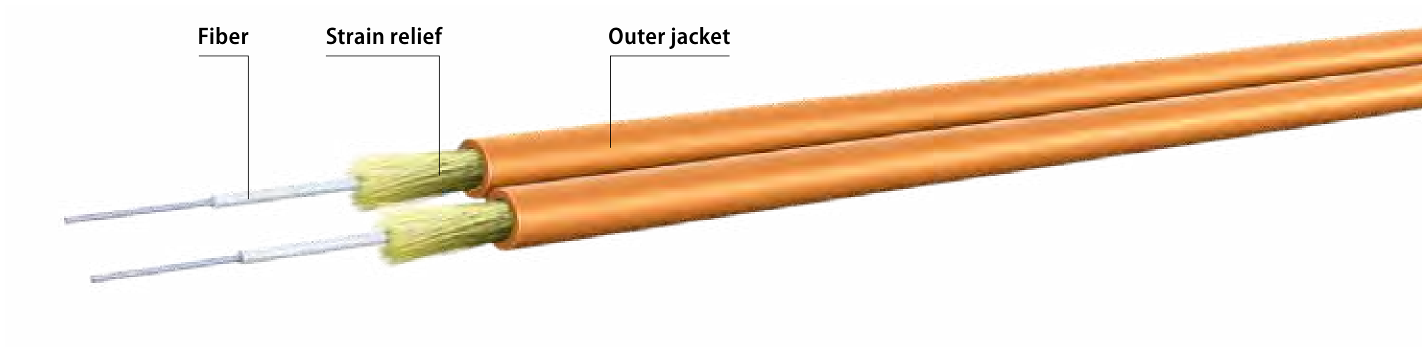


I-V(ZN)H 2×1	
Order no.	depending on fiber, on request
Application	for indoor installation
Length	500 m and above

Step-index singlemode
VIS-IR

Polarization maintaining fibers
VIS-IR

Fiber specifications singlemode special fibers		I-V(ZN)H	I-V(ZN)Y	A-V(ZN)11Y	I-V(ZN)Y 2×1	I-V(ZN)H 2×1
Order no.		depending on fiber, on request				
Composition	Outer jacket material	FRNC	PVC	PUR	PVC	FRNC
	Buffer tube material	–	–	–	–	–
	No. of fibers	1	1	1	2	1
	Outer Ø [mm]	2.2	2.2	3.0	2.2 × 4.5	2.2 × 4.5
Mechanical properties	Min. bending radius [mm]	depending on fiber, on request				
	Max. pull force [N]	depending on fiber, on request				
Thermal properties	Operating temperature [°C]	depending on fiber, on request				



Cables with singlemode special fibers

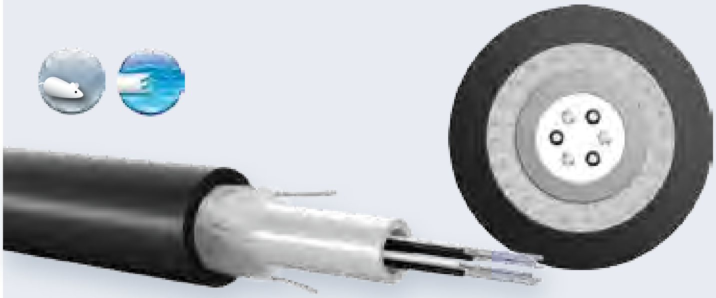
for indoor and outdoor installation

I-V(ZN)H2Y

Order no.	depending on fiber, on request
Application	for outdoor installation
Length	500 m and above

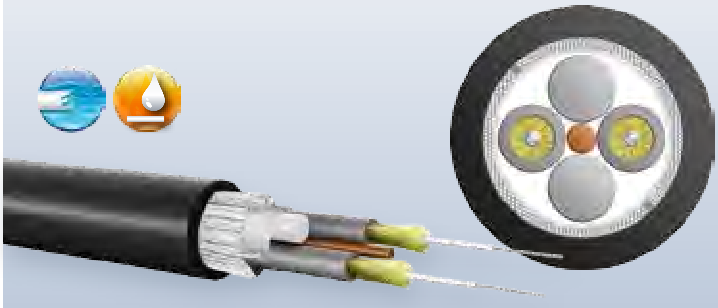
AT-V(ZN)Y11Y

Order no.	depending on fiber, on request
Application	for indoor and outdoor installation
Length	500 m and above



ADQ(ZN)BH

Order no.	depending on fiber, on request
Application	for outdoor installation
Length	500 m and above



AT-VQ(ZN)HB2Y

Order no.	depending on fiber, on request
Application	for outdoor installation
Length	500 m and above

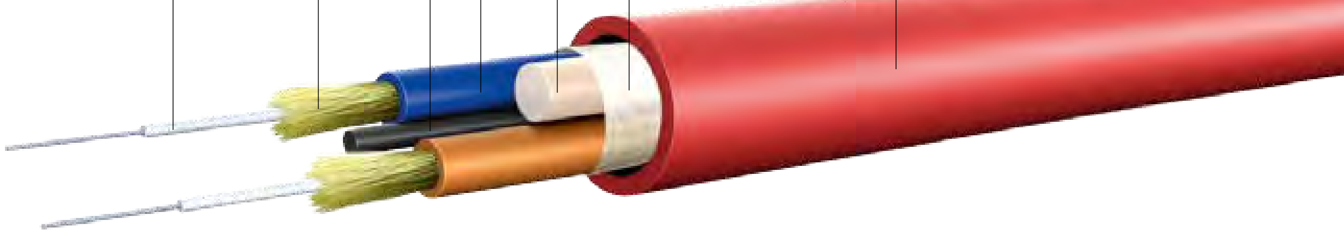
I-V(ZN)H11Y

Order no.	depending on fiber, on request
Application	for indoor installation
Length	500 m and above

Step-index singlemode
VIS-IR

Polarization maintaining fibers
VIS-IR

Fiber specifications singlemode special fibers		I-V(ZN)H2Y	AT-V(ZN)Y11Y	ADQ(ZN)BH	AT-VQ(ZN)HB2Y	I-V(ZN)H11Y
Order no.		depending on fiber, on request				
Composition	Outer jacket material	PE	PUR	PBT(P)	PE	PUR
	Buffer tube material	FRNC	PVC	FRNC	PBT(P)	FRNC
	No. of fibers	2	2	2	2	2
	Outer Ø [mm]	7.0	7.0	7.0	7.0	7.5
Mechanical properties	Min. bending radius [mm]	depending on fiber, on request				
	Max. pull force [N]	depending on fiber, on request				
Thermal properties	Operating temperature [°C]	depending on fiber, on request				

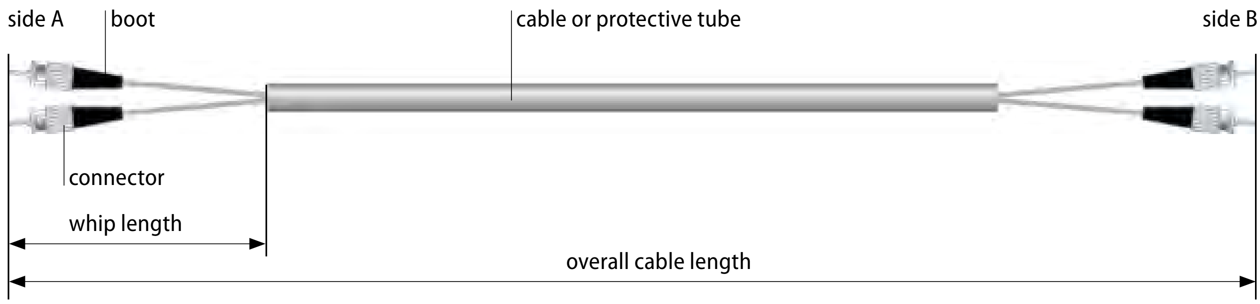


Pre-assembled cables with singlemode special fibers

Description of the composition of pre-assembled singlemode fibers

- Standard whip lengths 20 ±4 cm
- Overall length tolerances ±2%
- Different variants are available as protective tubes, for example metal corrugated tube with and without additional cladding, silicone tubes, PVC tubes
- With simplex cables, the protective tube can also be joined directly to the connector body
- Requests deviating from the above specification require a detailed analysis.

Contact us – we will find the proper solution for you.



The production of fibers and cables in LEONI's own facilities and their careful assembly under laboratory conditions ensure superior properties and maximum reliability.

In addition to standard products, we offer a range of special product functionalities and customer-specific assembly.

Service features

- All fiber and cable types (including hybrid cables)
- All connector types
- Every attenuation grade for different customer requirements
- Every length, even for single unit order sizes
- Customer-specific assembly
- Customer-specific cable printing
- Additional selective printing of the cable jacket during the process of cutting to length

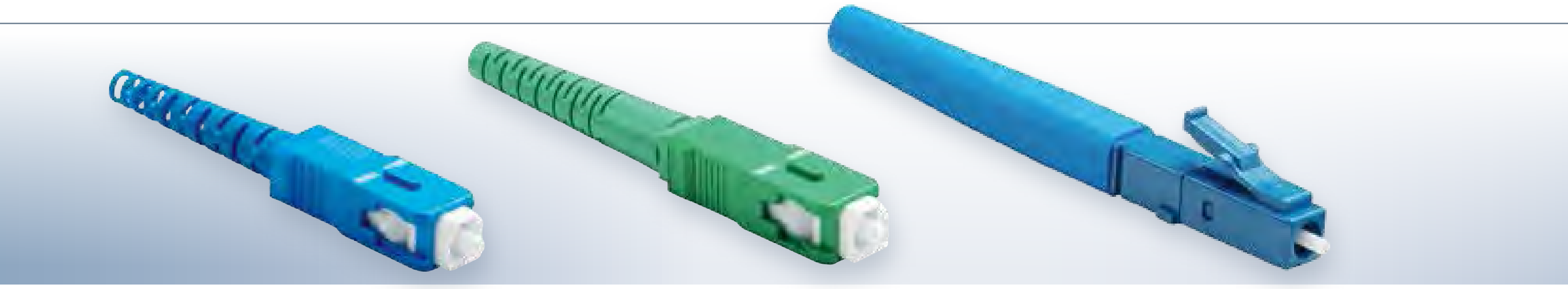
Quality assurance

The optical attenuation is defined according to the IEC61300-3-4 C standard for singlemode fibers. The result is shown on the label.

Connectors for singlemode special fibers

with ceramic ferrule

	FCPC connector	FC-APC connector	ST connector (BFOC)	SMA connector
Order no.	SFER-SK0-47-0050	SFER-SK0-47-0060	SFER-SK0-47-0010	SFER-SK0-04-0160
Hole	125 µm – 126 µm	125 µm – 126 µm	125 µm – 126 µm	125 µm – 126 µm
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing
Ferrule	ceramic	ceramic	ceramic	ceramic
Features	incl. blue or yellow boot and dust cap	incl. green boot and dust cap	incl. yellow boot and dust cap	incl. black boot and dust cap



	SC-PC connector	SC-APC connector	LC-PC connector
Order no.	SFER-SK0-47-0020	SFER-SK0-47-0070	SFER-SK0-56-0020
Hole	125 µm – 126 µm	125 µm – 126 µm	125 µm – 126 µm
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing
Ferrule	ceramic	ceramic	ceramic
Features	incl. blue boot and dust cap	incl. green boot and dust cap	incl. blue boot and dust cap

Different connector types and colours on request.

Adapters for singlemode special fibers

Special adapters are available on request.
Pre-assembled cables with singlemode special fibers

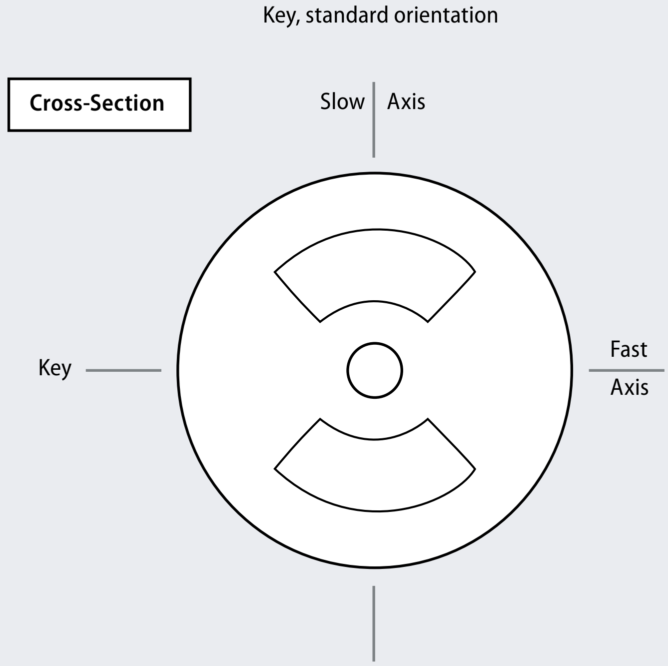
Due to our in-house production of fibers and cables through to assembly and development, excellent properties and high reliability can be achieved.

In addition to standard products, we offer a range of special product functionalities as well as customer-specific assembly.

Further basic information on connector losses and types
Chapter 12 | Principles
→ page 370 ff

Order numbers for pre-assembled cables are fiber-dependent and are generated according to the customer's request. For the assembly of PM cables or PM pigtaills, addtional information is needed:

- Alignment of the fiber axis relative to the connector key; a differentiation is made here between
  – orientation parallel to the slow axis (slow axis alignment) as standard orientation and
  – orientation relative to the fast axis
- The extinction rate should also be specified (see chapter "Measurements on special singlemode fibers")
- The required angular tolerance relative to the axis alignment must also be specified if necessary angle missalignment ± 2.5° (➔ this value is guaranteed by LEONI as standard feature)



FiberTech® Multimode special fibers

Silica/silica, sapphire, non-oxidic glasses

Multimode special fibers are used in various applications in the industrial sector, in medicine, spectroscopy, sensor technologies and high power laser applications.

Due to their versatility and their advantages, multimode fibers allow the development of demanding, innovative technologies in all areas of data and power transmission with maximum performance and tolerance to mechanical stress, radioactivity and UV radiation.

As a global provider of fibers with long-term experience in the development and manufacturing of multimode special fibers, we offer a large portfolio of fibers that cover the complete wavelength range from ultraviolet to far infrared. Concerning the fibers geometry you can choose core diameters ranging from 10 µm to 2.7 mm as well as a variety of circular and non-circular core/cladding fiber designs.

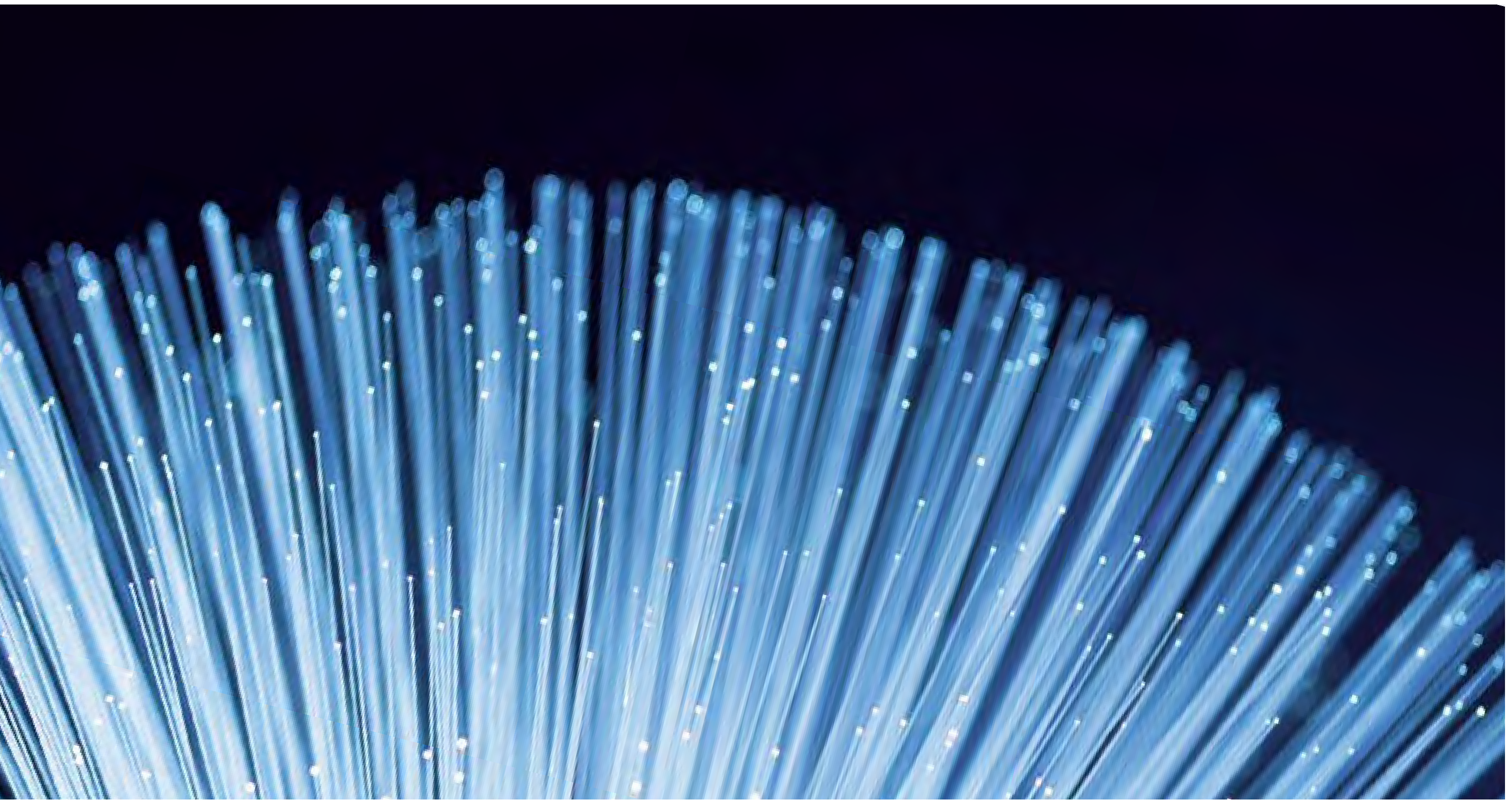
We fulfil requirements concerning the numerical aperture from 0.1 to 0.36. For the refractive index profile we offer step-index, graded-index or customer-specific profile options.

Our silica/silica fibers can be coated with acrylate, high-temperature acrylate, silicone, polyimide and ORMOCER® coatings. Additional jacketings with Nylon®- oder Tefzel®-Buffermaterials protect the fibers during the operation in different temperature ranges and under different environmental influences.

In addition to multimode special fibers we also manufacture capillaries and tapers.

All our special fiber products can be adjusted to customer specific requirements. Our production capacities allow us to control production quantities according to demand starting from the prototype up to the certified production of large fiber quantities. Thereby we support you in the development of innovative technologies, in the hitting of ambitious growth targets, individual strategies of product diversification and in the adherence to time requirements.

All fibers can be specifically assembled according to your application fields.

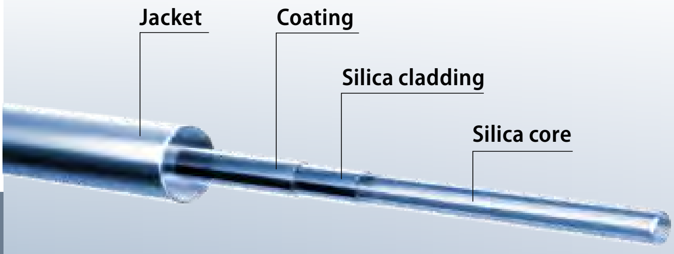


FiberTech® UV-VIS fiber specifications

Silica/silica

Step-index multimode

UV-VIS



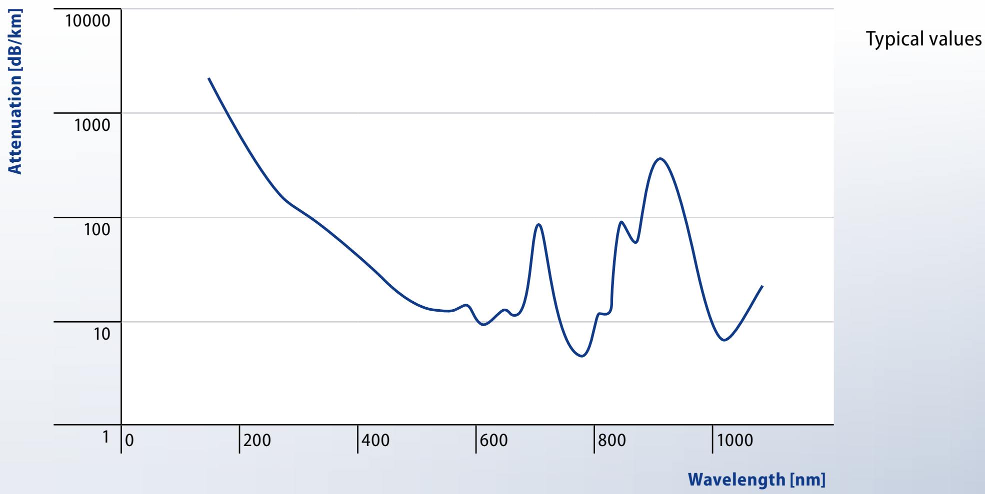
ORMOCER® coating
available for continuous use at 200 °C

With these step-index fibers, the core and cladding consist of pure fused silica glass with high OH content. The fibers are used in a wavelength range from 190 nm to 1100 nm (UV-VIS). The fibers themselves are covered with a coating either consisting of acrylate, silicone or polyimide.

These multimode fibers are not only used in optical data transmission, but also in sensor technology, spectroscopy, medical technology and laser applications.

	Step-index multimode: UV-VIS						
Core Ø [µm] (±2 %)	50	50	100	105	115	200	300
Clad Ø [µm] (±2 %)	55	125	110	125	125	220	330
	Fibers with coating						
	Coating – single acrylate	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –40 °C to 85 °C (optionally 150 °C)					
Coating Ø [µm] (±3 %)	100	200	200	200	200	345	450
Order no.:	84800002N	84800003N	84800004N	84800005N	84800006N	84800007N	84800009N
Fiber code no.:	N00	N01	N02	N03	N04	F72	N05
	Coating – dual acrylate	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –40 °C to 85 °C (optionally 150 °C)					
Coating Ø [µm] (±3 %)	—	245	230	245	245	400	—
Order no.:	—	84800032N	84800033N	84800034N	84800035N	84800036N	—
Fiber code no.:	—	N13	N14	N15	N16	N17	—
	Coating – polyimide	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –190 °C to 385 °C (briefly up to 400 °C)					
Coating Ø [µm] (±3 %)	60	140	125	140	140	245	355
Order no.:	84800039N	84800191N	84800192N	84800193N	84800040N	84800194N	84800196N
Fiber code no.:	N18	N19	A16	N20	N21	B52	N22
	Fibers with coating and jacket						
	Coating – acrylate / jacket – Nylon®	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –40 °C to 85 °C					
Jacket Ø [µm] (±5 %)	—	500	500	500	500	600	700
Order no.:	—	84800102N	84800103N	84800104N	84800105N	84800106N	84800108N
Fiber code no.:	—	N26	N27	N28	N29	N30	N31
	Coating – silicone / jacket – Tefzel®	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –40 °C to 150 °C					
Jacket Ø [µm] (±5 %)	—	500	500	500	—	600	700
Order no.:	—	84800161N	84800162N	84800163N	—	84800105N	84800166N
Fiber code no.:	—	N40	N41	N42	—	N43	N44

Short-term bending radius: 100 x clad radius | long-term bending radius: 600 × clad radius
Fibers with jacket are offered in different colours | Tefzel®: black, blue, transparent | Nylon®: black, blue, transparent, yellow, red, white
Note: fiber code applies to black jackets, other colours on request



Step-index multimode: UV-VIS

Core Ø [µm] (±2 %)	365	400	500	600	800	910	1000	1500
Clad Ø [µm] (±2 %)	400	440	550	660	880	1000	1100	1650

Fibers with coating

Coating – single acrylate
Numerical aperture 0.22 (0.1 to 0.28 on request)
Temperature range −40 °C to 85 °C (optionally 150 °C)

Coating Ø [µm] (±3 %)	550	550	770	840	1000	1250	1350	1850
Order no.:	84800011N	84800012N	84800014N	84800015N	84800016N	84800017N	84800018N	84800019N
Fiber code no.:	N06	D19	N07	N08	N09	N10	N11	N12

Coating – polyimide
Numerical aperture 0.22 (0.1 to 0.28 on request)
Temperature range −190 °C to 385 °C (briefly up to 400 °C)

Coating Ø [µm] (±3 %)	425	465	575	685	—	—	—	—
Order no.:	84800197N	84800198N	84800200N	84800201N	—	—	—	—
Fiber code no.:	N23	N24	N25	E24	—	—	—	—

Fibers with coating and jacket

Coating – acrylate / jacket – Nylon®
Numerical aperture 0.22 (0.1 to 0.28 on request)
Temperature range −40 °C to 85 °C

Jacket Ø [µm] (±5 %)	800	800	1000	1000	1300	1400	1500	2000
Order no.:	84800110N	84800111N	84800113N	84800114N	84800115N	84800116N	84800117N	84800118N
Fiber code no.:	N32	N33	N34	N35	N36	N37	N38	N39

Coating – silicone / jacket – Tefzel®
Numerical aperture 0.22 (0.1 to 0.28 on request)
Temperature range −40 °C to 150 °C

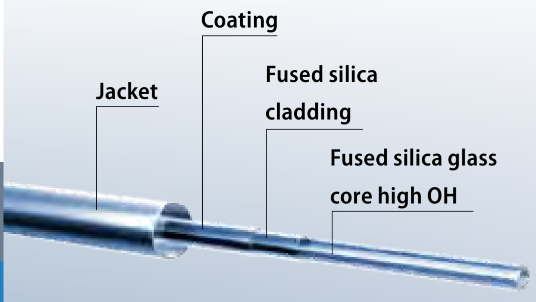
Jacket Ø [µm] (±5 %)	800	800	1000	1000	1300	1400	1500	2100
Order no.:	84800167N	84800168N	84800170N	84800171N	84800172N	84800202N	84800173N	84800203N
Fiber code no.:	N45	N46	N47	E31	N48	N49	N50	A59

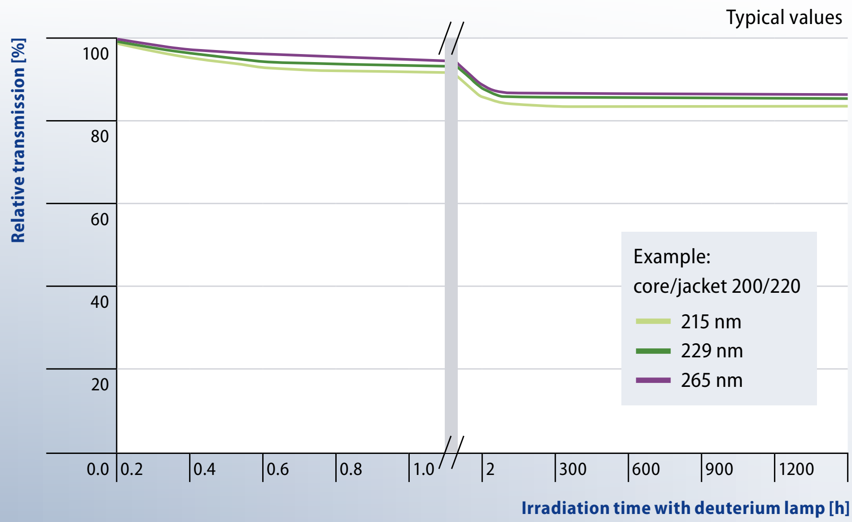
Short-term bending radius: 100 x clad radius | long-term bending radius: 600 × clad radius
Fibers with jacket are offered in different colours | Tefzel®: black, blue, transparent | Nylon®: black, blue, transparent, yellow, red, white
Note: fiber code applies to black jackets, other colours on request

ultrasol® fibers

(solarization-stable fibers)

Also as
fiber bundles!





Progressive absorption of the fibers to the point of complete failure occurs when using UV-VIS fibers < 240 nm. Our solarisation-stable fibers can be used for applications in this critical range.

These newly developed fibers with high OH content are characterised by very good transmission in the 190–250 nm range. A deuterium light source was used for the measurement.

Solarisation-stable fibers are also available as fiber bundles with a single-fiber core from 30 µm.

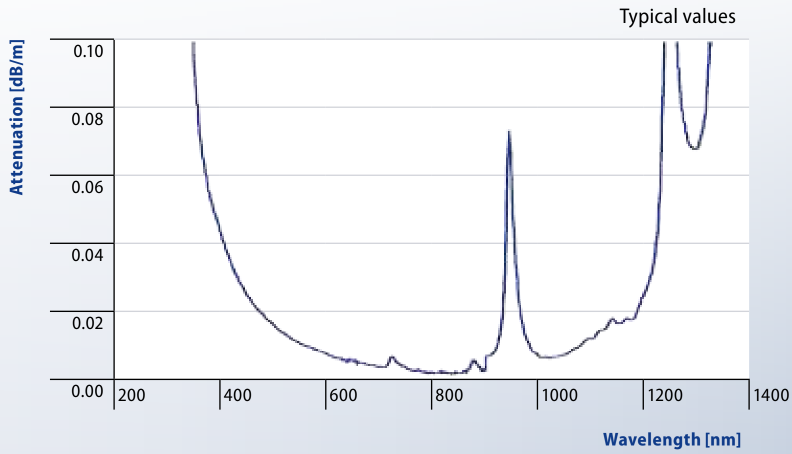
	Step-index multimode: UV-VIS					
Core Ø ±2 % [µm]	100	200	300	400	500	600
Clad Ø ±2 % [µm]	110	220	330	440	550	660
	Coating single acrylate					
Coating Ø ±3 % [µm]	160	270	400	520	630	740
Order no.:	84808011F	84808012F	84808013F	84808014F	84808016F	84808017F
Fiber code no.:	U00	U01	U02	U03	U05	U06
	Coating polyimide					
Coating Ø ±3 % [µm]	135	245	355	465	575	685
Order no.:	84808003F	84808004F	84808005F	84808006F	84808008F	84808009F
Fiber code no.:	U20	U21	U22	U23	U25	U26

Nylon® oder Tefzel® optionally available.
Further specifications (including CCDR) are possible.

FiberTech® High Power Small Core

HPSC fiber

Attenuation curve of a high-power transmission fiber (Ultra-Version)



The HPSC fiber is a step-index multimode fiber that consists of an undoped silica core and a fluorine-doped silica cladding.

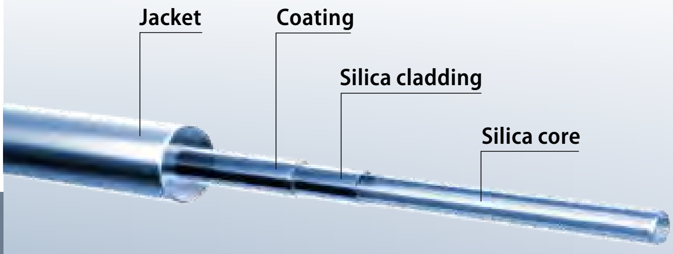
It is the ideal solution for laser transmission and applications in sensorics, which require absolute stability in the transmission of high-power signals. HPSC fibers guarantee high-power transmission in both, UV-near and visible range (from 280 nm up to 750 nm) with highest stability and reliability.

	High Power Small Core			
Core Ø ±3.0 [µm]	10	15	20	25
Clad Ø ±2.0 [µm]	125	125	125	125
Transmission properties				
Numerical aperture	0.100 ± 0.015	0.100 ± 0.015	0.100 ± 0.015	0.100 ± 0.015
Attenuation at 600 nm [dB/km]	≤ 20	≤ 20	≤ 20	≤ 20
Operating wavelength [nm]	280…750	280…750	280…750	280…750
	acrylate coating Temperature range −60 °C to 85 °C			
Coating Ø ±10 [µm]	245	245	245	245

Transmissions stability (specifies values)	Standard	Ultra
Time until transmission decrease to 90 % [h] (1.0 W, 446 nm)	> 5	> 40

FiberTech® VIS-IR fiber specifications

Step-index multimode
VIS-IR



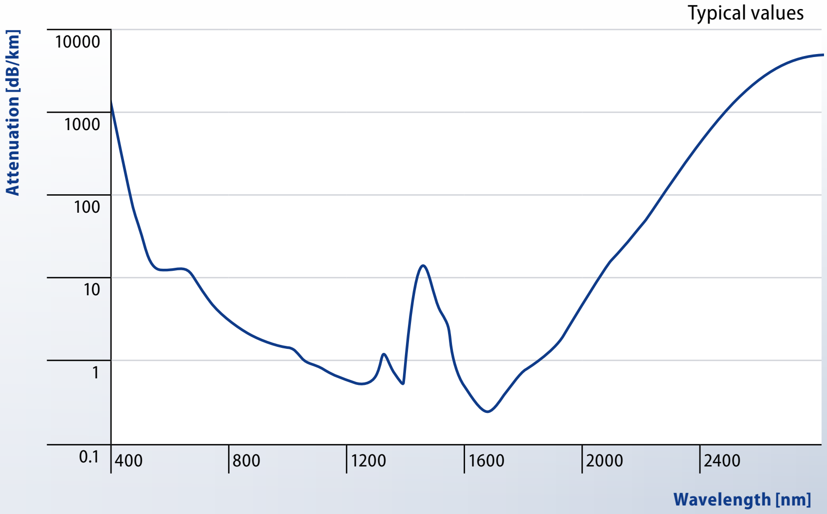
The core of glass fibers for IR consists of pure fused silica glass with low OH content and uniform refractive index across the entire diameter. The fibers are used in a wavelength range from 400 nm to 2400 nm (VIS-IR). The fibers themselves are covered with a coating either consisting of acrylate, silicone or polyimide.

The multimode fibers are not only used in optical data transmission, but also in sensor technology, spectroscopy, medical technology and laser applications.

ORMOCER® coating
available for continuous use at 200 °C

	Step-index multimode: VIS-IR								
Core Ø [µm] (±2 %)	40	50	60	90	100	100	100	105	200
Clad Ø [µm] (±2 %)	125	125	125	125	110	120	140	125	220
	Fibers with coating								
	Coating – single acrylate	Numerical aperture 0.22 (0.1 to 0.4 on request) Temperature range −40 °C to 85 °C							
Coating Ø [µm] (±3 %)	200	200	200	200	200	200	220	200	345
Order no.:	84810001N	84810003N	84810004	84810005N	84810006N	84810007N	84810008N	84810009N	848100010N
Fiber code no.:	N51	N52	N53	N54	N55	N56	N57	A73	N58
	Coating – dual acrylate	Numerical aperture 0.22 (0.1 to 0.4 on request) Temperature range −40 °C to 85 °C (optional −60 °C to 150 °C)							
Coating Ø [µm] (±3 %)	245	245	245	245	230	240	260	245	400
Order no.:	84810041N	84810043N	84810044N	84810045N	84810046N	84810047	84810048N	84810049N	84810050N
Fiber code no.:	N67	N68	N69	N70	N71	N72	N73	A75	N74
	Coating – polyimide	Numerical aperture 0.22 (0.1 to 0.4 on request) Temperature range −190 °C to 385 °C							
Coating Ø [µm] (±3 %)	140	140	140	140	125	140	165	140	245
Order no.:	84810191N	84810193N	84810194N	84810195N	84810196N	84810197N	84810198N	84810199N	84810200N
Fiber code no.:	N77	N78	N79	N80	N81	N82	N83	N84	B35
	Fibers with coating and jacket								
	Coating – acrylate / jacket – Nylon®	Numerical aperture 0.22 (0.1 to 0.4 on request) Temperature range −40 °C to 85 °C							
Jacket Ø [µm] (±5 %)	500	500	500	500	500	500	500	500	500
Order no.:	84810101N	84810103N	84810104N	84810105N	84810106N	84810107N	84810108N	84810109N	84810119N
Fiber code no.:	P00	P01	P02	P03	P04	P05	P06	P07	B24
	Coating – silicone / jacket – Tefzel®	Numerical aperture 0.22 (0.1 to 0.4 on request) Temperature range −40 °C to 150 °C							
Jacket Ø [µm] (±5 %)	500	500	500	500	500	500	500	500	500
Order no.:	84810161N	84810162N	84810163N	84810164N	84810165N	84810166N	84810167N	84810168N	84810169N
Fiber code no.:	P13	P14	P15	P16	P17	P18	P19	P20	P21

Short-term bending radius: 100 x clad radius | long-term bending radius: 600 × clad radius
Fibers with jacket are offered in different colours | Tefzel®: black, blue, transparent | Nylon®: black, blue, transparent, yellow, red, white
Note: fiber code applies to black jackets, other colours on request



Step-index multimode: VIS-IR										
Core Ø [µm] (±2 %)	200	200	365	400	400	500	600	800	1000	1500
Clad Ø [µm] (±2 %)	240	280	400	440	480	550	660	880	1100	1650

Fibers with coating

Coating – single acrylate
Numerical aperture 0.22 (0.1 to 0.4 on request)
Temperature range –40 °C to 85 °C

Coating Ø [µm](±3 %)	400	450	550	560	660	700	840	1000	1300	1850
Order no.:	84810011N	84810012N	84810014N	84810015N	84810016N	84810017N	84810583N	84810020N	84810022N	84810024N
Fiber code no.:	J62	N59	N60	N61	N62	N63	L74	N64	N65	N66

Coating – dual acrylate
Numerical aperture 0.22 (0.1 to 0.4 on request)
Temperature range –40 °C to 85 °C (optionally –60 °C to 150 °C)

Coating Ø [µm](±3 %)	400	500	—	—	—	—	—	—	—	—
Order no.:	84810051N	84810052N	—	—	—	—	—	—	—	—
Fiber code no.:	N75	N76	—	—	—	—	—	—	—	—

Coating – polyimide
Numerical aperture 0.22 (0.1 to 0.4 on request)
Temperature range –190 °C to 385 °C

Coating Ø [µm](±3 %)	265	305	425	465	505	575	685	—	—	—
Order no.:	84810201N	84810202N	84810204N	84810205N	84810206N	84810207N	84810208N	—	—	—
Fiber code no.:	N85	N86	N87	N88	N89	N90	E06	—	—	—

Fibers with coating and jacket

Coating – acrylate / jacket – Nylon®
Numerical aperture 0.22 (0.1 to 0.4 on request)
Temperature range –40 °C to 85 °C

Jacket Ø [µm](±5 %)	600	600	800	800	800	1000	1000	1300	1600	2000
Order no.:	84810110N	84810111N	84810113N	84810114N	84810115N	84810116N	84810117N	84810118N	84810525N	84810537N
Fiber code no.:	P08	P09	P10	D05	P11	D60	E00	P12	A49	L03

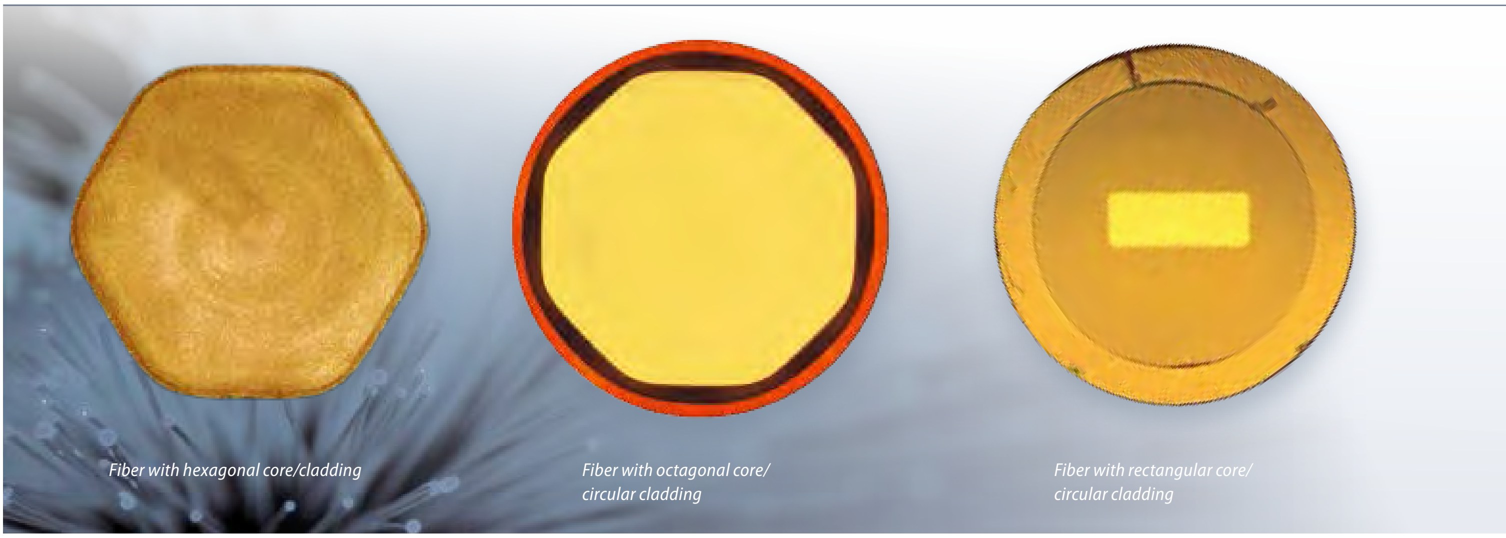
Coating – silicone / jacket – Tefzel®
Numerical aperture 0.22 (0.1 to 0.4 on request)
Temperature range –40 °C to 150 °C

Jacket Ø [µm](±5 %)	600	600	800	800	800	1000	1000	1300	1500	2250
Order no.:	84810170N	84810171N	84810173N	84810174N	84810175N	84810176N	84810177N	84810178N	84810121N	84810179N
Fiber code no.:	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31

Short-term bending radius: 100 x clad radius | long-term bending radius: 600 × clad radius
Fibers with jacket are offered in different colours | Tefzel®: black, blue, transparent | Nylon®: black, blue, transparent, yellow, red, white
Note: fiber code applies to black jackets, other colours on request

FiberTech® NCS Non Circular Shape fibers

Step-index fibers with non-circular geometry



Fiber with hexagonal core/cladding

Fiber with octagonal core/circular cladding

Fiber with rectangular core/circular cladding

NCS fibers – Step-index fiber series with non-circular core or cladding geometries

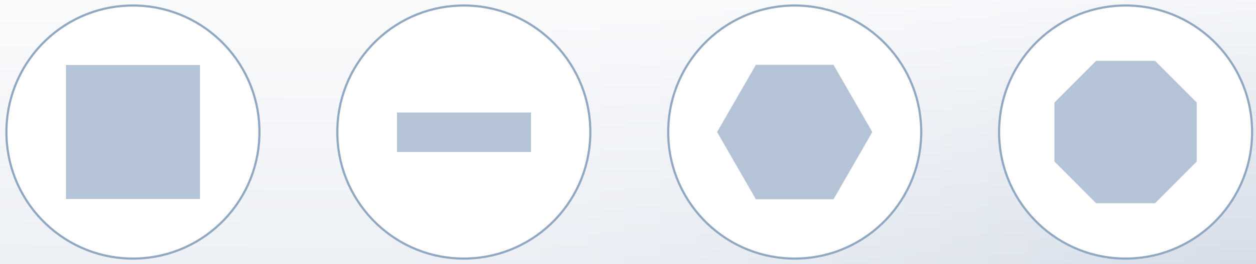
NCS is our fluorine-doped step-index multimode fiber series, with fibers featuring a non-circular undoped fused silica core and/or a corresponding fluorine-doped fused silica cladding.

NCS fibers can be customized concerning structure and thickness of the cladding and also regarding the numerical aperture (NA). In addition it is possible to optimize the most important fiber parameters – such as their performance at UV/VIS, VIS/NIR and VIS/IR wavelengths – by specifying the OH content of the core. Thereby we can offer innovative solutions for the special requirements of laser technology, high-performance data transmission, imaging and spectroscopy or medical applications.

Hexagonal step-index fibers ➔
are especially suited for the manufacturing of compact fiber bundles, improving transmission efficiency in industrial and medical applications. As part of fiber optic cables, our innovative fiber shapes help to optimize the guiding of laser light to the operation area.

Fibers with square core shape ➔
generating a nearly square output beam, they are the choice for several high-power applications. Light from a square diode laser can be coupled into a square fiber a lot easier. Compared to a circular fiber profile, this allows a more uniform treatment of the material - particularly in welding technology and heat treatment, as the beam moves laterally over the material's surface.

Fibers with rectangular shape ➔
can improve the signal strength in fiber laser applications by minimizing the energy density decrease at the end of the fiber core. This decrease occurs in particular when the emitted power is launched into a circular fiber from a rectangular solid state laser. An improved coordination of dimensions and profiles enables the transmission of light by laser diodes with energy densities as needed for medical applications in particular.



square *rectangular* *hexagonal* *octagonal*

Properties
- Variety of customer-specific core and/or cladding shapes
- High performance step-index multimode fibers
- Perfect fiber geometries
- Improved transmission efficiency in the fiber bundle
- Support of cost-efficient system designs

Applications
- Laser technology
- High-power transmission
- Imaging
- Spectroscopy
- Medicine

Performance characteristics and available configurations

	NCS-fibers – Properties
	specified values
Core material	undoped fused silica
Cladding	fluorine-doped fused silica
CCDR	1.05 – 1.2
Numerical aperture	(0.10 – 0.26) ±0.02
OH content	high or low
Operating wavelength	UV/VIS VIS/NIR VIS/IR
Coating	acrylate, HTC200 (high-temperature coating), PI300 (polyimide)

	Core shape – standard circular cladding			
Geometrical properties	square	rectangular	hexagonal	octagonal
Core Ø (edge to edge) [µm]	55 × 55	55 (±3 µm) × 150 (±15 µm)	100	190
Jacket Ø [µm]	300	300 (±10 µm)	125	200
Coating Ø [µm]	380	380 (+10 µm / –20 µm)	245	400
	Core shape – non-circular cladding			
Core Ø (edge to edge) [µm]			100	190
Jacket Ø [µm]			125	200
Coating Ø [µm]			245	400

Further diameters on request.

FiberTech® Active DoubleClad fibers

Fibers for fiber lasers

Our comprehensive portfolio of tailor-made fibers for the transmission of high-power lasers was developed due to the industrial demands concerning cost-efficient fiber lasers with multi-kW output power:

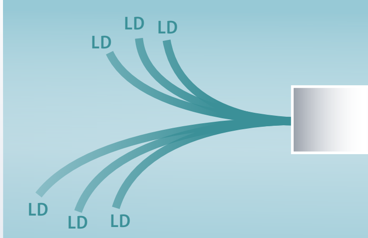
We offer you a YDCF ytterbium-doped active fiber series with corresponding passive fibers as well as pump fibers and combiner fibers as multimode version with standard circular core but also LargeCore fibers with non-circular fiber design.

Applications:

- Materials processing
- Printing industry (direct printing technique)
- Marking of materials
- Medical technology
- Aviation and defense

Fibers for fiber lasers:

Laser beam delivery of diodes in pump fibers



Pump fibers for launching power

Standard (circular core)
Core Ø 105 / 200 / 400 / 600 µm

Customer-specific:
Rectangular core
Customer-specific core/fiber design

YDCF ytterbium-doped fiber series

YDCF ytterbium-doped DoubleClad fibers combine high transmission performance with maximum beam quality and optimized coupling.
The fiber's stability and reliability support the longevity of pump diodes in modern fiber laser systems and allow cost-efficient solutions for high-power laser applictions in industry, military and medicine.

Applications:

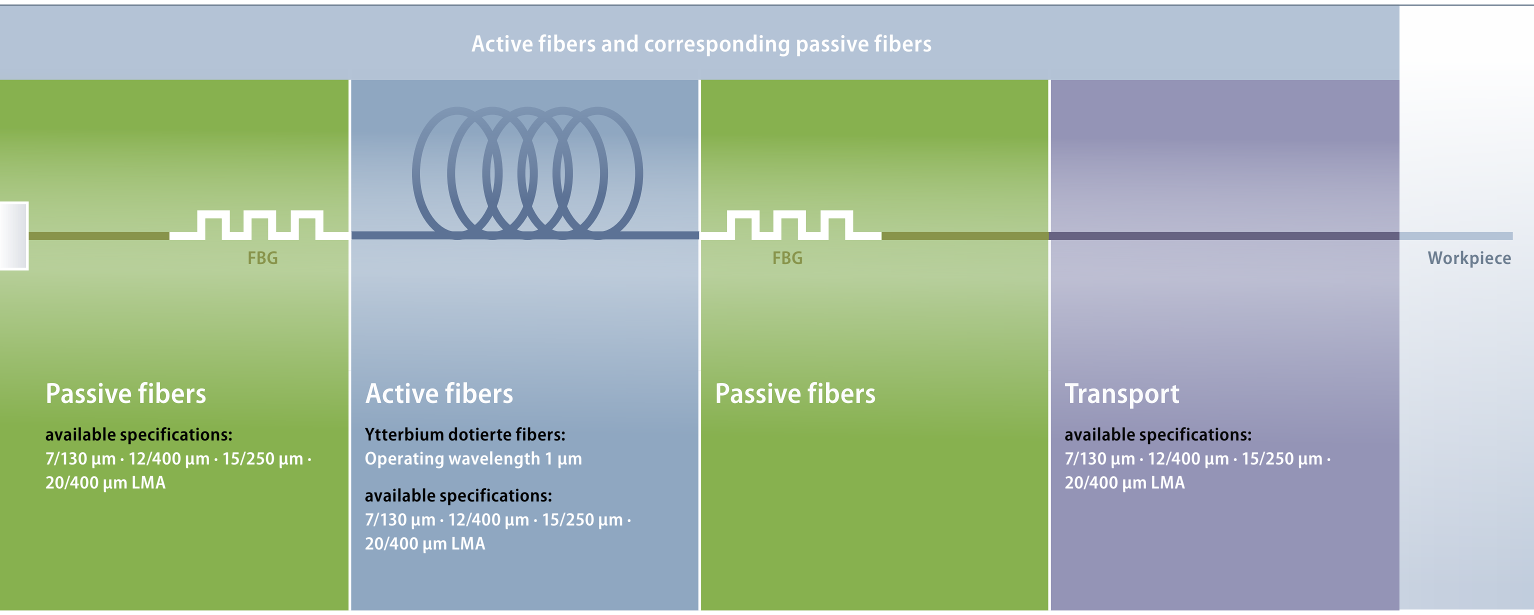
- Mid- to high-power fiber lasers and CW amplifiers
- Materials processing (cutting, welding, ablation)
- Printing industry
- Material marking

Properties:

- Maximum absorption and coupling efficiency, good splicing properties
- Excellent fiber geometry increases power transfer by precise core alignment
- High long-term stability of output power
- High temperature stability and increased operating temperature ranges
- High power conversion efficiency for cost savings on high power diode pumping
- High power output and high quality beam shape profile
- Large high-NA cladding
- High Yb-concentration allows minimal fiber length for optimized laser system design

Double-clad fiber (Yb) design specifications

	YDCF 7/130	YDCF 12/400	YDCF 15/250	YDCF 20/400
Core Ø [µm]	7 ±1	12 ±2	15 ±2	20 ±2
Clad Ø [µm]	130 ±3	400 ±15	250 ±5	400 ±15
Coating Ø [µm]	250 ±15	520 ±15	340 ±15	520 ±15
Outer cladding material	low-index polymer	low-index polymer	low-index polymer	low-index polymer
Operating wavelength range [nm]	1040–1110	1040–1110	1040–1110	1040–1110
Cladding-absorption at 915 nm [dB/m]	0.6	0.6	0.6	0.25
Cladding-absorption at 975 nm [dB/m]	1.8	1.8	1.8	0.8
Core NA	0.12 ±0.02	0.12 ±0.02	0.08 ±0.015	0.06 ±0.01
Cladding NA	0.46	0.46	0.46	0.46
Slope efficiency [%]	75	75	75	75
Corresponding passive fiber	PFL 7/130	PFL 12/400	PFL 15/250	PFL 20/400



PFL passive fibers series

Our passive fibers offer maximum pump output efficiency and output power in fiber laser applications. They were developed to fit with the diameters and numerical apertures of our ytterbium-doped double-clad active fibers. In addition we can offer you customer-specific passive fiber solutions for each of your active fiber specifications.

Properties

- Design developed to match with our active fibers and industrially available standard active fiber geometries
- Maximum pump output efficiency
- Minimum signal loss and coupling loss
- Support of quality, cost and time optimizing concepts in laser manufacturing processes

Applications:

- Fiber lasers and amplifiers
- Fiber laser components
- Highly efficient resonator fibers
- High-performance output power delivery

Further basic information on lasers
Chapter 12 | Principles
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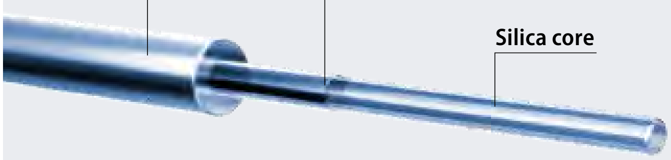
	Passive fiber design specifications			
	PFL 7/130	PFL 12/400	PFL 15/250	PFL 20/400
Core Ø [µm]	7 ±1	12 ±2	15 ±2	20 ±2
Clad Ø [µm]	130 ±3	400 ±15	250 ±5	400 ±15
Coating Ø [µm]	250 ±15	520 ±15	340 ±15	520 ±15
Outer cladding material	low-index polymer	low-index polymer	low-index polymer	low-index polymer
Core NA	0.12 ±0.02	0.12 ±0.02	0.08 ±0.015	0.06 ±0.01
Cladding NA	0.46	0.46	0.46	0.46
Corresponding active fiber	YDCF 7/130	YDCF 12/400	YDCF 15/250	YDCF 20/400

FiberTech® HPCS and PCS fibers

Hard Plastic Clad Silica and Plastic Clad Silica fibers



In addition to the widely used silica/silica fibers, there is a further fiber type with an optical core made from fused silica glass and an optical cladding made from polymer.

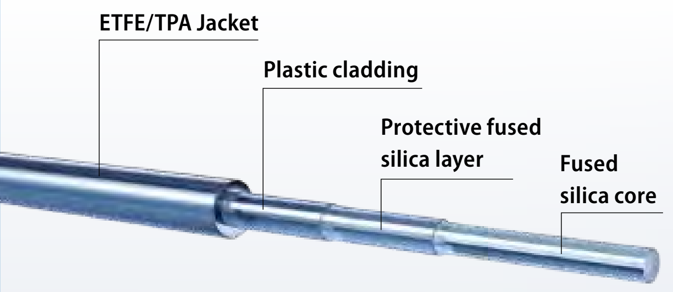
The main advantage of this design compared with the conventional design is the increased numerical aperture, which can be adjusted to a value of up to 0.49.

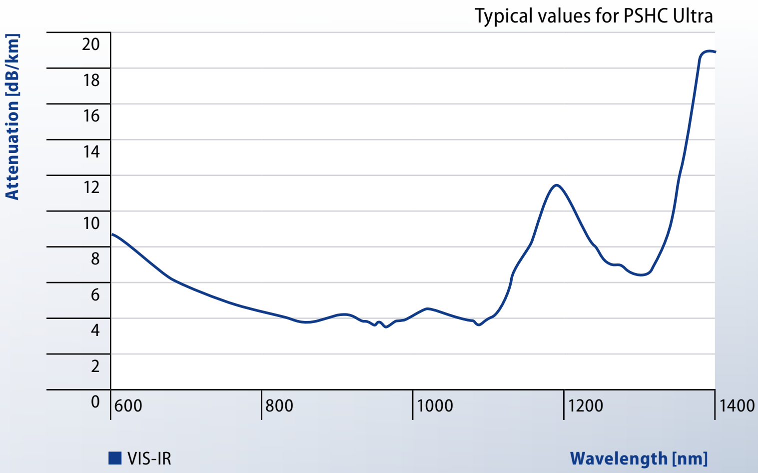
The special properties of this fiber are defined by the special material combination. The mechanical and thermal properties usually differ greatly depending on the manufacturer and polymer used, while the optical properties are often identical. The use of this type of fiber must therefore be agreed with the manufacturer on a case-by-case basis.

The PCF fibers (see page 168) are specially designed for transferring data when using quick-assembly connectors. The PCS and HPCS fibers are optimised for use in the medical laser area and in spectroscopy. They are not suitable for the applications described for PCF fibers.

FiberTech® PSHC Pure Silica Hard Clad fiber

200/230 series – Low OH fiber





The PSHC (Pure Silica Hard Clad) 200/300 fiber for applications in a broad operating wavelength range consists of a fluorine-doped protective fused silica layer around the core glass.

All over the most diverse industrial sectors PSHC displays lowest attenuation values and highest reliablility under difficult environmental conditions. Its laser damage threshold is high and so is its fatigue resistance. The large core diameter of the fiber allows easy handling and efficient coupling into LED or laser sources. The special low-index polymer cladding guarantees high thermal stability and enables the application of crimp-and-cleave technologies. The easily strippable buffer material supports fast and simple assembly and higher productivity in the downstream construction steps.

- PSHC with **ETFE buffer material** is the perfect choice for challenging environmental conditions because of highest reliability under fluctuations in temperature or air humidity
- PSHC with **TPA buffer material** is ideal for the manufacturing of LSZH Low Smoke Zero Halogen cables for indoor applications.

	Pure Silica Hard Clad 200/300 fibers – Step-index profile	
	PSHC Ultra	**PSHC Standard**
Core material	Fused silica, low OH	
Core Ø [µm] (±2 %)	200	
Jacket Ø [µm] (+0/–10 µm)	230	
Buffer Ø (±50 µm)	500	
Buffer material	ETFE/TPA	
Numerical aperture*	0.37 ±0.02	
Attenuation at 650nm [dB/km]	≤ 9	n. a.
Attenuation at 850nm [dB/km]	≤ 5	≤ 6
Attenuation at 940nm [dB/km]	≤ 5	n. a.

	Buffer properties **TPA**	Buffer properties **ETFE**
Operating temperature [°C]	–40 to +85	–60 to +125
Proof test [Gpa]	0.5 ±0.1	0.5 ±0.1

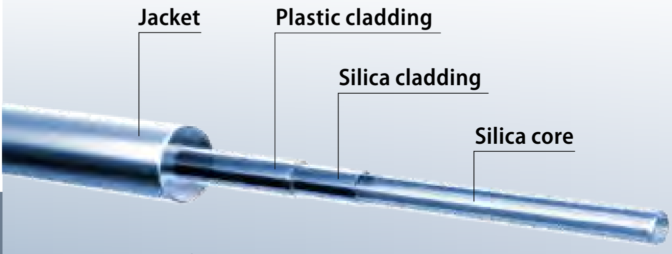
	Environmental proptertries **TPA**		Environmental proptertries **ETFE**	
Attenuation increase	specified values at 850 nm / 1300 nm			
changes in temperature [dB/km]	–40 °C / +85 °C	≤ 0.5	–60 °C / +125 °C	≤ 0.5
for dry heat [dB/km], 30 days	+85 °C	≤ 1	+125 °C	≤ 1
for damp heat [dB/km], 30 days, 85% r.h.	+85 °C	≤ 1	+85 °C	≤ 1
for water immersion [dB/km], 30 days	+23 °C	≤ 1	+23 °C	≤ 1

* *NA value based on a fiber length of 2 m at 850 nm and max. intensity 50 %*
Launch conditions: NA = 0.3 and spot size 100 µm

FiberTech® Passive DoubleClad fibers

High power fibers (CW or pulsed)

Step-index
DoubleClad design



Design A

Here you can find pre-assembled laser products:
Chapter 05 | Industrial lasers
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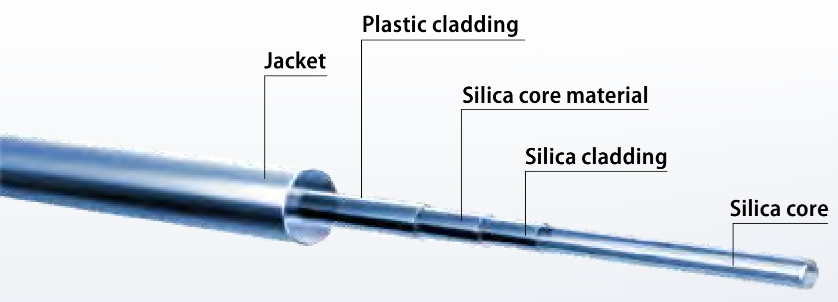
Silica fibers with high power transmission are required for the high-power laser sector.
In order to optimize the propagation of energy while minimizing bend losses at the same time, silica/silica multimode fibers can be coated with an additional optical polymer cladding (design A). Another option is to provide the doped silica cladding with an additional silica core in combination with an optical polymer coating (design B).

	UV-VIS						
Core Ø [µm] (±2 %)	200	200	273	300	365	400	400
Clad Ø [µm] (±2 %)	220	240	300	330	400	420	440
	Fiber with low index hardclad coating and Nylon jacket						
Jacket Ø ±5 %	400	450	450	520	580	600	650
Order no.:	on request						
	Fiber with low index hardclad coating and Tefzel jacket						
Jacket Ø ±5 %	400	430	450	520	580	600	650
Order no.:	on request						
Core Ø [µm] (±2 %)	50	100	105	200	300	300	400
Clad Ø [µm] (±2 %)	125	110	125	220	330	365	440
	Fiber with low index silicone coating and Tefzel jacket						
Jacket Ø ±5 %	50	100	105	200	300	300	400
Order no.:	on request						
	VIS-IR						
Core Ø [µm] (±2 %)	200	200	273	300	365	400	400
Clad Ø [µm] (±2 %)	220	240	300	330	400	420	440
	Fiber with low index hardclad coating and Nylon jacket						
Jacket Ø ±5 %	400	450	450	520	580	600	650
Order no.:	84810590N	84810340N	84810591N	84810596N	on request	84810592N	84810593N
Fiber code.:	S00	S01	S02	S03	—	S05	S06
	Fiber with low index hardclad coating and Tefzel jacket						
Jacket Ø ±5 %	400	430	450	520	580	600	650
Order no.:	84810300N	84810277N	84810575N	84810303N	84810304N	84810305N	84810306N
Fiber code.:	S16	S17	S18	S19	S20	S21	S22
Core Ø [µm] (±2 %)	50	100	105	200	300	300	400
Clad Ø [µm] (±2 %)	125	110	125	220	330	365	440
	Fiber with low index silicone coating and Tefzel jacket						
Jacket Ø ±5 %	500	500	500	600	650	800	800
Order no.:	84810162N	84810165N	84810168N	84810169N	84810122N	884810173N	84810174N
Fiber code.:	S30	S31	S33	S34	S35	S36	S37

Short-term bending radius: 100 × clad radius | Long-term bending radius: 600 × clad radius
Fibers with jacket are available in different colours | Tefzel®: black, blue, transparent | Nylon®: black blue, transparent, yellow, red, white



Design B

Further basic information on lasers:
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→ page 362 ff

UV-VIS

Core Ø [µm] (±2 %)	500	550	600	800	1000	1200
Clad Ø [µm] (±2 %)	550	605	660	880	1100	1320
	Fiber with low index hardclad coating and Nylon jacket					
Jacket Ø ±5 %	730	780	1000	1200	1400	1600
Order no.:	on request					
	Fiber with low index hardclad coating and Tefzel jacket					
Jacket Ø ±5 %	730	780	870	1200	1400	1600
Order no.:	on request					

Core Ø [µm] (±2 %)	500	600	800	910	1000	1500
Clad Ø [µm] (±2 %)	550	660	880	1000	1100	1650
	Fiber with low index silicone coating and Tefzel jacket					
Jacket Ø ±5 %	1000	1000	1300	1400	1500	2100
Order no.:	on request					

VIS-IR

Core Ø [µm] (±2 %)	500	550	600	800	1000	1200
Clad Ø [µm] (±2 %)	550	605	660	880	1100	1320
	Fiber with low index hardclad coating and Nylon jacket					
Jacket Ø ±5 %	730	780	1000	1200	1400	1600
Order no.:	84810597N	84810594N	84810140N	84810533N	84810585N	84810023N
Fiber code.:	S08	S09	S10	S11	S12	S13
	Fiber with low index hardclad coating and Tefzel jacket					
Jacket Ø ±5 %	730	780	870	1200	1400	1600
Order no.:	84810307N	84810308N	84810310N	84810312N	84810313N	on request
Fiber code.:	S23	S24	S25	S26	S27	—

Core Ø [µm] (±2 %)	400	500	600	800	1000	1500
Clad Ø [µm] (±2 %)	480	550	660	880	1100	1650
	Fiber with low index silicone coating and Tefzel jacket					
Jacket Ø ±5 %	800	1000	1000	1300	1500	2250
Order no.:	848101174N	84810175N	84810177N	848101798N	84810121N	84810179N
Fiber code.:	P26	P27	P28	P29	P30	P31

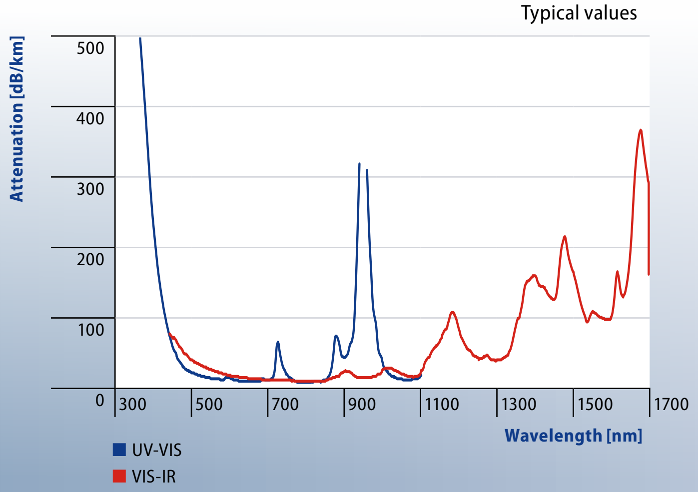
Short-term bending radius: 100 × clad radius | Long-term bending radius: 600 × clad radius
Fibers with jacket are available in different colours | Tefzel®: black, blue, transparent | Nylon®: black blue, transparent, yellow, red, white

FiberTech® HPCS fiber specifications

Hard Plastic Clad Silica fiber specifications

NA 0.28-0.49

Alternative HPCS



The designation hard plastic clad silica (HPCS) stands for the combination of fused silica glass core and polymer cladding consisting of a fluorinated acrylate. This combination offers a cost-effective alternative to the silica/silica glass fiber.

This fiber type can be used to transport low to medium power ratings over short distances with relatively low losses. A Tefzel® or Nylon® layer is additionally applied as a jacket (as a buffer function) to improve the mechanical, chemical and thermal properties.

	Hard Plastic Clad Silica (HPCS) standard NA 0.37 (optionally up to 0.49)						
Core Ø [µm] (±2 %)	125	200	300	400	600	800	1000
Clad-Ø [µm] (±3 %)	150	230	330	430	630	840	1080
Jacket Ø [µm] (±5 %)	500	500	500	730	950	1000	1400
	HPCS-IR fiber with Nylon® jacket Temperature range −40 °C to 85 °C						
Fiber type	HPCS125IRN	HPCS200IRN	HPCS300IRN	HPCS400IRN	HPCS600IRN	HPCS800IRN	HPCS1000IRN
Order no.	84890105N	84890107N	84890111N	84890114N	84890117N	84890118N	84890101N
Fiber code no.:	Q00	Q01	Q02	Q03	Q04	Q05	Q06
	HPCS-IR fiber with Tefzel®-Jacket Temperature range −40 °C to 150 °C						
Fiber type	HPCS125IRT	HPCS200IRT	HPCS300IRT	HPCS400IRT	HPCS600IRT	HPCS800IRT	HPCS1000IRT
Order no.	84890120N	84890109N	84890112N	84890115N	84890116N	84890119N	84890102N
Fiber code no.:	Q10	Q11	Q12	Q13	Q14	Q15	Q16
	HPCS-UV fiber with Nylon® jacket Temperature range −40 °C to 85 °C						
Fiber type	HPCS125UVN	HPCS200UVN	HPCS300UVN	HPCS400UVN	HPCS600UVN	HPCS800UVN	HPCS1000UVN
Order no.	84890218N	84890204N	84890208N	84890213N	84890211N	84890215N	84890201N
Fiber code no.:	Q20	Q21	Q22	Q23	Q24	Q25	Q26
	HPCS-UV fiber with Tefzel® jacket Temperature range −40 °C to 150 °C						
Fiber type	HPCS125UVT	HPCS200UVT	HPCS300UVT	HPCS400UVT	HPCS600UVT	HPCS800UVT	HPCS1000UVT
Order no.	84890217N	84890207N	84890209N	84890210N	84890212N	84890216N	84890214N
Fiber code no.:	Q30	Q31	Q32	Q33	Q34	Q35	Q36

Please ask for further specifications.

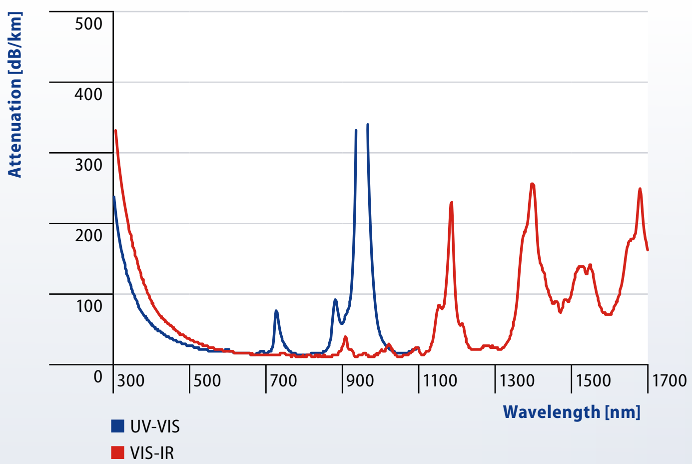
Fibers with jacket are available in different colours | Tefzel®: black, blue, transparent | Nylon®: black blue, transparent, yellow, red, white
Note: Fiber code applies to black, further colours on request.

FiberTech® PCS fiber specifications

Plastic Clad Silica fiber specifications

NA 0.37
Alternative PCS

Typical values



The designation plastic clad silica (PCS), as with the HPCS fiber, stands for a combination of fused silica glass core and silicone-plastic cladding. Silicone guarantees higher temperature resistance, which means that higher power ratings can be transmitted. This fiber type can be used to transport medium to high power ratings over short distances with relatively low losses.

A Tefzel® or Nylon® layer is additionally applied as a jacket with buffer function to improve the mechanical, chemical and thermal properties.

Plastic Clad Silica (PCS) Standard NA 0.37

Core Ø [µm] (±2 %)	125	200	300	400	600	800	1000
Clad Ø [µm] (±3 %)	200	350	450	550	800	950	1250

	PCS-IR fiber with Nylon® jacket	Temperature range −40 °C to 85 °C					
Fiber type	PCS125IRN	PCS200IRN	PCS300IRN	PCS400IRN	PCS600IRN	PCS800IRN	PCS1000IRN
Order no.	84880312N	84880305N	84880314N	84880307N	84880308N	84880416N	84880318N
Fiber code no.:	Q40	Q41	Q42	Q43	Q44	Q45	Q46
Jacket Ø [µm] (±5 %)	400	500	650	850	1000	1300	1650

	PCS-IR fiber with Tefzel® jacket	Temperature range −40 °C to 150 °C					
Fiber type	PCS125IRT	PCS200IRT	PCS300IRT	PCS400IRT	PCS600IRT	PCS800IRT	PCS1000IRT
Order no.	84880311N	84880306N	84880313N	84880315N	84880309N	84880417N	84880301N
Fiber code no.:	Q50	Q51	Q52	Q53	Q54	Q55	Q56
Jacket Ø [µm] (±5 %)	400	500	650	850	950	1300	1650

	PCS-UV fiber with Nylon® jacket	Temperature range −40 °C to 85 °C					
Fiber type	PCS125UVN	PCS200UVN	PCS300UVN	PCS400UVN	PCS600UVN	PCS800UVN	PCS1000UVN
Order no.	84880418N	84880406N	84880413N	84880409N	84880411N	84880414N	84880420N
Fiber code no.:	Q60	Q61	Q62	Q63	Q64	Q65	Q66
Jacket Ø [µm] (±5 %)	400	500	650	850	1000	1300	1650

	PCS-UV fiber with Tefzel® jacket	Temperature range −40 °C to 150 °C					
Fiber type	PCS125UVT	PCS200UVT	PCS300UVT	PCS400UVT	PCS600UVT	PCS800UVT	PCS1000UVT
Order no.	84880419N	84880407N	84880408N	84880410N	84880412N	84880415N	84880402N
Fiber code no.:	Q70	Q71	Q72	Q73	Q74	Q75	Q76
Jacket Ø [µm] (±5 %)	400	500	650	850	950	1300	1650

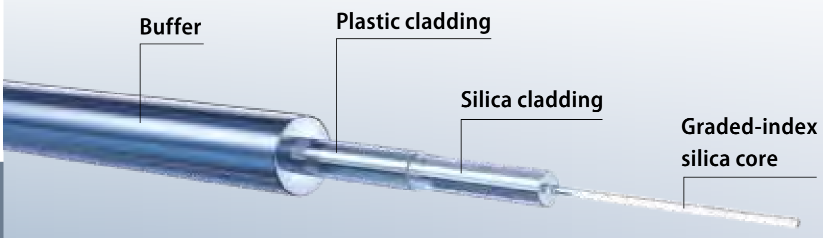
Please ask for further specifications.

Fibers with jacket are available in different colours | Tefzel®: black, blue, transparent | Nylon®: black blue, transparent, yellow, red, white
Note: Fiber code applies to black, further colours on request.

FiberTech® Graded-index polymer clad fiber

GIPC (Graded Index Polymer Clad) fiber series – multimode fiber

with OM1 & OM2 performance



The GIPC fiber series was developed particularly for applications under the demanding environmental conditions of short and medium distance communications.

GIPC50 and GIPC62 meet the requirements concerning robust fiber design while offering the bandwidth performance of a standard telecommunications fiber according to OM2 (GIPC 50) or OM1 (GIPC 62). The 200 µm-form factor enables the fiber to withstand a threefold higher mechanical load compared to a 125 µm diameter standard fiber (30 N instead of 10 N).

Equipped with our special coating, the fiber offers optimum performance characteristics concerning thermal properties. Due to their easily removable 500 µm ETFE buffer material and excellent fiber geometry, GIPC fibers enable quick, cost-efficient and simple handling with crimp-and-cleave assembly.

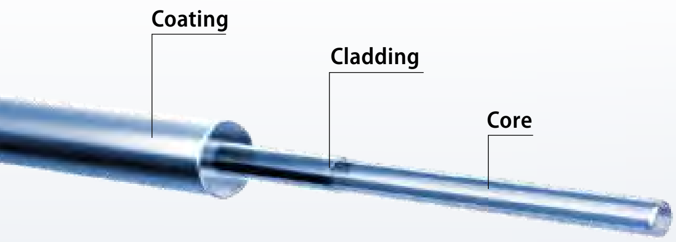
	GIPC50 – 50/200/230/500	GIPC62 – 62.5/200/230/500
Fiber properties and measurements acc. to IEC 60793-2-10	specific values	
Core material	Ge-doped fused silica	
Core Ø	50 ±2.5 µm	62.5 ±2.5 µm
Core non-circularity	≤ 5 %	
Core-cladding concentricity error	≤ 1.5 µm	
Cladding material	Fused silica	
Jacket Ø	200 ±3 µm	
Cladding non-circularity	≤ 1 %	
Coating material (others on request)	UV-cured acrylate	
Coating Ø (others on request)	232 (+0 /–4) µm	
Core-coating concentricity error	≤ 3 µm	
Buffer material	ETFE	
Buffer Ø	500 ±30 µm	

Optical properties		specific values	
Attenuation	at 850 nm	≤ 2.4 dB/km	≤ 3.2 dB/km
	at 1300 nm	≤ 0.8 dB/km	≤ 1.0 dB/km
Bandwidth	at 850 nm	> 500 MHz × km	> 200 MHz × km
	at 1300 nm	> 500 MHz × km	> 500 MHz × km
Link length at 1 Gb/s	850 nm	> 600 µm	> 350 µm
	1300 nm	> 600 µm	> 550 µm
Numerical aperture		0.200 ±0.015	0.275 ±0.015

* The specified attenuation values apply to undyed fibers
** Bend-induced attenuation at 850 nm and 1300 nm; 100 turns around a mandrel with 75 mm diameter

FiberTech® MIR and FIR fibers

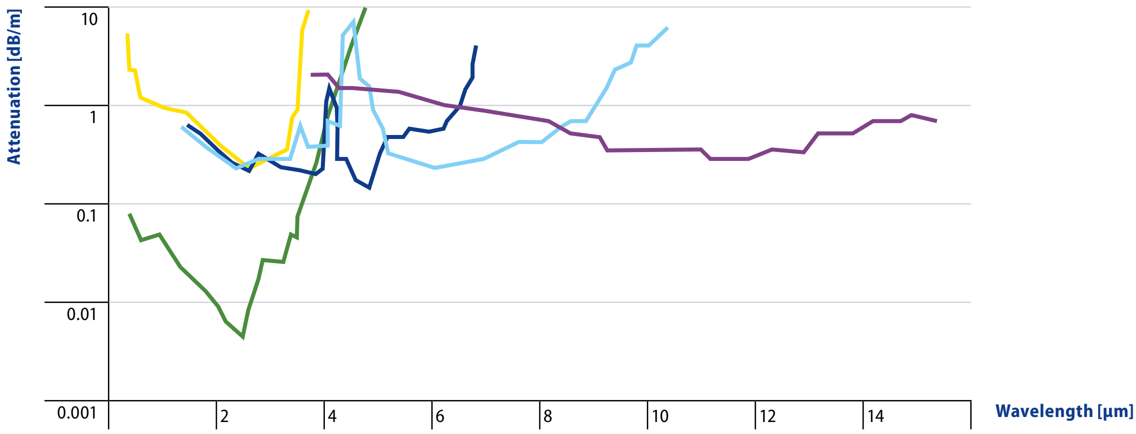
Step-index multimode
MIR & FIR



Optical fibers absorb very strongly starting from a wavelength range of approximately 2500 nm. Therefore special fibers, which work within the middle infrared range, were developed.

Differently doped glass fibers, polycrystalline or crystalline waveguides are used in the medium to far infrared range. Typical applications are endoscopy and spectroscopy.

Attenuation curves of MIR and FIR fibers



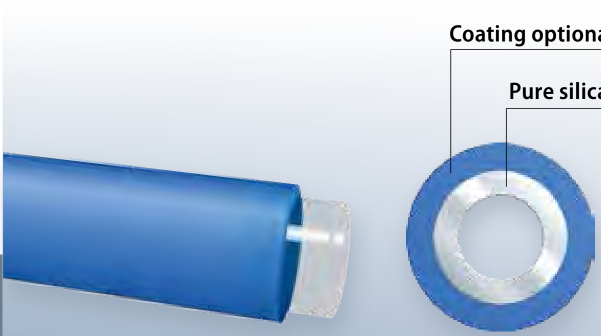
	MIR- and FIR-fibers – Properties				
Description of the structure	Chalcogenide IR fibers CIRSe*	Chalcogenide IR fibers CIRS*	Fluoride glass fibers ZrF	Polycrystalline IR fibers PIR	Sapphire SAP
Core material	Selenium compound	As_2S_3 compound	Heavy metal fluoride compound (zirconium fluoride base)	AgBrCl compound	Sapphire
Clad	Selenium compound	AsS compound	Heavy metal fluoride compound	AgBrCl compound, Cl-enriched	
Coating	Dual acrylate	Dual acrylate	Dual acrylate	Dual acrylate	PTFE
Core Ø	SM Multimode 50 – 700 µm	SM Multimode 50 – 750 µm	SM Multimode 50 – 750 µm	Multimode 200 – 900 µm	Multimode 150 – 425 µm
Properties					
Wavelength range	2 – 9 µm	2 – 6 µm	400 nm – 4 µm	4 µm – 18 µm	400 nm – 3.5 µm
Temperature (without coating)	–100°C to +200°C	–10°C to +120°C	–10°C to +80°C	–100°C to +200°C	Up to +1000°C
Areas of application	Chemical sensors, fiber amplifiers, fiber lasers	Chemical sensors, fiber amplifiers, fiber lasers	IR sensor technology, IR interferometry, IR laser transmission, fiber amplifiers, fiber lasers	Chemical sensors, temperature sensors	Medical technology, laser light transmission, chemical sensors, Er: YAG lasers
Order no.	on request 8483000××	on request 8483002××	on request SM 8483006×× MM 8483004××	on request	on request

** Available solely as pre-assembled version.*

Special optical fibers

03

Capillaries and tapers



Capillaries

Description

- Good strength properties
- Available for UV and IR range
- Pressure resistant
- Polyimide coating for high-temperature applications and chemically harsh environments
- Smooth inner surface

Application

- Electrophoresis
- Chromatography
- Connection of fibers
- Fiber splices
- Fiber optic components
- High-pressure miniature conduits
- Beam optics

Properties

■ Inner Ø	50–2000 µm
■ Wall thickness	30–1000 µm
■ Ø-tolerance	on request
■ Length (depending on Ø)	1 m to 10 km
■ End face processing	cut or broken

Properties (optional)

■ Polyimide coating	–190 to 385 °C
■ Acrylate coating	–40 to 85 °C
■ High-temperature acrylate coating	–40 to 150 °C

Fiber tapers

Description

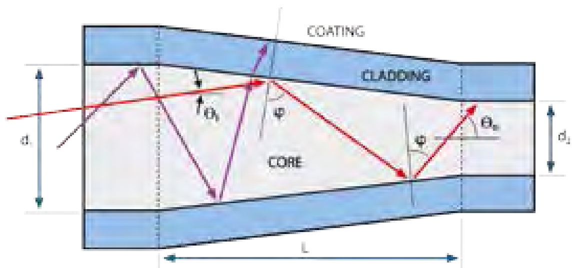
Lightguides made from synthetic fused silica with different input and output core diameters or NA-converters.

Application

Laser applications for materials processing and spectroscopy

Composition

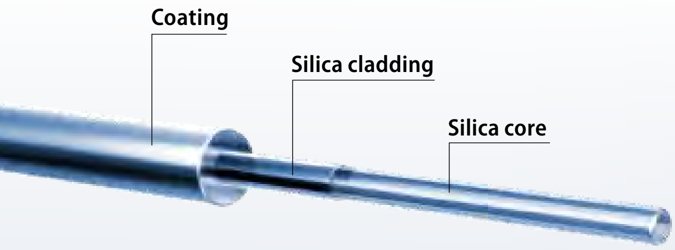
Input/output ratio: up to 1:5 assembly with various tubes, standard and special connectors possible



FiberTech® VIS-IR fiber specifications

Graded-index multimode fibers

Grade-index multimode
VIS-IR



In many demanding applications in industry and data transmission, optical fibers are exposed to special challenges as can be: extreme temperature fluctuations in fire-alarms, temperature sensors or industrial equipment. For these environmental conditions, the graded-index multimode fiber with extendend temperature range was developed.

ORMOCER® coating
available for continuous use at 200 °C

LEONI provides a complete set of optical fiber solutions that withstand extreme temperatures between –190 °C and 385 °C.

Properties

- Individual combinations of bandwidth and attenuation values for special applications available on customer request
- High-performance broadband fibers for use in the 1 Gb/s and 10 Gb/s range, further customer-specific solutions on request
- Different coatings especially for applications under demanding environmental conditions including acrylate, high-temperature acrylate, polyimide and Ormocer®
- excellent splicing properties

Applications

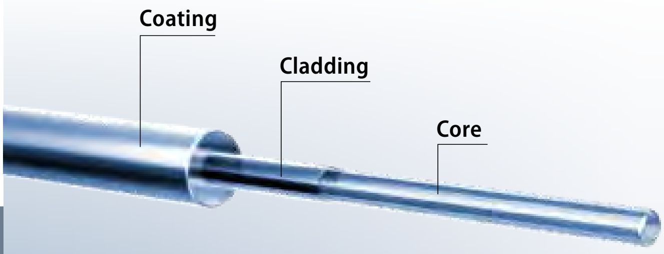
- Data transmission and communication
- Fiber optic sensors

	Graded-index multimode fibers: VIS-IR						
Core Ø [µm] (±2 %)	50	62.5	85	100	200	400	600
Clad Ø [µm] (±2 %)	125	125	125	140	280	560	840
	Fibers with coating						
Transmision properties							
Numerical aperture	0.200 ±0.015	0.275 ±0.015	0.26	0.290 ± 0.020	0.29	0.29	0.29
Attenuation at 850 nm [dB/km]	≤ 2.4 – ≤ 2.6	≤ 2.8 – ≤ 3.2	3.5/3	≤ 3.5 – ≤ 5.0	6	8	10
Attenuation at 1300 nm [dB/km]	≤ 0.6 – ≤ 0.8	≤ 0.6 – ≤ 1.0	1/0.9	≤ 1.0 – ≤ 2.0	3	4	5
Bandwidth at 850 nm [MHz × km]	≤ 400 – ≤ 750	≤ 160 – ≤ 400	200	≤ 50 – ≤ 200	150	100	100
Bandwidth at 1300 nm [MHz × km]	≤ 500 – ≤ 1200	≤ 200 – ≤ 600	200	≤ 100 – ≤ 300	150	100	100
	Coating – acrylate Temperature range –40 °C to 85 °C						
Coating Ø [µm](±3 %)	250	250	250	260	450	700	1050
Order no.:	84810501N	84810502N	84810503N	84810504N	84810505N	84810506N	84810507N
Fiber code no.:	P80	P81	P82	P83	P84	P85	P86
	Coating – polyimide Temperature range –190 °C to 385 °C						
Coating Ø [µm] (±3 %)	140	140	140	165	305	585	—
Order no.:	84810511N	84810512N	84810513N	84810514N	84810515N	84810516N	—
Fiber code no.:	P90	P91	P92	P93	P94	P95	—

Nylon® oder Tefzel® optionally available.
Fibers with jacket are available in different colours | Tefzel®: black, blue, transparent| Nylon®: black, blue, transparent, yellow, red, white

FiberTech® Multimode 50/125 special fibers

for sensor technology



Multimode fibers are excellently suited for use as sensors in medicine, industrial applications, oil and gas exploration and monitoring of pipelines or fire prevention.

Our low-OH multimode sensor fibers were developed especially for data transmission with large bandwidths. They display minimum spectral attenuation over a wide wavelength range from 850 nm to 1400 nm. Provided with an optional 500 µm coating, our sensor fibers are particularly suited for applications under demanding environmental conditions. Optional high-temperature or polyimide coatings protect the fibers in high temperature ranges. Phosphorus-free core material compositions are available (type FPQ).

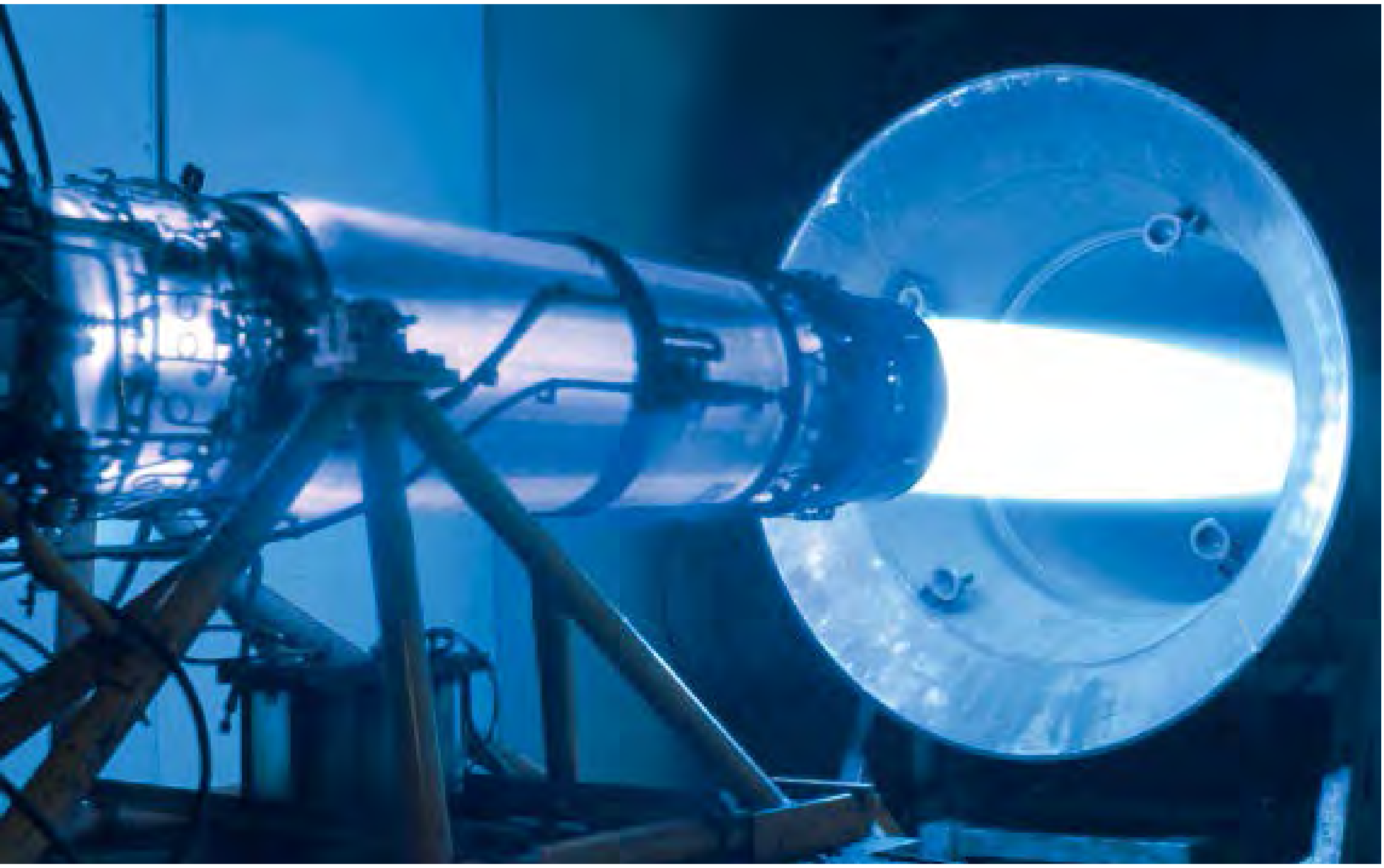
Our sensor fibers allow easy handling and are universally spliceable.

Fiber properties and measurements gemäß IEC 60793-2-10	specific values
Core Ø	50 ± 2.5 µm
Core non-circularity	≤ 5.0 %
Core-cladding concentricity error	≤ 1.5 µm
Cladding Ø	125 ± 2.0 µm
Cladding non-circularity	≤ 1.0 %
Coating material (others on request)	acrylate
Coating Ø (others on request)	245 ± 10.0 µm
Coating-cladding concentricity error	≤ 10.0 µm
Colour (dyed –24 colours possible)	natural
Standard lengths (customer-specific lengths on request)	1.1 – 8.8 km

Optical properties		specific values
Attenuation coefficient*	**850 nm** **1300 nm**	≤ 2.4 dB/km ≤ 0.5 dB/km
Attenuation (OH-peak)	**bei 1383nm**	≤ 0.5 dB/km
Attenuation discontinuities	**OTDR 1300 nm**	< 0.05 dB
Macrobending loss**		≤ 0.5 dB
Numerical aperture		0.200 ± 0.015
Refractive index (eff.)	**850 nm** **1300 nm**	1.483 1.478

* The specified attenuation values apply to undyed fibers
** Bend-induced attenuation at 850 nm and 1300 nm; 100 turns around a mandrel with 75 mm diameter

FiberTech® LargeCore special assemblies



Assembling optical fibers and fiber optic cables for special environments and applications

Fiber optical technologies offer superior solutions for many application areas. Still, especially under harsh environmental conditions such as high or low temperatures or corrosive, chemically aggressive behaviour, the standard assemblies are not sufficient.

Therefore LEONI offers a multitude of special assemblies, which allow the use of fiber optic components and cables even under such circumstances. Regardless of whether the optical fiber is intended for data or signal transmission or as intrinsic sensor, LEONI provides the appropriate technology in order to guarantee flawless and reliable functioning under adverse environmental conditions.

- ➔ **Fiber assemblies for high and low temperatures**
  For use at extreme temperatures LEONI offers different fiber types with metal coating:
  Aluminium coating
  Temperature range –273 °C to 400 °C
  Copper or gold coating
  Temperature range –273 °C to 700°C
- ➔ **Multimode graded-index fibers**
- ➔ **Multimode step-index fibers**

Find out more about assembly examples and options:
Chapter 10 | Optical components
➔ page **298 ff**

Connectors

for high power

- Different connectors based on SMA905 are available as joining elements in the high power range.
- Depending on the fiber type, up to 50 kW/cm² (type 1), 200 kW/cm² (type 2) or 500 kW/cm² of CW laser power can be transmitted.
- In pulsed operation the indicated values can be exceeded by a factor of up to 1000.
- Assemblies, single-unit productions and special designs in cooperation with the customer according to the customer's design are possible. This includes the drafting and individual test criteria depending on the application.

Further basic information on connector loss and connector types:

Chapter 12 | Principles
→ page 370 ff

LD-80BD laser cable with fiber break detection

Connectors for LargeCore assemblies

with metal or copper ferrule

Here you can find an extensive overview of LargeCore assemblies:
Chapter 05 | Industrial lasers
→ page 92 ff

	Standard SMA connector	High Power SMA connector LC 100
Order no.	depending on fiber, on request	depending on fiber, on request
Hole	128 – 1500 µm	128 – 1500 µm
Assembly	crimping/gluing/polishing	clamping/polishing
Ferrule	metal Ø 3.17 mm	metal Ø 3.17 mm connector long 45 mm / short 30 mm
Features	free-standing fiber, hex nut or knurled union nut	free-standing fiber, adhesive-free assembly, long or short design, hex nut or knurled union nut available

	High Power LC 1000	Special high-power connector	Advanced High Power connector
Order no.	depending on fiber, on request	depending on fiber, on request	depending on fiber, on request
Hole	480 – 1100 µm	480 – 1500 µm	150 – 1700 µm
Assembly	clamping/polishing	clamping/polishing	clamping/polishing ; gluing/polishing
Ferrule	metal length 57 mm, Ø 10 oder 15 mm	metal length 10 mm, Ø 4 mm	copper length 10mm, Ø 4 mm
Features	mode stripper free-standing fiber adhesive-free compatible with standard laser systems	free-standing fiber in ceramic insert adhesive-free assembly	free-standing fiber copper connector body definable fiber position compatible with standard 4 mm laser systems key optional

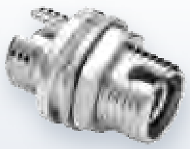
Connectors

with metal or ceramic ferrule

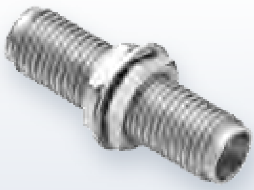
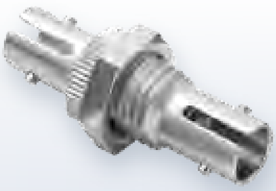
	DIN connector	ST connector (BFOC)		FC-PC connector
Order no.	depends on fiber, on request	depends on fiber, on request	depends on fiber, on request	depends on fiber, on request
Hole	128 – 1500 µm	125 µm – 1000 µm	125 µm – 600 µm	125 µm – 1000 µm
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing
Ferrule	metal	metal	ceramic	metal, ferrule with spring or fixed
Features	key (anti-twist) knurled union nut	incl. orange or black boot and dust cap	incl. black boot and dust cap	incl. red boot and dust cap

	FC-PC connector	FC-APC connector	SMA connector knurl	
Order no.	depends on fiber, on request	depends on fiber, on request	depends on fiber, on request	depends on fiber, on request
Hole	125 µm – 600 µm	125 µm – 600 µm	125 µm – 1500 µm	125 µm – 1500 µm
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing
Ferrule	ceramic	ceramic	metal	ceramic
Features	incl. black boot and dust cap	incl. black boot and dust cap	incl. black boot and dust cap	incl. black boot and dust cap

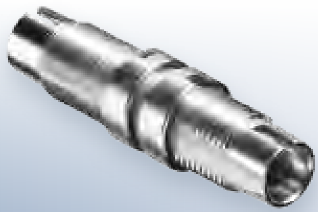
Adapters



	Adapter for FCPC PCF		Adapter for SC PCF
Order no.	SKUP-2XFCP-0010	SKUP-2XFCP-0020	SKUP-2XSCR-0010
Fiber Ø	SM, MM	SM, MM	MM
Housing	metal with metal insert	metal with ceramic insert	plastic with ceramic insert


	Adapter for FSMA PCF	Adapter for ST PCF	Adapter for LC PCF
Order no.	SKUP-2XSMA-0010	SKUP-2XXST-0010	SKUP-2XXLC-0010
Fiber Ø	MM	MM	SM, MM
Housing	metal without seperate insert	metal with metal insert	metal with ceramic insert



	DIN adapter
Order no.	SKUP-2×DIN-0010
Housing	metal with metal insert
Features	hexagonal fitting

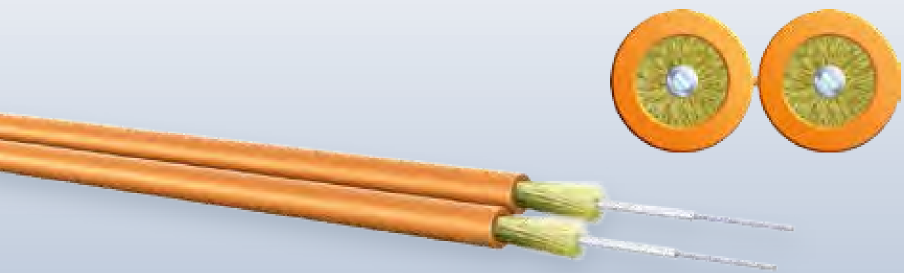
Data and control cables

Design examples

I-V(ZN)H 1	
Order no.	depending on fiber, on request
Application	for fixed indoor installation
Length	500 m and above

I-V(ZN)Y	
Order no.	depending on fiber, on request
Application	for indoor installation
Length	500 m and above

A-V(ZN)11Y	
Order no.	depending on fiber, on request
Application	for outdoor installation
Length	500 m and above



I-V(ZN)Y 2×1	
Order no.	depending on fiber, on request
Application	for indoor installation
Length	500 m and above

I-V(ZN)H 2×1	
Order no.	depending on fiber, on request
Application	for indoor installation
Length	500 m and above

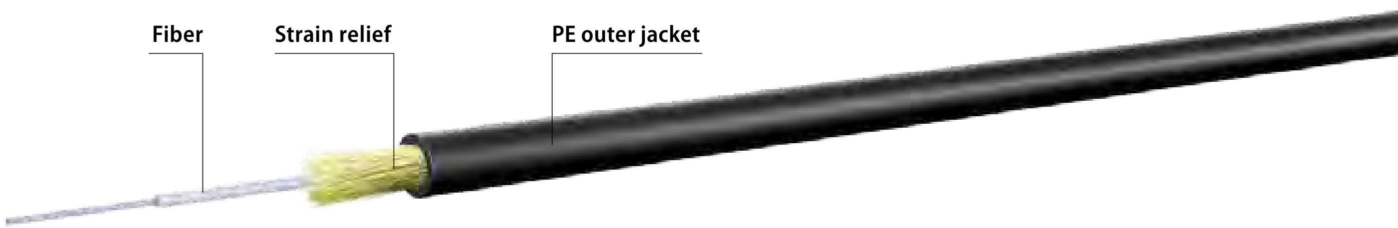
Info

An increase of up to 2 dB/km in the fiber attenuation value is to be expected when fibers are combined into cables.

Good mechanical protection is usually needed for using fibers in a variety of different applications.

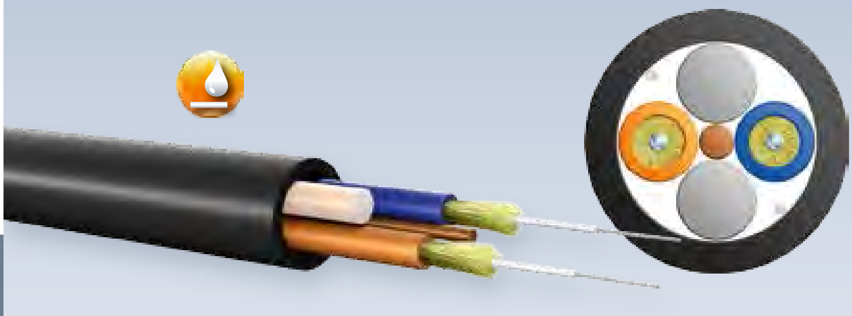
For smaller lengths (<200 m), we offer a range of different protective tubes from the simple PVC tube to the costly metal corrugated tube (Chapter 11 | Accessories from page 336). The fibers are pulled into the tube. For longer lengths (>200 m) it is possible to manufacture a cable.

Specifications LargeCore fiber cables		I-V(ZN)H 1	I-V(ZN)Y	A-V(ZN)11Y	I-V(ZN)Y 2×1	I-V(ZN)H 2×1
Order no.		depending on fiber, on request				
Composition	Outer jacket material	FRNC	PVC	PUR	PVC	FRNC
	Buffer tube material	–	–	–	–	–
	No. of fibers	1	1	1	2	1
	Outer Ø [mm]	2.2	2.2	3.0	2.2 × 4.5	2.2 × 4.5
Mechanical properties	Min. bending radius [mm]	depending on fiber, on request				
	Max. pull force [N]	depending on fiber, on request				
Thermal properties	Operating temperature [°C]	depends on fiber and material, on request				



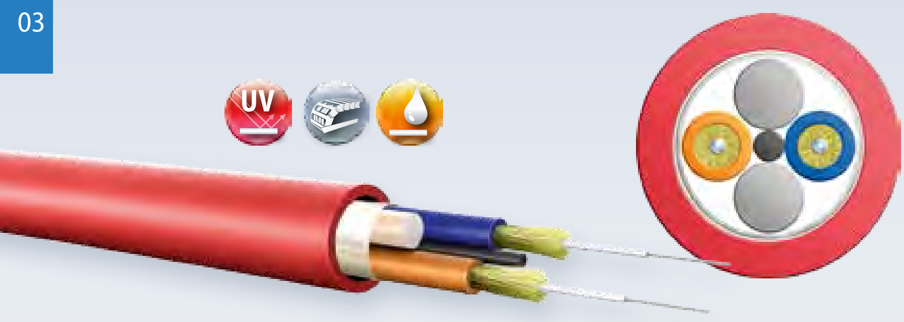
Data and control cables

Design examples



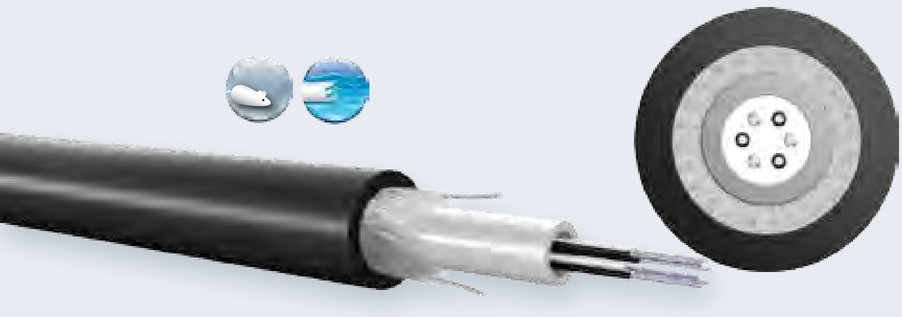
I-V(ZN)H2Y

Order no.	depending on fiber, on request
Application	for outdoor installation
Length	500 m and above



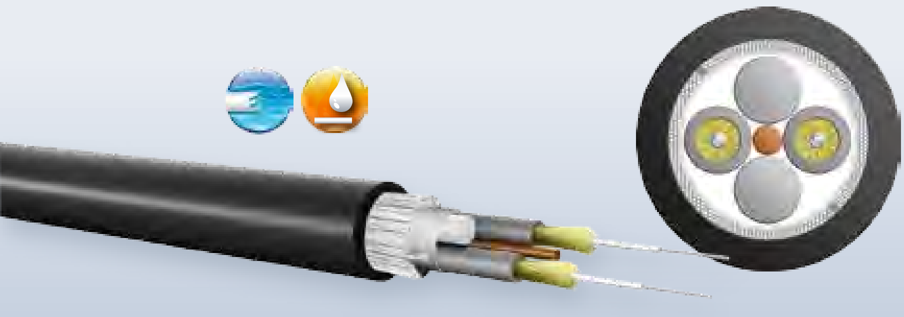
AT-V(ZN)Y11Y

Order no.	depending on fiber, on request
Application	for indoor and outdoor installation
Length	500 m and above



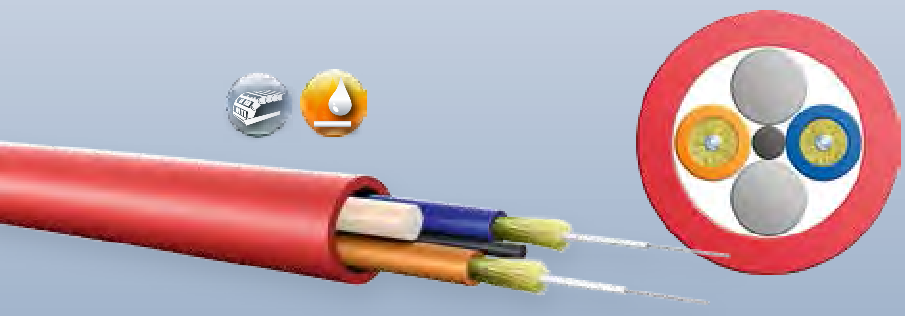
A-DQ(ZN)BH

Order no.	depending on fiber, on request
Application	for outdoor installation
Length	500 m and above



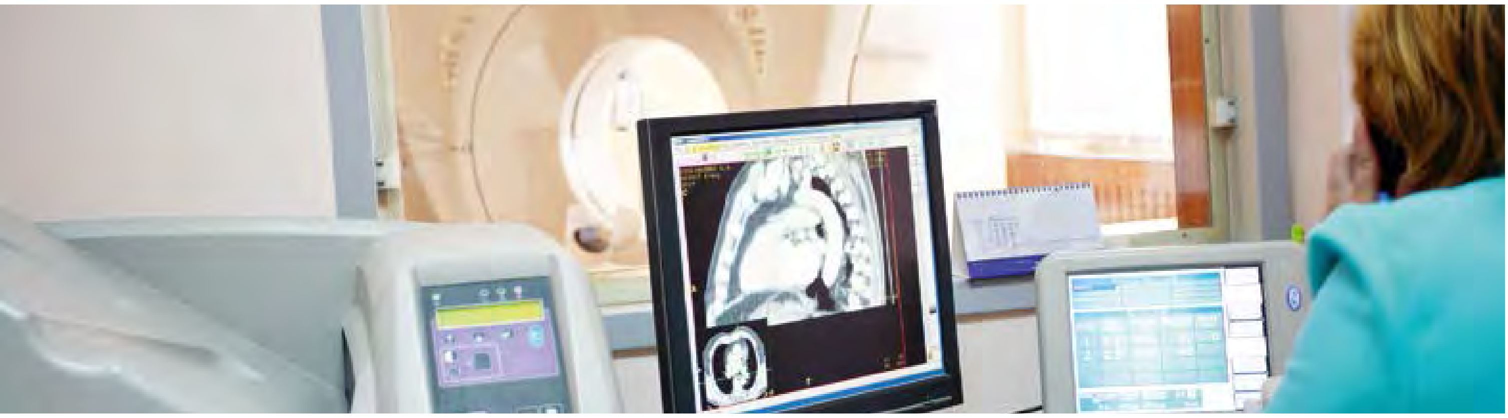
AT-VQ(ZN)HB2Y

Order no.	depending on fiber, on request
Application	for outdoor installation
Length	500 m and above



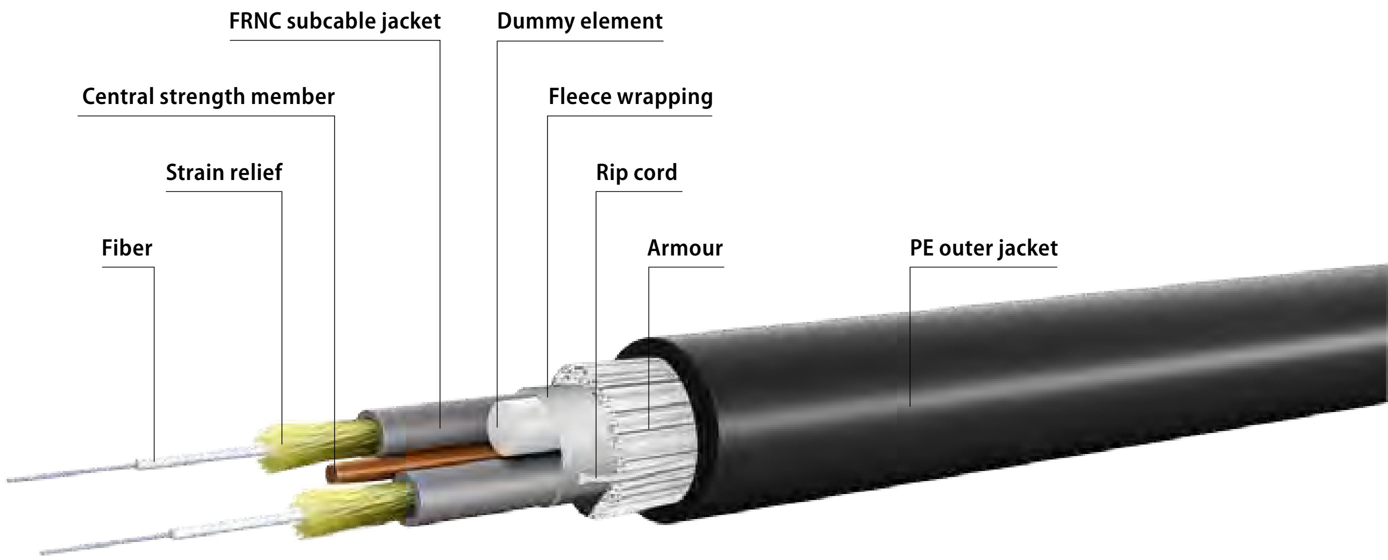
I-V(ZN)H11Y

Order no.	depending on fiber, on request
Application	for indoor installation
Length	500 m and above



Specifications LargeCore fiber cables		I-V(ZN)H2Y	AT-V(ZN)Y11Y	A-DQ(ZN)BH	AT-VQ(ZN)HB2Y	I-V(ZN)H11Y
Order no.		depending on fiber, on request				
Composition	Outer jacket material	PE	PUR	PE	PUR	FRNC/PE
	Buffer tube material	FRNC	PVC	FRNC	PVC	PVC
	No. of fibers	2	2	2	2	2
	Outer Ø [mm]	7.0	7.0	7.0	7.0	7.5
Mechanical properties	Min. bending radius [mm]	depending on fiber, on request				
	Max. pull force [N]	depending on fiber, on request				
Thermal properties	Operating temperature [°C]	depending on fiber, on request				

possible structure of a cable design



Assembly of LargeCore special fibers

All cables and sensors are produced according to the customer's specifications

Service features

- Almost all fiber and cable types (including hybrid cables) as well as protective tube types
- Every attenuation grade for different customer requirements
- Every length, even for single unit order sizes
- Customer-specific assembly
- Customer-specific cable printing
- Additional selective printing of the cable jacket possible during the process of cutting to length

Connectors

We offer connectors

- **for LargeCore fibers**
  - → for all fiber diameters
  - → for many cable diameters
- **with metal ferrule** available from 125–1000 µm
- **with ceramic ferrule** available from 125–800 µm
- **Connector types** SMA, FC/PC, DIN, ST and customer-specific connectors

Protective tube variants (see chapter tubes)

- PTFE
- PVC
- Metal – PVC
- Metal – silicone
- Stainless steel

Quality assurance

The optical attenuation is defined according to IEC61300-3-4 C for LargeCore fibers.

Fields of application

Lighting
Biotechnology
Energy research
Explosion-proof lighting
Fluid level sensors
High-temperature resistant series
High vacuum
Nuclear facilities
Communications systems
Laser marking
Laser welding/joining, laser separating
Air and space travel
Semiconductor production
Measuring instruments
Defense technology
Mode-mixing designs for all fibers and fiber bundle types
Non-linear optics
Optical pyrometers
Quality control

Type designation

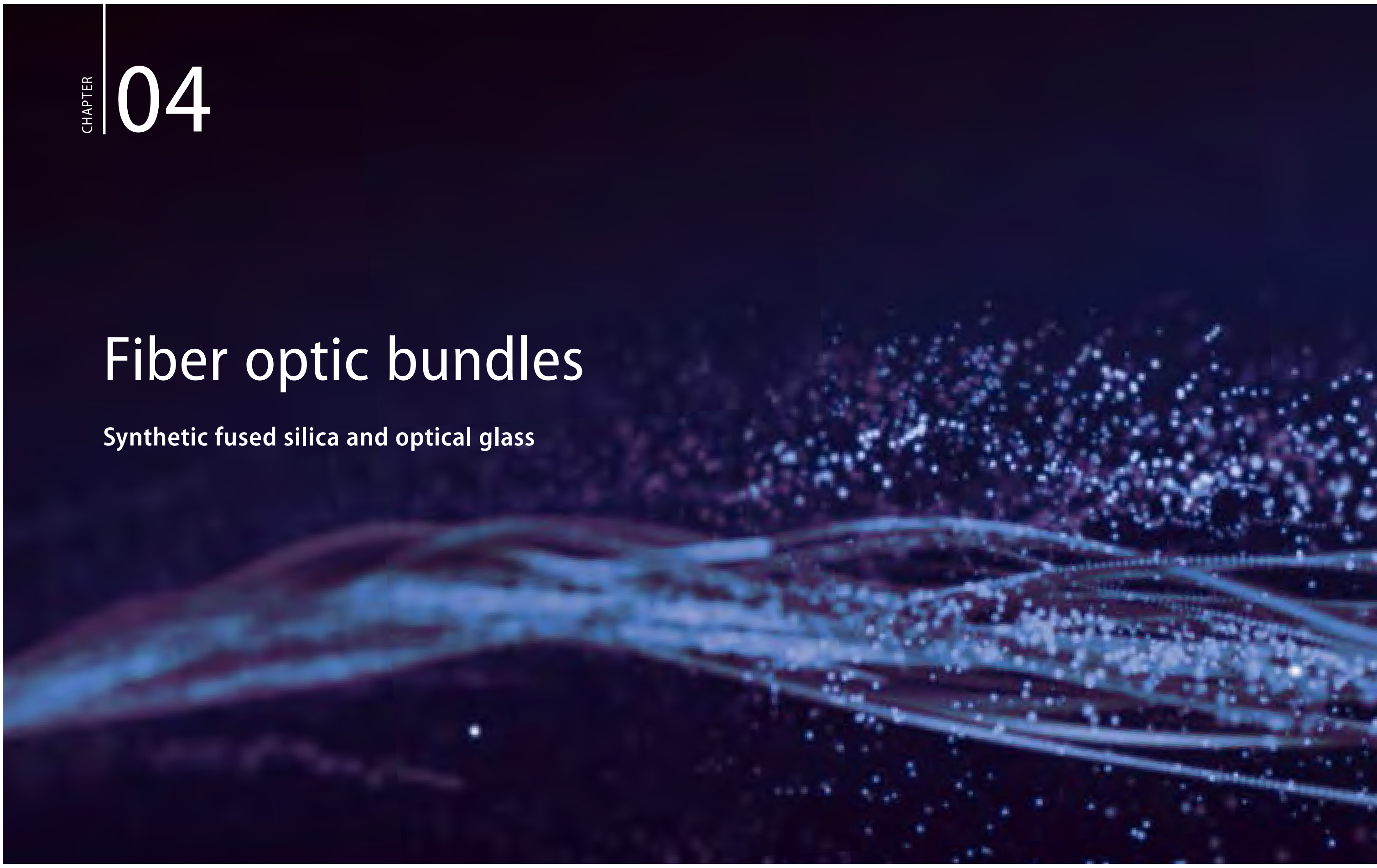
for pre-assembled LargeCore fiber cables

CM 003 × A01 – 08 / 4.4 gy 03 × 02 / 03 × 09 – 5500 mm 001 (Example)

Fiber optical single cable	CS
Fiber optical multi-cable	CM
Fiber optical bundle cable	CB
Sensor	SE
No. of fibers in bundle or bundle Ø	e.g. 003
Fiber type (code no./cable type)	e.g. A01
Primary cable tube	**Code**
None	00
PVC	01
Polyamide (PA)	02
Fluoropolymer (PTFE)	03
PEEK	04
Polyurethane (PU)	05
Polyethylene (PE)	06
Silicone (S)	07
Metal – PVC	08
Metal – PA	09
Metal – PU	10
Metal – S	11
Metal – single-interlocked	12
Metal – double-interlocked	13
Metal – limited bending	14
Other special shapes…	15 …
Outer Ø (mm)	e.g. 4.4
Tube colour	**Code**
Blue	bl
Yellow	yl
Black	bk
orange	or
Green	gn
White	wt
Natural	nt
Transparent	tr
Violet	vi
Grey	gy
Connector, side A	
Number (in units)	e.g. 03
Type	**Code**
SMA – knurl	01
SMA – hexagon	02
SMA – free-standing knurl	03
SMA – free-standing hexagon	04
DIN	05
DIN – resilient	06
FC-PC	07
FC-APC	08
ST	09
High power 4 mm	10
LC100 short	11
LC100 long	12
LC1000/10	13
LC1000/15	14
Special connector … (acc. to customer's specification)	15
Advanced high power connector	16 …
Connector, side B	
Number (in units)	e.g. 03
Type	**Code**
see above	e.g. 09
Assembly	
Overall length	e.g. 5500
Length unit	mm
	cm
	m
Version no.	e.g. 001

Special optical fibers

03



CHAPTER 04

Fiber optic bundles

Synthetic fused silica and optical glass

LEONI produces customer-specific fiber optic bundles made from UV-conductive silica/silica (high-OH), IR-conductive silica/silica (low-OH), plastic or optical glasses with different refractive indices as appropriate to the requirement for the optically conductive material on its own drawing systems.

The individual fibers are generally between 30 µm and 150 µm in diameter, but can be drawn to customer-specific diameters on request. The lengths of the fiber optic bundles vary between 4, 5, 10 and 20 m.

The bundle diameters are individually produced according to the customer's wishes.

The fiber bundles are available specifically for endoscopic applications in different radiation angles of 67° (LB type), 83° (LA type), 90° (LW2 type) and ≥100° (L120.3 type) for optimum illumination. Our range also includes UV-resistant (solarisation-stable) silica/silica fibers. In addition to endoscopy, they are also used in spectrometry, lighting and sensor technology.

The individual fibers are coated with glass finish (autoclavable up to 150 °C) or polyimide (can be used up to 300 °C) as appropriate to the assembly and temperature requirements.
The thickness of the coatings is ≤1 µm. They have a protective function and also simplify the further processing. In addition to the standard lengths and diameters, the fiber bundles can also be supplied as pre-assembled optical waveguides with polished end faces.

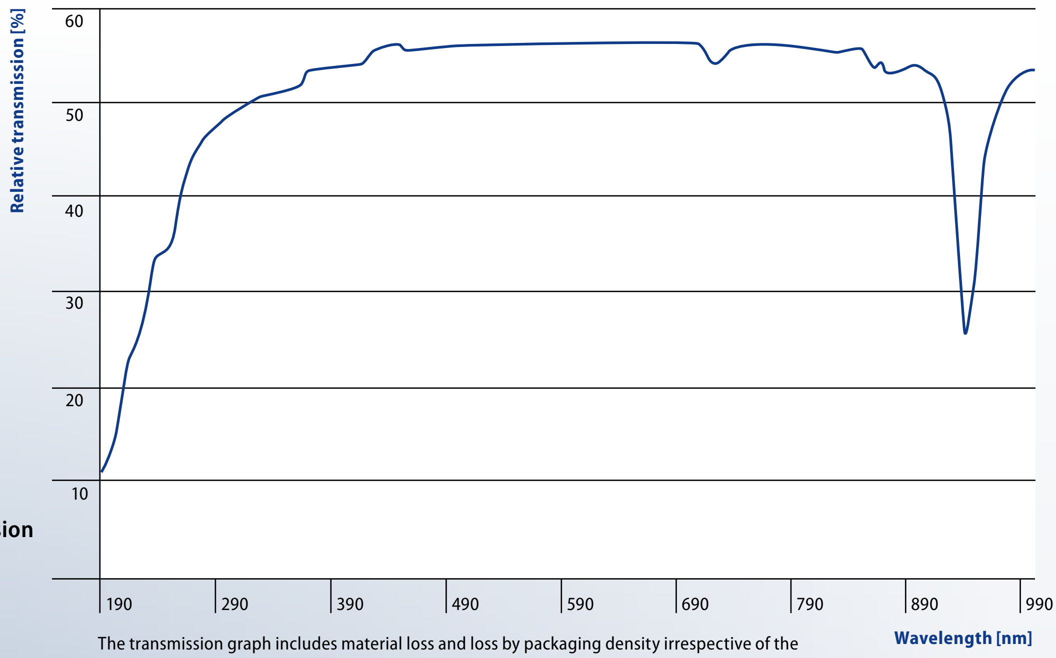
Further basic information on fiber bundles:
Chapter 12 | Principles
→ page 396 ff

04. Fiber optic bundles

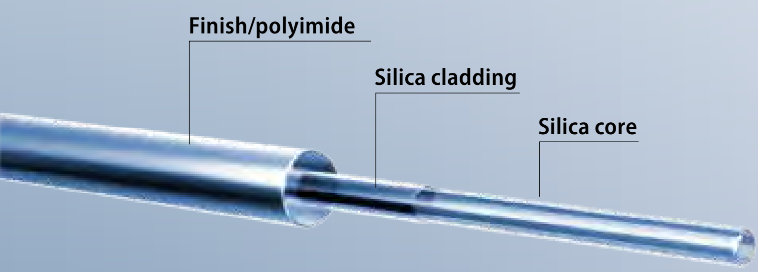
FiberTech® Fiber optic bundle (silica / silica)

Fiber optic bundle
UV-VIS

spectral transmission (length 1 m)



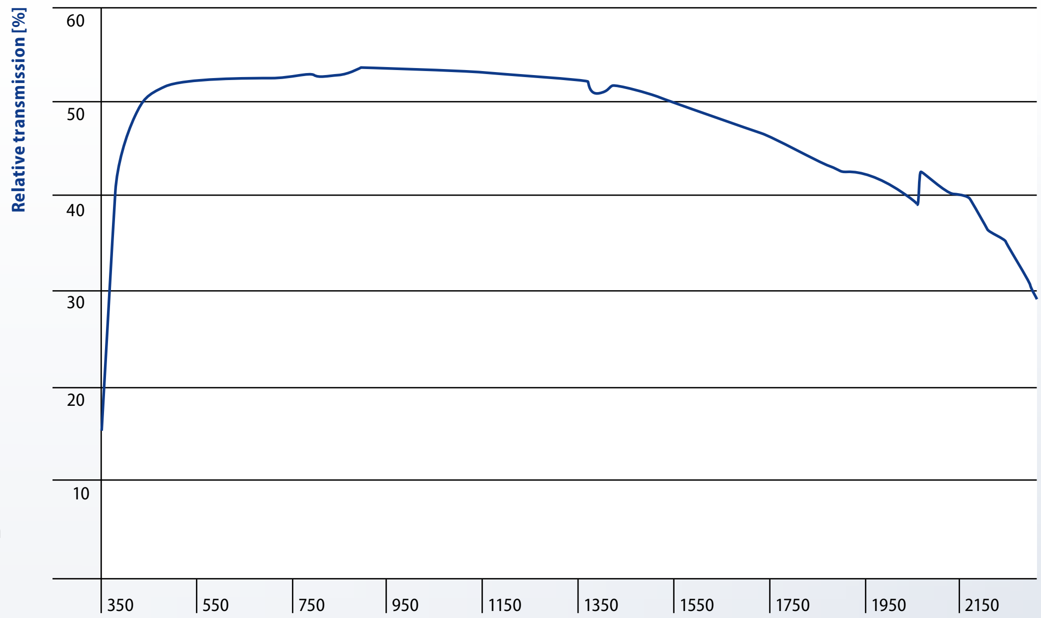
The transmission graph includes material loss and loss by packaging density irrespective of the indvidual fiber diameter and bundle diameter.



	Properties of individual fibers UV-VIS			
Fiber Ø (incl. cladding and coating) [µm]	30	50	80	105
CCDR	1.1			
Acceptance angle	25°			
Numerical aperture	0.22 ± 0.02 (0.1 or 0.36 on request)			
Temperature resistance with finish [°C]	200°C			
Temperature resistance with polyimide [°C]	300°C			
	Properties of fiber optic bundle			
Bundle Ø [mm]	0.3 – 6 (other dimensions on request)			
Bending radius [mm]	40 – 60 depending on bundle Ø			

Fiber optic bundle
VIS-IR

spectral transmission (length 1 m)



The transmission graph includes material loss and loss by packaging density irrespective of the indvidual fiber diameter and bundle diameter.

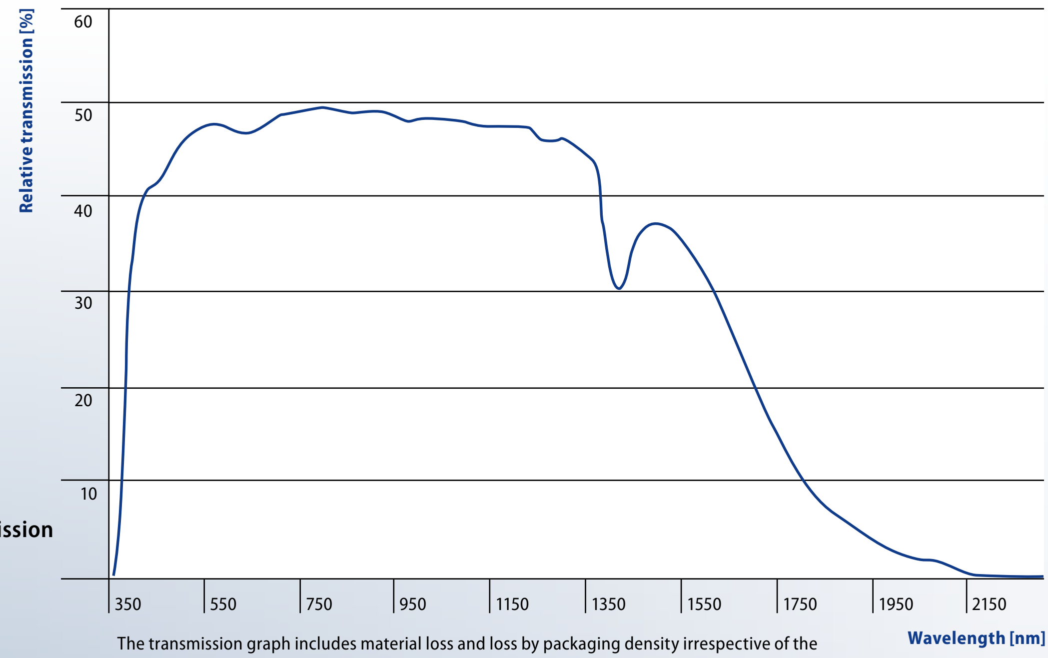
	Properties of individual fibers VIS-IR				
Fiber Ø (incl. cladding and coating) [µm]	30	50	70	80	105
CCDR	1.2				
Acceptance angle	25°				
Numerical aperture	0.22 ± 0.02 (0.1 or 0.36 on request)				
Temperature resistance with finish [°C]	200 °C				
Temperature resistance with polyimide [°C]	300 °C				
	Properties of fiber optic bundle				
Bundle Ø [mm]	0.3 – 6 (other dimensions on request)				
Bending radius [mm]	40 – 60 depending on bundle Ø				

FiberTech® Fiber optic bundle (optical glass / optical glass)

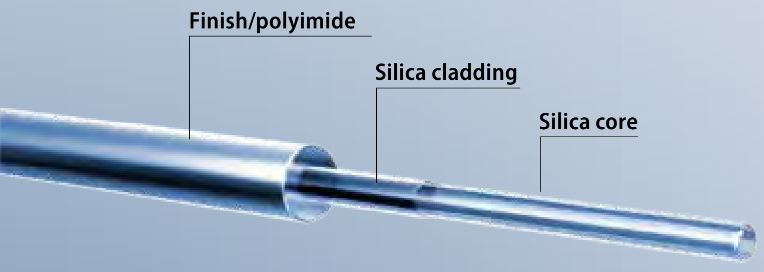
LB type

Fiber optic bundle
VIS

spectral transmission (length 1 m)



The transmission graph includes material loss and loss by packaging density irrespective of the indvidual fiber diameter and bundle diameter.



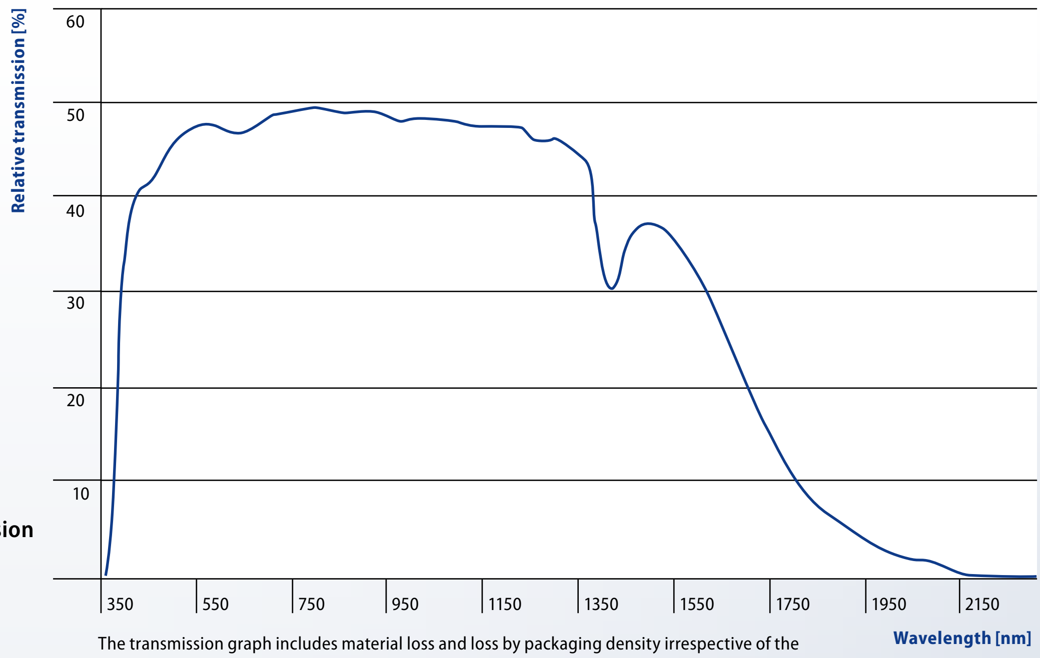
	Properties of individual fibers LB type			
Fiber Ø (incl. cladding and coating) [µm]	**30**	**50**	**60**	**70**
CCDR	1.1			
Acceptance angle	67°			
Numerical aperture	0.56			
Temperature resistance with finish [°C]	200 °C			
Temperature resistance with polyimide [°C]	300 °C			
	Properties of fiber optic bundle			
Bundle Ø [mm]	0.3 – 6 (other dimensions on request)			
Bending radius [mm]	40 – 60 depending on bundle Ø			

FiberTech® Fiber optic bundle (optical glass / optical glass)

LA1 type

Fiber optic bundle
VIS

spectral transmission (length 1 m)



The transmission graph includes material loss and loss by packaging density irrespective of the indvidual fiber diameter and bundle diameter.

	Properties of individual fibers LA1 type			
Fiber Ø (incl. cladding and coating) [µm]	**30**	**50**	**60**	**70**
CCDR	1.1			
Acceptance angle	83°			
Numerical aperture	0.66			
Temperature resistance with finish [°C]	200 °C			
Temperature resistance with polyimide [°C]	300 °C			
	Properties of fiber optic bundle			
Bundle Ø [mm]	0.3 – 6 (other dimensions on request)			
Bending radius [mm]	40 – 60 depending on bundle Ø			

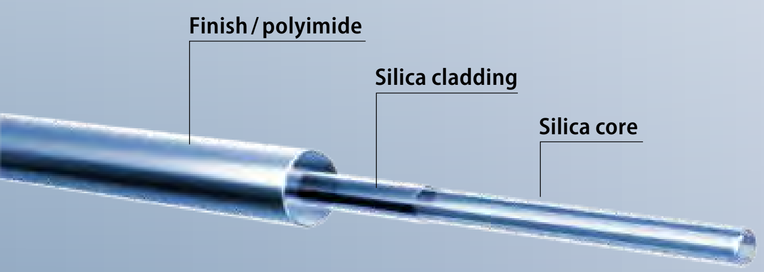
FiberTech® Fiber optic bundle (optical glass / optical glass)

LW2 type

Fiber optic bundle
VIS

spectral transmission (length 1 m)

The transmission graph includes material loss and loss by packaging density irrespective of the indvidual fiber diameter and bundle diameter.



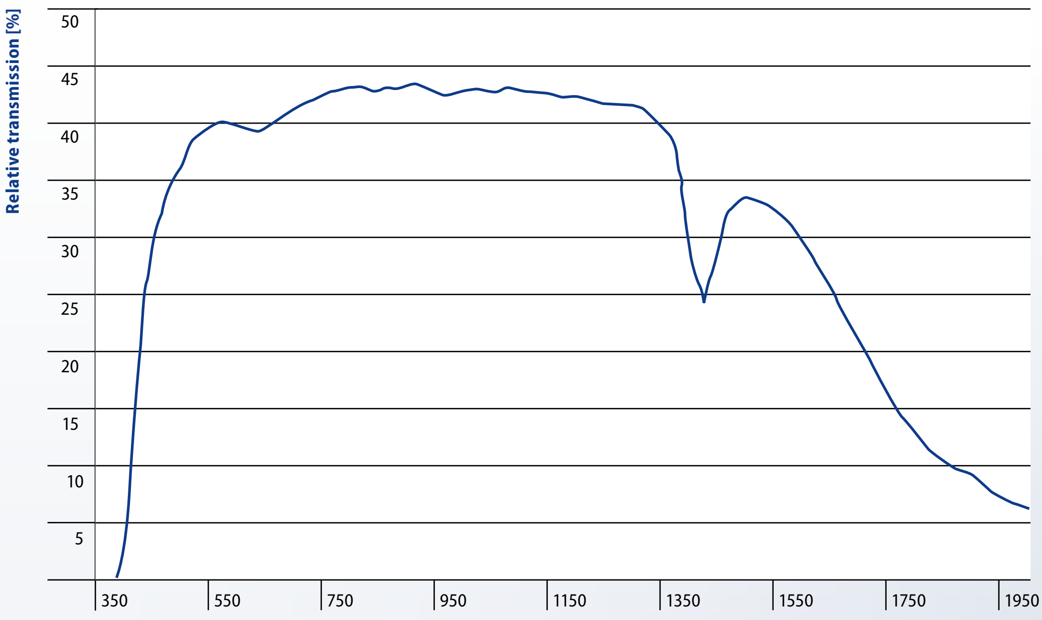
	Properties of individual fibers LW2 type			
Fiber Ø (incl. cladding and coating) [µm]	**30**	**50**	**60**	**70**
CCDR	1.1			
Acceptance angle	93°			
Numerical aperture	0.72			
Temperature resistance with finish [°C]	200 °C			
Temperature resistance with polyimide [°C]	300 °C			
	Properties of fiber optic bundle			
Bundle Ø [mm]	0.3 – 6 (other dimensions on request)			
Bending radius [mm]	40 – 60 depending on bundle Ø			

FiberTech® Fiber optic bundle (optical glass / optical glass)

L120.3 type

Fiber optic bundle
VIS

spectral transmission (length 1 m)



The transmission graph includes material loss and loss by packaging density irrespective of the indvidual fiber diameter and bundle diameter.

	Properties of individual fibers L120.3-VIS		
Fiber Ø (incl. cladding and coating) [µm]	**30**	**50**	**70**
CCDR		1.1	
Acceptance angle		≥ 100°	
Numerical aperture		0.87	
Temperature resistance with finish [°C]		200 °C	
Temperature resistance with polyimide [°C]		300 °C	
		Properties of fiber optic bundle	
Bundle Ø [mm]		0.3 – 6 (other dimensions on request)	
Bending radius [mm]		40 – 60 depending on bundle Ø	

Assembly of fiber optic bundles

LEONI assembles optical fibers from the suitable base materials (optical glass or silica) to guarantee the optimum transmission of the UV light through the visible range to the IR range.

Here you can find corresponding assembly examples:
Chapter 10 | Optical components
→ page 298 ff

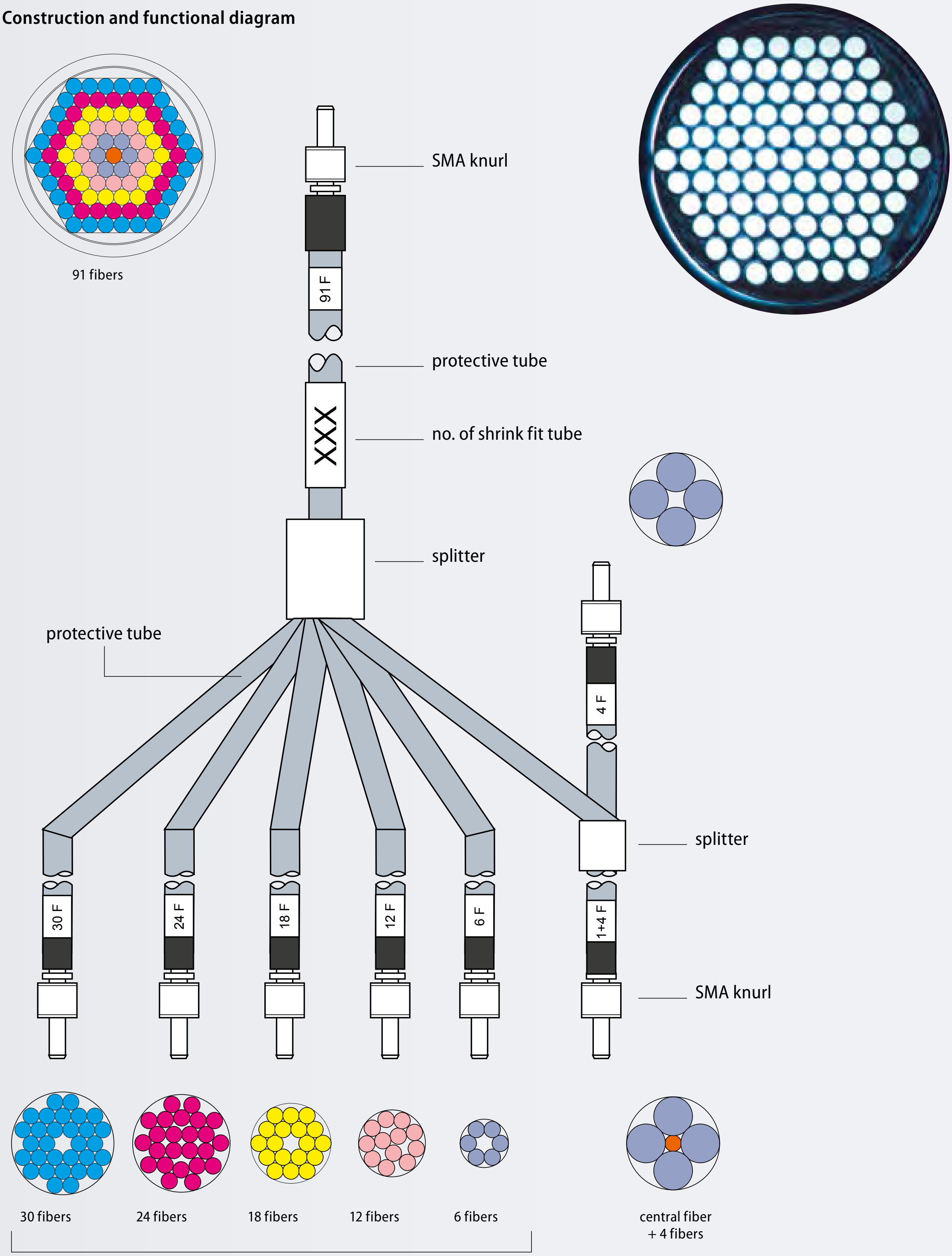
Advantages

- The used fibers and cables come from our own production facilities, which means you can be confident of always getting the most economical product.
- Ultra modern lapping, polishing and cleaving techniques guarantee maximum transmission properties.
- These transmission properties can be further optimised in some applications through the use of anti-reflective surfaces .
- Product diameters and lengths are individually adapted during assembly.
- A selection of protective tube types are presented in chapter 11 | Accessories.
- The assembled fiber bundles can cover a temperature range from –60 °C to +300° C as appropriate to the application.
- Customer-specific connector selection: SMA, SC, ST connectors or tailor-made ferrules.

Example of a multi-legged fiber optic bundle

Construction and functional diagram

Construction and functional diagram



Arrangement of the fibers in these individual connectors can differ.

CHAPTER 05

Industrial lasers

Optical fibers and cables for industrial laser products

We are able to influence the product design at **at every stage of the process** according to your wishes!

LEONI Fiber Optics Laser cables are based on **LOSCH High-Power Technology** and are specially designed for transferring laser beam energy generated by industrial and medical laser systems. The applications for LEONI laser cables include all fiber-coupled laser systems emitting in the UV to IR wavelength region, as for example high-power semiconductor lasers, solid-state lasers and fiber lasers.

Fused silica fibers and capillaries

LEONI produces a variety of fused silica step-index and graded-index laser fibers with different fiber dimensions and coating/ jacket material. LEONI has performed intensive research to experimentally determine the laser beam damage threshold of these fibers, and can therefore assist customers to exactly find the right product (➔ www.leoni-fiber-optics.com).
Silica capillaries are also available, used for beam guiding of ultra-short pulses in the femto-second range.

Laser cables with SMA and FC interface

LEONI offers a variety of different laser cables with F-SMA/ SMA905 connectors, depending on the beam power levels. All connectors have a free-standing fiber tip. CuSMA cables with their distinctive copper alloy ferrule and excellent fiber alignment provide good heat removal and fiber centration. Maximum laser power transmission can be achieved with the SMA500 cables, with an even superior heat transfer capability. The CuFC connectors provide a connector interface for FC-style applications including a key employed as an anti- rotation feature.

Laser cables with LD-80 interface

The LD-80 is compatible with the Ø 4x10 mm Industrial Industry Standard. The extremely accurate, keyed connector allow for plug- and play connections. High power transmission is achieved by the copper alloy ferrule and the excellent fiber alignment. Laser safety is ensured by using steel-armored protection tubes and, in some of the products, by an electrical fiber break-detect system.

Laser cables with ModeStrip technology

Fiber cladding modes are the radiation modes within a fiber which are not confined within the fiber core but guided within the fiber cladding, due to the beam reflection at the interface between the silica clad and coating material. Some laser

High-power multimode step-index fibers	High-power multimode graded-index fibers	Fused silica capillaries
Fiber coupling	High-power connector	High fiber centration
Fiber guided beam transmission	Mode stripping	Hybrid optical/electrical cable solutions
Keyed fiber connectors	Liquid-cooled connectors	Cables with break-detection

Further basic information on lasers:
Chapter 12 | Principles
→ page 362 ff

applications require that the fiber radiation is limited to the fiber core, in this case the cladding modes have to be removed or stripped. LOSCH High-Power Technology has integrated the mode-stripping feature into the connector and offers different cooling solutions for managing the heat dissipation.

Robotic laser cables

These cables are optimized to effectively transport highest laser powers of up to several kW from the laser system to the workpiece. Main applications are the beam delivery to an optical system mounted on an industrial robot, therefore these cables are known in the market as robotic cables. Different standardized connector interfaces with nozzle diameters of 10 mm (LLK-LP) and 15 mm (LLK-HP) are available to achieve compatibility with common laser systems. Fiber break-detection and thermal control of the connector ensure laser safety requirements during operation.

The robotic laser cables are based on the proven LOSCH High-Power Technology and include efficient heat removal by using copper alloy material and the high-accuracy fiber centration.

05. Industrial lasers

Overview FiberTech® Laser cables

Two key parameters of laser systems are necessary to select the appropriate fiber cable

At first, the laser beam quality defines the minimum core diameter and the numerical aperture of the optical fiber. Secondly, the laser average power has to be taken into account to select the connector type. Due to reflection losses at the fiber-to-air interface inside the connector part of the laser energy will be dissipated.

LEONI laser cables with LOSCH Technology, besides of it's excellent fiber alignment, include several features to efficiently remove heat energy from the inner part of the connector.

Also, the maximum average power depends on the coupling conditions between laser system and optical fiber, in the case of optimum coupling 100% of the laser power is coupled into the fiber core. Therefore, as the specific coupling conditions are not known, the maximum power rating in the following overview can only be meant as a guide-line.

Product and fiber core diameter	Connector	Connector cooling	Max. average power W*	Mode stripping	Part no. family
Standard SMA fiber cables					
200 µm	Standard SMA free-standing	Air convection	50	NO	**FCL15-x FCL16-x**
400 µm			100		
600 µm			100		
800 µm			100		
1000 µm			100		
CuSMA fiber cables					
100 µm	Cu ferrule, SMA free-standing	Air convection	50	NO	**FCL23-x**
200 µm			200		
400 µm			400		
600 µm			400		
800 µm			400		
1000 µm			400		
SMA500 fiber cables					
100 µm	Cu ferrule, SMA free-standing	Air convection/ conduction cooling	50	NO	**FCL24-x**
200 µm			250		
400 µm			500		
600 µm			500		
800 µm			500		
SMA500MS fiber cables					
100 µm	Cu ferrule, SMA free-standing	Air convection/ conduction cooling	50	YES	**FCL25-x**
200 µm			200		
400 µm			200		
SMA500L fiber cables					
100 µm	Cu ferrule, SMA free-standing	Liquid cooling	50	YES	**FCL26-x**
200 µm			200		
400 µm			200		
CuFC fiber cables					
100 µm	Cu ferrule, SMA free-standing	Air convection	50	NO	**FCL27-x**
200 µm			200		
400 µm			400		

* Note: The maximum Average laser power rating is based on the feedback from our customers and can only be meant as a guide-line, as it depends of the coupling conditions.

Product and fiber core diameter	Connector	Connector cooling	Max. average power W*	Mode stripping	Part no. family
CuFC-L fiber cables					
100 µm	Cu ferrule, FC free-standing	Liquid cooling	50	YES	**FCL28-x**
200 µm			200		
400 µm			400		
LD-80 fiber cables					
100 µm	Cu ferrule, 4 mm diameter free-standing	Air convection	100	NO	**FCL30-x**
200 µm			300		
300 µm			600		
400 µm			800		
600 µm			800		
800 µm			800		
1000 µm			800		
LD-80MS fiber cables					
100 µm	Cu ferrule, 4 mm diameter free-standing	Air convection/ conduction cooling	50	YES	**FCL31-x**
200 µm			200		
400 µm			200		
LD-80BD fiber cables with break detect					
100 µm	Cu ferrule, 4 mm diameter free-standing	Air convection	100	NO	**FCL34-x**
200 µm			300		
300 µm			600		
400 µm			800		
600 µm			800		
800 µm			800		
1000 µm			800		
LD-80R Robotic fiber cables					
300 µm	Cu ferrule, 10 or 15 mm diameter	Air convection	2000	NO	**FCL32-x**
400 µm			3000		
600 µm			5000		
800 µm			5000		
1000 µm			5000		

* Note: The maximum Average laser power rating is based on the feedback from our customers and can only be meant as a guide-line, as it depends of the coupling conditions.

Type designation

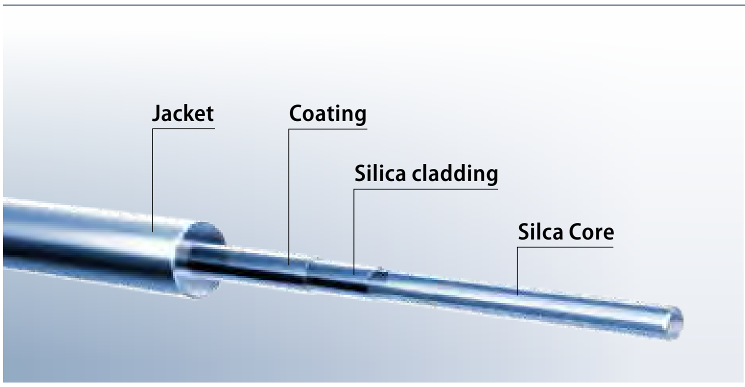
for FiberTech® laser cables

CL S 0400 IR 08 / 08.0 bl 23 / 23- 0300 cm 001 (Example)

Laser cables	CL
Fiber type	
Step-index 0.22 NA	S
Graded index	G
Step-index 0.15 NA	A
Step-index 0.12 NA	B
Core diameter [µm]	...
Transmission range	
VIS/IR spectral range	IR
UV/VIS spectral range	UV
Cable type	
PVC (polyvinyl chloride)	01
PTFE (fluorpolymer)	03
Peek	04
PE (polyethylene)	06
Squarelock tube, PVC coated	08
Squarelock tube, uncoated	11
Cable outer diameter [mm]	...
Cable colour	
red	rd
blue	bl
green	gr
black	bk
orange	or
white	wt
grey	gy
natural	nt
Connector side A / side B	
Standard SMA freestanding hex	15
Standard SMA freestanding curl	16
CuSMA	23
SMA500	24
SMA500MS	25
SMA500L	26
CuFC	27
CuFC-L	28
LD-80	30
Robotic laser cable	32
LD-80BD	34
Cable length	...
Cable length unit	
mm	mm
cm	cm
m	m
Version	...

FiberTech® VIS-IR fiber specifications

Step-index multimode
VIS-IR



Business Units Fiber Optics' step-index multimode fibers with a fused silica core are the material of choice for laser beam transmission. The low OH content and the uniform refractive index guarantees low beam distortion and low absorption in the VIS-IR wavelength range of 400 nm–2400 nm.

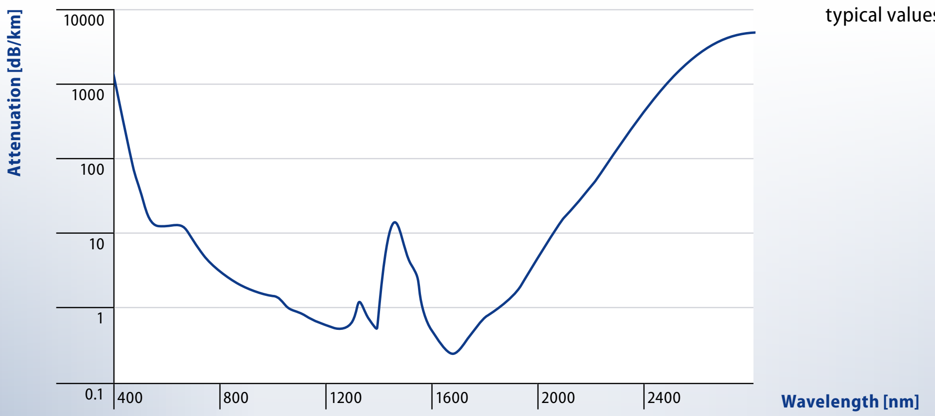
The cladding consists of fluorine-doped fused silica and defines the beam-guiding properties and the numerical aperture of the fiber. The standard numerical aperture is 0.22, other apertures are available on request

Tailored to the various applications the fibers are available with different coating and jacket materials. Silicone and hard-clad (fluorine-doped high-temperature acrylate) enables high power laser beam transmission with average power levels of up to several kilowatts. For both materials the refractive index is lower than the refractive index of the fiber cladding. Therefore radiation not confined within the fiber core will propagate along the fiber as cladding modes. Special connectors are available to remove or strip these cladding modes, their energy is transformed into heat.

The Business Unit Fiber Optics has performed extensive research to experimentally determine the laser beam damage threshold for the fiber and coating materials using laser probe beams and can therefore assist customers to exactly find the right product.

	Step-index multimode: VIS-IR								
Core Ø [µm] (±2 %)	40	50	60	90	100	100	100	105	200
Clad-Ø [µm] (±2 %)	125	125	125	125	110	120	140	125	220
	Fibers with coating								
	Coating – single acrylate			Numerical aperture 0.22 (0.1 on request) Temperature range −40 °C to 85 °C					
Coating Ø [µm] (±3 %)	200	200	200	200	200	200	220	200	345
Order no.:	84810001N	84810003N	84810004	84810005N	84810006N	84810007N	84810008N	84810009N	848100010N
	Coating – dual acrylate			Numerical aperture 0.22 (0.1 on request) Temperature range −40 °C to 85 °C					
Coating Ø [µm] (±3 %)	245	245	245	245	230	240	260	245	400
Order no.:	84810041N	84810043N	84810044N	84810045N	84810046N	84810047	84810048N	84810049N	84810050N
	Fibers with coating and jacket								
	Coating – acrylate / jacket – Nylon®			Numerical aperture 0.22 (0.1 on request) Temperature range −40 °C to 85 °C					
Jacket Ø [µm] (±5 %)	500	500	500	500	500	500	500	500	500
Order no.:	84810101N	84810103N	84810104N	84810105N	84810106N	84810107N	84810108N	84810109N	84810119N
	Coating – silicone / jacket – Tefzel®			Numerical aperture 0.22 (0.1 on request) Temperature range −40 °C to 150 °C					
Jacket Ø [µm] (±5 %)	500	500	500	500	500	500	500	500	500
Order no.:	84810161N	84810162N	84810163N	84810164N	84810165N	84810166N	84810167N	84810168N	84810169N

Short-term bending radius: 100 x jacket radius | long-term bending radius: 600 x jacket radius
Fibers with jacket are available in different colours | Tefzel®: black, blue, transparent | Nylon®: black, blue, transparent, yellow, red, white

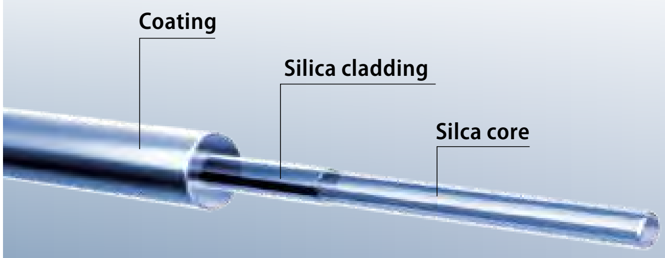


	Step-index multimode: VIS-IR									
Core Ø [µm] (±2 %)	**200**	**200**	**365**	**400**	**400**	**500**	**600**	**800**	**1000**	**1500**
Clad-Ø [µm](±2 %)	**240**	**280**	**400**	**440**	**480**	**550**	**660**	**880**	**1100**	**1650**
	Fibers with coating									
	Coating – single acrylate			Numerical aperture 0.22 (0.1 on request) Temperature range −40 °C to 85 °C						
Coating Ø [µm](±3 %)	400	450	550	560	660	700	840	1000	1350	1850
Order no.:	84810011N	84810012N	84810014N	84810015N	84810016N	84810017N	84810583N	84810020N	84810022N	84810024N
	Coating – dual acrylate			Numerical aperture 0.22 (0.1 on request) Temperature range −40 °C to 85 °C						
Coating Ø [µm](±3 %)	400	500	—	—	—	—	—	—	—	—
Order no.:	84810051N	84810052N	—	—	—	—	—	—	—	—
	Fibers with coating and jacket									
	Coating – acrylate / jacket – Nylon®			Numerical aperture 0.22 (0.1 on request) Temperature range −40 °C to 85 °C						
Jacket Ø [µm](±5 %)	600	600	800	800	800	1000	1000	1300	1600	2000
Order no.:	84810110N	84810111N	84810113N	84810114N	84810115N	84810116N	84810117N	84810118N	84810525N	84810537N
	Coating – hardclad / jacket – Tefzel®			Numerical aperture 0.22 (0.1 on request) Temperature range −40 °C to 150 °C						
Jacket Ø [µm](±5 %)	—	—	580	650	—	—	880	1200	1400	—
Order no.:	—	—	84810304N	84810306N	—	—	84810310N	84810312N	84810313N	—
	Coating – silikon / jacket – Tefzel®			Numerical aperture 0.22 (0.1 on request) Temperature range −40 °C to 150 °C						
Jacket Ø [µm](±5 %)	600	600	800	800	800	1000	1000	1300	1500	2250
Order no.:	84810170N	84810171N	84810173N	84810174N	84810175N	84810176N	84810177N	84810178N	84810121N	84810179N

Short-term bending radius: 100 x jacket radius | long-term bending radius: 600 x jacket radius
Fibers with jacket are available in different colours | Tefzel®: black, blue, transparent | Nylon®: black, blue, transparent, yellow, red, white

VIS-IR fiber specifications

Grade-index multimode
VIS-IR



The Busines Unit Fiber Optics is a leading producer of high-quality multimode fibers with graded index profile used for data transmission. Based on this expertise LEONI Fiber Optics offers an extended product range of graded-index fibers for laser beam transmission applications.

The light rays within graded-index fibers will not follow a zig-zag-path as in the case of a step-index profile. The fiber acts as a lens duct with the advantage that the input NA and the beam diameter at the fiber input will be preserved. Due to the doping of the fiber core graded-index fibers have a lower laser damage threshold and a higher numerical aperture in comparison with step-index fibers.

	Grade-index multimode: VIS-IR						
Core Ø [µm] (±2 %)	50	62.5	85	100	200	400	600
Jacket Ø [µm] (±2 %)	125	125	125	140	280	560	840
	Fibers with coating						
Transmission properties							
Numerical aperture	0.2	0.275	0.26	0.29	0.29	0.29	0.29
Attenuation at 850 nm [dB/km]	3/2.7	3.5/3.2	3.5/3	4/3.5	6	8	10
Attenuation at 1300 nm [dB/km]	1/0.7	1/0.9	1/0.9	1.5/1.0	3	4	5
Bandwidth at 850 nm [MHz x km]	300/600	300/400	200	200	150	100	100
Bandwidth at 1300 nm [MHz x km]	600/1200	550/1000	200	200	150	100	100
	Coating – acrylate Temperature range −40 °C to 85 °C						
Coating Ø [µm](±3 %)	250	250	250	260	450	700	1050
Order no.:	84810501N	84810502N	84810503N	84810504N	84810505N	84810506N	84810507N

Nylon® or Tefzel® Jackets optionally available..
Fibers with jacket are available in different colours | Tefzel®: black, blue, transparent | Nylon®: black, blue, transparent, yellow, red, white

FiberTech® Standard SMA laser cables

with hex nut

CLS□□□□IR01/05.5bl15/15-□□□□cm100

Description

Laser cable with F-SMA free-standing fiber connectors and PVC protection tube and stainless steel connector cuffs. Applicable for laser beam delivery of up to 100 W.

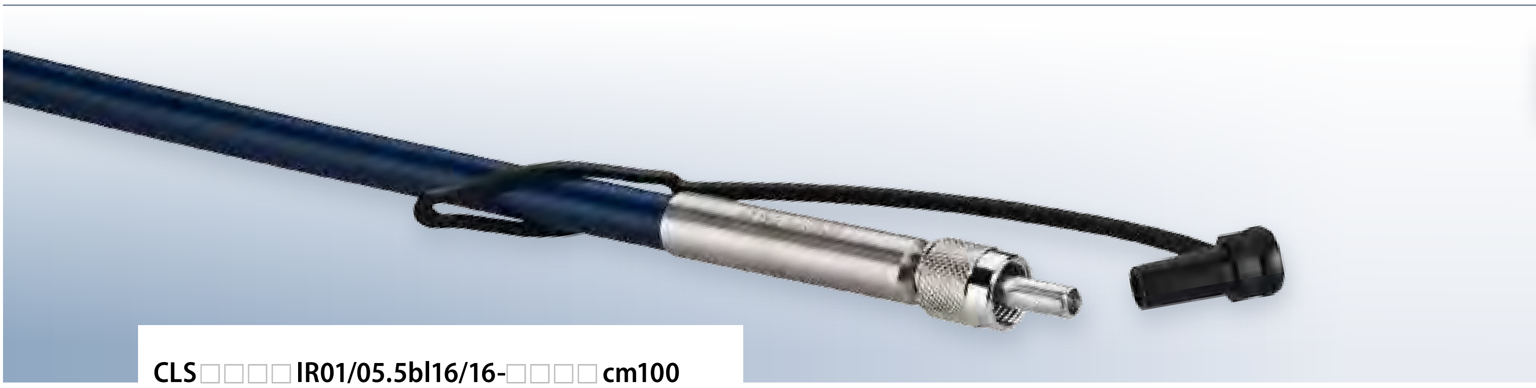
Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
- SMA905 (F-SMA) connector with free-standing fiber tip
- Hex nut
- Aramid yarn, blue PVC protection tube
- Stainless-steel connector cuffs
- Average laser power up to 100 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
200	2	CLS0200IR01/05.5bl15/15-0200cm100	**FCL15-20200-1000**
400		CLS0400IR01/05.5bl15/15-0200cm100	**FCL15-40200-1000**
600		CLS0600IR01/05.5bl15/15-0200cm100	**FCL15-60200-1000**
800		CLS0800IR01/05.5bl15/15-0200cm100	**FCL15-80200-1000**
1000		CLS1000IR01/05.5bl15/15-0200cm100	**FCL15-90200-1000**
200	3	CLS0200IR01/05.5bl15/15-0300cm100	**FCL15-20300-1000**
400		CLS0400IR01/05.5bl15/15-0300cm100	**FCL15-40300-1000**
600		CLS0600IR01/05.5bl15/15-0300cm100	**FCL15-60300-1000**
800		CLS0800IR01/05.5bl15/15-0300cm100	**FCL15-80300-1000**
1000		CLS1000IR01/05.5bl15/15-0300cm100	**FCL15-90300-1000**
200	5	CLS0200IR01/05.5bl15/15-0500cm100	**FCL15-20500-1000**
400		CLS0400IR01/05.5bl15/15-0500cm100	**FCL15-40500-1000**
600		CLS0600IR01/05.5bl15/15-0500cm100	**FCL15-60500-1000**
800		CLS0800IR01/05.5bl15/15-0500cm100	**FCL15-80500-1000**
1000		CLS1000IR01/05.5bl15/15-0500cm100	**FCL15-90500-1000**

FiberTech® Standard SMA laser cables

with knurled nut



CLS□□□□IR01/05.5bl16/16-□□□□cm100

Description

Laser cable with F-SMA free-standing fiber connectors and PVC protection tube and stainless steelconnector cuffs. Connector with knurled nut for eysy connector attachment without tools. Applicable for laser beam delivery of up to 100 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
- SMA905 (F-SMA) connector with free-standing fiber tip
- Knurled union nut
- Aramid yarn, blue PVC protection tube
- Stainless-steel connector cuffs
- Average laser power up to 100 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
200	2	CLS0200IR01/05.5bl16/16-0200cm100	**FCL16-20200-2000**
400		CLS0400IR01/05.5bl16/16-0200cm100	**FCL16-40200-2000**
600		CLS0600IR01/05.5bl16/16-0200cm100	**FCL16-60200-2000**
800		CLS0800IR01/05.5bl16/16-0200cm100	**FCL16-80200-2000**
1000		CLS1000IR01/05.5bl16/16-0200cm100	**FCL16-90200-2000**
200	3	CLS0200IR01/05.5bl16/16-0300cm100	**FCL16-20300-2000**
400		CLS0400IR01/05.5bl16/16-0300cm100	**FCL16-40300-2000**
600		CLS0600IR01/05.5bl16/16-0300cm100	**FCL16-60300-2000**
800		CLS0800IR01/05.5bl16/16-0300cm100	**FCL16-80300-2000**
1000		CLS1000IR01/05.5bl16/16-0300cm100	**FCL16-90300-2000**
200	5	CLS0200IR01/05.5bl16/16-0500cm100	**FCL16-20500-2000**
400		CLS0400IR01/05.5bl16/16-0500cm100	**FCL16-40500-2000**
600		CLS0600IR01/05.5bl16/16-0500cm100	**FCL16-60500-2000**
800		CLS0800IR01/05.5bl16/16-0500cm100	**FCL16-80500-2000**
1000		CLS1000IR01/05.5bl16/16-0500cm100	**FCL16-90500-2000**

FiberTech® Standard SMA laser cables

with squarelock tube

CLS□□□□IR08/08.0bk15/15-□□□□cm100

Description

Laser cable with F-SMA freestanding fiber connectors and PVC coated steel-armored protection tube. Applicable for laser beam delivery of up to 100 W

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
- SMA905 (F-SMA) connector with free-standing fiber tip
- Hex nut
- Squarelock, black PVC-coated protection tube
- Electrical isolation from end to end
- Average laser power up to 100 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
200	2	CLS0200IR08/08.0bk15/15-0200cm100	**FCL15-20200-2000**
400		CLS0400IR08/08.0bk15/15-0200cm100	**FCL15-40200-2000**
600		CLS0600IR08/08.0bk15/15-0200cm100	**FCL15-60200-2000**
800		CLS0800IR08/08.0bk15/15-0200cm100	**FCL15-80200-2000**
1000		CLS1000IR08/08.0bk15/15-0200cm100	**FCL15-90200-2000**
200	3	CLS0200IR08/08.0bk15/15-0300cm100	**FCL15-20300-2000**
400		CLS0400IR08/08.0bk15/15-0300cm100	**FCL15-40300-2000**
600		CLS0600IR08/08.0bk15/15-0300cm100	**FCL15-60300-2000**
800		CLS0800IR08/08.0bk15/15-0300cm100	**FCL15-80300-2000**
1000		CLS1000IR08/08.0bk15/15-0300cm100	**FCL15-90300-2000**
200	5	CLS0200IR08/08.0bk15/15-0500cm100	**FCL15-20500-2000**
400		CLS0400IR08/08.0bk15/15-0500cm100	**FCL15-40500-2000**
600		CLS0600IR08/08.0bk5/15-0500cm100	**FCL15-60500-2000**
800		CLS0800IR08/08.0bk15/15-0500cm100	**FCL15-80500-2000**
1000		CLS1000IR08/08.0bk15/15-0500cm100	**FCL15-90500-2000**

FiberTech® CuSMA laser cables

CLS□□□□IR08/08.0bl23/23-□□□□cm100

Description

Laser cable with F-SMA freestanding fiber connectors and PVC coated steel-armored protection tube. Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Applicable for laser beam delivery of up to 400 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- SMA905 (F-SMA) connector with free-standing fiber tip, hex nut
- Keyed SMA905 (F-SMA) connectors on request
- All copper alloy parts for improved heat removal
- Fiber centricity < 5 µm fiber core to ferrule
- Squarelock, blue PVC-coated protection tube
- Metal connector cuffs to cable
- Electrical isolation from end to end
- Average laser power up to 400 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
100	2	CLS0100IR08/08.0bl23/23-0200cm100	**FCL23-10200-2000**
200		CLS0200IR08/08.0bl23/23-0200cm100	**FCL23-20200-2000**
400		CLS0400IR08/08.0bl23/23-0200cm100	**FCL23-40200-2000**
600		CLS0600IR08/08.0bl23/23-0200cm100	**FCL23-60200-2000**
800		CLS0800IR08/08.0bl23/23-0200cm100	**FCL23-80200-2000**
1000		CLS1000IR08/08.0bl23/23-0200cm100	**FCL23-90200-2000**
100	3	CLS0100IR08/08.0bl23/23-0300cm100	**FCL23-10300-2000**
200		CLS0200IR08/08.0bl23/23-0300cm100	**FCL23-20300-2000**
400		CLS0400IR08/08.0 bl23/23-0300cm100	**FCL23-40300-2000**
600		CLS0600IR08/08.0bl23/23-0300cm100	**FCL23-60300-2000**
800		CLS0800IR08/08.0bl23/23-0300cm100	**FCL23-80300-2000**
1000		CLS1000IR08/08.0bl23/23-0300cm100	**FCL23-90300-2000**
100	5	CLS0100IR08/08.0bl23/23-0500cm100	**FCL23-10500-2000**
200		CLS0200IR08/08.0bl23/23-0500cm100	**FCL23-20500-2000**
400		CLS0400IR08/08.0bl23/23-0500cm100	**FCL23-40500-2000**
600		CLS0600IR08/08.0bl23/23-0500cm100	**FCL23-60500-2000**
800		CLS0800IR08/08.0bl23/23-0500cm100	**FCL23-80500-2000**
1000		CLS1000IR08/08.0bl23/23-0500cm100	**FCL23-90500-2000**

FiberTech® SMA500 laser cables

Industrial lasers

05

CLS□□□□IR08/08.0bl24/24-□□□□cm100

Description

Laser cable with F-SMA freestanding fiber connectors and PVC coated steel-armored protection tube. Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Applicable for laser beam delivery of up to 500 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with
  NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- SMA905 (F-SMA) connector with free-standing fiber tip, hex nut
- Keyed SMA905 (F-SMA) connectors on request
- All copper alloy parts for improved heat removal
- Fiber centricity < 5 µm fiber core to ferrule
- Squarelock, blue PVC-coated protection tube
- Metal connector cuffs to cable
- Electrical isolation from end to end
- Average laser power up to 500 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
100	2	CLS0100IR08/08.0bl24/24-0200cm100	**FCL24-10200-2000**
200		CLS0200IR08/08.0bl24/24-0200cm100	**FCL24-20200-2000**
400		CLS0400IR08/08.0bl24/24-0200cm100	**FCL24-40200-2000**
600		CLS0600IR08/08.0bl24/24-0200cm100	**FCL24-60200-2000**
800		CLS0800IR08/08.0bl24/24-0200cm100	**FCL24-80200-2000**
1000		CLS1000IR08/08.0bl24/24-0200cm100	**FCL24-90200-2000**
100	3	CLS0100IR08/08.0bl24/24-0300cm100	**FCL24-10300-2000**
200		CLS0200IR08/08.0bl24/24-0300cm100	**FCL24-20300-2000**
400		CLS0400IR08/08.0 bl24/24-0300cm100	**FCL24-40300-2000**
600		CLS0600IR08/08.0bl24/24-0300cm100	**FCL24-60300-2000**
800		CLS0800IR08/08.0bl24/24-0300cm100	**FCL24-80300-2000**
1000		CLS1000IR08/08.0bl24/24-0300cm100	**FCL24-90300-2000**
100	5	CLS0100IR08/08.0bl24/24-0500cm100	**FCL24-10500-2000**
200		CLS0200IR08/08.0bl24/24-0500cm100	**FCL24-20500-2000**
400		CLS0400IR08/08.0bl24/24-0500cm100	**FCL24-40500-2000**
600		CLS0600IR08/08.0bl24/24-0500cm100	**FCL24-60500-2000**
800		CLS0800IR08/08.0bl24/24-0500cm100	**FCL24-80500-2000**
1000		CLS1000IR08/08.0bl24/24-0500cm100	**FCL24-90500-2000**

FiberTech® SMA500 MS ModeStrip laser cables

CLS□□□□IR08/08.0bl25/25-□□□□cm100

Description

Laser cable with F-SMA freestanding fiber connectors and PVC coated, steel-armored protection tube.

Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Integrated convection-cooled cladding-mode stripper (ModeStrip). Applicable for laser beam delivery of up to 200 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- SMA905 (F-SMA) connector with free-standing fiber tip, hex nut
- Keyed SMA905 (F-SMA) connectors on request
- All copper alloy parts for improved heat removal
- Fiber centricity < 5 µm fiber core to ferrule
- Squarelock, blue PVC-coated protection tube
- Metal connector cuffs to cable with heatsink
- Convection-cooled ModeStripper for cladding mode removal
- Electrical isolation from end to end
- Average laser power up to 200 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
100	2	CLS0100IR08/08.0bl25/25-0200cm100	**FCL25-10200-2000**
200		CLS0200IR08/08.0bl25/25-0200cm100	**FCL25-20200-2000**
400		CLS0400IR08/08.0bl25/25-0200cm100	**FCL25-40200-2000**
100	3	CLS0100IR08/08.0bl25/25-0300cm100	**FCL25-10300-2000**
200		CLS0200IR08/08.0bl25/25-0300cm100	**FCL25-20300-2000**
400		CLS0400IR08/08.0 bl25/25-0300cm100	**FCL25-40300-2000**
100	5	CLS0100IR08/08.0bl25/25-0500cm100	**FCL25-10500-2000**
200		CLS0200IR08/08.0bl25/25-0500cm100	**FCL25-20500-2000**
400		CLS0400IR08/08.0bl25/25-0500cm100	**FCL25-40500-2000**

FiberTech® SMA500L ModeStrip laser cables

liquid-cooled

CLS□□□□IR08/08.0bl26/26-□□□□cm100

Description

Laser cable with F-SMA freestanding fiber connectors and PVC coated, steel-armored protection tube.

Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Integrated liquid-cooled cladding-ModeStripper. Applicable for laser beam delivery of up to 500 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- SMA905 (F-SMA) connector with free-standing fiber tip, hex nut
- Keyed SMA905 (F-SMA) connectors on request
- All copper alloy parts for improved heat removal
- Fiber centricity < 5 µm fiber core to ferrule
- Squarelock, blue PVC-coated protection tube
- Metal connector cuffs to cable
- Liquid-cooled ModeStripper for cladding mode removal
- Electrical isolation from end to end
- Average laser power up to 500 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
100		CLS0100IR08/08.0bl26/26-0200cm100	**FCL26-10200-2000**
200	2	CLS0200IR08/08.0bl26/26-0200cm100	**FCL26-20200-2000**
400		CLS0400IR08/08.0bl26/26-0200cm100	**FCL26-40200-2000**
100		CLS0100IR08/08.0bl26/26-0300cm100	**FCL26-10300-2000**
200	3	CLS0200IR08/08.0bl26/26-0300cm100	**FCL26-20300-2000**
400		CLS0400IR08/08.0 bl26/26-0300cm100	**FCL26-40300-2000**
100		CLS0100IR08/08.0bl26/26-0500cm100	**FCL26-10500-2000**
200	5	CLS0200IR08/08.0bl26/26-0500cm100	**FCL26-20500-2000**
400		CLS0400IR08/08.0bl26/26-0500cm100	**FCL26-40500-2000**

FiberTech® CuFC laser cables

CLS□□□□IR08/08.0bl27/27-□□□□cm100

Description

Laser cable with keyed FC-type freestanding fiber connectors and PVC coated, steel-armored protection tube. Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Applicable for laser beam delivery of up to 400 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- Keyed FC connector (anti-twist), free-standing fiber tip, hex nut
- All copper alloy parts for improved heat removal
- Fiber centricity < 5 µm fiber core to ferrule
- Squarelock, blue PVC-coated protection tube
- Metal connector cuffs to cable with heatsink
- Electrical isolation from end to end
- Average laser power up to 400 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
100	2	CLS0100IR08/08.0bl27/27-0200cm100	**FCL27-10200-2000**
200		CLS0200IR08/08.0bl27/27-0200cm100	**FCL27-20200-2000**
400		CLS0400IR08/08.0bl27/27-0200cm100	**FCL27-40200-2000**
100	3	CLS0100IR08/08.0bl27/27-0300cm100	**FCL27-10300-2000**
200		CLS0200IR08/08.0bl27/27-0300cm100	**FCL27-20300-2000**
400		CLS0400IR08/08.0 bl27/27-0300cm100	**FCL27-40300-2000**
100	5	CLS0100IR08/08.0bl27/27-0500cm100	**FCL27-10500-2000**
200		CLS0200IR08/08.0bl23/23-0500cm100	**FCL27-20500-2000**
400		CLS0400IR08/08.0bl27/27-0500cm100	**FCL27-40500-2000**

FiberTech® CuFC ModeStrip laser cables

liquid-cooled

CLS□□□□IR08/08.0bl28/28-□□□□cm100

Description

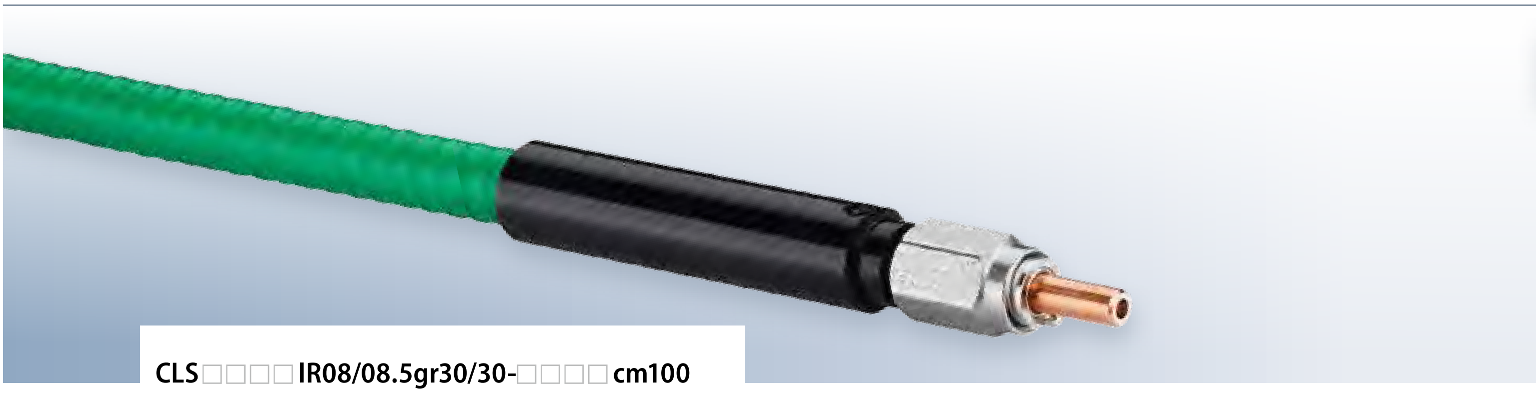
Laser cable with keyed FC-type freestanding fiber connectors and PVC coated, steel-armored protection tube. Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Integrated liquid-cooled cladding-ModeStripper. Applicable for laser beam delivery of up to 400 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- Keyed FC connector (anti-twist), free-standing fiber tip, hex nut
- All copper alloy parts for improved heat removal
- Fiber centricity < 5 µm fiber core to ferrule
- Squarelock, blue PVC-coated protection tube
- Metal connector cuffs to cable
- Liquid-cooled ModeStripper for cladding mode removal
- Electrical isolation from end to end
- Average laser power up to 400 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
100	2	CLS0100IR08/08.0bl28/28-0200cm100	**FCL28-10200-2000**
200		CLS0200IR08/08.0bl28/28-0200cm100	**FCL28-20200-2000**
400		CLS0400IR08/08.0bl28/28-0200cm100	**FCL28-40200-2000**
100	3	CLS0100IR08/08.0bl28/28-0300cm100	**FCL28-10300-2000**
200		CLS0200IR08/08.0bl28/28-0300cm100	**FCL28-20300-2000**
400		CLS0400IR08/08.0 bl28/28-0300cm100	**FCL28-40300-2000**
100	5	CLS0100IR08/08.0bl28/28-0500cm100	**FCL28-10500-2000**
200		CLS0200IR08/08.0bl28/28-0500cm100	**FCL28-20500-2000**
400		CLS0400IR08/08.0bl28/28-0500cm100	**FCL28-40500-2000**

FiberTech® LD-80 laser cables



CLS□□□□IR08/08.5gr30/30-□□□□cm100

Description

Laser cable with LD-80 freestanding fiber connectors and PVC coated steel-armored protection tube. Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Applicable for laser beam delivery of up to 800 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- Ø 4 mm x 10 mm connectors with key (anti-twist), free-standing fiber tip, hex nut
- All copper alloy parts for improved heat removal
- Fiber centricity < 5 µm fiber core to ferrule
- Squarelock, green PVC-coated protection tube
- Metal connector cuffs to cable
- Electrical isolation from end to end
- Average laser power up to 800 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
100	2	CLS0100IR08/08.5gr30/30-0200cm100	**FCL30-10200-2000**
200		CLS0200IR08/08.5gr30/30-0200cm100	**FCL30-20200-2000**
400		CLS0400IR08/08.5gr30/30-0200cm100	**FCL30-40200-2000**
600		CLS0600IR08/08.5gr30/30-0200cm100	**FCL30-60200-2000**
800		CLS0800IR08/08.5gr30/30-0200cm100	**FCL30-80200-2000**
1000		CLS1000IR08/08.5gr30/30-0200cm100	**FCL30-90200-2000**
100	3	CLS0100IR08/08.5gr30/30-0300cm100	**FCL30-10300-2000**
200		CLS0200IR08/08.5gr30/30-0300cm100	**FCL30-20300-2000**
400		CLS0400IR08/08.5gr30/30-0300cm100	**FCL30-40300-2000**
600		CLS0600IR08/08.5gr30/30-0300cm100	**FCL30-60300-2000**
800		CLS0800IR08/08.5gr30/30-0300cm100	**FCL30-80300-2000**
1000		CLS1000IR08/08.5gr30/30-0300cm100	**FCL30-90300-2000**
100	5	CLS0100IR08/08.5gr30/30-0500cm100	**FCL30-10500-2000**
200		CLS0200IR08/08.5gr30/30-0500cm100	**FCL30-20500-2000**
400		CLS0400IR08/08.5gr30/30-0500cm100	**FCL30-40500-2000**
600		CLS0600IR08/08.5gr30/30-0500cm100	**FCL30-60500-2000**
800		CLS0800IR08/08.5gr30/30-0500cm100	**FCL30-80500-2000**
1000		CLS1000IR08/08.5gr30/30-0500cm100	**FCL30-90500-2000**

FiberTech® LD-80MS ModeStrip laser cables

CLS□□□□IR08/08.5gr31/31-□□□□cm100

Description

Laser cable with LD-80 freestanding fiber connectors and PVC coated steel-armored protection tube. Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Integrated convection-cooled cladding-ModeStripper. Applicable for laser beam delivery of up to 200 W.

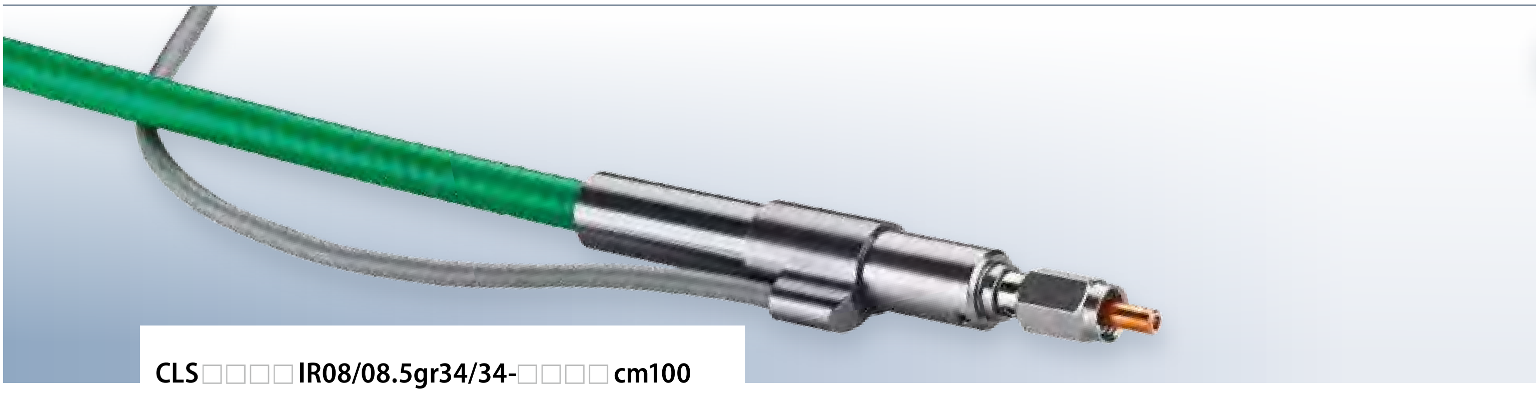
Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- Ø 4 mm x 10 mm connectors with key (anti-twist), free-standing fiber tip, hex nut
- All copper alloy parts for improved heat removal
- Fiber centricity < 5 µm fiber core to ferrule
- Squarelock, green PVC-coated protection tube
- Metal connector cuffs to cable
- Convection-cooled ModeStripper for cladding mode removal
- Electrical isolation from end to end
- Average laser power up to 200 W with adequate convection cooling means

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
100		CLS0100IR08/08.5gr31/31-0200cm100	**FCL31-10200-2000**
200	2	CLS0200IR08/08.5gr31/31-0200cm100	**FCL31-20200-2000**
400		CLS0400IR08/08.5gr31/31-0200cm100	**FCL31-40200-2000**
100		CLS0100IR08/08.5gr30/30-0300cm100	**FCL30-10300-2000**
200	3	CLS0200IR08/08.5gr31/31-0300cm100	**FCL31-20300-2000**
400		CLS0400IR08/08.5gr31/31-0300cm100	**FCL31-40300-2000**
100		CLS0100IR08/08.5gr30/30-0500cm100	**FCL30-10500-2000**
200	5	CLS0200IR08/08.5gr31/31-0500cm100	**FCL31-20500-2000**
400		CLS0400IR08/08.5gr31/31-0500cm100	**FCL31-40500-2000**

FiberTech® LD-80BD laser cables

with fiber break detection



CLS□□□□IR08/08.5gr34/34-□□□□cm100

Description

Laser cable with LD-80 freestanding fiber connectors and PVC coated steel-armored protection tube. Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Fiber break detection ensures laser safety requirements. Applicable for laser beam delivery of up to 800 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- Ø 4 mm x 10 mm connectors with key (anti-twist), free-standing fiber tip, hex nut
- All copper alloy parts for improved heat removal
- Fiber centricity < 5 µm fiber core to ferrule
- Squarelock, green PVC-coated protection tube
- Metal connector cuffs to cable
- Fiber break detection
- Electrical isolation from end to end
- Average laser power up to 800 W

Fiber core Ø [µm]	Cable length [m]	Type designation	Order no.
100	2	CLS0100IR08/08.5gr34/34-0200cm100	**FCL34-10200-2000**
200		CLS0200IR08/08.5gr34/34-0200cm100	**FCL34-20200-2000**
400		CLS0400IR08/08.5gr34/34-0200cm100	**FCL34-40200-2000**
600		CLS0600IR08/08.5gr34/34-0200cm100	**FCL34-60200-2000**
800		CLS0800IR08/08.5gr34/34-0200cm100	**FCL34-80200-2000**
1000		CLS1000IR08/08.5gr34/34-0200cm100	**FCL34-90200-2000**
100	3	CLS0100IR08/08.5gr34/34-0300cm100	**FCL34-10300-2000**
200		CLS0200IR08/08.5gr34/34-0300cm100	**FCL34-20300-2000**
400		CLS0400IR08/08.5gr34/34-0300cm100	**FCL34-40300-2000**
600		CLS0600IR08/08.5gr34/34-0300cm100	**FCL34-60300-2000**
800		CLS0800IR08/08.5gr34/34-0300cm100	**FCL34-80300-2000**
1000		CLS1000IR08/08.5gr34/34-0300cm100	**FCL34-90300-2000**
100	5	CLS0100IR08/08.5gr34/34-0500cm100	**FCL34-10500-2000**
200		CLS0200IR08/08.5gr34/34-0500cm100	**FCL34-20500-2000**
400		CLS0400IR08/08.5gr34/34-0500cm100	**FCL34-40500-2000**
600		CLS0600IR08/08.5gr34/34-0500cm100	**FCL34-60500-2000**
800		CLS0800IR08/08.5gr34/34-0500cm100	**FCL34-80500-2000**
1000		CLS1000IR08/08.5gr34/34-0500cm100	**FCL34-90500-2000**

FiberTech® LD-80R robotik laser cables

Description

Laser cable with industrial standard 10 mm x 54 mm and 15 mm x 54 mm high power fiber connectors and highly flexible polymer-aramid protection tube. Copper based high-accuracy fiber ferrule for effective heat removal and high fiber centricity. Fiber break detection and connector temperature monitoring circuit complies with laser safety requirements.
Applicable for laser beam delivery of up to 5000 W.

Properties / Composition

- VIS-IR all-silica (silica/silica) step-index fiber with NA = 0.22
  NA = 0.12 on request
  Graded-index fiber on request
- Standard fiber core diameters
  200 µm, 300 µm, 400 µm, 600 µm, 800 µm, 1000 µm
- Industrial standard connector interface
  Ø 10 mm x 54 mm or Ø 15 mm x 54 mm
  nozzles compatible with LLK-LP and LLK-HP
- All copper alloy parts for improved heat removal
- Highly flexible polymer-aramid protection tube
- Fiber break detection with electrical interface in connector
- Connector temperature monitoring
- Average laser power up to 5000 W

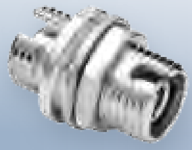
Info

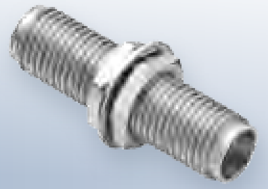
Due to the custom-specific cable length this product is available on request.

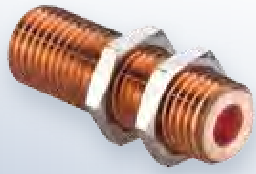
Please contact us for more information.

Receivers and adapters
Dust caps

Adapters





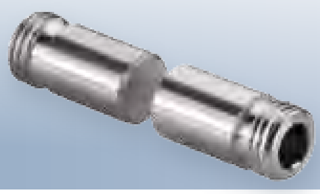


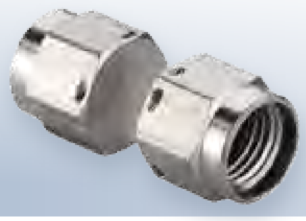
	Adapter for FC	Adapter for F-SMA	Adapter for F-SMA, copper
Order no.	SKUP-2XFCP-0010	SXUP-2XSMA-0010	FCLA-23A-2000
Application	Connection of FC fiber connectors	Connection of F-SMA fiber connectors	Connection of F-SMA fiber connectors

Receivers and adapters

	Adapter for LD-80, liquid-cooled	Receiver for LD-80
Order no.	FCLA-30A-2010	FCLA-30R-2000
Application	Connection of LD-80 fiber connectors	Front-plate attachment of LD-80 fiber connector, free-space coupling

Dust caps





	SMA dust cap, stainless steel	LD-80 dust cap, stainless steel, O-ring sealed
Order no.	FCLA-15D-2000	FCLA-30D-2000
Application	F-SMA fiber cables	LD-80 fiber cables

CHAPTER 06

Medical devices / laser probes

for pulsed and CW lasers in medicine

Customer-specific BareFibers with different colours, diameters and lengths are available for all products and designs

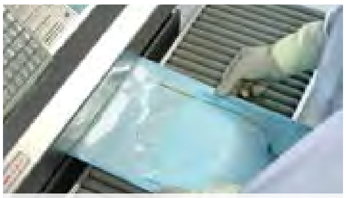
Many years of experience, numerous innovations, high quality and the cost-efficiency of our products assure your success in applied medicine.

Services

- Customer-specific product design is possible
- Fibers for different wavelengths with different numerical apertures (NA) as well as particularly low OH content are available
- Manufacturing of medical fibers for laser energy transmission mainly in the wavelength range from 266 nm to 2200 nm
- Manufacturing of medical probes for the laser energy transmission of argon, Nd:YAG, excimer, KTP, holmium, alexandrite and diode lasers
- in-house sterilization (EtO) for short delivery periods
- Series production of surgical, ophthalmological, urological, dental and endovascular probes with biocompatible materials.

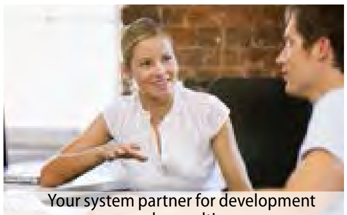
Fields of application:

Aesthetic surgery and Phlebology	Endoscopy	Ophthalmology
Children's surgery	ENT	Orthopaedics
Dentistry	Gastroenterology	Pneumology
Dermatology	Gynaecology	Urology


Packaging and in-house sterilization

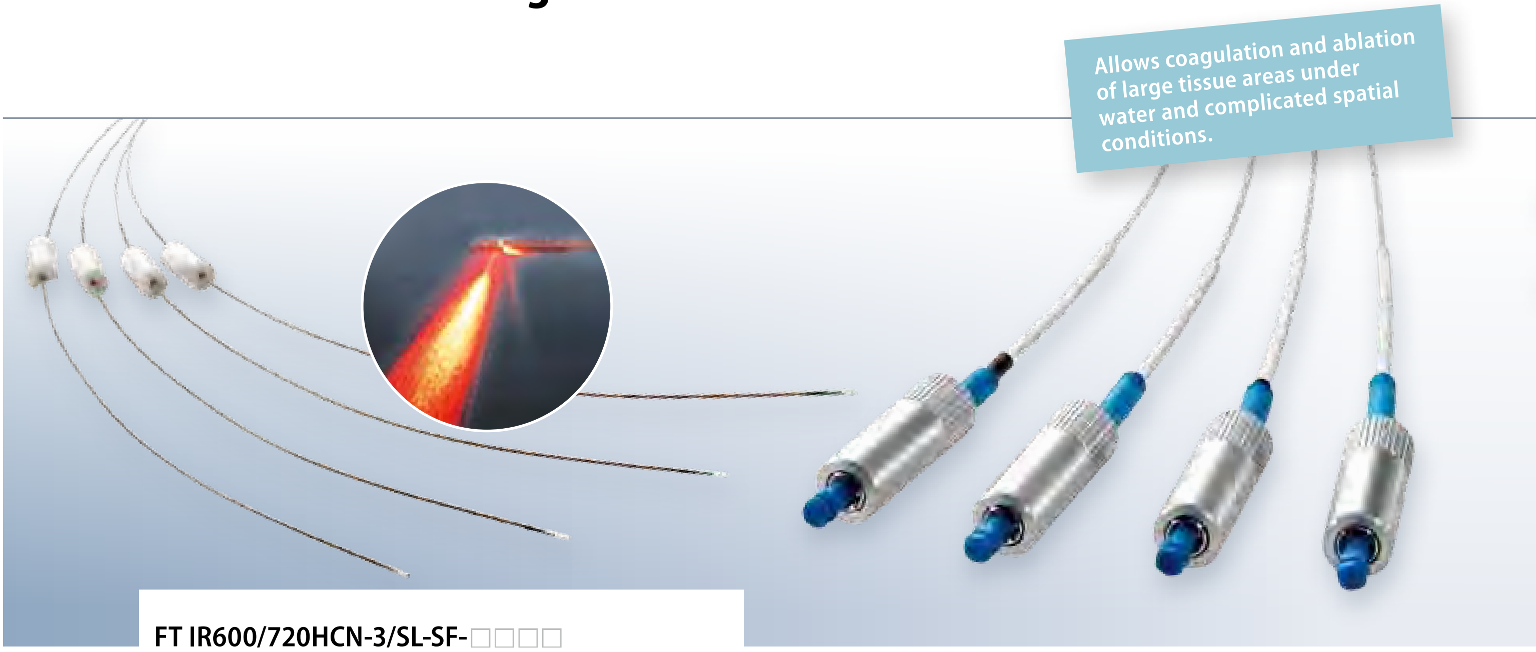

Fiber assembly under clean room conditions


in-house preform and fiber production


Your system partner for development and consulting

06. Medical devices / laser probes

FiberTech® SideFiring Fiber



FT IR600/720HCN-3/SL-SF-□□□□

Description

Fiber optic probes with lateral radiation and excellent beam quality. The SideFiring fibers with their special design are characterised by a long service life and are tested and wellregarded in clinics around the world.

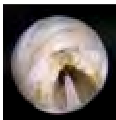
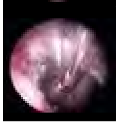
Properties / Composition

- Endometrium EtO-sterilized, double packed (pouch in pouch)
- Suitable for 532 nm up to 2200 nm CW
- Capillary Ø 1750 or 2050 µm
- Handling aid and capillaries with beam direction marking
- High-power F-SMA905 connector (free-standing)
- Optimisation for customer-specific laser devices possible
- Standard length 3 m

Note

UV fibers are available on request.

Applications

	**Urology**	Resection of prostate
	**Gynaecology**	Endometrium ablation

Wavelength	Core Ø [µm]	Ø Capillary [µm]	Type designation	Order no.*
IR	600	1750	FT IR600/720HCN-3/SL-SF-1750	**M280200S**
IR	600	2050	FT IR600/720HCN-3/SL-SF-2050	**M280300S**

* S = sterile, N = non sterile

FiberTech® CurvedBall BareFiber

Allows coagulation and ablation of large tissue areas under water and complicated spatial conditions.

FT IR□□□/□□□ ST-3/SL-CB

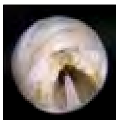
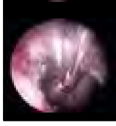
Description

The new generation of contact fibers is characterised by high ablation rates, reduced operation time and high reliability. Laterally focused laser energy allows precise cuts. Cost effective alternative to SideFiring Fiber

Properties / Composition

- EtO-sterilized, double packed (pouch in pouch)
- Suitable for 532 nm up to 2200 nm CW
- High power F-SMA905 connector (free-standing)
- F-SMA extension sleeve available in various colours, laser inscription possible.
- Customer-optimized designs on request
- Standard length 3 m, NA = 0.22

Applications

	**Urology**	Resection of prostate Excision of tumors Urethral stricture
	**Gynaecology**	Laser laparoscopic adhesiolysis

Core Ø [µm]	Clad Ø [µm]	Fiber Ø [µm]	Ball Ø [µm]	Type designation	Order no.*
400	440	750	660	FT IR400/440ST-3/SL-CB	**M280704S**
600	720	1100	1000	FT IR600/720HCN-3/SL-CB	**M280703S**
600	660	1000	1000	FT IR600/660ST-3/SL-CB	**M280708S**
800	880	1100	1300	FT IR800/880ST-3/SL-CB	**M280710S**

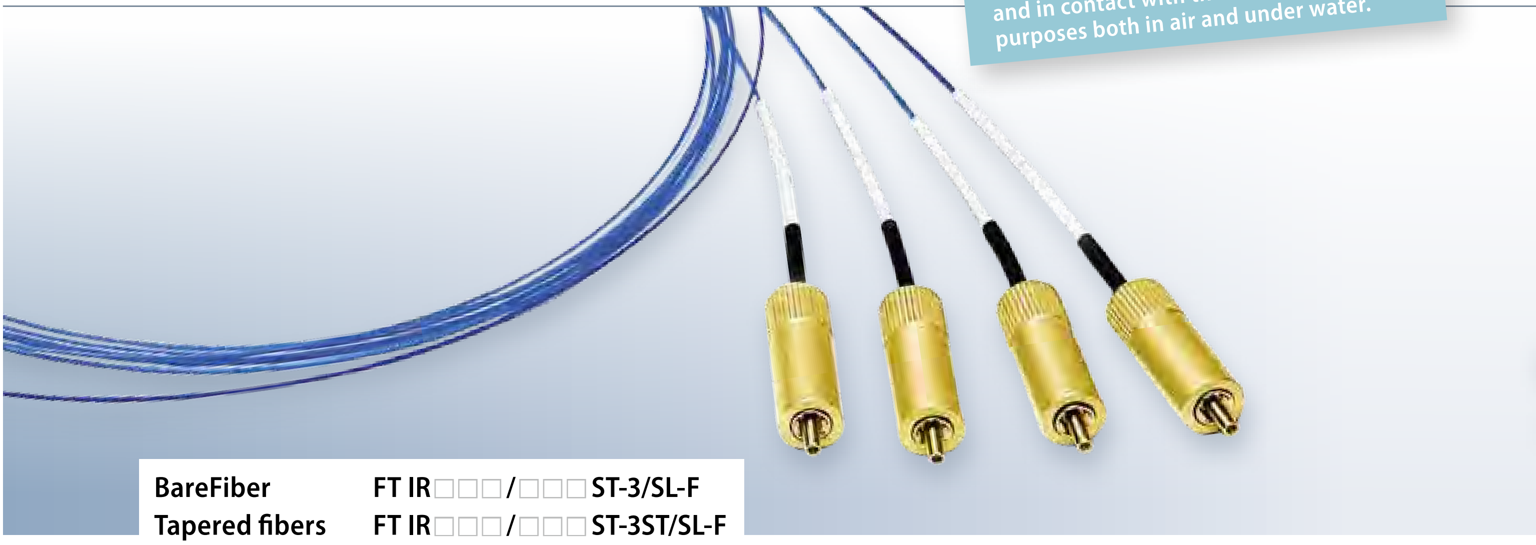
* S = sterile, N = non sterile

LEONI

Fiber**Tech**® **BareFiber**

disposable / reusable

Allows contactless laser applications – for coagulation; and in contact with the tissue – for cutting purposes both in air and under water.



BareFiber FT IR□□□/□□□ST-3/SL-F
Tapered fibers FT IR□□□/□□□ST-3ST/SL-F

Description

High quality silica/silica fiber with a wide range of application options.

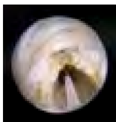
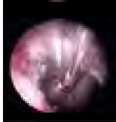
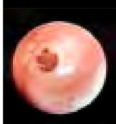
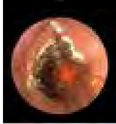
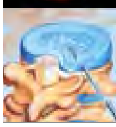
Properties / Composition

- EtO-sterilized, double packed (pouch in pouch)
- F-SMA extension sleeve available in various colours, laser inscription possible
- Suitable for 532 nm up to 2200 nm CW
- Standard (SM) or high power (SL) F-SMA905 connector
- Customer-optimized designs on request
- Various accessories available (strippers, cleavers, etc.)
- Standard length 3 m, NA = 0.22

Note

UV fibers are available on request.

Applications

	**Urology**	Resection of prostate Lithotripsy of urinary calculi Partial nephrectomy
	**Gynaecology**	Septum dissection adhesiolysis
	**ENT**	Exision of tumors Tonsillectomy Chondroplasty
	**Pneumology**	Removal of multiple lung metastases
	**Orthopaedics**	Discectomy Menisectomy Chondroplasty

Core Ø [µm]	Clad Ø [µm]	Fiber Ø [µm]	Type designation	Order no. reusable BareFiber*	Order no. disposable BareFiber*
200	240	420	FT IR200/240ST-3/SL-F	**M220150S**	**M210150S**
272	300	600	FT IR272/300ST-3/SL-F	**M220200S**	**M210200S**
365	400	700	FT IR365/400ST-3/SL-F	**M220300S**	**M210300S**
400	440	750	FT IR400/440ST-3/SL-F	**M220900S**	**M210900S**
550	605	900	FT IR550/605ST-3/SL-F	**M220500S**	**M210500S**
600	660	1000	FT IR600/660ST-3/SL-F	**M220600S**	**M210600S**
800	880	1350	FT IR800/880ST-3/SL-F	**M220700S**	**M210700S**
1000	1100	1500	FT IR1000/1100ST-3/SL-F	**M220800S**	**M210800S**

Tapered fibers

Core Ø [µm] approx.	Core Ø [µm] dist.	Fiber Ø [µm]	Type designation	Order no.*
400	200	420	FT IR400/200ST-3ST/SL-F	**M230106S**
400	300	650	FT IR400/300ST-3ST/SL-F	**M230205S**

* S = sterile, N = non sterile

FiberTech® SlimVersion BareFiber

disposable / reusable

Suited for laser applications, especially in combination with thin flexible endoscopes.

FT IR□□□/□□□ST-3ST/SL-F

Description

High quality silica/silica fiber with a wide range of application options.

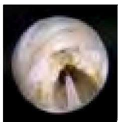
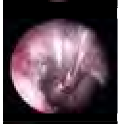
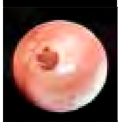
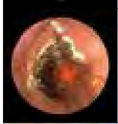
Properties / Composition

- For diodes, ND:YAG-, KTP- and other laser devices
- EtO-sterilized, double packed (pouch in pouch)
- F-SMA extension sleeve available in various colours, laser inscription possible
- Suitable for 532 nm up to 2200 nm
- Standard (SM) or high-power (SL) F-SMA905 connector
- Customer-optimized designs on request
- Standard length 3 m, NA = 0.22

Note

UV fibers are available on request.

Applications

	**Urology**	Resection of prostate Lithotripsy of urinary calculi Partial nephrectomy
	**Gynaecology**	Septum dissection adhesiolysis
	**ENT**	Exision of tumors Tonsillectomy Chondroplasty
	**Pneumology**	Removal of multiple lung metastases
	**Orthopaedics**	Discectomy Menisectomy Chondroplasty

Core Ø [µm]	Clad Ø [µm]	Fiber Ø [µm]	Type designation	Order no.*
200	240	400	FT IR200/240HCT-3/SL-F	**M240150S**
272	300	450	FT IR272/300HCT-3/SL-F	**M240200S**
365	400	580	FT IR365/400HCT-3/SL-F	**M240300S**
400	440	650	FT IR400/440HCT-3/SL-F	**M240900S**
550	605	780	FT IR550/605HCT-3/SL-F	**M240500S**
600	660	880	FT IR600/660HCT-3/SL-F	**M240600S**
800	880	1200	FT IR800/880HCT-3/SL-F	**M240700S**
1000	1100	1400	FT IR1000/1100HCT-3/SL-F	**M240800S**

* S = sterile, N = non sterile

FiberTech® HardClad BareFiber

disposable / reusable

BareFiber FT IR□□□T-3/SM-F
Glue free FT IR□□□T-3/SGFM-F

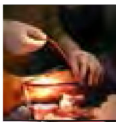
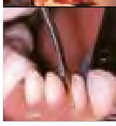
Description

Fiber optic probes with increased NA (NA=0.37) and excellent beam quality.

Properties / Composition

- EtO-sterilized, double packed (pouch in pouch)
- length marking on the fiber for optimum treatment control available (scale with centimeter and decimeter spacing)
- male/female LuerLock for catheter connection available (with "L" in the product code)
- F-SMA extension sleeve available in various colours, laser inscription possible
- suitable for 532 nm up to 1470 nm, low OH
- F-SMA905 connector, customer-specific connectors can be assembled
- Standard length 3 m, NA = 0.37

Applications

	**Aesthetic surgery**	Laser lipolysis Angiodyplasia and hemangioma Coagulation of leg veins
	**Dentistry**	Parodontal treatment Preparation of root chanels Oral surgery

Core Ø [µm]	Fiber Ø [µm]	Type designation	Order no.*
200	500	FT IR200T-3/SM-F	**M200200S**
300	520	FT IR300T-3/SM-F	**M200300S**
400	730	FT IR400T-3/SM-F	**M200400S**
600	800	FT IR600T-3/SM-F-SLIM	**M200600S**
600	950	FT IR600T-3/SM-F	**M200800S**
800	1000	FT IR800T-3/SM-F	**M201000S**

Core Ø [µm]	Fiber Ø [µm]	Type designation	Order no. HardClad Glue free*
400	730	FT IR400T-3/SGFM-F	**M290400S**
600	800	FT IR600T-3/SGFM-F-SLIM	**M290600S**
600	950	FT IR600T-3/SGFM-F	**M290800S**

* S = sterile, N = non sterile

FiberTech® BareFiber for holmium lasers

and other pulsed lasers

BareFiber	**FT IR□□□/□□□ST-3/SHL-F**
Tapered fibers	**FT IR□□□/□□□ST-3ST/SHL-F**

Description

High-quality silica/silica fiber developed for the high demands of pulsed laser devices.

Properties / Composition

- EtO-sterilized, double packed (pouch in pouch)
- Special high-power F-SMA905 connector (SHL)
- New F-SMA slim extension sleeve (Ø 10 mm) available in various colours, laser inscription possible
- Available as disposable or reusable BareFiber "flat rounded" tip design for safe insertion possible (only for disposable BareFiber)
- Suitable for 532 nm up to 2200 nm
- Customer-optimized designs on request
- Various accessories available (strippers, cleavers, etc.)
- Standard length 3 m, NA = 0.22

Applications

	**Urology**	Lithotripsy Opening of urethral strictures Soft tissue treatment

Core Ø [µm]	Clad Ø [µm]	Fiber Ø [µm]	Type designation	Order no.*
200	240	420	FT IR200/240ST-3/SHL-F	**M340220S**
272	300	600	FT IR272/300ST-3/SHL-F	**M340200S**
365	400	700	FT IR365/400ST-3/SHL-F	**M340300S**
550	605	900	FT IR550/605ST-3/SHL-F	**M340500S**
600	660	1000	FT IR600/660ST-3/SHL-F	**M340600S**
800	880	1350	FT IR800/880ST-3/SHL-F	**M340700S**

Tapered fibers

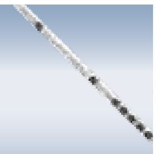
Core Ø [µm] prox.	Core Ø [µm] dist.	Fiber Ø [µm]	Type designation	Order no.*
400	200	420	FT IR400/200ST-3ST/SHL-F	**M230109S**
400	300	560	FT IR400/300ST-3ST/SHL-F	**M230207S**
500	300	560	FT IR500/300ST-3ST/SHL-F	**M230652S**

* S = sterile, N = non sterile

FiberTech® BallTip BareFiber

Allows a homogenous spherical illumination in vessels without mechanical traumatization of the intima.

FT IR □□□/□□□ PIT-3/SM-B



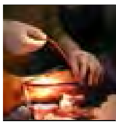
Description

High-quality silica / silica fiber. The atraumatic tip construction enables treatments without the otherwise usual catheters. This design is characterised by an enhanced energy profile.

Properties / Composition

- EtO-sterilized, double packed (pouch in pouch)
- Enhanced emission pattern compared to FlatTip through lens-shaped tip design
- Length marking on the fiber for optimum treatment control available (scale with centimeter and decimeter spacing)
- Male/female LuerLock available
- F-SMA extension sleeve available in various colours, laser inscription possible
- Suitable for 532 nm up to 2200 nm, low OH
- Other fiber diameters and ball diameters on request
- Standard length 3 m, NA = 0.22

Applications

	**Aesthetic surgery**	Ablation of varicose veins

Core Ø [µm]	Clad Ø [µm]	Fiber Ø [µm]	Ball Ø [µm]	Type designation	Order no.*
550	605	780	1000	FT IR550/605PIT-3/SM-B	**M300300S**
1000	1100	1500	1500	FT IR1000/1100ST-3/SM-B	**M300301S**

* S = sterile, N = non sterile

FiberTech® CapillaryTip BareFiber

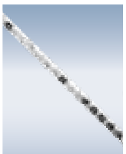
The BareFiber, protected by a capillary tube with molded tip, allows an atraumatic frontal illumination of tissue.

FT IR600N-3/SM-FCT

Description

The atraumatic tip construction enables treatments without the otherwise usual catheters and at the same time displays an enhanced energy profile.

Properties / Composition



- EtO-sterilized, double packed (pouch in pouch)
- Enhanced emission pattern compared to FlatTip through lens-shaped tip design
- Length marking on the fiber for optimum treatment control available (scale with centimeter and decimeter spacing)
- Male/female LuerLock male/female available
- F-SMA extension sleeve available in various colours, laser inscription possible
- Suitable for 532 nm up to 1470 nm, low OH
- Standard length 3 m, NA = 0.37

Applications

Aesthetic surgery	Laser lipolysis Ablation of varicose veins

Core Ø [µm]	Fiber Ø [µm]	Capillary Ø (OD) [µm]	Type designation	Order no.*
600	950	1200	FT IR600N-3/SM-FCT	**M320600S**

* S = sterile, N = non sterile

Fiber**Tech**® BareFiber

for dentistry

FT IR □□□/□□□ PI-3/SM-F

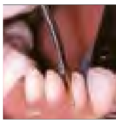
Description

The polyimide fibers guarantee very high mechanical stability with the smallest outer diameter.

Properties / Composition

- F-SMA905 connector, customer-specific connectors can be assembled
- Suitable for 532 nm up to 2200 nm, low OH
- Available with germanium-doped silica/silica fibers (NA = 0.37 / 0.40)
- Autoclavable
- Polyimide coating
- Biocompatible protection tube with 2.0 mm outer diameter
- Distal 10 cm of fibers free-standing
- Laser-inscribed handpieces available
- Standard length 3 m, NA = 0.22

Applications

	Dentistry	Parodontal treatment Preparation of root chanels Oral surgery

Accessories

- Dental handpiece HPD1
- Autoclavable
- Connection for Luer cannulae
- Single-part fiber clamping system

Core Ø [µm]	Fiber Ø [µm]	Tube Ø [µm]	Type designation	Order no.*
200	265	2000	FT IR200/240PI-3/SM-F	**M250200N**
320	410	2000	FT IR320/385PI-3/SM-F	**M250300N**
400	465	2000	FT IR400/440PI-3/SM-F	**M250400N**
600	685	2000	FT IR600/660PI-3/SM-F	**M250600N**

Dental handpiece

Dental handpiece	**HPD1**	**MHPD1**

* S = sterile, N = non sterile

FiberTech® BareFiber

for orthopaedics

The polyimide-coated fiber, freely guided in a silicon catheter and with a free-standing distal length, is suited for applications with orthopaedic guiding needles.

FT IR □□□/□□□ PI-3/SM-F

Description

The polyimide fibers guarantee very high mechanical stability with the smallest outer diameter,

Properties / Composition

- F-SMA905 connector, customer-specific connectors can be assembled
- Suitable for 532 nm up to 2200 nm, low OH
- EtO-sterilized, double packed (pouch in pouch)
- Polyimide coating
- Biocompatible protective tube with 2.00 mm outer diameter
- Distal 20 cm of fibers free-standing
- Laser-inscribed handpieces available
- Standard length 3 m, NA = 0.22

Applications

	Orthopaedics	Discectomy Menisectomy Chondroplasty

Core Ø [µm]	Fiber Ø [µm]	Tube Ø [µm]	Type designation	Order no.*
200	265	2000	FT IR200/240PI-3/SM-F	**M330200S**
320	410	2000	FT IR320/385PI-3/SM-F	**M330300S**
400	465	2000	FT IR400/440PI-3/SM-F	**M330400S**
600	685	2000	FT IR600/660PI-3/SM-F	**M330600S**

* S = sterile, N = non sterile

FiberTech® BareFiber

Gas or liquid flushed

Gives free sight during a laser application in hollow organs by flushing them with gas or liquid.

FT IR□□□T-3/SM-GLC-□□□□
FT IR□□□/□□□ HCT-3/SM-GLC-□□□□

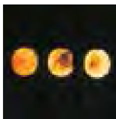
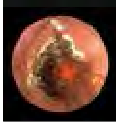
Description

Especially interesting for the gastroenterological discipline.

Properties / Composition

- F-SMA905 connector, customor-specific connectors can be assembled
- Suitable for 532 nm up to 2200 nm, low OH
- EtO-sterilized, double packed (pouch in pouch)
- Luer adapters for rinsing medium
- F-SMA extension sleeve available in various colours
- Laser inscription possible
- Silica/silica fiber, NA = 0.22
- HardClad fiber, NA = 0.37

Applications

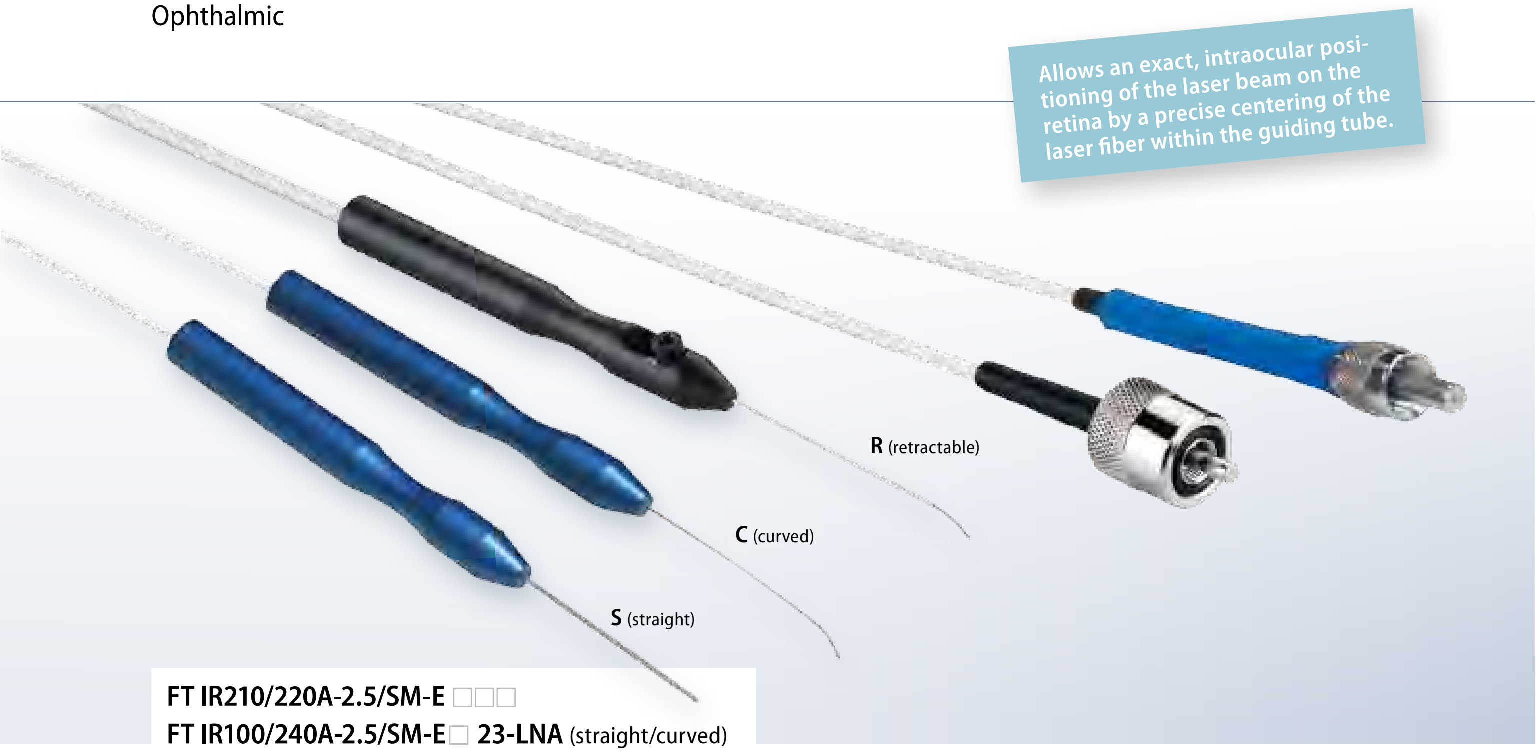
	**Gastro-enteology**	Recanalization of oesophagus carcinoma
	**Pneumology**	Recanalization in tracheal carcinoma Tissue ablation

Core Ø [µm]	Fiber Ø [µm]	Outer Ø [µm]	Type designation	Order no.*
400	730	1800	FT IR400T-3/SM-GLC-1800	**M260100S**
600	950	2100	FT IR600T-3/SM-GLC-2100	**M260200S**
400**	750	1800	FT IR400/440HCT-3/SM-GLC-1800	**M260300S**
600**	1000	2100	FT IR600/660HCT-3/SM-GLC-2100	**M260400S**

* S = sterile, N = non sterile
** NA = 0.22

FiberTech® EndoProbes

Ophthalmic



FT IR210/220A-2.5/SM-E □□□
FT IR100/240A-2.5/SM-E□ 23-LNA (straight/curved)

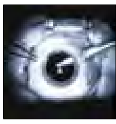
Description

The probes are characterised by their high-quality, ergonomical design and have an anodised metal handpiece.

Properties / Composition

- Excellent mechanical and optical quality
- Fibers centric in the cannula, minimal adhesive gap
- EtO-sterilized, double packed (pouch in pouch)
- Standard NA = 0.22, available low NA = 0.11
- Many connector types available (F-SMA, FC/PC, ceramic ferrules, etc.)
- Laser inscription possible (handpiece and/or extension sleeve)
- Endoprobes available in 20, 23, 25 gauge
- Straight (S), curved (C) and retractable (R) versions available

Applications



Ophthalmology	Vitrectomy

Further basic information on ophthalmic probes:
Chapter 12 | Principles
→ page 404 ff

Type	Core Ø [µm]	Type designation	Order no.*
Endo 20G straight	210	FT IR210/220A-2.5/SM-ES20	**M270100S**
Endo 20G curved	210	FT IR210/220A-2.5/SM-EC20	**M270150S**
Endo 23G straight	210	FT IR210/220A-2.5/SM-ES23	**M270200S**
Endo 23G curved	210	FT IR210/220A-2.5/SM-EC23	**M270250S**
Endo 23G straight**	100	FT IR100/240A-2.5/SM-ES23-LNA	**M270300S**
Endo 23G curved**	100	FT IR100/240A-2.5/SM-EC23-LNA	**M270350S**
Endo 25G straight	210	FT IR210/220A-2.5/SM-ES25	**M270400S**
Endo 25G curved	210	FT IR210/220A-2.5/SM-EC25	**M270450S**
Endo 23R retractable	210	FT IR210/220A-2.5/SM-ER23	**M270600S**

* S = sterile, N = non sterile
** NA = 0.11

FiberTech® RetinopexyProbes / CycloProbes

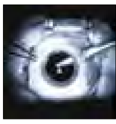
Ophthalmic

FT IR600/□□□AN-2.5/SM-□□

Description

The probes are characterised by their high-quality, ergonomical design and have an anodised metal handpiece.

Applications



Ophthalmology	Vitrectomy

Properties / Composition

- Excellent mechanical and optical quality
- EtO-sterilized, double packed (pouch in pouch)
- Many connector types available (F-SMA, FC / PC, ceramic ferrules, etc.)
- Laser inscription possible (handpiece and/or extension sleeve)
- CycloProbe with ball made from fiber material, Ø 900 µm
- RetinoPexyProbe with laterally decoupling laser beam

Further basic information on ophthalmic probes::
Chapter 12 | Principles
→ page 404 ff

Type	Core Ø [µm]	Type designation	Order no.*
Cyclo 900	600	FT IR600/900AN-2.5/SM-CS	**M270800S**
Retinopexy	600	FT IR600/630AN-2.5/SM-RP	**M270900S**

* S = sterile, N = non sterile

Fiber**Tech**® Handpieces & accessories

for BareFibers

MHPS□-□□-□□□

Description

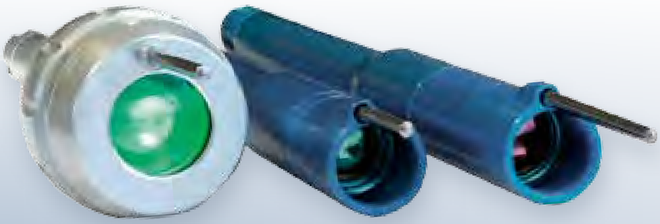
Surgical handpieces with cannulae made from stainless steel.

Properties / Composition

- Autoclavable
- Single-part fiber clamping system
- Various needle shapes/lengths/diameters available
- Handpieces, e.g. for ENT, Dentistry, Urology, etc.

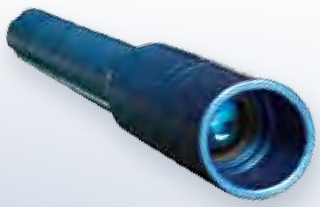
Chirugische Handstücke	Length [mm]	Type designation / Order no.	
		for Core Ø 400 µm	for Core Ø 600 µm
Short curved (45°)	20	MHPS1-20-400	MHPS1-20-600
	40	MHPS1-40-400	MHPS1-40-600
	60	MHPS1-60-400	MHPS1-60-600
Offset	60	MHPS2-60-400	MHPS2-60-600
	80	MHPS2-80-400	MHPS2-80-600
	100	MHPS2-100-400	MHPS2-100-600
	120	MHPS2-120-400	MHPS2-120-600
Curved	50	MHPS3-50-400	MHPS3-50-600
	75	MHPS3-75-400	MHPS3-75-600
	100	MHPS3-100-400	MHPS3-100-600
	125	MHPS3-125-400	MHPS3-125-600
Straight	20	MHPS4-20-400	MHPS4-20-600
	40	MHPS4-40-400	MHPS4-40-600
	60	MHPS4-60-400	MHPS4-60-600
	80	MHPS4-80-400	MHPS4-80-600
	100	MHPS4-100-400	MHPS4-100-600
	120	MHPS4-120-400	MHPS4-120-600
	140	MHPS4-140-400	MHPS4-140-600
	160	MHPS4-160-400	MHPS4-160-600
	180	MHPS4-180-400	MHPS4-180-600
	200	MHPS4-200-400	MHPS4-200-600

FiberTech® Handpieces & accessories



Focusing handpiece, manually adjustable

Focusing handpiece, 30 mm and 50 mm



Bleaching handpiece

Handpieces

Description

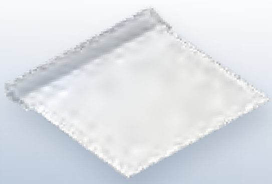
Handpieces for dermatology and dentistry.

Properties / Composition

- Handpieces with variable spot diameter (1x to 3x fiber core diameter)
- Dermatological handpieces with spacers (30 and 50 mm focal distance)
- Handpieces with connected assembled fiber in a protective tube
- Bleaching handpieces

Designation	Order no.
Focusing handpiece, 30 mm with 600 µm fibers, length 3 m and SMA905 connector	**HPD-D30-600**
Focusing handpiece, 50 mm with 600 µm fibers, length 3 m and SMA905 connector	**HPD-D50-600**
Bleaching handpiece with 600 µm fibers, length 3 m and SMA905 connector	**HPD-B-600**

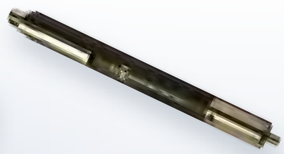
Ceramic scissors



Ceramic blade

SMA-Fiber microscope

Fiber stripper



SMA fiber checktool

Accessories

Overview

- Ceramic scissors
- Ceramic blade
- SMA fiber microscope
- Fiber stripper ➔ adjusting of stripping length
  ➔ adjusting of diameter
- SMA fiber checktool

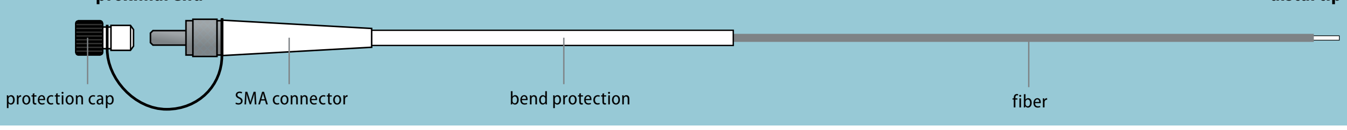
Accessories	Product code	Order no.
Ceramic scissor – cleave tool	CS1	**M310050**
Ceramic blade – cleave tool	CB1	**M310100**
SMA-Fiber microscope	MS1	**M310300**
Fiber stripper 0.12 to 0.40 mm	FS1	**M310400**
Fiber stripper 0.30 to 1.00 mm	FS2	**M310450**
SMA-Fiber checktool	FC1	**M310200**

Type designations

for FiberTech® BareFiber

FT IR 600/660 S T - 3.5 T / S L - F - 2050 (Example)

Manufacturer	
FiberTech® LEONI Fiber Optics Gmbh, as per MDA (German Medical Devices Act)	**FT**
Fiber type	
High OH	**UV**
Low OH	**IR**
Low OH NA = 0.38/0.40	**GE**
Core diameter [µm]	e.g. 600
Cladding diameter [µm] **or core diameter distal [µm]** (Core diameter distal for tapered fibers only)	e.g. 660
Coating	
Acrylate	**A**
Silicone	**S**
Polyimide	**PI**
HardClad	**HC**
Buffer/jacket	
Tefzel®	**T**
Nylon®	**N**
Product length [m]	e.g. 3.5
Fiber design	
Tapered	**T**
Spliced Tapered	**ST**
Connector type	
F-SMA905	**S**
FC/PC	**F**
DIN	**D**
BST	**B**
Special connector	**X**
Connector design	
Glue free	**GF**
Standard	**M**
High power (free standing)	**L**
Holmium	**H**
Programmable	**P**
Distal Tip	
Flat	**F**
Flat rounded	**FR**
Flat CapillaryTip	**FCT**
Ball	**B**
CurvedBall	**CB**
Orb	**O**
Spherical	**S**
Sidefire	**SF**
Gas/liquid cooled	**GLC**
Special designs	
Distal outer diameter [µm]	e.g. 2050
Slim	**SLIM**



FiberTech® Components

for endoscopy

Fiber bundles with endooptics

Description

Single-branched and multi-branched optical fibers with endooptics such as lenses, tilted mirrors, homogenisers or prisms so that the light beam can be tailored to the customer's requirements.

Application

- Spectrometry
- Analytical technology
- Sensor technology
- With glass or plastic optical fibers also for lighting and decoration

Composition

- Individual fibers made from optical glass (when transmitting visible light) or silica (when transmitting UV/IR light)
- Protective tubes, receptacles and adhesives as appropriate to temperature and ambient conditions

Length

Up to 100 m

Light-guide cones

Description

Light-guide rod with differently sized cross-sectional areas at both ends ➔ changing the aperture of a light beam.

Cones bunch light from an optical waveguide with a large cross section into an optical waveguide with a small cross section.

Application

Endoscopy

Composition

Mono or fiber cones possible

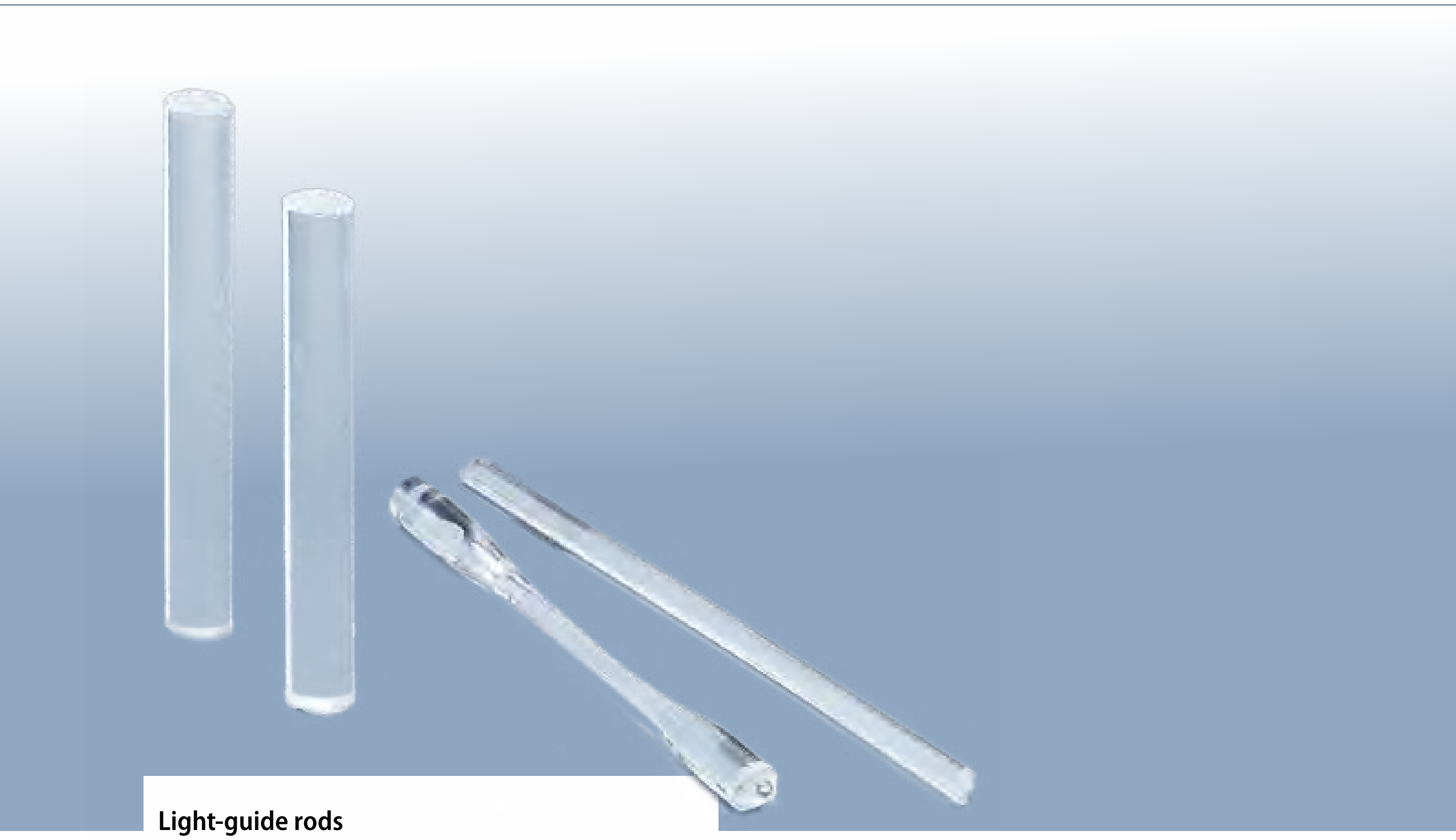
- Mono cone with core and cladding
- Fiber cone consisting of several handred individual fibers ➔ enlarging or reducing photographic-grade line possible
- Diameter 0.1 mm to ≤ 10 mm (others on request)

Receptacles

Stainless steel housing, as per medical standard.

Components

for dentistry and other applications



Light-guide rods

Description

Optical fiber made from silica, optical glass or plastic with large cross-sectional area as well as a core and cladding.

Application

For applications with high light transmission where the optical waveguide does not have to be flexible.

Light-guide rods are frequently also used at the ends of optical waveguides consisting of fiber bundles in order to homogenise the emitted light.

Composition

- Diameter 0.1 mm to ≤ 10 mm (others on request)

Versions

Customer-specific: also tapered if required (tapering across specific areas of the cross-sectional area of the light-guide rod).

Qualitiy testing and materials

Production conditions

Biocompatibility

All of our medical devices meet the applicable requirements of EN ISO for biological assessment of medical devices. The biocompatibility of the materials used was demonstrated by NAMSA under tests, which included:

- Cytotoxicity
- Sensitization
- Systemic Toxicity (acute toxicity)
- Irritation or intracutaneous reactivity
- Hemocompatibility

Our medical devices are produced in clean rooms of ISO Class 8. The clean rooms and our products are subject to regular hygiene monitoring to ensure safety of sterilization of 10^{-6}.

EtO in-house

Sterilization

Our medical products are in-house sterilized using the EtO method in a validated procedure and are delivered sterile.

During the reprocessing, our reusable medical products can be sterilized again in the autoclave. The suitablility of this method was verified in an efficiency validation. It was shown that repeated reprocessing has no negative influence on the performance, the materials and biocompatibility of the products.

Intelligent solutions

for demanding applications in medical technology

LEONI`s Business Unit Healthcare offers an integrated range of products and services from engineering and design to the manufacturing of cables and cable assembly. As a system supplier we support your development and meet the challenges of your specific needs.

www.leoni-healthcare.com

CHAPTER

07

POF

Polymer Optical Fiber

In polymer optical fibers (POF), both the fiber core and the cladding are made of polymers. Key advantages of polymer optical fibers are high flexibility (high alternate bending resistance with smaller bending radii) as well as more economical connecting and transmission technology than in the case of glass.

Moreover, this type of fiber also has all the major benefits of a fiber optical cable connection:

- **EMC security**
- **Clear galvanic separation**
- **No crosstalk**
- **Low weight**

POF can by now be used to bridge distances up to 70 meters, which is normally sufficient for both industrial environments and smaller office as well as home networks. It is even possible to cover distances up to 150 meters by selecting suitable active components.

Globally unparalleled quality assurance

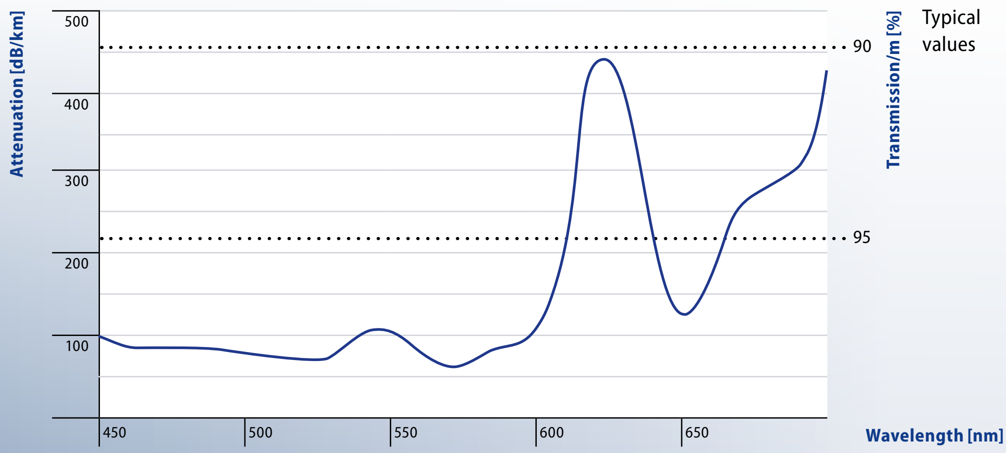
LEONI performs a 100% final check of optical attenuation on all POF cables in series production. This enables us to guarantee first-class quality for our products. Attenuation measurements on entire cable drums (250 and 500 m) represent a particular challenge due to the high optical attenuation of the POF. LEONI uses a measurement system specifically developed for this purpose with an extremely high attenuation budget at 650 nm.

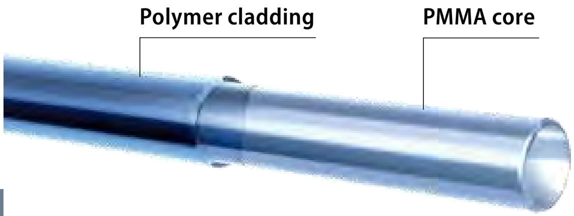
POF cables and assemblies are suitable for a variety of application fields, and LEONI offers innovative solutions for the most diverse tasks. In the industrial sector (A&D), the focus is mainly on the behaviour under harsh environmental conditions, chemical resistance and for example drag chain suitability.

07. POF – Polymer Optical Fiber

POF fiber specifications

Fiber type
Standard



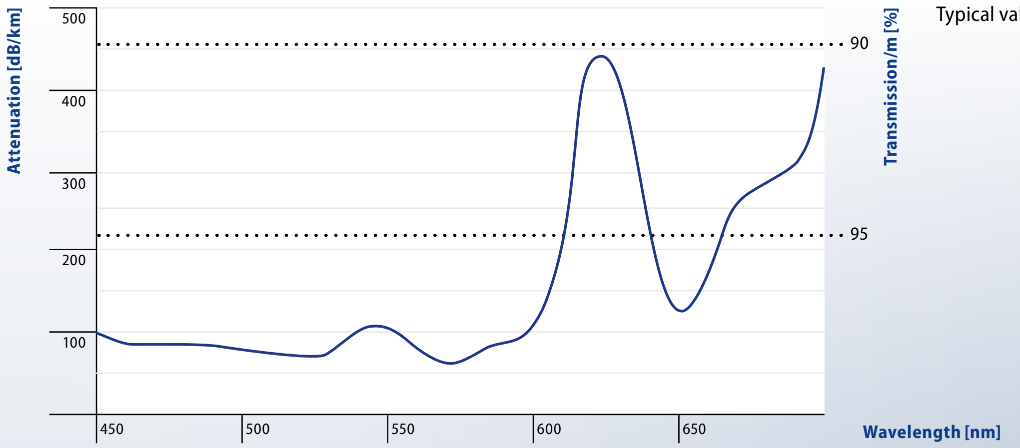


Standard POF is made of a super pure polymethylmethacrylate (PMMA) fiber core, which is cladded with a fluoropolymer jacket. The large fiber core facilitates coupling to transmitter and receiver elements and allows the use of low-cost connector systems, some of which have been specially developed for plastic fiber optics.

LEDs in the wavelength range of 650 to 670 nm are used as transmitter elements. POF has a relative attenuation minimum of 160 dB/km in this range. This attenuation can be slightly increased depending on the cable design. PIN diodes are used as receivers at the other end of the transmission path. Because of the attenuation, the link length is typically limited to less than 100 m. Nowadays, green LEDs are used to get a smaller attenuation of about 100 dB/km. The attenuation minimums of the POF are in the green, yellow and red wavelength range.

	Standard POF					
Order no.	84860101B	84860102B	84860103B	84860104B	84860105B	84860106B
Designation	P240/250	P486/500	P735/750	P980/1000	P1470/1500	P1960/2000
Designation acc. to IEC 60793-2		A4c	A4b	A4a		
Geometric/thermal properties						
Core Ø	240 ± 23 µm	486 ± 30 µm	735 ± 45 µm	980 ± 60 µm	1470 ± 90 µm	1960 ± 120 µm
Jacket Ø	250 ± 23 µm	500 ± 30 µm	750 ± 45 µm	1000 ± 60 µm	1500 ± 90 µm	2000 ± 120 µm
Operating temperature	–55 °C to +70 °C	–55 °C to +70 °C	–55 °C to +70 °C	–55 °C to +85 °C	–55 °C to +70 °C	–55 °C to +70 °C
Transmision properties						
Wavelength	650 nm	650 nm	650 nm	650 nm	650 nm	650 nm
Max. attenuation	300 dB/km	200 dB/km	180 dB/km	160 dB/km	180 dB/km	180 dB/km
Min. bandwidth (MHz × 100 m)				10		
Numerical aperture	0.5	0.5	0.5	0.5	0.5	0.5

Fiber type
Special



Typical values

The numerical aperture of the fiber as well as the temperature resistance can be changed by using different cladding materials. High NA POF (fibers with a higher numerical aperture) permit higher power coupling in the fiber. However increasing the NA results in a lower bandwidth.

POF fibers are subject to natural aging (see the chapter Principles of fiber optics from page 375). The maximum operating temperature of standard POF is restricted to 85 °C by the cladding material. The temperature resistance can be increased up to 105°C by using another cladding material. However this also increases the kilometric attenuation slightly. The PMMA core material is the limiting factor for even higher temperatures.

	Low NA POF	high-temperature POF	
Order no.	available as cabled fiber, order no. on request	available as cabled fiber, order no. on request	
Designation	P980/1000 0.3	P980/1000 high-temperature POF	P485/500 high-temperature POF
Designation acc. to IEC 60793-2			
Geometric/thermal properties			
Core Ø	980 ± 60 µm	980 ± 60 µm	485 ± 30 µm
Jacket Ø	1000 ± 60 µm	1000 ± 60 µm	500 ± 30 µm
Operating temperature	–40 °C to +85 °C	–55 °C to +105 °C	–55 °C to +105 °C
Transmision properties			
Wavelength	650 nm	650 nm	650 nm
Max. attenuation	160 dB/km	200 dB/km	200 dB/km
Numerical aperture	0.3	0.58	0.58

Fiber**Connect**® POF cables

for direct connector assembly

V-2Y 1P980/1000

Order no.	84A00100S000
Code no.	11
Application	light mechanical stress
Assembly	direct connector assembly
Length	500 m, 1000 m, 2500 m

V-Y 1P980/1000

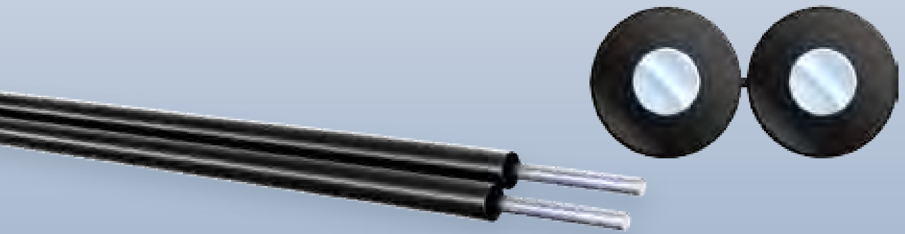
Order no.	84A00200S777
Code no.	14
Application	light mechanical stress
Assembly	direct connector assembly
Length	500 m, 1000 m

V-4Y 1P980/1000

Order no.	84A00300S000
Code no.	12
Application	for heavy mechanical stress and highly flexible applications with small bending radii
Assembly	direct connector assembly
Length	500 m, 1000 m, 5000 m

V-4Y 1P980/1000

Order no.	84A00300S262
Code no.	16
Application	for heavy mechanical stress and highly flexible applications with small bending radii
Assembly	direct connector assembly
Length	500 m, 1000 m, 5000 m



V-2Y 2×1P980/1000

Order no.	84B00100S000
Code no.	13
Application	light mechanical stress
Assembly	direct connector assembly
Length	500 m, 2500 m

POF cables in colour

POF cables of the **84A00100SXXX** series are available in different colours according to the customer's wishes.

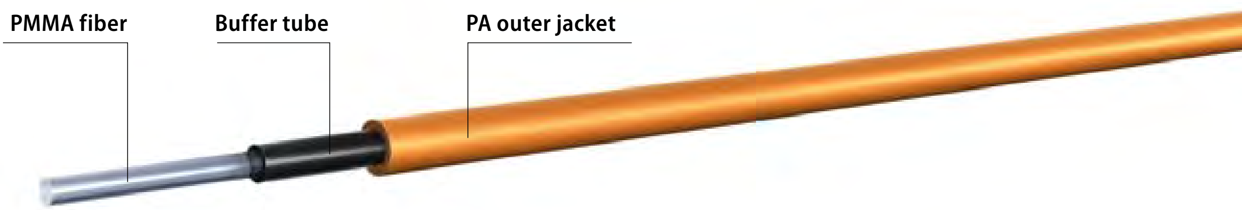
With POF cables with multiple buffered fibers, different buffer tube colours can be used for better differentiation. This technical solution is more easily distinguishable and more economical than uniformly black buffered fibers with printed identification and therefore offers the user major advantages during installation.

Order table for colours

Colour	Order no.	Colour	Order no.
● black	84A00100S000	● blue	84A00100S555
● yellow	84A00100S111	● green	84A00100S666
● orange	84A00100S222	● grey	84A00100S777
● red	84A00100S333	● brown	84A00100S888
● violet	84A00100S444	○ white	84A00100S999

POF cable specifications			V-2Y 1P980/1000	V-Y 1P980/1000	V-4Y 1P980/1000	V-4Y 1P980/1000	V-2Y 2×1P980/1000
Order no.			84A00100S000	84A00200S777	84A00300S000	84A00300S262	84B00100SXXX see table on page 143
Composition	Buffer tube material		PE	PVC	PA	PA	PE
	No. of POF elements (980/1000 µm)		1	1	1	1	2
	Outer Ø [mm]		2.2	2.2	2.2	2.2	2.2 × 4.4
Mechanical properties	Min. bending radius [mm]	during installation	25	25	20	20	25
		long-term	25	25	20	20	25*
	Max. pull force [N]	short-term	15	15	60	60	20
		long-term	5	5	10	10	10
	Approx. cable weight [kg/km]		3.8	3.8	4.3	4.3	7.6
Thermal properties	Operating temperature [°C]		–55 to +85	–40 to +85	–55 to +85	–55 to +85	–55 to +85
Attenuation	[dB/km] at 650 nm (Laser)		< 160	< 160	< 160	< 160	< 160
	[dB/km] at 660 nm (LED)		< 230	< 230	< 230	< 230	< 230

* over flat side

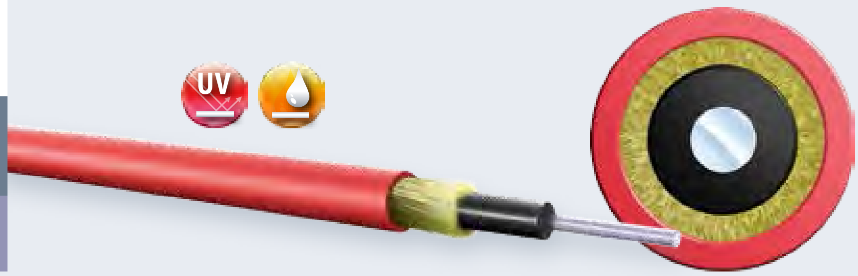


FiberConnect® POF cables

for direct connector assembly

I-V4Y(ZN)11Y 1P980/1000 HEAVY	
Order no.	84C00100S333
Code no.	21
Application	in harsh industrial environments, suitable for drag chains
Assembly	direct connector assembly
Length	500 m

I-VY(ZN)Y 1P980/1000	
Order no.	84C00200S333
Code no.	26
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m



I-V2Y(ZN)11Y 1P980/1000 3.6 mm	
Order no.	84C00800S333
Code no.	23
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m

I-V2Y(ZN)11Y 1P980/1000 6.0 mm	
Order no.	84C01000S333
Code no.	22
Application	in harsh industrial environments, suitable for drag chains
Assembly	direct connector assembly
Length	500 m

I-V2Y(ZN)HH 2×1P980/1000	
Order no.	84D00900S222
Code no.	32
Application	flexible applications with low dynamic stress, for fixed installation
Assembly	direct connector assembly
Length	500 m

POF cables are divided into the following fiber groups:

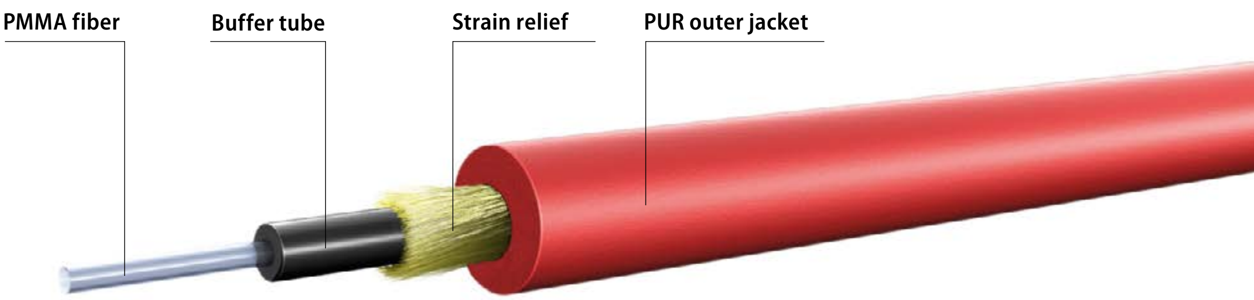
POF buffered fibers:

Step-index standard
Step-index POF low/high NA
Step-index high-temperature
Step-index for fast Ethernet
Graded-index

POF cables are available for indoors and outdoors. A wide range of constructions are available depending on the requirement. Special requirements in terms of flexibility, resistance to oil, resistance to UV, freedom from halogen or flame retardancy are met by selecting suitable components.

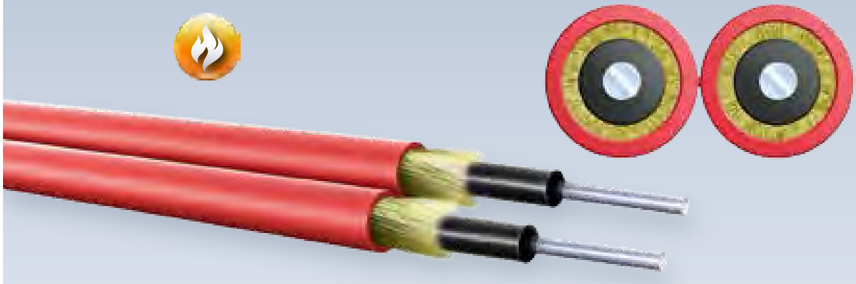
POF cable specifications			I-V4Y(ZN)11Y 1P980/1000 HEAVY	I-VY(ZN)Y 1P980/1000	I-V2Y(ZN)11Y 1P980/1000 3.6 mm	I-V2Y(ZN)11Y 1P980/1000 6.0 mm	I-V2Y(ZN)HH 2×1P980/1000
Order no.			84C00100S333	84C00200S333	84C00800S333	84C01000S333	84D00900S222
Composition	Buffer tube material		PA	PVC	PE	PE	PE
	Outer jacket material		PUR	PVC	PUR	PUR	FRNC
	No. of POF elements (980/1000 µm)		1	1	1	1	2
	Outer Ø [mm]		6.0	3.6	3.6	6.0	4.7 × 8.2
Mechanical properties	Min. bending radius [mm]	during installation	50	70	70	70	70
		long-term	30	50	50	50	50*
	Max. pull force [N]	short-term	500	250	250	400	400
		long-term	200	100	100	100	100
	Approx. cable weight [kg/km]		32	12	11	32	43
Thermal properties	Operating temperature [°C]		–20 to +70	–20 to +70	–20 to +70	–20 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 160	< 190	< 160	< 160	< 190
	[dB/km] at 660 nm (LED)		< 230	< 290	< 230	< 230	< 290

* over flat side



Fiber**Connect**® POF cables

for direct connector assembly



I-V2Y(ZN)H 2×1P980/1000

Order no.	84D03000S222
Code no.	31
Application	flexible applications with low dynamic stress, for fixed installation
Assembly	direct connector assembly
Length	500 m

I-V4Y(ZN)11Y 2P980/1000 HEAVY

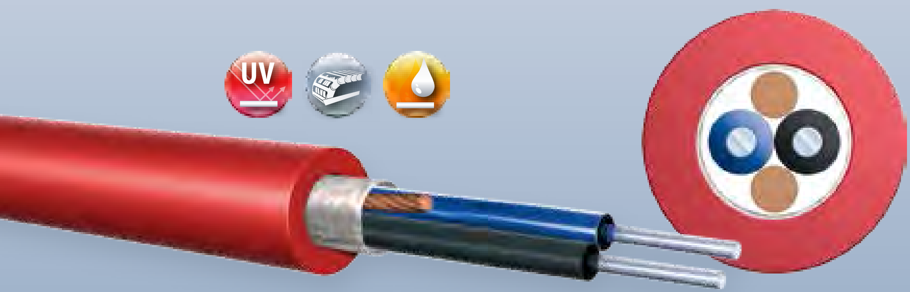
Order no.	84D01100S333
Code no.	24
Application	in harsh industrial environments
Assembly	direct connector assembly
Length	500 m

I-V2Y(ZN)Y 2P980/1000

Order no.	84D01600S333
Code no.	33
Application	flexible Application with low dynamic stress, for fixed installation
Assembly	direct connector assembly
Length	500 m

I-V2Y(ZN)11Y 2P980/1000

Order no.	84D02000S333
Code no.	34
Application	in harsh industrial environments
Assembly	direct connector assembly
Length	500 m



I-V2Y(ZN)11Y 2P980/1000 FLEX

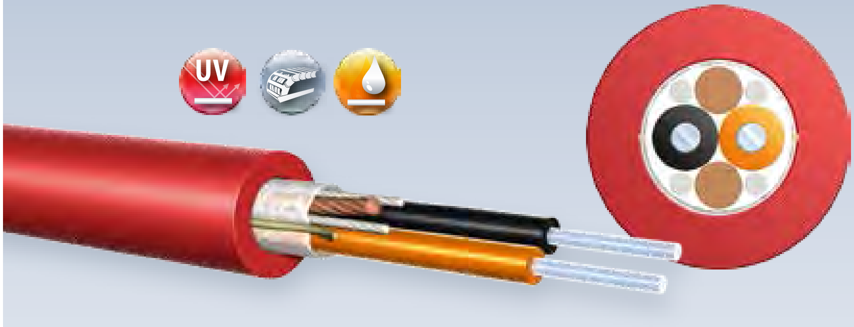
Order no.	84D00500S333
Code no.	25
Application	in harsh industrial environments, suitable for drag chains
Assembly	direct connector assembly
Length	500 m
Variants	dummy elements can be replaced by copper elements

POF cable specifications			I-V2Y(ZN)H 2×1P980/1000	I-V4Y(ZN)11Y 2P980/1000 HEAVY	I-V2Y(ZN)Y 2P980/1000	I-V2Y(ZN)11Y 2P980/1000	I-V2Y(ZN)11Y 2P980/1000 FLEX
Order no.			84D03000S222	84D01100S333	84D01600S333	84D02000S333	84D00500S333
Composition	Buffer tube material		PE	PA	PE	PE	PE
	Outer jacket material		FRNC	PUR	PVC	PUR	PUR
	No. of POF elements (980/1000 µm)		2	2	2	2	2
	Outer Ø [mm]		3.6 × 7.5	6.0	6.0	5.6	6.4
Mechanical properties	Min. bending radius [mm]	during installation	70	60	90	90	90
		long-term	50*	40	60	60	60
	Max. pull force [N]	short-term	400	500	400	400	200
		long-term	100	200	100	100	100
	Approx. cable weight [kg/km]		28	33	54	28	30
Thermal properties	Operating temperature [°C]		–20 to +70	–20 to +70	–20 to +70	–20 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 190	< 160	< 200	< 200	< 220
	[dB/km] at 660 nm (LED)		< 290	< 230	< 290	< 290	< 350

* over flat side

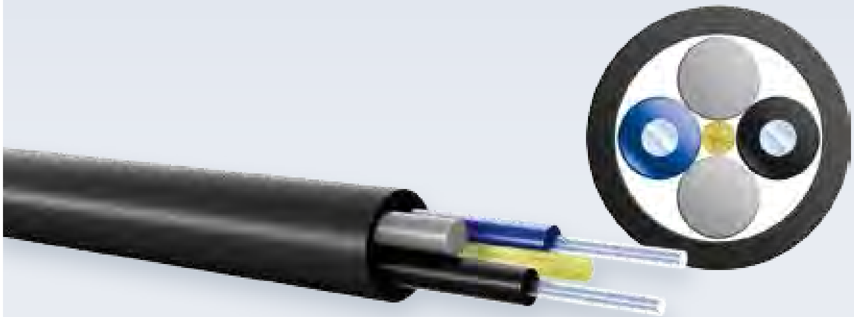
Fiber**Connect**® POF cables

for direct connector assembly



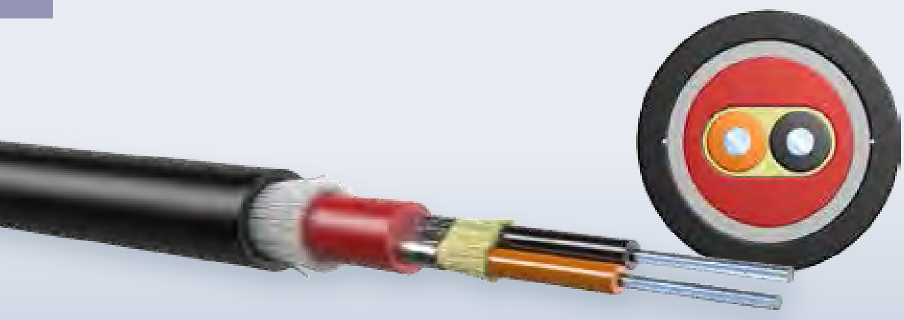
I-V4Y(ZN)11Y 2P980/1000 FLEX

Order no.	84D00300S383
Code no.	36
Application	in harsh industrial environments, suitable for drag chains
Assembly	direct connector assembly
Length	500 m
Variants	dummy elements can be replaced by copper elements



AT-(ZN)V2Y2Y 2P980/1000

Order no.	84D02500S000
Code no.	37
Application	splittable cable cable for fixed outdoor installation
Assembly	direct connector assembly
Length	500 m
Variants	dummy elements can be replaced by copper or POF elements



A-V4Y(ZN)11YB2Y 2P980/100

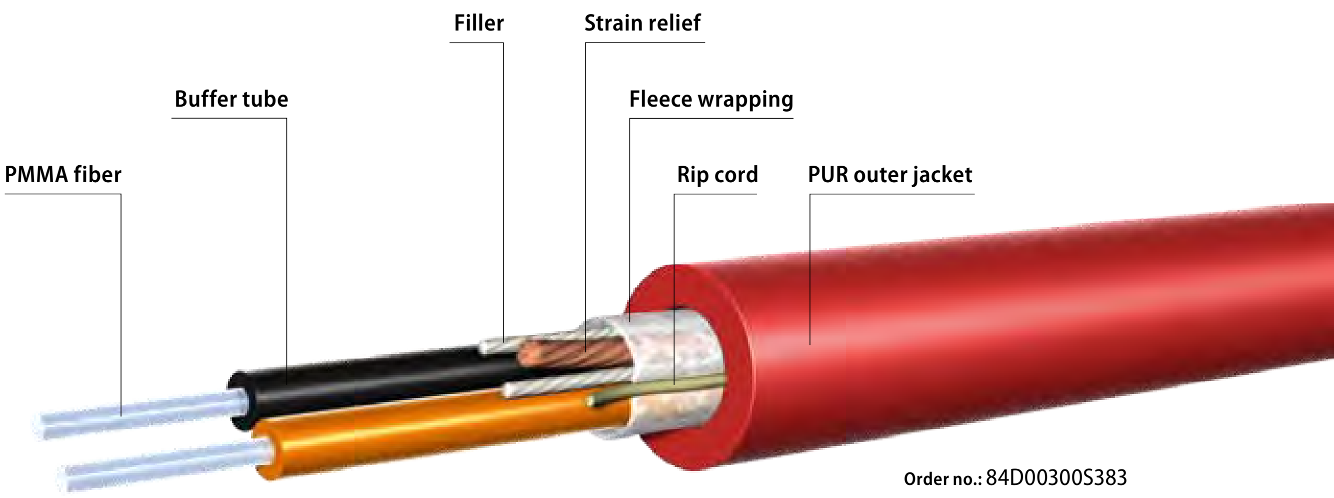
Order no.	84D03100S000
Code no.	N/A
Application	splittable cable for fixed outdoor installation
Assembly	direct connector assembly
Length	500 m

I-V4Y11Y 4P980/1000

Order no.	84E00200S333
Code no.	39
Application	in harsh industrial environments, suitable for drag chains
Assembly	direct connector assembly
Length	500 m

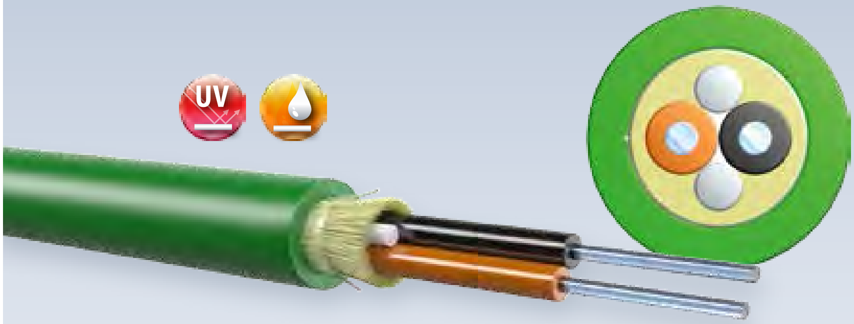
POF cable specifications			I-V4Y(ZN)11Y 2P980/1000 FLEX	AT-(ZN)V2Y2Y 2P980/1000	A-V4Y(ZN)11YB2Y 2P980/100	I-V4Y11Y 4P980/1000
Order no.			84D00300S383	84D02500S000	84D03100S000	84E00200S333
Composition	Buffer tube material		PA	PE	PA	PA
	Outer jacket material		PUR	PE	PUR	PUR
	No. of POF elements (980/1000 µm)		2	2	2	4
	No. of copper elements		–	–	–	–
	Outer Ø [mm]		8.0	7.0	9.4	7.5
Mechanical properties	Min. bending radius [mm]	during installation	60	90	90	70
		long-term	40	60	135	50
	Max. pull force [N]	short-term	400	200	1000	500
		long-term	100	100	200	200
	Approx. cable weight [kg/km]		55	33	64	42
Thermal properties	Operating temperature [°C]		–20 to +70	–25 to +70	–40 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 190	< 220	< 170	< 190
	[dB/km] at 660 nm (LED)		< 290	< 350	< 230	< 290

07



Order no.: 84D00300S383

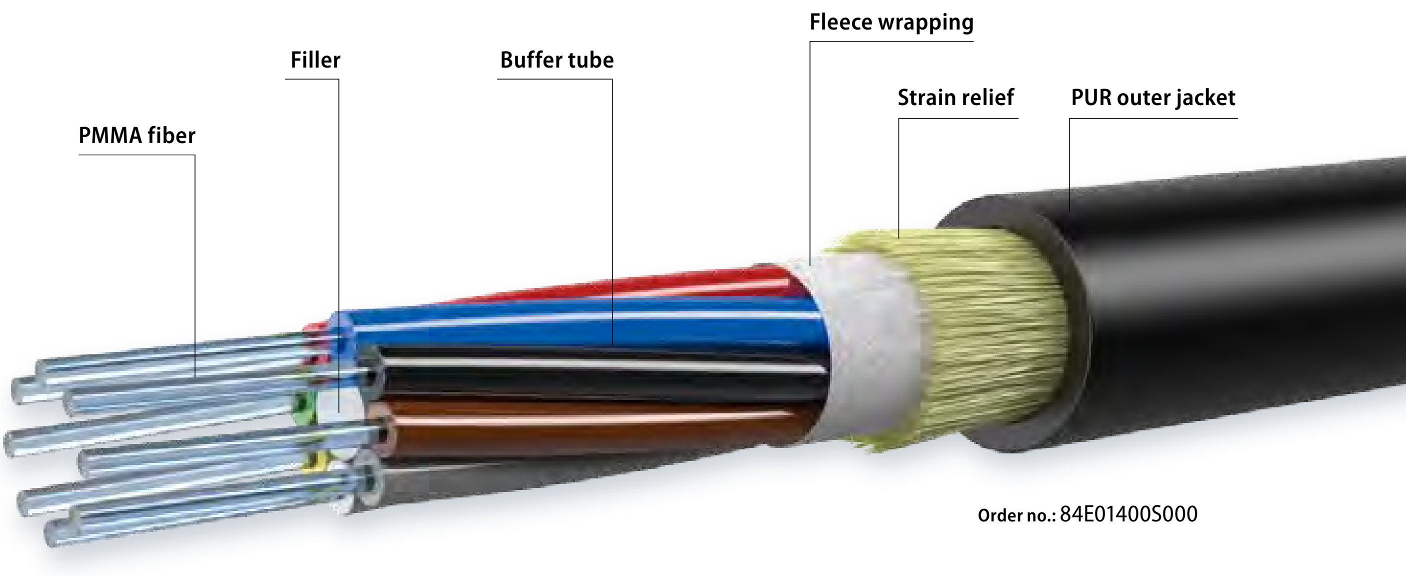
Fiber**Connect**® POF cables
for direct connector assembly



I-V4Y(ZN)11Y 2P980/1000 Rugged Flex PNO	
Order no.	84D05300S666
Code no.	N/A
Application	in harsh industrial environments, for flexible installation in conduits, ducts and on trays, suitable for drag chains
Assembly	direct connector assembly
Length	500 m

I-V2Y(ZN)11Y 8P980/1000	
Order no.	84E01400S000
Code no.	21
Application	in harsh industrial environments, for flexible installation in conduits, ducts and on trays
Assembly	direct connector assembly
Length	500 m

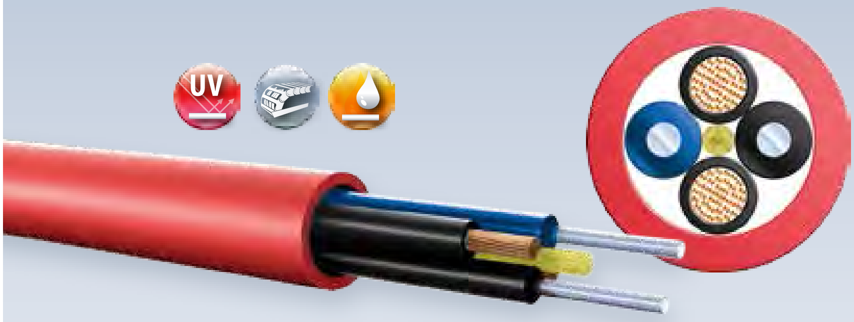
POF cable specifications			I–V4Y(ZN)11Y 2P980/1000 Rugged Flex PNO	I–V2Y(ZN)11Y 8P980/1000
Order no.			84D05300S666	84E01400S000
Composition	Buffer tube material		PA	PE
	Outer jacket material		PUR	PUR
	No. of POF elements (980/1000 µm)		2	8
	No. of copper elements		–	–
	Outer Ø [mm]		8.0	8.0
Mechanical properties	Min. bending radius [mm]	during installation	60	180
		long-term	40	120
	Max. pull force [N]	short-term	200	2000
		long-term	100	500
	Approx. cable weight [kg/km]		42	110
Thermal properties	Operating temperature [°C]		−40 to +80	−40 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 180	< 230
	[dB/km] at 660 nm (LED)		< 275	< 330



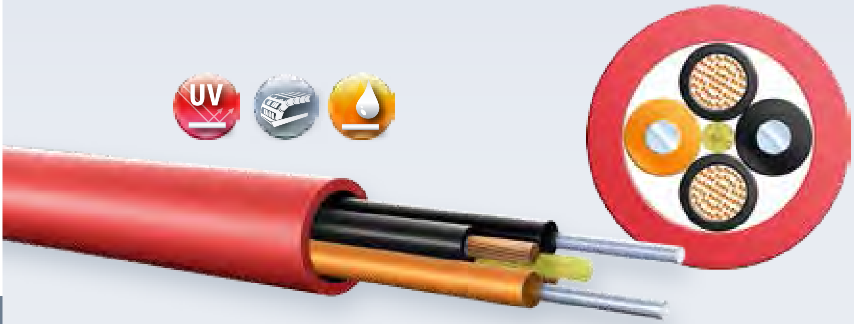
Order no.: 84E01400S000

FiberConnect® POF hybrid cables

for direct connector assembly

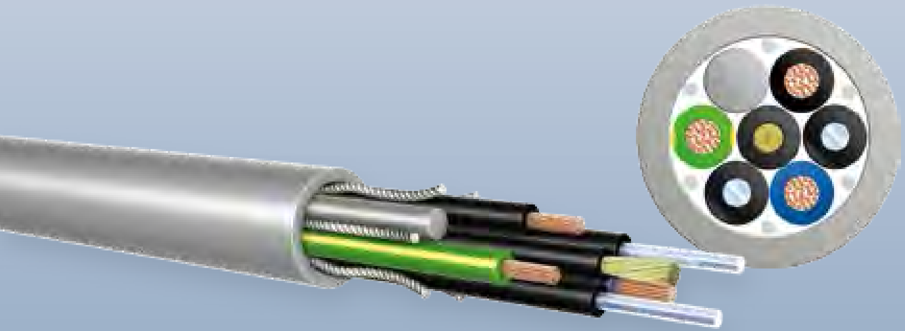


I-(ZN)V2Y11Y 2P980/1000 +2×1.0 qmm	
Order no.	84D00600S333
Code no.	29
Application	in harsh industrial environments, suitable for drag chains
Composition	2 copper elements (e.g. for energy supply) and 2 POF buffered fibers (e.g. for data transmission)
Assembly	direct connector assembly
Length	500 m



I-(ZN)V4Y11Y 2P980/1000+2×1.0 qmm	
Order no.	84D02800S333
Code no.	38
Application	in harsh industrial environments, suitable for drag chains
Composition	2 copper elements (e.g. for energy supply) and 2 POF buffered fibers (e.g. for data transmission)
Assembly	direct connector assembly
Length	500 m

I-(ZN)V4Y11Y 2P980/1000+4×1.5 qmm	
Order no.	84D01400S444
Code no.	41
Application	in harsh industrial environments, suitable for drag chains
Composition	4 copper elements (e.g. for energy supply) and 2 POF buffered fibers (e.g. for data transmission)
Assembly	direct connector assembly
Length	500 m

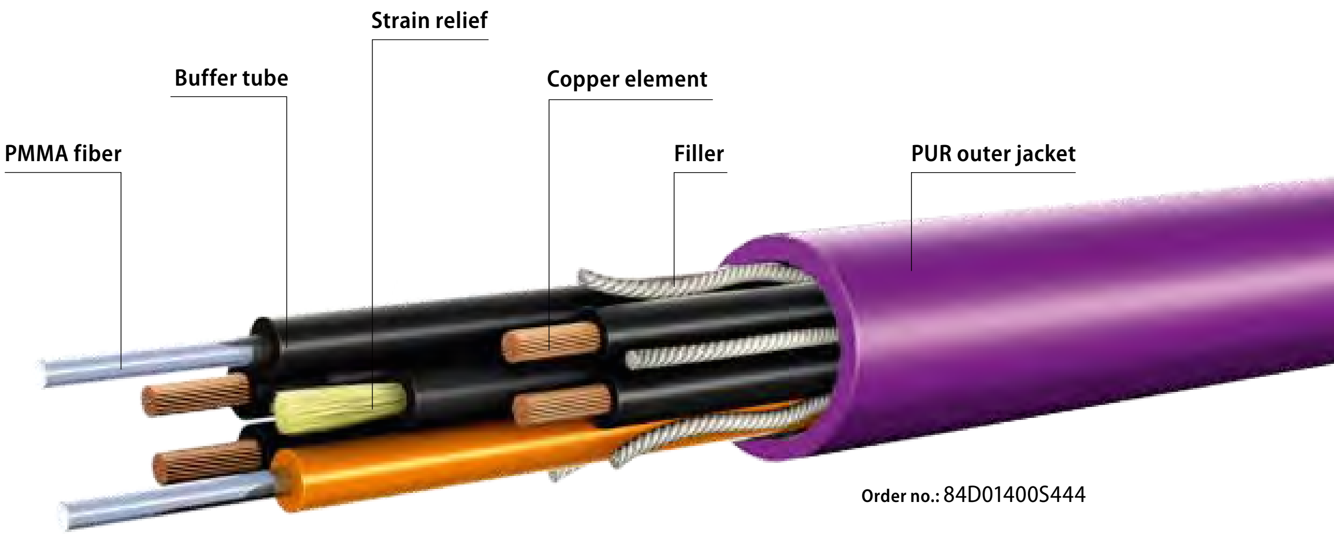


I-(ZN)V4YY 2P980/1000+3×1.5qmm	
Order no.	84D01800S707
Code no.	42
Application	flexible applications with low dynamic stress
Composition	3 copper elements (e.g. for energy supply) and 2 POF buffered fibers (e.g. for data transmission)
Assembly	direct connector assembly
Length	500 m

Info

Hybrid cables, consisting of different optical fibers and electrical conductors, are produced on a customer-specific basis.

POF cable specifications			I-(ZN)V2Y11Y 2P980/1000 +2×1.0 qmm	I-(ZN)V4Y11Y 2P980/1000 + 2×1.0 qmm	I-(ZN)V4Y11Y 2P980/1000 +4×1.5 qmm	I-(ZN)V4YY 2P980/1000 +3×1.5 qmm
Order no.			84D00600S333	84D02800S333	84D01400S444	84D01800S707
Composition	Buffer tube material		PE	PA	PA	PA
	Outer jacket material		PUR	PUR	PUR	PVC
	No. of POF elements (980/1000 µm)		2	2	2	2
	No. of copper elements		2	2	4	3
	Outer Ø [mm]		7.5	7.5	10.6	10.7
Mechanical properties	Min. bending radius [mm]	during installation	90	70	110	110
		long-term	60	50	70	70
	Max. pull force [N]	short-term	200	400	400	200
		long-term	100	100	100	100
	Approx. cable weight [kg/km]		62	42	146	132
Thermal properties	Operating temperature [°C]		–20 to +70	–20 to +70	–20 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 220	< 190	< 230	< 230
	[dB/km] at 660 nm (LED)		< 350	< 290	< 330	< 330



Order no.: 84D01400S444

Fiber**Connect**® POF cables

for direct connector assembly

I-V4Y(ZN)11Y 1P980/1000 6.0 mm UL AWM Style 5422

Order no.	84C01200S333
Code no.	3A
Application	in harsh industrial environments, suitable for drag chains
Assembly	direct connector assembly
Length	500 m

I-V2Y(ZN)11Y 1P980/1000 5.5 mm UL AWM Style 5422

Order no.	84C01300S333
Code no.	2A
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m

I-V4Y(ZN)11Y 2P980/1000 FLEX UL AWM Style 5422

Order no.	84D03500S383
Code no.	1A
Application	in harsh industrial environments, suitable for drag chains
Assembly	direct connector assembly
Length	500 m

Info

Hybrid cables, consisting of different optical fibers and electrical conductors, are produced on a customer-specific basis.

Cables with UL (Underwriter Laboratories) approval
Cables with UL approval guarantee safety and reliability in the intended application areas. They are specifically tailored to the requirements of the North American market, however demand for them is increasing in Asia and Europe, where they are being used more and more. Insurance companies, public authorities, planners and other regulatory authorities above all place their confidence in UL-approved optical cables with singlemode / multimode or plastic fibers.

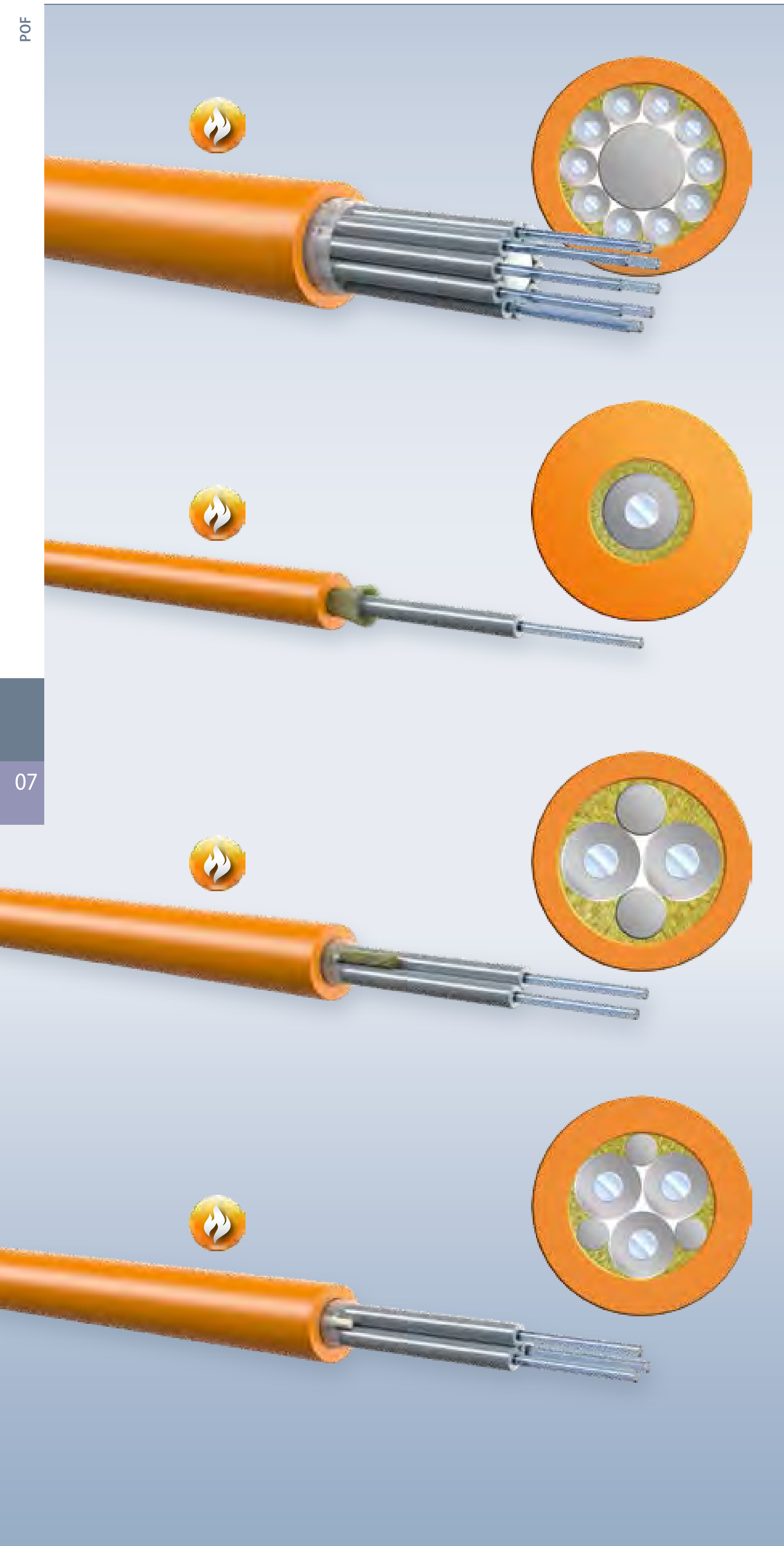
Optical cables are described in the standard UL 1651-Fiber Optic Cable and categorised according to OFNP (plenum), OFNR (riser) and OFN (general purpose). Optical cables can also be classified according to the UL 758-Appliance Wiring Material (AWM) standard. UL cables have to meet very high requirements for fire performance in particular, including generation of smoke gas.

Overview of all standard test procedures:
Chapter 12 | Principles
→ page 381 ff

POF cable specifications			I-V4Y(ZN)11Y 1P980/1000 6.0 mm UL AWM Style 5422	I-V2Y(ZN)11Y 1P980/1000 5.5 mm UL AWM Style 5422	I-V4Y(ZN)11Y 2P980/1000 FLEX UL AWM Style 5422
Order no.			84C01200S333	84C01300S333	84D03500S383
Composition	Buffer tube material		PA	PE	PA
	Outer jacket material		PUR	PUR	PUR
	No. of POF elements (980/1000 µm)		1	1	2
	No. of copper elements		–	–	–
	Outer Ø [mm]		6.0	5.5	8.0
Mechanical properties	Min. bending radius [mm]	during installation	50	70	60
		long-term	30	50	40
	Max. pull force [N]	short-term	500	400	400
		long-term	200	100	100
	Approx. cable weight [kg/km]		32	23	23
Thermal properties	Operating temperature [°C]		–20 to +70	–20 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 160	< 190	< 180
	[dB/km] at 660 nm (LED)		< 230	< 290	< 275
Flammtest	tested acc. to UL VW-1		for harsh industrial environments	suitable for flexible applications in areas with low dynamic stress	for harsh industrial environments

Fiber**Connect**® POF cables

for direct connector assembly



10 X POF J-VY 10P980/1000 200A… LG OG	
Order no.	V46916-U10-U1
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m

1 X POF J-VY 1P980/1000 200A… OG	
Order no.	V46916-U1-U6
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m

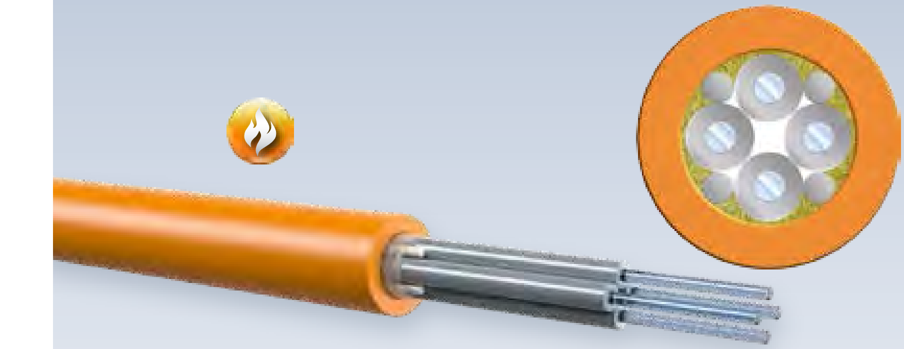
2 X POF J-V(ZN)Y 2P980/1000 200A… LG OR	
Order no.	V46916-U2-U9
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m

3 X POF J-VY 3P980/1000 200A… LG OG	
Order no.	V46916-U3-U1
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m

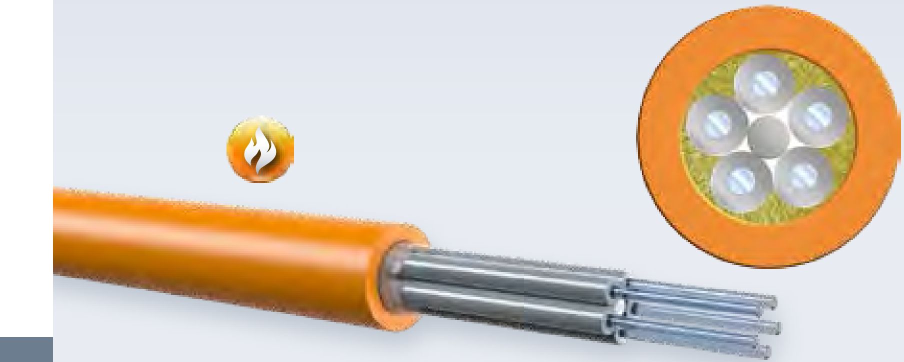
POF cable specifications			J-VY 10P980/1000 200A…LG OG	J-V(ZN)Y 1P980/1000 200A… OG	J-V(ZN)Y 2P980/1000 200A… LG OR	J-VY 3P980/1000 200A…LG OG
Order no.			V46916-U10-U1	V46916-U1-U6	V46916-U2-U9	V46916-U3-U1
Composition	Buffer tube material		PVC	PVC	PVC	PVC
	Outer jacket material		PVC	PVC	PVC	PVC
	No. of POF elements (980/1000 µm)		10	1	2	3
	Outer Ø [mm]		12.9	6.0	7,7	7,9
Mechanical properties	Min. bending radius [mm]	cable	7.5 × Ø	7.5 × Ø	≥ 100	7.5 × Ø
		single element	5 × Ø	5 × Ø	≥ 100	5 × Ø
Thermal properties	Operating temperature [°C]		−40 to +60	−40 to +60	−40 to +60	−40 to +60
Attenuation	[dB/km] at 650 nm (Laser)		200	200	200	200
	[dB/km] at 660 nm (LED)		260	260	260	260

Fiber**Connect**® POF cables

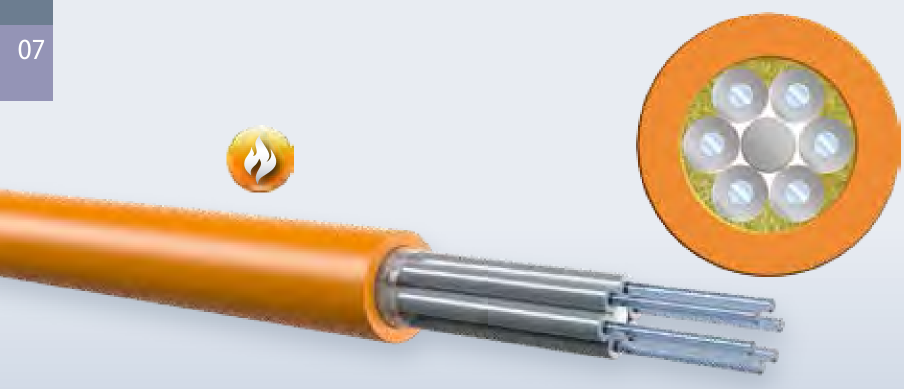
for direct connector assembly



4 X POF J-VY 4P980/1000 200A… LG OG	
Order no.	V46916-U4-U1
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m



5 X POF J-VY 5P980/1000 200A… LG OG	
Order no.	V46916-U5-U1
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m

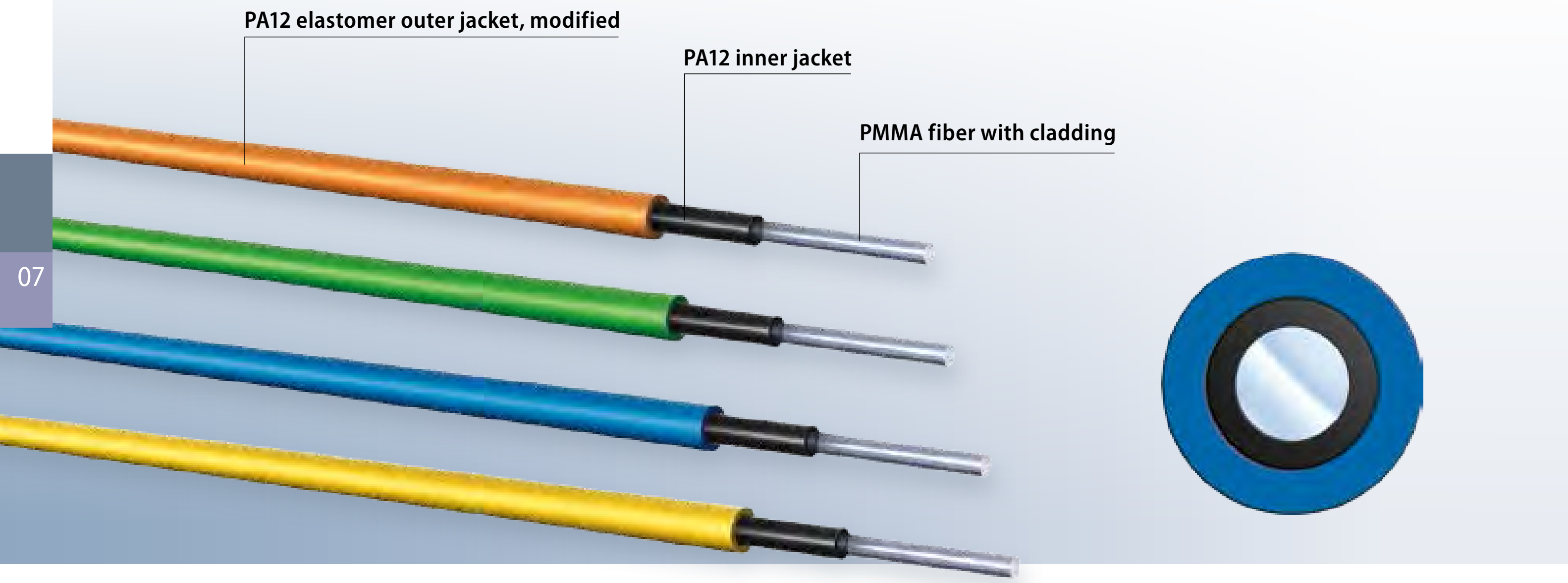


6 X POF J-VY 6P980/1000 200A… LG OG	
Order no.	V46916-U6-U1
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	500 m

POF cable specifications			J-VY 4P980/1000 200A… LG OG	J-VY 5P980/1000 200A… LG OG	J-VY 6P980/1000 200A… LG OG
Order no.			V46916-U4-U1	V46916-U5-U1	V46916-U6-U1
Composition	Buffer tube material		PVC	PVC	PVC
	Outer jacket material		PVC	PVC	PVC
	No. of POF elements (980/1000 µm)		4	5	6
	Outer Ø [mm]		8.8	9.3	9.9
Mechanical properties	Min. bending radius [mm]	cable	7.5 × Ø	7.5 × Ø	7.5 × Ø
		single element	5 × Ø	5 × Ø	5 × Ø
Thermal properties	Operating temperature [°C]		−40 to +60	−40 to +60	−40 to +60
Attenuation	[dB/km] at 650 nm (Laser)		200	200	200
	[dB/km] at 660 nm (LED)		260	260	260

LEONI **Dacar® FP automotive cables**

Optical fibers for use in vehicles



Electronic systems are increasingly being used instead of mechanical components in automotive development to realise more and more comfort and safety functions. This means ever increasing complexity of the vehicle electronics with a fastgrowing number of functions, sensors and actuators.

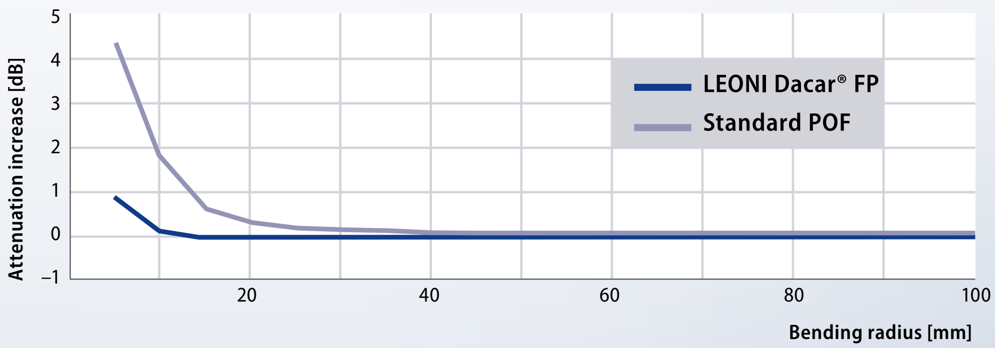
To meet these high technical requirements, LEONI has developed a special assembly technique and an innovative cable for data communication and even slightly modified the fiber for this application.

The buffer tube always consists of two polyamide layers: a black inner jacket to rule out possible interference from outside light and a coloured outer jacket (blue, green, yellow or orange).

The fiber consists of a PMMA core and optimised double cladding.

This construction significantly reduces the attenuation that occurs when the optical fiber is bent compared with standard polymer optical fiber (POF).

Graph:
Attenuation increase as a function of bending radius (standard POF compared to LEONI Dacar® FP)

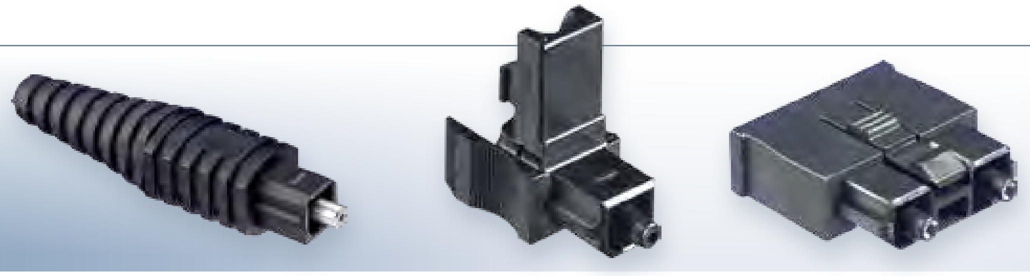


LEONI Dacar® FP	
Order no.	see table
Application	for data communication within the vehicle, for high mechanical stress and highly flexible applications with small bending radii
Assembly	direct connector assembly
Length	5000 m

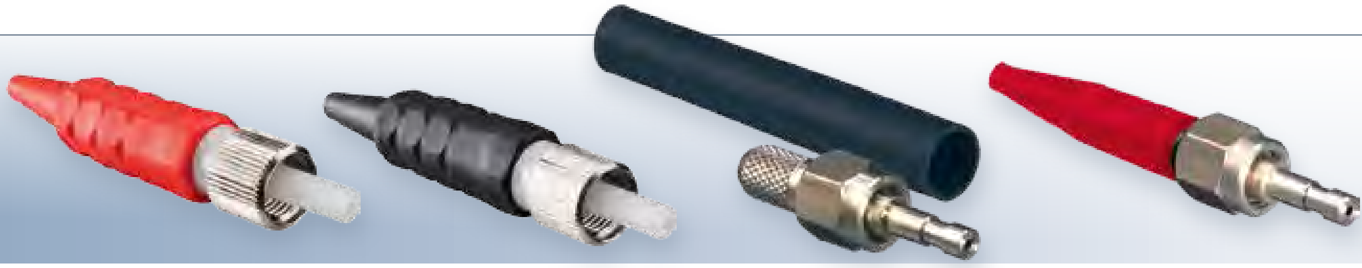
Colour	Code no.	Order no.
orange	17	84A00500S262
green	C7	84A00500S666
blue	C8	84A00500S519
yellow	C9	84A00500S201

Fiber**Connect**® POF connectors

with metal or plastic ferrules



	F05 connector POF		F07 connector POF
Order no.	SF05-SS0-20-0010	SF05-SV0-02-0010	SF07-DG0-08-0010
Compatibility	TOCP155/TOCP155P/ TOCP172	TOCP155/TOCP155P/ TOCP174	TOCP200/TOCP200P/ TOCP255/TOCP255P
Fiber Ø	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	2.2 mm
Assembly	crimping/polishing	clamping/polishing	clamping/hot plate
Ferrule	metal	plastic	plastic
Reference cable	KF05-F0511050cm for attenuation measurement 0.5 m	KF05-F0511050cm for attenuation measurement 0.5 m	KF07-F0713050cm for attenuation measurement 0.5 m
Features	incl. crimping sleeve, black boot, dust cap	incl. dust cap	incl. dust cap
Stripping	A2 / A6	A2 / A6	A2 / A6
Crimping	C3	–	–
Polishing	P2 / P3 / P7	P2 / P3 / P7	P10



	FSMA connector POF			
Order no.	SSMA-SS0-13-0020	SSMA-SS0-13-0030	SSMA-SS0-02-0020	SSMA-SS0-02-0030
Fiber Ø	1000 µm	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	6.0 mm	3.6 mm
Assembly	crimping/polishing	crimping/polishing	crimping/polishing	crimping/polishing
Ferrule	plastic	plastic	metal	metal
Reference cable	KSMA-SMA11050cm for attenuation measurement 0.5 m	KSMA-SMA11050cm for attenuation measurement 0.5 m	KSMA-SMA11050cm for attenuation measurement 0.5 m	KSMA-SMA11050cm for attenuation measurement 0.5 m
Features	incl. red boot and dust cap	incl. black boot and dust cap	incl. crimping sleeve, black boot and dust cap, also as knurled variant	incl. crimping sleeve, red boot and dust cap, also as knurled variant
Stripping	A2 / A6	A2 / A6	A2 / A6	A2 / A6
Crimping	C1	C1	C1	–
Polishing	P10	P10	P2 / P3 / P6	P10

Info

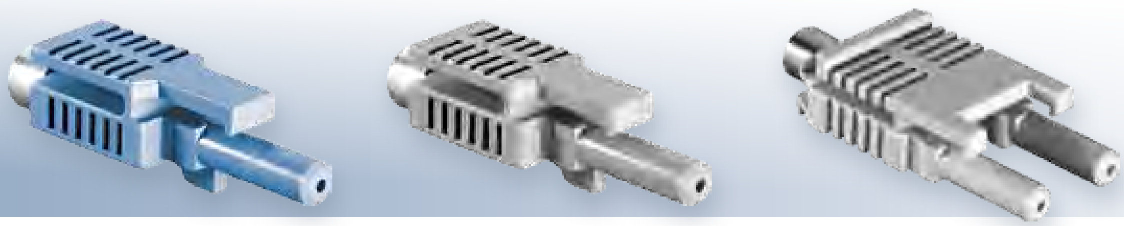
Connectors for POF differ not only in terms of their construction, but also in the technology used to attach to the cable (crimping or clamping) and in the technology used to process the end face. The focus here is on lapping and polishing as well as hot plate technology.

	FSMA connector POF			
Order no.	SSMA-SS0-02-0050	SSMA-SS0-02-0060	SSMA-SS0-02-0070	SSMA-SV0-02-0010
Fiber Ø	1000 µm	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	6.0 mm	2.2 mm
Assembly	crimping/polishing	crimping/polishing	crimping/polishing	clamping/polishing
Ferrule	metal	plastic	plastic	metal
Reference cable	KSMA-SMA11050cm for attenuation measurement 0.5 m	KSMA-SMA11050cm for attenuation measurement 0.5 m	KSMA-SMA11050cm for attenuation measurement 0.5 m	KSMA-SMA11050cm for attenuation measurement 0.5 m
Features	incl. black boot and dust cap, also as hexagonal variant	incl. black boot and dust cap	incl. crimping sleeve, black boot and dust cap	incl. black boot and dust cap
Stripping	A2 / A6	A2 / A6	A2 / A6	A2 / A6
Crimping	C1	C1	C1	–
Polishing	P2 / P3 / P6	P2 / P3 / P6	P2 / P3 / P6	P2 / P3 / P6

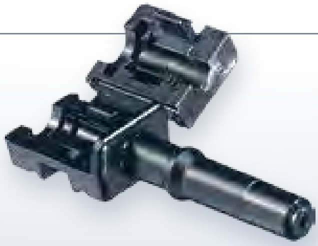
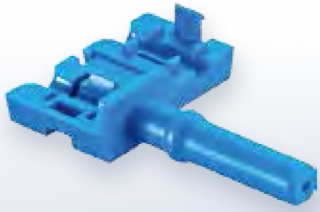
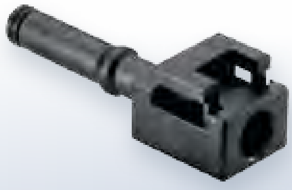
FiberConnect® POF connector

with metal or plastic ferrules

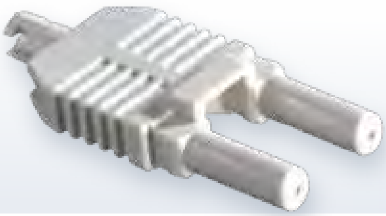
	HP connector POF		
Order no.	SXHP-SS0-20-0020	SXHP-SS0-19-0010	SXHP-SSO-19-0020
Compatibility	–	HFBR4511	HFBR4501
Fiber Ø	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	2.2 mm
Assembly	crimping/polishing	crimping/polishing	crimping/polishing
Ferrule	metal	plastic	metal
Reference cable	KHPS-HPS11050cm for attenuation measurement 0.5 m	KHPS-HPS11050cm for attenuation measurement 0.5 m	KHPS-HPS11050cm for attenuation measurement 0.5 m
Features	incl. green boot and dust cap	incl. crimping sleeve and dust cap	incl. crimping sleeve and dust cap
Stripping	A2 / A6	A2 / A6	A2 / A6
Crimping	C3	C3	C3
Polishing	P1 / P2 / P3 / P8	P1 / P2 / P3 / P8	P1 / P2 / P3 / P8



	HP connector POF		
Order no.	SXHP-SS0-19-0030	SXHP-SS0-19-0040	SXHP-DS0-19-0020
Compatibility	HFBR4513	HFBR4503	HFBR4516
Fiber Ø	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	2.2 mm
Assembly	crimping/polishing	crimping/polishing	crimping/polishing
Ferrule	plastic	plastic	plastic
Reference cable	KHPS-HPS11050cm for attenuation measurement 0.5 m	KHPS-HPS11050cm for attenuation measurement 0.5 m	KHPD-HPD13050cm for attenuation measurement 0.5 m
Features	incl. crimping sleeve	incl. crimping sleeve	incl. crimping sleeve and dust cap
Stripping	A2 / A6	A2 / A6	A2 / A6
Crimping	C3	C3	C3
Polishing	P1 / P2 / P3	P1 / P2 / P3	P1 / P2 / P3

	HP connector POF		HP connector POF rugged
Order no.	SXHP-SV0-19-0010	SXHP-SV0-19-0020	SXHP-SV0-02-0010
Compatibility	HFBR 4531	HFBR4533	–
Fiber Ø	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	2.2 mm
Assembly	clamping/polishing	clamping/polishing	clamping/polishing
Ferrule	plastic	plastic	plastic
Reference cable	KHPS-HPS11050cm for attenuation measurement 0.5 m	KHPS-HPS11050cm for attenuation measurement 0.5 m	KHPS-HPS11050cm for attenuation measurement 0.5 m
Features	incl. dust cap	incl. dust cap	without dust cap
Stripping	A2 / A6	A2 / A6	A2 / A6
Polishing	P1 / P2 / P3 / P8	P1 / P2 / P3	P1 / P2 / P3 / P8



	HP connector duplex POF	Anti-kink protection sleeve for HP connector	HP connector POF latching
Order no.	SXHP-DS0-19-0010	SKNS-CZ0-20-0010 **in blue** SKNS-GZ0-20-0010 **in grey**	SXHP-SV0-19-0030
Compatibility	HFBR 4506	HFBR 4501, 4503, 4511 and 4513	HFBR4532
Fiber Ø	1000 µm		1000 µm
Cable Ø	2.2 mm		2.2 mm
Assembly	crimping/polishing		clamping/polishing
Ferrule	plastic		plastic
Reference cable	KHPD-HPD13050cm for attenuation measurement 0.5 m		KHPS-HPS11050cm for attenuation measurement 0.5 m
Features	incl. crimping sleeve and dust cap		incl. dust cap
Stripping	A2 / A6		A2 / A6
Crimping	C3		–
Polishing	P1 / P2 / P3		P1 / P2 / P3

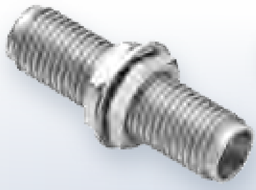
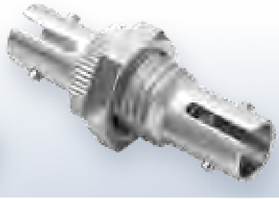
FiberConnect® POF connector

with metal or plastic ferrules

	ST connector (BFOC) POF		SC connector POF
Order no.	SXST-SS0-22-0010	SXST-SV0-02-0010	SXSC-SS0-02-0010
Fiber Ø	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	2.2 mm
Assembly	crimping/polishing	clamping/polishing	crimping/polishing
Ferrule	metal	metal	metal
Reference cable	KXST-XST11050cm for attenuation measurement 0.5 m	KXST-XST11050cm for attenuation measurement 0.5 m	KXSC-XSC11050cm for attenuation measurement 0.5 m
Features	incl. crimping sleeve, black boot and dust cap	inkl. black boot and dust cap	incl. crimping sleeve, black boot and dust cap
Stripping	A2 / A6	A2 / A6	A2 / A6
Crimping	C1	–	C3
Polishing	P2 / P3 / P9	P2 / P3 / P9	P2 / P3

	SCRJ connector duplex IP20	End sleeve
Order no.	SSCR-DV0-02-0010	SENH-SH0-23-0010
	–	SFH diodes
Fiber Ø	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm
Assembly	clamping/polishing	hot plate
Ferrule	metal	plastic
Reference cable	KSCR-SCR13050cm for attenuation measurement 0.5 m	–
Features	inkl. black boot and dust cap	without dust cap
Stripping	A2 / A6	A2 / A6
Crimping	–	–
Polishing	P2 / P3 / P6	–

FiberConnect® POF adapters

	Adapter for F05 POF	Adapter for F07 POF	Adapter for FSMA POF	Adapter for ST POF
Order no.	SKUP-2XF05-0010	SKUP-2XF07-0010	SKUP-2XSMA-0010	SKUP-2XXST-0010
Fiber Ø	1000 µm	1000 µm	1000 µm	1000 µm
Ferrule	plastic	plastic	metal without separate insert	metal with metal insert

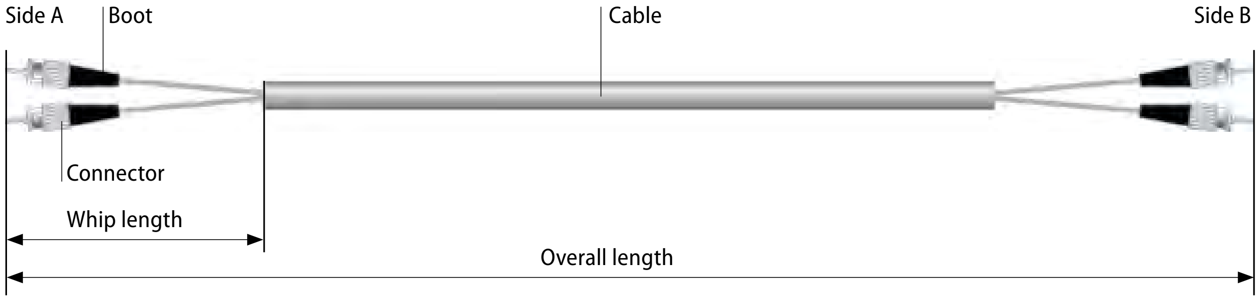


	Adapter for HP POF		Adapter for SCRJ POF
Order no.	SKUP-2XHPS-0020	SKUP-2XHPS-0030	SKUP-2XSCR-0010
Compatibility	HFBR 4515	HFBR 4505	–
Fiber Ø	1000 µm	1000 µm	1000 µm
Ferrule	plastic without separate metal insert	plastic without separate metal insert	plastic with ceramic insert

Pre-assembled POF cables

Description of the structure of pre-assembled POF outdoor cables

- Standard whip lengths 20 ±4 cm
- Overall length tolerances (±2 %)



The production of fibers and cables in LEONI's own facilities and their careful assembly under laboratory conditions ensure superior properties and maximum reliability. In addition to standard products, we offer a range of special product functionalities as well as customer-specific assembly.

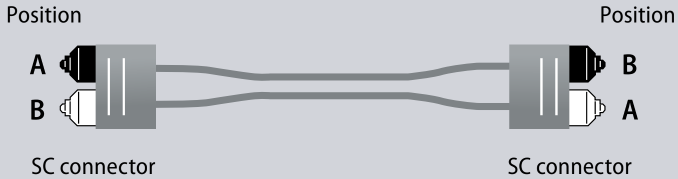
Service features

- All fiber and cable types (including hybrid cables)
- All connector types
- Every attenuation grade for different customer requirements
- Every length, even for single unit order size
- Customer-specific assembly
- Customer-specific cable printing
- Additional selective printing of the cable jacket during the process of cutting to length

Quality assurance

The optical attenuation is defined according to IEC60793-1-40 B for POF. The result is shown on the label.

Assembly with logical crossing
(= no physical crossing)



Note on polarity

Please note that our products for standard and special assembly are produced acc. to ANSI/TIA/EIA-568-B.1 with logical crossing.

The products can also be assembled with physical crossing on request (please specify when ordering).

Order number scheme

for POF cable assembly

KXST– XST 32 325 cm (Example)

Cable assembly	**K**
Connector type Side A	
BFOC (ST®)	**XST**
FSMA	**SMA**
HP simplex	**HPS**
HP duplex	**HPD**
F05, TOSLINK compatible	**F05**
F07, TOSLINK compatible	**F07**
SC	**XSC**
SCRJ	**SCR**
End sleeve	**ENH**
SMI	**SMI**
Connector type Side B (see above)	e.g. XST
POF cables code no.	
e.g. I-V2Y(ZN)HH	**32**
AT-(ZN)V2Y2Y 2P980	**37**
Length	
128, 010, …	e.g. 325
Unit	
mm, cm, m, …	e.g. cm
Variants	
Customer specific	

Order example:

K XST-XST 32 325 cm

3.25 meters,
duplex connection cable
(cable type: I-V2Y(ZN)
HH2×1P980/1000,
PMMA fiber with PE buffer tube
and FRNC outer jacket
assembled with ST connectors

CHAPTER

08

PCF

Polymer Cladded Fiber

Polymer cladded fibers (PCF) have been available on the market for many years and are characterized by being very robust and easy to assemble.

PCF consists of a glass core with polymer cladding. What is especially important here is the good adhesion of the cladding material to the glass core, which does not go without saying because of the different expansion coefficients especially at high temperatures. That is where many products on the market differ most.

Worldwide there are a vast number of different abbreviations for PCF such as PCS, HCS and HPCF.

LEONI uses a fiber with NA = 0.37, which shows especially low attenuation at 650 and 850 nm, as its standard PCF. The low attenuation makes it possible to bridge distances of up to 500 m in systems designed for PCF with 650 nm and distances of up to 4 km in systems with 850 nm.

PCF cables and cable assemblies are suitable for a wide range of applications.

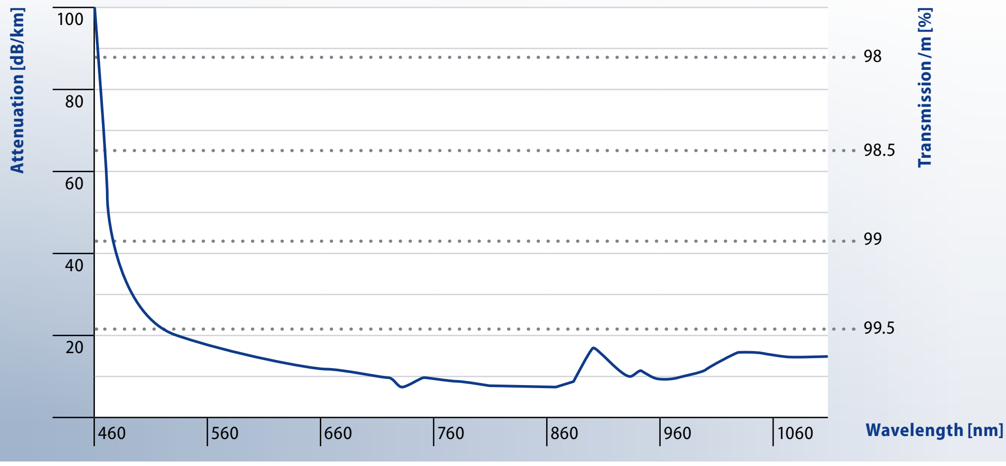
Therefore different materials and components customized for the respective application are available. These can be industrial cables for the chemically and mechanically demanding A&D environment as well as temperature and torsion resistant solutions for the control of wind turbines.

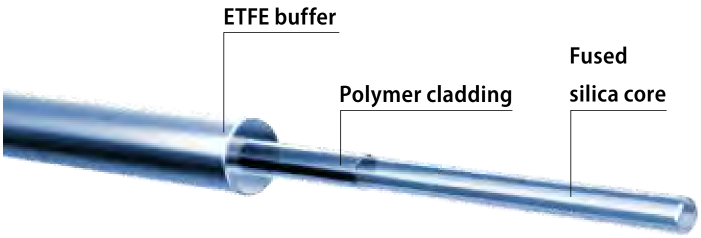
In some cases connector solutions for quick and easy field assembly can be realized.

08. PCF – Polymer Cladded Fiber

Fiber specifications

Fiber type
Standard





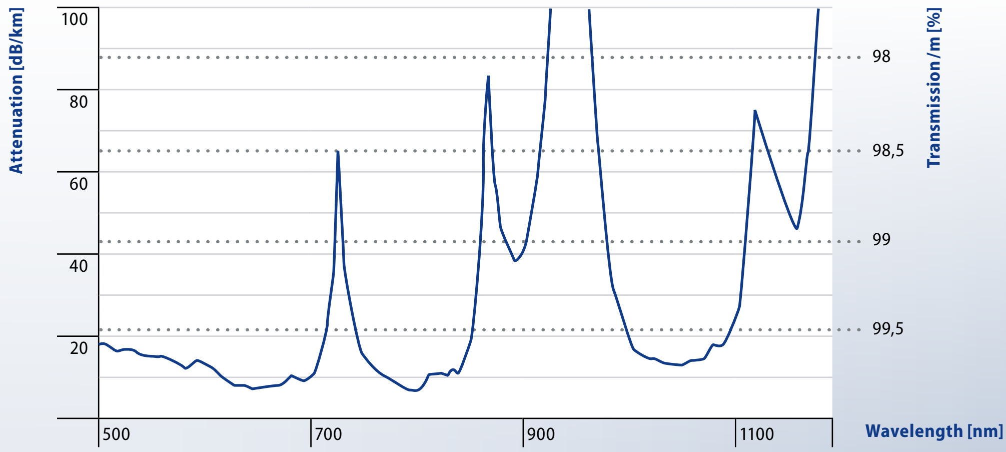
The combination of the PCF consisting of a fused silica glass core and a polymer cladding offers the optimum blend of advantages of POF and fused silica.

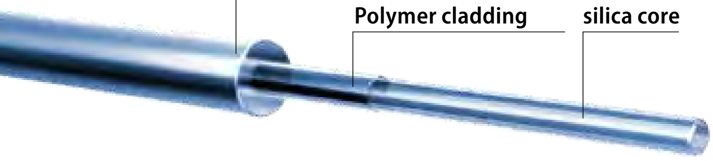
A Tefzel® layer is additionally applied as a buffer to improve the mechanical and thermal properties. The same transmitter and receiver components are used for PCF as for POF (650 nm).

	Polymer Cladded Fiber (PCF) K200/230							
Order no.	84850001T	84850002T	84850003T	84850004T	84850005T	84850006T	84850007T	84850008T
Transmision properties								
Core [µm] (±2%)	125	200	300	400	600	800	1000	1500
Cladding [µm] (±2%)	140	230	330	430	630	830	1035	1535
Attenuation at 850 nm	12	6	8	8	8	8	8	15
Bandwidth [MHz × km] at 850 nm	20	20	15	13	9	7	5	N/A
NA	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Mechanical properties								
Short-term bending radius [mm]	9	10	15	29	58	73	73	182
Long-term bending radius [mm]	15	16	24	47	94	94	118	295

FiberConnect® Graded-index PCF

Fiber type
Special





Standard PCF with 200 µm core diameter and 230 µm cladding is mainly used in industrial automation as well as in the cabling for wind-power and solar-power systems. It offers high mechanical resistance as well as cost-effective and direct connector assembly.

Transmission rates are constantly increasing in industrial settings (up to 10 Gigabit Ethernet), which means that the bandwidth of the standard PCF is no longer sufficient at 15 MHz x km.

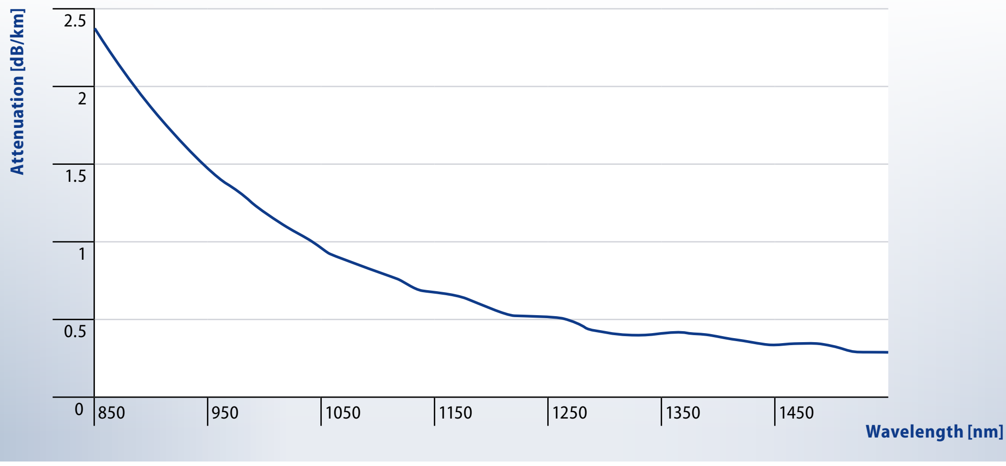
The bandwidth of optical fibers with step-index profile such as standard PCF is drastically restricted by the modal dispersion. The use of gradient-index fibers is the best solution to this problem

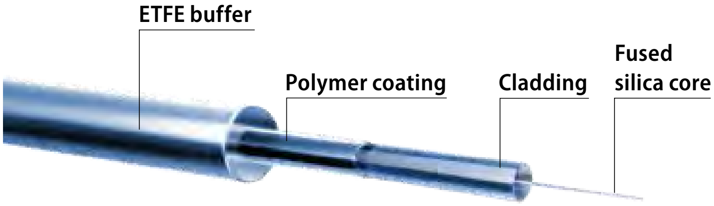
	GK 200/230
Transmision properties	
Core [µm] (±2%)	200
Cladding [µm] (±2%)	230
Buffer [µm] (±5%)	500
Attenuation at 850nm [dB/km]	< 12
Bandwidth [MHz × km] at 850 nm	> 20
NA	0.4

Please inform us of your special requirements.

FiberConnect® Fast fiber type – even faster, higher data rate

Fiber type
Fast





The cleavable multimode fiber with polymer cladding, ETFE buffer and gradient-index core is the ideal solution for communication applications that require high bandwidths in harsh industrial environments. The adapted PCF fiber design has a positive influence on the fiber properties in terms of service life, mechanical resilience as well as higher moisture and temperature resistance in comparison with standard multimode glass fibers with 62.5 µm core.

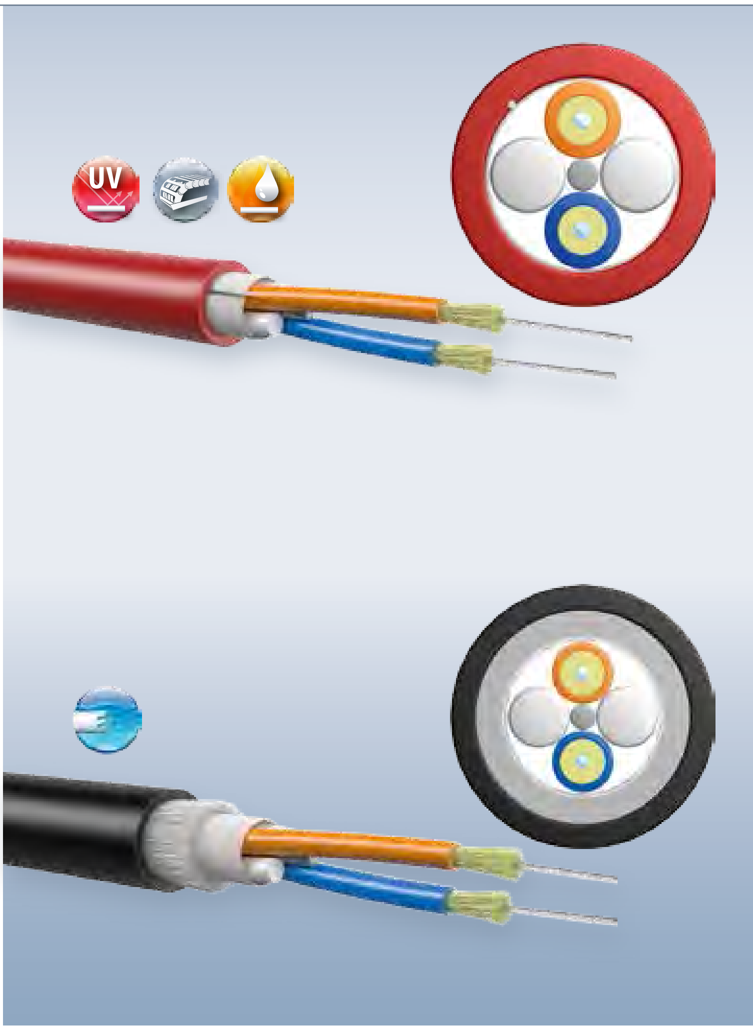
The use of a polymer coating also enables connectors to be crimped or clamped directly to the fibers for quick and efficient assembly in the field.

	GK 62.5/200/230
Order no.	84850043F
Transmision properties	
Core [µm] (±2%)	62.5
Cladding [µm] (±2%)	200
Coating [µm] (±2%)	230
Buffer (µm) (+-5%)	500
Attenuation at 850 nm	3.2
Attenuation at 1300 nm	0.9
Bandwidth [MHz × km] at 850 nm	200
Bandwidth [MHz × km] at 1300 nm	500
NA	0.275
Mechanical properties	
Short-term bending radius [mm]	10
Long-term bending radius [mm]	30

- Large bandwidth
- Faster, more efficient assembly technique compared to SM or MM fibers
- Reduced overall installation cost due to compatibility with PCF cleaving technique
- High resilience: flexible, resistant to ageing, low influence of temperature and humidity
- Compatible transmitter elements: LEDs, Laser diodes, VCSELs, RCLEDs

FiberConnect® PCF cables

for direct connector assembly



A-V(ZN)Y11Y 2GK62.5/200/230

Order no.	84Q04700L333
Code no.	N/A
Application	■ in harsh industrial environments ■ abrasion-resistant PU jacket ■ splittable outdoor cable for fixed indoor and outdoor installation in cable ducts and conduits as well as on trays, ■ suitable for drag chains
Assembly	direct connector assembly
Length	2000 m

AT-VQ(ZN)HB2Y 2GK62.5/200/230

Order no.	84Q02100L000
Code no.	N/A
Application	splittable outdoor cable for fixed installation
Longitudinal watertightness	per EN 187 000, test procedure 605 method B (1 m cable, 1 m water column, 24 hours)
Assembly	direct connector assembly
Length	2000 m

PCF cable specifications			A-V(ZN)Y11Y 2GK62.5/200/230	AT-VQ(ZN)HB2Y 2GK62.5/200/230
Order no.			84Q04700L333	84Q02100L000
Composition	Inner jacket material		PVC	FRNC
	Outer jacket material		PUR	PE
	No. of PCF elements (62.5/200/230)		2	2
	No. of copper elements		0	0
	Buffered fiber Ø [mm]		2.2	2.2
	Outer Ø [mm]		7.4	9.4
Mechanical properties	Min. bending radius [mm]	during installation	105	140
		long-term	75	95
	Max. pull force [N]	short-term	800	3000
		long-term	200	1500
	Approx. cable weight [kg/km]		45	70
Thermal properties	Operating temperature [°C]		−40 to +85	−20 to +70
Attenuation (at room temperature)	[dB/km] at 850 nm		< 3.2	< 3.2
	[dB/km] at 1300 nm		< 0.9	< 0.9

FiberConnect® PCF cables

for direct connector assembly

I-V(ZN)Y 1K200/230

Order no.	84P00300T222
Code no.	72
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	2000 m

A-V(ZN)11Y 1K200/230

Order no.	84P00600T000
Code no.	74
Application	in harsh industrial environments, for flexible installation indoors and outdoors
Assembly	direct connector assembly
Length	2000 m

V-Y 1K200/230

Order no.	84P00800T000
Code no.	N/A
Application	for flexible applications in areas with low dynamic stress
Assembly	direct connector assembly
Length	2000 m

I-V(ZN)Y 2×1K200/230

Order no.	84Q00300T222
Code no.	61
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	2000 m

I-V(ZN)H 2×1K200/230

Order no.	84Q01000T222
Code no.	66
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	2000 m

PCF

Info

PCF cables are available for both indoor and outdoor use. We offer many different designs to meet the large variety of applications in the industrial environment.

Special requirements in terms of flexibility, resistance to oil, resistance to UV light, freedom from halogen or flame retardancy are satisfied by selecting suitable materials.

PCF cable specifications			I-V(ZN)Y 1K200/230	A-V(ZN)11Y 1K200/230	V-Y 1K200/230	I-V(ZN)Y 2×1K200/230	I-V(ZN)H 2×1K200/230
Order no.			84P00300T222	84P00600T000	84P00800T000	84Q00300T222	84Q01000T222
Composition	Inner jacket material		–	–	–	–	–
	Outer jacket material		PVC	PUR	PVC	PVC	FRNC
	No. of PCF elements (200/230)		1	1	1	2	2
	Core Ø [mm]		–	–	–	–	–
	Outer Ø [mm]		2.2	3.0	2.2	2.2 × 4.5	2.2 × 4.5
Mechanical properties	Min. bending radius [mm]	during installation	60	60	50	60*	60*
		long-term	30	30	30	30	30
	Max. pull force [N]	short-term	300	800	10	300	300
		long-term	100	400	10	100	100
	Approx. cable weight [kg/km]		5	6.5	5.5	10	11
Thermal properties	Operating temperature [°C]		–20 to +70	–20 to +70	–20 to +70	–20 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 10	< 10	< 10	< 10	< 10
	[dB/km] at 850 nm (LED)		< 8	< 8	< 8	< 8	< 8

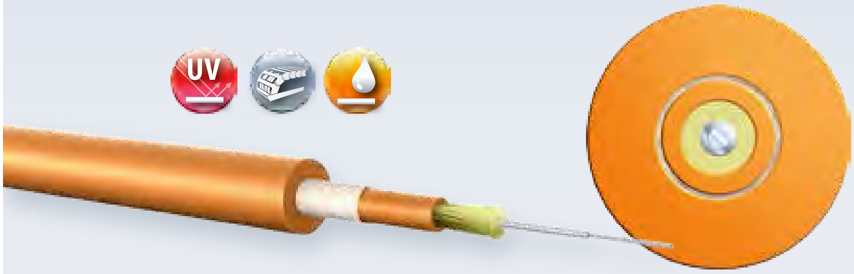
* over flat side

Fiber**Connect**® **PCF cables**

for direct connector assembly

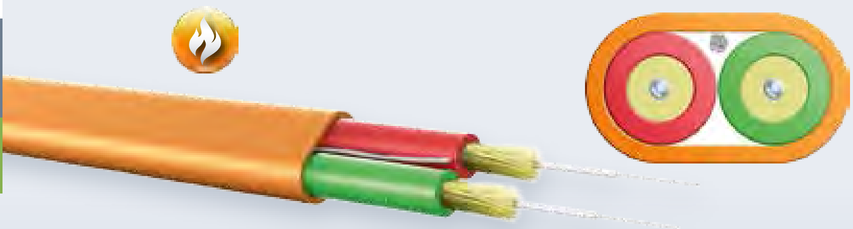
I-V(ZN)YY 1K200/230

Order no.	84P00900T222
Code no.	71
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	2000 m



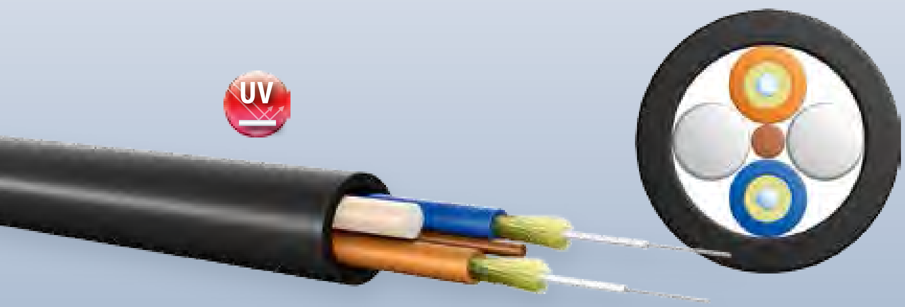
I-V(ZN)Y11Y 1K200/230

Order no.	84P00700T222
Code no.	N/A
Application	■ for application in harsh industrial environments ■ for flexible application in areas with low dynamic stress ■ for installation in cable ducts, conduits and on trays ■ suitable for drag chains
Assembly	direct connector assembly
Length	2000 m



I-V(ZN)HH 2×1K200/230

Order no.	84Q00700T222
Code no.	64
Application	flexible applications with low dynamic stress
Assembly	direct connector assembly
Length	2000 m

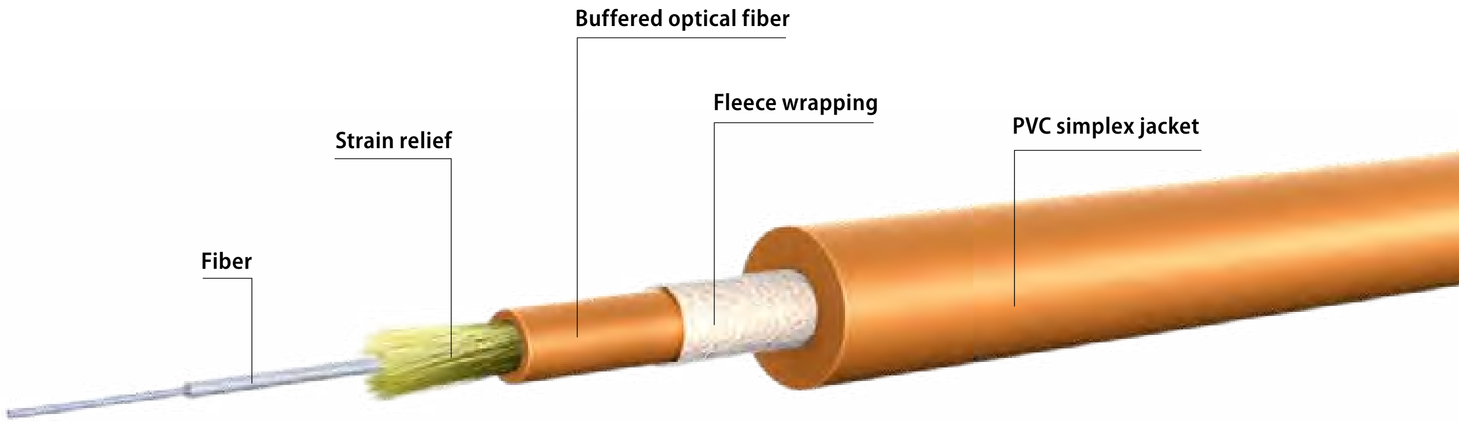


I-V(ZN)H2Y 2K200/230

Order no.	84Q00400T000
Code no.	63
Application	splittable cable for fixed installation indoors and outdoors
Assembly	direct connector assembly
Length	2000 m

PCF cable specifications			I-V(ZN)YY 1K200/230	I-V(ZN)Y11Y 1K200/230	I-V(ZN)HH 2×1K200/230	I-V(ZN)H2Y 2K200/230
Order no.			84P00900T222	84P00700T222	84Q00700T222	84Q00400T000
Composition	Inner jacket material		PVC	PVC	FRNC	FRNC
	Outer jacket material		PVC	PUR	FRNC	PE
	No. of PCF elements (200/230)		1	1	2	2
	No. of copper elements		–	–	–	–
	Core Ø [mm]		2.2	2.2	2.9	2.2
	Outer Ø [mm]		5.0	5.0	3.9 × 6.8	7.0
Mechanical properties	Min. bending radius [mm]	during installation	60	40	50*	70
		long-term	40	60	30	50
	Max. pull force [N]	short-term	300	300	800	800
		long-term	100	100	200	200
	Approx. cable weight [kg/km]		28	25	31	38
Thermal properties	Operating temperature [°C]		–20 to +70	–20 to +85	–20 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 10	< 10	< 10	< 10
	[dB/km] at 850 nm (LED)		< 8	< 8	< 8	< 8

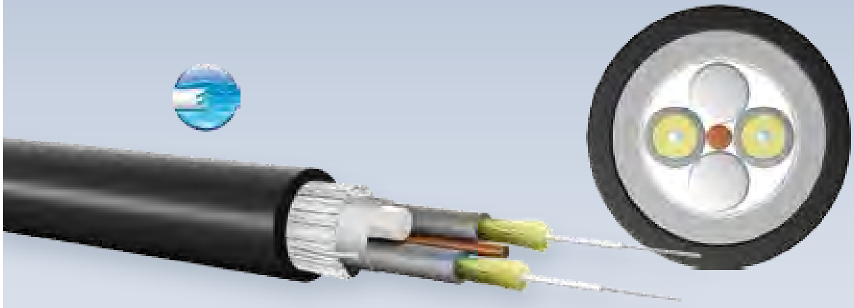
* over flat side



Order no.: 84P00700T222

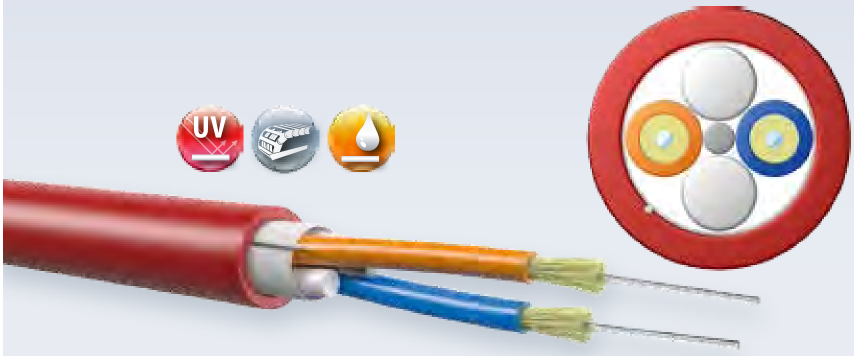
FiberConnect® PCF cables

for direct connector assembly



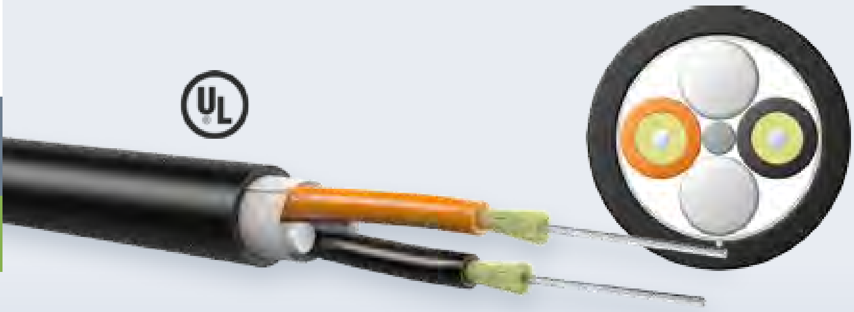
AT-VQ(ZN)HB2Y 2K200/230

Order no.	84Q00200T000
Code no.	75
Application	splittable cable for fixed installation, longitudinally watertight
Assembly	direct connector assembly
Length	2000 m



AT-V(ZN)Y11Y 2K200/230

Order no.	84Q04700T333
Code no.	D6
Application	■ abrasion-resistant PU jacket ■ suitable for drag chains ■ for fixed installation indoors and outdoors
Assembly	direct connector assembly
Length	2000 m



I-V(ZN)YY 2K200/230

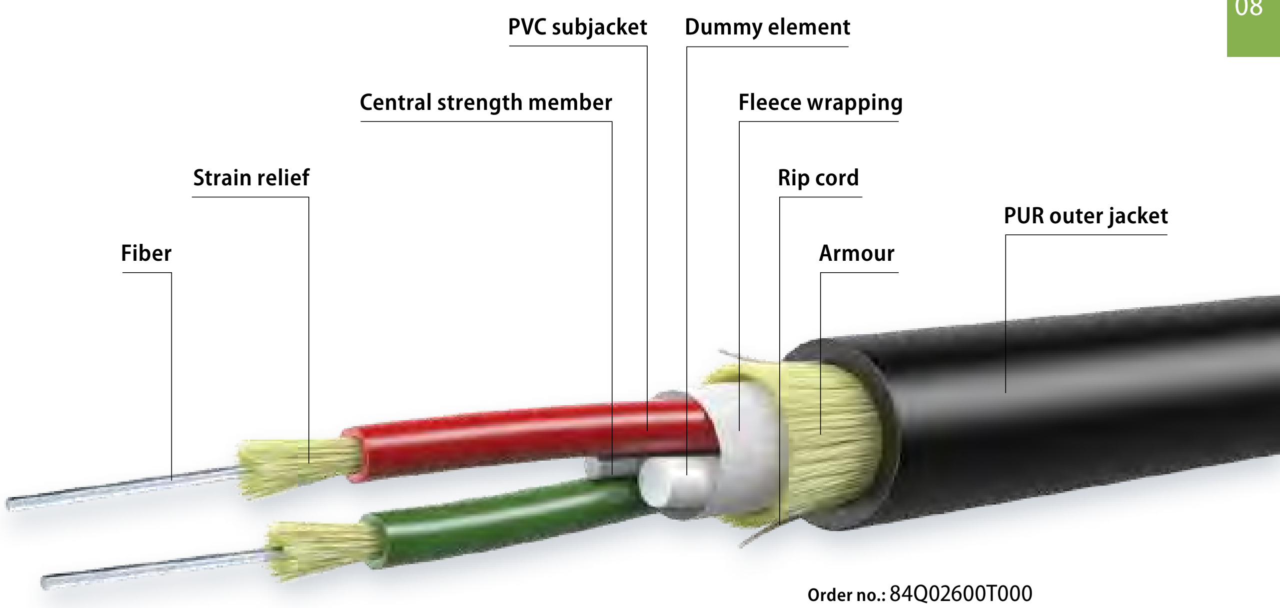
Order no.	84Q02300T000ZUL00
Code no.	6H
Application	Indoor cable for fixed installation in cable ducts and conduit as well as for shunting purposes ➔ UL listed
Assembly	direct connector assembly
Length	2000 m

AT-V(ZN)Y(ZN)11Y 2K200/230

Order no.	84Q02600T000
Code no.	N/A
Application	■ for flexible installation in conduits, ducts and on trays ■ suitable for drag chains
Assembly	direct connector assembly
Length	2000 m

PCF cable specifications			AT-VQ(ZN)HB2Y 2K200/230	AT-V(ZN)Y11Y 2K200/230	I-V(ZN)YY 2K200/230	AT-V(ZN)Y(ZN)11Y 2K200/230
Order no.			84Q00200T000	84Q04700T333	84Q02300T000ZUL00	84Q02600T000
Composition	Inner jacket material		FRNC	PVC	PVC	PVC
	Outer jacket material		PE	PUR	PVC	PUR
	No. of PCF elements (200/230)		2	2	2	2
	Core Ø [mm]		2.9*	2.2	2.2	2.2
	Outer Ø [mm]		10.5	7.4	7.2	8.8
Mechanical properties	Min. bending radius [mm]	during installation	150	110	30	30
		long-term	200	70	50	50
	Max. pull force [N]	short-term	1500	800	800	2000
		long-term	500	200	100	800
	Approx. cable weight [kg/km]		90	45	45	85
Thermal properties	Operating temperature [°C]		–20 to +70	–40 to +85	–40 to +90	–25 to +75
Attenuation	[dB/km] at 650 nm (Laser)		< 10	< 10	< 10	< 10
	[dB/km] at 850 nm (LED)		< 8	< 8	< 8	< 8

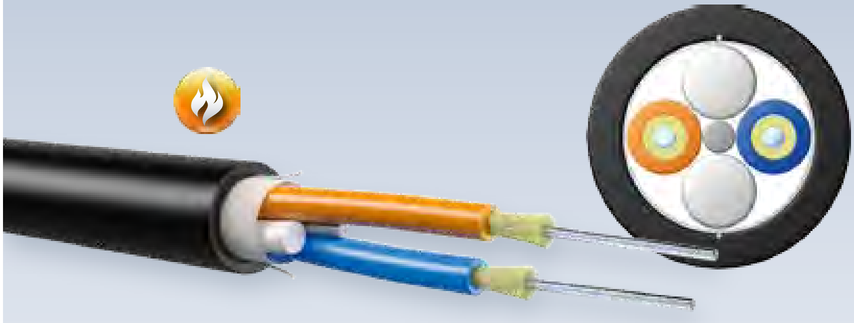
* * also in Ø 2.2 mm special size



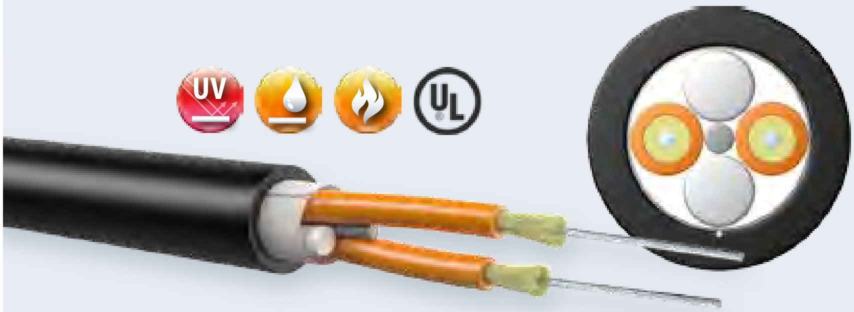
Order no.: 84Q02600T000

FiberConnect® PCF cables

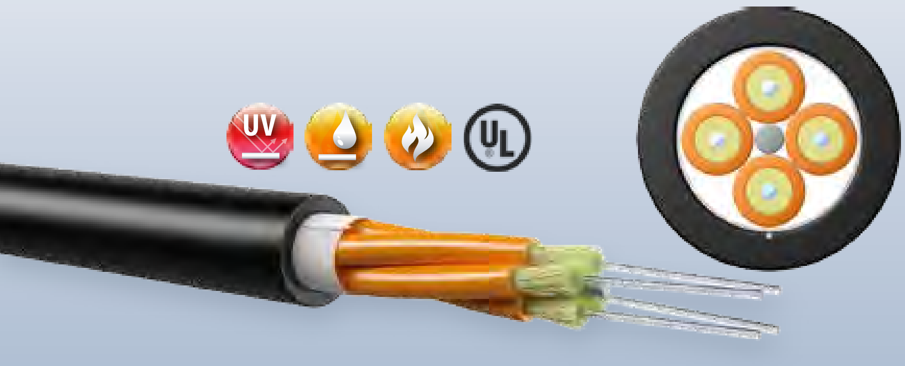
for direct connector assembly



AT-V(ZN)HH 2K400/430	
Order no.	84Q05400Z000
Code no.	D6
Fiber type	PCF 400/430µm
Application	■ for flexible application in areas with low dynamic stress ■ splittable outdoor cable for fixed installation ■ indoors and outdoors in cable ducts and conduits as well as on trays
Assembly	direct connector assembly
Length	2000 m

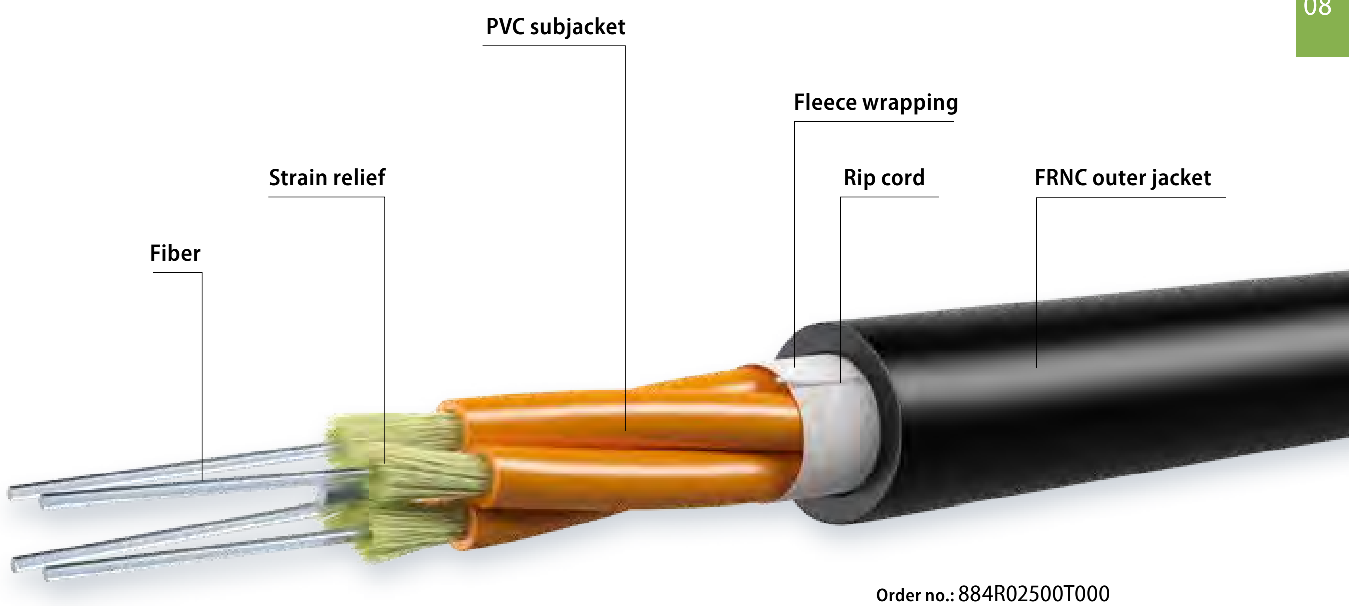


AT-V(ZN)HH 2K200/230	
Order no.	84Q05800T000
Code no.	N/A
Application	■ in harsh industrial environments ■ splittable breakout cable for fixed installation indoors and outdoors in cable ducts and conduits as well on trays ■ specially developed for data transmission between cable cabinets in wind power plants
Length	2000 m



AT-V(ZN)HH 4K200/230	
Order no.	84R02500T000
Code no.	N/A
Application	■ in harsh industrial environments ■ splittable breakout cable for fixed installation indoors and outdoors in cable ducts and conduits as well as on trays ■ specially developed for data transmission between cable cabinets in wind power plants
Assembly	direct connector assembly
Length	2000 m

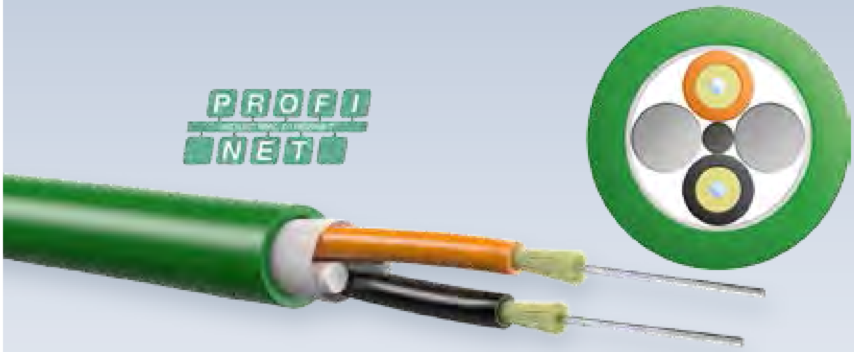
PCF cable specifications			AT-V(ZN)HH 2K400/430	AT-V(ZN)HH 2K200/230	AT-V(ZN)HH 4K200/230
Order no.			84Q05400Z000	84Q05800T000	84R02500T000
Composition	Inner jacket material		FRNC	FRNC	FRNC
	Outer jacket material		FRNC	FRNC	FRNC
	No. of PCF elements (200/230)		2	2	4
	Core Ø [mm]		2.5	2.2	2.2
	Outer Ø [mm]		8.9	7.8	7.8
Mechanical properties	Min. bending radius [mm]	during installation	90	78	78
		long-term	135	117	117
	Max. pull force [N]	short-term	800	800	800
		long-term	200	–	–
	Approx. cable weight [kg/km]		75	63	72
Thermal properties	Operating temperature [°C]		–20 to +70	–40 to +70	–40 to +70
Attenuation	[dB/km] at 650 nm (Laser)		–	< 10	< 10
	[dB/km] at 850 nm (LED)		< 8	< 8	< 8



Order no.: 884R02500T000

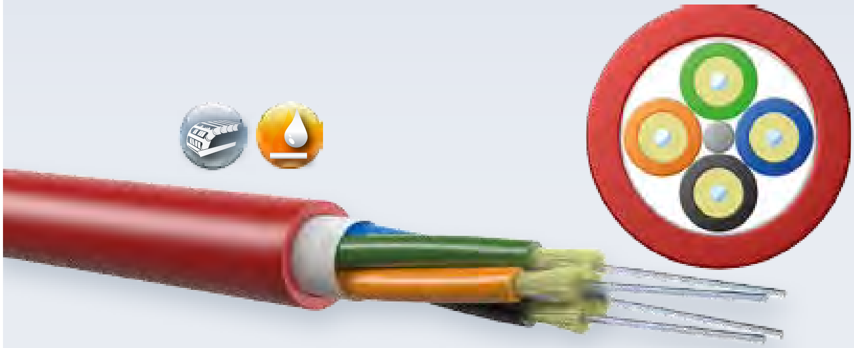
Fiber**Connect**® PCF cables

for direct connector assembly



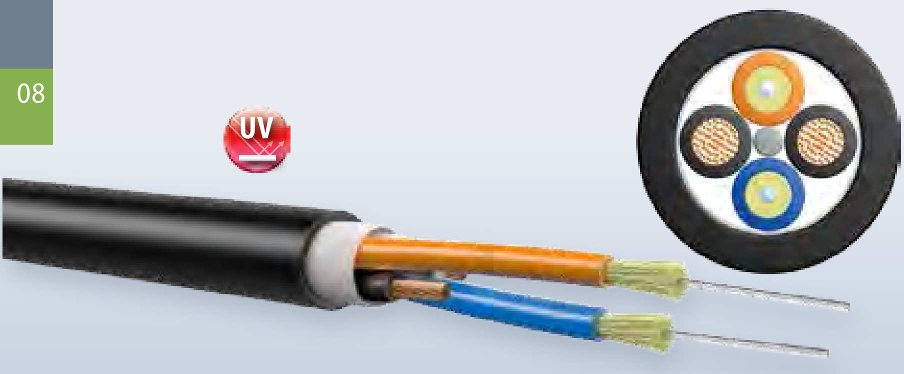
I-V(ZN)YY 2K200/230

Order no.	84Q05200T666
Code no.	N/A
Application	▪ for fixed installation indoors and outdoors ▪ PROFINET type B
Assembly	direct connector assembly
Length	2000 m



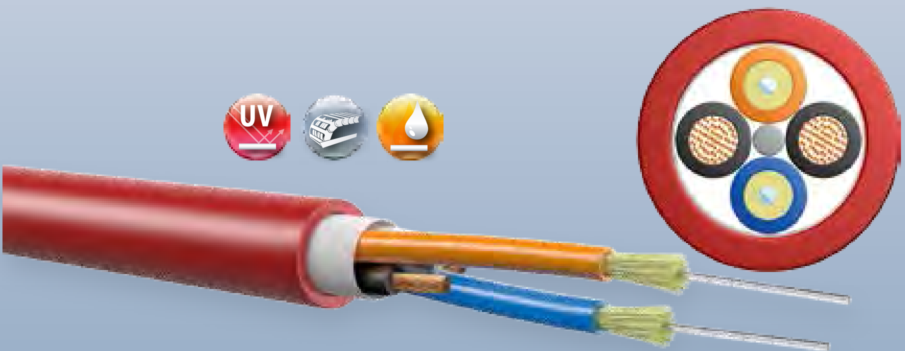
AT-V(ZN)Y11Y 4K200/230

Order no.	84R02000T333
Code no.	DE
Application	▪ in harsh industrial environments ▪ splittable breakout cable for fixed installation indoors and outdoors in cable ducts and conduits as well as on trays ▪ suitable for drag chains
Assembly	direct connector assembly
Length	2000 m



AT-V(ZN)Y2Y 2K200/230+2×1qmm

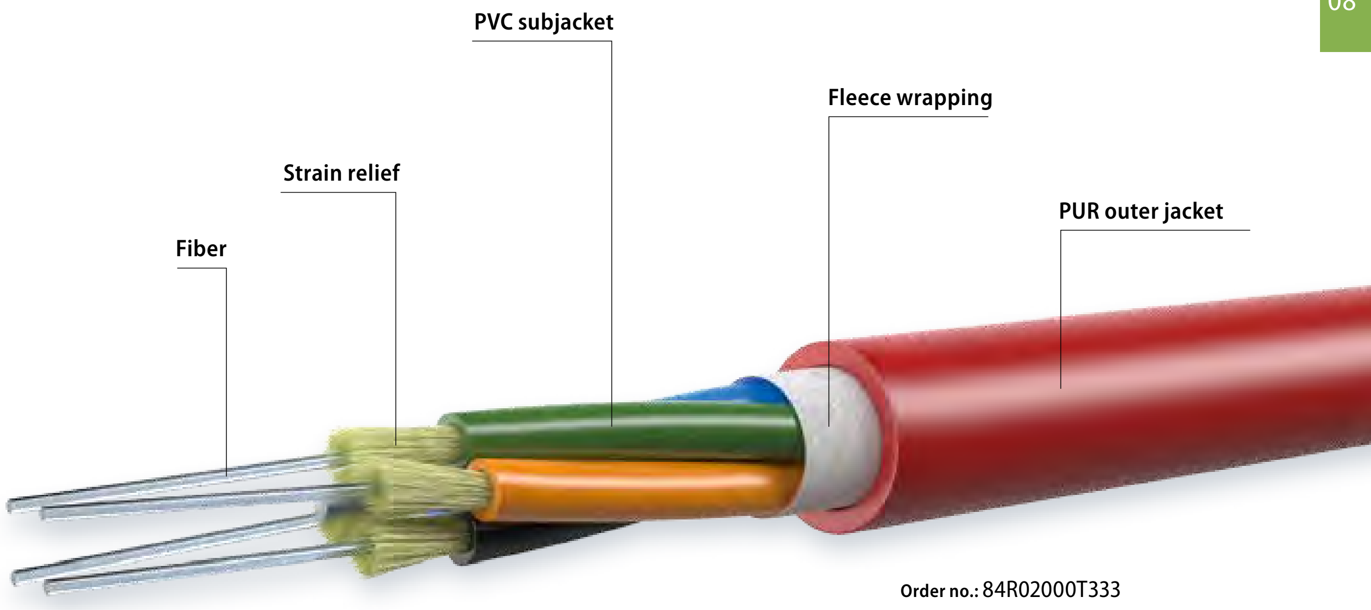
Order no.	84Q05900T000
Code no.	N/A
Application	for fixed installation indoors and outdoors in cable ducts and conduits as well as on trays
Assembly	direct connector assembly
Length	2000 m



I-V(ZN)Y11Y 2K200/230+2×1qmm

Order no.	84Q03000T333
Code no.	62
Application	splittable indoor cable for harsh industrial environments, fixed installation, suitable for drag chains
Assembly	direct connector assembly
Length	2000 m

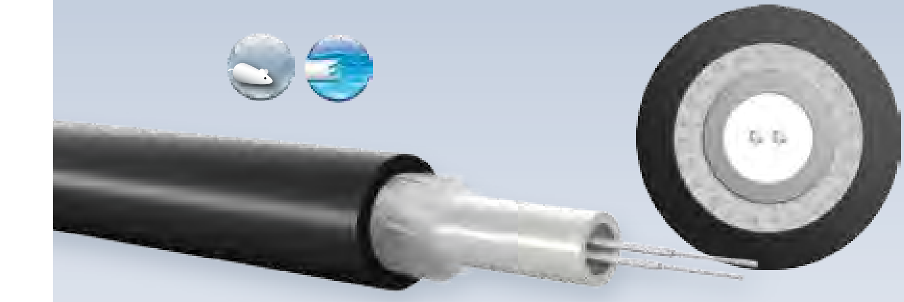
PCF cable specifications			I-V(ZN)YY 2K200/230	AT-V(ZN)Y11Y 4K200/230	AT-V(ZN)Y2Y K200/230+ 2×1qmm	I-V(ZN)Y11Y 2K200/230+ 2×1qmm
Order no.			84Q05200T666	84R02000T333	84Q05900T000	84Q03000T333
Composition	Inner jacket material		PVC	PVC	PVC	PVC
	Outer jacket material		PVC	PUR	PE	PUR
	No. of PCF elements (200/230)		2	4	2	2
	No. of copper elements		—	—	2	2
	Core Ø [mm]		2.2	2.2	2.2	2.2
	Outer Ø [mm]		7.2	7.4	8.0	7.6
Mechanical properties	Min. bending radius [mm]	during installation	30	70	80	70
		long-term	50	110	120	50
	Max. pull force [N]	short-term	800	800	400	800
		long-term	100	200	100	200
	Approx. cable weight [kg/km]		45	45	65	65
Thermal properties	Operating temperature [°C]		−25 to +75	−40 to +85	−20 to +70	−20 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 10	< 10	< 10	< 10
	[dB/km] at 850 nm (LED)		< 8	< 8	< 8	< 8



Order no.: 84R02000T333

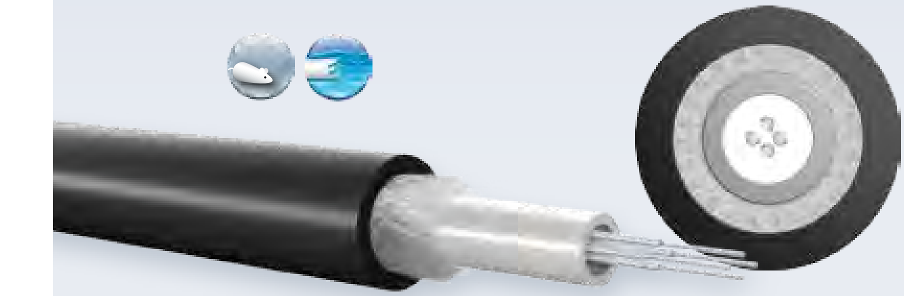
FiberConnect® PCF cables

for direct connector assembly



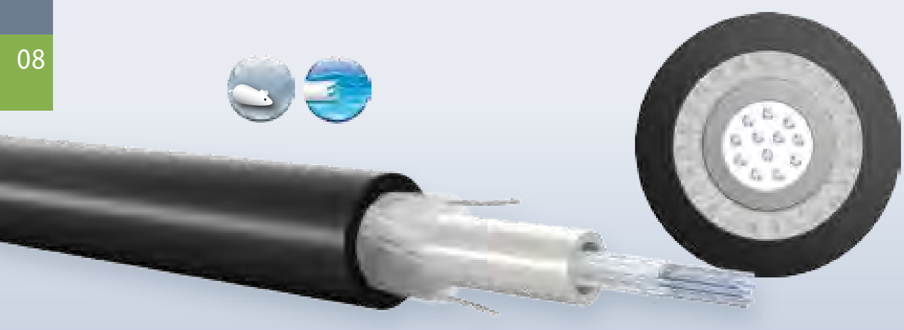
A-DQ(ZN)B2Y 2K200/230

Order no.	84S00400T000
Code no.	76
Application	■ longitudinally watertight cable with non-metallic rodent protection ■ for fixed outdoor installation ■ for running directly in the ground
Length	2000 m



A-DQ(ZN)B2Y 4K200/230

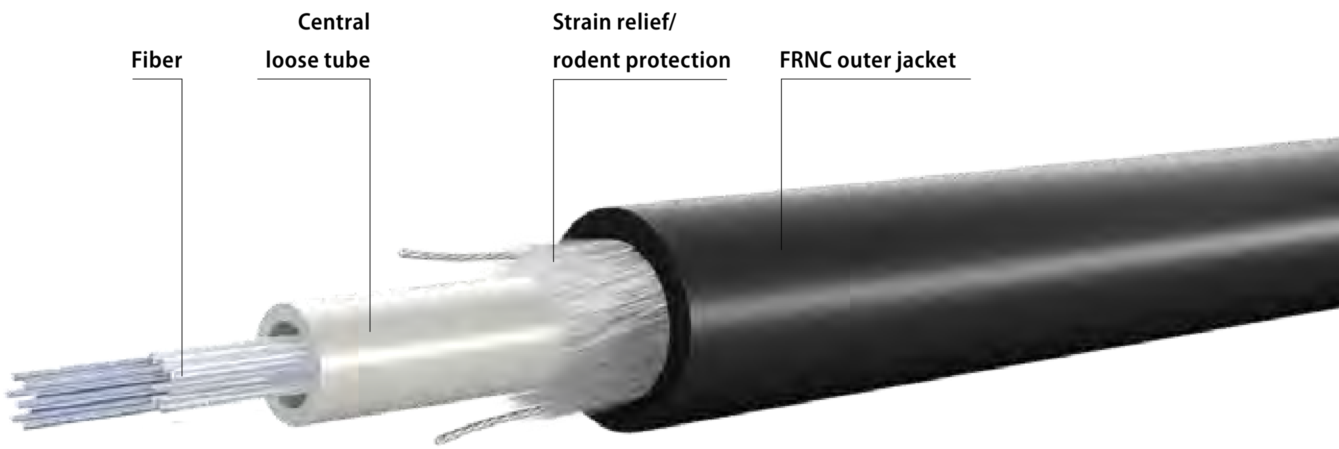
Order no.	84S00800T000
Code no.	D7
Application	■ longitudinally watertight cable with non-metallic rodent protection ■ for fixed outdoor installation ■ for running directly in the ground
Assembly	direct connector assembly
Length	2000 m



A-DQ(ZN)BH 9K200/230

Order no.	84S00100T000
Code no.	79
Application	■ longitudinally watertight cable with non-metallic rodent protection ■ for running directly in the ground ■ for fixed indoor and outdoor installation
Length	2000 m

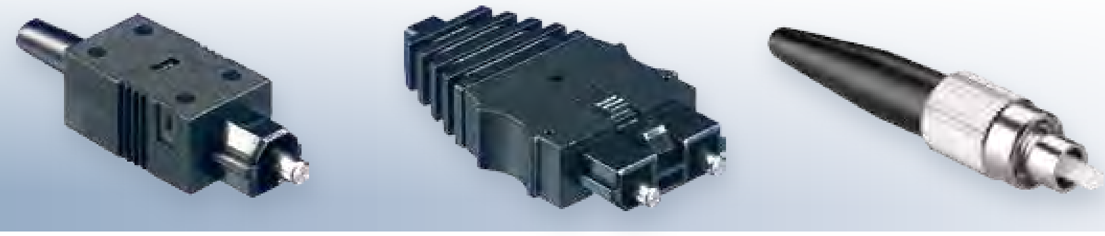
PCF cable specifications			I-VY 6K200/230	A-DQ(ZN)B2Y 2K200/230	A-DQ(ZN)B2Y 4K200/230	A-DQ(ZN)BH 9K200/230
Order no.			84R00500T000	84S00400T000	84S00800T000	84S00100T000
Composition	Inner jacket material		PVC	–	–	–
	Outer jacket material		–	PE	PE	FRNC
	No. of PCF elements (200/230)		6	2	4	9
	Core Ø [mm]		2.2	3.5	4.5	4.5
	Outer Ø [mm]		–	7.5	8.5	8.5
Mechanical properties	Min. bending radius [mm]	during installation	70	150	170	170
		long-term	100	110	130	130
	Max. pull force [N]	short-term	–	1500	1500	1500
		long-term	–	1200	1200	1200
	Approx. cable weight [kg/km]		40	47	76	82
Thermal properties	Operating temperature [°C]		–20 to +70	–20 to +70	–20 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (Laser)		< 10	< 10	< 10	< 10
	[dB/km] at 850 nm (LED)		< 8	< 8	< 8	< 8



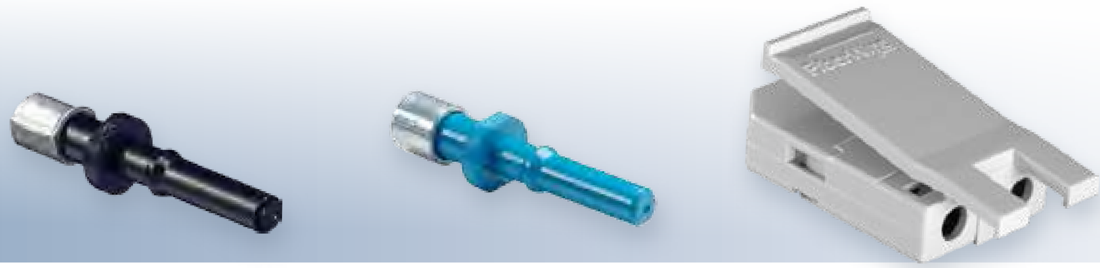
Order no.: 84S00100T000

Fiber**Connect**® PCF connectors

with metal, ceramic or plastic ferrules



	FO5 connector PCF	FO7 connector PCF	FCPC connector PCF
Order no.	SF05-SC0-08-0010	SF07-DC0-08-0010	SFCP-SK0-04-0030
Compatibility	TOCP101Q, TOCP151Q, CF-1571	TOCP201Q, CF-2071	–
Fiber Ø	230 µm	230 µm	230 µm
Cable Ø	2.2 mm	2.2 mm	2.2 mm
Assembly	crimping/cleaving	crimping/cleaving	crimping/gluing/polishing
Ferrule	metal	metal	ceramic
Reference cable	KF05-F05 72050cm for attenuation measurement 0.5 m	KF07-F07 61050cm for attenuation measurement 0.5 m	KFCP-FCP 72050cm for attenuation measurement 0.5 m
Features	incl. crimping sleeve, black boot and dust cap	incl. crimping sleeve, black boot and dust cap	incl. crimping sleeve, black boot and dust cap
Assembly	K4	K4	on request



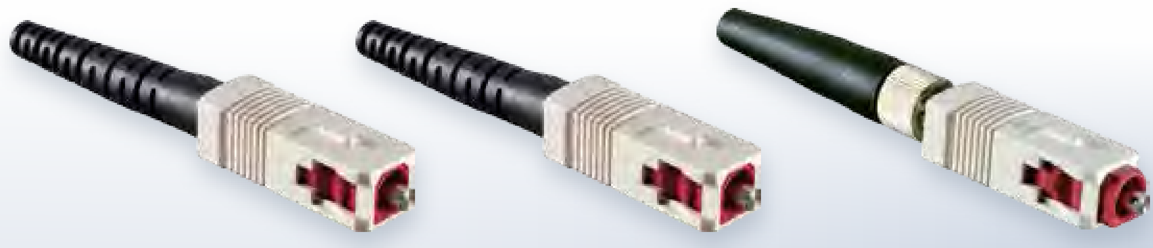
	HP connector PCF	
Order no.	SXHP-SC0-32-0010*	SXHP-SC0-32-0020
Compatibility	HFBR 4521, V-PIN 2005	HFBR 4521, V-PIN 2005
Fiber Ø	230 µm	230 µm
Cable Ø	2.2 mm	2.2 mm
Assembly	crimping/cleaving	crimping/cleaving
Ferrule	plastic	plastic
Reference cable	KHPS-HPS 72050cm for attenuation measurement 0.5 m	KHPS-HPS 72050cm for attenuation measurement 0.5 m
Features	incl. crimping sleeve and dust cap	incl. crimping sleeve and dust cap
Assembly	K5	on request

HP connector housing PCF
SGEH-DC0-10-0010
BP 04703
–
2.2 mm

*** special note:**

The HP connectors with order no. SXHP-SC0-32-0010 must be ordered seperately.

PCF



	SC connector PCF		
Order no.	SXSC-SK0-02-0010	SXSC-SK0-02-0020	SXSC-SW0-02-0010
Fiber Ø	230 µm	230 µm	230 µm
Cable Ø	3.0 mm	2.2 mm	2.2 mm
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	clamping/cleaving
Ferrule	metal	metal	metal
Reference cable	KXSC-XSC 72050cm for attenuation measurement 0.5 m	KXSC-XSC 72050cm for attenuation measurement 0.5 m	KXSC-XSC 72050cm for attenuation measurement 0.5 m
Features	incl. crimping sleeve, black boot and dust cap	incl. crimping sleeve, black boot and dust cap	inkl. black boot and dust cap
Assembly	on request	on request	on request

	Fiber end sleeves PCF	
Order no.	SENH-SK0-02-0010	SENH-SK0-02-0020
Fiber Ø	230 µm	230 µm
Cable Ø	2.2 mm	2.2 mm
Assembly	gluing/polishing	gluing/polishing
Ferrule	metal	plastic
Reference cable	–	–
Features	only connector, suitable for SFH diodes	only connector, suitable for SFH diodes
Assemblyieren	on request	on request

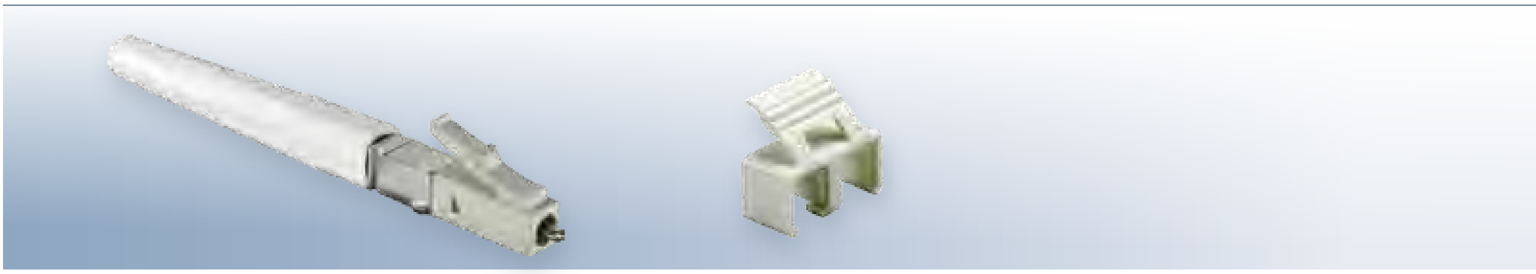
Connectors for PCF differ not only in terms of their construction, but also in the technology used to attach to the cable (crimping, gluing or clamping) and in the technology used to process the end face. The focus here is on cleaving and grinding or polishing.

08

PCF

FiberConnect® PCF connector

with metal, ceramic or plastic ferrules



	LC connector PCF (small form factor connector)	LC duplex clamp PCF
Order no.	SFER-SK0-56-0050	SKLA-DU0-01-0010
Fiber Ø	230 µm	–
Cable Ø	2.0 – 3.0 mm	–
Assembly	crimping/gluing/polishing	clipping
Ferrule	ceramic	
Reference cable	KXLC-XLC 72050cm for attenuation measurement 0.5 m	
Features	only connector body	
Assembly	on request	

08

	SCRJ connector duplex IP20		SCRJ connector duplex IP67
Order no.	SSCR-DK0-02-0030	SSCR-DW0-02-0010	SSCR-DK0-02-0020
Fiber Ø	230 µm	230 µm	230 µm
Cable Ø	2.2 mm	2.2 mm	3.0 mm
Assembly	crimping/gluing/polishing	clamping/cleaving	crimping/gluing/polishing
Ferrule	metal	metal	metal
Reference cable	KSCR-SCR 61050cm for attenuation measurement 0.5 m	KSCR-SCR 61050cm for attenuation measurement 0.5 m	KSCR-SCR 61050cm for attenuation measurement 0.5 m
Features	incl. black boot and dust cap	incl. black boot and dust cap	incl. grey boot and dust cap
Assembly	on request	on request	on request

	FSMA connector PCF		
Order no.	SSMA-SK0-01-0010	SSMA-SK0-01-0020	SSMA-SW0-02-0010
Fiber Ø	230 µm	230 µm	230 µm
Cable Ø	2.2 mm	3.0 mm	2.2 mm
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	clamping/cleaving
Ferrule	metal	metal	metal
Reference cable	KSMA-SMA 72050cm for attenuation measurement 0.5 m	KSMA-SMA 72050cm for attenuation measurement 0.5 m	KSMA-SMA 72050cm for attenuation measurement 0.5 m
Features	incl. crimping sleeve, black boot and dust cap	incl. crimping sleeve, black boot and dust cap	incl. crimping sleeve, black boot and dust cap
Assembly	on request	on request	K1

	FSMA connector PCF		
Order no.	SSMA-SW0-02-0020	SSMA-SK0-04-0020	SSMA-SK0-04-0030
Fiber Ø	230 µm	230 µm	230 µm
Cable Ø	3.0 mm	3.0 mm	2.2 mm
Assembly	clamping/cleaving	crimping/gluing/polishing	crimping/gluing/polishing
Ferrule	metal	ceramic	ceramic
Reference cable	KSMA-SMA 72050cm for attenuation measurement 0.5 m	KSMA-SMA 72050cm for attenuation measurement 0.5 m	KSMA-SMA 72050cm for attenuation measurement 0.5 m
Features	incl. black boot and dust cap	incl. black boot and dust cap	incl. black boot and dust cap
Assembly	K1	on request	on request

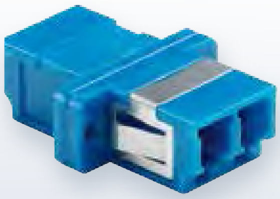
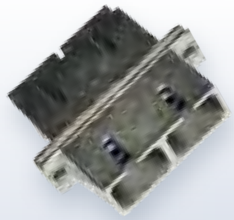
Fiber**Connect**® PCF connector

with metal, ceramic or plastic ferrules

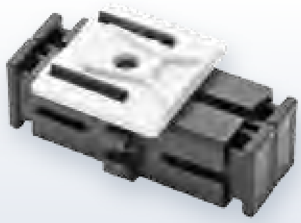
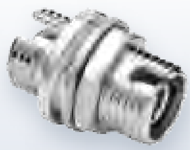
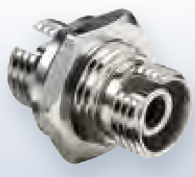
	ST connector (BFOC) PCF		
Order no.	SXST-SK0-01-0020	SXST-SK0-01-0030	SXST-SK0-04-0030
Fiber Ø	230 µm	230 µm	230 µm
Cable Ø	2.2 mm	3.0 mm	3.0 mm
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing
Ferrule	metal	metal	ceramic
Reference cable	KXST-XST 72050cm for attenuation measurement 0.5 m	KXST-XST 72050cm for attenuation measurement 0.5 m	KXST-XST 72050cm for attenuation measurement 0.5 m
Features	incl. crimping sleeve, black boot and dust cap	incl. crimping sleeve, black boot and dust cap	incl. crimping sleeve, black boot and dust cap
Assembly	on request	on request	on request

	ST connector (BFOC) PCF		
Order no.	SXST-SW0-02-0010	SXST-SW0-02-0020	SXST-SW0-02-0030
Fiber Ø	230 µm	230 µm	230 µm
Cable Ø	2.2 mm	2.5 mm	3.0 mm
Assembly	clamping/cleaving	clamping/cleaving	clamping/cleaving
Ferrule	metal	metal	metal
Reference cable	KXST-XST 72050cm for attenuation measurement 0.5 m	KXST-XST 72050cm for attenuation measurement 0.5 m	KXST-XST 72050cm for attenuation measurement 0.5 m
Features	inkl. black boot and dust cap	inkl. black boot and dust cap	inkl. black boot and dust cap
Assembly	K2	K2	K2

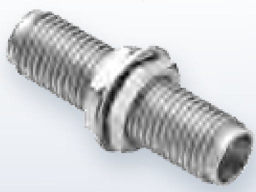
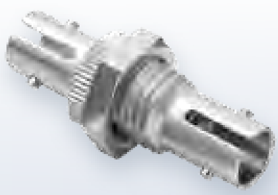
FiberConnect® PCF adapters


	Adapter for LC duplex PCF	Adapter for SC duplex PCF	Adapter for HP PCF
Order no.	NSKUP-2XXLC-0010	NSKUP-2XXSC-0010	SKUP-2XHPS-0010
Compatibility	–	–	AP 04707
Fiber Ø	230 µm	230 µm	230 µm
Housing	plastic with ceramic insert	metal with ceramic insert	plastic with metal insert

	Adapter for SCRJ PCF	Adapter for FCPC PCF	
Order no.	SKUP-2XSCR-0010	SKUP-2XFCP-0010	SKUP-2XFCP-0020
Fiber Ø	230 µm	230 µm	230 µm
Housing	plastic with ceramic insert	metal with metal insert	metal with ceramic insert

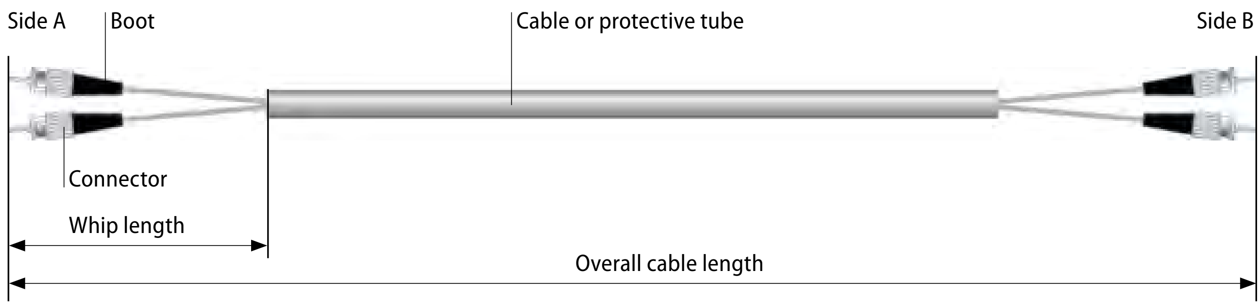
	Adapter for FSMA PCF	Adapter for ST PCF
Order no.	SKUP-2XSMA-0010	SKUP-2XXST-0010
Fiber Ø	230 µm	230 µm
Housing	metal without seperate insert	metal without seperate insert

Pre-assembled PCF cables

Description of the structure of pre-assembled indoor and outdoor PCF cables

Description of the structure of pre-assembled indoor PCF cables

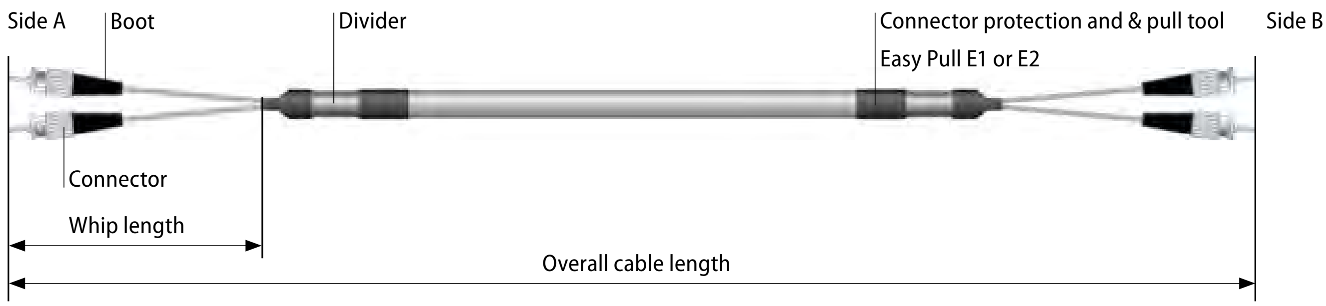
- Standard whip length 20 ±4 cm
- Overall length tolerance ±2 %



Description of the structure of pre-assembled outdoor PCF cables

- Whip length according to customer's wishes
- Overall length tolerances ±2

Direct connector assembly in the field is much more complex with gel-filled outdoor cables than with indoor cables. Our Easy Pull installation system therefore includes as standard fully tested cable ends with pre-assembled connectors for multi-fiber loose tubes with up to 32 fibers.



The production of fibers and cables in LEONI's own facilities and their careful assembly under laboratory conditions ensure superior properties and maximum reliability. In addition to standard products, we offer a range of special product functionalities and execute customer-specific assembly.

Service features

- All fiber and cable types (including hybrid cables)
- All connector types
- Every attenuation grade for different customer requirements
- Every length, even for small order sizes
- Customer-specific assembly
- Customer-specific cable printing
- Additional selective printing of the cable jacket during the process of cutting to length.

Quality assurance

The optical attenuation for POF is defined according to IEC60793-1-40 B for cleave connectors and in IEC 61300-3-4 C for glue connectors. The result is shown on the label.

Order number scheme

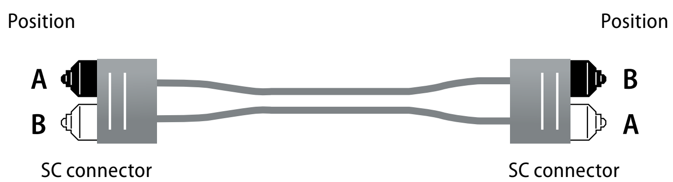
for PCF cable assembly

K XST – XST 64 325 cm (Example)

Cable assembly	**K**
Connector type Side A	
BFOC (ST®)	**XST**
FSMA	**SMA**
HP simplex	**HPS**
HP duplex	**HPD**
F05, TOSLINK compatible	**F05**
F07, TOSLINK compatible	**F07**
SC	**XSC**
SCRJ	**SCR**
End sleeve	**ENH**
LC	**XLC**
FC/PC	**FCP**
Connector type Side B (see above)	e.g. XST
PCF cables code no.	
e.g. I-V(ZN)HH 2×1K200/230	**64**
A-V(ZN)11Y 1K200/230	**74**
Length	
128, 010, …	e.g. 325
Unit	
mm, cm, m, …	e.g. cm
Variants	
e.g. EZH E1	

Order example:
K XST-XST 64 325 cm
3.25 m, duplex connection cable
(cable type: I-V(ZN)HH 2X 1K200/230,
PCF fiber with FRNC inner jacket and
FRNC outer jacket)
assembled with ST connectors

Assembly with logical crossing
(= no physical crossing)



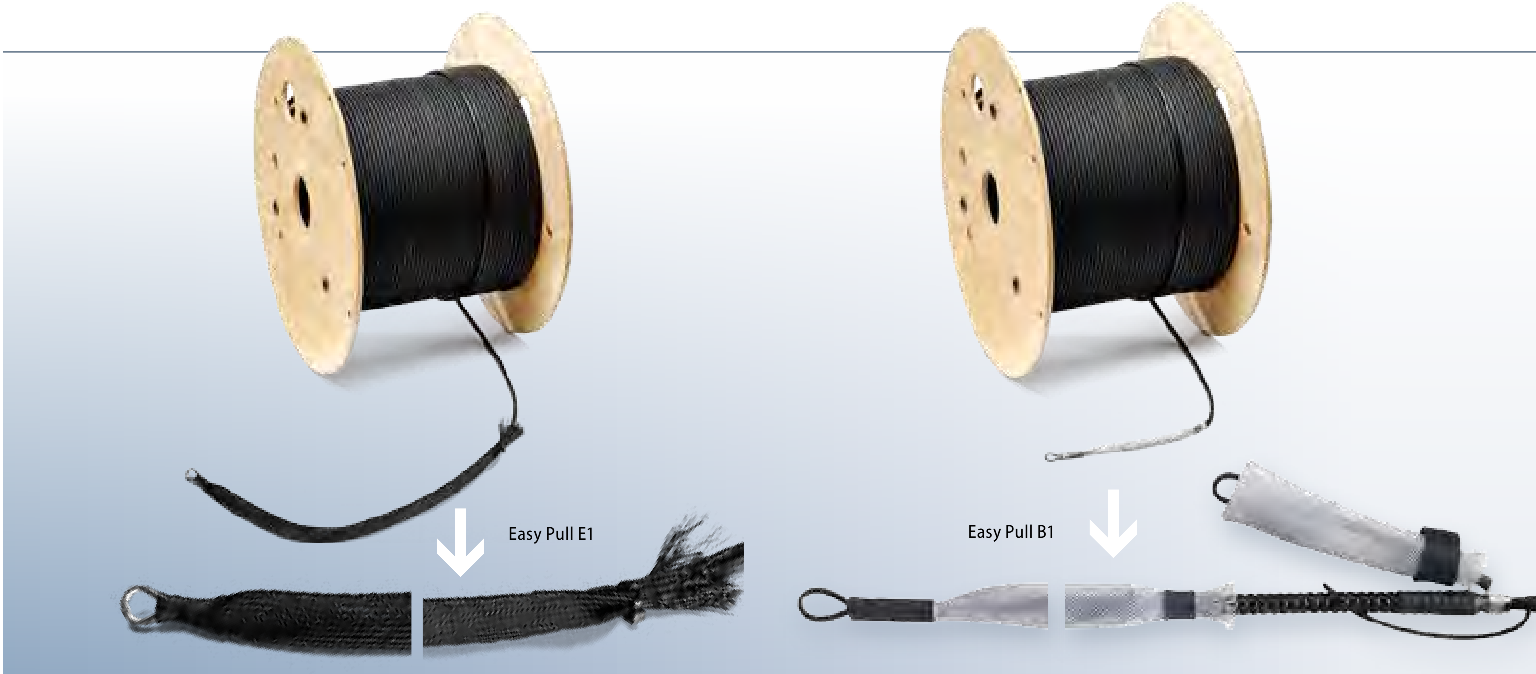
Note on polarity

Please note that our products for standard and special assembly are produced acc. to ANSI/TIA/EIA-568-B.1 with logical crossing.

The products can also be assembled with physical crossing on request (please specify when ordering).

Fiber**Connect**® Easy Pull

Installation aid system for fiber numbers from 1 to 32



Easy Pull E1 / Easy Pull B1

Easy Pull E1

The installation system can be used for assemblies with up to four single fibers. The connectors are optimally protected against damage during installation (in accordance with protection class IP20) and pulling in the cables is made much easier.

Once the cables have been pulled in, the installation protection can be easily removed and the connectors can be joined to the adapters or transceivers as usual at the destination. Gauging the assembly in the plant is an integral part of the delivery package

Easy Pull B1

new

Now available: the installation aid system Easy Pull B1.

Thinner and more compact compared to Easy Pull E1, for assemblies with one connector only. With flexible loop for easy installation in narrower ducts. Can remain on cable after installation for further use if required

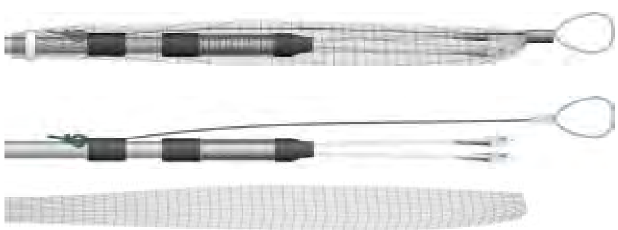
Number of fibers n	1	2	3
Min. bending radius of cable	as per cable datasheet		
Min. bending radius buffered fiber/whip	—	30 mm	30 mm
Min. hole Ø for through-feeds with cabinets and walls	*	30 mm	30 mm
Max. pull force on tool	200 N	500 N	600 N

* depending on connector type

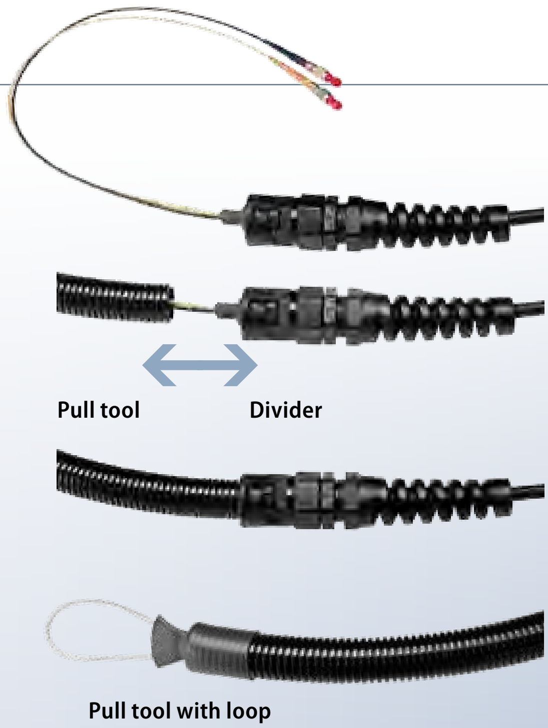
Fanout

The fanout specially developed for the Easy Pull E1 system contains no metal and is especially sturdy despite its low weight.

Its design means that the wall bushings needed during installation are only marginally larger than the divider itself. All that is needed to remove the installation protection is a sharp knife and a cutting pliers.



Here you can find
the corresponding cable:
Chapter 08 | PCF
Chapter 09 | Fiber optic cables



Easy Pull E2

Description

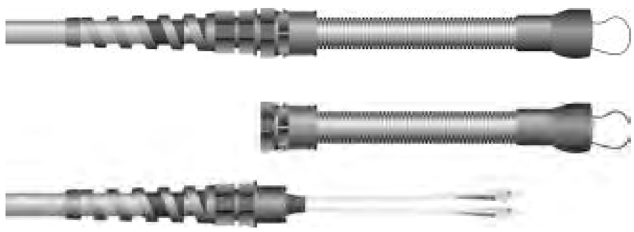
This installation system can be used to protect assemblies with up to 32 single fibers (with IP54 protection). The protective conduit can be easily unlatched and removed after pulling in. The connectors can be joined to adapters or transceivers as normal. Gauging the assembly in the plant is an integral part of the delivery package.

Fanout

The fanout specially developed for the Easy Pull E2 system contains no metal and is especially sturdy despite its low weight. The installation protection is splashproof and offers good protection against mechanical damage. The high flexibility permits trouble-free installation, even under difficult conditions. The installation protection can be removed without any tools.

Properties

- Sturdy, watertight, flexible and UV-resistant protective conduit made from PA 6, with pulling eye
- Cable gland can be used for quick and secure fixing in control cabinets and boxes
- Torsion-free removal of the protective conduit for protecting the connector
- With more than two fibers, the individual whips are graduated in accordance with the customer's requirements

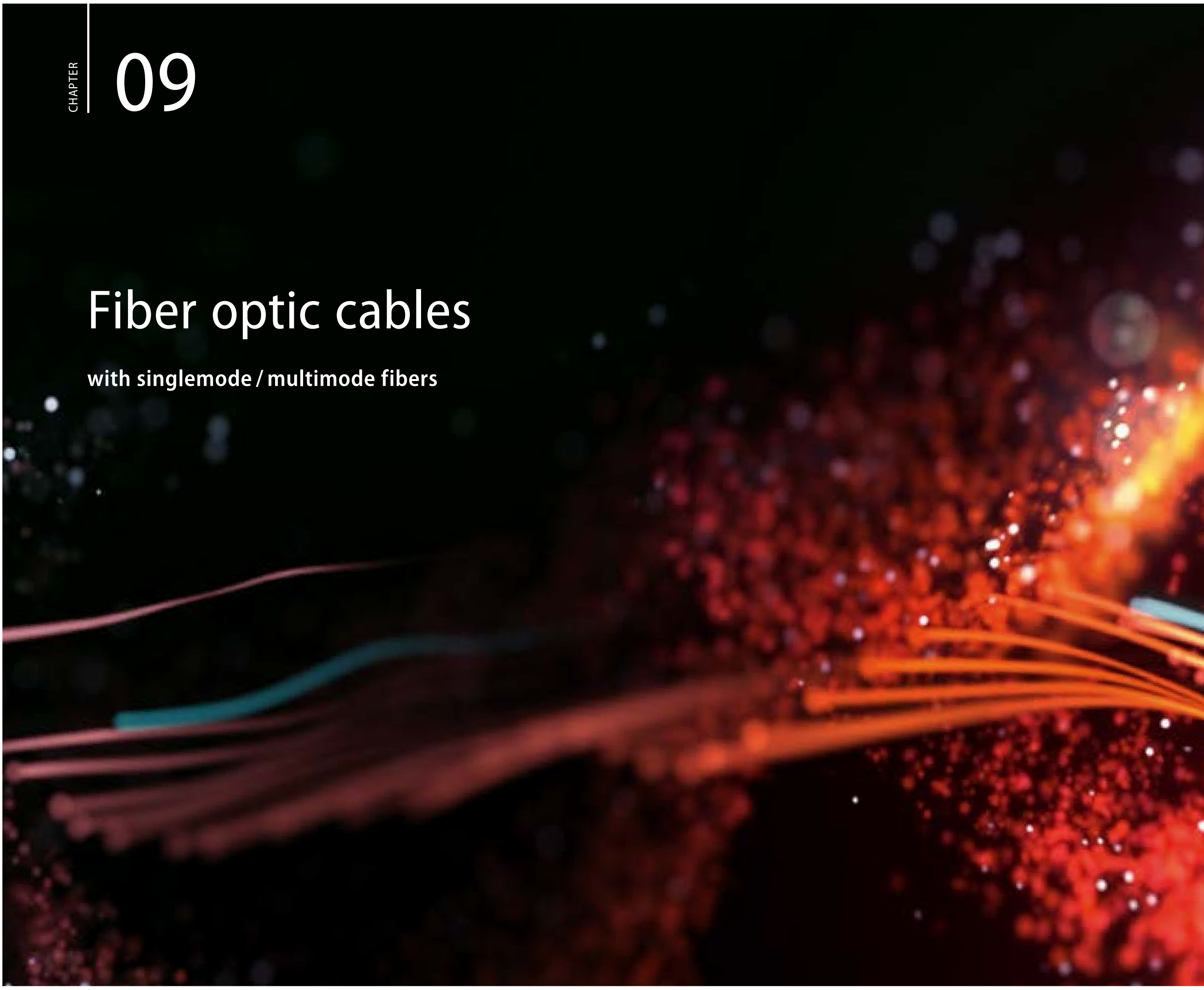


Number of fibers n	2	4	5 to 12	13 to 32
Min. bending radius of cable	acc. to cable datasheet			
Min. bending radius buffered fiber/whip	30 mm	30 mm	30 mm	30 mm
Outer Ø fanout element	14 mm	14 mm	21 mm	30 mm
Resistance to apex pressure (protective conduit)	350 N	350 N	350 N	350 N
Max. pull force on tool	500 N	500 N	600 N	600 N
PG gland	M20 (PG13.5)	M25 (PG21)	M25 (PG21)	M50 (PG36)
Outer Ø of protective conduit	20 mm	30 mm	30 mm	55 mm
Min. hole Ø for throughfeeds with cabinets and walls	35 mm	40 mm	45 mm	60 mm
Material (protective conduit)	PA 6 (flame-retardant / halogen-free / UV-stable)			

CHAPTER 09

Fiber optic cables

with singlemode / multimode fibers



Fast and trouble-free communications are taken for granted nowadays. The Business Unit Fiber Optics supplies customer-specific solutions for this purpose for a wide variety of requirements and applications (sensor technology, plant engineering, telecommunications and many more).

Optical fibers provide the ideal solution for future-proof installations.

They allow not only high rates of data transmission with extensive spare capacity, but also the highest possible degree of operating security.

In this chapter you can find a selection of our fiber optic cable products:
Industrial cables, office cables, outdoor cables, FTTH-applications, marine cables, military cables, cables with UL approval, connectors and adapters, as well as pulling-aid systems.

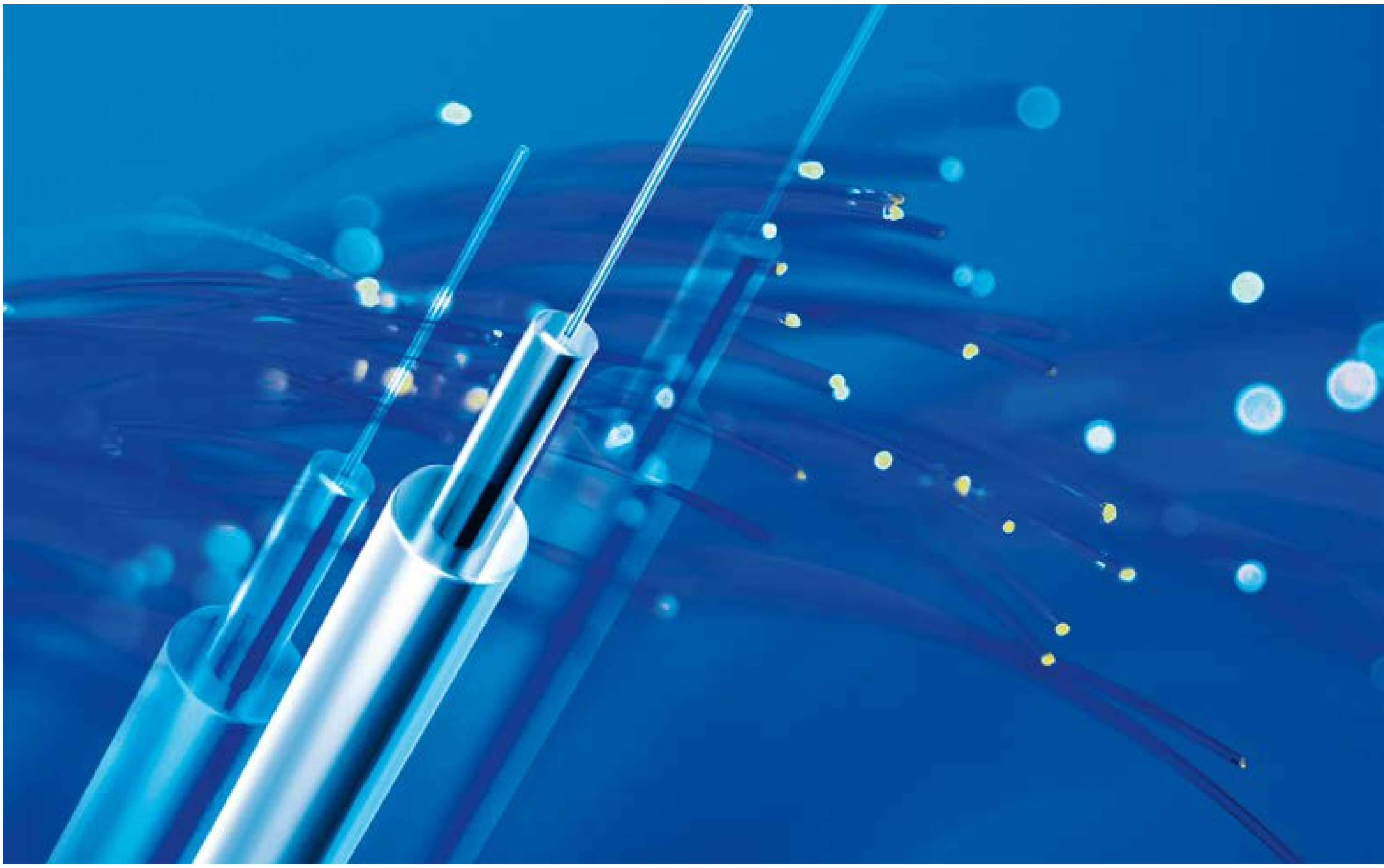
It would exceed the scope of this catalog to illustrate all possibilities. You are looking for a solution to your problem?
We develop and produce cable solutions for your applications.

Please contact us, we are looking forward to your call.

Further basic information on cables:
Chapter 12 | Principles
→ page 378 ff.

09. Fiber optic cables with singlemode / multimode fibers

Fiber specifications



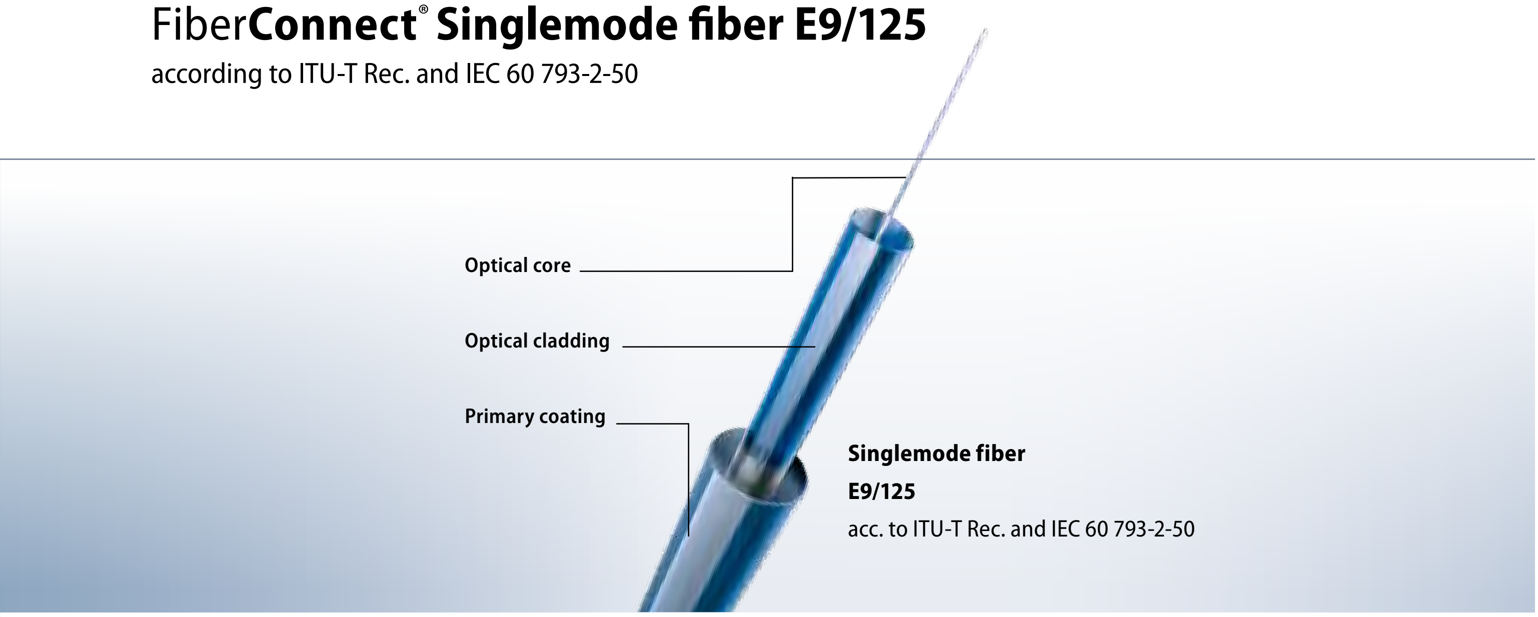
For our extensive range of cables we resort to all standardised fibers from the IEC series, the ISO series or the ITU-T series.

Both singlemode fibers (E9/125) as well as multimode fibers (G50/125, G62.5/125 and G100/125) are available in conventional and bend insensitive quality for this purpose.

If desired, we can also offer radiation hard fibers and special fibers.

FiberConnect® Singlemode fiber E9/125

according to ITU-T Rec. and IEC 60 793-2-50



Singlemode fiber E9/125

according to ITU-T Rec. G.652.D, ITU-T Rec. G.657.A1, ITU-T Rec. G.657.A2/B2 G.657.A2/B2, ITU-T Rec. G.657.B3 and IEC 60 793-2-50
other fiber types e. g. ITU-T G.655 or ITU-T G.657 on request

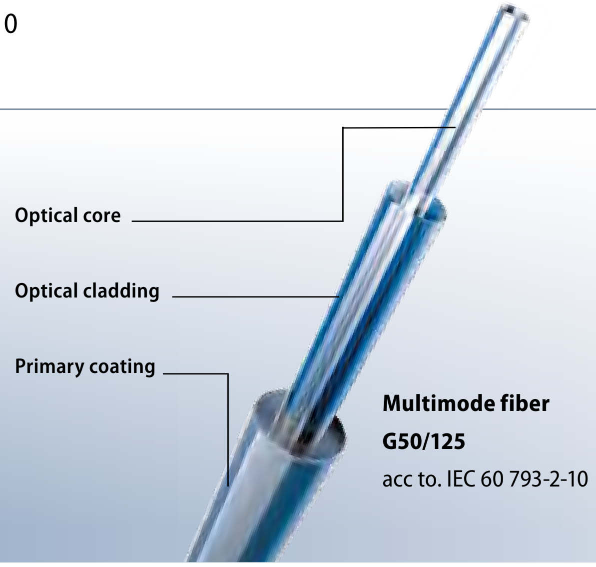
Geometric/mechanical properties

Cladding diameter [µm]	125 ± 0.7	Mode field/cladding concentricity error [µm]	< 0.5
Coating diameter [µm]	245 ± 10	Excentricity of coating [µm]	< 12
Cladding non-circularity	< 1 %	Screen test	1 % Expansion for 1 s (≙ 100 kpsi)

Transmission properties	Fiber type A (tight buffered fiber) resp. B (multi fiber loose tube)		Fiber type E resp. Fiber type P		Fiber type U		Fiber type K	
	according to ITU-T G.652.D and ISO 11801 Type OS 2 IEC 60793-2-50 B1.3		according to ITU-T G.657.A1 IEC 60793-2-50 B6_a1		according to ITU-T G.657.A2/B2 IEC 60793-2-50 B6_a2		according to ITU-T G.657.B3 IEC 60793-2-50 B6_b3	
Wavelength [nm]	1310	1550	1310	1550	1310	1550	1310	1550
Attenuation max. [dB/km]			0.36	0.22	0.36	0.22	0.36	0.22
Attenuation tight buffered fibers (fiber type A) max. [dB/km]	0.38	0.28						
Attenuation multi-fiber loose tube (fiber type B) max. [dB/km]	0.36	0.22						
Dispersion coefficient max. [ps/nm × km]	3.5	18	3.5	18	3.5	18	3.5	18
Zero dispersion wavelength [nm]	1302 – 1322		1302 – 1322		1304 – 1324		1304 – 1324	
Zero dispersion slope [ps/nm² × km]	≤ 0.090		≤ 0.092		≤ 0.092		≤ 0.092	
Cut-Off wavelength (cabled) [nm]	≤ 1260		≤ 1260		≤ 1260		≤ 1260	
Polarization mode dispersion [ps/√km]	≤ 0.2		≤ 0.2		≤ 0.2		≤ 0.2	
Effective group index of refraction	1.4695	1.4701	1.4695	1.4701	1.4670	1.4677	1.4670	1.4680
Mode field diameter at 1310 µm [µm]	9.2 ±0.4		8.9 ±0.4		8.6 ±0.4		8.6 ±0.4	

FiberConnect® Multimode fiber G50/125

according to IEC 60 793-2-10



Radiation resistance

All fiber types are also available in a radiation-hard version or with approval according to MIL-PRF-49291C (6B MMF 62.5/125; 1B MMF 50/125; 7C SMF 9/125).

OM3 and OM4 fibers are available in bend-insensitive quality on request.

Multimode fiber G50/125 according to IEC 60 793-2-10

Geometric/mechanical properties

Core diameter [µm]	50 ± 2,5	Cladding non-circularity (%)	< 1
Cladding diameter [µm]	125 ± 1	Core/cladding concentricity error [µm]	< 1.5
Coating diameter [µm]	245 ± 10	Excentricity of coating [µm]	< 10
Core non-circularity	< 5 %	Screen test	1 % expansion for 1 s (≙ 100 kpsi)

	Conventional fibers										Bend-insensitive fibers					
Transmission properties	**Fiber type F**		**Fiber type G**		**Fiber type H**		**Fiber type I**		**Fiber type J**		**Fiber type X**		**Fiber type V**		**Fiber type W**	
	(OM2) IEC 60793-2-10 A1a.1		**(OM2+)** IEC 60793-2-10 A1a.1		**(OM2++)** IEC 60793-2-10 A1a.1		**(OM3)** IEC 60793-2-10 A1a.2		**(OM4)** IEC 60793-2-10 A1a.3		**(OM2BI)** IEC 60793-2-10 A1a.1		**(OM3BI)** IEC 60793-2-10 A1a.2		**(OM4BI)** IEC 60793-2-10 A1a.3	
Wavelength [nm]	850	1300	850	1300	850	1300	850	1300	850	1300	850	1300	850	1300	850	1300
Attenuation max. [dB/km]	3.0	1.0	2.7	0.8	2.7	0.7	2.5	0.7	2.5	0.7	3.0	1.0	2.5	0.7	2.5	0.7
Bandwidth OFL min. [MHz × km]	500	500	500	1000	600	1200	1500	500	3500	500	500	500	1500	500	3500	500
Bandwidth EMB min. [MHz × km]							2000		4700				2000		4700	
Effective group index of refraction	1.483	1.478	1.483	1.478	1.483	1.478	1.483	1.478	1.483	1.475	1.483	1.478	1.483	1.478	1.483	1.478
Numerical aperture	0.200 ± 0.020		0.200 ± 0.015													

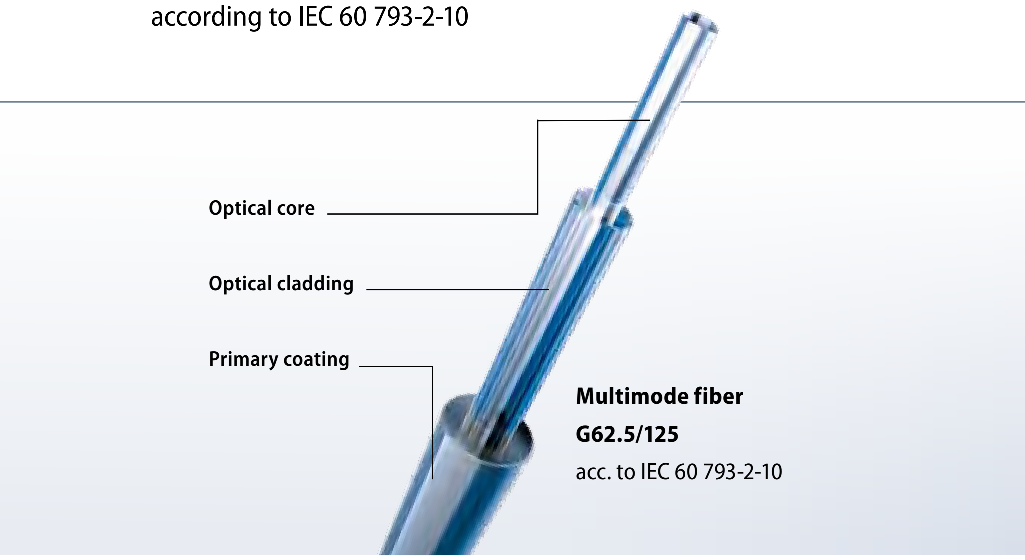
Applications and link lengths

	G50/125							
	F	G	H	I	J	X	V	W
Type according to ISO 11801: 09/2002	OM2	OM2+	OM2++	OM3	OM4	OM2BI	OM3BI	OM4BI
Gigabit Ethernet 1000BASE-SX (850 nm)	500 m	525 m	750 m	1,000 m	1,040 m	500 m	1,000 m	1,040 m
Gigabit Ethernet 1000BASE-LX (1300 nm)	550 m	1,000 m	2,000 m	550 m	600 m	550 m	550 m	600 m
10 Gigabit Ethernet 10GBASE-SX (850 nm)				300 m*	550 m		300 m	550 m
10 Gigabit Ethernet 10GBASE-LX4 (1310 nm WDM)				300 m	300 m		300 m	300 m

* 10 GE link length acc. to ISO 11801.2

FiberConnect® Multimode fiber G62.5/125 and G100/140

according to IEC 60 793-2-10



Radiation resistance

All fiber types are also available in a radiation-hard version or with approval according to MIL-PRF 49291C (6B MMF 62.5/125; 1B MMF 50/125; 7C SMF 9/125).

Multimode fiber G62.5/125 according to IEC 60 793-2-10

Geometric/mechanical properties

Core diameter [µm]	62.5 ± 3
Cladding diameter [µm]	125 ± 2
Coating diameter [µm]	245 ± 10
Core non-circularity	< 5 %
Cladding non-circularity	< 1 %
Core/cladding concentricity error [µm]	< 1.5
Excentricity of coating [µm]	< 10
Screen test	1 % Expansion for 1 s (≙ 100 kpsi)

Multimode fiber G100/140 according to IEC 60 793-2-10

Geometric/mechanical properties, fiber type Q

Core diameter [µm]	100 ± 4
Cladding diameter [µm]	140 ± 3
Coating diameter [µm]	250 ± 15
Core non-circularity	< 6 %
Cladding non-circularity	< 2 %
Core/cladding concentricity error [µm]	< 3.0
Excentricity of coating [µm]	< 12.5
Screen test	1 % Expansion for 1 s (≙ 100 kpsi)

Übertragungseigenschaften	Fiber type L (OM1) IEC 60793-2-10 A1b		Fiber type M (OM1+) IEC 60793-2-10 A1b		Fiber type Q IEC 60793-2-10 A1d	
Wavelength [nm]	850	1300	850	1300	850	1300
Attenuation max. [dB/km]	3.2	0.9	3.0	0.8	5.0	2.0
Bandwidth OFL min. [MHz × km]	200	500	300	800	100	100
Effective group index of refraction	1.497	1.493	1.497	1.493	1.497	1.492
Numerical aperture	0.275 ± 0.015		0.275 ± 0.015		0.290 ± 0.020	

Applications and link lengths

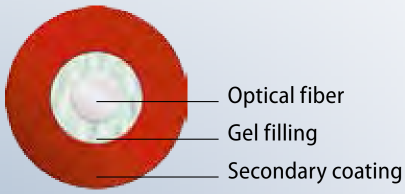
		G62.5/125	
		L	M
Type according to ISO 11801: 09/2002		OM1	OM1+
Gigabit Ethernet 1000BASE-SX	(850 nm)	350 m	500 m
Gigabit Ethernet 1000BASE-LX	(1300 nm)	550 m	1,000 m
10 Gigabit Ethernet 10GBASE-SX	(850 nm)		
10 Gigabit Ethernet 10GBASE-LX4	(1310 nm WDM)		

* 10 GE link length acc. to ISO 11801.2

FiberConnect® Buffered optical fibers

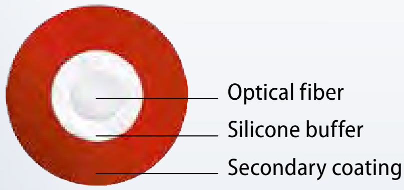
Buffered fibers for the modular structure of the tight buffered fiber cables

STB900 – semi-tight buffered fiber



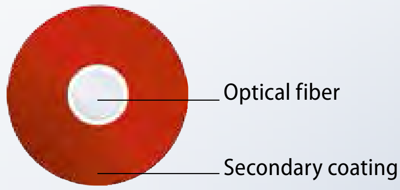
V-...

TB900L – tight buffered fiber



V-...

STB900H – semi-tight buffered fiber



V-...

Properties/applications (STB900)

- For splicing as pigtail
- As connection cables in equipment and distribution cabinets
- High flexibility
- Very good kink resistance
- Longitudinally waterproof due to gel filling
- Available without gel filling for pigtails (STB900)
- Ease of installation and assembly (2000 mm and more can be stripped in one piece)
- Primary and secondary coating available in 12 colours

Properties/applications (TB900L)

- In equipment and distributor cabinets as two-sided pre-assembled cable
- Resistant to temperature fluctuations
- High resistance to external mechanical loads such as bending or transverse pressures and environmental influences
- Easy stripping (up to 80 mm in one piece)
- Ease of installation, because of no gel filling

Properties/applications (STB900H)

- For splicing as pigtail
- As connection cables in equipment and distribution cabinets
- High flexibility
- Very good kink resistance
- Ease of installation and assembly (1500 mm and more can be stripped in one piece)
- Primary and secondary coating available in 12 colours

Further basic information on cables:
Chapter 12 | Principles
→ page 378 ff.

Thermal properties

transport and storage	–20 °C to +50 °C
installation	+5 °C to +40 °C
operating temperature	–10 °C to +60 °C

Mechanical properties

min. mechanical properties	30 mm
max. pull force long-term	5 N
max. crush-resistance, long-term	200 N

Buffered fiber	Ø [µm]	Type	Order no.	Strippable in one piece	Flexi-bility	Resistance to temperature fluctuation	Ease of installation	Suitable for spli-cing	Note
TB500A	500	Mini tight buffered fiber upcoated	8499998Z□	to 50 mm	+++	+++	++	No	■ Miniaturised optical cables suitable for SFFC (Small Form Factor Connector, e.g. MT-RJ) ■ Ideal for stripping machines for extreme operating temperatures
TB600	600	Mini tight buffered fiber	84950116□	to 80 mm	++	++	+	No	■ Suitable for SFFC (Small Form Factor Connector, e.g. MT-RJ)
TB600A	600	Mini tight buffered fiber upcoated	8499998Y□	to 50 mm	+++	+++	++	No	■ Suitable for SFFC (Small Form Factor Connector, z. B. MT-RJ) ■ Ideal for stripping machines for extreme operating temperatures
TB600L	600	Mini tight buffered fiber flexible	8499800U□	to 50 mm	+++	+++	+	No	■ Suitable for SFFC (Small Form Factor Connector, z.B. MT-RJ) ■ Flexible, for extreme operating tempeatures
TB900	900	Thight buffered fiber	84998000□	to 50 mm	++	+++	+	No	■ In equipment and distributor cabinets as two-sided pre-assembled cable ■ High resistance to external mechanical loads such as bending or transverse pressures and environmental influences.
LB900	900	Superstrip fiber	84998006□	to 2000 mm	+++	+	+++	Yes	■ For splicing as pigtail ■ For indoor cables in equipment and distribution cabinets as well as on cable trays ■ Very good kink resistance ■ Primary and sencondary coating available in 12 colours
STB900	900	Semi-tight buffered fiber	84998001□	to 2000 mm	+++	+	+++	Yes	■ for splicing as pigtail ■ As connecting cable in equipment and distributor cabinets ■ Very good kink resistance ■ Longitudinally watertight due to gel filling ■ Primary and sencondary coating available in 12 colours
TB900A	900	Thight buffered fiber upcoated	8499998X□	to 50 mm	+++	+++	++	No	■ All indoor cables for two-sided connector assembly ■ Ideal for stripping machines ■ For extreme operating temperatures
STB900U unfilled	900	Semi-tight buffered fiber dry core	84998009□	to 2,000 mm	++	+	+++	Yes	■ Pigtail assembly ■ Primary and secondary coating available in 12 colours
STB900H	900	Semi-tight buffered fiber dry core, flame retar-dant (FRNC)	84998007□	to 1,500 mm	++	++	+++	Yes	■ All indoor cables pigtail assembly ■ Primary and secondary coating available in 12 colours
Loose tube	1400	Loose tube, gel-filled	84997101□	to 2,000 mm	++	++	+	Yes	■ suitable for cables in harsh industrial environ-ments ■ suitable for drag chain cables
TB900L	900	Tight buffered fiber flexible with Hytrel®	8499800L□	to 50 mm	+++	+++	+	No	■ Flexible, for extreme operating temperatures
TB900BAR	900	Tight buffered fiber with Hytrel® with 500µm coated fiber	8499800V□	to 50 mm	++	+++	+	No	■ Buffered fiber for extreme operating tem-peratures ■ With little attenuation loss when bended

Handling and safety notes

when using fiber optic cables

Please observe the following when installing optical fibers:

- Valid installation regulations for optical fibers
- Valid industrial safety guidelines for handling optical fibers
- VDE regulations (DIN EN 50174-3 Information technology – Cabling installation)

The following applies for the disposal of fiber optic cables:
According to the directive on the European list of waste materials (Abfallverzeichnis-Verordnung – AVV)
Date of issue: 10.12.2001
as of: last amended by Art. 5 (22) G v. 24.02.2012 I 212
the waste code for fiber optic cables is **10 11 03**.

The following regulations also apply:

- The drums must always be stored and transported standing on their flanges
- Please note the limit values specified in the respective data sheet
- Do not remove the protective packaging from the cable ends during installation
- Do not go below the permitted bending radius (see data sheet)
- Avoid soiling and mechanical loading of the assembled connectors
- Do not exceed the maximum tensile load of the cable in axial direction during and after installation (use suitable aids)
- The maximum tensile load only applies in conjunction with adhesion with the strain relief elements
- Installation is not permitted if the ambient temperature is exceeded or gone below (specific value in the data sheet)
- Cable runs must be selected so as to avoid mechanical loads as far as possible and also minimise future loads
- Mechanical stresses, for example caused by movement, must be prevented, even during provisional installation
- Compression of the outer jacket, for example by cable ties, must be avoided when securing the cables
- After installation: carefully free the cable ends from the packaging/pull tool
- All cable ends must be protected from the ingress of moisture before, during and after installation
- Immersion with water must be avoided – the fibers and connectors must not come into contact with water
- Optical fibers must be unwound from the coil or ring without torsion so that no kinks or twists can occur
- Install fiber optic cables with extreme care. Please make sure that the fibers are neither overstretched nor compressed – in addition to immediate damage, this also poses the threat of problems with the long-term behaviour
- When installing in protective conduits, please make sure that these have no sharp edges and that kinks are avoided
- The attenuation of each cable must be checked immediately after installation using a suitable calibrated meter, else warranty claims may be forfeited
- Body and eye protection must be worn when handling bare fibers from glass optical fibers, including if the cable is damaged
- Please note all regulations relating to eye safety

Buffer tube and jacketing material

of fiber optic cables

Balancing application and fire prevention criteria
The jacket around the cable is designed to protect the optical fiber(s) from the effects of mechanical, thermal and chemical action as well as the ingress of moisture. In the event of a fire, however, the cable jacket should prevent a fire from spreading and stop toxic and corrosive gases from being produced.

The use of halogen-free, flame-retardant materials is advisable in order to protect equipment and buildings in but above all to protect people. In harsh environments, PUR and PVC, in particular, are used owing to their high resistance to oils and their abrasion resistance. PE is also commonly used as a jacket material for outdoor applications.

However, it is often extremely difficult to meet all the requirements using just one jacket material. To best satisfy the prevailing local operating conditions, the Business Unit Fiber Optics offers the user a choice of four standard materials.

Please contact us if the criteria for your particular application are not met by the cable constructions in this catalogue. Additional requirements can often be met through customised measures when making the jacket (e.g. aluminium tape or special mixtures of materials)

Cable jacket material

Material properties	TPE-O (FRNC)	TPE-U (PUR)	PVC	PE
Resistance to ageing	+	+	+	+
Absence of halogen	+	+	– –	+
Flame retardancy	+	+	+	●
Elasticity	–	+	●	–
Abrasion resistance	–	++	+	●
low smoke gas generation	++	●	–	●
low emission of corrosive gases	++	●	– –	+/●
low smoke gas toxicity	++	●	– –	+/●
no toxicological risk	++	●	–	+/●

General resistance to	TPE-O (FRNC)	TPE-U (PUR)	PVC	PE
UV light	1)	1)	1)	1)
Water absorption	–	–	+	+
Gas diffusion	–	2)	–	●
Fuels	–	+	+/–	+
Petroleum/lubricants	–	++	●	+
Organic solvents	–	+ 3)	–	+ 4)
Alcohol	–	+	+	+
Oxidants	–	–	+	–
Acids	+	+	+	++
Alcaline solutions	+	+	+	++
Saline solutions	+	+	+	+

++ excellent
\+ good
● depending on recipe
– weak
– – insufficient

1) UV resistance can be increased by adding black colour pigments or UV stabilisers

2) Permeation depends on the type of gas e.g. Ar, CH_4, N_2, O_2 low gas permeation; CO_2, H_2, He higher gas permeation

3) low swelling in saturated hydrocarbons; significant swelling in aromatic hydrocarbons, aliphatic esters cause swelling, highly polar organic solvents dissolve under underuchpolare

4) Swelling in aliphatic and aromatic hydrocarbons and chlorinated hydrocarbons

Note: instead of FRNC (flame retardant non corrosive), often the expression LSOH or LSZH (low smoke zero halogen) or HFFR (halogen free flame retardant) is used.

Type designations

for fiber optic cables

I – V (ZN) H H 4G50/125 STB900 2,5 (Example)

Application area	
Indoor cable	I
Universal cable	U
Outdoor cable	A
Splittable outdoor cable	AT
Buffered fiber type	
Tight buffered fiber	V
Unfilled multi-fiber loose tube	B
Gel-filled multi-fiber loose tube	D
Gel-filled loose tube	W
Fiber	F
Constructional composition	
Constructional composition	Q
Grease-filled	F
Fiber optic cable with copper elements	S
Non-metallic strain relief	(ZN)
Aluminium sheath	(L)
Steel strain relief	(ZS)
Armour	B
Corrugated steel jacket	(SR)
Inner jacket mixtures	
PVC (polyvinyl chloride)	Y
PE (Polyethylenee)	2Y
PA (polyamide)	4Y
ETFE (tetrafluoroethylene)	7Y
PP (polypropylene)	9Y
TPE-U (polyurethane)	11Y
TPE-E (thermoplastic copolyster elastomer, e.g. Hytrel®)	12Y
H stands for an FRNC jacket; TPE-O (thermoplastic polyolefin elastomer) is used	H
Outer jacket mixtures	
see inner jacket mixtures	e.g. **H**
Number of fibers or fiber bundling	
Number of fibers	n
Number of multi-fiber loose tubes × number of fibers per multi-fiber loose tube	n×m
Fiber type/fiber core diameter/ fiber cladding diameter	
Singlemode fiber (silica/silica)	E
Multimode graded-index fiber (silica/silica)	G
Multimode step-index fiber (silica/silica)	S
PCF Multimode step-index fiber (glass/polymer)	K
PCF Multimode graded-index fiber (glass/polymer)	GK
POF polymer fiber (polymer/polymer)	P
Optical transmission properties and buffered fiber types	
a) a) Fiber attenuation / Wavelength range / Bandwidth (only for PCF- and POF-Fibers) xx Attenuation [dB/km], z Wavelength range [nm], A = 650 nm, B = 850 nm, F = 1300 nm, H = 1550 nm yy Bandwidth (MHz×km for PCF), (MHz×100 m for POF)	xx z yy
b) Buffered fiber type (only with silica/silica Fibers)	
Miscellaneous, e.g. plant-specific details	
■ Diameter of single element or cable outer diameter ■ Dimensions with flat cables (e.g. 2.2×4.5 mm) ■ Data on copper buffered fibers with hybrid cables (e.g. 4×0.75 mm²) ■ Data on strain relief (e.g. 2500 N)	e.g. **2.5**

further examples:

Indoor cable (silica/silica)
I–V (ZN) H H 4G50/125 STB900 2.5
➔ Indoor cable (breakout)
with tight buffered fibers
Single elements 2.5 mm
with nonmetallic strain relief and
FRNC jacket
FRNC outer jacket
4 fibers or single elements
Fiber type: G50/125
Buffered fiber type: semi-tight buffered
fiber with 900 µm
Diameter of single element: 2.5 mm

Outdoor cable (silica/silica)
A–D Q (ZN)2Y (SR) 2Y 4X12 G62.5/125
➔ Outdoor cable with loose tubes,
longitudinally watertight with swellers
Non-metallic strain relief under PE
intermediate cladding
Corrugated steel cladding
with PE outer jacket
4 multi-fiber loose tubes with
12 fibers each
Fiber type: G62.5/125

Outdoor cable (PCF)
**AT–V (ZN) Y 11Y 2 K200/230
10A17 / 8B20 7,4 MM**
➔ splittable outdoor cables (breakout)
with tight buffered fibers Single
elements with non-metallic strain relief
and PVC jacket PUR outer jacket
2 Fibers or single elements
Fiber type PCF: K200/230
Attenuation:10 dB/km bei 650 nm
Bandwidth 17 MHz × km
Attenuation: 8 dB/km bei 850 nm
Bandwidth 20 MHz × km
Total diameter of cable: 7.4 mm

Indoor cable (POF)
**I–V 2Y (ZN) 11Y 1 P980/1000 160A10
6,0 MM**
➔ Indoor cable with tight buffered
fibers POF fiber with PE buffer tube
with non-metallic strain relief over it
PUR outer jacket
1 buffered fiber
Fiber type POF: P980/1000
Attenuation: 160 dB/km bei 650 nm
Bandwidth 10 MHz × 100m
Total diameter of cable: 6.0 mm

Colour codes

Fiber optic cable colour code for multi-fiber loose tubes and LEONI standard cable colour code

LEONI Fiber colour code acc. to IEC 60304

Fiber no.	Fiber optic cable colour code
1	red
2	green
3	blue
4	yelllow
5	white
6	grey
7	brown
8	violet
9	turquoise
10	black
11	orange
12	pink

Fiber no.	Fiber optic cable colour code with ring marking
13	red
14	green
15	blue
16	yelllow
17	white
18	grey
19	brown
20	violet
21	turquoise
22	transparent (no ring marking)
23	orange
24	pink

LEONI standard cable colour code:

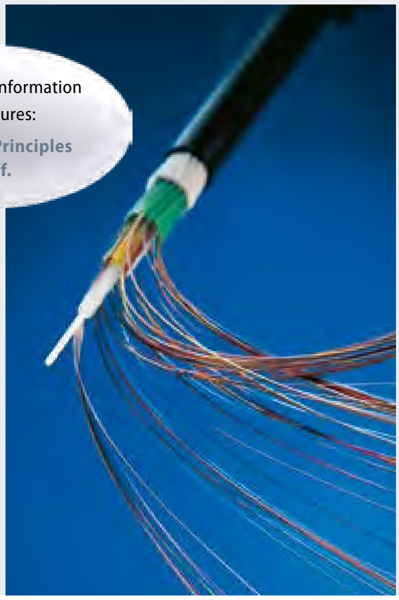
Fiber no.	colour of jacket
000	black
111	yelllow
222	orange
333	red
353	pink
414	magenta
444	violet
555	blue
655	turquoise
666	green
707	light grey
777	grey
888	brown
909	transparent
999	white

Standards

Fiber optic cables of the Business Unit Fiber Optics fulfil one or more of the following standards:

- DIN VDE 0888
- DIN VDE 0472
- DIN VDE 0473
- EN 50 173
- ITU-T Rec G.651 to G.657
- IEC 60793
- IEC 60794

Further basic information on test procedures:
Chapter 12 | Principles
→ page 381 ff.



Packaging units

Disposable or KTG reusable drums

Drums

Optical cables can be delivered on disposable drums or KTG reusable drums. These are supplied on loan solely under the conditions of the Kabeltrommel GmbH & Co.KG; Camp Spich Strasse 55/59; 53842 Troisdorf, Germany. We can send these conditions to you on request. You can also download them on www.kabeltrommel.de.

All cables with POF, PCF and special fibers are supplied on disposable drums. The standard packaging units are:

POF 250 m and 500 m for twisted cables;
500 m for non-twisted cables;
500, 1000, 2000 and 5000 m for buffered fibers

PCF 2000 m

Other packaging untis according to customer's wishes possible.

KTG reusable drums

Type	Flange Ø	Core Ø	Total width	Layer width	Hole	Spool weight	Load-bearing capacity
	mm	mm	mm	mm	mm	ca. kg	max. kg
KT081	800	400	520	400	80	31	400
KT101	1000	500	710	560	80	71	900
KT121	1250	630	890	670	80	144	1700
KT141	1400	710	890	670	80	175	2000
KT161	1600	800	1100	850	80	280	3000
KT181	1800	1000	1100	840	80	380	4000
KT201	2000	1250	1350	1045	125	550	5000
KT221	2240	1400	1450	1140	125	710	6000
KT250	2500	1400	1450	1140	125	875	7500

Disposable drums (K… = plastic; H… = plywood flange; G… = timber flange)

Type	Flange Ø	Core Ø	Total width	Layer width	Hole	Spool weight
	mm	mm	mm	mm	mm	approx. kg
K3000	300	212	103	90	51	0.7
K3002	300	190	208	180	52	1.2
H5001	500	400	116	100	46	3.5
H5005	500	312	331	315	80	3.7
H6007	600	312	335	315	80	5.0
H6008	600	312	410	390	80	4.6
H7603	760	470	544	520	80	12.0
H1001	1000	500	590	560	80	15.0
G1001	1000	500	650	550	80	49.0
G1201	1200	630	840	745	80	74.0
G1401	1400	800	840	745	80	193.0
G1601	1600	1000	1050	930	80	240.0
G1801	1800	1000	1110	1000	85	300.0

Order no. scheme

for fiber optic cables

Cable composition	Number of fibers in cable	Buffered fiber type	Fiber type
☐☐☐☐☐	☐☐	☐	☐

see product page

Number of fibers in cable

00 = 1 fiber
01 = 2 fibers
02 = 4 fibers
03 = 6 fibers
04 = 8 fibers
xx = 2 × n fibers

Over 198 fibers seperate letter code

Buffered fiber type

A Multi-fiber loose tube cable

2 = loose tubes with 2 fibers
3 = loose tubes with 4 fibers
4 = loose tubes with 6 fibers
5 = loose tubes with 8 fibers
6 = loose tubes with 10 fibers
7 = loose tubes with 12 fibers
B = loose tubes with 16 fibers
D = loose tubes with 20 fibers
F = loose tubes with 24 fibers

B Tight buffered fiber cable

0 = tight buffered fiber type TB900
1 = Semi-tight buffered gel-filled fiber type STB900
6 = Semi-tight buffered fiber type LB900
7 = Semi-tight buffered fiber type STB900H
9 = Semi-tight buffered fiber type STB900U
L = Tight buffered fiber type TB900L
U = Tight buffered fiber type TB600L
X = Tight buffered fiber type TB900A
Y = Mini tight-buffered fiber upcoated type TB600A
Z = Mini tight-buffered fiber upcoated type TB500A
V = Tight buffered fiber type TB900BAR

Fiber type

A = 0.38F3.5/0.28H18 OS2
B = 0.36F3.5/0.22H18 OS2
F = 3.0B500/1.0F500 OM2
G = 2.7B500/0.8F1000 OM2+
H = 2.7B600/0.7F1200 OM2++
I = 2.5B1500/0.7F500 OM3
J = 2.5B3500/0.7F500 OM4
K = 0.36F3.5/0.22H18 OS2
L = 3.2B200/0.9F500 OM1
M = 3.0B300/0.8F800 OM1+
P = 0.36F3.5/0.22H18 OS2
U = 0.36F3.5/0.22H18 OS2
V = 2.5B3500/0.7F500 OM3BI
W = 2.5B1500/0.7F500 OM4BI
Q = 5.0B100/2.0F100
X = 3.0B500/1.0F500 OM2BI

Order examples

8	4	0	1	0	0	4	0	G	I-V(ZN)HH 8G50/125
8	4	0	3	2	0	2	3	L	U-DQ(ZN)BH 4G62.5/125

FiberConnect® Industrial cables

In industry, one frequently faces a wide variety of technical requirements that cannot be met with conventional cables. The Business Unit Fiber Optics is the specialist for application-optimised optical cables in industrial settings.

Extensive know-how, many years of experience and a highly flexible production setup enable us to design and produce the right cable for even the most demanding areas.

Further basic information on cables:

Chapter 12 | Principles
→ page 378 ff.

We offer

- cables with oil-resistant jacket materials
- cables with high flexibility and high bending radii for mobile use in drag chains
- cables for the greatest bending stresses, such as in component placement machines in the electronics industry
- cables for extremely high temperature ranges up to 300 °C
- cables with radiation-resistant fibers
- cables with leak-proof buffered fiber filling gels
- longitudinally welded stainless steel conduits

and much more

On the following pages you will find a selection of high-quality products. We will be pleased to advise you if you cannot find the right product for your specific requirements. We can develop and produce the cable solution for your application.

FiberConnect® Simplex cable PUR

I-V(ZN)11Y 1…

Order no.	**84 006 00**☐ ☐
Standardisation	IEC 60794-2

Description

Oil-resistant patch cable in distribution systems as well as for connecting terminals in harsh industrial environments.

Composition

Cable core fiber (STB)	Tight buffered (TB) or semi-tight buffered
Strain relief elements	non-metallic (aramid)
Cable jacket	Polyurethane (PUR)
Colour of jacket	● orange for multimode, ● yellow for singlemode ➔ other colours possible!

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

Outer dimensions	2.8 mm	
Weight	6 kg/km	
Min. bending radius	static	30 mm
	dynamic	45 mm
Max. pull force		400 N
Max. crush resistance		500 N/dm
Resistance to impacts		3 impacts/1 Nm

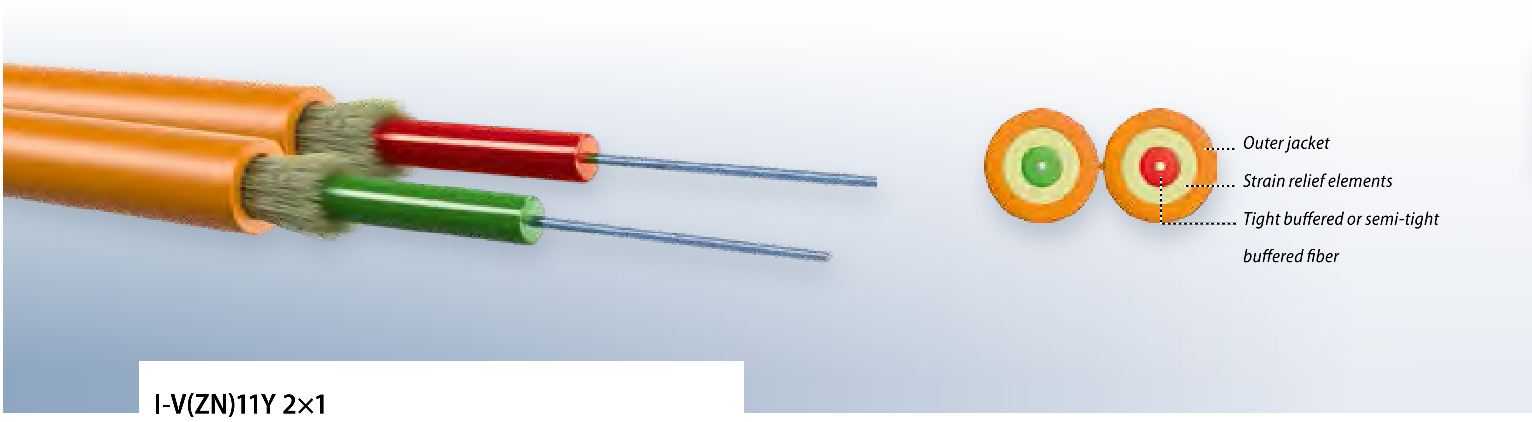
Chemical properties

Very good resistance to oil, petrol, acids and alkaline solutions.

Fire performance

The cable is halogen-free and flame-retardant.

FiberConnect® Duplex cable PUR



I-V(ZN)11Y 2×1

Order no.	**84 007 01** ☐ ☐
Standardisation	IEC 60794-2

Description

Oil-resistant patch cable in distribution systems as well as for connecting terminals in harsh industrial environments.

Composition

Cable core fiber (STB)	Tight buffered (TB) or semi-tight buffered
Strain relief elements	non-metallic (aramid)
Cable jacket	Polyurethane (PUR)
Colour of jacket	● orange for multimode ● yellow for singlemode ➔ other colours possible

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

Outer dimensions	3.0 × 6.0 mm	
Weight	15 kg/km	
Min. bending radius	static	30 mm
	dynamic	60 mm
Max. pull force		600 N
Max. crush resistance		500 N/dm
Resistance to impacts		3 impacts/1 Nm
Resistance to impacts		5 impacts/3 Nm

Chemical properties

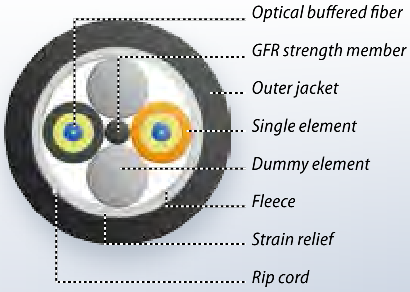
Very good resistance to oil, petrol, acids and alkaline solutions.

Fire performance

The cable is halogen-free and flame-retardant.

FiberConnect® Breakout cable

with rodent protection



AT-V(ZN)H(ZN)B2YFR 2… 2,1

Order no.	**84 216**□□ □ □
Standardisation	IEC 60794-3, DIN VDE 0888 part 5

Description

Breakout cable for fixed installation indoors and outdoors with nonmetallic rodent protection. Suitable for direct connector assembly. Jacket material with very low water absorption suitable for running directly in the ground.

Composition

Breakout single element	Tight buffered or semi-tight buffered fiber with non-metallic strain relief elements (aramid) and a halogen-free, flame-retardant subcable jacket, Ø 2.1 mm, Colours: ● orange and ● black
Cable core	GFR central strength member, over that two breakout single elements and two dummy elements stranded in one layer
Tape	1 fleece layer
Armour	multifunctional glass rovings as non-metallic strain relief and rodent protection
Cable jacket	halogen-free and flame-retardant material
Colour of jacket	● black

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
2	7.8	55	0.86
4	7.8	61	0.83

Thermal properties

Transport/storage	– 40 °C to + 80 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 80 °C

Mechanical properties

Outer dimensions	7.8 mm	
min. bending radius	static	80 mm
	dynamic	120 mm
max. pull force	2000 N	
max.crush resistance	2000 N/dm	
Resistance to impacts	5 impacts/2 Nm	

Fire performance

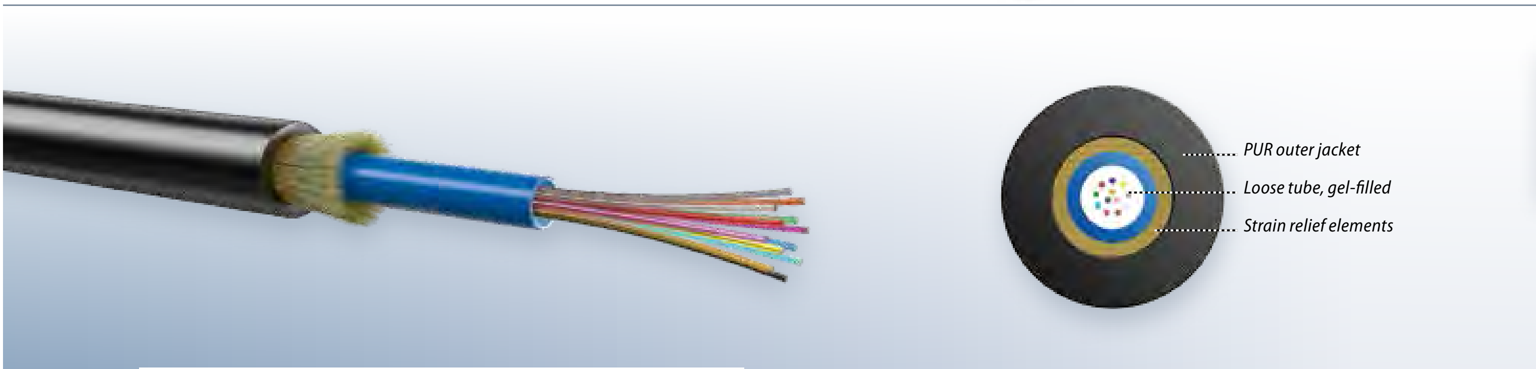
Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Note

UV resistant outer jacket

Mobile camera cable

with central multi-fiber loose tube, suitable for drag chains



U-DQ(ZN)11Y n…

Order no.	**84 023** □□ □ □
Standardisation	IEC 60794-2

Description

Light, flexible and non-metallic cable that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits. Suitable for fixed and flexible use in harsh industrial environments.

Composition

Cable core	Loose tube, gel-filled
Strain relief	Aramid covering
Cable jacket	Polyurethane (PUR)
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 25 °C to + 50 °C
Operating temperature	– 25 °C to + 70 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		2500 N
Max. crush resistance		3000 N/dm
Resistance to impacts		5 impacts/3 Nm

Fire performance

Cable is flame-retardant

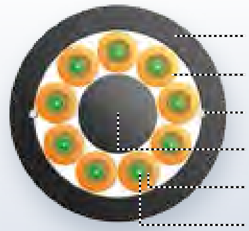
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Chemical properties

Very good resistance to oil, petrol, acids and alkaline solutions.

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	6.5	34	0.55
24	7.7	53	0.76

FiberConnect® Breakout cable suitable for drag chains



AT-V(ZN)YY n… 2.5

Order no.	**84 206**☐☐ ☐ ☐
Standardisation	IEC 60794-2

Description

Rugged breakout cable suitable for drag chains that can be used both inside and outside buildings and in harsh industrial environments. For direct connector assembly.

Composition

Cable core	GFR central strength member with stranded elements, designed as tight buffered (TB) or semi-tight buffered fiber (STB), gel-filled with non-metallic strain relief elements (aramid) and PVC subcable jacket (Ø 2.5 mm)
Colour	● orange for multimode ● yellow for singlemode
Cable jacket	Polyvinyl chloride (PVC)
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 80 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 80 °C

Mechanical properties

Max. crush resistance	800 N/dm
Resistance to impacts	10 impacts/2 Nm
Drag chain test	5 000 000 cycles

Fire performance

Flame retardancy	IEC 60332-1-2

Chemical properties

Good resistance to oil, petrol, acids and alkaline solutions.

Number of fibers	Outer Ø	Weight	Min. bending radius static	Min. bending radius dynamic	Max. pull force	Fire load
	mm	kg/km	mm	mm	N	MJ/m
2	9.5	80	95	140	800	1.20
4	9.5	85	95	140	800	1.20
6	10.5	110	105	155	1200	1.36
8	12.3	150	125	185	1200	1.52
10	13.8	170	140	205	1200	1.68
12	15.6	210	155	235	1200	1.84

FiberConnect® Breakout cable, suitable for drag chains

oil resistant

AT-V(ZN)Y11Y n… 2. 5

Order no.	**84 207** □□ □ □
Standardisation	IEC 60794-2

Description

Rugged breakout cable suitable for drag chains that can be used both inside and outside buildings and in harsh industrial environments. For direct connector assembly. With oil-resistant outer jacket.

Composition

Cable core	GFR central strength member, designed as tight buffered (TB) or semi-tight buffered (STB) fiber, gel-filled with non-metallic strain relief elements (Aramid) and PVC subcable jacket (Ø 2.5 mm)
Colour	● orange for multimode ● yellow for singlemode
Cable jacket	Polyurethane (PUR)
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 80 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 80 °C

Mechanical properties

max crush resistance	800 N/dm
Resistance to impacts	10 Schläge/2 Nm
Drag chain test	5 000 000 cycles

Fire performance

Flame retardancy	IEC 60332-1-2

Chemical properties

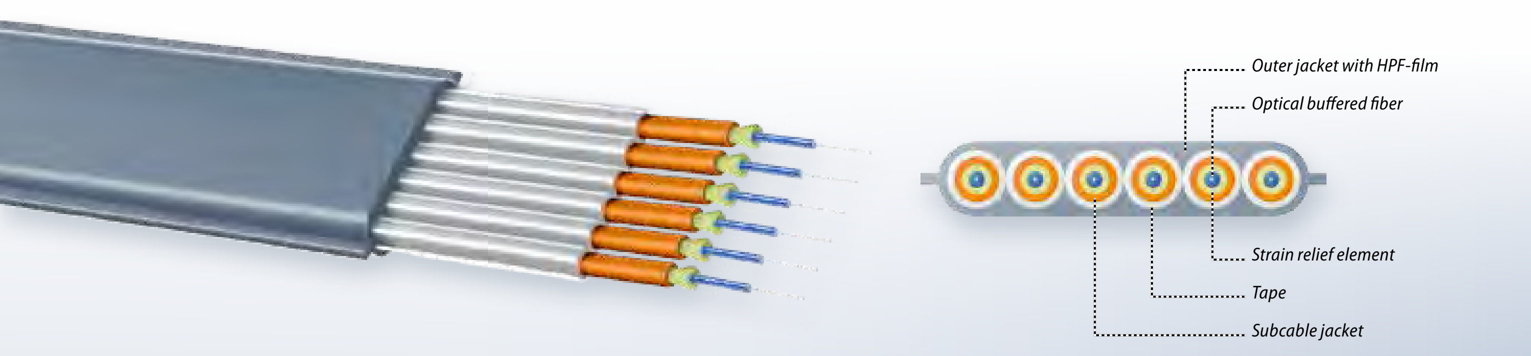
Very good resistance to oil, petrol, acids and alkaline solutions.

Note

Cable jacket with high abrasion resistance.

Number of fibers	Outer Ø	Weight	Min. bending radius static	Min. bending radius dynamic	Max. pull force	Fire load
	mm	kg/km	mm	mm	N	MJ/m
2	9.5	80	95	140	800	1.20
4	9.5	85	95	140	800	1.20
6	10.5	110	105	155	1200	1.36
8	12.3	150	125	185	1200	1.52
10	13.8	170	140	205	1200	1.68
12	15.6	210	155	235	1200	1.84

FiberConnect® High performance flex flat cable



HPF-FO-Cable n…

Order no.	**see table**
Standardisation	IEC 60794-2

Description

Drag cable with maximum flexibility, low friction and low abrasion for applications in industrial clean rooms and in medical technology.

Composition

Cable core	Several single fiber cables arranged in parallel with buffered fiber type TB600, non-metallic strain relief elements (Aramid) and TPE subcable jacket taped with ePTFE, diameter 1.6 mm
Cable jacket	HPF film
Colour of jacket	grey

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 60 °C

Mechanical properties

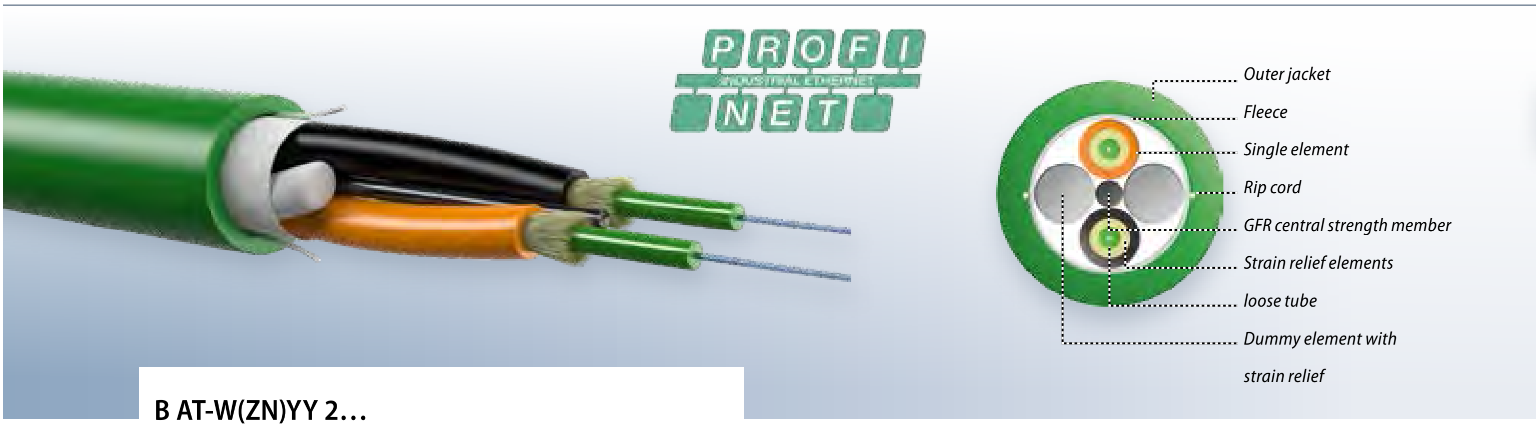
Min. bending radius	dynamic	50 mm (over flat side)

Fire performance

No requirements.

Number of tubes	Total width	Weight	Order no.
	mm	kg/km	
4	10.0	20	**84950772** ☐
6	14.0	30	**84950773** ☐
8	19.0	40	**84950774** ☐
12	27.0	60	**84950776** ☐

FiberConnect® Profinet type B duplex indoor cable



B AT-W(ZN)YY 2…

Order no.	**84950544** ☐
Standardisation	PROFINET standard

Description

Bus cable for PROFINET applications in industrial settings for fixed installation in cable ducts and conduits.

Composition

Cable core	Stranding consistant of two PVC single cables with buffered fibers 1.4 mm and non-metallic strain reliefs elements (Aramid) (Ø 2.9 mm)
Cable jacket	Flame retardant poly vinyl chloride (PVC)
Colour of jacket	● black and ● orange (with printed arrows)

Thermal properties

Transport/storage	– 20 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 70 °C

Mechanical properties

Outer dimensions		9.2 mm
Weight		72 kg/km
Min. bending radius	static	90 mm
	dynamic	135 mm
Max. pull force		600 N
Max. crush resistance		500 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2

Chemical properties

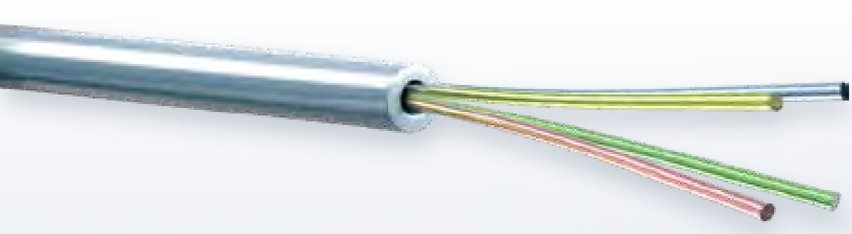
good resistance to oil, petrol, acids and alkaline solutions.

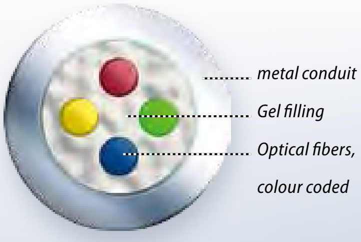
Note

The cable is also available with a polyurethane (PUR) jacket.

FiberConnect® Stainless steel conduit

with optical fibers





Stainless steel conduit n…

Order no.	**see table**
Standardisation	IEC 60794-4

The optimum solution for protecting the fibers from oil and water

Description

For use in optical ground wires (OPGW) as well as for environments with aggressive media and high mechanical loads.

Composition

- Optical fibers, colour coded
- Gel filling
- Longitudinally welded, hermetically sealed metal conduit made from stainless steel
- DIN 17441, Type 1.4301 or ASTM 304
- Thickness 0.2 mm, diameter see table

Thermal properties

Transport/storage	– 40 °C to + 80 °C
Installation	– 20 °C to + 80 °C
Operating temperature	– 40 °C to + 80 °C

Mechanical properties

Min. bending radius	see table
Max. pull force	see table

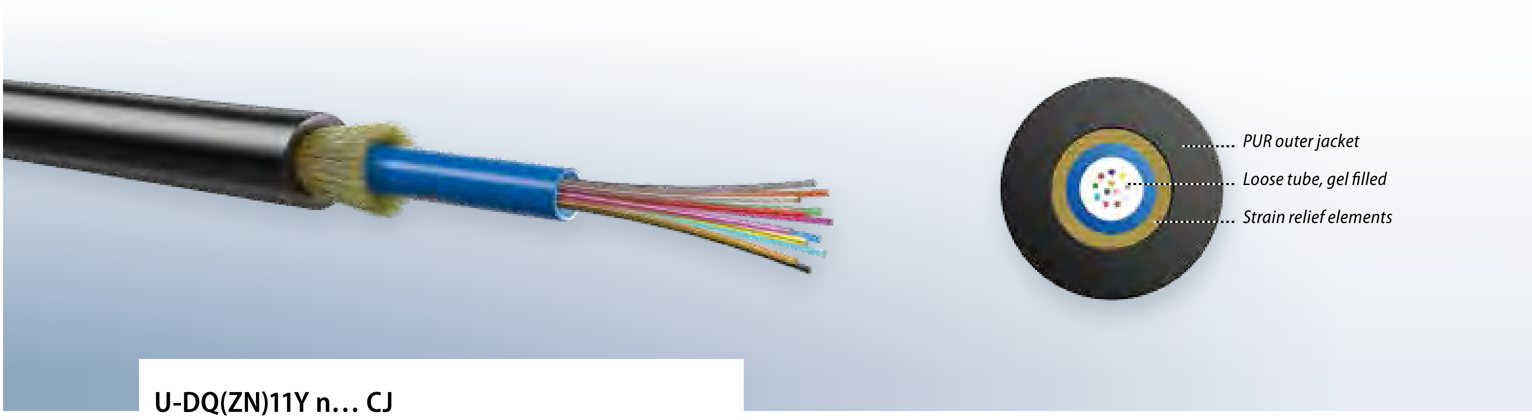
Note

- Also available without gel filling
- Fibers with polyimide coating can be used
- Conduits with copper coating on request
- Conduits with silicone cladding on request

Number of fibers	Rohr-Ø	Weight	Min. bending radius	Max. pull force	Order no.
	mm	kg/km	mm	N	
2	1.17	6.5	50	150	**84950802** ☐
2	1.45	7.3	70	190	**84950806** ☐
4		7.3	70	190	**84950808** ☐
2	1.80	11.2	80	230	**84950810** ☐
4		11.2	80	230	**84950812** ☐
2	2.00	12.5	80	260	**84950818** ☐
4		12.5	80	260	**84950820** ☐
2	2.20	13.5	90	290	**84950822** ☐
4		13.5	90	290	**84950824** ☐
2	3.20	21.5	100	420	**84950827** ☐
4		21.5	100	420	**84950829** ☐
6		21.5	100	420	**84950831** ☐

Fiber**Connect**® Central loose tube cable

with leak-proof, cross-linked gel filling



U-DQ(ZN)11Y n… CJ

Order no.	**84 057** □□ □ □
Standardisation	IEC 60794-2

Description

Especially suited as a longitudinally waterproof optical universal cable for mobile use for constant reeling in and out as well as in drag chains.

Composition

Cable core	Loose tube, gel-filled with cross-linked two-component gel
Strain relief	Aramid yarns
Cable jacket	Polyurethane (PUR)
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 25 °C to + 50 °C
Operating temperature	– 25 °C to + 70 °C

Number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	6.5	36	0.55
24	7.7	50	0.76

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		2500 N
Max. crush resistance		3000 N/dm
Resistance to impacts		5 impacts/2 Nm

Fire performance

Cable is flame retardant.

Chemical properties

Very good resistance to oil, petrol, acids and alkaline solutions.

2-component gel cable

The cross-linked gel fixes the excess length of the fibers in the loose tube so there is no localised banking up of the excess lengths during movement.

This design is therefore especially suited as a longitudinally watertight optical universal cable for mobile use for constant reeling in and out as well as in drag chains. The cross-linked gel retains its consistency even at high temperatures, thereby preventing the gel leaking out when dealing with installation distances with big drops or with vertical installation.

Splice trays filling up with gel and sagging fibers are therefore a thing of the past.

Further basic information on fire prevention and test methods:
Chapter 12 | Principles
→ page 385 ff.

FiberConnect® Office cables

Office cabling is typically divided into primary, secondary and tertiary cabling. Indoor and universal cables are frequently used in the secondary and tertiary areas.

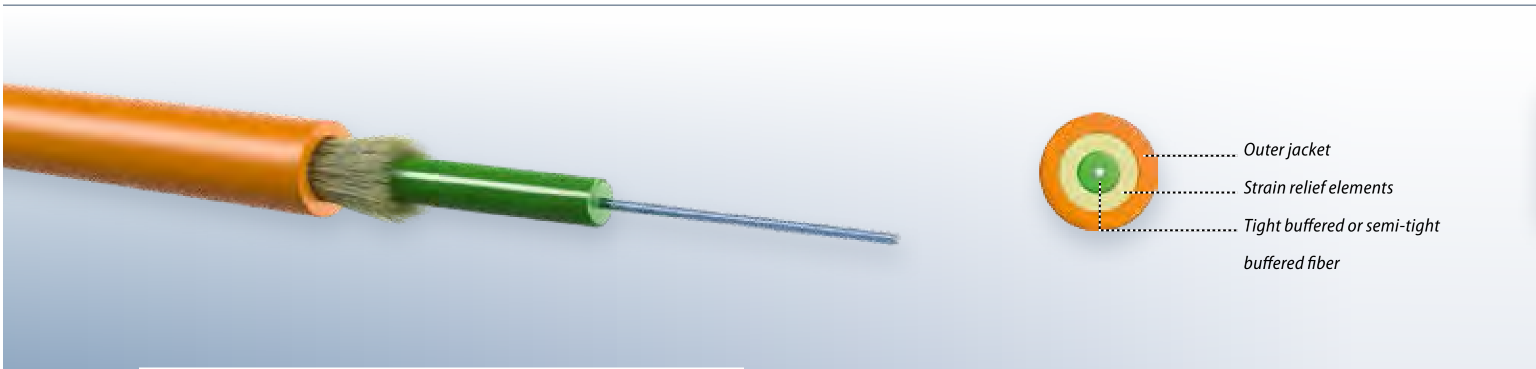
FiberConnect® optical indoor cables are ideally suited to the manufacturing of assembled connection cables for all conceivable cabling structures and network topologies. Either multimode fibers with different specifications or singlemode fibers are used for these cables, depending on the required data rate and the distance to be covered.

Optical indoor cables with a halogen-free and flame-retardant jacket are required in order to fulfil the strict fire prevention requirements for indoor installations, since they are guaranteed not to propagate fire and not to produce corrosive and toxic gases.

Flexibility, greatly reduced weight, small outer diameter and ruggedness are some of the differing requirements depending on the field of application that are fulfilled with cables from the FiberConnect® series.

The range of FiberConnect® optical indoor cables includes simplex and duplex cables, mini breakout cables as well as flat and round breakout cables.

Fiber**Connect**® **Simplex cable**



I-V(ZN)H 1…

Order no.	**84**□□□ □□ □ □
Standardisation	IEC 60794-2

Description

Ideal for use as a patch cable in distribution systems as well as for connecting terminals due to the high flexibility and small diameter.

Composition

Cable core	tight buffered (TB) or semi-tight buffered fiber (STB)
Strain relief	Non-metallic (aramid)
Cable jacket	Halogen-free and flame-retardant material
Colour of jacket	● orange for multimode ● yellow for singlemode ➔ other colours possible

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

Min. bending radius	static	30 mm
	dynamic	60 mm

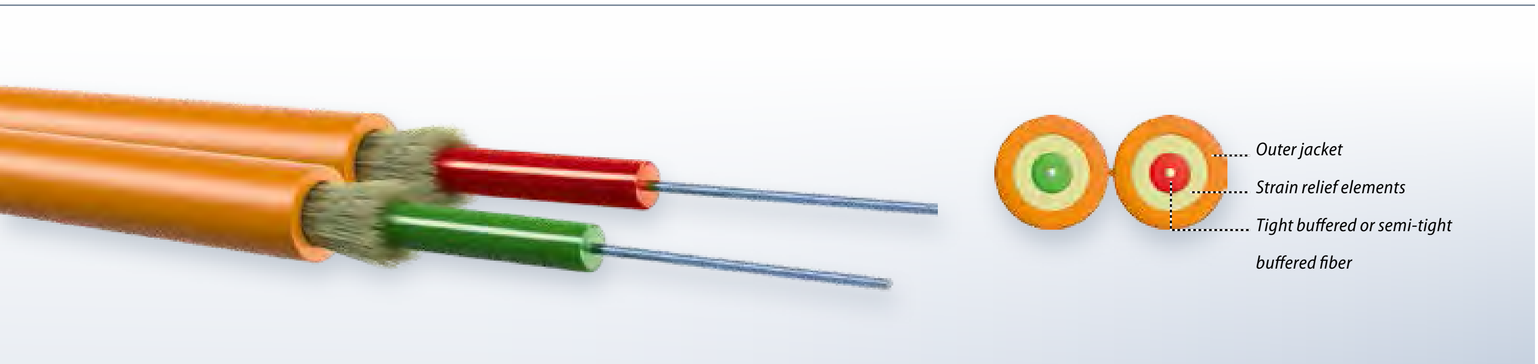
Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Outer Ø	Type	Weight	max. pull force long-term	max. - crush resistance long-term	Fire load	Order no. TB	Order no. STB
mm		kg/km	N	N/dm	MJ/m		
1.6	I-V(ZN)H 1…	2.9	200	100	0.09	**84950216**□ **TB600L**	**84950878**□ **STB600**
1.8	I-V(ZN)H 1…	3.7	200	100	0.10	**84950559**□ **TB900L**	**84950212**□ **STB900**
2.0	I-V(ZN)H 1…	5.0	300	100	0.11	**8404200L**□ **TB900L**	**84042001**□ **STB900**
2.1	I-V(ZN)H 1…	5.1	300	100	0.12	**8405600L**□ **TB900L**	**84056001**□ **STB900**
2.4	I-V(ZN)H 1…*	5.7	400	150	0.16	**84950846**□ **TB900L**	**84950007**□ **STB900**
2.8	I-V(ZN)H 1…	7.9	400	150	0.18	**8400300L**□ **TB900L**	**84003001**□ **STB900**
3.0	I-V(ZN)H 1…	8.1	400	150	0.21	**84950560**□ **TB900L**	**84950347**□ **STB900**
3.4	I-V(ZN)H 1…*	12.0	400	150	0.32	**84950770**□ **TB900L**	**84950194**□ **STB900**

* according to TS 0011/96 Deutsche Telekom

FiberConnect® Duplex cable



I-V(ZN)H 2×1…

Order no.	**84**□□□ □□ □ □
Standardisation	IEC 60794-2

Description

Ideal for use as a patch cable in distribution systems as well as for connecting terminals due to the high flexibility and small diameter.

Composition

Cable core	Tight buffered (TB) or semi-tight buffered fiber (STB)
Strain relief	Non-metallic (aramid)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● orange for multimode ● yellow for singlemode ➔ other colours possible

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

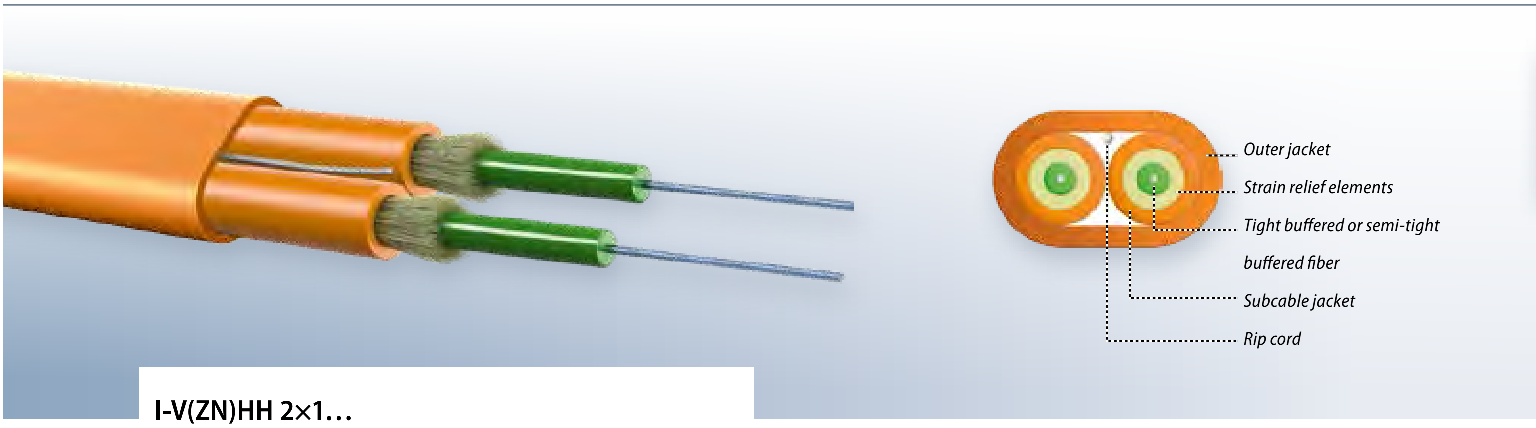
Min. bending radius	static	30 mm
	dynamic	60 mm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Outer Ø	Type	Weight	max. pull force long-term	max. - crush resistance long-term	Fire load	Order no. TB	Order no. STB
mm		kg/km	N	N/dm	MJ/m		
1.6 × 3.3	I-V(ZN)H 2×1…	5.8	400	200	0.18	84950867□ TB600L	84950877□ STB600
1.8 × 3.7	I-V(ZN)H 2×1…	7.4	400	200	0.20	84950869□ TB600L	84950199□ STB600
1.8 × 3.7	I-V(ZN)H 2×1…	7.4	400	200	0.20	84950875□ TB900L	84950□□□□ STB900
2.0 × 4.1	I-V(ZN)H 2×1…	9.0	400	200	0.22	8400401L□ TB900L	84004011□ STB900
2.1 × 4.3	I-V(ZN)H 2×1…	9.0	400	400	0.24	84950479□ TB900L	84950235□ STB900
2.35 × 4.8	I-V(ZN)H 2×1…	12.6	400	400	0.31	84950076□ TB900L	84950253□ STB900
2.8 × 5.7	I-V(ZN)H 2×1…	15.8	600	600	0.36	8400501L□ TB900L	84005011□ STB900
3.0 × 6.1	I-V(ZN)H 2×1…	17.5	600	600	0.42	84950876□ TB900L	84950250□ STB900

FiberConnect® Breakout cable, flat



I-V(ZN)HH 2×1…

Order no.	**84**□□□ □□ □ □
Standardisation	IEC 60794-2

Description

Light, thin and rugged indoor cable for use as a patch cable in distribution systems, as connection cable for terminals as well as for workstation cabling. For direct connector assembly.

Composition

Cable core	Two single-fiber cables (TB or STB) arranged in parallel beside each other with non-metallic strain relief elements (aramid) and a halogen-free, flame-retardant subcable jacket (Ø see table)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● orange for multimode ● yellow for singlemode

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

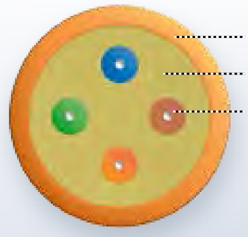
Min. bending radius (over flat side)	static	35 mm
	dynamic	65 mm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Single element	Cable outer dimensions	Type	Weight	max. pull force long-term	max. - crush resistance long-term	Fire load	Order no. TB	Order no. STB
mm	mm		kg/km	N	N/dm	MJ/m		
1.7	2.8 × 4.5	I-V(ZN)HH 2×1…	16.5	400	400	0.58	84950881□ TB600L	84950887□ STB600
1.8	2.9 × 4.7	I-V(ZN)HH 2×1…	17.5	400	400	0.60	84950882□ TB600L	84950886□ STB600
2.0	3.1 × 5.2	I-V(ZN)HH 2×1…	19.0	600	400	0.63	84070□□□ TB900L	84070□□□ STB900
2.1	3.1 × 5.2	I-V(ZN)HH 2×1…	19.0	600	400	0.63	84017□□□ TB900L	84017□□□ STB900
2.5	3.7 × 6.2	I-V(ZN)HH 2×1…	26.0	600	600	0.65	8401101L□ TB900L	84011011□ STB900
2.8	4.0 × 6.8	I-V(ZN)HH 2×1…	32.0	600	600	0.83	8401201L□ TB900L	84012011□ STB900

FiberConnect® Mini breakout cable



I-V(ZN)H n…

Order no.	**84 026** ☐☐ ☐ ☐ with UV resistant FRNC material: **84 039** ☐☐ ☐ ☐
Standardisation	IEC 60794-2

Description

Ideal for workstation cabling due to the high flexibility and small dimensions. Non-metallic indoor cable for direct connector assembly.

Composition

Cable core	Tight buffered (TB) or semi-tight buffered fiber (STB)
Strain relief	Non-metallic (aramid)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● orange for multimode ● yellow for singlemode

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 5 °C to + 70 °C

Mechanical properties

Max. pull force	800 N
Max. crush resistance	500 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of fibers	Outer Ø	Weight	Min. bending radius static	Min. bending radius dynamic	Fire load
	mm	kg/km	mm	mm	MJ/m
2	4.2	14	40	65	0.45
4	5.6	21	55	85	0.47
6	5.9	25	60	90	0.50
8	6.1	30	60	90	0.52
12	7.0	38	70	95	0.55
16	8.4	59	85	120	0.74
24	9.4	72	95	135	0.92

All mini breakout cables available with TB and STB fibers
Order no. on request

Fiber optic cables (SM / MM)

FiberConnect® Breakout cable

I-V(ZN)HH n…

Order no.	**see table**
Standardisation	IEC 60794-2

Description

Non-metallic, rugged cable for installation in the riser and horizontal indoor area. For direct connector assembly.

Composition

Cable core	Stranded single elements designed as tight buffered fiber (TB) or semi-tight buffered fiber (STB) with non-metallic strain relief elements (aramid) and halogen-free, flame-retardant subcable jacket (Ø see table)
Cable jacket	halogen-free, flame-retardant material
Colour of jacket	● orange for multimode ● yellow for singlemode

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Note

The cable is alternatively available with non-metallic rodent protection (B).

09

Single cable with 1.8 mm Ø, buffered fiber: TB600, tight buffered fiber with Ø 600 µm

Order no. **84 015 ☐☐ Z ☐**

Number of fibers	Outer Ø	Weight	Min. bending radius static	Min. bending radius dynamic	Max. pull force long-term	Max. crush resistance long-term	Fire load
	mm	kg/km	mm	mm	N	N/dm	MJ/m
2	6.0	35	60	85	600	800	0.63
4	6.0	35	60	85	600	800	0.63
6	6.9	47	70	105	800	800	0.89
8	8.3	69	85	125	800	800	1.22
10	9.9	105	100	150	800	800	2.01
12	11.0	119	110	165	800	800	2.37
16	10.7	106	110	160	1000	800	2.03
18	11.3	116	115	170	1000	800	2.27
20	11.7	129	120	180	1200	800	2.54
24	12.9	162	130	200	1200	800	3.11
48	17.2	245	175	260	1200	800	5.43

Single cable with 2.0 mm Ø, tight buffered fiber, semi-tight buffered fiber or superstrip fiber with 900 µm

Order no. **84 054 □□ L□ (TB900L) | 84 054 □□ 1□ (STB900) | 84 054 □□ 7□ (STB900H)**

Number of fibers	Outer Ø	Weight	Min. bending radius static	Min. bending radius dynamic	Max. pull force long-term	Max. crush resistance long-term	Fire load
	mm	kg/km	mm	mm	N	N/dm	MJ/m
2	6.8	45	70	105	800	1000	1.08
4	6.8	45	70	105	800	1000	1.08
6	8.0	60	80	120	1000	1000	1.15
8	9.4	85	95	145	1000	1000	1.28
10	10.8	125	110	165	1000	1000	1.39
12	12.3	150	125	190	1000	1000	1.54
16	11.6	140	120	180	1000	1000	1.56
18	12.6	160	130	195	1000	1000	1.88
20	14.1	180	145	220	1000	1000	2.07
24	14.2	200	150	225	1000	1000	2.23

Single cable with 2.1 mm Ø, tight buffered fiber, semi-tight buffered fiber or superstrip fiber with Ø 900 µm

Order no. **84 013 □□ L□ (TB900L) | 84 013 □□ 1□ (STB900) | 84 013 □□ 7□ (STB900H)**

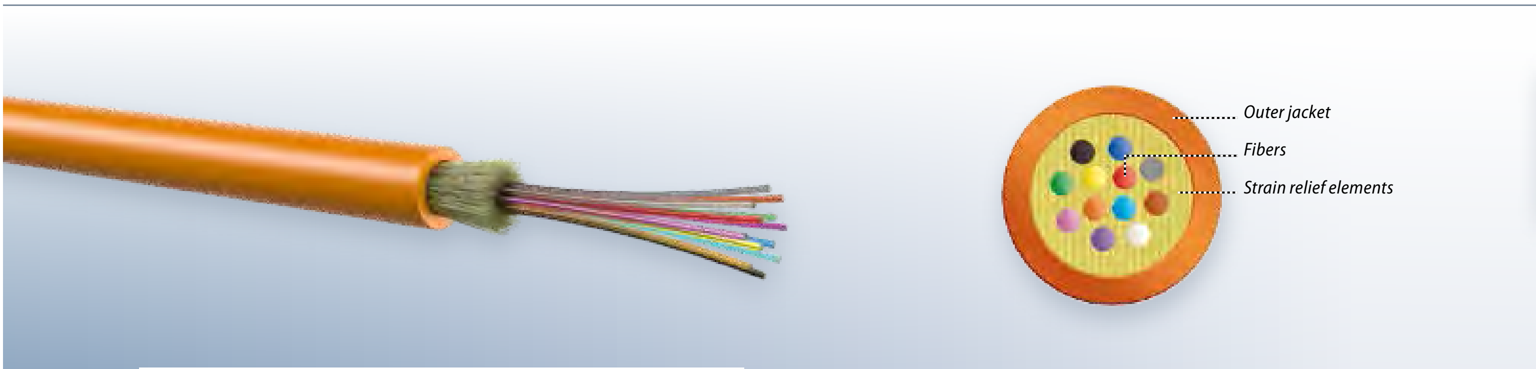
Number of fibers	Outer Ø	Weight	Min. bending radius static	Min. bending radius dynamic	Max. pull force long-term	Max. crush resistance long-term	Fire load
	mm	kg/km	mm	mm	N	N/dm	MJ/m
2	7.0	40	70	105	800	1000	1.10
4	7.0	45	70	105	800	1000	1.10
6	8.2	65	80	120	1000	1000	1.18
8	9.8	95	95	145	1000	1000	1.31
10	11.0	135	110	165	1000	1000	1.42
12	12.5	155	125	190	1000	1000	1.57
16	12.0	140	120	180	1000	1000	1.62
18	13.0	160	130	195	1000	1000	2.00
20	14.5	205	145	220	1000	1000	2.10
24	15.0	210	150	225	1000	1000	2.35

Single cable with 2.5 mm Ø, tight buffered fiber, semi-tight buffered fiber or superstrip fiber with Ø 900 µm

Order no. **84 010 □□ L□ (TB900L) | 84 010 □□ 1□ (STB900) | 84 010 □□ 7□ (STB900H)**

Number of fibers	Outer Ø	Weight	Min. bending radius static	Min. bending radius dynamic	Max. pull force long-term	Max. crush resistance long-term	Fire load
	mm	kg/km	mm	mm	N	N/dm	MJ/m
2	7.5	45	75	115	800	1500	1.20
4	7.5	50	75	115	800	1500	1.20
6	9.0	75	90	135	1200	1500	1.36
8	11.0	110	110	165	1200	1500	1.52
10	13.0	160	130	195	1200	1500	1.68
12	14.5	182	145	215	1200	1500	1.80
16	14.0	160	140	210	1200	1500	1.84
18	14.5	175	145	215	1200	1500	1.92
20	16.0	225	160	240	1200	1500	2.16
24	17.0	245	175	260	1200	1500	2.48

FiberConnect® Indoor cable for multifiber connectors



I-F(ZN)H n…

Order no.	**84 071** □□ □ □
Standardisation	IEC 60794-2

Description

For fixed installation in cable ducts and conduits as well as for shunting purposes. Suitable for direct connector assembly on MTP® connectors/MP0®connector suitable.

Composition

Cable core	(2–24) optical fibers
Strain relief	Non-metallic (aramid)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● orange for multimode ● yellow for singlemode

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

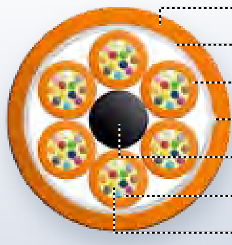
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. crush resistance		150 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Max. Number of fibers	Outer-Ø	Wall thickness	Weight	max. Pull force	Fire load
	mm	mm	kg/km	N	MJ/m
8	2.8	0.5	7	300	0.12
12	3.0	0.5	8	300	0.14
24	4.5	1.0	18	450	0.31

FiberConnect® Indoor cable for multifiber connectors



I-F(ZN)HH n×m… 3.0

Order no.	**84 021** □□ □ □
Standardisation	IEC 60794-2

Description

Splittable indoor cable for fixed installation in cable ducts and conduits. Suitable for direct connector assembly on MTP® or MPO® connectors.

Composition

Cable core	GFR central strength member in the core, over that single elements stranded in layers (2–12) 12 optical fibers in a single element with Ø 3.0 mm
Strain relief	Non-metallic (aramid)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● orange

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

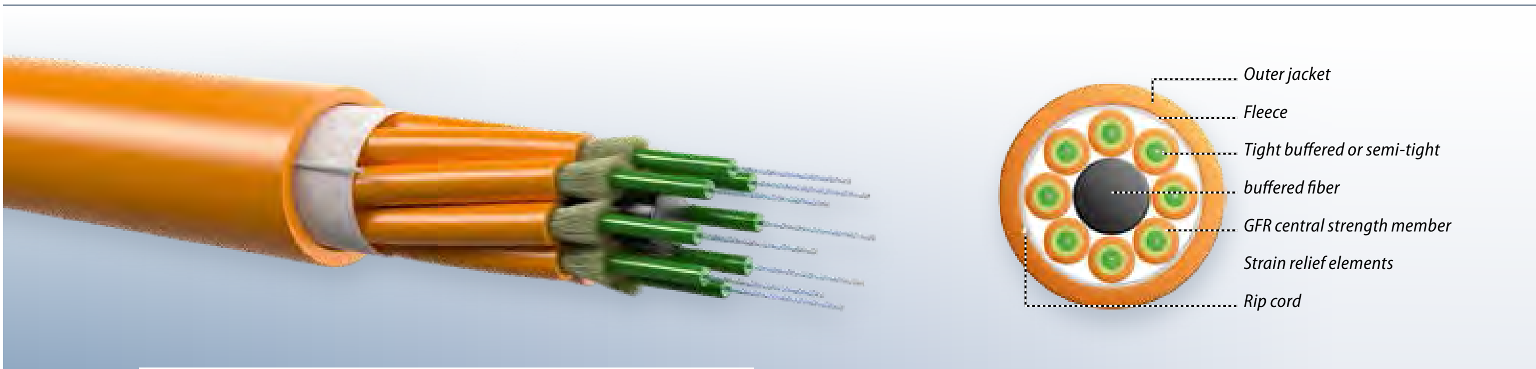
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. crush resistance		1000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Single elements	Outer Ø	Wall thickness	Weight	max. Pull force	Fire load
	mm	mm	kg/km	N	MJ/m
2	8.9	0.8	70	800	1.16
4	8.9	0.8	70	800	1.16
6	10.8	0.8	100	1000	1.71
8	13.1	0.9	150	1000	2.57
10	14.6	0.9	185	1000	3.69
12	16.5	0.9	230	1000	4.96

FiberConnect® Breakout cable with central strength member



AT-V(ZN)HH n… 2.1

Order no.	**84 213** □□ □ □
Standardisation	IEC 60794-2

Description

Splittable outdoor cable for fixed installatin in cable ducts and conduits. Suitable for direct connector assembly.

Composition

Cable core	GFR central strength member in the core, over that single elements designed as tight buffered(TB) and semi-tight buffered (STB) fiber, gel filled with non-metallic strain relief elements (Aramid) and a halogen-free, flame retardant subcable jacket (Ø 2.1 mm), stranded in layers (2–24)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● orange for multimode ● yellow for singlemode

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 25 °C to + 70 °C

Mechanical properties

Min. bending radius	static	10 × outer diameter
	dynamic	15 × outer diameter
Max. crush resistance		1000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of fibers	Outer Ø	Wall thickness	Weight	Fire load	Pull force
	mm	mm	kg/km	MJ/m	N
2	7.0	0.9	40	1.10	800
4	7.0	0.9	45	1.10	800
6	8.2	0.9	65	1.18	1000
8	9.6	0.9	95	1.31	1000
10	11.0	1.0	135	1.42	1000
12	12.5	1.0	135	1.57	1000
16	12.0	1.0	140	1.62	1000
18	13.0	1.0	160	2.00	1000
20	14.5	1.0	205	2.10	1000
24	15.0	1.0	210	2.35	1000
26	15.5	1.0	225	2.45	1000
36	17.6	1.1	300	3.89	1000

Further basic information on fire prevention and test procedures:
Chapter 12 | Principles
→ page 385 ff.

Fiber**Connect**® Outdoor cables

Optical outdoor cables are used in the campus area of local networks (LAN) as well as for bridging over the long distances in the MAN (Metropolitan Area Network) and WAN (Wide Area Network).

Especially high mechanical demands with regard to ruggedness and resistance are placed on outdoor cables to guarantee stability with respect to environmental influences such as frost and humidity. The Business Unit Fiber Optics offers the right cable for different ambient conditions.

Non-metallic or metallic armour protects the fibers against destruction by rodents and serves as a humidity barrier. The standard outer jacket made of black PE (Polyethylenee) is halogen-free and UV-resistant

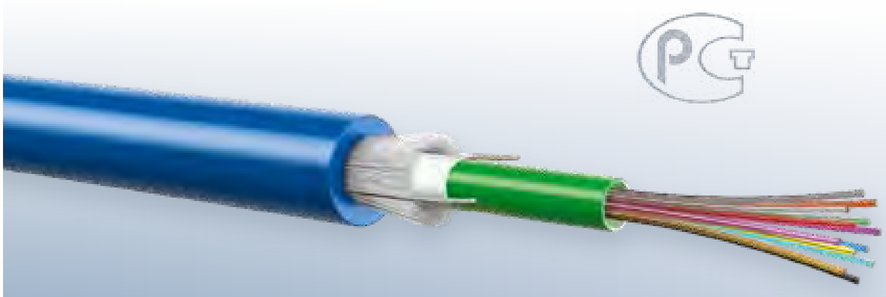
Universal cables that can be used both indoors and outdoors are frequently recommended for the primary and secondary cabling for local networks (LAN). The universal field of application of these cables avoids interfaces between the campus area and the buildings and does away with the time-consuming splicing, thereby reducing installation times and costs. Universal cables must therefore meet both the requirements profile for outdoor cables as well as the strict fire prevention requirements for indoor cables.

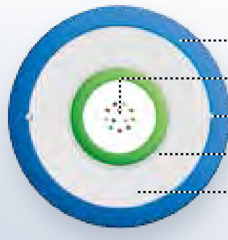
Universal cables with an integrated metallic humidity barrier are also offered for this as appropriate to the environment and installation conditions. Universal cables with an aluminium jacket or corrugated steel jacket are suitable for running directly in the ground, doing away with the need to use a HDPE protective conduit. The halogen-free and flame-retardant cable jackets of the Fiber-Connect® optical universal cables guarantee adherence with the strict fire prevention requirements for cables for indoor use.

LEONI

FiberConnect® Universal cable with functional integrity 90 min

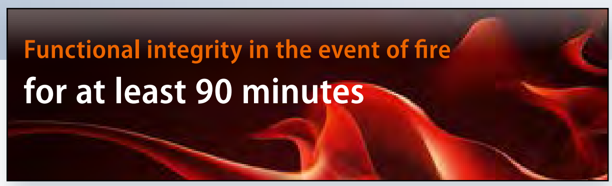
rodent protected , with central multi-fiber loose tube (2500 N)





U-D(ZN)BH n…FS

Order no.	**84 040** □□ □ □
Standardisation	IEC 60794-2



Description

Non-metallic, light and flexible cable with increased tensile strength that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.

Composition

Cable core	Loose tube, gel-filled inner fire protection tape
Armour	Multifunctional reinforced glass rovings, moisture blocking, as non-metallic strain relief elements and rodent protection
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● blue

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		2500 N
Max. crush resistance		3000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

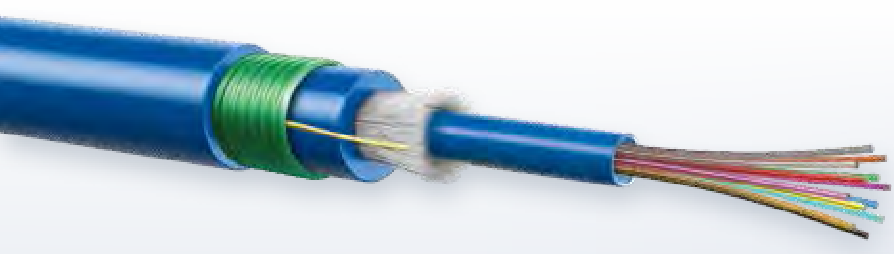
Functional integrity test

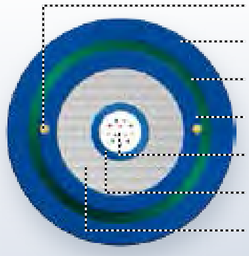
Acc. to IEC 60 331-11, IEC 60 331-25 and EN 50200 90 min (VDE test report).

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	10.3	115	1.03
24	10.8	125	1.28

FiberConnect® Universal cable with functional integrity 120 min

rodent protected and transversely waterproof ,
with central multi-fiber loose tube (2500 N)





U-DQ(ZN)H(SR)H n… FS

Order no.	84 047 ☐☐ ☐ ☐
Standardisation	IEC 60794-2

Functional integrity in the event of fire
for at least 120 minutes

Description

Mechanically rugged cable with increased tensile strength that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.

Composition

Cable core	Loose tube, gel-filled inner fire barrier
Strain relief	Non-metallic (glass rovings), moisture blocking
Inner jacket	Halogen-free and flame-retardant
Corrugated steel conduit	as fire barrier and rodent protection
Outer jacket	Halogen-free, flame-retardant material
Colour of jacket	● blue

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		2500 N
Max. crush resistance		2500 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

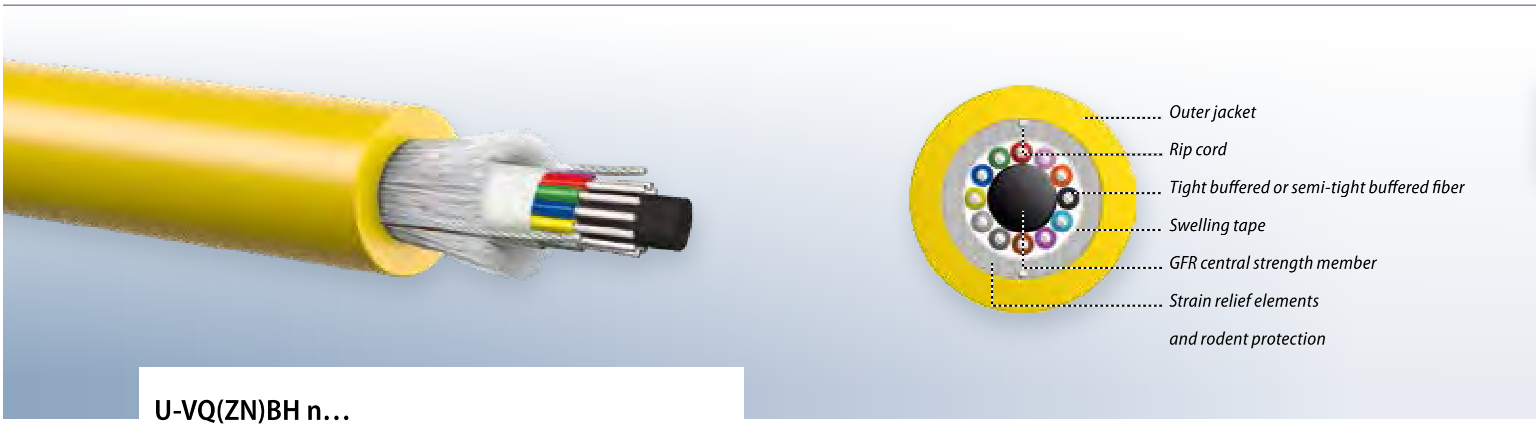
Functional integrity test

Acc. to IEC 60 331-11, IEC 60 331-25 and EN 50200
120 min (VDE test report).

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	12.5	215	2.8
24	12.5	215	2.8

FiberConnect® Universal cable with stranded tight buffered fibers

rodent-protected



U-VQ(ZN)BH n…

Order no.	**84** □□□ □□ □ □
	with UV-resistant FRNC material: **84 045** □□ □ □
Standardisation	IEC 60794-2

Description

Cable for use inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits. Non-metallic universal cable for direct connector assembly.
Suitable for all types of installation in protective conduits.

Composition

Cable core	GFR central strength member with stranding elements, designed as tight buffered (TB) or semi-tight buffered (STB) fiber and, if applicable, dummy elements.
Armour	Multifunctional reinforced glass rovings moisture-blocking as non-metallic strain relief elements and rodent protection
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	yellow

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Mechanical properties

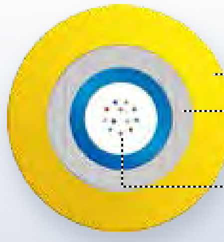
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		2500 N
Max. crush resistance		1000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of fibers	Outer Ø	Weight	Fire load	Order no.		Order no.	
	mm	kg/km	MJ/m	TB		STB	
4	9.4	130	1.03	84950890□	TB900L	84950495□	STB900
6	9.4	130	1.03	84950251□	TB900L	84950910□	STB900
8	9.4	130	1.03	84950891□	TB900L	84950712□	STB900
10	9.8	145	1.21	84950892□	TB900L	84950911□	STB900
12	9.8	145	1.21	84950893□	TB900L	84950522□	STB900
16	10.8	150	1.37	84950906□	TB900L	84950912□	STB900
20	10.8	150	1.37	84950895□	TB900L	84950913□	STB900
24	11.1	155	1.44	84950896□	TB900L	84950914□	STB900

FiberConnect® Universal cable with central multi-fiber loose tube (1750 N) rodent-protected



U-DQ(ZN)BH n… 1750 N

Order no.	**84 025** □□ □ □ with UV resistant FRNC material: UV **84 043** □□ □ □ with material suited for direct burial: **84 068** □□ □ □
Standardisation	IEC 60794-2

Description

Non-metallic, light and flexible cable that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.

Composition

Cable core	L oose tube, gel-filled
Armour	Multifunctional glass rovings, moisture blocking as non-metallic strain relief elements and rodent protection
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● yellow

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Mechanical properties

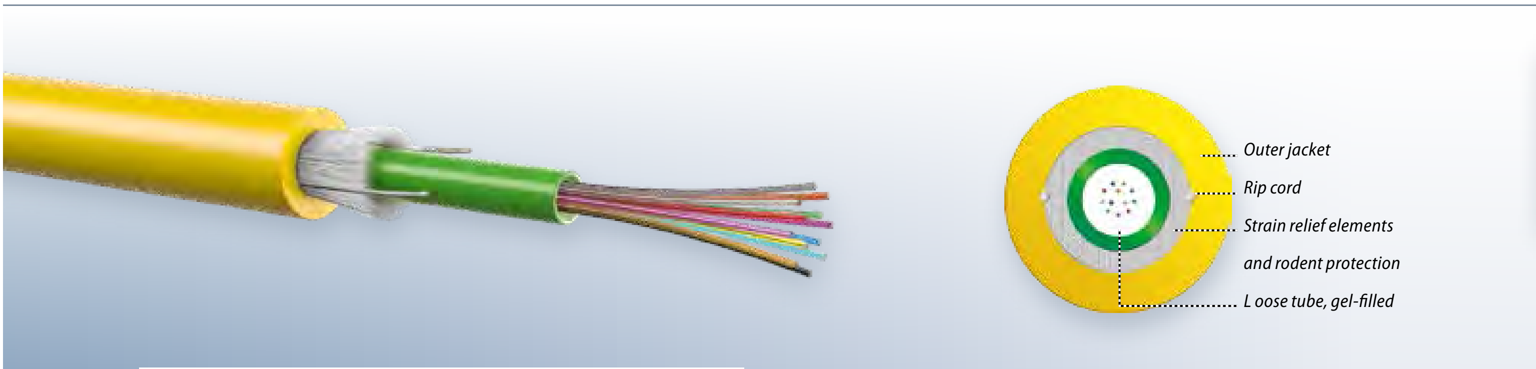
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		1750 N
Max. crush resistance		1500 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. C
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	7.0	55	0.71
24	7.5	60	0.79

Fiber**Connect**® Universal cable with central multi-fiber loose tube (2500 N) rodent-protected



U-DQ(ZN)BH n… 2500 N

Order no.	**84 032** ☐☐ ☐ ☐ with UV resistant FRNC material: **84 076** ☐☐ ☐ ☐ with material suited for direct burial: **84 052** ☐☐ ☐ ☐
Standardisation	IEC 60794-2

Description

Non-metallic, light and flexible cable with increased tensile strength that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.

Composition

Cable core	Loose tube, gel-filled
Armour	multifunctional, reinforced glass rovings, moisture blocking as non-metallic strain relief elements and rodent - protection
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	yellow

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	9.2	100	1.25
24	9.7	110	1.34

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

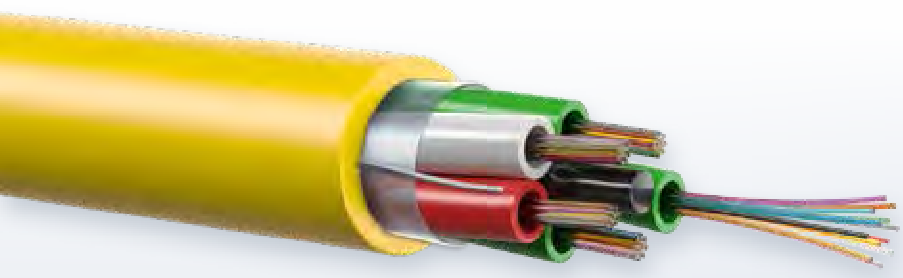
Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		2500 N
Max. crush resistance		3000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

FiberConnect® Universal cable with stranded multi-fiber loose tubes



U-DH n×m…

Order no.	84 029 □□ □ □ with UV resistant FRNC material: 84 049 □□ □ □
Standardisation	IEC 60794-2

Description

Non-metallic cable, can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.

Composition

Cable core	GFR strength members with stranding elements, designed as loose tubes and, if applicable, dummy elements
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	yellow

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 × m	**12**	10.5	105	2.2
2 × m	**24**	10.5	105	2.2
3 × m	**36**	10.5	105	2.2
4 × m	**48**	10.5	105	2.2
5 × m	**60**	10.5	105	2.2
6 × m	**72**	11.0	125	2.6
8 × m	**96**	12.4	145	3.0

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

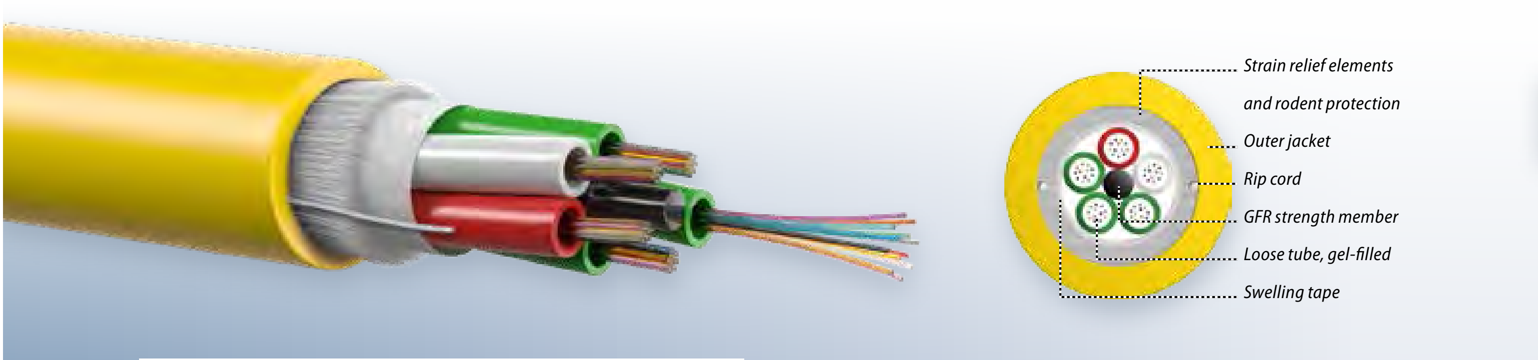
Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		1500 N
Max. crush resistance		2000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

FiberConnect® Universal cable with stranded multi-fiber loose tubes rodent-protected



U-DQ(ZN)BH n×m…

Order no.	**84 033** ☐☐ ☐ ☐ with UV resistant FRNC material: UV **84 044** ☐☐ ☐ ☐ with material suited for direct burial: **84 055** ☐☐ ☐ ☐
Standardisation	IEC 60794-2

Description

Non-metallic cable, can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.

Composition

Cable core	GFR strength member with stranding elements, desiged as loose tubes and, if appliccable, dummy elements.
Armour	multifunctional reinforced glass rovings moisture blocking as non-metallic strain relief elements and rodent protection
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	yellow

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		6000 N
Max. crush resistance		3000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

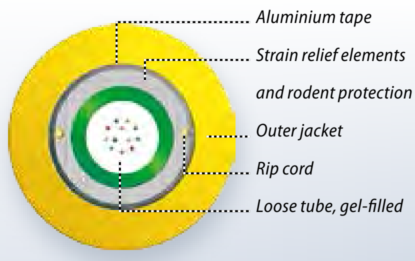
Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 × m	**12**	12.5	185	3.1
2 × m	**24**	12.5	185	3.1
3 × m	**36**	12.5	185	3.1
4 × m	**48**	12.5	185	3.1
5 × m	**60**	12.5	185	3.1
6 × m	**72**	13.4	200	3.2
8 × m	**96**	14.4	225	3.4
10 × m	**120**	15.9	250	3.7
12 × m	**144**	17.7	305	4.5

All rodent-protected universal cables with stranded multi-fiber loose tubes are also availble in designs with different pull forces.

Pull force	Order no.
4000 N	84069 ☐☐ ☐ ☐
6000 N	84033 ☐☐ ☐ ☐
9000 N	84058 ☐☐ ☐ ☐

FiberConnect® Universal cable with central multi-fiber loose tube

transversely waterproof



U-DQ(ZN)(L)H n…

Order no.	84 034□□ □ □

Description

Can be used both inside and outside buildings. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.

Composition

Cable core	Loose tube, gel-filled
Strain relief	non-metallic (glass rovings), moisture blocking
Aluminium taping	as absolute moisture barrier
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● yellow

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		2500 N
Max. crush resistance		1000 N/dm

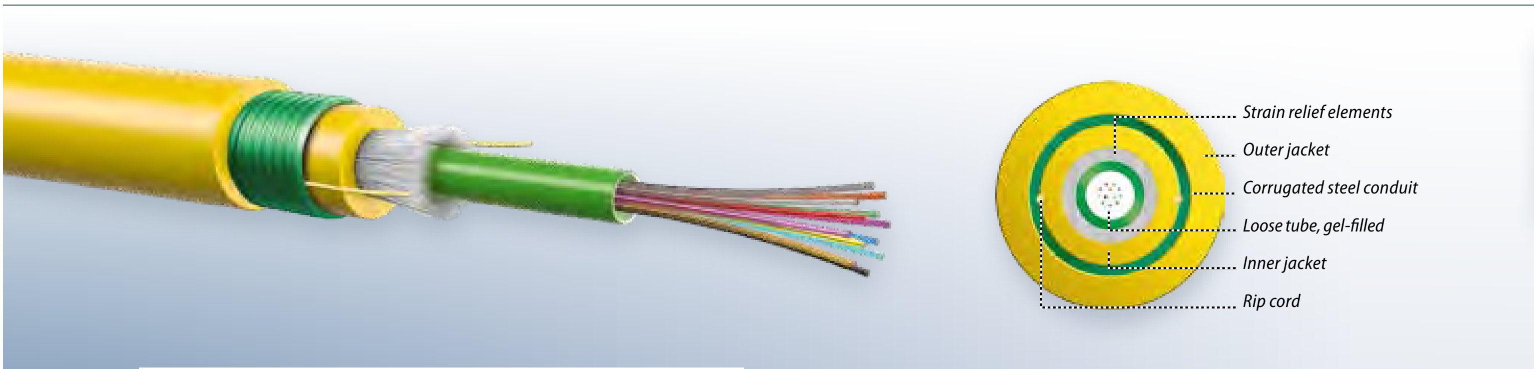
Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	10.8	160	1.50
24	11.3	165	1.57

FiberConnect® Universal cable with central multi-fiber loose tube

rodent-protected, transversely waterproof



U-DQ(ZN)H(SR)H n…

Order no.	**84 051** ☐☐ ☐ ☐ with UV resistant FRNC material: **84 044** ☐☐ ☐ ☐ with material suited for direct burial: **84 062** ☐☐ ☐ ☐

Description

Can be used both inside and outside buildings. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.

Composition

Cable core	Loose tube, gel-filled
Strain relief	non-metallic (glass rovings), moisture blocking
Inner jacket	halogen-free, flame-retardant corrugated
steel conduit	as highly effective rodent protection
Outer jacket	Halogen-free, flame-retardant material
Colour of jacket	● yellow

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	12.5	215	2.80
24	12.5	215	2.80

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Mechanical properties

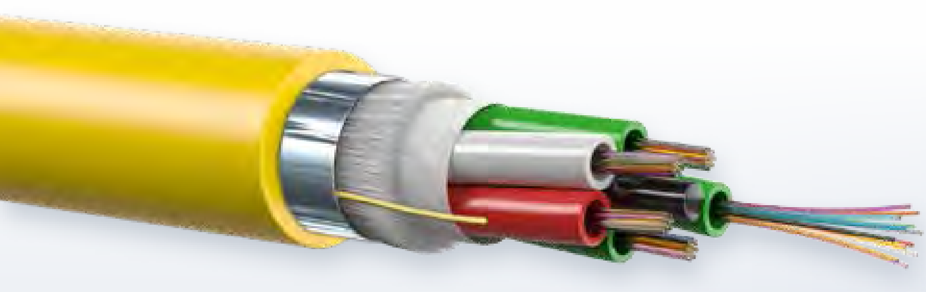
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		2500 N
Max. crush resistance		2500 N/dm

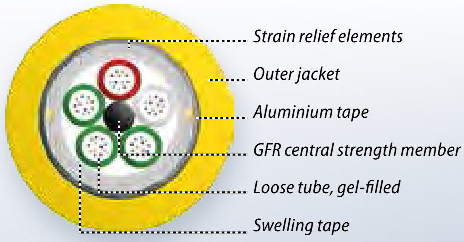
Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

FiberConnect® Universal cable with stranded multi-fiber loose tubes

transversely waterproof





U-DQ(ZN)(L)H n×m…

Order no.	**84 035** □□ □ □
	with UV resistant FRNC material: **84** □□□ □□ □ □

Description

Can be used both inside and outside buildings. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.

Composition

Cable core	GFR central strength member with stranding elements designed as gel-filled loose tubes and, if applicable, dummy elements
Strain relief	non-metallic (glass rovings), moisture blocking
Aluminium taping	as absolute moisture barrier
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● yellow

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		3000 N
Max. crush resistance		1500 N/dm

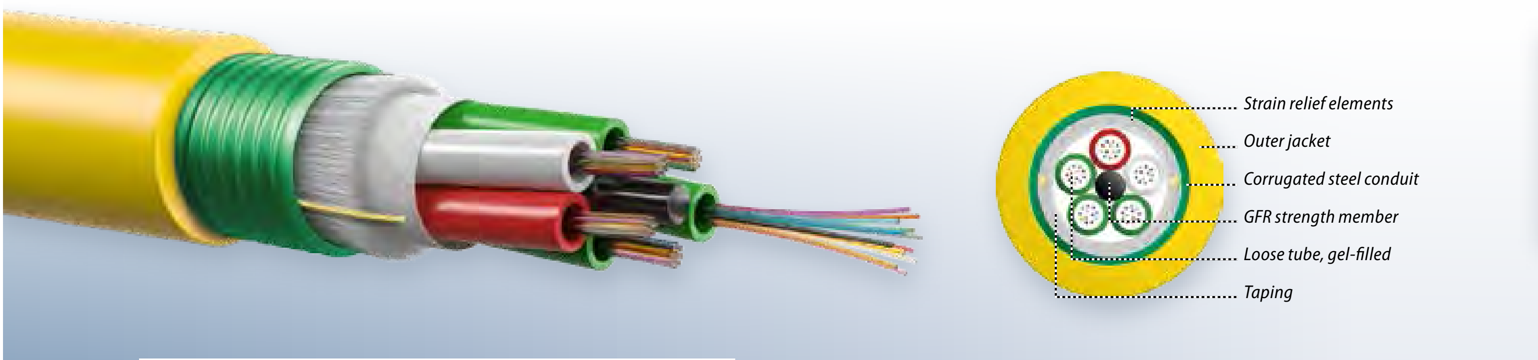
Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 × m	**12**	12.1	170	2.73
2 × m	**24**	12.1	170	2.73
3 × m	**36**	12.1	170	2.73
4 × m	**48**	12.1	170	2.73
5 × m	**60**	12.1	170	2.73
6 × m	**72**	13.0	190	3.13
8 × m	**96**	14.4	230	3.28
10 × m	**120**	15.9	270	3.60
12 × m	**144**	17.7	320	4.39

Fiber**Connect**® Universal cable with stranded multi-fiber loose tubes

rodent-protected, transversely waterproof



U-DQ(ZN)(SR)H n×m…

Order no.	**84 037** ☐☐ ☐ ☐
	with UV resistant FRNC material: **84 046** ☐☐ ☐ ☐

Description

Can be used both inside and outside buildings. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.

Composition

Cable core	GFR strength members with stranding elements, designed as gel-filled loose tubes and, if applicable, dummy elements
Strain relief	non-metallic (glass rovings), moisture blocking
Corrugated steel conduit	as highly effective rodent protection
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	yellow

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		3000 N
Max. crush resistance		2000 N/dm

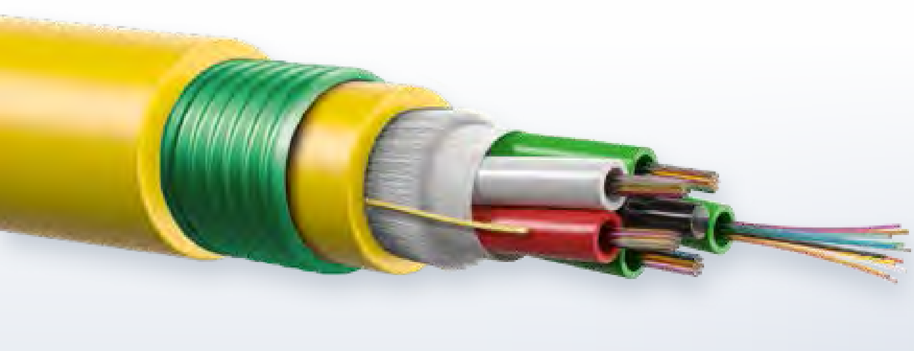
Fire performance

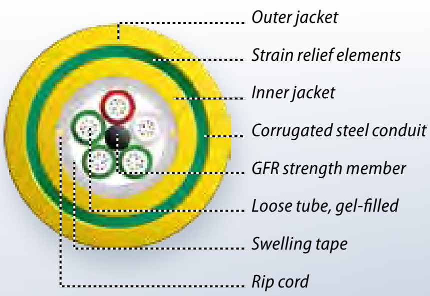
Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 × m	**12**	12.7	200	3.45
2 × m	**24**	12.7	200	3.45
3 × m	**36**	12.7	200	3.45
4 × m	**48**	12.7	200	3.45
5 × m	**60**	12.7	200	3.45
6 × m	**72**	16.5	305	4.05
8 × m	**96**	16.5	305	4.05
10 × m	**120**	16.5	305	4.05

FiberConnect® Outdoor cable with stranded multi-fiber loose tubes

rodent-protected, transversely waterproof





U-DQ(ZN)H(SR)H nxm… UV

Order no.	**84 085** □□ □ □
Standardisation	IEC 60794-3

Description

Can be used both inside and outside buildings. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.

Composition

Cable core	GFR strength member with stranding elements, designed as gel-filled loose tubes (Ø 2.4 mm) and, if applicable, dummy elements. Swelling tape.
Strain relief	non-metallic (glass rovings), moisture blocking
Inner jacket	Halogen-free, flame-retardant material
Corrugated steel conduit	as highly effective rodent protection
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● yellow

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

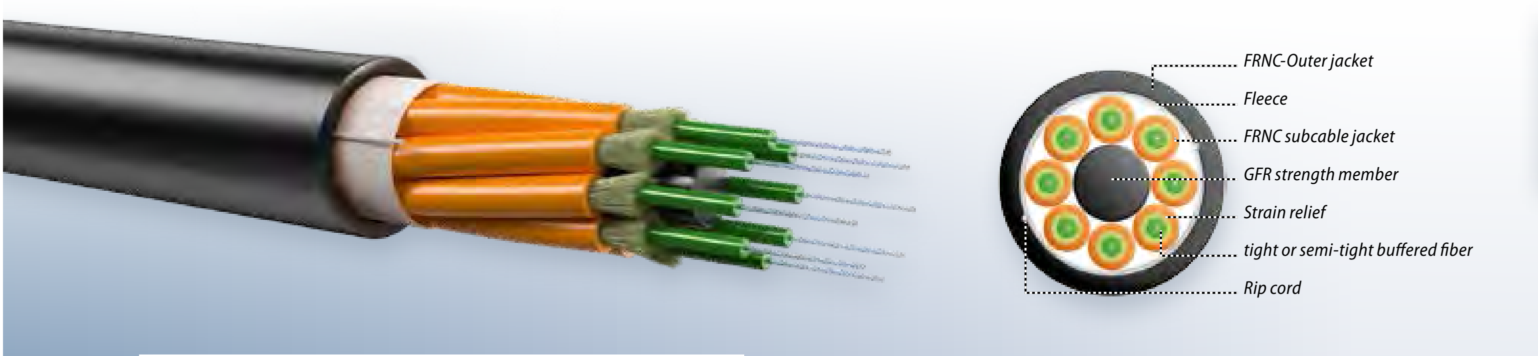
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force on jacket		4000 N
Max. crush resistance		3000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load	Min. bending radius during installation	Min. bending radius installed
		mm	kg/km	MJ/m	mm	mm
1 × m	**12**	16.7	360	4.15	340	250
2 × m	**24**	16.7	360	4.15	340	250
3 × m	**36**	16.7	360	4.15	340	250
4 × m	**48**	16.7	360	4.15	340	250
5 × m	**60**	16.7	360	4.15	340	250
6 × m	**72**	18.8	430	4.63	380	285
8 × m	**96**	18.8	430	4.63	380	285
12 × m	**144**	21.0	510	5.33	420	315

FiberConnect® Splittable outdoor cable



AT-VQ(ZN)HH n… 2.5

Order no.	**84 202** ☐☐ ☐ ☐
Standardisation	IEC 60794-2

Description

Splittable outdoor cable for fixed installation in cable ducts and conduits. Suitable for direct connector assembly.

Composition

Cable core	GFR strength member in the core, over that single elements designed as tight buffered (TB) and semi-tight buffered (STB) fiber, gel-filled with non-metallic strain relief elements (aramid) and halogen-free, flame-retardant subcable jacket (Ø 2.5 mm) stranded in layers (2–24)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 25 °C to + 60 °C

Mechanical properties

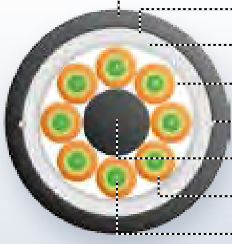
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. crush resistance		1500 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of fibers	Outer Ø	Wall thickness	Weight	Fire load	Max. pull force
	mm	mm	kg/km	MJ/m	N
2	**8.5**	1.0	65	1.20	800
4	**8.5**	1.0	65	1.20	800
6	**10.0**	1.1	80	1.38	1200
8	**11.9**	1.2	110	1.55	1200
10	**13.6**	1.2	150	1.72	1200
12	**15.2**	1.2	180	1.88	1200
16	**15.2**	1.4	190	1.94	1200
18	**16.0**	1.4	175	1.90	1200
20	**16.3**	1.5	220	2.25	1200
24	**18.5**	1.5	280	2.61	1200

FiberConnect® Splittable outdoor cable



AT-VQ(ZN)H(ZN)B2Y n… 2.5

Order no.	**84 205** ☐☐ ☐ ☐
Standardisation	IEC 60794-2

Description

Splittable, transversely water resistant outdoor cable with non-metallic rodent protection for fixed installation indoors and outdoors in cable ducts, conduits and cable trays. The single cables are longitudinally waterproof. For direct connector assembly.

Composition

Cable core	GFR strength member in the core, over that breakout single elements designed as tight buffered (TB) or semi-tight buffered (STB)f, gel-filled with non-metallic strain relief elements (aramid) and a halogen -free flame retardant subcable jacket (Ø 2.5 mm) stranded in layers (2–24)
Armour	Multifunctional reinforced glass rovings as non-metallic strain relief elements and rodent protection
Cable jacket	Polyethylene
Colour of jacket	● black

Number of fibers	Outer Ø	Wall thickness	Weight	Fire load	max. Pull force
	mm	mm	kg/km	MJ/m	N
2	**10.0**	1.0	85	1.20	2500
4	**10.0**	1.0	90	1.20	2500
6	**11.0**	1.2	115	1.38	3000
8	**13.0**	1.2	145	1.55	3000
10	**14.5**	1.2	175	1.72	3000
12	**16.0**	1.2	210	1.88	3000
16	**16.0**	1.5	215	1.94	3000
20	**18.0**	1.5	315	2.25	3000
24	**19.0**	1.5	360	2.61	3000

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

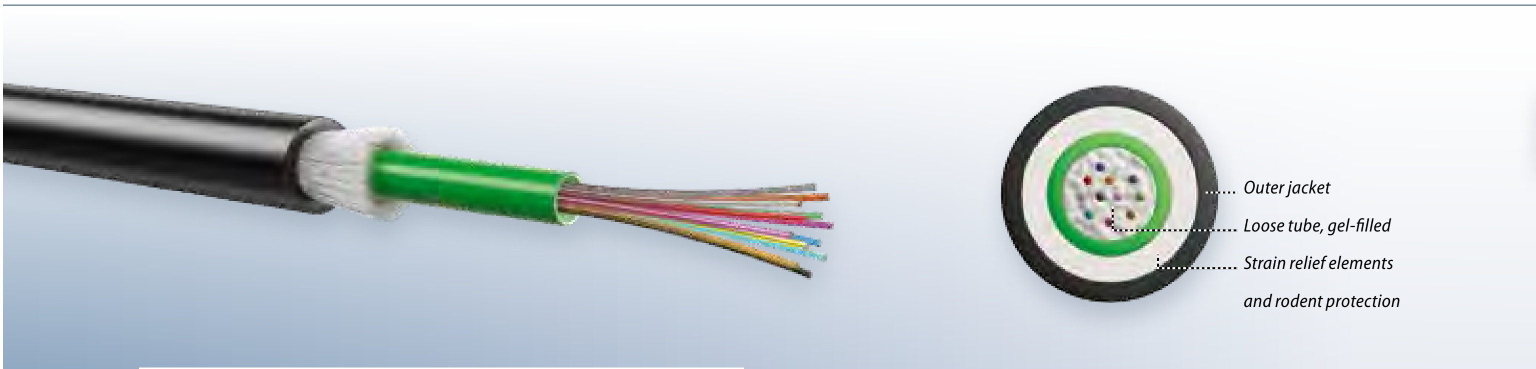
Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. crush resistance		1500 N/dm

Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Fiber**Connect**® Outdoor cable with central multi-fiber loose tube (1750 N) rodent-protected



A-DQ(ZN)B2Y n… 1750 N

Order no.	**84 305** □□ □ □
Standardisation	IEC 60794-3

Description

Light, flexible and non-metallic outdoor cable for primary cabling and the backbone area. For pulling into conduits, installation on cable trays or directly in the ground.

Composition

Cable core	Loose tube, gel-filled
Armour	multifunctional glass rovings, moisture blocking as strain relief and rodent protection
Cable jacket	Polyethylene
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		1750 N
Max. crush resistance		1500 N/dm

Fire performance

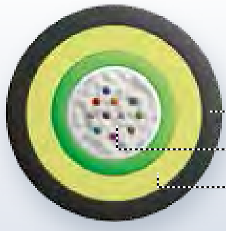
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Note

The Polyethylene jacket offers good protection against transversal water ingress.

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	7.0	42	1.10
24	7.5	47	1.20

FiberConnect® Direct buried cable



A-DQ(ZN)2Y n… 1750 N ZB

Order no.	**84 375** □□ □ □
Standardisation	IEC 60794-3

Description

Light, flexible and non-metallic outdoor cable for primary cabling and the backbone area. For pulling into contduits, installation on cable trays or directly in the ground.

Composition

Cable core	Two-layer loose tube, gel-filled, diameter 3.5 mm (up o 12 fibers), 4.0 mm (to 24 fibers) Colour: yellow (E9/125), green (G50/125) and blue (G62.5/125).
Strain relief	Non-metallic (aramid)
Cable jacket	Polyethylene
Colour of jacket	● black

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

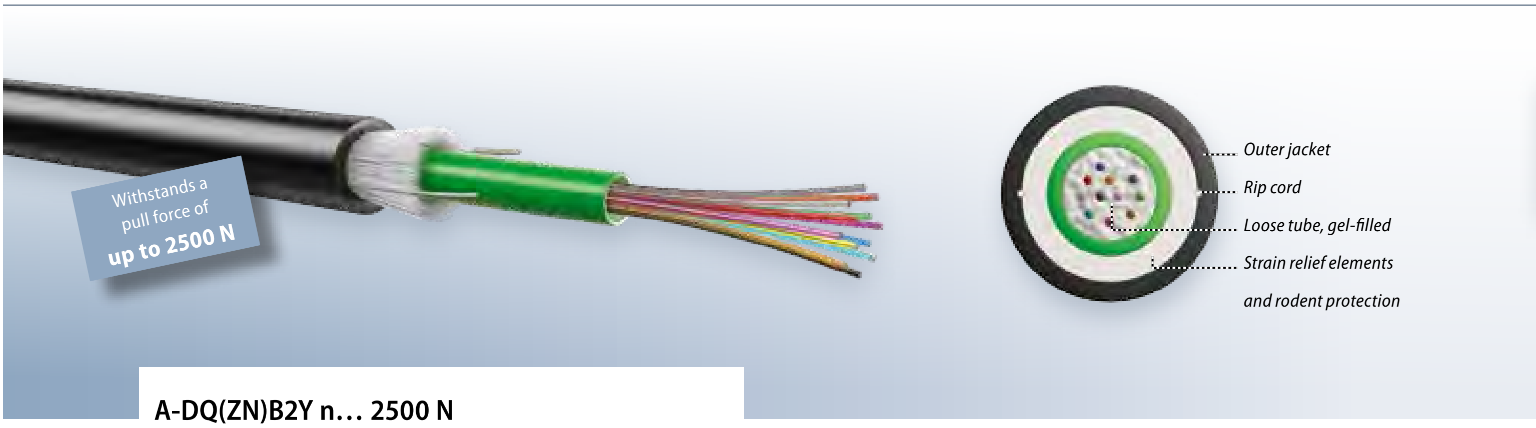
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		1750 N
Max. crush resistance		2000 N/dm

Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	7.0	37	1.5
24	7.5	42	1.7

FiberConnect® Outdoor cable with central multi-fiber loose tube (2500 N) rodent-protected



A-DQ(ZN)B2Y n… 2500 N

Order no.	84 321□□ □ □
Standardisation	IEC 60794-3

Description

Non-metallic construction for primary cabling and the backbone area. For pulling into conduits, installation on cable trays or directly in the ground.

Composition

Cable core	Loose tube, gel-filled
Armour	multifunctional reinforced glass rovings, moisture blocking as strain relief and rodent protection
Cable jacket	Polyethylene with imprint
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	9.2	76	1.90
24	9.7	81	2.00

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		2500 N
Max. crush resistance		3000 N/dm

Fire performance

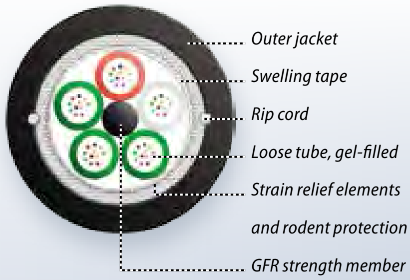
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Note

The Polyethylene jacket offers good protection against transversal water ingress.

FiberConnect® Outdoor cable with stranded multi-fiber loose tubes

rodent-protected, dry core



A-DQ(ZN)B2Y n×m…

Order no.	**84 316**□□ □ □
Standardisation	IEC 60794-3

Description

Non-metallic, rugged outdoor cable. Installation-friendly because of the grease-free cable core. Installation in conduits, on cable trays and directly in the ground.

Composition

Cable core	GFR strength member with stranding elements designed as gel-filled loose tubes and, if applicable, dummy elements
Armour	multifunctional reinforced glass rovings as non-metallic strain relief elements and rodent protection
Cable jacket	Polyethylene with hot stamped marking
Colour of jacket	● black

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 × m	**12**	11.4	115	4.1
2 × m	**24**	11.4	115	4.1
3 × m	**36**	11.4	115	4.1
4 × m	**48**	11.4	115	4.1
5 × m	**60**	11.4	115	4.1
6 × m	**72**	12.3	135	4.5
8 × m	**96**	13.7	160	5.0
10 × m	**120**	15.2	190	5.5
12 × m	**144**	17.0	230	6.2
16 × m	**192**	17.3	240	6.2
24 × m	**288**	20.2	320	6.2

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		4000 N
Max. crush resistance		3000 N/dm

Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Note

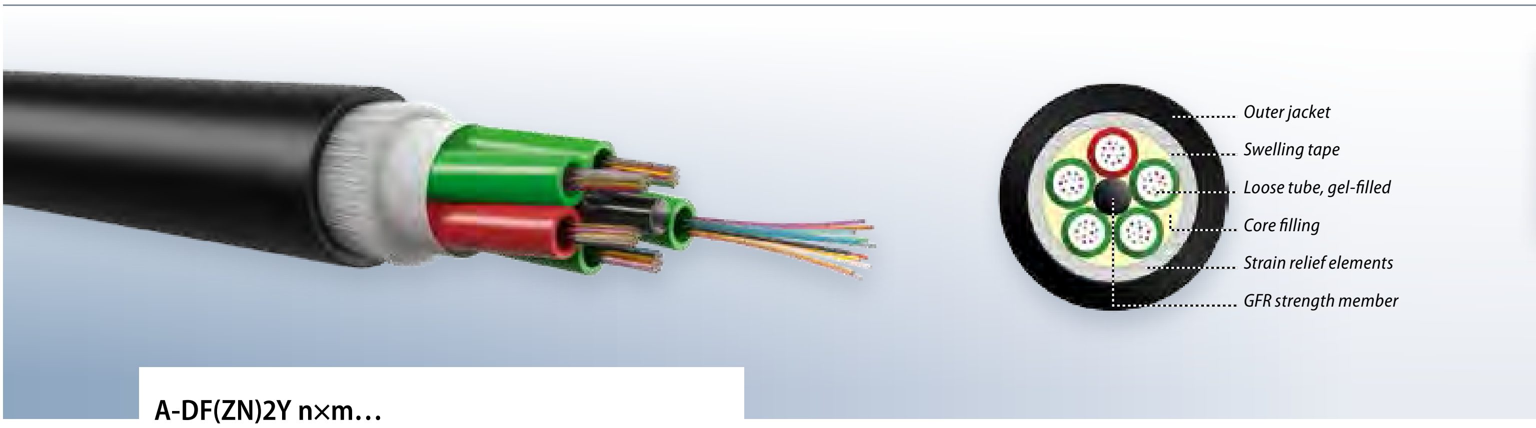
- The Polyethylene jacket offers good protection against transversal water ingress
- Higher fiber counts and pull forces on request
- Also available with aluminium layer or corrugated steel jacket.

All rodent-protected universal cables with stranded multi-fiber loose tubes are also available with different pull forces.

Pull force	Order no.
4000 N	84316□□ □ □
6000 N	84346□□ □ □
9000 N	84330□□ □ □

FiberConnect® Outdoor cable with stranded multi-fiber loose tubes

grease-filled



A-DF(ZN)2Y n×m…

Order no.	**84 300** ☐☐ ☐ ☐
Standardisation	IEC 60794-3

Description

Non-metallic cable for primary cabling and the backbone area. For pulling into conduits, installation on cable trays or directly in the ground.

Composition

Cable core	GFR strength member with stranding elements, designed as gel-filled loose tubes and, if applicable, dummy elements. Cable core filled with petroleum jelly
Strain relief	Glass rovings
Cable jacket	Polyethylene with hot stamped marking
Colour of jacket	● black

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 × m	**12**	11.4	120	4.3
2 × m	**24**	11.4	120	4.3
3 × m	**36**	11.4	120	4.3
4 × m	**48**	11.4	120	4.3
5 × m	**60**	11.4	120	4.3
6 × m	**72**	12.3	135	4.6
8 × m	**96**	13.7	170	5.1
10 × m	**120**	15.2	200	5.7
12 × m	**144**	17.0	240	6.5
16 × m	**192**	16.8	255	7.4

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force	≤ 7 stranding element 3000 N	
	> 7 stranding element 4000 N	
Max. crush resistance		3000 N/dm

Fire performance

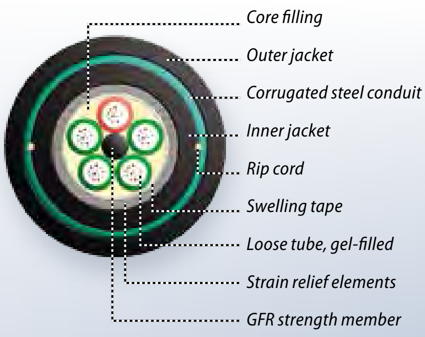
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Note

- The Polyethylene jacket offers good protection against transversal water ingress
- Also available with aluminium layers, corrugated steel jacket and copper elements

FiberConnect® Outdoor cable with stranded multi-fiber loose tubes

rodent-protected, grease-filled



A-DF(ZN)2Y(SR)2Y n×m…

Order no.	**84 310** □□ □ □
Standardisation	IEC 60794-3

Description

Rugged outdoor cable for primary cabling and the backbone area. For pulling into contduits, installation on cable trays or directly in the ground.

Composition

Cable core	GFR strength member with stranding elements designed as gel-filled loose tubes and, if applicable, dummy elements. Cable core filled with petroleum jelly.
Strain relief	Glass rovings
Inner jacket	Polyethylene, ● black
Corrugated steel conduit	as highly effective rodent protection
Cable jacket	Polyethylene with hot stamped marking
Colour of jacket	● black

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force	≤ 7 stranding elements 3000 N	
	> 7 stranding elements 4000 N	
Max. crush resistance		3000 N/dm

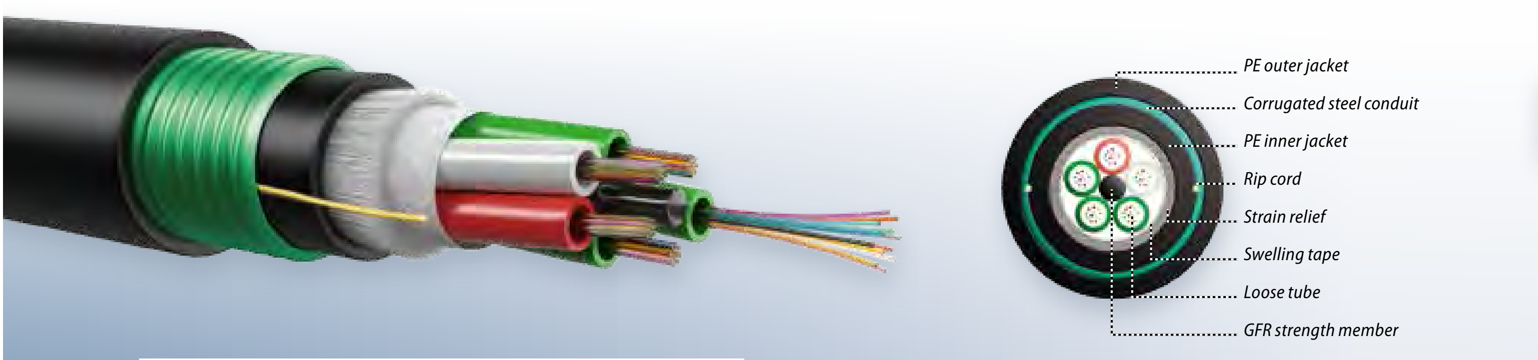
Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 × m	**12**	16.7	275	10.4
2 × m	**24**	16.7	275	10.4
3 × m	**36**	16.7	275	10.4
4 × m	**48**	16.7	275	10.4
5 × m	**60**	16.7	275	10.4
6 × m	**72**	17.5	335	12.0
8 × m	**96**	18.8	335	12.0
10 × m	**120**	21.8	335	12.5
12 × m	**144**	21.8	370	13.1
16 × m	**192**	21.8	380	13.8

Fiber**Connect**® **Outdoor cable with stranded multi-fiber loose tubes**

rodent-protected, transversely waterproof



A-DQ(ZN)2Y(SR)2Y n×m…

Order no.	**84 329**□□ □ □
Standardisation	IEC 60794-3

Description

Dry-core, longitudinally and transversely waterproof fiber optic outdoor cable with highly effective rodent protection. For direct burial, installation in conduits, ducts or on trays, also suited for vertical ladders.
Suitable for all installation techniques (e. g. pulling and blowing in).

Composition

Cable core	GFR strength member with stranding elements, designed as gel-filled loose tubes (Ø 2.4 mm) and, if applicable, dummy elements
Strain relief	Glass rovings
Inner jacket	Polyethylene
Corrugated steel conduit	as highly effective rodent protection
Cable jacket	Polyethylene with hot stamped marking
Colour of jacket	● black

Composition	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/km
1 × m	**12**	16.7	275	10.4
2 × m	**24**	16.7	275	10.4
3 × m	**36**	16.7	275	10.4
4 × m	**48**	16.7	275	10.4
5 × m	**60**	16.7	275	10.4
6 × m	**72**	16.7	275	12.0
8 × m	**96**	18.8	340	12.0
10 × m	**120**	21.0	335	12.5
12 × m	**144**	21.0	370	13.1

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

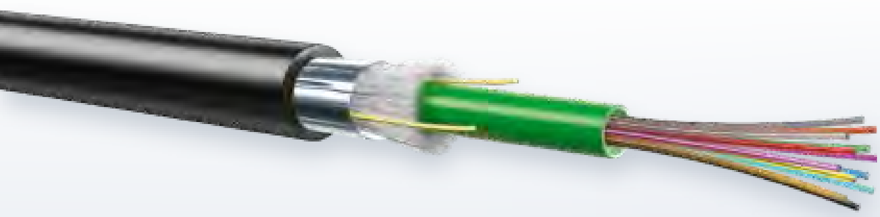
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force	≤ 7 stranding elements 3000 N	
	> 7 stranding elements 4000 N	
Max. crush resistance		1000 N/dm

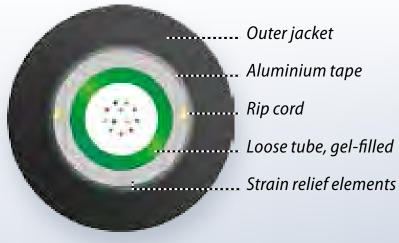
Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

FiberConnect® Outdoor cable with central multi-fiber loose tube

transversely waterproof





A-DQ(ZN)(L)2Y n…

Order no.	**84 333** □□ □ □
Standardisation	IEC 60794-3

Description

Light outdoor cable with diffusion barrier. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.

Composition

Cable core	Loose tube, gel-filled
Strain relief	non-metallic (glass rovings), moisture blocking
Alumimium taping	as absolute moisture barrier
Cable jacket	Polyethylene with imprint
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		2500 N
Max. crush resistance		1000 N/dm

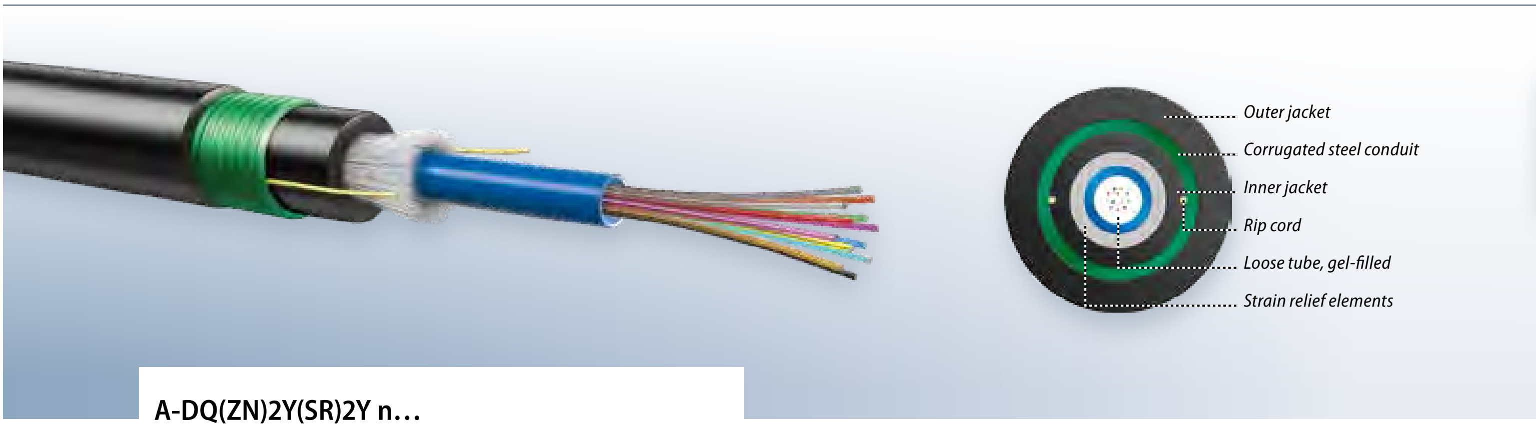
Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	10.8	128	1.42
24	11.3	135	1.62

FiberConnect® Outdoor cable with central multi-fiber loose tube

rodent-protected, transversely waterproof



A-DQ(ZN)2Y(SR)2Y n…

Order no.	**84 331** □□ □ □
Standardisation	IEC 60794-3

Description

Rugged outdoor cable for installation in cable ducts, conduits, on cable trays or directly in the ground.

Composition

Cable core	loose tube, gel-filled
Strain relief	non-metallic (glass rovings), moisture blocking
Inner jacket	Polyethylene, ● black
Corrugated steel conduit	as highly effective rodent protection
Outer jacket	Polyethylene with imprint
Colour of jacket	● black

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 70 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		2500 N
Max. crush resistance		2500 N/dm

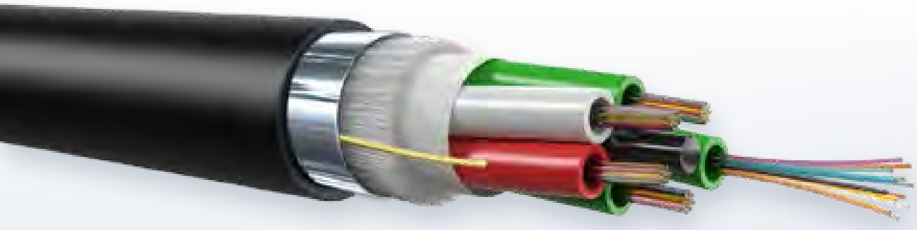
Fire performance

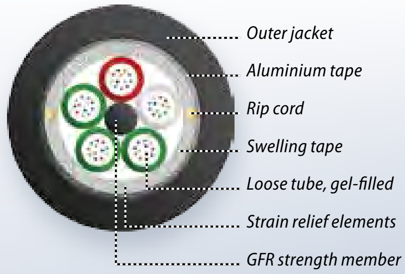
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	12.5	160	1.8
24	12.5	160	1.8

FiberConnect® Outdoor cable with stranded multi-fiber loose tubes

transversely waterproof





A-DQ(ZN)(L)2Y n×m…

Order no.	**84 326** ☐☐ ☐ ☐
Standardisation	IEC 60794-3

Description

Rugged outdoor cable with diffusion barrier. For installation in cable ducts and conduits, on cable trays or directly in the ground.

Composition

Cable core	GFR strength member with stranding elements, designed as gel-filled loos tubes and , if applicable, dummy elements
Strain relief	Non-metallic (glass rovings), moisture blocking
Aluminium taping	as absolute moisture barrier
Cable jacket	Polyethylene with hot stamped marking
Colour of jacket	● black

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		3000 N
Max. crush resistance		1500 N/dm

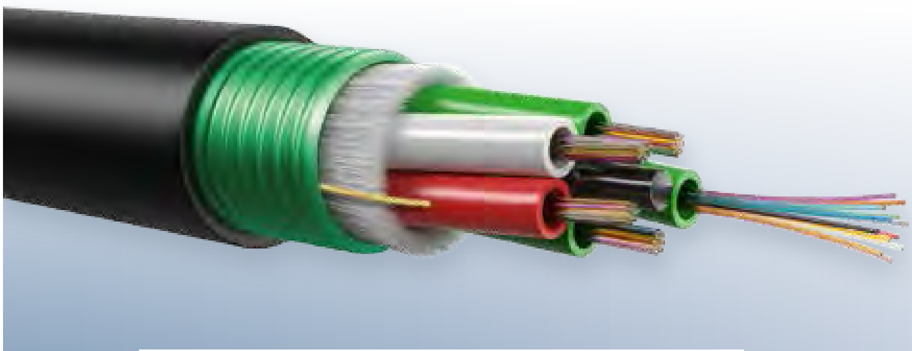
Fire performance

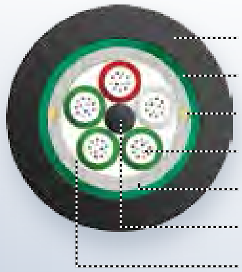
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 × m	**12**	12.1	140	4.9
2 × m	**24**	12.1	140	4.9
3 × m	**36**	12.1	140	4.9
4 × m	**48**	12.1	140	4.9
5 × m	**60**	12.1	140	4.9
6 × m	**72**	13.0	160	5.6
8 × m	**96**	14.4	200	5.9
10 × m	**120**	15.9	240	6.4
12 × m	**144**	17.7	280	7.2

FiberConnect® Outdoor cable with stranded multi-fiber loose tubes

rodent-protected, transversely waterproof





A-DQ(ZN)(SR)2Y n×m…

Order no.	**84 334** ☐☐ ☐ ☐
Standardisation	IEC 60794-3

Description

Rugged outdoor cable for installation in cable ducts or conduits, on cable trays or directly in the ground.

Composition

Cable core	GFR strength member with stranding elements, designed as gel-filled loose tubes and , if applicable, dummy elements
Strain relief	Non-metallic (glass rovings), moisture blocking
Corrugated steel conduit	as highly effective rodent protection
Cable jacket	Polyethylene with hot stamped marking
Colour of jacket	● black

Thermal properties

Transport/storage	– 40 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 60 °C

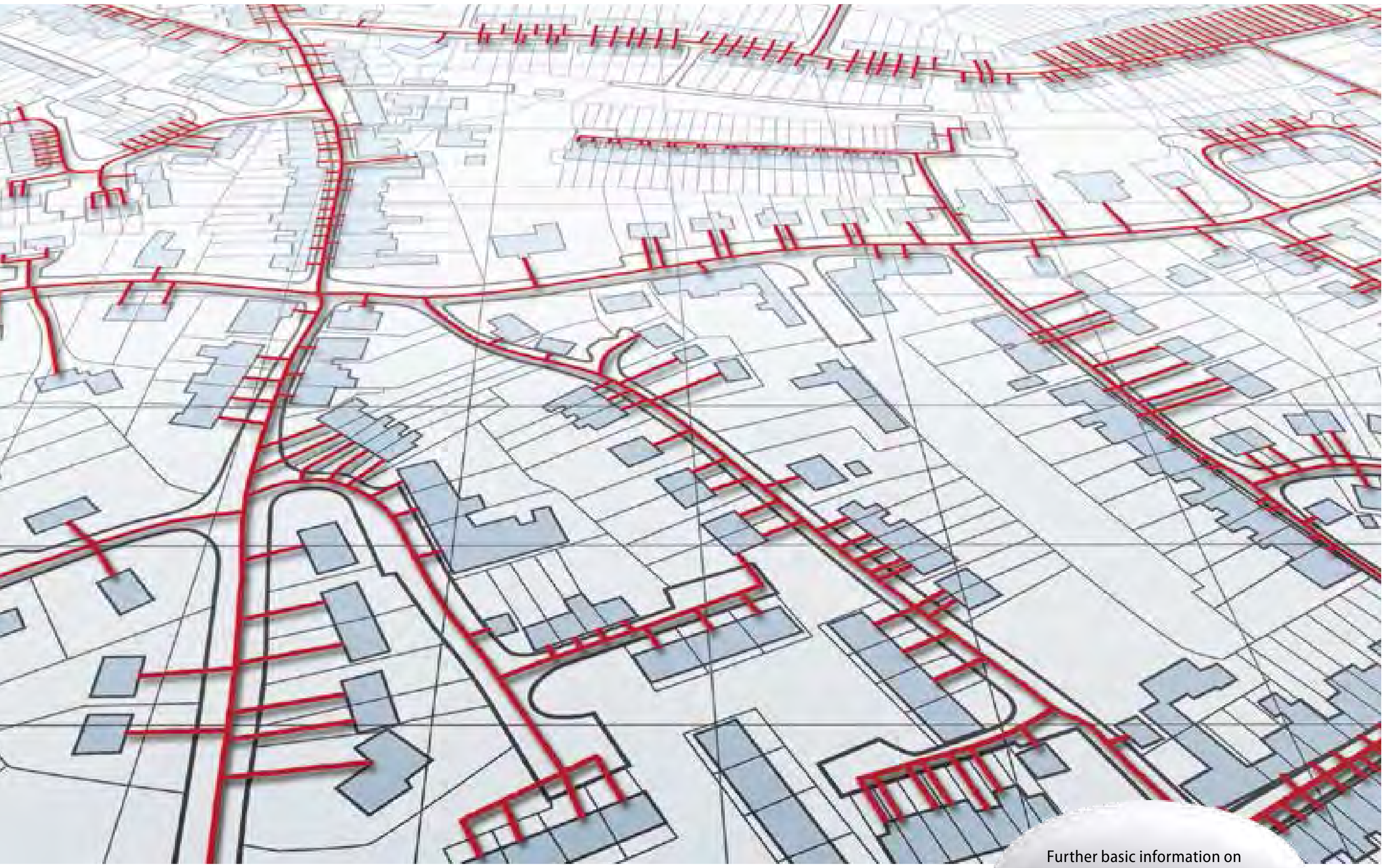
Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		3000 N
Max. crush resistance		2000 N/dm

Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 × m	**12**	12.7	165	4.6
2 × m	**24**	12.7	165	4.6
3 × m	**26**	12.7	165	4.6
4 × m	**48**	12.7	165	4.6
5 × m	**60**	12.7	165	4.6



Further basic information on fire prevention and test methods:
Chapter 12 | Principles
→ page 385 ff.

FiberConnect® Cables for FTTH applications

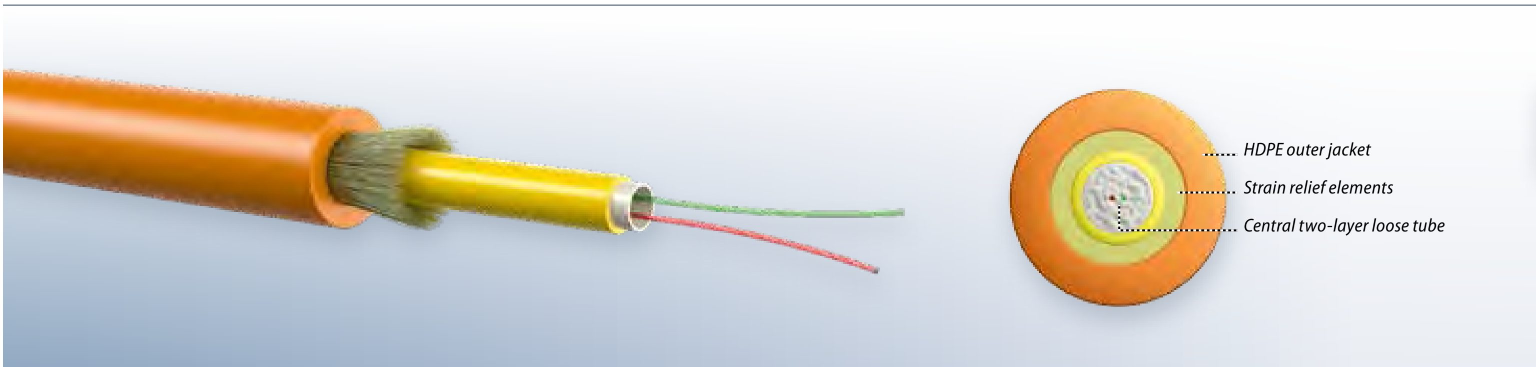
Modern households are demanding ever higher data rates for communication via the Internet and for the wide range of services offered by providers of broadband applications such as television stations and providers of video-on-demand.

That is why the DSL connections based on copper cables used in households are increasingly yielding to a modern high-speed network based on fiber optic cables, called Fiber To The Home (FTTH).

LEONI has a wide range of cable products specifically tailored to this application. The cables are run directly in the ground or blown into empty conduits installed underground, depending on the method of installation. Blowing cables into empty conduits offers the greatest advantages and has established itself as the standard as it permits the most flexibility when equipping the conduits with different cables, simplifies the development and recabling of complete residential estates and lowers costs. The cables must be especially thin and light for blowing in. The surface must display optimum sliding properties to permit the longest possible blow-in lengths.

The product range includes stranded cables with a large number of fibers and small outer diameters (MiniCable) as well as drop cables with just two or four fibers with a central loose tube (MicroCable). In addition to these cables for outdoor use, we also offer cables for indoor installation that meet the requirements for fire prevention in buildings. Since extremely narrow bending radii are required for installation in buildings and for the connection technology, innovative singlemode fibers of the type G657 are used for this.

FiberConnect® Direct buried cable



A-DQ(ZN)2Y 2E9/125 G657A1 5.5

Order no.	**84 366012 E**
Standardisation	IEC 60794-3

Description

Longitudinally waterproof optical outdoor cable for direct burial, installation in conduits, cable ducts and/or cable trays. Also suitable for vertical ladders. Machine-driven pulling in with a winch only permitted with a documenting force measuring device.

Composition

Cable core	Two-layer loose tube, gel-filled, diameter 2.4 mm, colour: yellow (E9/125) Inner layer: polycarbonate (PC) outer layer: polybutylene terephtalate (PBTP) colour code fibers (1–2): red, green
Strain relief	Non-metallic (aramid)
Cable jacket	Polyethylene (HDPE)
Colour of jacket	● orange

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 25 °C to + 70 °C

Mechanical properties

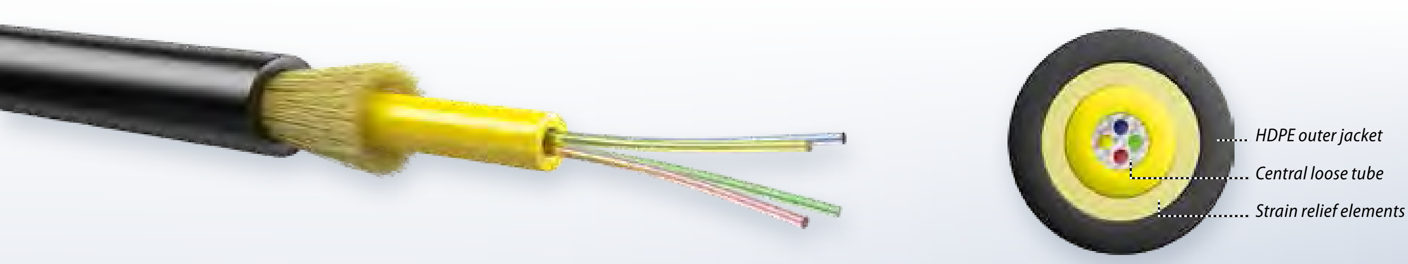
outer diameter		approx. 5.5 mm
Leitungsgewicht		approx. 21.0 kg/km
Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		600 N
Max. crush resistance		5000 N/dm

Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

FiberConnect® Micro duct cable

with central multi-fiber loose tube



A-D(ZN)2Y n… MDC

Order no.	**84 344**□□ □ □
Standardisation	IEC 60794-5

Description

Mini cable for blowing or pulling into micro ducts. The outdoor cable is light and flexible and can be installed with minimal bending radii.

Composition

Cable core	Mini loose tube, gel-filled
Strain relief	Non-metallic (aramid)
Cable jacket	HDPE with Imprint
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 25 °C to + 70 °C

Mechanical properties*

Min. bending radius	up to 4 Fibers	static	25 mm
		dynamic	40 mm
	up to 12 Fibers	static	40 mm
		dynamic	60 mm
	up to 24 Fibers	static	60 mm
		dynamic	80 mm

* with bend-insensitive fibers G.657.A1; bending radii up to 15 mm

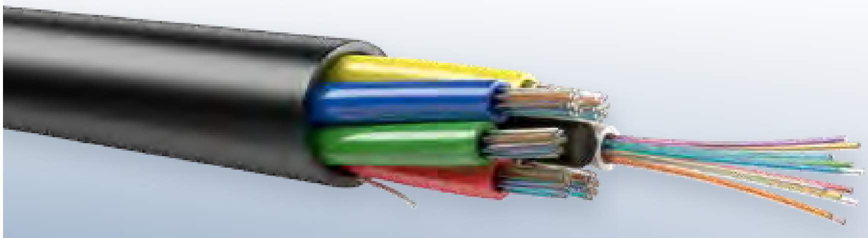
Fire performance

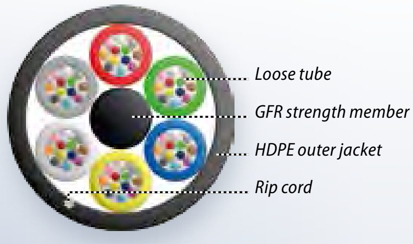
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of fibers	Outer Ø	Weight	Max. pull force long-term	Max. crush resistance long-term	Fire load
	mm	kg/km	N	N/dm	MJ/m
2	2.0	3.9	300	500	0.18
4	2.0	3.9	300	500	0.18
6	2.3	4.4	300	500	0.22
8	2.3	4.4	300	200	0.22
10	2.3	4.6	300	200	0.26
12	2.3	4.6	300	200	0.26
24	3.9	12.7	450	200	0.51

FiberConnect® Mini multi-fiber loose tube

with stranded multi-fiber loose tubes





A-DQ2Y n… LTMC

Order no.	**84 345** □□ □ □
Standardisation	IEC 60794-5

Description

Mini cable for blowing or pulling into micro ducts. The outdoor cable is light and flexible and can be installed with minimal bending radii.

Composition

Cable core	GFR strength member with stranding elements, designed as gel-filled loose tubes and , if applicable, dummy elements
Cable jacket	HDPE with imprint
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 25 °C to + 70 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		500 N
Max. crush resistance		500 N/dm
Resistance to impacts		3 impacts/2 Nm

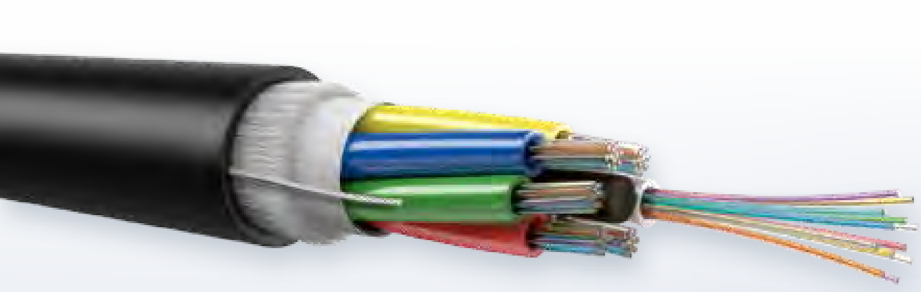
Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of tubes	Max. number of fibers	Outer Ø	Weight
		mm	kg/km
1 × m	**12**	5.8	26
2 × m	**24**	5.8	26
3 × m	**36**	5.8	26
4 × m	**48**	5.8	26
5 × m	**60**	5.8	26
6 × m	**72**	5.8	26
8 × m	**96**	6.8	39
10 × m	**120**	7.8	52
12 × m	**144**	8.8	68
18 × m	**216**	9.1	73

FiberConnect® Outdoor cable with stranded multi-fiber loose tubes

Mini multi-fiber loose tube cable, rodent-protected



A-DQ(ZN)B2Y n×m…

Order no.	**84 376** ☐☐ ☐ ☐
Standardisation	IEC 60794-5

Description

Non-metallic rugged mini cable suitble for blowing into FTTH conduit systems.

Composition

Cable core	GFR strength member with stranding elements, designed as gel-filled loose tubes 1.6 mm and, if applicable, dummy elements and swelling tape
Armour	Multifunctional, reinforced glass rovings as non-metallic strain relief elements and rodent protection
Cable jacket	HDPE jacket with imprint
Colour of jacket	● black

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 25 °C to + 70 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		1500 N
Max. crush resistance		1500 N/dm

Fire performance

Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of tubes	Max. number of fibers	Outer Ø	Weight
		mm	kg/km
1 × m	**12**	8.3	68
2 × m	**24**	8.3	68
3 × m	**36**	8.3	68
4 × m	**48**	8.3	68
5 × m	**60**	8.3	68
6 × m	**72**	8.3	68
8 × m	**96**	9.4	84
10 × m	**120**	10.3	98
12 × m	**144**	11.3	114

Fiber**Connect**® FTTH indoor cable

Duplex cable

I-V(ZN)H 2… TB600 2.8

Order no.	**84 950 120**
Standardisation	IEC 60794-2

Description

For fixed installation inside buildings in cable ducts and conduits as well as for shunting purposes.
For direct connector assembly.

Composition

Cable core	Buffered fiber type TB600, diameter 0.6 mm one buffered fiber red, further buffered fiber yellow (E9/125), green (G50/125) or blue (G62.5/125)
Strain relief	Non-metallic (aramid)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	◯ white

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 5 °C to + 70 °C

Mechanical properties

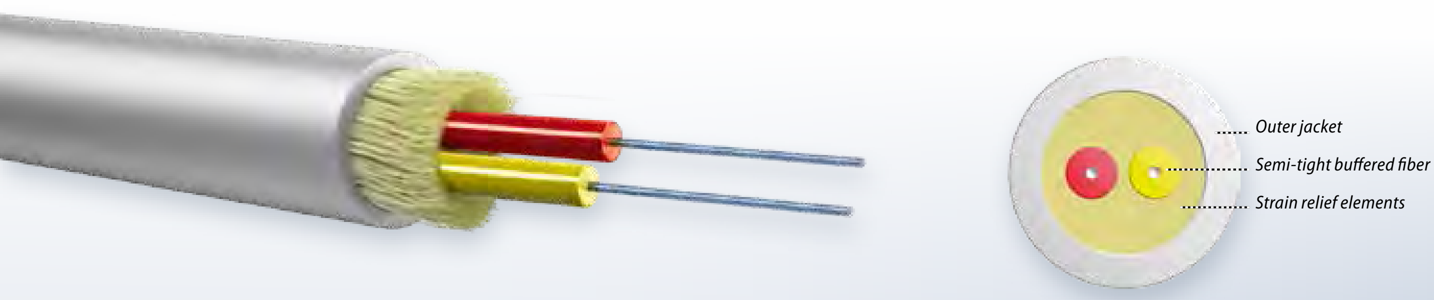
outer diameter		2.8 mm
Cable weight		7.5 kg/km
Min. bending radius	static	30 mm
	dynamic	60 mm
with fiber type G657A1	static	15 mm
Max. pull force		300 N
Max. crush resistance		100 N/dm
Resistance to impacts		3 impacts/1 Nm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2
Fire load	0.20 MJ/m

FiberConnect® FTTH indoor cable

Mini breakout cable



I-V(ZN)H 2… STB900H 2.8

Order no.	**84 950 746**
Standardisation	IEC 60794-2

Description

For fixed installation inside buildings in cable ducts and conduits as well as for shunting purposes.
Ideal for workstation cabling.
For direct connector assembly.

Composition

Cable core	Buffered fiber type STB900H, diameter 0.9 mm one buffered fiber red, further buffered fiber yellow (E9/125), green (G50/125) or blue (G62.5/125)
Strain relief	Non-metallic (aramid)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	◯ white

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

outer diameter		2.8 mm
Cable weight		8.0 kg/km
Min. bending radius	static	30 mm
	dynamic	45 mm
with fiber type G657A1	static	15 mm
Max. pull force		300 N
Max. crush resistance		100 N/dm
Resistance to impacts		3 impacts/1 Nm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2
Fire load	0.20 MJ/m


Type Approval Certificate

GL

Germanischer Lloyd


Type Approval Certificate

GL

Germanischer Lloyd

FiberConnect® Marine cables

Type approval from Germanischer Lloyd (GL) and Det Norske Veritas (DNV) ensures that the shipyards install optical cables tested and certified in accordance with valid standards. In shipbuilding in particular, the reliable interaction of many components is of crucial importance for trouble-free operation.

It is also vital in the event of fire to be able to rely on the function of the fiber optic cables for a verified period (functional integrity).


DNV

DET NORSKE VERITAS

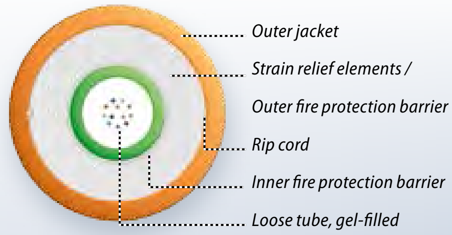
TYPE APPROVAL CERTIFICATE

Leoni Fiber Optics GmbH

Further basic information on
fire performance and test methods:
Chapter 12 | Principles
→ page 385 ff.

FiberConnect® Universal cable with functional integrity 90 min

rodent-protected



GL U-D(ZN)BH n… FS

Order no.	**84 040□□ □ □ 222 ZGELO**
Standardisation	IEC 60794-2

Functional integrity in the event of fire
for at least 90 minutes

Description

Non-metallic, light and flexible cable with approval by Germanischer Lloyd and Det Norske Veritas (DNV).
For fixed installation on ships and offshore facilities in safety-related areas.

Composition

Cable core	Loose tube, gel-filled Inner fire protection barrier
Armour	multifunctional, reinforced glass rovings as non-metallic strain relief elements and rodent protection
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● orange

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 60 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		2500 N
Max. crush resistance		3000 N/dm
Resistance to impacts		10 impacts/2 Nm

Fire performance

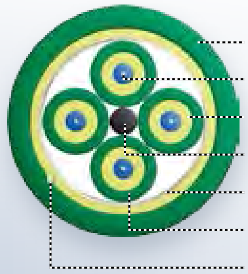
Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Functional integrity test

According to IEC 60 331-11, IEC 60 331-25 and EN 50200
90 min (VDE test report)

Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	10.3	115	1.03
24	10.8	125	1.28

FiberConnect® Breakout cable



GL AT-V(ZN)H(ZN)H n…

Order no.	**see table**
Standardisation	IEC 60794-2

Description

Non-metallic, light and flexible cable with approval by Germanischer Lloyd and Det Norske Veritas (DNV).
For fixed installation on ships and offshore facilities in areas at risk of fire.

Composition

Cable core	GFR strength member with stranding elements, designed as semi-tight buffered fiber (STB900H), gel-filled with non-metallic strain relief elements (aramid) and a halogen-free, flame-retardant subcable jacket (Ø 2.9 mm)
Strain relief	Aramid yarns
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● RAL 6029 mint green

Thermal properties

Transport/storage	– 25 °C to + 80 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 20 °C to + 80 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. pull force		1200 N
Max. crush resistance		1000 N/dm
Resistance to impacts		10 impacts/2 Nm

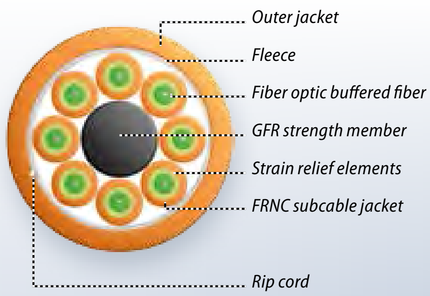
Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Number of fibers max.	Outer Ø	Weight	Fire load	Order no.
	mm	kg/km	MJ/m	
2	10.1	85	1.28	**84950481 ☐ 688 ZGELO**
4	10.1	85	1.28	**84950478 ☐ 688 ZGELO**
6	11.8	120	1.59	**84950482 ☐ 688 ZGELO**
8	13.6	160	1.80	**84950483 ☐ 688 ZGELO**
10	15.4	200	2.14	**84950484 ☐ 688 ZGELO**
12	17.2	245	2.48	**84950485 ☐ 688 ZGELO**

FiberConnect® Breakout cable with central strength member

according to VG 95218-30 type B



AT-V(ZN)HH n… TB900L 2.2 VG

Order no.	**84 066** □□ □ □
Standardisation	VG 95218-30 type B and IEC 60794-2

Description

Splittable breakout cable for fixed installation on ships on and below decks but not under water. For direct connector assembly.

Composition

Cable core	GFR strength member in the core, over that single elements designed as tight buffered fiber (TB900L) with non-metallic strain relief elements (aramid) and a halogen-free, flame-retardant subcable jacket (Ø 2.2 mm), stranded in layers (2–16)
Cable jacket	Halogen-free, flame-retardant and oil restistant material (FRNC)
Colour of jacket	● orange

Thermal properties

Transport/storage	– 33 °C to + 85 °C
Installation	– 10 °C to + 50 °C
Operating temperature	– 33 °C to + 85 °C

Mechanical properties

Min. bending radius	static	15 × outer diameter
	dynamic	20 × outer diameter
Max. crush resistance		2000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-24 Cat. C
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Chemical properties

Very good restistance to oil, grease, acids and alkaline solutions.

Number of fibers max.	Outer-Ø	Wall thickness	Weight	Pull force
	mm	mm	kg/km	N
2	7.7	1.1	69	1200
4	7.7	1.1	69	1200
6	9.1	1.1	88	1800
8	10.4	1.1	125	2400
10	12.2	1.3	175	2400
12	13.5	1.3	205	2400
16	13.3	1.3	200	2400

Further basic information on
fire prevention and test methods:
Chapter 12 | Principles
→ page 385 ff.

FiberConnect® Military cables

The military frequently uses optical cables in mobile use for connecting command posts due to their protection against tapping.

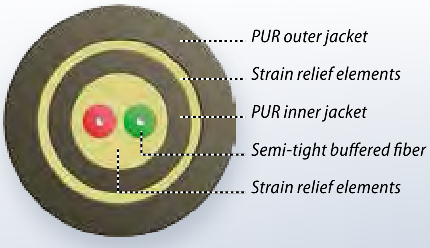
These cables must be resistant to abrasion, reelable at all temperatures and they should reliably protect the fibers despite their small outer diameter. This type of cable is usually assembled with optical lens connectors.

In addition, optical cables are used in military technology such as tanks and artillery for connecting weapon control systems. These cables have to withstand enormous mechanical stress and temperatures.

Regardless of whether you need cables for tactical field use or for other special applications – we have the solution.

FiberConnect® Tactical field cable

Approved by the German Federal Office of Defence Technology and Procurement (BWB)



A-V(ZN)11Y(ZN)11Y 2…

Order no.	**84 950 00 3** ☐
Standardisation	BWB TL 6020-0001 certified and prEN 177000

Description

For military tactical field use and inside buildings.
For direct connector assembly.

Composition

Cable core	2 semi-tight buffered fibers
Strain relief	Non-metallic (aramid)
Inner and outer jacket	Polyurethane (PUR)
Colour of jacket	● RAL 6031 bronze green or customer-specific

Thermal properties

Transport/storage	– 55 °C to + 80 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 70 °C

Mechanical properties

outer diameter		6.0 mm
Cable weight		30.0 kg/km
Min. bending radius	static	25 mm
	dynamic	25 mm
Max. pull force		2000 N
Max. crush resistance		1000 N/dm
Resistance to impacts		30 impacts/2 Nm

Fire performance

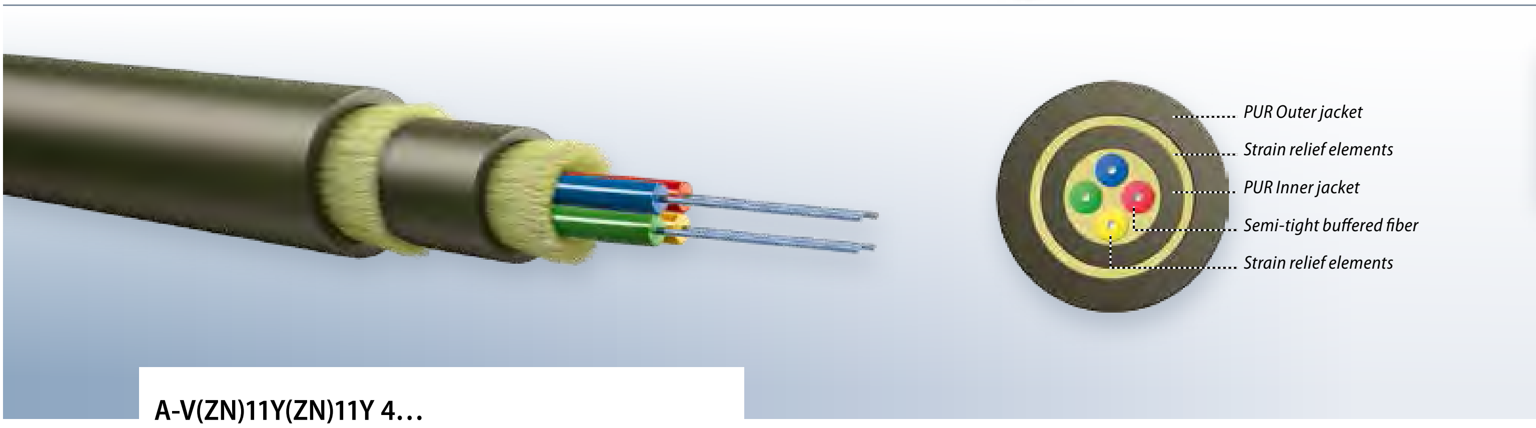
Flame retardancy	IEC 60332-1-2

Chemical properties

Very good resistance to oil, petrol, acids and alkaline solutions.

FiberConnect® Tactical field cable

Approved by the German Federal Office of Defence Technology and Procurement (BWB)



A-V(ZN)11Y(ZN)11Y 4…

Order no.	**84 950 04 2** ☐
Standardisation	BWB TL 6020-0001 with approval and prEN 177000

Description

For military tactical field use and inside buildings.
For direct connector assembly.

Composition

Cable core	4 semi-tight buffered fibers
Strain relief	Non-metallic (aramid)
Inner and outer jacket	Polyurethane (PUR)
Colour of jacket	● RAL 6031 bronze-green or customer-specific

Thermal properties

Transport/storage	– 55 °C to + 80 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 40 °C to + 70 °C

Mechanical properties

outer diameter		6.0 mm
Cable weight		33 kg/km
Min. bending radius	static	90 mm
	dynamic	120 mm
Max. pull force		2000 N
Max. crush resistance		1000 N/dm
Resistance to impacts		30 impacts/2 Nm

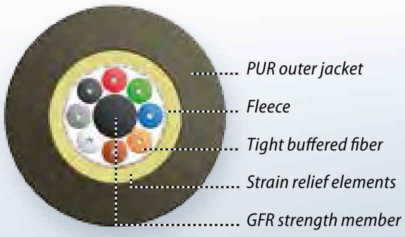
Fire performance

Flame retardancy	IEC 60332-1-2

Chemical properties

Very good resistance to oil, petrol, acids and alkaline solutions.

FiberConnect® Mobile outdoor cable



A-V(ZN)11Y(ZN)11Y 2…

Order no.	**84… see table below**
Standardisation	IEC 60794-2

Description

For mobile and flexible use outdoors, inside buildings and in harsh industrial environments.
Suitable for use in drag chains. For direct connector assembly.

Composition

Cable core	GFR strength member with stranding elements designed as tight buffered fiber (TB900L) and, if applicable, dummy elements
Strain relief	Aramid yarns
Cable jacket	Polyurethane (PUR)
Colour of jacket	● RAL 6031 bronze-green or customer-specific

Thermal properties

Transport/storage	– 55 °C to + 80 °C
Installation	– 5 °C to + 55 °C
Operating temperature	– 40 °C to + 70 °C

Mechanical properties

Min. bending radius	static	10 × outer diameter
	dynamic	15 × outer diameter
Max. pull force		2000 N
Max. crush resistance		1000 N/dm
Resistance to impacts		50 impacts/2 Nm
Drag chain test		1 000 000 cycles

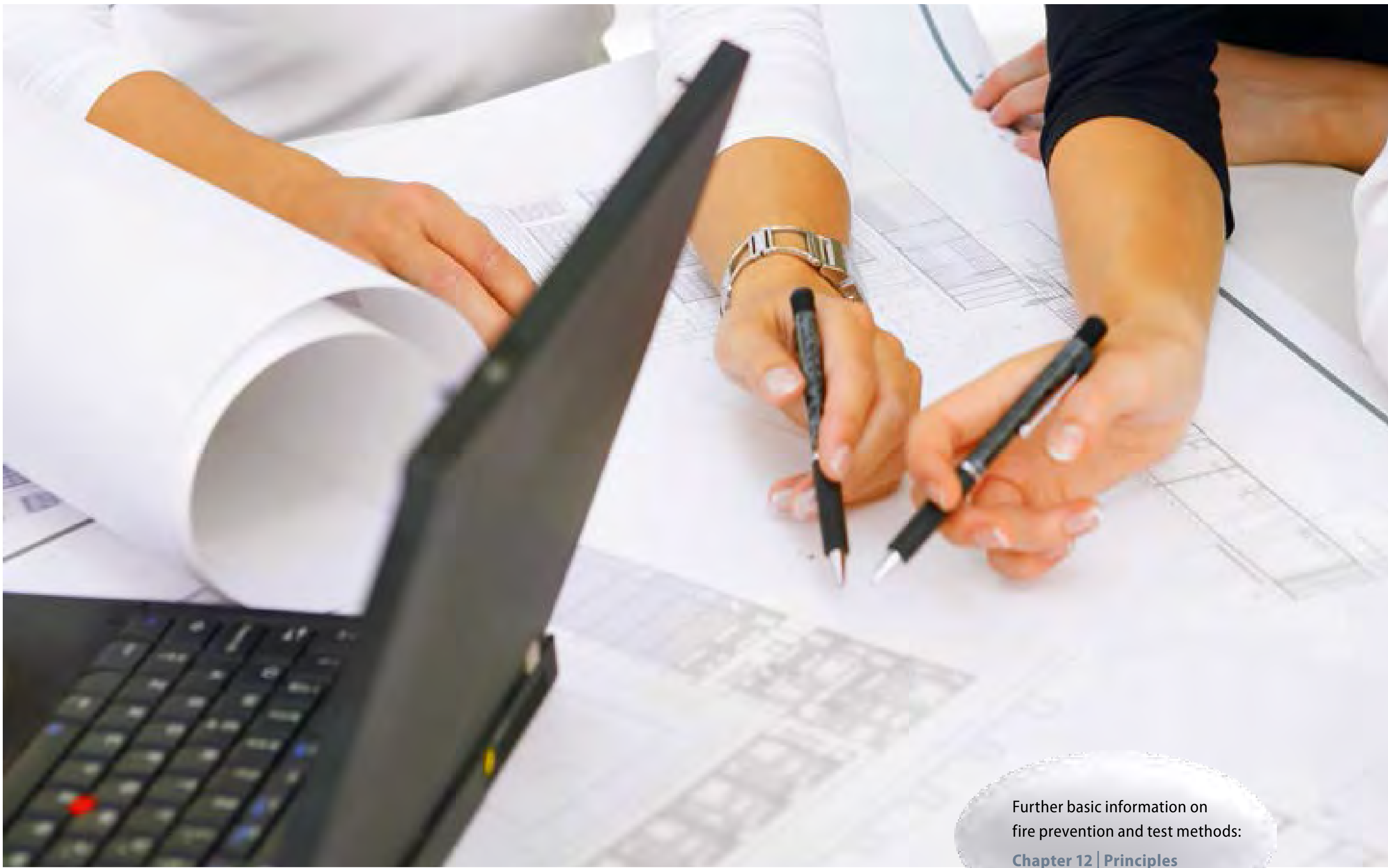
Fire performance

Absence of halogen	IEC 60754-1

Chemical properties

Very good resistance to oil, petrol, acids and alkaline solutions.

Max. number of fibers	Outer Ø	Weight	Order no. TB
	mm	kg/km	
2	6.0	28	**84950572□ TB900L**
4	6.0	32	**84950863□ TB900L**
6	6.0	32	**84950864□ TB900L**
8	7.5	52	**84950285□ TB900L**
10	8.8	67	**84950865□ TB900L**
12	8.8	67	**84950866□ TB900L**



Further basic information on
fire prevention and test methods:
Chapter 12 | Principles
→ page 385 ff.

FiberConnect® Fiber optic cables with UL approval

Cables with UL approvals (Underwriter Laboratories)
Cables with UL approval guarantee safety and reliability in the intended application areas. They are specifically tailored to the requirements of the North American market, however demand for them is increasing in Asia and Europe, where they are more and more demanded and used.

Insurance companies, public authorities, planners and other regulatory authorities above all place their confidence in UL-approved optical cables with singlemode/multimode or plastic fibers.

Fiber optic cables are described in the standard UL 1651- Fiber Optic Cable and categorised according to OFNP (plenum), OFNR (riser) and OFN (general purpose). UL cables have to meet very high requirements for fire performance in particular, including generation of smoke gas.

FiberConnect® Simplex indoor cable

I-V(ZN)H 1… UL OFNR

Order no.	**84 950 40 7** ☐
Standardisation	IEC 60794-2

Description

Indoor cable with UL approbation type OFNR (Riser) for USA and Canada. Ideal for use in distribution systems as well as for connecting terminals.

Composition

Cable core	Flame-retardant semi-tight buffered fiber (STB900H)
Strain relief	Non-metallic (aramid)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● blue

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

outer diameter		2.9 mm
Cable weight		10.0 kg/km
Min. bending radius	static	30 mm
	dynamic	60 mm
Max. pull force		400 N
Max. crush resistance		150 N/dm

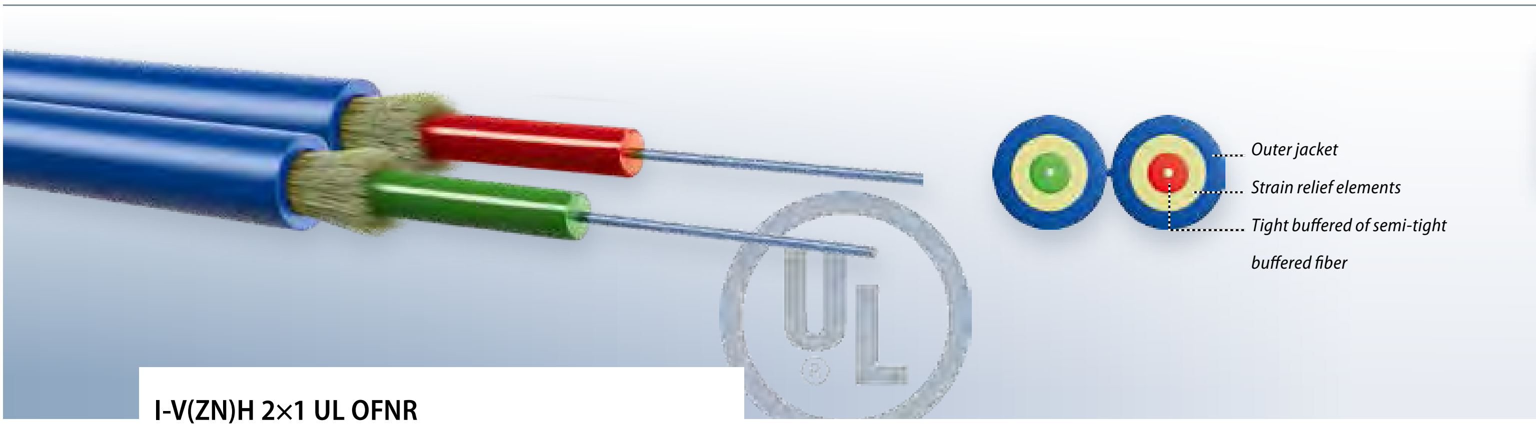
Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2
Fire load	0.18 MJ/m

Approval (UL approbation type)

- OFNR FT4 (NEC Article 770, UL 1651)
- c(UL)us

Fiber**Connect**® Duplex indoor cable



I-V(ZN)H 2×1 UL OFNR

Order no.	**84 005 01 7□ ZUL00**
Standardisation	IEC 60794-2

Description

Indoor cable approbation type OFNR (Riser) for USA and Canada. Ideal for use in distribution systems as well as for connecting terminals.

Composition

Cable core	2 flame-retardant semi-tight buffered fibers
Strain relief	Non-metallic (aramid)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● blue

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

Outer dimensions		2.8 mm × 5.7 mm
Cable weight		15.8 kg/km
Min. bending radius	static	30 mm
	dynamic	60 mm
Max. pull force		600 N
Max. crush resistance		600 N/dm

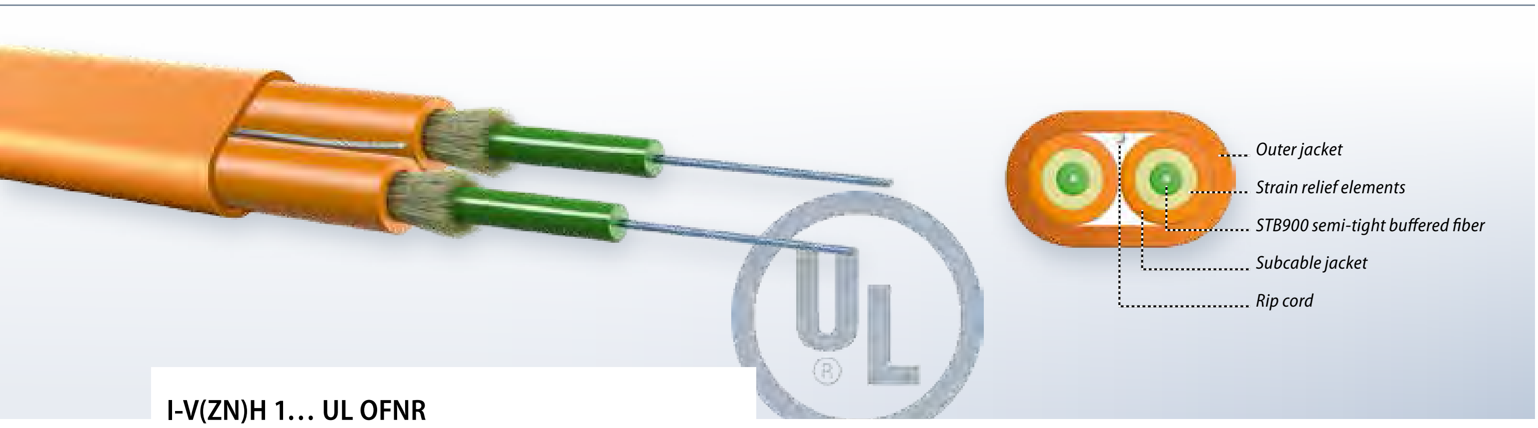
Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2
Fire load	0.36 MJ/m

Approval (UL approbation type)

- OFNR FT4 (NEC Article 770, UL 1651)
- c(UL)us

FiberConnect® Duplex indoor cable



I-V(ZN)H 1… UL OFNR

Order no.	**84 011 01 1☐ ZUL00**
Standardisation	IEC 60794-2

Description

Indoor cable with UL approbation type OFNR (Riser). Ideal for use in distribution systems, for connecting terminals as well as for fixed installation.

Composition

Cable core	Two single-fiber cables (STB900) arranged in parallel beside each other with non-metallic strain relief elements (aramid) and a halogen-free, flame-retardant subcable jacket (Ø 2.5 mm)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● orange for multimode ● yellow for singlemode

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

Outer dimensions		3.7 × 6.2 mm
Cable weight		26.0 kg/km
Min. bending radius (over flat side)	static	35 mm
	dynamic	65 mm
Max. pull force		600 N
Max. crush resistance		600 N/dm

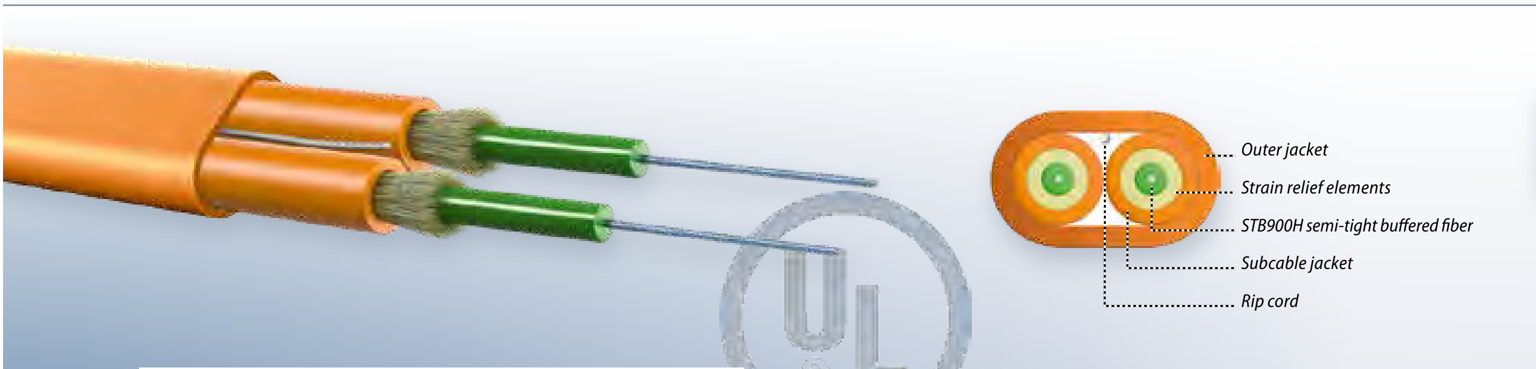
Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2
Fire load	0.65 MJ/m

Approval (UL approbation type)

OFNR (NEC Article 770, UL 1651)

Fiber**Connect**® Duplex indoor cable



I-V(ZN)HH 2×1 UL OFN

Order no.	**84 950 50 0□**
Standardisation	IEC 60794-2

Description

Indoor cable with UL approbation type OFN (General Purpose) for USA and Canada. Ideal for use in distribution systems, for connecting terminals as well as for fixed installation.

Composition

Cable core	Two single-fiber cables STB900H arranged in parallel beside each other with non-metallic strain relief elements (aramid) and a halogen-free, flame-retardant subcable jacket (Ø 2.0 mm)
Cable jacket	Halogen-free, flame-retardant material
Colour of jacket	● orange for multimode ● yellow for singlemode

Thermal properties

Transport/storage	– 25 °C to + 70 °C
Installation	– 5 °C to + 50 °C
Operating temperature	– 10 °C to + 70 °C

Mechanical properties

Outer dimensions		3.0 × 5.0 mm
Cable weight		18.5 kg/km
Min. bending radius	static	30 mm
	dynamic	60 mm
Max. pull force		600 N
Max. crush resistance		1000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2
Fire load	0.62 MJ/m

Approval (UL approbation type)

- OFN FT1 75 °C (NEC Article 770, UL 1651)
- c(UL)us

FiberConnect® Duplex outdoor cable

AT-V(ZN)YY 2… UL OFNR

Order no.	**84 950 63 2**☐
Standardisation	IEC 60794-2

Description
Extremely temperature-stable and UV-hard outdoor cable, tested according to UL OFNR flame test. Ideal for use in harsh environments such as mobile base stations.

Composition

Cable core	Stranding consisting of two PVC single cables with tight buffered fibers (TB900L) with non-metallic strain relief elements (aramid) (Ø 2.4 mm)
Cable jacket	Flame-retardant polyvinyl chloride (PVC)
Colour of jacket	● black

Thermal properties

Transport/storage	– 55 °C to + 85 °C
Installation	– 20 °C to + 60 °C
Operating temperature	– 40 °C to + 85 °C

Mechanical properties

outer diameter		7.0 mm
Weight		44.0 kg/km
Min. bending radius (over flat side)	static	70 mm
	dynamic	105 mm
Max. pull force		600 N
Max. crush resistance		800 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2

Approval (UL approbation type)
- OFNR FT4 (NEC Article 770, UL 1651)
- c(UL)us

Fiber**Connect**® Duplex outdoor cable

AT-V(ZN)YY 2… UL AWM Style

Order no.	**84 950 50 4** ☐
Standardisation	IEC 60794-2

Description

Extremely temperature-stable and UV-hard outdoor cable, tested acc. to UL VW-1 flame test. Ideal for use in harsh environments such as mobile base stations.

Composition

Cable core	Stranding consisting of two PVC single elements with tight buffered fibers (TB900A) with non-metallic strain relief elements (aramid) (Ø 2.4 mm)
Cable jacket	Flame-retardant polyvinyl chloride (PVC)
Colour of jacket	● black

Thermal properties

Transport/storage	– 55 °C to + 85 °C
Installation	– 20 °C to + 60 °C
Operating temperature	– 40 °C to + 85 °C

Mechanical properties

outer diameter		7.0 mm
Weight		44.0 kg/km
Min. bending radius (over flat side)	static	70 mm
	dynamic	105 mm
Max. pull force		800 N
Max. crush resistance		800 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and VW-1 flame test

Approval (UL approbation type)

UL-AWM Style 5432

FiberConnect® Splittable outdoor cable

AT-V(ZN)YY n… UL OFNR

Order no.	**84 217** □□ □ □
Standardisation	IEC 60794-2

Description

Extremely temperature-stable and UV resistant outdoor cable, tested acc. to UL OFNR flame test. Ideal for use in harsh environments such as mobile base stations and wind turbines.
For direct connector assembly.

Composition

Cable core	GFR strength member in the core, over that single elements stranded in one layer. Single element (TB900L) made from PVC (Ø 2.2 mm). Orange colour for multimode and yellow for singlemode and non-metallic strain relief elements (aramid).
Cable jacket	Flame-retardant polyvinyl chloride (PVC)
Colour of jacket	● black

Thermal properties

Transport/storage	−40 °C to + 85 °C
Installation	− 5 °C to + 50 °C
Operating temperature	− 40 °C to + 85 °C

Mechanical properties

Min. bending radius	static	10 × outer diameter
	dynamic	15 × outer diameter
Max. crush resistance		1000 N/dm

Fire performance

Flame retardancy
- IEC 60332-1-2 and IEC 60332-3-22 Cat. A
- OFNR FT4 (NEC Article 770, UL 1651)
- c(UL)us

Approval (UL approbation type)

- OFNR FT4 (NEC Article 770, UL 1651)
- c(UL)us

Chemical properties

- Good resistance to oil, petrol, acids and alkaline solutions
- UV resistance of outer jacket acc. to DIN EN ISO 4892-2, test method A, UV applications up to 500 hours

Max. number of fibers	Outer Ø	Wall thickness	Weight	max. Pull force
	mm	mm	kg/km	N
2	7.8	1.2	60	800
4	7.8	1.2	60	800
6	9.2	1.2	85	1200
8	10.5	1.2	110	1200
10	11.9	1.2	140	1200
12	13.3	1.2	180	1200

Fiber**Connect**® Splittable outdoor cable

AT-V(ZN)Y(ZN)Y n … UL OFNR

Order no.	**84 218**☐☐ ☐ ☐
Standardisation	IEC 60794-2

Description

Extremely temperature-stable and UV-resistant outdoor cable, tested acc. to UL OFNR flame test. Ideal for use in harsh environments such as mobile base stations and wind turbines.
For direct connector assembly.

Composition

Cable core	GFR strength member in the core, over that single elements stranded in one layer. Single element (TB900L) made from PVC (Ø 2.2 mm), orange colour for multimode and yellow for singlemode and non-metallic strain relief elements (aramid)
Cable jacket	Flame-retardant polyvinyl chloride (PVC)
Colour of jacket	● black

Thermal properties

Transport/storage	−40 °C to + 85 °C
Installation	− 5 °C to + 50 °C
Operating temperature	− 40 °C to + 85 °C

Mechanical properties

Min. bending radius	static	10 × outer diameter
	dynamic	15 × outer diameter
Max. crush resistance		2000 N/dm

Fire performance

Flame retardancy
- IEC 60332-1-2 and IEC 60332-3-22 Cat. A
- OFNR FT4 (NEC Article 770, UL 1651)
- c(UL)us

Approval (UL approbation type)

- Type OFNR FT4 (NEC Article 770, UL 1651)
- c(UL)us

Chemical properties

- Good resistance to oil, petrol, acids and alkaline solutions
- UV-hardness of outer jacket acc. to DIN EN ISO 4892-2, test method A, UV applications up to 500 hours

Max. number of fibers	Outer--Ø	Wall thickness	Weight	Max. pull force
	mm	mm	kg/km	N
2	8.4	1.2	70	2000
4	8.4	1.2	70	2000
6	10.1	1.2	95	3000
8	11.4	1.2	120	3000
10	12.8	1.2	150	3000
12	14.2	1.2	190	3000

FiberConnect® Splittable outdoor cable

Breakout cable for wind turbines

AT-V(ZN)HH n… TB900L

Order no.	**84 222** ☐☐ ☐ ☐
Standardisation	IEC 60794-2

Description

Developed especially for data transmission between control cabinets in wind power plants.

- For flexible use in the revolving cable harness in wind power plants
- UL OFNR flame test
- Ideal for use in wind turbines
- For direct connector assembly

Composition

Cable core	GRF strength member in the core, over that single elements stranded in one layer. Single element (TB900L) from flame-retardant FRNC (Ø 2,2 mm), orange colour for multimode and yellow for singlemode and non-metallic strain relief elements (aramid)
Cable jacket	Halogen-free, flame-retardant and oil-resistant material (FRNC)
Colour of jacket	● black

Number of fibers	Outer Ø	Weight	Pull force
	mm	kg/km	N
2	7.8	63	800
4	7.8	63	800
6	9.2	90	1200
8	10.5	110	1200
10	11.9	140	1200
12	13.3	189	1200

Thermal properties

Transport/storage	−40 °C to + 70 °C
Installation	− 25 °C to + 50 °C
Operating temperature	− 40 °C to + 70 °C

Mechanical properties

Min. bending radius	static	10 × outer diameter
	dynamic	15 × outer diameter
Torsion	IEC60794-1-2 E7	
	2000 cycles, rotation ±144°/m	
Max. crush resistance		1000 N/dm

Fire performance

Flame retardancy	IEC 60332-1-2 and IEC 60332-3-24 Cat. C
Smoke density	IEC 61034
Absence of halogen	IEC 60754-1
Acidity of combustion gases	IEC 60754-2

Approval (UL approbation type)

- UL 1651 OFNR (UL 1666) (NEC Article 770)

Chemical properties

- Very good resistance to oil, grease, acids and alkaline solutions
- Resistance of outer jackets to media and oil acc. to VG 95218-30 type B

FiberConnect® Optical fiber assembly

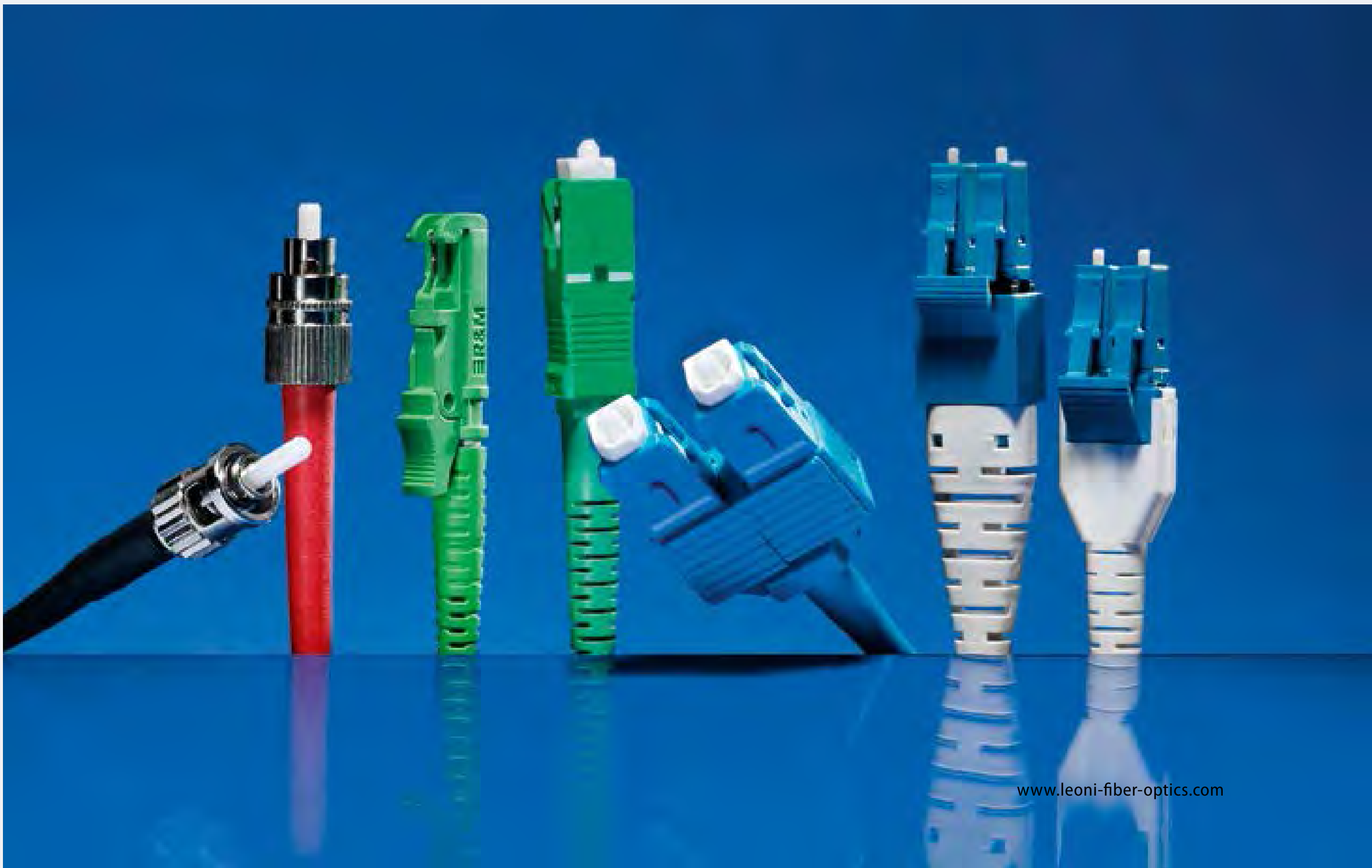
Almost all connectors can be combined with the cables listed on pages 211 to 281.

Lengths ≥ 100 m are supplied on plywood reels as standard.

In the case of multi-fiber loose tube cables, the assembly can be equipped with the economical "Easy Pull" cabling system (see page 292/293) or the extremely rugged "Heavy Trunk" cabling system (see page 294).

Customer-specific requirements for pulling tool, connector protection, packaging, labelling, boot colour, length, length tolerance, whip length and whip length tolerance are possible whether taking delivery of a single unit or a high volume.

Various components can also be installed in 19" slots or vertical insert modules on request.



Assembly and sale of component parts for the following connector types:

Connector type	**SM** (E9/125)	**MM** G50/125) in OM2, OM3 and OM3e	**MM** G62.5/125) in OM1 and OM1e	**MM** with 140 µ cladding
ST/SPC	✔	✔	✔	on request
ST/UPC	✔	✔	✔	on request
SC/SPC	✔	✔	✔	✔
SC/UPC	✔	✔	✔	✔
SC/APC 8°	✔	✔	✔	✔
SC/APC 9°	✔	✔	✔	✔
SCRJ/SPC	✔	✔	✔	✔
SCRJ/UPC	✔	✔	✔	✔
SCRJ/APC 8°	✔	✔	✔	✔
SCRJ/APC 9°	✔	✔	✔	✔
LC/SPC	✔	✔	✔	on request
LC/UPC	✔	✔	✔	on request
LC/APC 8°	✔	✔	✔	on request
LC-uniboot I/SPC	✔	✔	✔	on request
LC-uniboot I /UPC	✔	✔	✔	on request
LC-uniboot I /APC 8°	✔	✔	✔	on request
LC-uniboot II/SPC	✔	✔	✔	on request
LC-uniboot II /UPC	✔	✔	✔	on request
LC-uniboot I I/APC 8°	✔	✔	✔	on request
FC/SPC	✔	✔	✔	✔
FC/UPC	✔	✔	✔	✔
FC/APC 8°	✔	✔	✔	✔
DIN/SPC	✔	✔	✔	on request
DIN/UPC	✔	✔	✔	on request
DIN/APC 8°	✔	✔	✔	on request
FSMA 905	✔	✔	✔	✔
FSMA 906	✔	✔	✔	on request
MTRJ female	✔	✔	✔	✘
MTRJ male	✔	✔	✔	✘
E2000/UPC™	✔	✔	✔	on request
E2000/APC 8°™	✔	✔	✔	on request
E2000/UPC compact™	✔	✔	✔	on request
E2000/APC 8° compact™	✔	✔	✔	on request

Typical values:

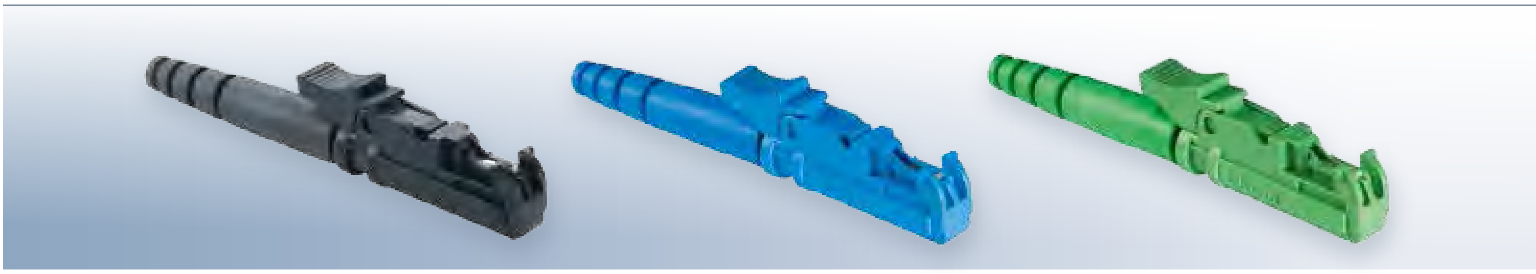
Connector type	**IL** (typ.)	**IL** (max.)	**RL** (min.)	**Form fidelity**
MM/SPC	≤ 0.2dB	≤ 0.3dB	≥ 35dB	acc. to IEC 61300-3-15 IEC 61300-3-16 IEC 61300-3-23
MM/UPC	≤ 0.2dB	≤ 0.3dB	≥ 40dB	
MM/APC	≤ 0.2dB	≤ 0.3dB	≥ 50dB	
SM/SPC	≤ 0.2dB	≤ 0.3dB	≥ 35dB	
SM/UPC	≤ 0.2dB	≤ 0.3dB	≥ 50dB	
SM/APC	≤ 0.2dB	≤ 0.3dB	≥ 70dB	
MTRJ SM	≤ 0.3dB	≤ 0.3dB	≥ 35dB	
MTRJ MM	≤ 0.3dB	≤ 0.3dB	≥ 20dB	
LC-uniboot MM/SPC	≤ 0.3dB	≤ 0.5dB	≥ 35dB	
LC-uniboot MM/UPC	≤ 0.3dB	≤ 0.5dB	≥ 40dB	
LC-uniboot MM/APC	≤ 0.3dB	≤ 0.5dB	≥ 50dB	
LC-uniboot SM/SPC	≤ 0.5dB	≤ 0.6dB	≥ 35dB	
LC-uniboot SM/UPC	≤ 0.5dB	≤ 0.6dB	≥ 50dB	
LC-uniboot SM/APC	≤ 0.5dB	≤ 0.6dB	≥ 70dB	

Almost all connector types can be assembled on buffered fibers with a diameter of 0.6 to 0.9 mm and 1.8 to 3.5 mm. E2000 type: R&M, SCRJ available as IP20 or IP67.

Connectors for singlemode/multimode fibers

with metal or ceramic ferrules

	DIN connector		
Product name	DIN/PC multimode	DIN/PC singlemode	DIN/APC8° singlemode
Order no.	SFER-SK0-53-0020	SFER-SK0-53-0010	SFER-SK0-53-0030
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm
Ferrule	ceramic	ceramic	ceramic
Cable Ø	0.9 – 3.0 mm	0.9 – 3.0 mm	0.9 – 3.0 mm
Locking	union nut	union nut	union nut
Housing	metal	metal	metal
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing



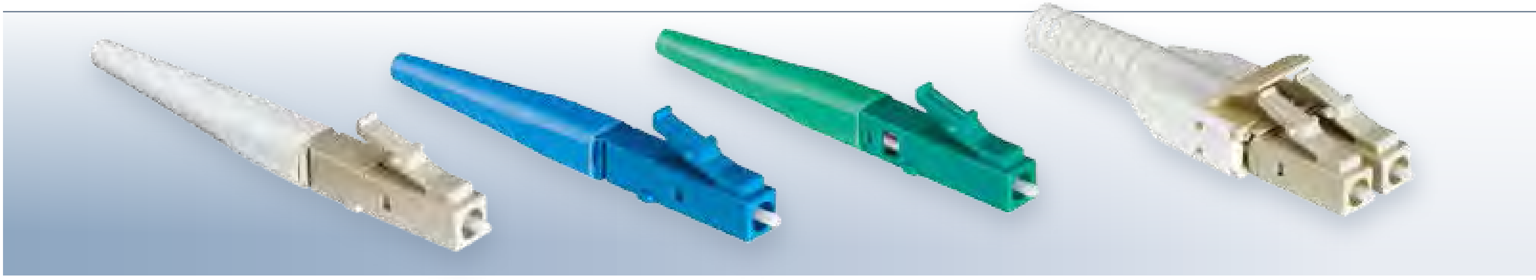
	E2000 connector		
Product name	E2000/PC multimode	E2000/PC singlemode	E2000/APC8° singlemode
Order no.	SFER-SK0-12-0010	SFER-SK0-12-0020	SFER-SK0-12-0030
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm
Ferrule	ceramic	ceramic	ceramic
Cable Ø	0.9 – 3.0 mm	0.9 – 3.0 mm	0.9 – 3.0 mm
Locking	push-pull system	push-pull system	push-pull system
Housing	plastic / colour black	plastic / colour black	plastic / colour black
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing

	FC connector		
Product name	FC/PC multimode	FC/PC singlemode	FC/APC singlemode
Order no.	SFER-SK0-47-0080	SFER-SK0-47-0050	SFER-SK0-47-0060
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm
Ferrule	ceramic	ceramic	ceramic
Cable Ø	0.9 – 3.0 mm	0.9 – 3.0 mm	0.9 – 3.0 mm
Locking	union nut	union nut	union nut
Housing	metal	metal	metal
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing

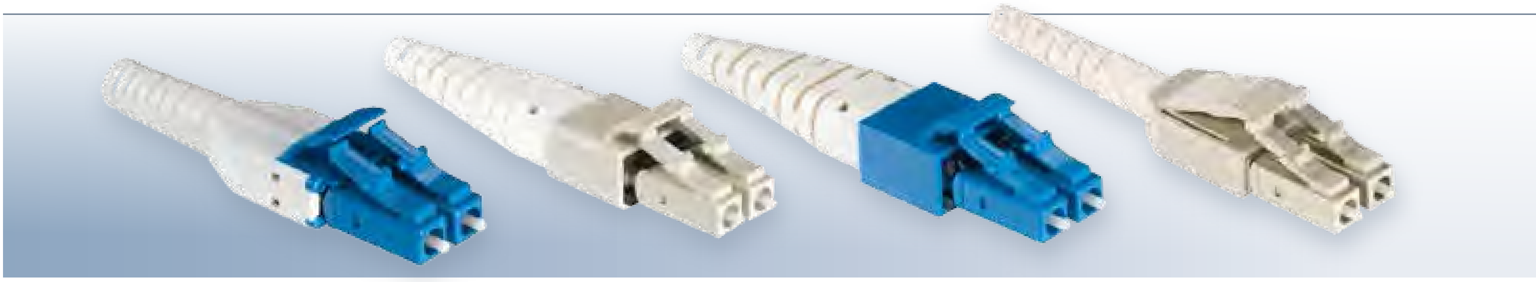
	FSMA connector		
Product name	FSMA905 multimode	FSMA905 multimode	FSMA905 singlemode
Order no.	SFER-SK0-49-0320	SFER-SK0-04-0150	SFER-SK0-04-0160
Fiber	50/125 µm or 62.5/125 µm	50/125 µm or 62.5/125 µm	9/125 µm
Ferrule	metal	ceramic	ceramic
Cable Ø	0.9 – 3.0 mm	0.9 – 3.0 mm	0.9 – 3.0 mm
Locking	union nut	union nut	union nut
Housing	metal	metal	metal
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing

Connectors for singlemode/multimode fibers

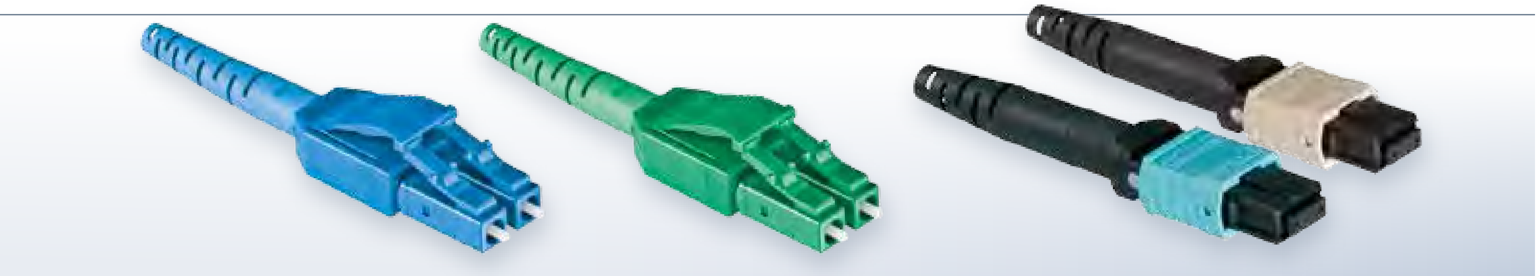
with thermoplastic or ceramic ferrules



	LC connector			
Product name	LC/PC multimode	LC/PC singlemode	LC/APC8° singlemode	LC uniboot/PC type1 multimode
Order no.	SFER-SK0-49-0010	SFER-SK0-49-0030	SFER-SK0-49-0180	SXLC-DK0-43-0010
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm	50/125 µm or 62.5/125 µm
Ferrule	ceramic	ceramic	ceramic	ceramic
Cable Ø	0.9 – 3.0 mm	0.9 – 3.0 mm	0.9 – 3.0 mm	2.8 – 3.0 mm
Locking	push-pull system	push-pull system	push-pull system	push-pull system
Housing	plastic / colour beige	plastic / colour blue	plastic / colour green	plastic / colour beige
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing



	LC connector			
Product name	LC uniboot/PC type1 singlemode	LC uniboot/PC type2 multimode	LC uniboot/PC type2 singlemode	LC uniboot/PC type6 multimode
Order no.	SXLC-DK0-43-0020	SXLC-DK0-56-0010	SXLC-DK0-56-0020	SXLC-DK0-56-0040
Fiber	9/125 µm	50/125 µm or 62.5/125 µm	9/125 µm	50/125 µm or 62.5/125 µm
Ferrule	ceramic	ceramic	ceramic	ceramic
Cable Ø	2.8 – 3.0 mm	2.8 – 3.0 mm	2.8 – 3.0 mm	2.8 – 3.0 mm
Locking	push-pull system	push-pull system	push-pull system	push-pull system
Housing	plastic / colour blue	plastic / colour beige	plastic / colour blue	plastic / colour beige
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing

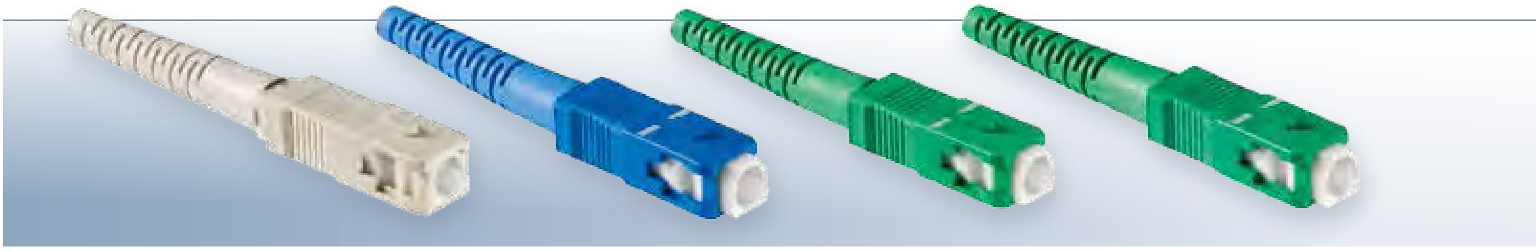


	LC connector		MTP connector
Product name	LC uniboot/PC type 6 singlemode	LC uniboot/APC8° type 6 singlemode	MTP
Order no.	SXLC-DK0-56-0050	SXLC-DK0-56-0060	depending on number and type of fiber
Fiber	9/125 µm	9/125 µm	9/125 µm, 50/125 µm or 62.5/125 µm
Ferrule	ceramic	ceramic	thermoplastic
Cable Ø	2.8 – 3.0 mm	2.8 – 3.0 mm	0.9 – 3.0 mm
Locking	push-pull system	push-pull system	push-pull system
Housing	plastic / colour blue	plastic / colour green	plastic/colour selectable: beige/aqua/ green/mustard
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing

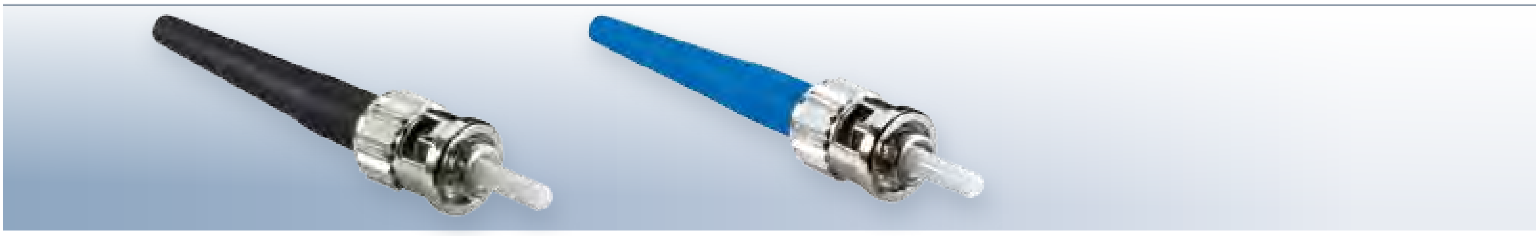
	MTRJ connector			
Product name	MTRJ/female multimode	MTRJ/male multimode	MTRJ/female singlemode	MTRJ/male singlemode
Order no.	SMTR-SK0-53-0010	SMTR-SK0-53-0020	SMTR-SK0-53-0030	SMTR-SK0-53-0040
Fiber	50/125 µm or 62.5/125 µm	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm
Ferrule	thermoplastic	thermoplastic	thermoplastic	thermoplastic
Cable Ø	2 × 1.8 mm	2 × 1.8 mm	2 × 1.8 mm	2 × 1.8 mm
Locking	push-pull system	push-pull system	push-pull system	push-pull system
Housing	plastic /colour black	plastic /colour black	plastic /colour black	plastic /colour black
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing

Connectors for singlemode/multimode fibers

with ceramic ferrules

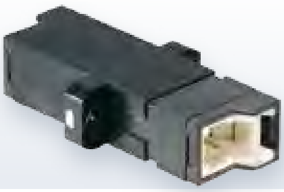
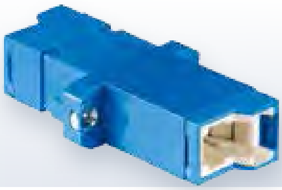
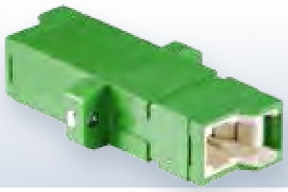


	SC connector			
Product name	SC/PC multimode	SC/PC multimodee	SC/APC8° singlemode	SC/APC9° singlemode
Order no.	SFER-SK0-47-0040	SFER-SK0-47-0020	SFER-SK0-47-0070	SFER-SK0-47-0090
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm	9/125 µm
Ferrule	ceramic	ceramic	ceramic	ceramic
Cable Ø	0.9 – 3.0 mm	0.9 – 3.0 mm	0.9 – 3.0 mm	0.9 – 3.0 mm
Locking	push-pull system	push-pull system	push-pull system	push-pull system
Housing	plastic / colour beige	plastic / colour blue	plastic / colour green	plastic / colour green
Assembly	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing	crimping/gluing/polishing

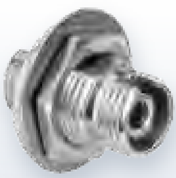


	ST connector	
Product name	ST/PC multimode	ST/PC singlemode
Order no.	SFER-SK0-47-0030	SFER-SK0-47-0010
Fiber	50/125 µm or 62.5/125 µm	9/125 µm
Ferrule	ceramic	ceramic
Cable Ø	0.9 – 3.0 mm	0.9 – 3.0 mm
Locking	bayonet catch	bayonet catch
Housing	metal	metal
Assembly	crimping/gluing/polishing	crimping/gluing/polishing

Adapters for singlemode/multimode fibers

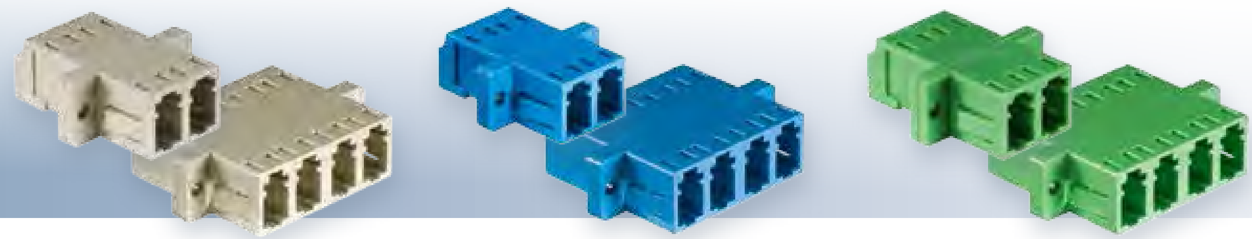
	E2000 adapter		
Product name	E2000/PC multimode	E2000/PC singlemode	E2000/APC singlemode
Order no.	NSKUP-2XE2K-0030 (simplex)	NSKUP-2XE2K-0020 (simplex)	NSKUP-2XE2K-0010 (simplex)
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm
Housing	plastic with PhBz insert	plastic with ceramic insert	plastic with ceramic insert



	FC adapter		
Product name	FC/PC multimode	FC/PC singlemode	FC/APC singlemode
Order no.	NSKUP-2XFCP-0050 (simplex)	NSKUP-2XFCP-0060 (simplex)	NSKUP-2XFCA-0020 (simplex)
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm
Housing	plastic with PhBz insert	plastic with ceramic insert	plastic with ceramic insert

	FSMA adapter
Product name	FSMA multimode
Order no.	NSKUP-2XSMA-0010 (simplex)
Fiber	50/125 µm or 62.5/125 µm
Housing	metal

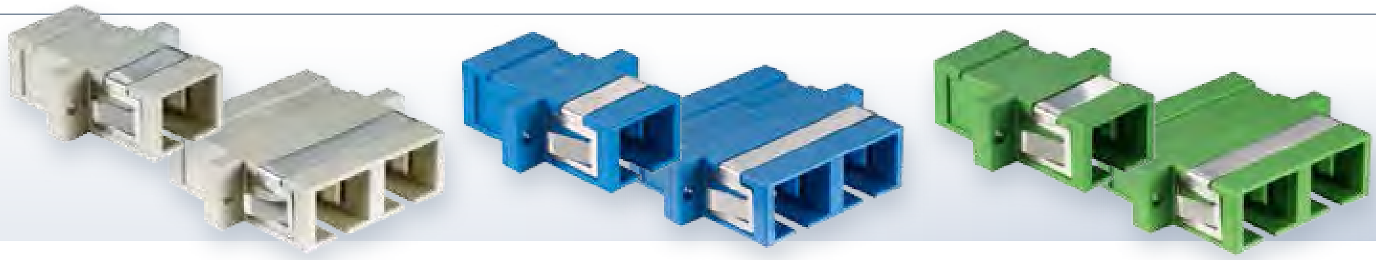
Adapters for singlemode/multimode fibers



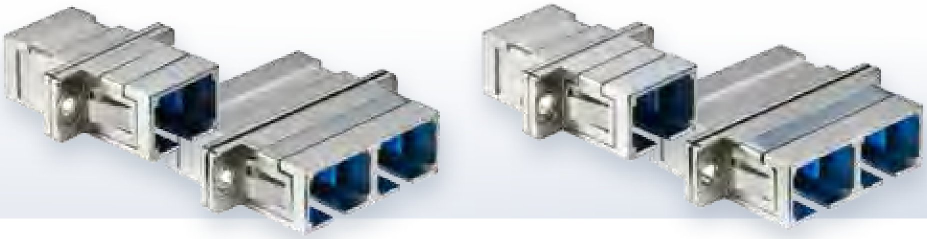
	LC adapter		
Product name	LC/PC multimode	LC/PC singlemode	LC/APC singlemode
Order no.	NSKUP-2XXLC-0040 (simplex) NSKUP-2XXLC-0030 (duplex) NSKUP-2XXLC-0100 (quad)	NSKUP-2XXLC-0020 (simplex) NSKUP-2XXLC-0010 (duplex) NSKUP-2XXLC-0110 (quad)	NSKUP-2XXLC-0060 (simplex) NSKUP-2XXLC-0050 (duplex) NSKUP-2XXLC-0120 (quad)
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm
Housing	plastic with PhBz insert	plastic with ceramic insert	plastic with ceramic insert

	LC adapter		
Product name	LC/PC multimode shuttered	LC/PC singlemode shuttered	LC/APC singlemode shuttered
Order no.	NSKUP-2XXLC-0070 (duplex)	NSKUP-2XXLC-0080 (duplex)	NSKUP-2XXLC-0090 (duplex)
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm
Housing	plastic with PhBz insert	plastic with ceramic insert	plastic with ceramic insert

	MTP adapter	MTRJ adapter
Product name	MTP	MTRJ
Order no.	NSKUP-2XMTP-0010	NSKUP-2XMTR-0020
Fiber	50/125 µm, 62.5/125 µm or 9/125 µm	50/125 µm, 62.5/125 µm or 9/125 µm
Housing	plastic	plastic



	SC adapter		
Product name	SC/PC multimode	SC/PC singlemode	SC/APC singlemode
Order no.	NSKUP-2XXSC-0020 (simplex) NSKUP-2XSCD-0020 (duplex)	NSKUP-2XXSC-0030 (simplex) NSKUP-2XSCD-0030 (duplex)	NSKUP-2XSCA-0010 (simplex) NSKUP-2XSCA-0020 (duplex)
Fiber	50/125 µm or 62.5/125 µm	9/125 µm	9/125 µm
Housing	plastic with PhBz insert	plastic with ceramic insert	plastic with ceramic insert

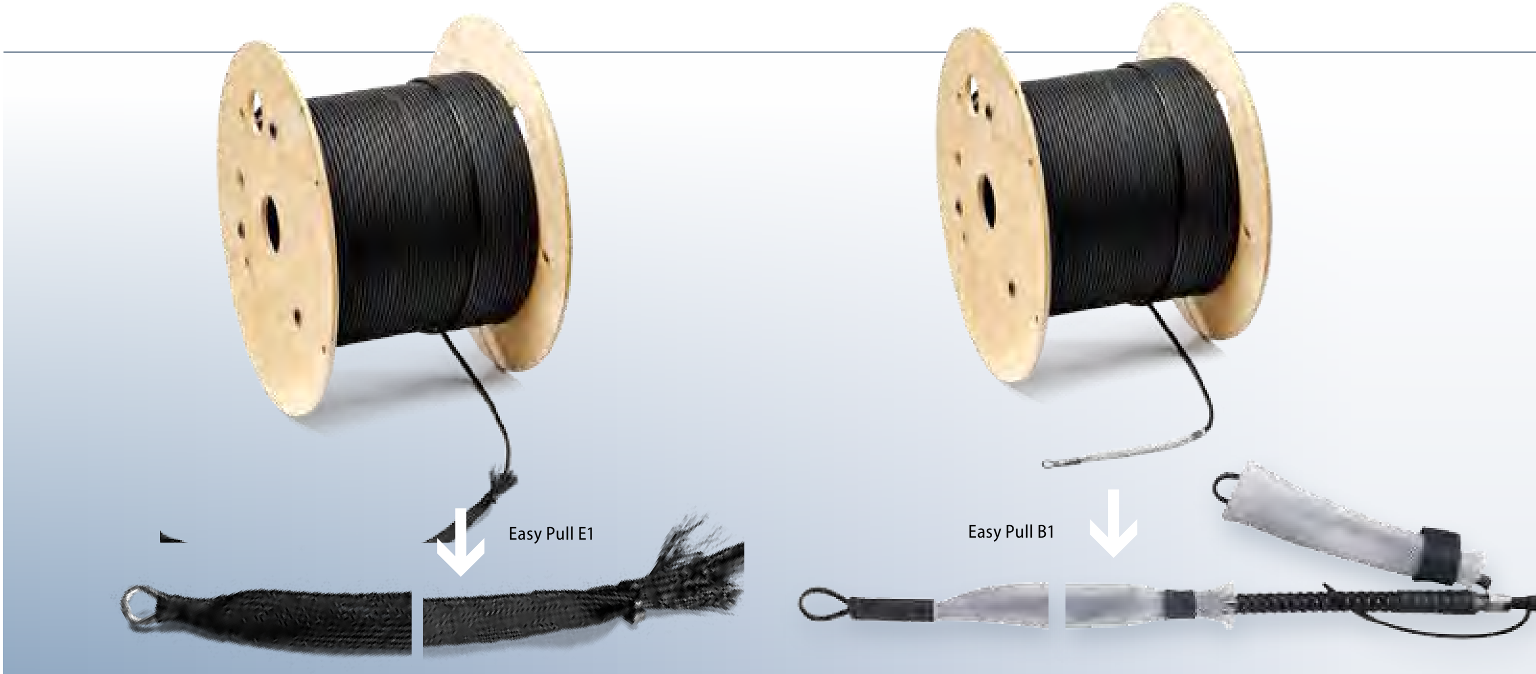


	SC adapter	
Product name	SC/PC multimode metal	SC/PC singlemode metal
Order no.	NSKUP-2XXSC-0040 (simplex) NSKUP-2XSCD-0040 (duplex)	NSKUP-2XXSC-0010 (simplex) NSKUP-2XSCD-0010 (duplex)
Fiber	50/125 µm or 62.5/125 µm	9/125 µm
Housing	Metall mit PhBz-Einsatz	Metall mit Ceramiceinsatz

	ST adapter	
Product name	ST/PC multimode	ST/PC singlemode
Order no.	NSKUP-2XXST-0020 (simplex)	NSKUP-2XXST-0030 (simplex)
Fiber	50/125 µm or 62.5/125 µm	9/125 µm
Housing	metal with PhBz insert	metal with ceramic insert

FiberConnect® Easy Pull

Installation aid system for fiber numbers from 1 to 32



Easy Pull E1 / Easy Pull B1

Easy Pull E1

The installation system can be used for assemblies with up to four single fibers. The connectors are optimally protected against damage during installation (in accordance with protection class IP20) and pulling in the cables is made much easier.

Once the cables have been pulled in, the installation protection can be easily removed and the connectors can be joined to the adapters or transceivers as usual at the destination. Gauging the assembly in the plant is an integral part of the delivery package

Easy Pull B1

new

Now available: the installation aid system Easy Pull B1.

Thinner and more compact compared to Easy Pull E1, for assemblies with one connector only. With flexible loop for easy installation in narrower ducts. Can remain on cable after installation for further use if required

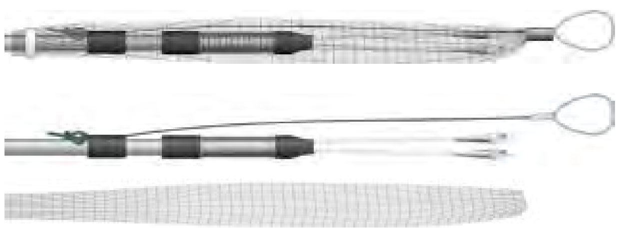
Number of fibers n	1	2	3
Min. bending radius of cable	as per cable datasheet		
Min. bending radius buffered fiber/whip	—	30 mm	30 mm
Min. hole Ø for through-feeds with cabinets and walls	*	30 mm	30 mm
Max. pull force on tool	200 N	500 N	600 N

* depending on connector type

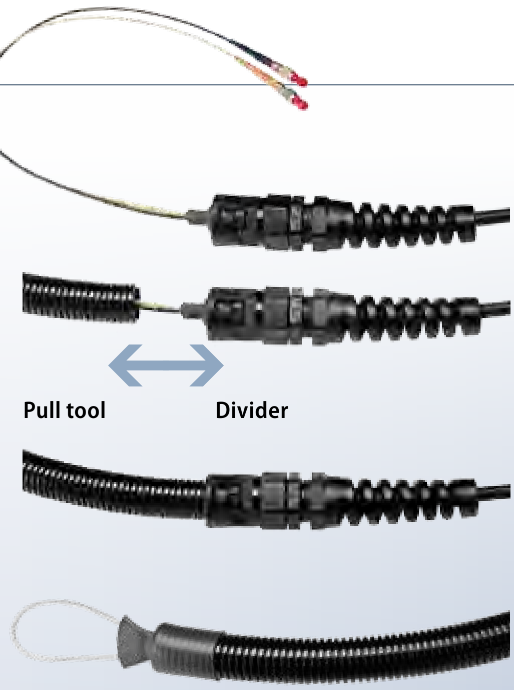
Fanout

The fanout specially developed for the Easy Pull E1 system contains no metal and is especially sturdy despite its low weight.

Its design means that the wall bushings needed during installation are only marginally larger than the divider itself. All that is needed to remove the installation protection is a sharp knife and a cutting pliers.



Here you can find
the corresponding cable:
Chapter 08 | PCF
Chapter 09 | Fiber optic cables



Easy Pull E2

Description

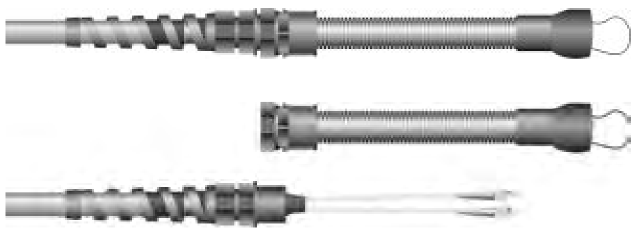
This installation system can be used to protect assemblies with up to 32 single fibers (with IP54 protection). The protective conduit can be easily unlatched and removed after pulling in. The connectors can be joined to adapters or transceivers as normal. Gauging the assembly in the plant is an integral part of the delivery package.

Fanout

The fanout specially developed for the Easy Pull E2 system contains no metal and is especially sturdy despite its low weight. The installation protection is splashproof and offers good protection against mechanical damage. The high flexibility permits trouble-free installation, even under difficult conditions. The installation protection can be removed without any tools.

Properties

- Sturdy, watertight, flexible and UV-resistant protective conduit made from PA 6, with pulling eye
- Cable gland can be used for quick and secure fixing in control cabinets and boxes
- Torsion-free removal of the protective conduit for protecting the connector
- With more than two fibers, the individual whips are graduated in accordance with the customer's requirements



Number of fibers n	2	4	5 to 12	13 to 32
Min. bending radius of cable	acc. to cable datasheet			
Min. bending radius buffered fiber/whip	30 mm	30 mm	30 mm	30 mm
Outer Ø fanout element	14 mm	14 mm	21 mm	30 mm
Resistance to apex pressure (protective conduit)	350 N	350 N	350 N	350 N
Max. pull force on tool	500 N	500 N	600 N	600 N
PG gland	M20 (PG13.5)	M25 (PG21)	M25 (PG21)	M50 (PG36)
Outer Ø of protective conduit	20 mm	30 mm	30 mm	55 mm
Min. hole Ø for throughfeeds with cabinets and walls	35 mm	40 mm	45 mm	60 mm
Material (protective conduit)	PA 6 (flame-retardant / halogen-free / UV-stable)			

FiberConnect® Heavy Trunk

Divider for multi-fiber loose tube cables

Applications

Building cabling, data center cabling, indoor cabling, outdoor cabling, industrial cabling

Properties

- Multi-fiber loose tube cable with factory-assembled connectors
- Extremely robust divider heads
- Graduated whip lengths to save space
- Whips dyed in the same colour as the fibers
- Bundle marking close to the divider head
- Water- and dust-tight according to IP67
- Tensile strength of the pulling tool = 1000 N
- Tensile strength of the divider head > 4000 N
- Crush resistance of the pulling tool = 20 kg/cm²
- Crush resistance of the dvider head ≥ 200 kg/cm²
- The thermal resistance is at least equal to that of the assembled cable
- Divider head with square countersinking for quick and tool-free installation in 19" racks

Lenghts

Nominal length between the connectors of the two longest whips

Length tolerances

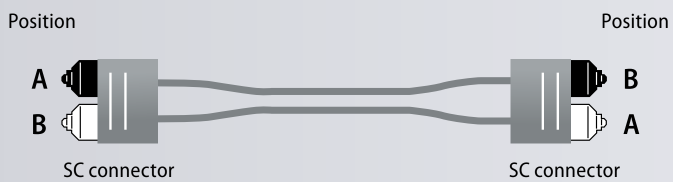
< 30 m	±50 cm
30–100 m	±100 cm
> 100 m	±2 %

Form of delivery

- Lengths < 50 m as a ring, larger lengths on plywood reel
- Test certificate with serial number, tester, test date, length, fiber type, connector type, cable batch, IL and RL
- OTDR test certificate on request

Assembly with logical crossing

(= no physical crossing)



Note on polarity

Please note that our products for standard and special assembly are produced acc. to ANSI/TIA/EIA-568-B.1 with logical crossing.

The products can also be assembled with physical crossing on request (please specify when ordering).

Fiber**Connect**® Splice / patch box 19"

fixed/telescopic – for installation in 19" cabinets

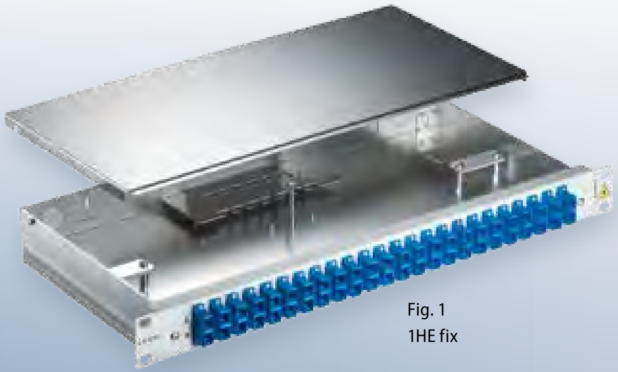


Fig. 1
1HE fix

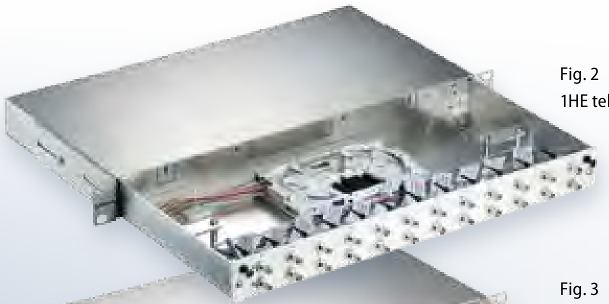


Fig. 2
1HE telescopic

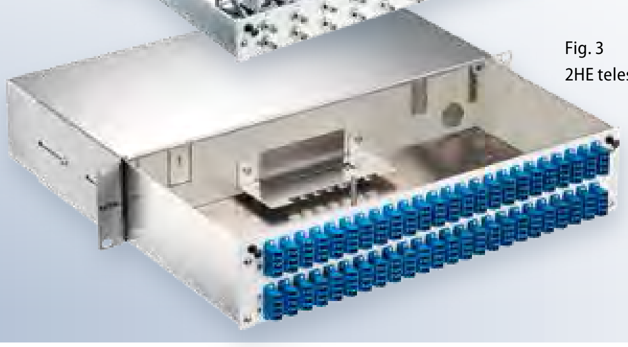


Fig. 3
2HE telescopic

1 HE fix / 1 HE telescopic / 2 HE telescopic

Features

- Completely non-corrosive design
- Cable entry possible from both sides
- For max. 96 splices (depending on adapter type)
- Anti-twist lock for splicing cassettes
- Prepared for grounding connection

Composition

Housing/Cover	Aluminium
Front plate	Galvanized sheet steel, powder coated colour: light grey, RAL 7035
Dimensions 1HE	44.5 mm × 483 mm × 223 mm (H×B×T)
Dimensions 2HE	87.9 mm × 483 mm × 223 mm (H×B×T)
Installation	2 prepared holes for quick installation of the LEONI HeavyTrunk-system divider heads

Scope of delivery splice box

Standard	Housing, cover, front cover, splicing cassette(s), cover for splicing cassette, cable clip-drill
Optional	Ready-to-splice stripped adapter(s), pigtails laid into adapters and splicing cassette

Scope of delivery patch box

Standard	Housing, cover, front cover
Optional	Cable clamp rail, adapter(s)

Accessories (optional) / further information

- Adapter types — page 289 ff.
- Connector types of the pigtails — page 284 ff.
- Fiber qualities of the pigtails — page 199 ff.
- Pigtail colours — page 207 ff.

Article	**1 HE fix** (Fig. 1)	**1 HE telescopic** (Fig. 2)	**2 HE telescopic** (Fig. 3)
Rückversetzbar um [mm]	–	0–50	0–50
Cable gland	2 × M20	2 × M20	1 × M20 + 1 × M25
available front covers	■ max. 12 × SC-duplex (LC-quad) ■ max. 24 × SC-duplex (LC-quad) ■ max. 12 × SC-simplex (LC-duplex / E2000 / MTRJ) ■ max. 24 × SC-simplex (LC-duplex / E2000 / MTRJ) ■ max. 24 × ST (FC) ■ max. 24 × E2000 compact	■ max. 12 × SC-duplex (LC-quad) ■ max. 24 × SC-duplex (LC-quad) ■ max. 12 × SC-simplex (LC-duplex / E2000 / MTRJ) ■ max. 24 × SC-simplex (LC-duplex / E2000 / MTRJ) ■ max. 24 × ST (FC) ■ max. 24 × E2000 compact	■ max. 24 × SC-duplex (LC-quad) ■ max. 48 × SC-duplex (LC-quad) ■ max. 24 × SC-simplex (LC-duplex / E2000 / MTRJ) ■ max. 48 × SC-simplex (LC-duplex / E2000 / MTRJ) ■ max. 48 × ST (FC) ■ max. 48 × E2000 compact

Different materials and colours availble on request.

FiberConnect® top-hat rail box

Mini splice box for installation on DIN rails – for 2 or 4 cable entries

Mini splice box with 2 cable entries

Mini splice box with 4 cable entries

Features

- Completely non-corrosive design
- One-side cable entry with PG11 possible
- For max. 24 splices (depending on adapter type)

Composition

Housing	Aluminium
	Galvanized sheet steel, powder coated
	colour:light grey, RAL 7035
Dimensions	125 × 35 × 129 mm (H×B×T)

Available front covers (standard versions)

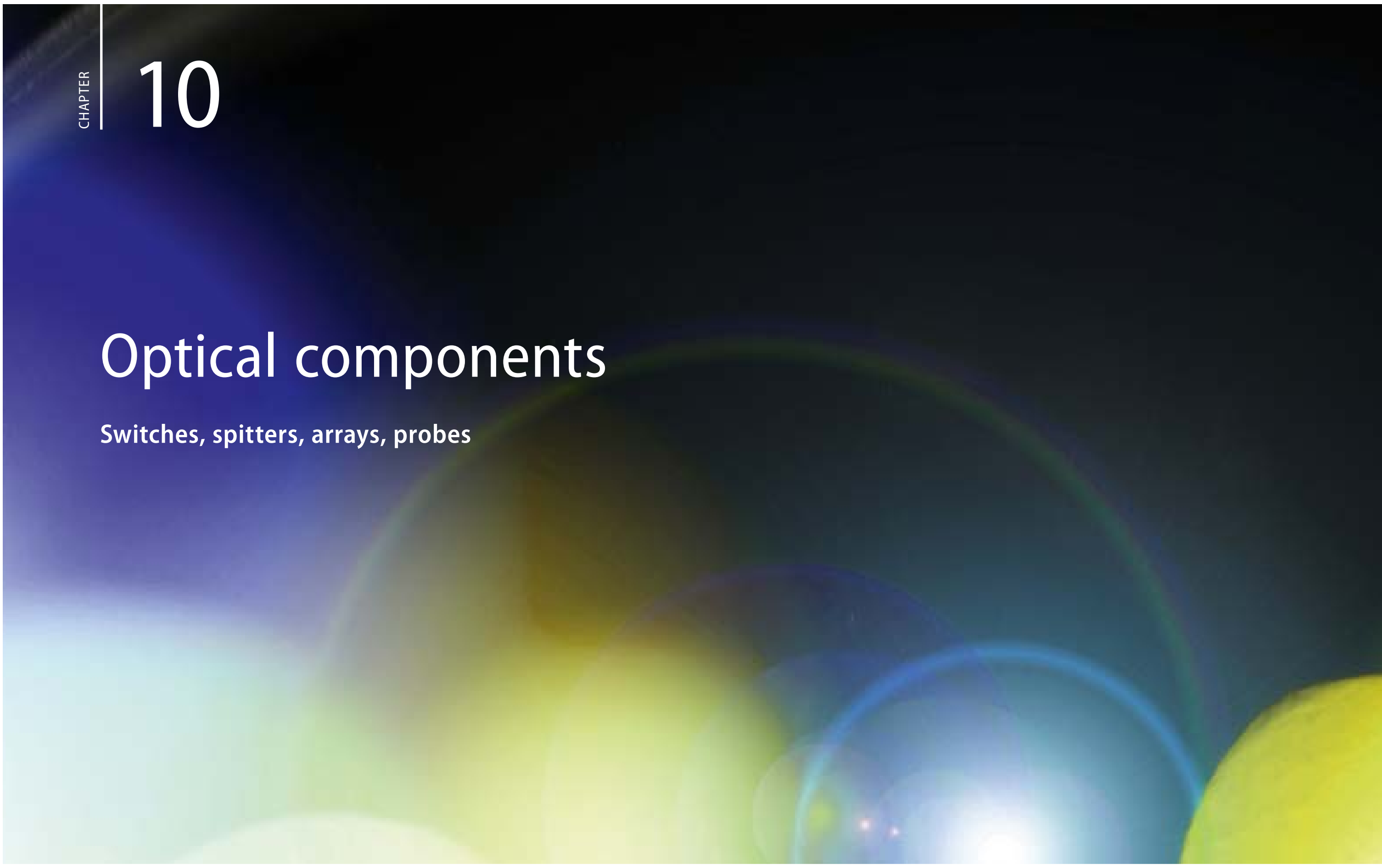
- 6 × SC-duplex / LC 4 entry
- 4 × SC-duplex / LC 4 entry
- 6 × LC-duplex / SC-simplex / E2000 / MTRJ
- 6 × ST (FC)

Scope of delivery patchbox

Housing, cover, PG11 cable gland

Accessories (optional) / further information

- Adapter types — page 289 ff.
- Connector types of pigtails — page 284 ff.
- Fiber qualities of pigtails — page 199 ff.
- Pigtail colours — page 199 ff.



CHAPTER

10

Optical components

Switches, spitters, arrays, probes

Light guides and components for illumination or detection, splitting and switching of light are required in many application fields in optical sensor technology and optical analytics.

We produce customer-specific assemblies that are reliable even under the toughest environmental conditions such as industrial environments or outer space.

For the measurement of:

- Transmission
- Transflectance
- Reflection
- Emission
- Physical, dynamic and geomtric parameters such as temperature, pressure, expansion
- Raman, Rayleigh and Brillouin scattering, fluorescence, etc.

We offer a variety of components for your complex applications:

- Fiber optic bundles and probes
- Fiber arrays
- Singlemode and multimode splitters for special applications
- Optical switches for singlemode and multimode applications

The special fibers, fiber optic cables and fiber components offered by LEONI have stood the test in a large variety of application fields, often under the most difficult circumstances.

Whether for use in space, in harsh industrial environments or at extreme temperatures – LEONI works out exceptional solutions and components for exceptional application areas.

Examples of the use of fiber optic components in the most diverse application areas are:

- Measuring probes in chemical industries
- Fiber measuring systems for astrophysics
- Fiber feed-throughs into a vacuum chamber for signal transmission
- Fiber systems for temperature measurement in the high temperature range
- Offshore measuring systems in wind turbines or on oil platforms

10. Optical components

FiberTech® Special optical components

Multi-branched fiber bundles

Description

Incoming light is directed to the required different positions via various individual arms (= splitter).

Application

- Spectroscopy
- Sensor technology
- Lighting

Composition

- One common fiber bundle and several individual fiber bundles as passive lightguide channels
- Individual fibers made from optical glass (when transmitting visible light) or silica (when transmitting UV/IR light)
- Protective tubes, receptacles and adhesives as appropriate to temperature and ambient conditions

Note

Examples of assembled fiber bundles can be found on page 82 ff.

Fiber bundles with end-optics

Description

Single-branched and multi-branched optical fibers with end-optics such as lenses, tilted mirrors, homogenisers or prisms so that the light beam can be tailored to the customer's requirements.

Application

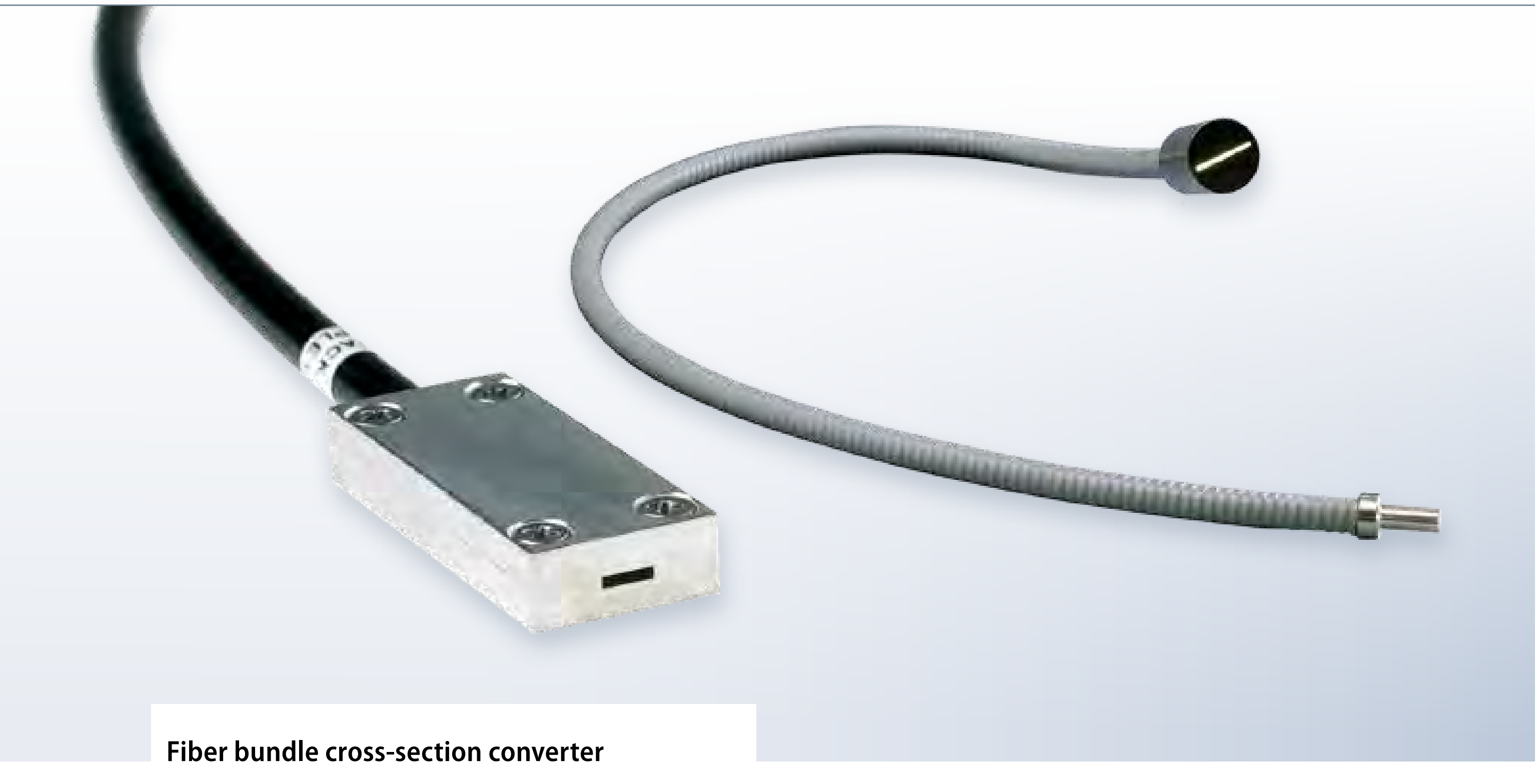
- Spectroscopy
- Sensor technology
- Lighting

Composition

- Individual fibers made from optical glass (when transmitting visible light) or fused silica(when transmitting UV/IR light)
- Protective tubes, receptacles and adhesives as appropriate to temperature and ambient conditions

Further basic information on fiber bundles and cross-section converters:

Chapter 12 | Principles
→ page 396 ff.



Fiber bundle cross-section converter

Description

For converting a circular light beam into a slot-shaped light beam. A bundle of fibers where the configuration in each end fitting varies (mapped bundles). Curves or patterns (one- or two-dimensional) can be achieved in end fittings suitable to the application.

Application

- Spectrometry
- Analysis technology
- Sensor technology, critical angle measurements, illumination, instrument or light source interfaces
- Aperture correction or any application where energy must be changed between input and output in either shape, pitch and/or configuration of the fibers within the bundle.

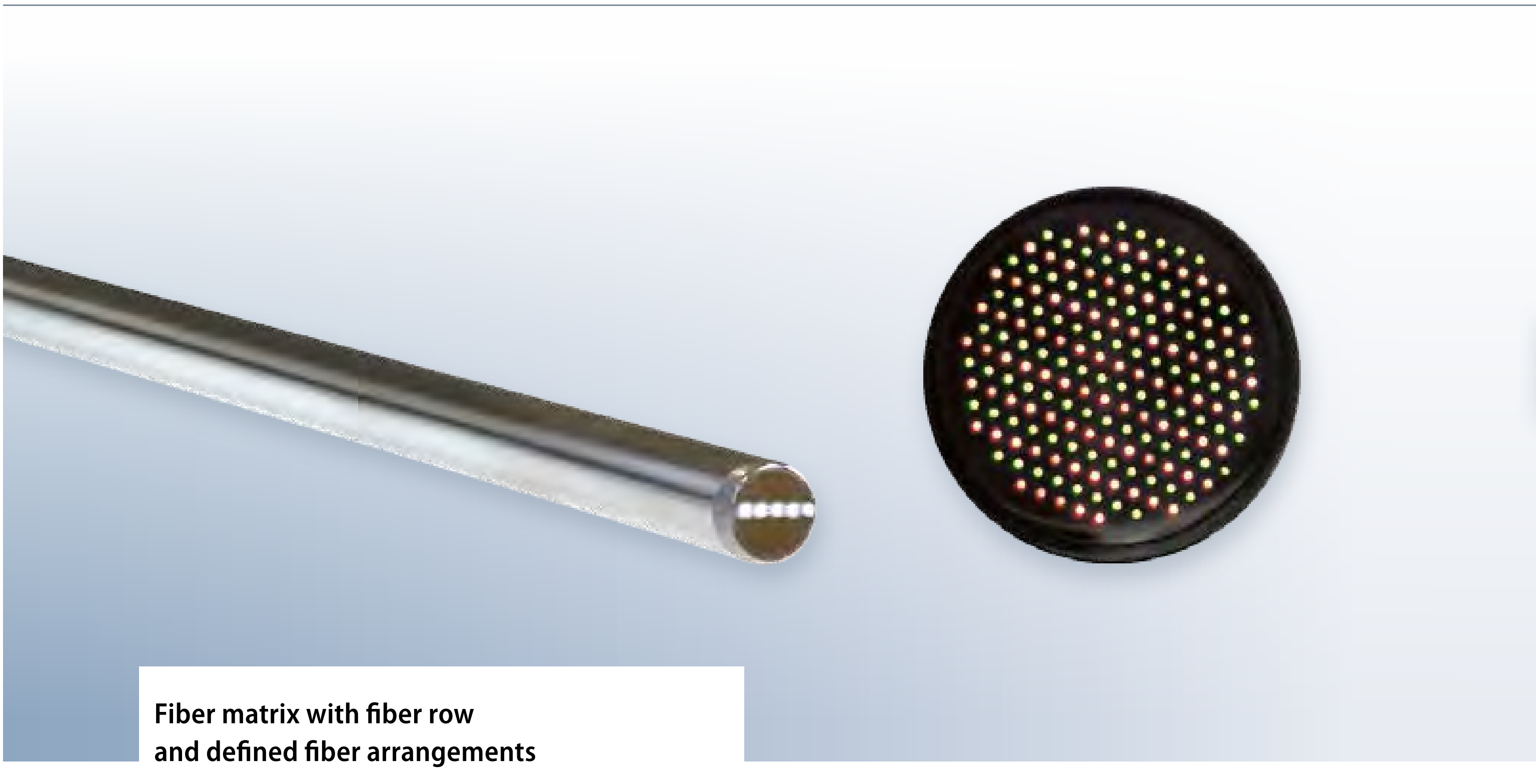
Composition

- Individual fibers made from optical glass (when transmitting visible or UV light) or silica (when transmitting IR light)
- Protective tubes, receptacles, adhesives and end-optics as appropriate to temperature and ambient conditions
- Wavelength ranges: UV-VIS or VIS-NIR
- Integrated with customer specific end fittings/ connectors (application dependent)
- Multi-branched bundle assemblies
- Special fiber configurations can be mapped into the end surface as required
- AR-coating optional
- Customer-specific according to application

Fiberpitch

- Customer-specific according to application
  ➔ pitch tolerances from 5 µm to submicron are possible for the distance between two adjacent fibers

FiberTech® Special optical components



Fiber matrix with fiber row and defined fiber arrangements

Description

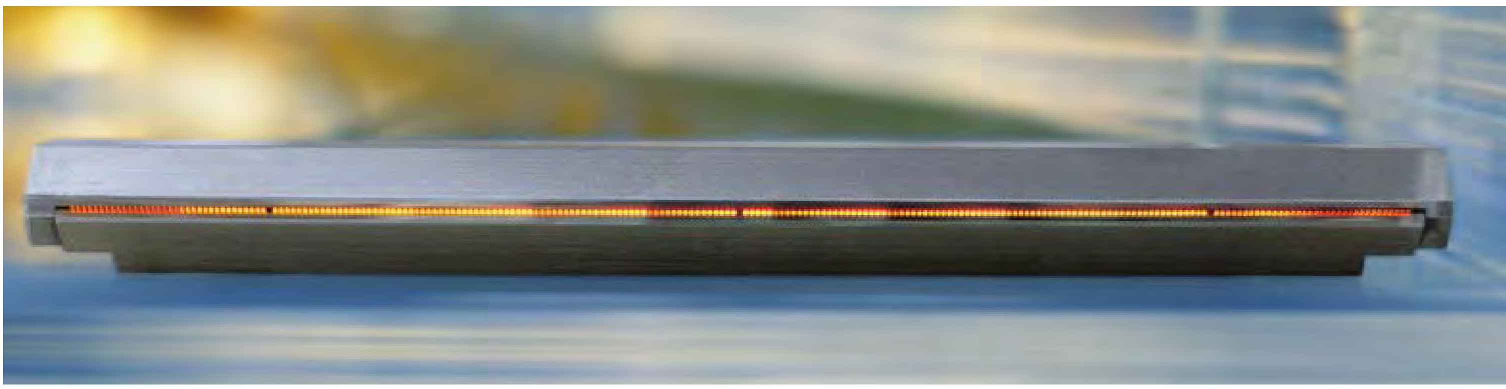
Optical fiber assembly with multiple LargeCore fibers with specific and high-precision arrangement of the fibers.

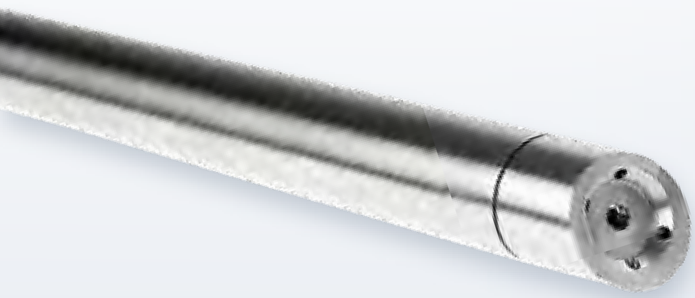
Application

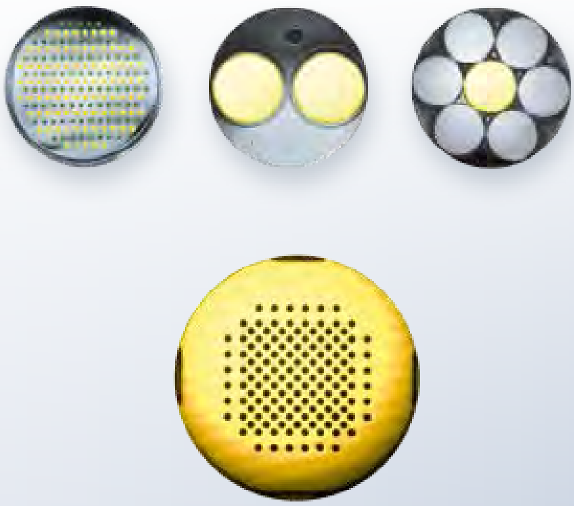
- Analytical technology
- Sensor technology (spectroscopy in the chemical, petrochemical and pharmaceutical industry, plant engineering, astrophysics, life sciences)

Composition

- Optical fibers made from synthetic fused silica
- Rigid and flexible assembly
- Polished finish of fiber end faces also for use with high-performance lasers







Reflectance probes with windows and integrated air purge

Description

Two-channel assemblies (standard version): one channel for energy input and a second channel for signal transmission, available in different configurations.

Application

Analysis of optical reflectance, on surfaces and in powders.

Composition

- Two individual fibers or fiber bundles
- Wavelength ranges: UV-VIS or VIS-NIR
- Standard SMA connectors, for interfacing source and detector, customer-specific end fittings possible on request
- Sapphire or silica windows, angled, in order to reduce back reflection and signal interference
- Integrated air purge for cleaning of end face optional
- Standard version: stainless steel housing on probe ends, further materials on request

Fiber optical probes

Description

Fiber optical probes for spectroscopic analysis technology.

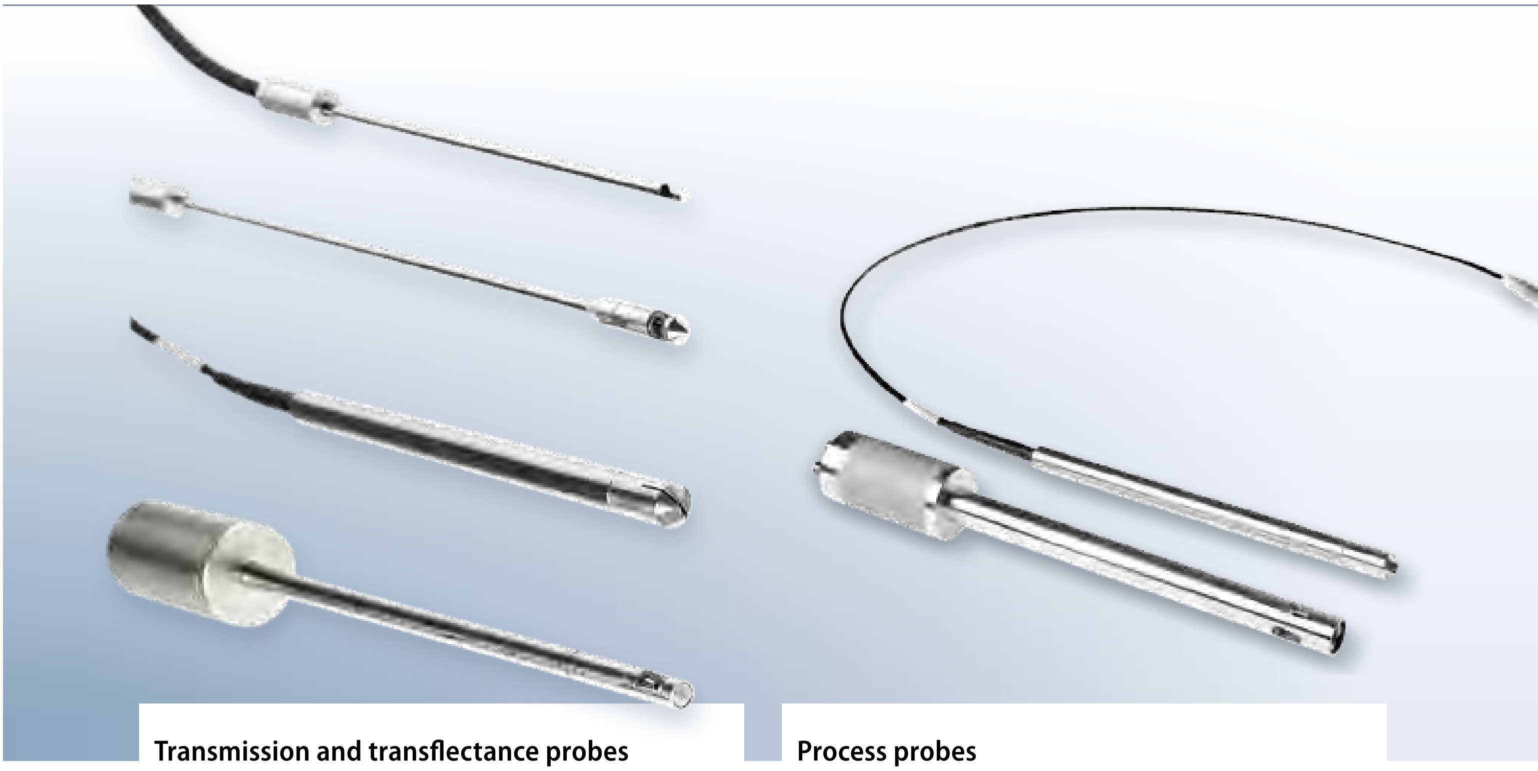
Application

Spectroscopic examinations of liquid, gaseous or solid matter.

Composition

- The optical fibers are assembled in a measuring head at one end, the connection end consists of several outgoing and incoming lines for spectroscopy systems
- Can be assembled with various tubes, standard or special connectors

FiberTech® Special optical components



Transmission and transflectance probes

Description

Two-channel assemblies (standard version): one channel for energy input and a second channel for signal transmission. Probes have a defined optical path length, also available with adjustable or interchangeable end fittings. Single pass or dual pass probes available.

Application

Optical transmission measurement, for example in liquids

Composition

- Two individual fiber bundles
- Wavelength ranges: UV-VIS or VIS-NIR
- Standard SMA connectors, for interfacing source and detector, customer-specific end fittings possible on request
- Two branches as standard version (for one source and one signal), multi-branched probes also available
- Lens optionally available
- Standard version: stainless steel housing on probe ends, further materials on request

Dimensions

- Mini-probes with diameters < 3 mm up to industrially robust probes with diameters > 25 mm
- Customer-specific lengths, depending on application

Process probes

Description

Two-channel assemblies (standard version): one channel for energy input and a second channel for signal transmission, available in different configurations.

Application

- Measurement of optical transmission
- Reflectance on liquids, powders and surfaces
- Suitable for difficult environmental conditions and harsh industrial environments

Composition

- Composition → as with transmission probes but with adapted materials and seals for the use in harsh industrial environments

Dimensions

- Probe ends with diameters < 3 mm up to industrially robust probes with diameters > 25 mm
- Lengths and dimensions according to customer request

Vacuum feed-through assemblies

Description

Optical components that create a transition from atmospheric areas to vacuum areas.

Application

- Spectrometry
- Analytical technology
- Optical sensing in vacuum areas

Composition

- Housing adapted to special flange and standard flange (CF, KF, etc.) with vacuum-tight fiber bundle or mono fiber passages
- With further fiber optic cables or direct connections for SMA, FCST, for example, or customer-specific connectors as appropriate to the customer's wishes.

Protected fiber assemblies

Description

For fiber cables, fiber bundles, probes or assemblies that require a sealed end against the environmental influences such as pressure and/or liquids.

Application

Allows spectroscopic/optical measurements or transmission of laser energy in a harsh environment

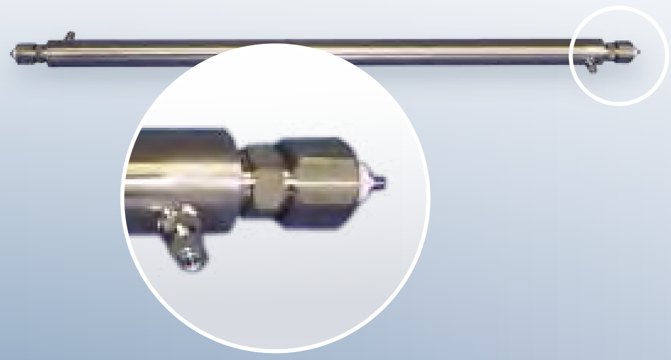
Composition

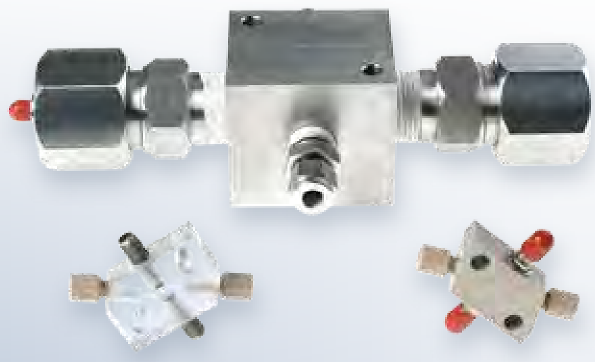
- Single fiber or fiber bundle
- Wavelength ranges: UV-VIS or VIS-NIR
- integrated with flanges, seals or sealing compounds appropriate for the environmental conditions
- Single branches or multi-branched fiber bundle assemblies

Dimensions

- Customer-specific depending on application (further information on request)

FiberTech® Special optical components





Flow cells

Application

- Designs in different types of stainless steel: type 316 stainless steel, Hastelloy 276C, Monel 1400, Inconel 600, plus special design in titanium
- Path lengths from 38 mm to 1016 mm (increments 38 mm)
- Sapphire windows
- SMA connectors
- Fiber end fitting with focusing or collimating optics
- Direct fiber-to-detector coupling
- Direct fiber-to-light source coupling

Wavelength

UV-VIS or VIS-NIR

Liquid flow cells

Description

For the measurement of transmission or fluorescence in flowing liquids. Stand-alone devices with fittings and integrated fiber optic connections.

Application

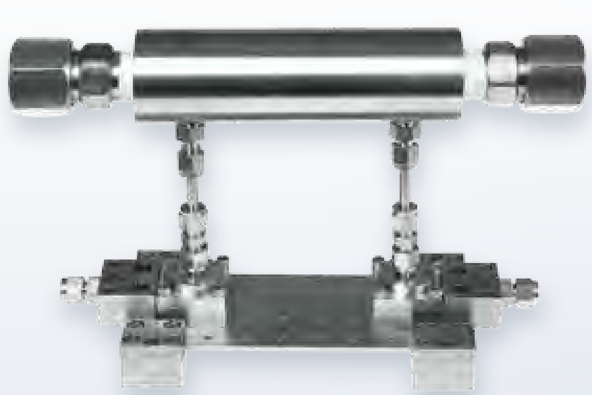
For industrial and laboratory applications

Composition

- Z-shaped liquid channel
- Colinear arrangement of the optical fittings for transmission measurement
- Non-colinear arrangement of the optical fittings for fluorescence measurement
- Solid construction for industrial applications, further special designs available according to application
- Various fittings: Luer, compression or weld fittings
- Standard SMA fiber optic connections
- Wavelength ranges: UV-VIS or VIS-NIR
- Stainless steel housing as standard version, further designs in plastic or special metals are available
- Glass or machined ceramics seals optionally available

Dimensions

- Application-specific
- Path lengths 10 mm to 1 m



Gas flow cells

Description

For the measurement of transmission in flowing or sampled gas. Stand-alone devices with fittings and integrated fiber optic connections. Compatibility according to NeSSI standard as an option.

Application

For industrial and laboratory applications

Composition

- Solid construction for industrial applications (further special designs available according to application)
- Various fittings: e.g. compression or weld fittings
- Standard SMA fiber optic connections
- Wavelength ranges: UV-VIS or VIS-NIR
- Stainless steel housing as standard version (further designs in plastic or special metals are available)
- Glass or machined ceramics seals optionally available

Dimensions

- Application-specific
- Path lengths 10 mm to 1 m

Fiber optical collimators and imagers

Description

Optical system for collimating laser light and for the coupling of collimated laser light into a transmission fiber.

Application

- Industrial laser technology
- Industrial image processing (e.g. printing)

Composition

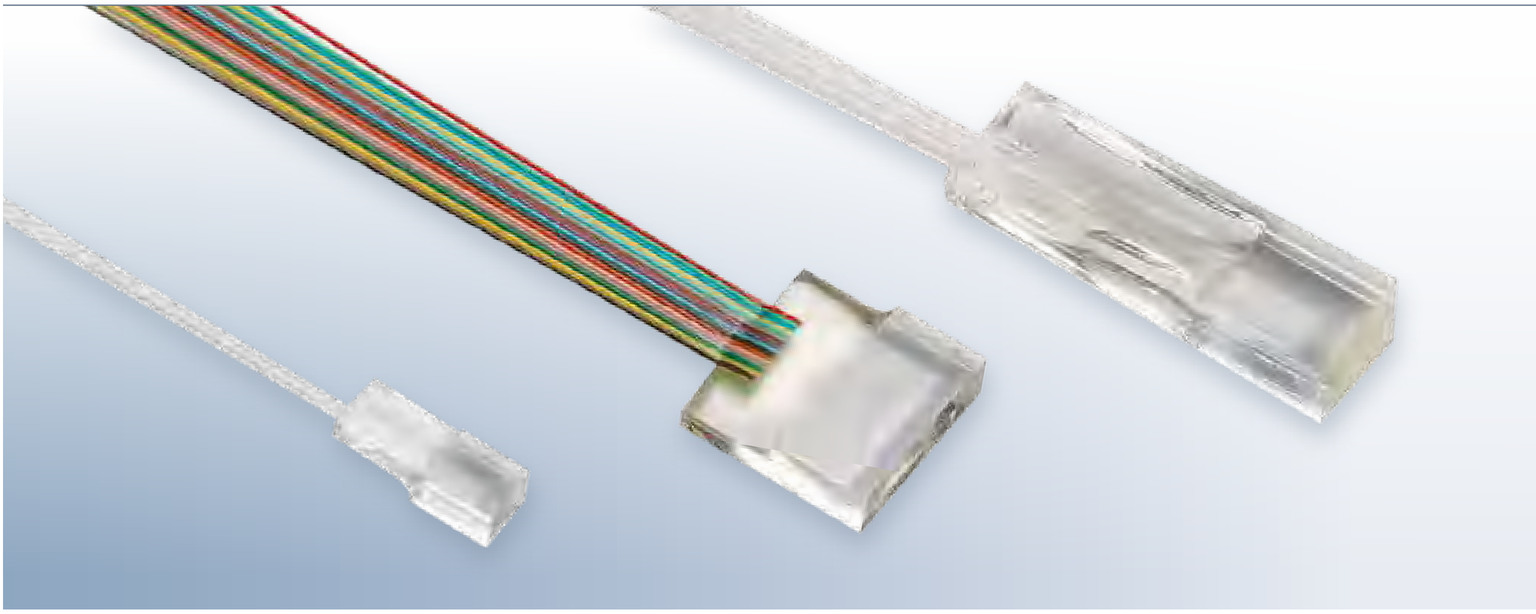
- Anodized aluminium or stainless steel housing
- Silica (UV) or optical glass (VIS/NIR) lenses with optional AR-coating, GRIN lenses optional)
- Standard SMA fiber optic connections
- Single axis adjustment in the optical axis

Dimensions

- Customer-specific: typ. Ø 6 mm – 75 mm
Lengths 12 mm – 150 mm
- Numerical apertures up to 0.38

Fiber**Tech**® **Fiber arrays**

for singlemode and multimode applications



Description

Fiber arrays are suitable, for example, for applications in the area of fiber optical switches, in sensor technology, in printing machines, for connecting to splitters and in free space optics.

Wavelength

- Available with a wide variety of different fiber types in a wide wavelength range from UV to IR light
- The spectrum ranges from standard singlemode fibers to LargeCore fibers (outer -Ø ≥ 1.0 mm)
- Arrays with a large number of fibers can be developed and produced on request

Polish

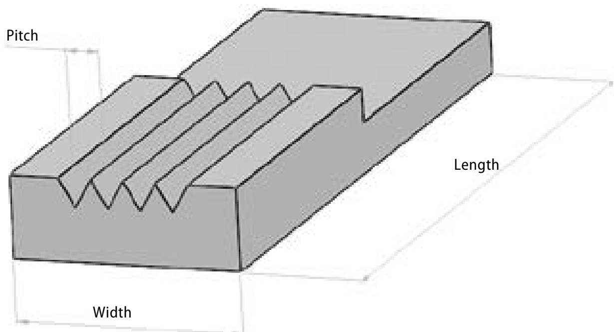
Arrays are supplied with 0° and 8°-polish. The fiber end faces can also be given an antireflective coating (from narrowband to broadband anti-reflective coatings).

Properties

- Almost all common connector types can be used: **FCPC, FCAPC, E 2000PC, E 2000 APC, SCPC, SCAPC, LCPC, LCAPC, ST, SMA,** (others on request)
- Arrays with up to 64 fibers and a pitch of 127 µm or 250 µm are available for the SM telecommunications fibers
- Positional accuracy of the fiber cores in the array better than 1.5 µm with single mode fibers
- Qualification in combination with planar waveguide chips to TELCORDIA 1209 and 1221
- Excellent long-term stability and mechanical strength
- Also suitable for use in harsh environments (–40 °C to +85 °C)

Dimensions

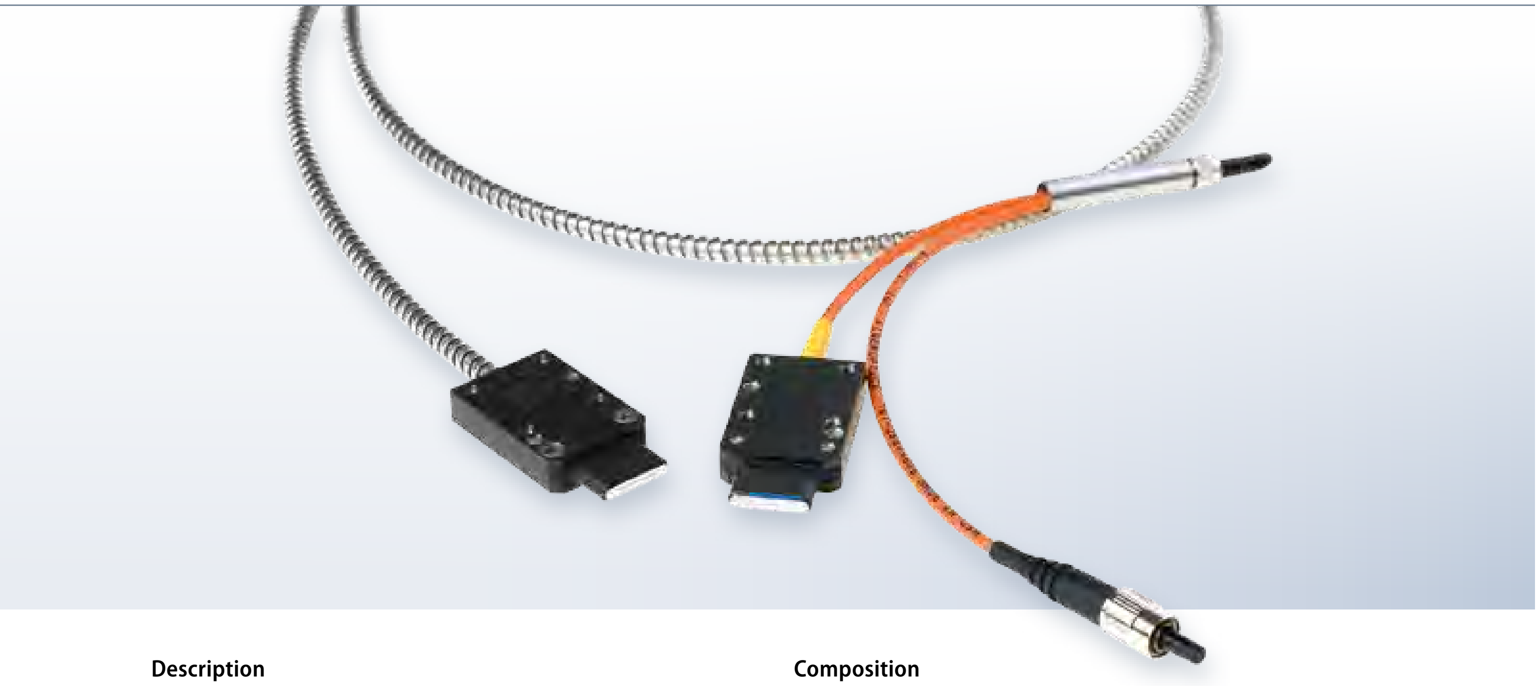
Two-dimensional arrays (customer-specific) have already been realised



Further basic information on fiber arrays:
Chapter 12 | Principles
→ page 399 ff.

FiberTech® Linear arrays and V-groove arrays

for singlemode and multimode applications



Description

Fiber bundle end fitting. The fibers are arranged in either a linear (single row) pattern or on centers of a defined spacing (pitch).

Application

- As cross section converters or for positional adaptation
- Alignment and interfacing of analytical setups (e.g. sensor heads) or for the interfacing with optical modules such as laser diode arrays.

Composition

- Fiber bundle
- Wavelength ranges: UV-VIS or VIS-NIR integrated with customer-specific fittings (depending on application)
- Single branches or multi-branched fiber bundle assemblies
- AR coating optionally available

Dimensions

Application-specific.

Fiber pitch

- Customer-specific depending on application
- Pitch tolerances from 5 µm to submicron are possible or the distances between adjacent fibers.

Fiber arrays for singlemode applications

Number of fibers	125 µm AD		125 µm AD	
	l×b×h [mm]	Pitch [µm]	l×b×h [mm]	Pitch [µm]
1	10.0×3.7×2.5	–	10.0×3.7×2.5	–
2	10.0×3.7×2.5	250	10.0×3.7×2.5	127
4	10.0×3.7×2.5	250	10.0×3.7×2.5	127
8	10.0×3.7×2.5	250	10.0×3.7×2.5	127
16	10.0×10.0×2.5	250	10.0×3.7×2.5	127
32			15.0×11.6×2.5	127
64			15.0×11.6×2.5	127

Fiber arrays for multimode applications

Number of fibers	125 µm AD		125 µm AD		200–280 µm AD		400–480 µm AD		600–680 µm AD		800–880 µm AD	
	l×b×h [mm]	Pitch [µm]	l×b×h [mm]	Pitch [µm]	l×b×h [mm]	Pitch [µm]	l×b×h [mm]	Pitch [µm]	l×b×h [mm]	Pitch [µm]	l×b×h [mm]	Pitch [µm]
1	10.0×3.7×2.5	–	10.0×3.7×2.5	–	12.5×5.0×3.05	–	12.5×5.0×3.05	–	12.5×5.0×3.05	–	12.5×5.0×3.05	–
2	10.0×3.7×2.5	250	10.0×3.7×2.5	127	13.0×5.0×3.05	300	16.5×5.0×3.05	500	18.5×5.0×3.05	700	18.5×5.0×3.05	1000
4	10.0×3.7×2.5	250	10.0×3.7×2.5	127	16.0×5.0×3.05	300	21.5×5.0×3.05	500	23.5×5.0×3.05	700	23.5×5.0×3.05	1000

Order number scheme

for fiber arrays

AR 004 83 H 2 08-13 00 (Example)

Array	**AR**
Number of fibers	**004**
Fiber type	
GIF100 / 140 / 250 NA 0,29	**83**
SMF28 9 / 125 / 250 / 900 µm tight buffer IR	**11**
AS400 / 480IRAN	**01**
others on request	**…**
Secondary coating	
0.9 mm Hytrel, black	**H**
Metal corrugated tube	**B**
PVC protection black 1.8 mm	**D**
others on request	**…**
Connector type	
all fibers with FC / PC	**2**
all fibers with FC / APC	**1**
all fibers with E 2000	**4**
others on request	**…**
Length in dm	z. B. 08
Chip	
MM 4-channel v-groove 125µm, glass, 0.25mm pitch 10×3.5×2.5mm	**13**
SM 16-channel v-groove 125µm, glass, 0.25mm pitch 10×3.5×2.5mm	**33**
MM 4-channel v-groove 830µm, glass, 1mm pitch 23.5×5×3.05mm	**24**
others on request	**…**
Variants	

Order example:
AR00483H208-1300
Array with 4 Fibers GI Fiber 100 / 140 / 250 NA 0.29,
FC / PC- connector,
0.9 mm Hytrel tube,
Length 80 cm,
Chip MM 4-channel v-groove 125 µm,
Glass,
Pitch 0.25 mm
Dimensions 10 × 3.5 × 2.5 mm (l × b × h)

Further basic information on planar waveguides:
Chapter 12 | Principles
→ page 398 ff.

FiberSplit® Optical splitters for singlemode and multimode applications

Our splitter products are based on planar waveguide technology that offers maximum performance and exceptional long-term stability – ion-exchange in glass. The standard products are low-loss and broadband singlemode splitters for the entire telecommunications wavelength range manufactured on 6-inch wafers with splitting rates of 1×2 to 1×64, including splitters such as 1×5 or 1×12.

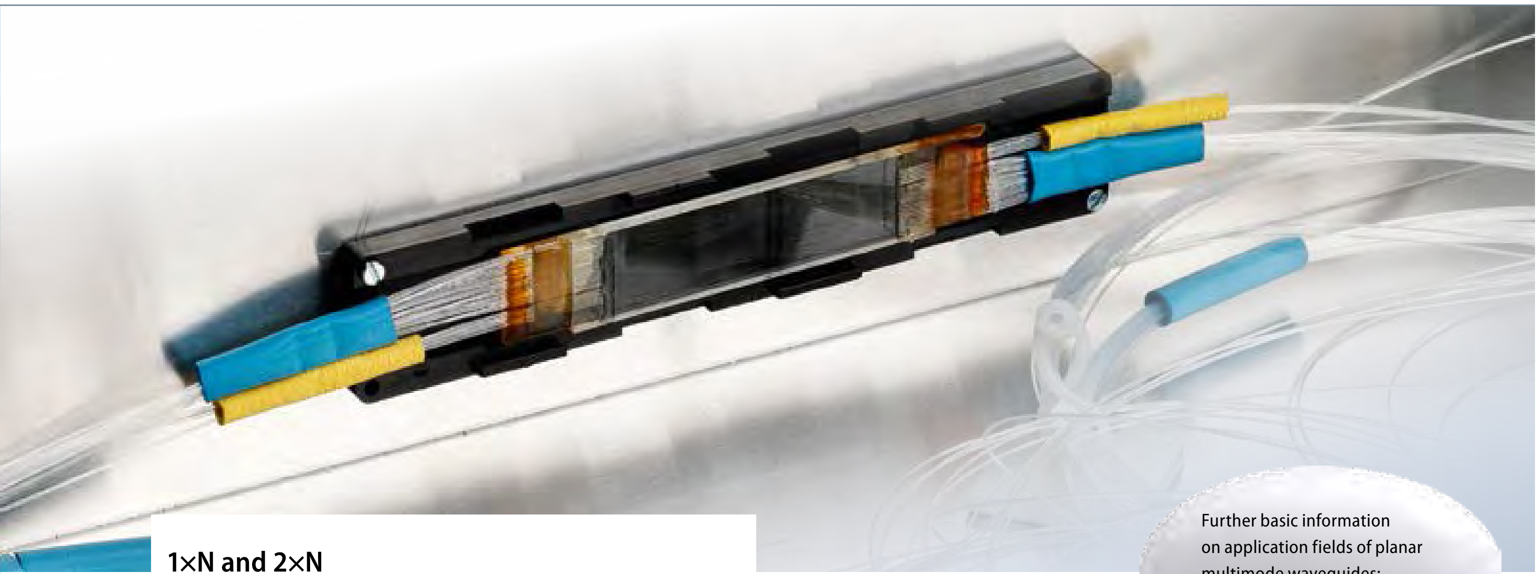
Our new multimode splitters are based on planar integrated optical waveguides and are produced by means of ion exchange in glass. Thus, they are very compact, robust and long-term stable. Whether in sensor technologies or in optical power transfer – there is a wide range of applications. Planar waveguide components for the near infrared wavelength range (NIR: 780 nm–1060 nm) are also available.

Special products can be developed customer-specific according to your requirements, also for the visible wavelength range (VIS).

The splitters are above all characterised by

- Very low insertion loss
- High uniformity
- High extinction rate
- Lowest PDL
- Widest bandwidth (780 nm – 1060 nm or 1260 nm – 1650 nm)
- Small, rugged metal housing
- Any fiber assembly
- Own connectors
- Exceptional long-term stability – tested according to Telcordia GR 1209 and 1221

FiberSplit® Splitter series
for multimode applications



1×N and 2×N

Further basic information on application fields of planar multimode waveguides:
Chapter 12 | Principles
→ page 408 ff.

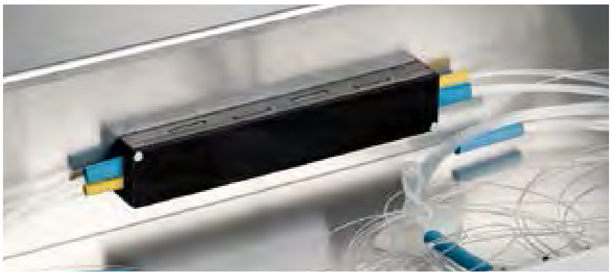
Description

The new multimode splitter series is based on planar integrated waveguides which are produced by means of ion exchange in glass. The multimode components are based exclusively on monolithic integrated, lithographically patterned waveguides. Thereby they are compact, robust and long-term stable and can be produced in high yield and favourable quantities .

The development and in-house manufacturing of planar multi-mode components is customer-specific. Waveguide-diameters from 50 µm up to 200 µm and NA from 0.2 up to 0.4 are possible. The number of input and output channels is currently limited to 32.

Application

- Laser applications
- Measuring techniques
- Sensor technology
- High-power beam combiners and high-power beam splitters



Monolithic integrated multiple multimode splitter with PCF fibers.

Composition		
Fiber length	≥ 1 m	
Housing dimension	160 mm × 40 mm × 12 mm (other shapes on request)	
Temperature range	Operating temperature	–20 °C to +70 °C
	Storage temperature	–20 °C to +70 °C

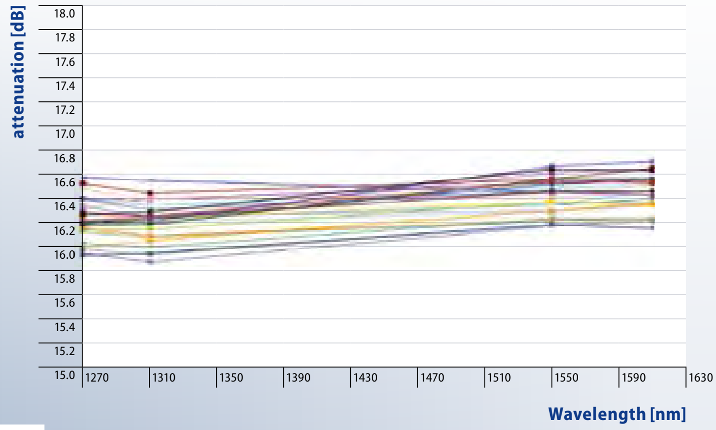
Splitter type	1×2	1×4	1×8	1×16	2×2	2×4	2×8	2×16
Max. insertion loss [dB]*	4	8	11	15	4	8	11.5	16
Max. uniformity [dB]	0.8	1.2	1.5	2.5	1	1.8	2	2.5
Central wavelength (depending on fiber type)	achromatic							

In the table the specifications of multimode splitters with core diameter 200 µm and numerical aperture 0.36 are listed, measured at room temperature. The components have been optimized for corresponding PCF fiber. Measured values for room temperature, without connector and under stable launching conditions with an LED. Our FiberSplit® products are generally suitable for the wavelength range from 450 nm to 2000 nm. The fiber may limit the wavelength range.

FiberSplit® Ultra-broadband splitter series

planar waveguide splitters for singlemode applications

typical values 1×32 splitter



1×N Ultra-broadband

Description

An optimum balance of performance versus cost is achieved based on the exchange of silver ions in a glass specially developed for this process.

Intelligent design and sophisticated in-house manufacturing methods give LEONI splitters exceptional quality and reliability and make them especially suitable for use under the harshest environmental conditions.

Product range

Standard products ➔ **1×2, 1×4, 1×8, 1×16, 1×32 and 1×64**

Customer-specific designs (on request):

e. g. 1×N with N≠2^n, e. g. 1×6, 1×10, 1×48

- Asymmetric splits, e. g. 80 % to 20 %
- Splitters for lower wavelengths, e. g. 780 nm to 1060 nm

Application

- For numerous applications within telecommunications and sensor technology
- For broadband splitting or combination of singlemode optical fibers

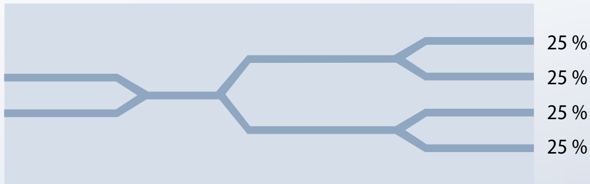
Composition	
Connectors	UPC or APC: SC, FC, LC, MU, E2000, ST, MPO, DIN
Trays	"plug & play" for different connector types e. g. LGX, Corning CCH
Inserts	19"-inserts with connector panels, 1, 2 or 3 HU (height units)
Fiber type	SMF 28 (9 / 125 / 250 µm), Single fiber version (highest reliability and flexibility) or ribbon type
Fiber length	≥ 1 m
Housing dimension	40 mm × 4 mm × 4 mm for 1×8 splitters (other shapes on request)
Temperature range	Operating temperature −40 °C to +85 °C Storage temperature −40 °C to +85 °C

Splitter type	1×2	1×4	1×8	1×16	1×32	1×64
Max. insertion loss [dB]*	3.9	7.0	10.2	13.5	16.7	20.4
Max. uniformity [dB]	0.5	0.8	1.0	1.0	1.3	1.8
Return loss	≥ 55 dB					
Directivity	≥ 55 dB					
Polarization-dependent loss	≤ 0.15 dB					
Wavelength ranges	1260–1360 nm and 1480–1650 nm					

* Applies across the entire wavelength and temperature range as well as for all polarization states.
The value is up to 0.3 dB higher for the extended wavelength range from 1360–1480 nm.

FiberSplit® Ultra-broadband splitter series

planar waveguide splitters for singlemode applications



2×N Ultra-broadband

Description

An optimum balance of performance versus cost is achieved based on the exchange of silver ions in a glass specially developed for this process.

Intelligent design and sophisticated in-house manufacturing methods give LEONI splitters exceptional quality and reliability and make them especially suitable for use under the harshest environmental conditions.

Product range

Standard products → **2×2, 2×4, 2×8, 2×16 and 2×32**

customer-specific designs (on request):

- Asymmetric splits, e. g. 80 % to 20 %
- Splitter for lower wavelength ranges, e. g. 780 nm to 1060 nm

Application

- For numerous applications within telecommunications and sensor technology
- For broadband splitting or combination of singlemode optical fibers

Composition		
Connectors	UPC or APC: SC, FC, LC, MU, E2000, ST, MPO, DIN	
Trays	“plug & play” for different connector types, e. g. LGX, Corning CCH	
Inserts	19"-inserts with connector panels 1, 2 or 3 HU (height units)	
Fiber type	SMF 28 (9 / 125 / 250 µm) (other types on request)	
Fiber length	≥ 1 m	
Housing dimension	40 mm × 4 mm × 4 mm for 2×2 splitters (other shapes on request)	
Temperature range	Operating temperature Storage temperature	−40 °C to +85 °C −40 °C to +85 °C

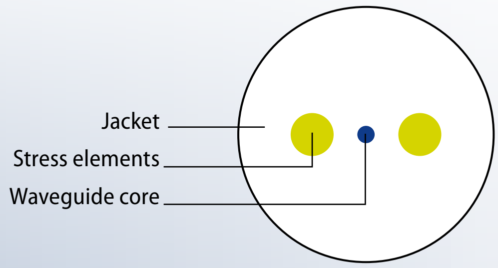
Splitter type	2×2	2×4	2×8	2×16	2×32
Max. insertion loss [dB]*	4.2	7.8	11.2	14.1	17.4
Max. uniformity [dB]	1.2	1.5	2.0	2.2	2.5
Return loss	≥ 55 dB				
Directivity	≥ 55 dB				
Polarization-dependent loss	≤ 0.15 dB				
Wavelength ranges	1260–1360 nm and 1480–1650 nm				

* Applies across the entire wavelength and temperature range as well as for all polarization states.
The value is up to 0.3 dB higher for the extended wavelength range from 1360–1480 nm.

FiberSplit® Broadband splitter series

polarization-maintaining (PM) planar splitters for singlemode applications

Panda fiber



1×N Broadband PM

Description

LEONI's planar PM splitters 1×N are developed for special applications that require high polarization retention.

The special ion exchange process for manufacturing the extremely stress-free waveguide structures on planar chips results in excellent and stable polarization properties even under extreme conditions.

Application

- For numerous applications in optical measurement technology and sensor technology
- For broadband splitting or combination of polarization-maintaining optical fibers

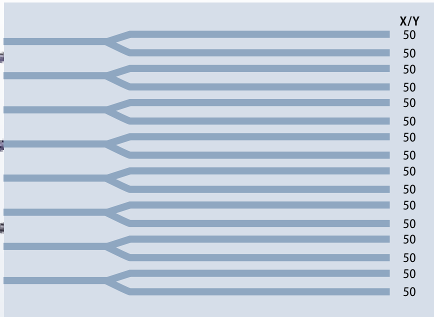
Composition		
Connectors	UPC or APC: FC, others on request	
Trays	"plug & play" for different connector types, e. g. LGX, Corning CCH	
Inserts	19"-inserts with connector panels 1, 2 o 3 HU (height units)	
Fiber type	Fujikura Panda SM 13-P / SM 15-P	
Fiber length	1 m	
Housing dimension	40 mm × 4 mm × 4 mm (other shapes on request)	
Temperature range	Operating temperature	–20 °C to +60 °C
	Storage temperature	–40 °C to +85 °C

Splitter type	1×2	1×4	1×8
Max. insertion loss [dB]*	3.9	7.4	10.8
Max. uniformity [dB]	0.5	0.9	1.0
Return loss		≥ 55 dB	
Directivity		≥ 55 dB	
Polarization-dependent loss		≤ 0.15 dB	
Wavelength ranges		depending on fiber type	

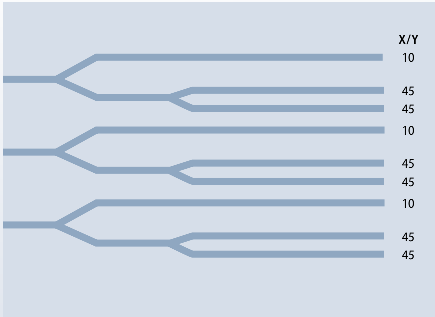
* Applies across the entire wavelength and temperature range as well as for all polarization states. The value is up to 0.3 dB higher for the extended wavelength range from 1360–1480 nm.

FiberSplit® Multiple ultra-broadband splitter series

planar monolithic integrated multi-splitters



(Graph above:) 8-fold 1×2 splitter



(Graph above:) customer-specific 3-fold 1×2 splitter with additional monitor channel

M-fold 1×N Ultra-broadband

Description

An optimum balance of performance versus cost is achieved based on the exchange of silver ions in a glass specially developed for this process.

Intelligent design and sophisticated in-house manufacturing methods give LEONI splitters exceptional quality and reliability and make them especially suitable for use under the harshest environmental conditions, both for singlemode and multimode splitters.

Product range

Standard products → **1×N M-fach (mit M=2 to 12)**

Customer-specific designs (on request):

- All singlemode splitter types also available as multiple splitters
- Multiple splitters for low wavelengths
- Multiple multimode splitters

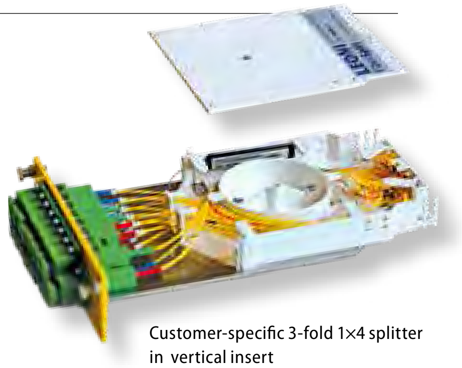
Application

- For numerous applications within telecommunications and sensor technology
- For broadband splitting or combination of singlemode optical fibers

Composition		
Connectors	UPC or APC: SC, FC, LC, MU, E2000, ST, MPO, DIN	
Trays	"plug & play" for different connector types, e.g. LGX, Corning CCH	
Inserts	19"-inserts with connector panels 1, 2 or 3 HU (height units)	
Fiber type	SMF 28 (9/125/250 µm) (other types on request)	
Fiber length	≥ 1 m	
Housing dimension	40 mm × 7 mm × 4 mm for 4-fold 1×4 splitters SM (other shapes on request)	
Temperature range	Operating temperature	−40 °C to +85 °C
	Storage temperature	−40 °C to +85 °C

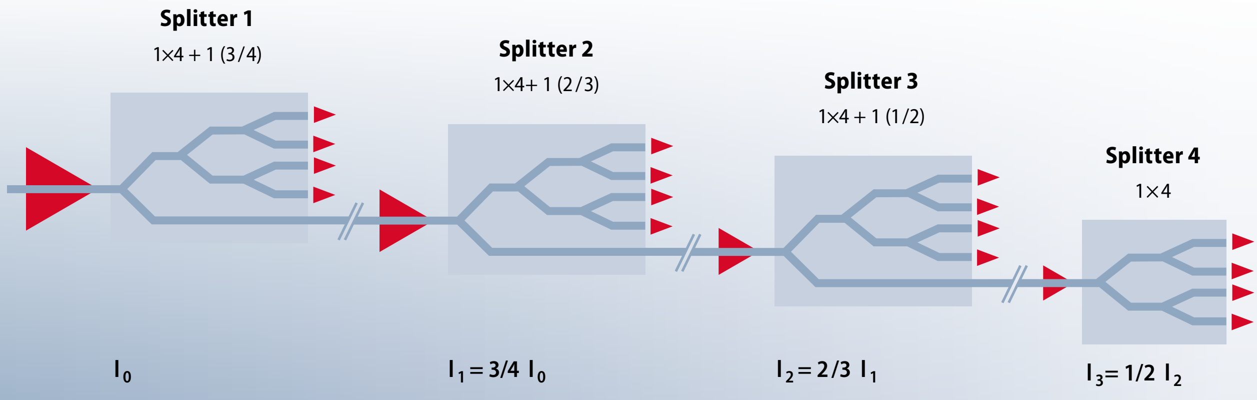
Splitter type	8-fach 1×2	12-fach 1×2	4-fach 1×4
Max. insertion loss [dB]*	3.9	4.2	7.4
Max. uniformity [dB]	0.5	0.7	0.9
Return loss	≥ 55 dB		
Directivity	≥ 55 dB		
Polarization-dependent loss	≤ 0.15 dB		
Wavelength ranges	1260–1360 nm and 1480–1650 nm		

* Applies across the entire wavelength and temperature range as well as for all polarization states. The value is up to 0.3 dB higher for the extended wavelength range from 1360–1480 nm.


Customer-specific 3-fold 1×4 splitter in vertical insert

FiberSplit® Broadband splitters

asymmetric optical power split for singlemode applications



1×N Ultra-broadband cascaded splitter

Description

Cascaded splitter composed of four single splitters equipped with four output channels each, i.e. 16 channels with the same optical power output and 3 bypass channels with an adequately reduced optical power (further cascade types with different splitting rates on request).

Application

- For numerous applications within telecommunications and sensor technology
- For asymmetric splitting of singlemode optical fibers

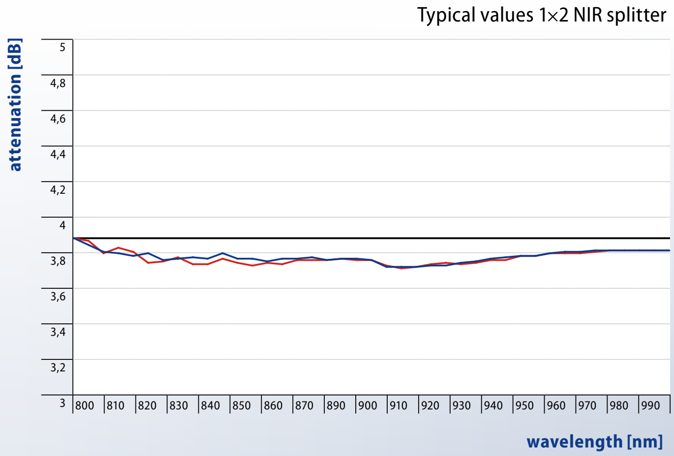
Composition	
Fiber type**	Singlemode fiber (9 / 125 / 250) (n ITU G.652D or G. 657A or equ.)
Fiber length	≥ 1 m
Housing dimension	min. 40 mm × 4 mm × 4 mm (other shapes on request)
Temperature range	Operating temperature −40 °C to +85 °C Storage temperature −40 °C to +85 °C

Optical specifications*	1×4 + 1 (3/4)	1×4 + 1 (3/4)	1×4 + 1 (3/4)	1×4
	Splitter level 1	Splitter level 2	Splitter level 3	Splitter level 4
Output channel IL (max.) [dB]	14.9	13.1	10.8	7.1
Output channel IL (min.) [dB]	12.9	11.6	9.7	6.5
Bypass channel IL (max.) [dB]	1.9	2.5	3.6	–
Bypass channel IL (min.) [dB]	1.3	1.9	3.0	–
Return loss RL	≥ 55 dB			
Directivity	≥ 55 dB			
Polarization-dependent loss PDL	≤ 0.15 dB			
Wavelength ranges	1260–1360 nm and 1480–1650 nm			

* Applies across the entire wavelength and temperature range as well as for all polarization states
** Other fiber / cable types and modified housings on request

FiberSplit® Ultra-broadband splitter series

for NIR (780 nm–1060 nm) / for singlemode applications



M-fold 1×N Ultra-broadband

Planar waveguide splitters

An optimum balance of performance versus price is achieved based on the exchange of silver ions in a glass specially developed for this process.

Intelligent design and sophisticated manufacturing methods give these splitters exceptional quality and reliability and make them especially suitable for use under the harshest environmental conditions.

Product range

Standard products ➔ **1×2, 1×4, 1×8**

Customer-specific designs (on request) e. g. 1×N with N≠2^n,

- Asymmetric splits
- Splitters for lower wavelengths available on request

Application

- For numerous applications in sensor technology
- For broadband splitting or combination of singlemode optical fibers

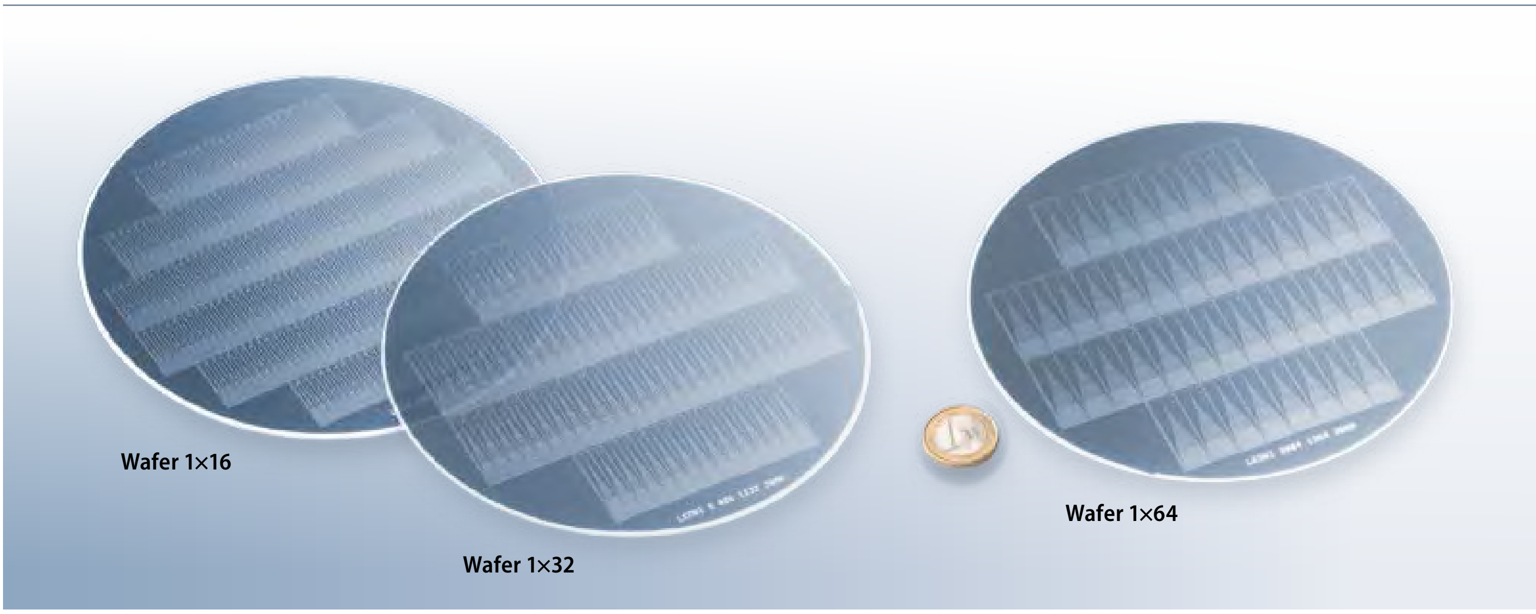
Composition		
Connectors	UPC or APC: SC, FC, LC, MU, E2000, ST, MPO, DIN	
Trays	"plug & play" for different connector types, e. g. B. LGX, Corning CCH	
Inserts	19"-inserts with connector panels, 1, 2 or 3 HU (height units)	
Fiber type	SMF 28 (9 / 125 / 250 µm), single fiber version (highest reliability and flexibility) or ribbon type	
Fiber length	≥ 1 m	
Housing dimension	40 mm × 4 mm × 4 mm for 1×8 splitters (other shapes on request)	
Temperature range	Operating temperature	−40 °C to +85 °C
	Storage temperature	−40 °C to +85 °C

Splitter type	1×2	1×4	1×8
Max. insertion loss [dB]*	3.9	7.4	10.8
Max. uniformity [dB]	0.5	0.9	1.0
Return loss		≥ 55 dB	
Directivity		≥ 55 dB	
Polarization-dependent loss		≤ 0.15 dB	
Wavelength ranges		780–1060 nm	

* Applies across the entire wavelength and temperature range as well as for all polarization states.

Fiber**Split**® 6-inch wafer

1×N ultra-broadband singlemode splitter series on 6" wafers



Description

The 1×N ultra-broadband singlemode splitter series is now also available in 6-inch wafer design.

An optimum balance of performance versus price is achieved based on the exchange of silver ions in a glass specially developed for this process.

Intelligent design and sophisticated manufacturing methods give these splitters exceptional quality and reliability and make them especially suitable for use under the harshest environmental conditions.

Product range

Standard products **1×4, 1×8, 1×16, 1×32 and 1×64**

Customer-specific designs, e. g. 1×N with $N \neq 2^n$

- Asymmetric splits
- Splitters for low wavelength ranges are available on request

Application

- For numerous applications in telecommunications and sensor technology
- For broadband splitting or combination of singlemode optical fibers

Splitter type	Quality grade		Design length Chip	Min. chip length after dicing and polishing	Chips per wafer	Yield (%)	
	Premium	Standard				Premium	Standard
1×4 Distance output channels 250 µm	IL* 6.8 dB Unif 0.5 dB PDL 0.1 dB	IL* 6.9 dB Unif 0.6 dB PDL 0.15 dB	13 × 2 mm	11 × 1.7 mm	520	85	90
1×8 Distance output channels 127 µm	IL* 9.8 dB Unif 0.6 dB PDL 0.1 dB	IL* 10.1 dB Unif 0.8 dB PDL 0.15 dB	13 × 2 mm	11 × 1.7 mm	520	85	90
1×16 Distance output channels 127 µm	IL* 13.0 dB Unif 0.7 dB PDL 0.1 dB	IL* 13.2 dB Unif 0.9 dB PDL 0.2 dB	20 × 2.6 mm	18 × 2.3	242	80	90
1×32 Distance output channels 127 µm	IL* 16.2 dB Unif 0.9 dB PDL 0.1 dB	IL* 16.4 dB Unif 1.1 dB PDL 0.2 dB	30 × 4.6 mm	28 × 4.3 mm	84	80	90
1×64 Distance output channels 127 µm	IL* 19.8 dB Unif 1.2 dB PDL 0.1 dB	IL* 20.1 dB Unif 1.5 dB PDL 0.20 dB	30 × 9 mm	28 × 8.7 mm	44	80	90

IL ➔ max. insertion loss [dB]
Unif ➔ uniformity of splitting [dB]
PDL ➔ polarization-dependent loss [dB]

* Applies across the entire wavelength and temperature range as well as for all polarisation states.
Value is up to 0.3 dB higher for the extended wavelength range from 1360–1480 nm.

FiberSplit® Splitter modules, inserts and trays

for direct installation in sockets, racks and cabinets

multiple multimode splitter with PCF fibers and ST connectors in a 19'' rack

Description

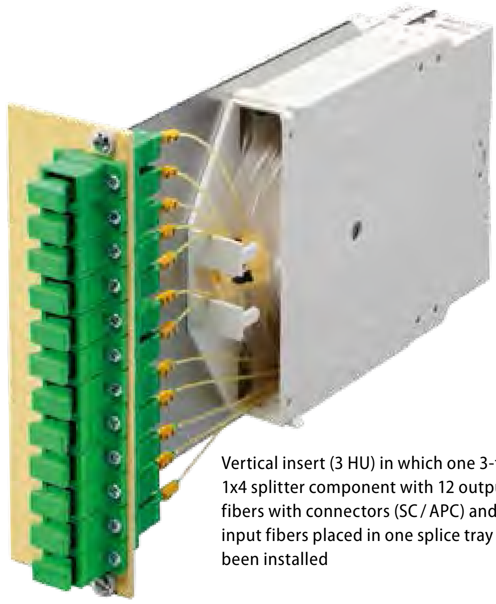
Based on the described splitter components, LEONI offers a wide range of further assemblies in modules, inserts and trays that are suitable for direct installation in sockets, racks or cabinets.

A range of housing shapes from the standard housing customary in the market to customer-specific housing solutions are available.

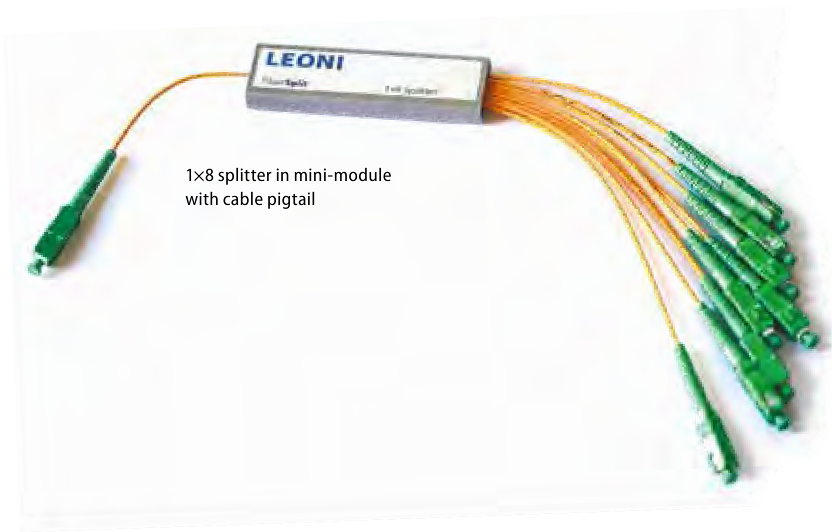
Further information and solution suggestions on request

Example

Vertical insert (3 HU) in which one 3-fold 1x4 splitter component with 12 output fibers with connectors (SC/APC) and three input fibers placed in one splice tray have been installed.



Vertical insert (3 HU) in which one 3-fold 1x4 splitter component with 12 output fibers with connectors (SC / APC) and three input fibers placed in one splice tray have been installed



1×8 splitter in mini-module with cable pigtail

Classification of planar waveguide components

The component series 1xN and 2xN made by LEONI are standard components for the telecommunication sector. These components are optimized particularly for the application in fiber optical distribution systems such as FTTX with a GPON architecture.

Our product portfolio also includes special components for telecommunication networks as well as for other fiber optical systems such as sensing, measuring or diagnostic systems, for which the optical properties can be adjusted and varied in numerous ways:

Possibilities cover singlemode waveguides for wavelengths ranging from 400 nm upwards, polarization maintaining waveguides, multimode waveguides with a large core diameter and a high numerical aperture.

All splitter types are available as:

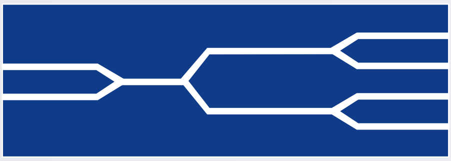
- **Splitter components with fiber ribbons or individual fibers – with or without connectors**
- **Splitter modules with customer-specific housings, trays or inserts**

➔ all singlemode splitters are also available as intermediate products in the form of 6-inch wafers.

Standard components

Applications:

- Telecommunications
- Subscriber loop (FTTX)
- FTTH
- CATV

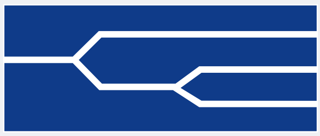


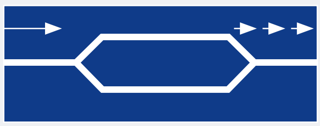
Special components

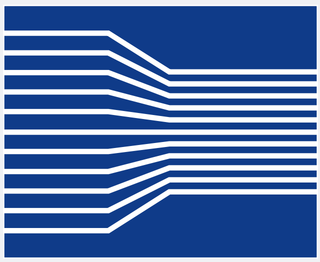
Applications:

- Telecommunications
- Sensor technology
- Metrology
- Biotechnology and Life Science
- Optical signal transmission

and many more







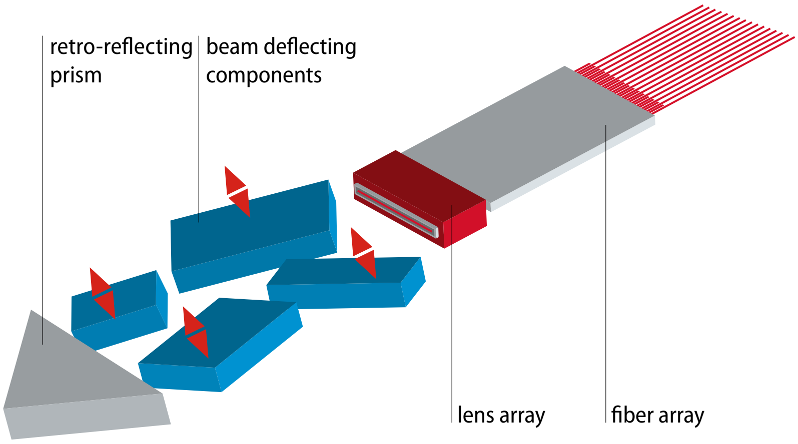
FiberSwitch®
Optical switches for singlemode and multimode applications

Applications and technology

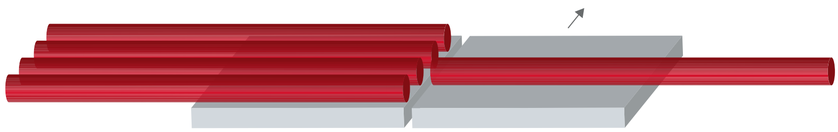
The compact and robust LEONI switches are mainly used for applications with the highest requirements in telecommunications, in measurement and testing, production and process monitoring as well as in the biomedical sector.

Examples of these complex applications include beam guiding systems for confocal and laser scan microscopy, fiber optical tension and temperature sensors for pipelines, bridges, tunnels etc., fiber optical measuring systems for environment monitoring and equipment for the testing of optoelectronical devices during the production process.

Further basic information on optical switches:
Chapter 12 | Principles
→ page 400 ff.



Schematic diagram of a fiber optical singlemode switch 1×16



Schematic diagram of a fiber optical multimode switch 1×4

The Fiber optical switches from LEONI are based on a unique patented micromechanical / microoptical concept. They provide excellent parameters, high flexibility and long term stability for various applications. The switches are available for a broad wavelength range from the ultraviolet to infrared and can be fabricated with practically all possible fiber types.

The switches can be easily integrated into an existing system due to maximum input power of 450 mW and standard interfaces (RS232, I^2C, TTL, USB, optional Ethernet). High channel numbers can be achieved without cascading, e. g. eol 1×16. With cascading almost any desired combination is possible.

Optical properties

- Low insertion loss
- Low polarization loss (eol-series)
- Excellent repeatability
- High optical isolation
- Extremely low back reflection (eol-series)
- Wide to ultrawide (mol series) spectral range
- Short switching times starting from 2.0 ms

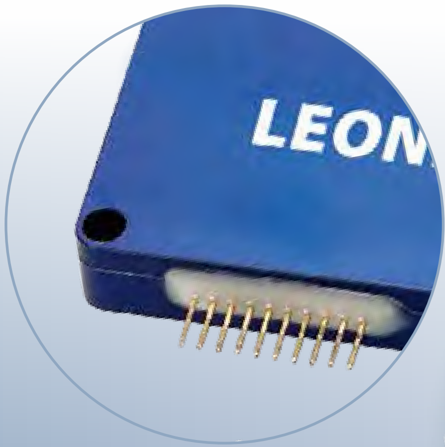
Housing properties

- Small, rugged metal housing
- Flexible housing options, compact housing or tabletop housing
- Connector assembly in the plant
- The integrated microcontroller provides various interfaces and control signals
- Low power consumption

Relialbility

- Excellent long-term reliability, tested according to Telcordia GR-1073
- Lifetime > 10^8 switching cycles

FiberSwitch® Fiber optical singlemode switches



eol 1×4
standard housing
(small version)

eol 1×2 · eol 1×4 · eol 2×2

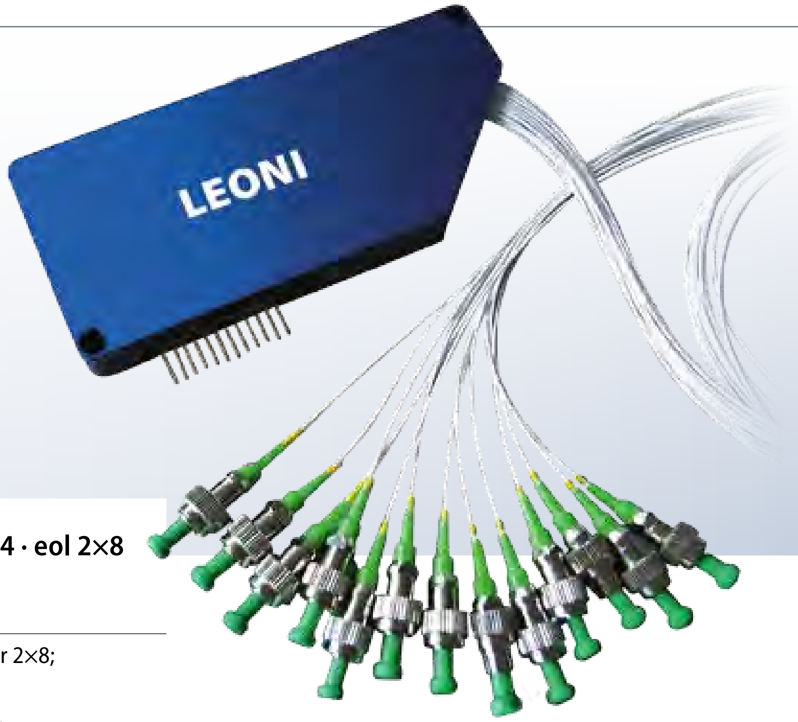
For requests please specify

- Number of channels (1×2, 1×4 or 2×2)
- Spectral range (operating wavelength range)
- Optical power (max.): High power versions available up to 1 W
- Fiber type (e.g. E9/125 or similar)
- Pigtail length (m)
- Connector type(s) (e.g. FC, SC, LC, E2000)
- Electrical interface (e.g. RS232,TTL,I2C, Ethernet, USB)
- Special requirements
- Switch versions 2×N see page 13

Spectral range		**VIS**	**NIR I**	**NIR II**	**IR**
Specifications					
Operating wavelength	[nm]	400 – 670	600 – 850	900 – 1200	1260 – 1380 1480 – 1650
max. insertion loss (typ.)	[dB]	2…2.5	1.4 (0.9)	1.4 (0.9)	1.0 (0.7)
Return loss	[dB]	> 40 (> 55 *)	> 55	> 60	> 60
Crosstalk	[dB]	≤ –55			
Repeatability	[dB]	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.005
Polarization dependent loss PDL	[dB]	≤ 0.05			
Switching times	[ms]	≤ 2			
Guaranteed lifetime	[switching cycles]	> 10^8			
Switching frequency	[s^{-1}]	≤ 50			
Operating voltage	[V]	5			
Power consumption	[mW]	< 450			
Operating temperature	[°C]	0 up to +60			
Storage temperature	[°C]	–40 up to +80			
Housing dimensions	[mm]	standard large (124 × 56 × 13)		standard small (75 × 50 × 13)	
Housing options*		Alu Compact table top, 19" rack; different sizes on request			

* on request

FiberSwitch® Fiber optical singlemode switches



eol 1×12
standard housing
(large version)

eol 1×8 · eol 1×12 · eol 1×16 · eol 2×4 · eol 2×8

For requests please specify

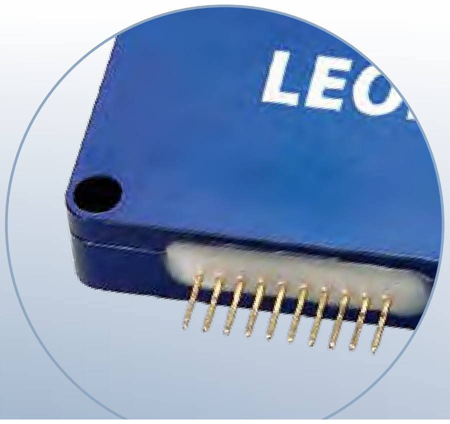
- Number of channels (1×8, 1×12, 1×16, 2×4 or 2×8; other channel counts on request)
- Spectral range (operating wavelength range)
- Optical power (max.): High power versions available up to 1 W
- Fiber type (e.g. E9/125 or similar)
- Pigtail length (m)
- Connector type(s) (e.g. FC, SC, LC, E2000)
- Electrical interface (e.g. RS232,TTL,I2C, Ethernet, USB)
- Special requirements
- Switch versions 2×N see page 13

Spectral range		VIS	NIR I	NIR II	IR
Specifications					
Operating wavelength	[nm]	400 – 670	600 – 900	900 – 1200	1260 – 1380 1480 – 1650
max. insertion loss (typ.)	[dB]	1.4 (0.9)*	1.4 (0.9)*	1.4 (0.9)*	1.0 (0.7)*
Return loss	[dB]	> 40	> 55	> 55	> 60
Crosstalk	[dB]	≤ –55			
Repeatability	[dB]	≤ 0.01			
Polarization dependent loss PDL	[dB]	≤ 0.1			
Switching times	[ms]	≤ 2			
Guaranteed lifetime	[cycles]	> 10^8			
Switching frequency	[s^{-1}]	≤ 50			
Operating voltage	[V]	5			
Power consumption	[mW]	< 450			
Operating temperature	[°C]	0 up to +60			
Storage temperature	[°C]	–40 up to +80			
Housing dimensions	[mm]	standard large (124 × 56 × 13)			
Housing options		Alu Compact table top, 19" rack; different sizes on request			

* For eol 1×16: max. insertion loss is 1.5 dB for IR version and 2.0 dB for all other versions

Fiber**Switch**® Fiber optical singlemode switches

(polarization maintaining)



eol 1×4
standard housing
(small version)

eol 1×2 PM · eol 1×4 PM · eol 1×8 PM · eol 1×12 PM · eol 1×16 PM

For requests please specify

- Number of channels (1×2, 1×4, 1×8, 1×12 or 1×16; other channel counts on request)
- Spectral range (operating wavelength range)
- Optical power (max.): High power versions available up to 1 W
- Fiber type (e.g. PMF)
- Pigtail length (m)
- Connector type(s) (e.g. FC, SC, LC, E2000)
- Electrical interface (e.g. RS232,TTL,I2C, Ethernet, USB)
- Special requirements

Spectral range		**VIS**	**NIR I**	**NIR II**	**IR**
Specifications					
Operating wavelength	[nm]	400 – 670	600 – 900	900 – 1200	1260 – 1380 1480 – 1650
Insertion loss	[dB]	1.4 (0.9)			
Return loss	[dB]	> 40	> 55	> 55	> 60
Crosstalk	[dB]	≤ –55			
Repeatability	[dB]	≤ 0.01			
Polarization extinction ratio PER	[dB]	18 (22)	20 (22)	20 (22)	20 (25)
Switching times	[ms]	≤ 2			
Guaranteed lifetime	[cycles]	> 10^8			
Switching frequency	[s^{-1}]	≤ 50			
Operating voltage	[V]	5			
Power consumption	[mW]	< 450			
Operating temperature	[°C]	0 up to +60			
Storage temperature	[°C]	–40 up to +80			
Housing dimensions	[mm]	standard small (75 × 50 × 13) or standard large (124 × 56 × 13)			
Housing options		Alu Compact table top, 19" rack; different sizes on request			

FiberSwitch® Fiber optical singlemode switches

(VIS, polarization maintaining)

VIS-PM

eol 1×N VIS · eol 1×N VIS-PM (N= 2…16) super-wideband

For requests please specify

- Number of channels N (N = 2…16;
  other channel counts on request)
- Spectral range (operating wavelength range)
- Optical power (max.):
  High power versions available up to 100 mW
- Fiber type (e.g. NUFERN PM-405-XP)
- Pigtail length (m)
- Connector type(s) (e.g. FC, SC, LC, E2000)
- Electrical interface (e.g. RS232,TTL,I2C, Ethernet, USB)
- Special requirements

	eol N×1 (λ-Combining)		eol 1×N (Mix-Assigning)	
Specifications				
Operating wavelength [nm]	400 – 670	488 – 670	400 – 670	488 – 670
max. insertion loss (typ.) [dB]	2.5 (2)	2.5 (2)	3.5 (3)	3 (2)
Return loss [dB]	> 40	> 40	> 40	> 40
Crosstalk [dB]	≤ –55			
Repeatability [dB]	0.01			
Polarization extinction ratio PER [dB]	18 (20)			
Switching times [ms]	2			
Guaranteed lifetime [cycles]	$\geq 10^8$			
Switching frequency $[s^{-1}]$	≤ 50			
Operating voltage [V]	5			
Power consumption [mW]	≤ 450			
Operating temperature [°C]	0 up to +60			
Storage temperature [°C]	–40 up to +80			
Housing dimensions (standard) [mm]	standard large (124 × 56 × 13)*			
Housing dimensions, e.g. socket version	Alu Compact			

* Custom housings on request

FiberSwitch® Fiber optical multimode switches

mol 1×9
standard housing
(multiple module)

mol 1×4
standard housing
large

mol 1×N (N = 1…16) · mol 2×N

For requests please specify

- Number of output channels N
- Spectral range (operating wavelength range / UV-VIS; VIS-IR; Broadband)
- Low-Etalon-Effect option available for spectroscopy
- Fiber type (e.g. core diameter, NA, GI or SI)
- Pigtail length (m)
- Connector type(s) (e.g. SMA, FC, ST)
- Electrical interface (e.g. RS232, TTL, I2C, Ethernet, USB)
- Special requirements
- Switch versions 2×N see page 13

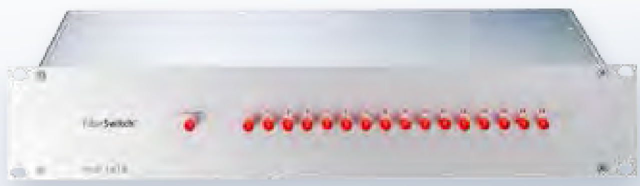
Core diameter		50–100 µm	
Specifications			
Number of output channels N		1…4	5…16
Operating wavelength	[nm]	Depending only on fiber characteristics	
Insertion loss	[dB]	< 1.0 (0.7)	< 2.0 (1.4)
Crosstalk	[dB]	< –60	
Repeatability	[dB]	0.03	
Switching times	[ms]	5	
Guaranteed lifetime	[cycles]	> 10^8	
Switching frequency	[s^{-1}]	≤ 50	
Operating voltage typ.	[V]	5	
Power consumption	[mW]	< 450	
Operating temperature	[°C]	0 up to +60	
Storage temperature	[°C]	–40 up to +80	
Housing dimensions (example) for pigtail version	[mm]	standard large	standard multiple module
Housing dimensions, e.g. for coupling sleeve version		Alu Compact 1	Alu Compact 4

Please note: To minimize back reflection and spectral etalon effects both AR coatings and angle polished fiber ends can be implemented; please request for this.

Selection of useable housing dimensions	
Standard large	124 × 56 × 13
Standard multiple module	172 × 134 × 13.5
Alu Compact 1	187 × 125 × 30-80
Alu Compact 2	227 × 166 × 30-80
Alu Compact 3	187 × 225 × 30-80
Alu Compact 4	227 × 266 × 30-80

FiberSwitch® Fiber optical multimode switches

mol 1×4 Alu Compact 4



mol 1×16 19" 2 HU

mol 1×N (N = 1 to 16) · mol 2×N

For requests please specify

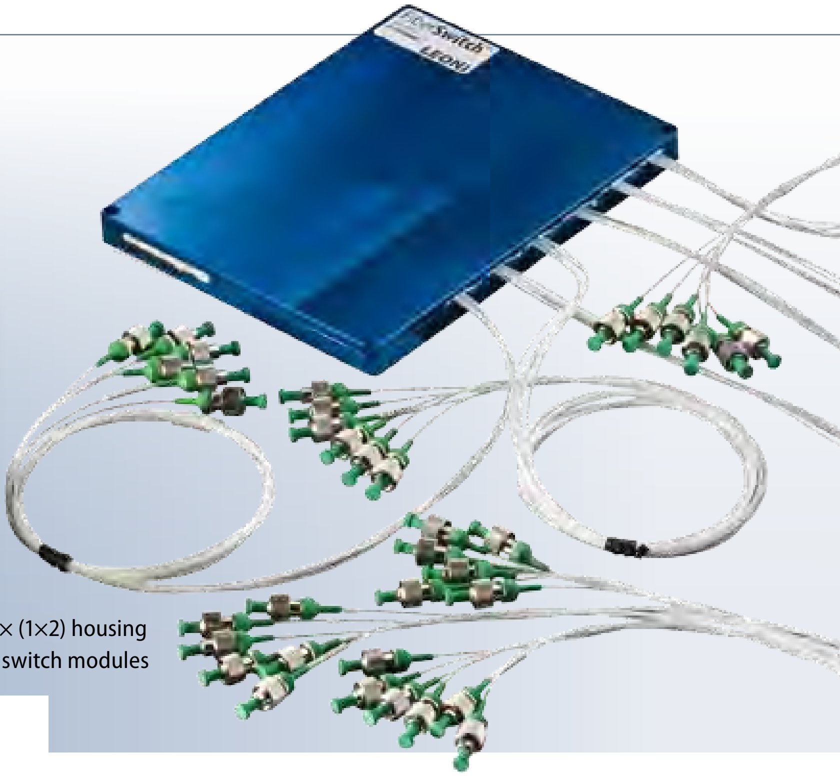
- Number of output channels N
- Spectral range
  (operating wavelength range / UV-VIS; VIS-IR; Broadband)
- Low-Etalon-Effect option available for spectroscopy
- Fiber type (e.g. core diameter, NA, GI or SI)
- Pigtail length (m)
- Connector type(s) (e.g. SMA, FC, ST)
- Electrical interface (e.g. RS232,TTL,I2C, Ethernet, USB)
- Special requirements
- Switch versions 2×N see page 13

Core diameter	200 µm		400 µm		600 µm		800 µm	
Specifications								
Number of output channels N	1…4	5…16	1…4	5…16	1…4	5…16	1…4	5…16
Operating wavelength [nm]	Depending only on fiber characteristics							
Insertion loss [dB]	< 1.0 (0.7)	< 2.0 (1.4)	< 1.0 (0.7)	< 2.0 (1.4)	< 1.0 (0.7)	< 2.0 (1.4)	< 1.0 (0.7)	< 2.0 (1.4)
Crosstalk [dB]	< –55		< –45		< –40		< –40	
Repeatability [dB]	0.03							
Switching times [ms]	5		10		20		20	
Guaranteed lifetime [cycles]	> 10^8							
Switching frequency [s^{-1}]	≤ 50							
Operating voltage typ. [V]	5							
Power consumption [mW]	< 450							
Operating temperature [°C]	0 up to +60							
Storage temperature [°C]	–40 up to +80							
Housing dimensions (example) for pigtail version [mm]	AluComp1	AluComp3	AluComp2	AluComp4	AluComp1 287 length	19" 2HU 340 depth	AluComp1 287 length	19" 3HU 340 depth
Housing dimensions (example) for coupling sleeve version [mm]	AluComp3	AluComp4	AluComp4	19" 2HU 280 depth	19" 1HU 280 depth	19" 2HU 340 depth	19" 1HU 280 depth	19" 3HU 340 depth

Please note: To minimize back reflection and spectral etalon effects both AR coatings and angle polished fiber ends can be implemented; please request for this.

FiberSwitch® Fiber optical multiple switches / switch systems

Switch system consisting of two eol 1×16
and one mol 1×16
with one control unit (interface selection:
Ethernet; USB or RS232)



eol 12 × (1×2) housing
with 6 switch modules

eol M × (1×N) · mol M × (1×N)

For requests please specify

- Number of channels (N 1…16)
- Number of switch modules M
- Spectral range
  (Operating wavelength range / UV-VIS; VIS-IR; Broadband)
- Maximum optical power
- Fiber type (e.g. E9/125 or similar or MM Core Diameter, NA, GI or SI)
- Pigtail length (m)
- Connector type(s) (e.g. FC, SC, SMA, ST)
- Electrical interface (z.B. RS232, TTL, Ethernet, USB)
- Special requirements
- Higher number of output channels N > 4 in different housing versions available
- Higher number of switching modules M upon request
- Further specifications please see pages for single switches

Switch systems

- Combinations of several different switches (incl. singlemode and multimode) in different housing versions, e.g. 19" racks available
- Control of different switches through one single interface

Number of channels	eol 1×2	eol 1×4	mol 1×2	mol 1×4
No. of switch modules M	2…12	2…6	2…6	2…6
Housing dimensions[mm]	130×106×13.5 (M 2…6)	130×106×13.5 (M 2…3)		
	134×172×13.5 (M 7…12)	134×172×13.5 (M 4…6)		
Housing options	Alu Compact table top, 19" rack; different sizes on request			

FiberSwitch® Fiber optical high channel count switches

Optical switch mol 1×1248 with 48-channel MPO connectorization

mol 1×400 19" rack mount switch box

eol 1×N · mol 1×N

For requests please specify

- Number of output channels N
- Spectral range (Operating wavelength range / UV-VIS; VIS-IR; Broadband)
- Low-Etalon-Effect option available for spectroscopy
- Fiber type (e.g. core diameter, NA, GI or SI)
- Pigtail length (m)
- Connector type(s) (e.g. SMA, FC, ST)
- Electrical interface (e.g. RS232,TTL,I2C, Ethernet, USB)
- Special requirements
- Switch versions 2×N see page 13

Switching principle		**standard**	**high speed version**	
Configuration		**cascaded**	**non-cascaded**	**cascaded**
Specifications				
Number of output channels N			≤ 100	> 100 (dep. on fiber type)
Insertion loss	[dB]	dep. on no. of cascades	≤ 1.0	dep. on no. of cascades
Switching frequency	[s^{-1}]	≤ 50	≤ 200	
Guaranteed lifetime	[cycles]	> 10^8		
Operating temperature	[°C]	0 up to +60		
Storage temperature	[°C]	−40 up to +80		
Housing options		19" racks or switch boxes in different sizes on request		

FiberSwitch® Fiber optical multichannel shutters

eol N (N= 1…32)

eol 10-channel Shutter 19" rack, 2 HU

eol N (N=1…32)

For requests please specify

- Channel number
  (N = 1, 2, 3…32; higher channel count on request)
- Spectral range (operating wavelength range)
- Optical power (max.): High power versions available up to 1 W
- Fiber type (e.g. E9/125 or similar)
- Pigtail length (m)
- Connector type(s) (e.g. FC, SC, LC, E2000)
- Electrical interface (z.B. RS232, TTL, I2C, Ethernet, USB)
- Special requirements

Spectral range		VIS	NIR I	NIR II	IR
Specifications					
Operating wavelength	[nm]	400 – 670	600 – 850	900 – 1200	1260 – 1380 1480 – 1650
Insertion loss max. (typisch)	[dB]	1.4 (0.9)	1.4 (0.9)	1.4 (0.9)	1.0 (0.7)
Return loss	[dB]	< 40	< 55	< 55	< 60
Crosstalk	[dB]	≤ 55			
Repeatability	[dB]	≤ 0.01			
Polarization dependent loss PDL	[dB]	≤ 0.1			
Switching times	[ms]	≤ 2			
Guaranteed lifetime	[cycles]	> 10^8			
Switching frequency	[s^{-1}]	≤ 50			
Operating voltage	[V]	5			
Power consumption	[mW]	< 450			
Operating temperature	[°C]	0 up to +60			
Storage temperature	[°C]	–40 up to +80			
Housing (standard)		19" rack 3 HU*			

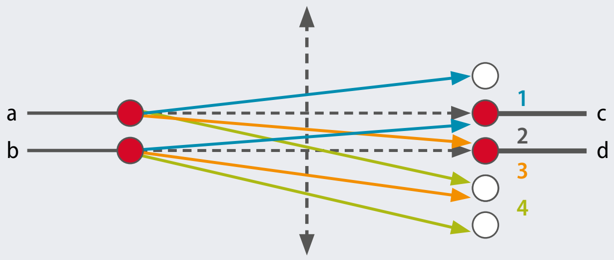
*) Custom housings on request

Switching principles of fiber optical switches

eol 2×N · mol 2×N

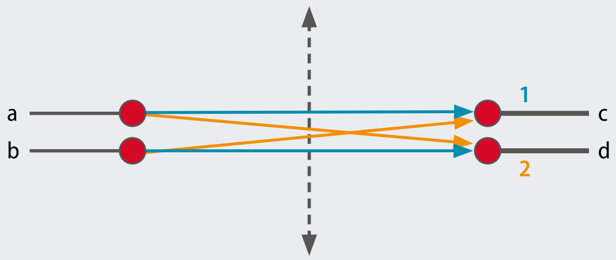
Version 1

eol 2×2 · mol 2×2 (4 switch positions)



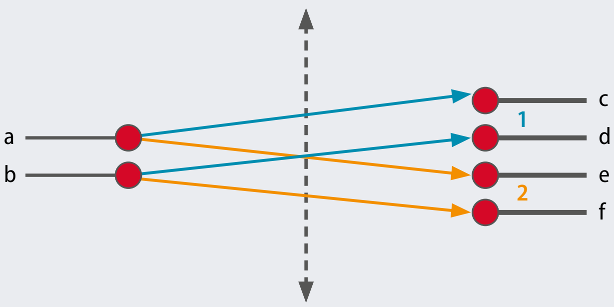
Version 2

eol 2×2 · mol 2×2 (2 switch positions)



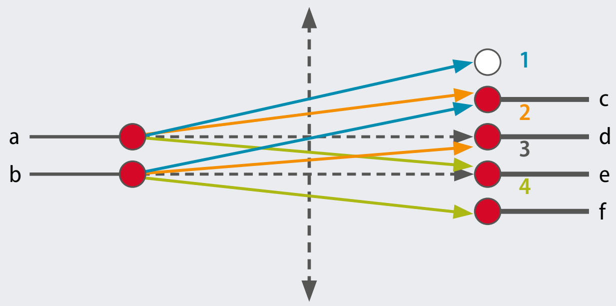
Version 3

eol 2×4 · mol 2×4 (2 switch positions)



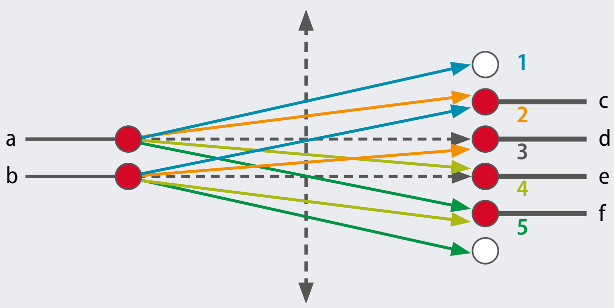
Version 4

eol 2×4 · mol 2×4 (4 switch positions)



Version 5

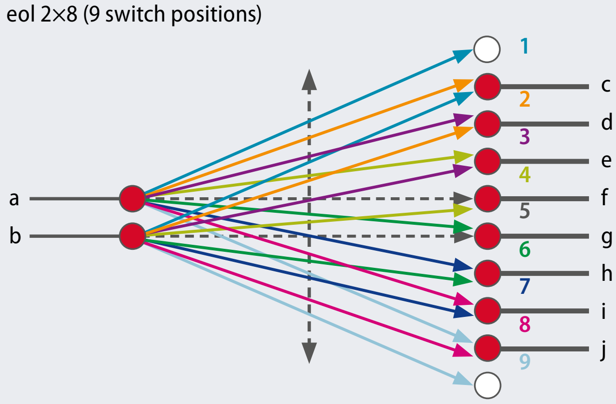
eol 2×4 · mol 2×4 (5 switch positions)



further configurations on request

Version 6

eol 2×8 (9 switch positions)



CHAPTER 11

Accessories

Protection tubes, loose tubes, tools and measurement devices

11. Accessories

FiberConnect® Protection Tubes

for a variety of optical fiber configurations – for protection from damage by longitudinal and transversal forces or environmental influences

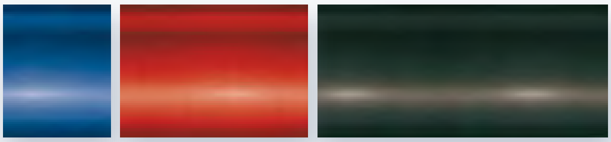
- **Maximum delivery length:**
  up to 200 m, but dependent on optical fiber diameter and type, tube diameter and type as well as cable composition
- **Minimum permitted bending radius:**
  dependent on optical fiber used, special tubes with limited bending can be used to protect the fibers
- **Mechanical properties:**
  in assessment table
- **Protection classes:**
  IP classes
- **Marking:**
  tubes can be printed with customer-specific marking

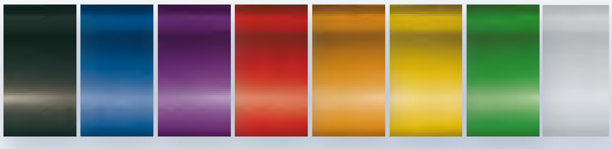
Affixing of warning and safety notices
Affixing warning markings is very helpful in ensuring proper handling of the cables during installation and maintenance work.

Options:
1. Printed shrink-fit tubes
in signal colours and variable intervals and lengths
2. Direct printing of the tubes
with warning notices

FiberConnect® Plastic tube

PVC / PTFE





PVC tube

Description

Cost-effective construction for lightweight indoor and outdoor cables.

Composition / Properties

Protection class	IP68
Operating temperature	–25 °C to +80 °C
Colours	● black ● blue ● red
Composition	smooth tube
Material	PVC
Properties	■ Bondability: good ■ Resistance to lateral compression: poor

Order no.	Inner-Ø approx.	Outer Ø approx.	Weight ±10 %	Minimum permitted bending radius*
	mm	mm	kg/m	mm
Z10097 blue	1.2	3	0.009	15
Z10098 black	1.2	3	0.009	15
Z10025 blue	2	4	0.013	25
Z10007 blue	2	5.5	0.027	30
Z10008 red	2.7	5	0.025	30
Z10101 black	2	2.7	0.004	15

* Applies to the tube only and is influenced by the fiber and cable inner composition used.

Further diameters on request.

PTFE tube

Description

For vacuum applications; in a medium temperature range; good gliding properties (cable inner constructions)

Composition / Properties

Protection class	IP68
Operating temperature	–60 °C to +260 °C
Colours	● black ● blue ● violet ● red ● orange ● yellow ● green ○ transparent
Composition	smooth tube
Material	PTFE
Properties	■ Bondability: good ■ Resistance to lateral compression: medium to good

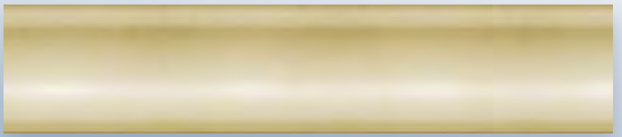
Order no.	Inner-Ø approx.	Outer Ø approx.	Weight ±10 %	Minimum permitted bending radius*
	mm	mm	kg/m	mm
Z10027 transparent	1.8	2.1	0.002	15
Z10074 transparent	1.5	2.5	0.007	15
Z10081 yellow	1.5	2.5	0.007	15
Z10075 green	1.5	2.5	0.007	15
Z10082 orange	1.5	2.5	0.007	15
Z10083 violet	1.5	2.5	0.007	15
Z20429 black	1.7	2.5	0.006	15
Z10024 Transparent	2	4	0.016	30

* Applies to the tube only and is influenced by the fiber and cable inner composition used.

Further diameters on request.

Fiber**Connect**® **Plastic tube**

PEEK / PA



PEEK tube

Description

For vacuum applications ➔

- large temperature range
- good gliding properties

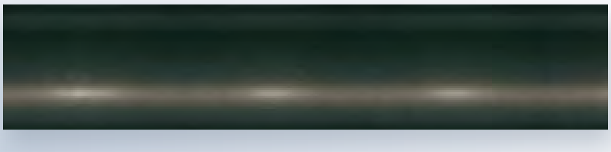
Composition / Properties

Protection class	IP68
Operating temperature	−40 °C to +220 °C
Colours	● beige
Composition	smoot tube
Material	PEEK
Properties	■ Bondability: good ■ Resistance to lateral compression: medium to good

Order no.	Inner-Ø approx.	Outer Ø approx.	Weight ±10 %	Minimum permitted bending radius*
	mm	mm	kg/m	mm
Z20809	1.01	1.59	0.002	30
Z20433	1.59	3.17	0.008	50

* Applies to the tube only and is influenced by the fiber and cable inner composition used.

Further diameters on request.



PA tube

Description

Polyamide, available electrically insulating and dissipative.

Composition / Properties

Protection class	IP68
Operating temperature	−40 °C to +90 °C
Colours	● black
Composition	smoot tube
Material	Polyamid
Properties	■ Bondability: good ■ Resistance to lateral compression: medium ■ Halogen-free ■ available electrically dissipative

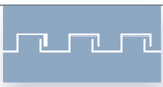
Order no.	Inner-Ø approx.	Outer Ø approx.	Weight ±10 %	Minimum permitted bending radius*
	mm	mm	kg/m	mm
Z20436	4	6	0.017	50
Z10102 electrically dissipative	4	6	0.017	50

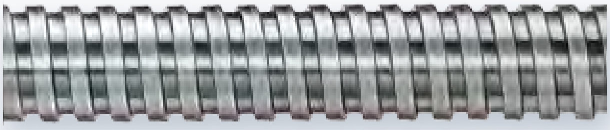
* Applies to the tube only and is influenced by the fiber and cable inner composition used.

Further diameters on request.

FiberConnect® Metal tube

Single / double interlocked metal profile





Metal tube

Description

Tube for medium weight cables with very wide operating temperature range.

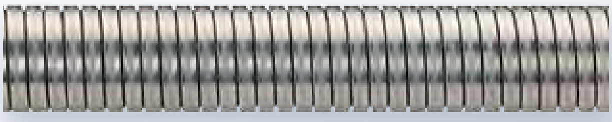
Composition / Properties

Protection class	IP40
Operating temperature	up to +600 °C
Composition	Metal convoluted tube with interlocked profile
Material	Stainless steel
Properties	■ Bondability: good ■ Resistance to lateral compression: good

Order no.	Inner-Ø approx.	Outer Ø approx.	Weight ±10 %	Minimum permitted bending radius*
	mm	mm	kg/m	mm
Z20436	1.5	2.9	0.012	15
Z10102	1.8	2.9	0.015	15
Z10005	3	4.7	0.027	15
Z10103	3.5	5.0	0.034	20
Z10703	4	5.8	0.037	20
Z20453	5	6.9	0.044	20
Z10104	6	8	0.06	25
Z10105	8	10	0.075	30

* Applies to the tube only and is influenced by the fiber and cable inner composition used.

Further diameters on request.



Metal tube (Agraff)

Description

Tube for medium weight cables with very wide operating temperature range plus improved tensile and torsional strength.

Composition / Properties

Protection class	IP40
Operating temperature	up to +600 °C
Composition	Metal convoluted tube with double interlocked profile
Material	Stainless steel
Properties	■ Bondability: good ■ Resistance to lateral compression: verygood

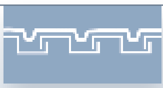
Order no.	Inner-Ø approx.	Outer Ø approx.	Weight ±10 %	Minimum permitted bending radius*
	mm	mm	kg/m	mm
Z10106	4	6	0.06	35
Z10001	6	7.9	0.11	40
Z20810	8	10	0.12	50
Z10250	14	17.5	0.24	60

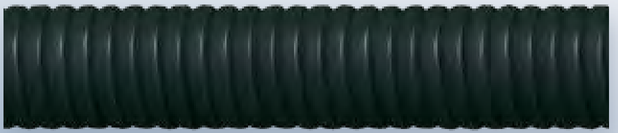
* Applies to the tube only and is influenced by the fiber and cable inner composition used.

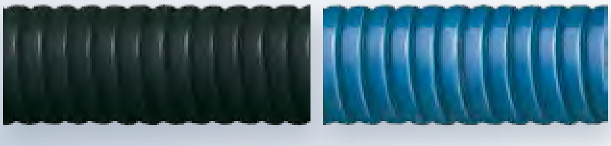
Further diameters on request.

FiberConnect® Metal/plastic tube

single / double interlocked metal profile







Metal/plastic tube

Description

Leakproof tube for medium weight indoor and outdoor cables.

Composition / Properties

Protection class	IP68
Material/ operating temperature	■ galvanized iron / PVC –25 °C to +80 °C ■ galvanized iron / polyamide –50 °C to +115 °C ■ galvanized iron / PVC electrically dissipating –50 °C to +115 °C
Colours	● black (further colours on reques)
Composition	metal convoluted tube with single interlocked profile, covered with plastic tube, available electrically (for application in explosion proof areas)
Properties	■ Bondability: good ■ Resistance to lateral compression: good

Order no.	Inner-Ø approx.	Outer Ø approx.	Weight ±10 %	Minimum permitted bending radius*	Material
	mm	mm	kg/m	mm	
Z10107	4	7	0.05	17	galvanized iron/PVC
Z20457	4.8	8	0.06	20	
Z10108	6	9	0.08	25	
Z10109	8	10.2	0.085	40	
Z10110	10	14	0.138	40	
Z10111	12	16	0.161	44	
Z20604	7	10	0.085	40	galvanized iron/ polyamide
Z21095	5	8	0.06	25	galvanized iron/PVC electrically dissipative

* Applies to the tube only and is influenced by the fiber and cable inner composition used.

Further diameters on request.

Metal/plastic tube (Agraff)

Description

Leakproof tube for medium weight indoor and outdoor cables with improved tensile and torsional strength.

Composition / Properties

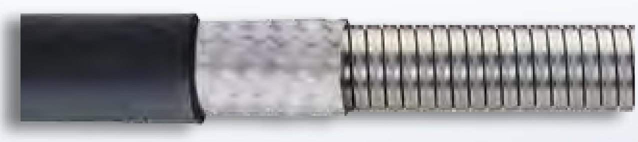
Protection class	IP68
Material/ operating temperature	■ Brass / silicone –60 °C to +260 °C ■ Stainless steel / silicone –60 °C to +260 °C ■ Galvanized iron / PUR –40 °C to +80 °C
Colours	● black, ● blue (further colours on reques)
Composition	metal convoluted tube with double interlocked profile, covered with plastic tube
Properties	■ Bondability: good ■ Resistance to lateral compression: very good

Order no.	Inner-Ø approx.	Outer Ø approx.	Weight ±10 %	Minimum permitted bending radius*	Material
	mm	mm	kg/m	mm	
Z20846	4.5	8.4	0.11	40	Brass/silicone ● black
Z20865	6	9.6	0.115	40	Stainless steel/silicone ● black
Z20610	7	10	0.13	44	Galvanized iron/ PUR ● blue

* Applies to the tube only and is influenced by the fiber and cable inner composition used.

Further diameters on request.

FiberConnect® Metal / silicone tube



Metal / silicone tube

Description

Protection tube for fiber bundles in medical and industrial technology.

Composition / Properties

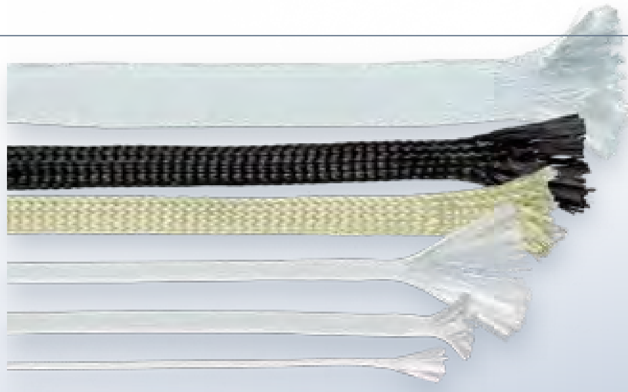
Protection class	IP68
Operating temperature	−60 °C to +260 °C
Colours	● black, ● grey
Composition	wound flattended wire coil with braid made of glass fiber yarn and silicone/ rubber cladding
Material	Stainless steel
Properties	■ Bondability: good ■ Resistance to lateral compression: good ■ resistant to tensile forces / flame resistant ■ good chemical resistance / halogen-free

Order no.	Inner-Ø approx. mm	Outer Ø approx. mm	Weight ±10 % kg/m	Minimum permitted bending radius* mm
Z10093	1.0	3.0	0.016	11
Z10092	1.5	3.5	0.02	13
Z20154	2.5	4.4	0.028	14
Z10112	3.0	5.3	0.044	20
Z10113	3.5	5.8	0.05	20
Z20448	4	6.5	0.058	25
Z20482	5	7.5	0.079	25
Z20599	7	10	0.141	45
Z10114	8	11.6	0.191	45
Z10115	10	13.6	0.241	75
Z10116	12	16.2	0.347	75
Z10238**	6	10	0.195	55

* Applies to the tube only and is influenced by the fiber and cable inner composition used.
** extra starke Ausführung.

Further diameters on request.

FiberConnect® Fabric tube



Fabric tube

Description

Protection tube for fiber bundles in medical and industrial technology.

Composition / Properties

Protection class	IP30	
Material/ Operating temperature	■ Glass fiber yarn ■ Aramid ■ Polyamide	up to +400 °C up to +150 °C up to +115 °C
Composition	braided fiber materials	
Properties	■ Bondability: good ■ Resistance to lateral compression: none	

Order no.	Ø approx. mm	Weight ±10 % kg/m	Material
Z10018	1.5	0.001	Glass fiber yarn
Z10120	3	0.002	Glass fiber yarn
Z10019	4	0.004	Glass fiber yarn
Z10122	8	0.003	Glass fiber yarn
Z10123	12.5	0.009	Aramid
Z10061	20	0.010	Polyamide

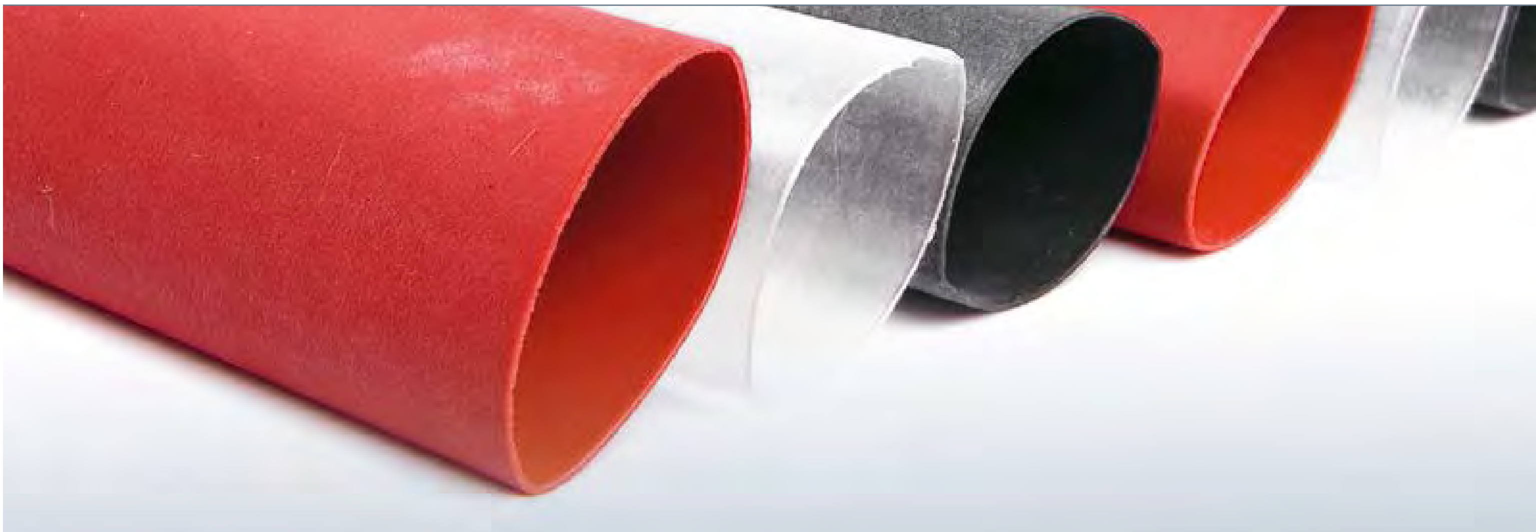
Further diameters on request.

Accessories

11

Properties of selected tube materials

Overview



Material properties	PE	PA	PVC	TPE-O (FRNC)	TPE-U (PUR)
Resistance to ageing	+	+	+	+	+
Absence of halogen	+	+	– –	+	+
Non-flammability	– –/●	–	+	+	+
Elasticity	–	+	●	–	+
Abrasion resistance	+/–	+	+	–	++
Low smoke gas generation	– –/●	+	–	++	●
Low emission of corrosive gases	+/●	++	– –	++	●
Low toxicity of smoke gas	+/●	++	– –	++	●
Toxicological safety	+/●	++	–	++	●

General resistance to	PE	PA	PVC	TPE-O (FRNC)	TPE-U (PUR)
UV light	1)	+	+	1)	1)
Water absorption	+	– –	+	–	–
Gas diffusion	●			–	2)
Fuels	+/–	+	+	–	+
Petroleum/lubricants	+	+	●	–	++
Organic solvents	+ 4)	+ 5)	–	–	+ 3)
Alcohol	+	+	+	–	–
Oxidants	–	–	+	–	–
Acids	++	–	+	+	– –
Alcaline solutions	+	+	+	+	– –
Saline solutions	+	–	+		–

++ excellent
\+ good
● depending on recipe
– weak
– – inadequate

1) UV resistance can be increased by adding black colour pigments or UV stabilisers

2) Permeation depends on type of gas, e.g. Ar, CH_4, N_2, O2 low gas permeation, CO_2, H2, He higher gas permeation

3) Low swelling in saturated hydrocarbons; strong swelling in aromatic hydrocarbons, aliphatic esters cause swelling, highly polar organic solvents dissolve under the effect of extreme swelling

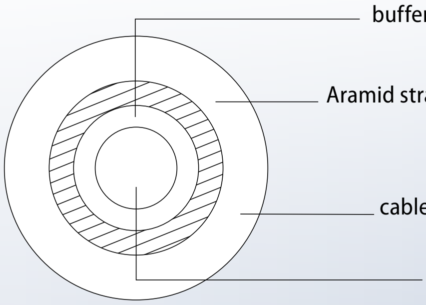
4) Swelling in aliphatic and aromatic hydrocarbons and chlorinated hydrocarbons

5) Not restistant to chlorinated hydrocarbons, resistant to hydrocarbons and aliphatic and aromatic solvents

FiberConnect® Loose tubes/cables

for cable dividers

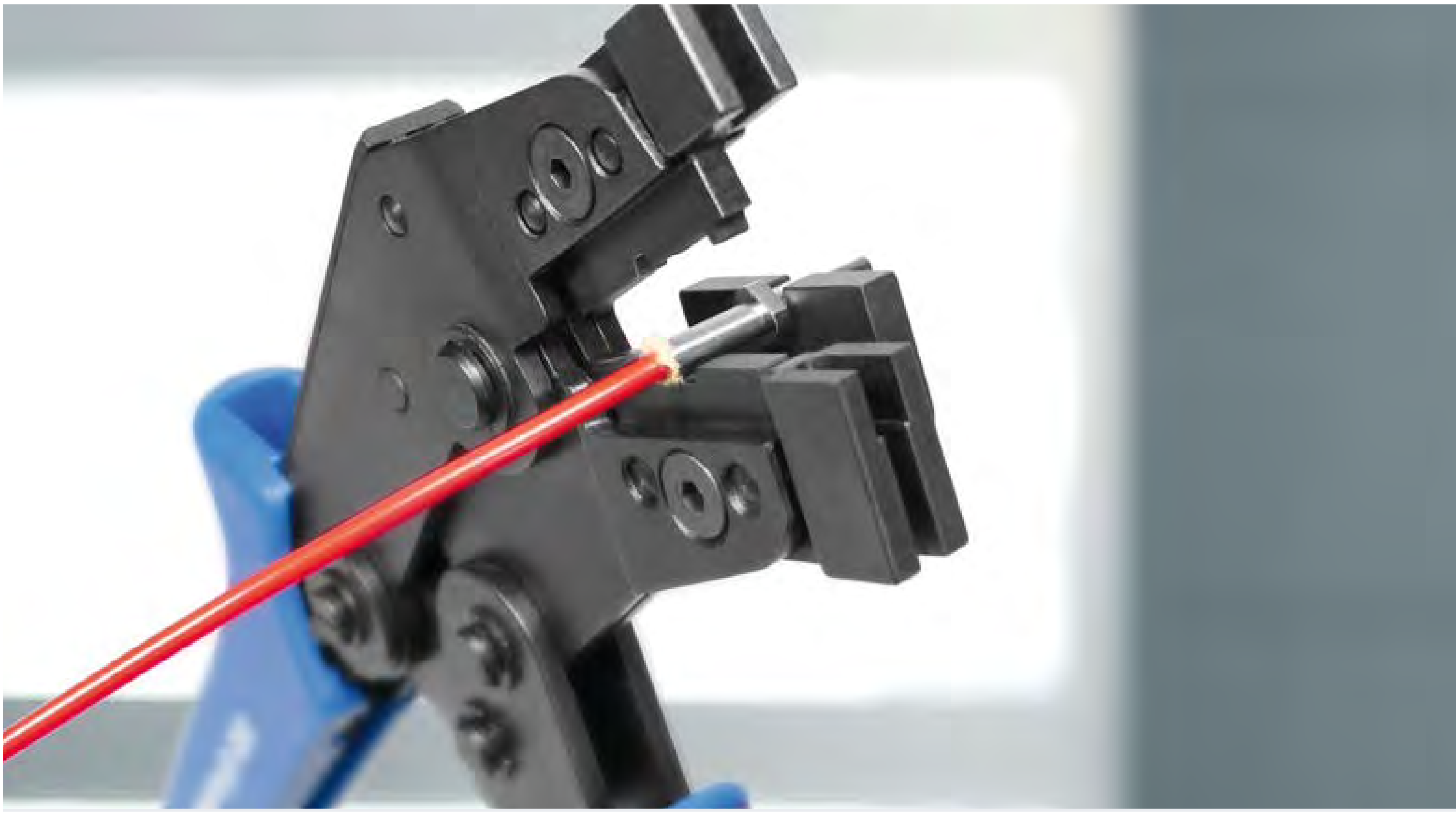
Loose tubes or loose cables for the direct assembly of multi fiber loose tube cables with divider elements for mechanical protection of the fibers.



Assembly	direct connector assembly
Buffer tube material	FRNC
Min. delivery quantity	2000 m
Makeup	disposable drum

Designation	**I-V(ZN)H 0 - LOOSE CABLE 0.5/0.9/2.1**	**I-V(ZN)H 0 - LOOSE CABLE 0.5/0.9/2.1**	**I I-V(ZN)H 0 - LOOSE CABLE 0.8/1.1/2.2**	**I-V(ZN)H 0 - LOOSE CABLE 0.8/1.1/2.2**
Order no.	84950139X111	84950139X222	84950220X000	84950220X222
Colour	RAL 1021. rapeseed yellow	RAL 2003. pastel orange	RAL 9005. jet black	RAL 2003. pastel orange
Cable outer Ø	2.1 mm	2.1 mm	2.2 mm	2.2 mm
Buffer tube outer Ø	0.9 mm	0.9 mm	1.1 mm	1.1 mm
Inner-Ø	0.5 mm	0.5 mm	0.8 mm	0.8 mm
Max. tensile force	300 N	300 N	300 N	300 N
Cable weight	approx. 4.5 kg/km	approx. 4.5 kg/km	approx. 6.6 kg/km	approx. 6.6 kg/km
Ambient temperature in operation	–5 °C to +70 °C	–5 °C to +70 °C	–5 °C to +70 °C	–5 °C to +70 °C

Designation	**I-V(ZN)H 0 - LOOSE CABLE 0.5/0.9/2.1**	**I-V(ZN)H 0 - LOOSE CABLE 0.5/0.9/2.1**	**I-V(ZN)H 0 - LOOSE CABLE 0.5/0.9/2.8**	**I-V(ZN)H 0 - LOOSE CABLE 0.5/0.9/2.8**
Order no.	84950139X666ZIF01	84950139X666ZIF12	84950132X222	84950132X666
	digit 1	digit 12		
Colour	RAL 6018. yellow green	RAL 6018. yellow green	RAL 2003. pastel orange	RAL 6018. yellow green
Cable outer Ø	2.1 mm	2.1 mm	2.8 mm	2.8 mm
Buffer tube outer Ø	0.9 mm	0.9 mm	0.9 mm	0.9 mm
Inner-Ø	0.5 mm	0.5 mm	0.5 mm	0.5 mm
Max. tensile force	300 N	300 N	300 N	300 N
Cable weight	approx. 4.5 kg/km	approx. 4.5 kg/km	approx. 4.5 kg/km	approx. 4.5 kg/km
Ambient temperature in operation	–5 °C to +70 °C	–5 °C to +70 °C	–5 °C to +70 °C	–5 °C to +70 °C



FiberConnect® Tools

Specially adapted tools are needed to assemble fiber optic cables with connectors. This selection of tools and aids is tailored to POF and PCF cables and connectors.

Their assembly is extremely straightforward in comparison with the conventional adhesive technology used with glass fiber optic cables and can be learned by non-specialists in a very short time. It takes between 1 and 5 minutes per connector to assemble these cables.

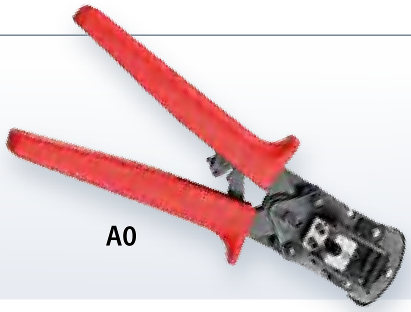
Suitable tools are available for the process steps from stripping through crimping and end face processing to final checking. This makes the assembly of POF in particular a cinch.
These assembly tools for PCF and POF are specially tailored to LEONI's cable constructions and connectors.

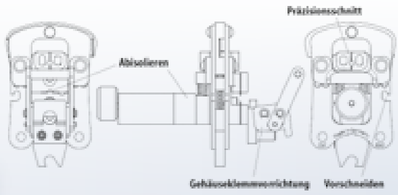
PCF fiber optic cables in particular can be quickly and easily assembled using the crimping/clamping and cleaving technique.
This popular technique is frequently used for field assembly. However the familiar technique for glass fiber optic cables with two-component adhesives and grinding/polishing is also commonly used.

Suitable measuring devices for a wide range of wavelengths are available for the final inspection.

FiberConnect® Stripper

A0



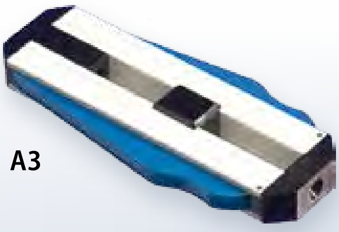


A1

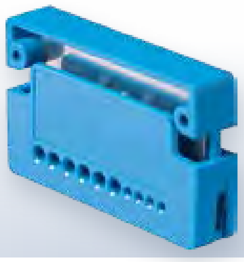
	Universal-assembly tool POF SCRJ	Stripper
Order no.	on request	Z012-SA0-3.6-6.0
Application	Rough cutting, precision cutting of the fiber end face, stripping of the 2.2 mm cable cladding and device for easy assembly of the SCRJ connectors POF	for Ø 6.0 + Ø 3.6 mm Simplex cables

A2

A3



A4



	Stripper	Buffer stripper	Cutter
Order no.	Z010-SA0-2.2	Z004-TA0-0.5	ZXXX-TD0-V2
Application	for cables with Ø O 2.2 mm specially for PCF and PA buffered fibers	for 230 µm PCF fibers	for POF buffered fibers and POF fibers up to Ø 2.3 mm

A5

A6

	Stripper	Precision stripper
Order no.	Z004-TA0-0.5-2.2	Z011-SA0-2.2
Application	for PCF buffered fibers cladding and fiber buffers	for Ø 2.2 mm PE buffered fibers

FiberConnect® Crimp- and cleave tools

	Universal crimp tool program
Order no.	ZXXX-CZ0 see table
Application/ Description	■ Hexagonal ■ Crimping capacities for a variety of connector types ■ can be equipped with 7 different crimp die types

Connector type	crimp dimension [mm]	Order no.
Universal crimp tool	–	BODY
Die for universal crimp tool	2.0/2.5/3.0	DIE1
	2.7/3.3/3.5	DIE2
	2.3/2.4/3.9	DIE3
	3.0/3.3/3.9/4.5	DIE4
	3.8/4.3/4.95	DIE5
	3.0/3.5/5.0	DIE6
	4.5/4.75/5.0	DIE7

Universal crimp tool POF
ZXXX-CB0 see table
for ST/ FSMA/ V-PIN (HP) connectors

Connector type	crimp dimension [mm]	Order no.
V-PIN	5.0	SHP-SS0-19-0010
V-PIN	5.0	SHP-DS0-19-0010
V-PIN Metall	3.0	SHP-SS0-20-0010
F05 Metall	5.0	SF05-SS0-20-0010
FSMA	3.0	SSMA-SS0-02-0050
FSMA	3.0	SSMA-SH0-02-0010
ST	3.5	SXST-SS0-22-0010

	Universal crimp tool PCF
Order no.	ZXXX-CC0 see table
Application	for PCF buffered fiber claddings and fiber buffers

Connector type	crimp dimension [mm]	Order no.
FSMA	anchor 3.3	SSMA-SS0-01-0030
ST	anchor 4.5	SXST-SK0-01-0020
ST	anchor 4.5	SXST-SK0-01-0030

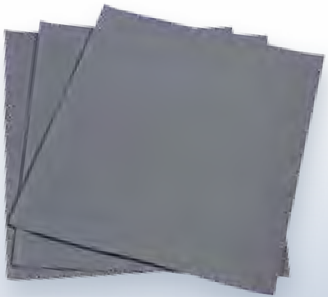
Cleave tool PCF
ZXXX-CB0 see table

Connector type	Order no.
for FSMA connectors PCF (clamp version)	ZSMA-TW0
for ST connectors PCF (clamp version)	ZXST-TW0
for HP connectors (V-PI N) PCF (Crimp and cleave version)	ZXHP-TW0
for F05/F07 connectors	ZF07-TW0
for SC connectors (clamp version)	ZXSC-TW0

FiberConnect® Polishing foils / lapping papers

P1

P2



P3

	Polishing set
Order no.	ZHP-PS0
Content	Lapping paper 600er grain Polishing foil 3 µm Polishing disc
Quantity	1 sheet each
Sheet size	100 × 100 mm

	Polishing foil 3 µm	Lapping paper 600
Order no.	Z 001-PS1	Z 002-PS1
Grain	3 µm	600er
Material	Al2O3	Al2O3
Quantity	10 sheets	10 sheets
Sheet size	216 × 279 mm	230 × 280 mm

P4

P5

	Diamond polishing foil 9 µm	Diamond polishing foil 1 µm
Order no.	Z005-PS1	Z007-PS1
Grain	9 µm	1 µm
Material	C (diamond)	C (diamond)
Quantity	15 sheets	10 sheets
Sheet size	230 × 280 mm	230 × 280 mm

FiberConnect® Polishing discs

P6

P7

P8

	ZSMA polishing disc	F05 polishing disc	HP polishing disc
Order no.	ZSMA-SP0	ZF05-SP0	ZHP-TP0
Application	for FSMA connectors (metal)	for F05 connectors (metal)	for HFBR connectors (non-latching) for POF and PCF, Ø 2.2 mm
Description	—	with wear indicatior	—

P9

P10

	Universal polishing disc 2.5 mm	ST polishing disc
Order no.	ZXXX-SP0-2.5	ZXST-SP0
Application	suitable for ST, SC, FC and LSA-DIN connectors	for ST connectors

FiberConnect® Fiber optic assembly kits

K1 + K2

Fiber optic assembly kit for FSMA connectors PCF (K1)

Description

The fiber optic assembly kits K1 and K2 are identical except for the cleave tool and the microscope adapter.

Content (can also be ordered seperately)	Order no.
Stripper for 230 µm PCF conductors	Z004-TA0-0.5-2.2
Kevlar scissors	ZXXX-TN0
Cleave tool FSMA	ZSMA-TW0
Container for fiber cutoffs	00405402
Card Cleaner	ZXX-TL0
Microscope, 100x magnification	ZXXX-TF0-V1
Microscope adapter	ZSMA-AF0-V1

Fiber optic assembly kit suitable for simplex FSMA connectors	Order no.
for PCF cables with buffered fiber Ø 2.2 mm	SSMA-SW0-02-001O
for PCF cables with buffered fiber Ø 3.0 mm	SSMA-SW0-02-0020
Fiber optic assembly kit	ZSMA-KW0

Fiber optic assembly kit for ST connectors PCF (K2)

Description

The fiber optic assembly kits K1 and K2 are identical except for the cleave tool and the microscope adapter.

Content (can also be ordered seperately	Order no.
Stripper for 230 µm PCF conductors	Z004-TA0-0.5-2.2
Kevlar scissors	ZXXX-TN0
Cleave tool – PCF ST	ZXST-TW0
Container for fiber cutoffs	00405402
Card Cleaner	ZXX-TL0
Microscope, 100x magnification	ZXXX-TF0-V1
Microscope adapter	ZXST-AF0-V1

Fiber optic assembly kit suitable for simplex ST connectors	Order no.
for PCF cables with buffered fiber Ø 2.2 mm	SXST-SW0-02-0010
for PCF cables with buffered fiber Ø 2.5 mm	SXST-SW0-02-0020
for PCF cables with buffered fiber Ø 3.0 mm	SXST-SW0-02-0030
Fiber optic assembly kit	ZXST-KW0

FiberConnect® Fiber optic assembly kits

Fiber optic assembly kit for SC connectors PCF (K3)

Description

Fiber optic assembly kit with crimp tool.

Content (can also be ordered seperately)	Order no.
Stripper for µm PCF conductor	Z004-TA0-0.5-2.2
Kevlar scissors	ZXXX-TN0
Crimp tool for F057F07 connectors PCF	ZF0507-CC0-REN
Cleave tool PCF ST	ZF07-TW0
Container for fiber cutoffs	00405402
Card Cleaner	ZXX-TL0
Microscope, 100x magnification	ZXXX-TF0-V1
Microscope adapter for F05 connectors	ZXST-AF0-V1

Assembly kit suitable for simplex SC connectors	Order no.
for PCF cables with buffered fiber Ø 2.2 mm	SXSC-SW0-02-0010

Assembly kit	ZXSC-KW0

Fiber optic assembly kit for F05/F07 connectors PCF (K4)

Description

Fiber optic assembly kit with crimp tool.

Content (can also be ordered seperately)	Order no.
Stripping tool for 230 µm PCF conductors	Z004-TA0-0.5-2.2
Kevlar scissors	ZXXX-TN0
Cleave tool PCF	ZXSC-TW0
Container for fiber cutoffs	00405402
Card Cleaner	ZXX-TL0
Microscope, 100x magnification	ZXXX-TF0-V1
Microscope adapter	ZXST-AF0-V1

Fiber optic assembly kit suitable for the following connectors	Order no.
Simplex F05 connector for PCF cables with buffered fiber Ø 2.2 mm	SF05-SC0-08-0010
Duplex F07 connector for PCF cables with buffered fiber Ø 2.5 mm	SF07-DC0-08-0010

Assembly kit	ZF0507-KC0

FiberConnect® Microscope

Fiber optic assembly kit for HP connectors PCF (K5)

Description

Fiber optic assembly kit with crimp tool.

Content (can also be ordered seperately)	Order no.
Stripping tool for 230 µm PCF conductors	Z004-TA0-0.5-2.2
Kevlar scissors	ZXXX-TN0
Crimp tool for HP connector V-Pin, PCF	ZXHP-CC0
Cleave tool PCF HP	ZXHP-TW0
Container for fiber cutoffs	00405402
Card Cleaner	ZXX-TL0
Microscope, 100x magnification	ZXXX-TF0-V1
Microscope adapter for HP connectors	ZXHP-AF0-V1

Fiber optic assembly kit suitable for the following connectors	Order no.
Simplex HP connectors for PCF cables with buffered fiber Ø 2.2 mm, compatible with HP HFBR 4521 and V-Pin 200S	SXHP-SC0-32-0010
Duplex housing for two simplex connectors	SXHP-DC0-32-0010
Assembly kit	ZXHP-KW0

Microscope

Description

Microscopes with 100x magnification are used to check the quality of the finished fiber faces of the POF and of cleaved PCF connectors.

Microscope	Order no.
with 100x magnification	ZXXX-TF0-V1

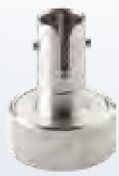
Note

Our camera-based microscope supplies even better results. It is adapted to all commonly used POF connectors. The interchangeable adapter is also used with the attenuation meter. The microscope works with up to 200x magnification.

The scope of delivery also includes a small monitor as well as the power supply unit connector for supplying the power. The device is suitable for both mass production and use on-site.

Fiber**Connect**® Measurement kit

Optical power meter with digital display


ST (BFOC)


HP


FSMA


HP


F05


FCPC

Interchangeable adapter, receiver side

Description

This meter is used to determine the power of a light source (LED or laser) or to measure the attenuation of a fiber optic cable when using a stabilised light source. The microprocessor technology used enables the meter to measure two wavelengths as well as display the results in µW or dBm. An automatic zero adjustment is carried out when the device is switched on. An interchangeable adapter system enables the connection of all commonly used optical fiber connectors.

Note: The device is supplied without adapters. Please order appropriate interchangeable adapters and reference cables for fiber optic cable connections separately.

Structure

Optical detector	Silicone PIN diode
Detector area	2.65 × 2.65 mm
Optical connection	Interchangeable adapter, screw-in
Display range	–50.0 to +3 dBm

Wavelenght meter	Order no.
660 / 850 nm	ZXXX-TM0
1300 / 1550 nm	ZXXX-TM0-1300
520 / 660 / 850 / 940 nm	ZXXX-TM0-4W

Description

The connector type and required wavelength are defined by means of simple push-in adapters. The basic device remains the same.

Connector type	Order no.
ST (BFOC)	ZXST-TX0
FSMA	ZSMA-TX0
F05	ZF05-TX0
HP (simplex and duplex)	ZHP-TX0
FCPC	ZFCPC-TX0

Optical transmitter – Wavelength depending on adapter

Description

Basic device with BNC adapter for connecting different fiber optic cable connector adapters. The connector adapters are available with the wavelengths 650 nm, 660 nm and 850 nm. The adapters for the wavelength 660 nm are specified as an example in the specified order numbers.

Note: The device is supplied without adapters. Please order appropriate active interchangeable adapters and reference cables for fiber optic cable connections separately.

Note for measurements with POF buffered fibers Ø 2.2 mm without connector:

The fiber ends of the POF buffered fibers to be measured must be cleanly cut (e.g. using the POF fiber cutter ZXXX-TD0-V2). The SMA 2.2 mm clamp connectors SSMA-SV0-02-0020 must be attached to the prepared fiber ends in such a way that the end face of the connector is flush with the ferrule. The buffered fibers “assembled” in this way can now be measured using the meter (with FSMA adapter) and the connectors can then be removed again.

Transmitter for wavelength	Order no.
520 to 940 nm	ZXXX-TS0
1300 nm	ZXXX-TS0-1300
1550 nm	on request

Active interchangeable adapter

Description

The connector type and required wavelength are defined by means of simple push-in adapters. The basic device remains the same.

Connector type	Order no.
ST (BFOC)	ZXST-TS0-660
FSMA	ZSMA-TS0-660
F05	ZF05-TS0-660
HP (simplex and duplex)	ZHPD-TS0-650

Further types on request

FiberConnect® Measurement kit

Accessories

Measurement kit for POF/PCF

Description

Set with transmitter and power meter - with various adapters.

Contents of measurment kit

- optical power meter with digital display
- opitcal transmitter, basic device with BNC connection
- transmitter adapter
- receiver adapter
- 2 power supply units for worldwide use
- reference cable, must be ordered seperately, depends on fiber type
- manual (german/english)
- case with foam inlay (dimensions of case: 486 × 460 × 136 mm)

Measurment kit suitable for connector type *	Order no.
ST (BFOC)	ZXST-KM0
FSMA	ZSMA-KM0
F05	ZF05-KM0
HP	ZXHP-KM0

* Further types on request, depends on fiber type

Measurement kit for optical fibers

Description

For singlemode or multimode. Set with transmitter and power meter - with various adapters.

Contents of measurement kit

- 1 light source for 850/1300 nm (multimode) or 1310/1550 nm (singlemode) with each 1 adapter for ST, FC and SC
- 1 powermeter (850, 1300, 1310,1490, 1550 and 1625 nm) with each 1 adapter for ST, FC and SC + software and USB cable
- 2 power supply units with various country-specific adapters
- 1 microscope(400x) for 2.5 mm ferrules + adapter for 1.25 mm ferrules
- 1 cleaning tool
- 1 red light source for 2.5 mm ferrules + adapter for 1.25 mm ferrules
- manual (german/english)
- case with foam inlay (dimensions of case: 486 × 460 × 136 mm)

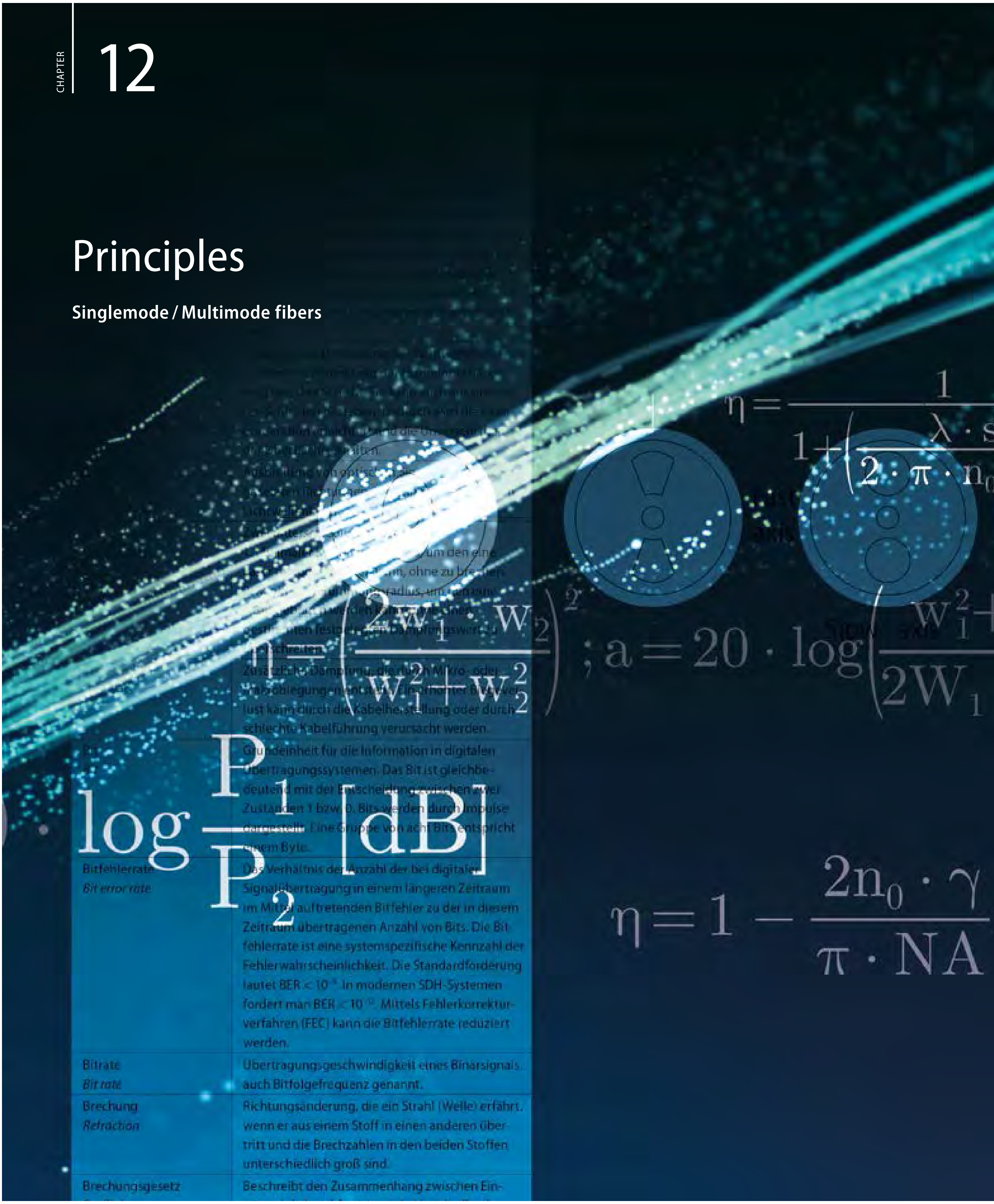
Suitable for all plugs	Order no.
multimode (all plugs)	NZXMM-KM0
singlemode (all plugs)	NZXSM-KM0

CHAPTER

12

Principles

Singlemode / Multimode fibers



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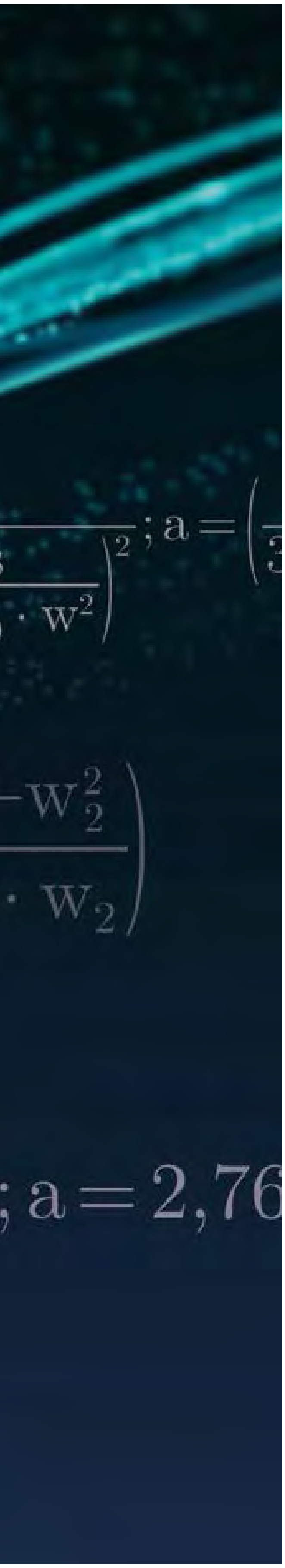


12. Principles

1. Optical waveguides in general

1.1 Spectrum of light

Light propagates in a vacuum as an electromagnetic wave at a speed of c_0 = 299,792.458 km/s. The spectrum of light spans a wide range from deep ultraviolet (UV) (wavelength λ = 100 nm) to the infrared (IR) (λ = 1 mm),although visible light only covers the range from 380 nm to 750 nm. Different types of optical waveguides are uses at different wavelengths depending on their transmission properties. The focus for waveguide applications is set on the range from the near UV (300 nm and above) to the low IR.

Within a homogenous medium, light propagates in a straight line and is described by the laws of geometric optics. Geometric optics are also used to explain the propagation behaviour in large waveguide structures, where there are many possible directions (modes) in which the light can travel (see chapter 1.2.). But as waveguide structures become ever smaller, the propagation of light can only be described in terms of wave theory. We then speak of monomode or singlemode waveguides, as propagation is only possible in one single direction - along the optical axis of the waveguide. The following chapters will describe the fundamental physical properties of waveguide components manufactured by LEONI.

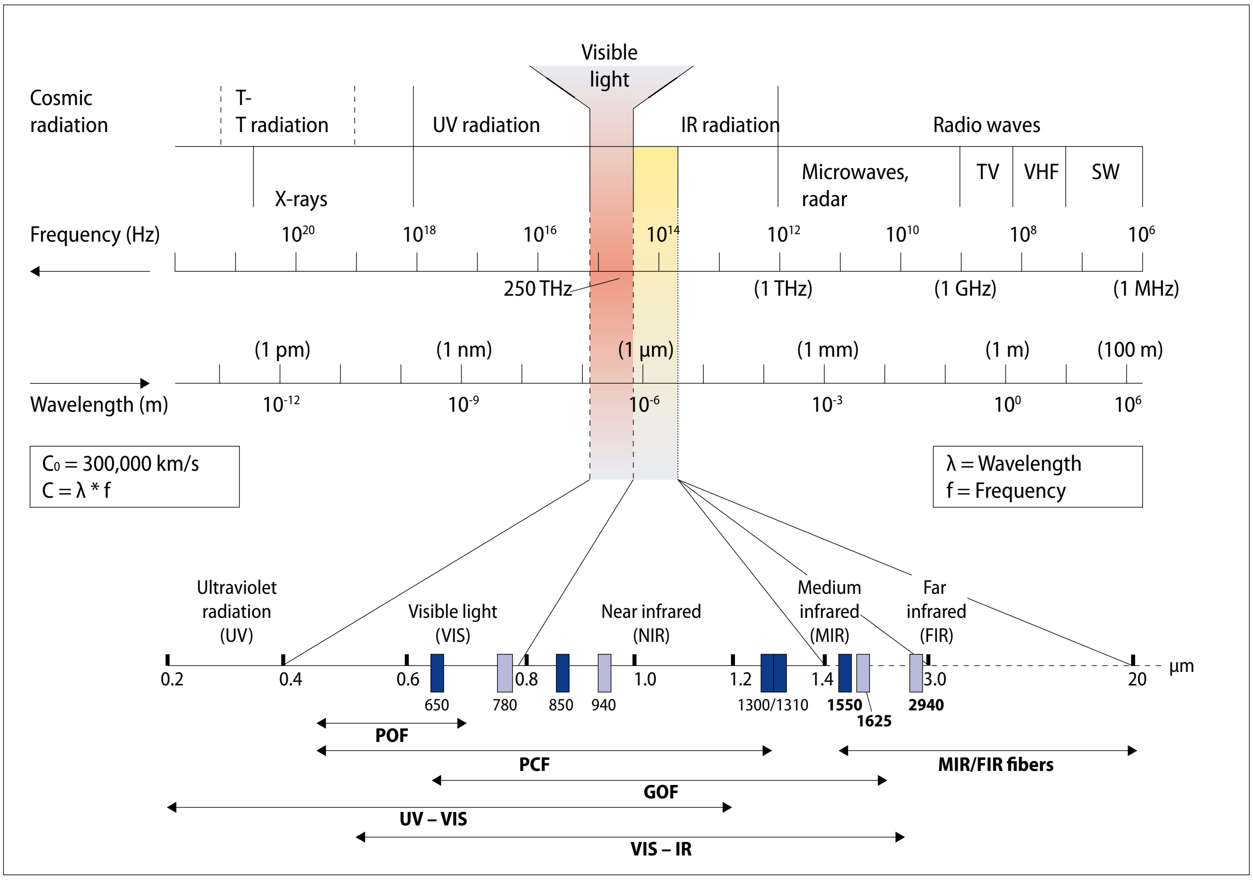


Figure 1: Electromagnetic Spectrum

1.2 Propagation of light in an optical waveguide

The basic principle of transmission in an optical waveguide is based on total internal reflection. When a light ray hits the boundary surface between a more optically dense medium with the refractive index n_1 and a less optically dense medium with the refractive index n_2, the ray is either refracted or totally reflected, depending on the angle of incidence α.

$$\frac{\sin\alpha}{\sin\beta} = \frac{n_1}{n_2} \quad [1\text{-}1]$$

α = angle of incidence, β = angle of reflection
n_2 = refractive index of the more optically dense medium
n_1 = refractive index of the less optically dense medium

At the transition between the more optically dense medium and the less optically dense medium, the ray is refracted away from the perpendicular and a portion of the light, which increases with an increasing angle of incidence, is reflected at the boundary surface. The greater the angle at which the light beam strikes the boundary is, the closer the refracted beam is to an angle of $\beta = 90°$ towards the perpendicular of incidence. With an even greater angle of incidence of the light ray, instead of being refracted the ray is totally reflected. Above a certain angle the light is reflected in its entirety; this angle is known as the critical angle of total internal reflection. The actual size of the critical angle of total internal reflection is a function of the difference between the refractive indices of the more optically dense medium and the less optically dense medium.

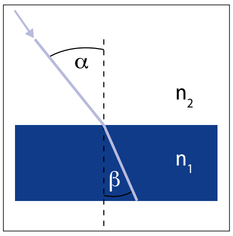


Figure 2: Refraction of light

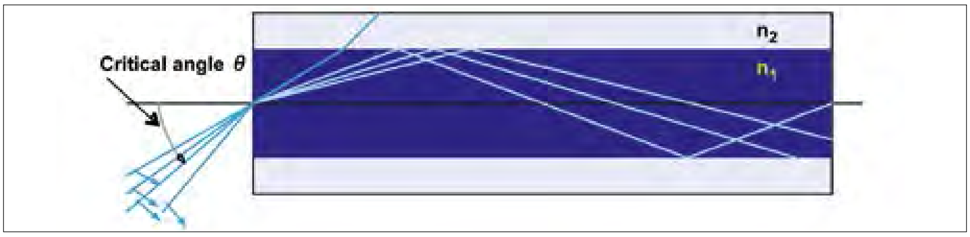


Figure 3: Light guidance in an optically more dense medium

1.3 Numerical aperture

The numerical aperture is a crucial variable for the coupling of light into an optical waveguide. It is calculated from the difference between the refractive indices for the core and the cladding.

The numerical aperture NA is calculated using the sine of the critical angle $\theta_{critical}$ as follows:

Only those rays of light that enter the fiber within a certain range of angles $\leq \theta_{critical}$ are guided along the fiber core.

Typical values of the NA for commercial fibers are in the range from 0.1 to 0.5, corresponding to an acceptance angle of between 6 and 30°.

$$NA = \sin\theta_{critital} = \sqrt{(n_1^2 - n_2^2)}$$

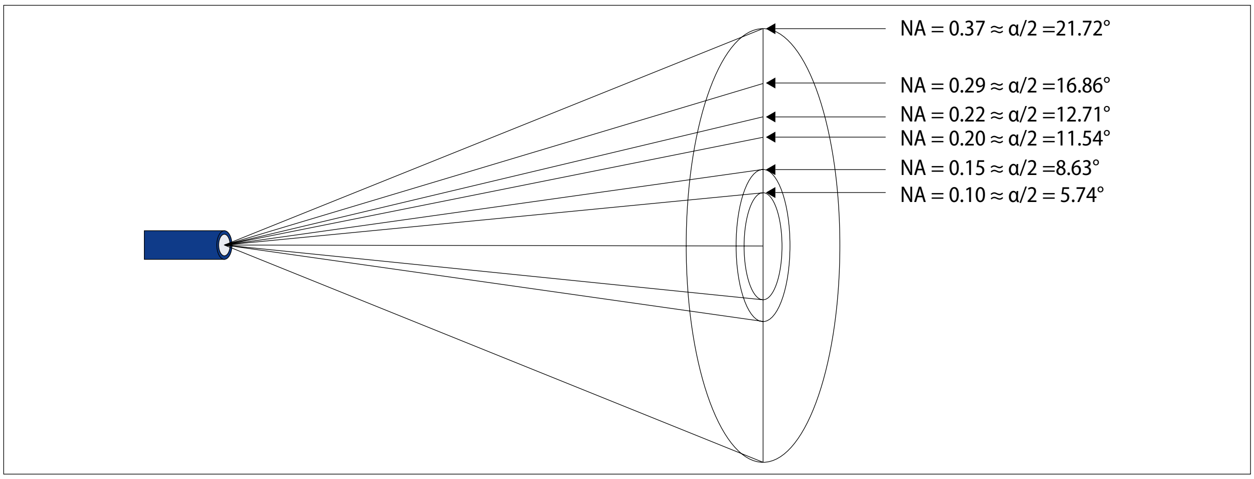


Figure 4: Typical acceptance angles of commercial glass fibers

1.4 Under-excitation, over-excitation

When light is launched into an optical waveguide, it often occurs that not all modes are excited equally. The critical angle or diameter of the incident ray often differs from the fiber parameters. Part of the ray which has an angle greater than the critical angle leaks out of the fiber and power is lost. This is known as over-excitation. In contrast, under-excitation is when the angle is smaller than the critical angle, i.e. the cross-section of the ray is smaller than the diameter of the core. When using gradient-index fibers (see chapter 2.1.3.), marginally greater path attenuation values are achieved even with under-excitation.

1.5 Joining two fibers

Two fibers can be joined together either by connecting the end faces of two fibers permanently, known as splicing, or by connecting two connectors in a coupling. Two identical connector types can be joined in a standard coupling and two different connectors can be joined in a hybrid coupling. The connection with the least influence (attenuation) on the guided light is a 'fusion splice', in which the two fiber ends are precisely aligned and then fused together using an electric arc.

1.6 Light sources and detectors

As a rule, for the majority of optical waveguide systems special light sources and detectors are used. A distinction is drawn between light sources displaying broad spectral characteristics (e.g. light bulbs and LEDs) and light sources emitting monochromatic light (e.g. lasers).

1.6.1 Laser

Laser light differs from light emitted by other sources not only because of its narrow spectral bandwidth but also because of its great coherence length and parallelism, to the effect that the properties of the generated light can be controlled particularly well. Therefore lasers are highly suited for the coupling of light into the fiber.
Lasers can be built in different ways. What they all have in common is an optical resonator with mirrors or semi-transparent mirrors on the end faces, which are perpendicular to the optical axis in combination with a material that can be excited to a metastable state by adding energy. If stimulated by a photon, the atoms which are in an excited state, can emit their energy by emitting photons of the same wavelength and phase. Depending on the gain medium used in the laser, we speak of gas lasers, dye (liquid) lasers or solid state lasers. By now, solid state lasers and semiconductor lasers in particular have become of greatest significance in optical waveguide systems.

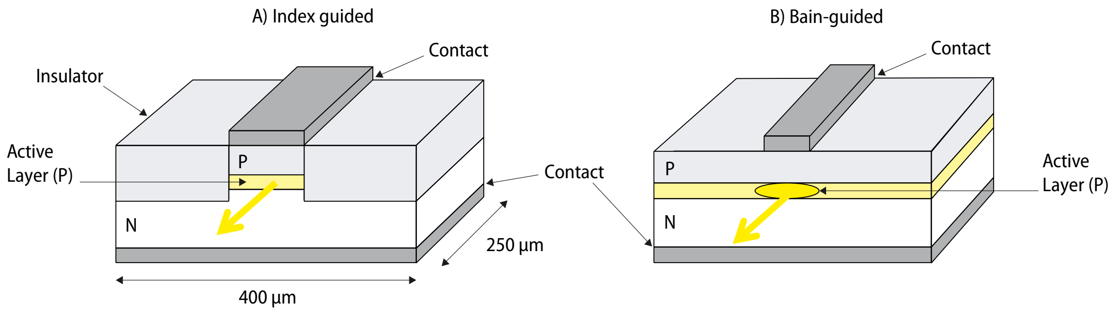


Figure 5: Schematic diagram of a semiconductor laser

Today, wavelengths from UV to IR can be generated depending on the employed semiconductor material. An overview is given in the tollowing table 1.

Substrate	Active layer	Wavelength [nm]
InGaN	InN_xGaN_{1-x}	375 to 570 nm approx.
GaAs	$Ga_xIn_yAl_zP$	650 to 750 nm
GaAs	$Ga_xAl_{1-x}As$	750 to 900 nm
InP	$In_xGa_yAs_zP$	920 to 1670 nm
GaSb	GaInAsSb	2000 to 2300 nm

Table 1: Semiconductor laser materials and emitted wavelength ranges

The semiconductor laser structure in figure 5 A) shows a buried heterostructure, in which the active laser layer is completely surrounded by a layer of lower refractive index, so the generated light is guided within the waveguide. Figure 5 B) on the other hand shows a so-called gain-guided stripe laser, as the waveguiding is not laterally limited in the first place. Instead, the lateral guidance is achieved by the inhomogeneous electrical field, which causes a decrease of attenuation in the middle below the contact strip and thus produces a stripe waveguide. Depending on the application, lasers with very low optical power of only a few mW or lasers with highest powers of several hundred Watts are used. The difficulty of coupling the laser light into the waveguide increases with the power density.
The use of appropriate optical coupling devices allows to shape the laser beam in such a way that the highest possible coupling efficiency is achieved. Thus, as much of the emitted light as possible can be launched into the waveguide.

The functionality of semiconductor lasers can be considerably broadened through complex layer structures or a combination of layers with intrinsic or extrinsic grid structures.
For instance DFB-Lasers (Distributed Feedback Lasers), based on Bragg-Grid structures, generate a very narrow line with strongly suppressed sidebands.

Another class of semiconductor lasers are the so-called VCSEL (Verical Cavity Surface Emitting Laser), in which light is emitted at the surface (parallel to the electrical field) and not, as with the lasers described above, at the edge (in a right angle to the field). The advantage of VCSEL is an improved round beam profile with little divergence on the one hand and the possibility to operate many lasers monolithically integrated on a wafer. Good beam characteristics also facilitate the coupling into the fiber.

Lately fiber lasers have gained importance. Fiber lasers combine the advantages of solid-state lasers with those of an optical fiber. Unlike with semiconductor lasers the excitation of the fiber core is achieved by pump light sources (preferably laser diodes). The laser active qualities of the core result from suitable doping with rare earth oxides (e.g. Er_2O_3, Nd_2O_3 or Yb_2O_3). The great length causes a high amplification performance.

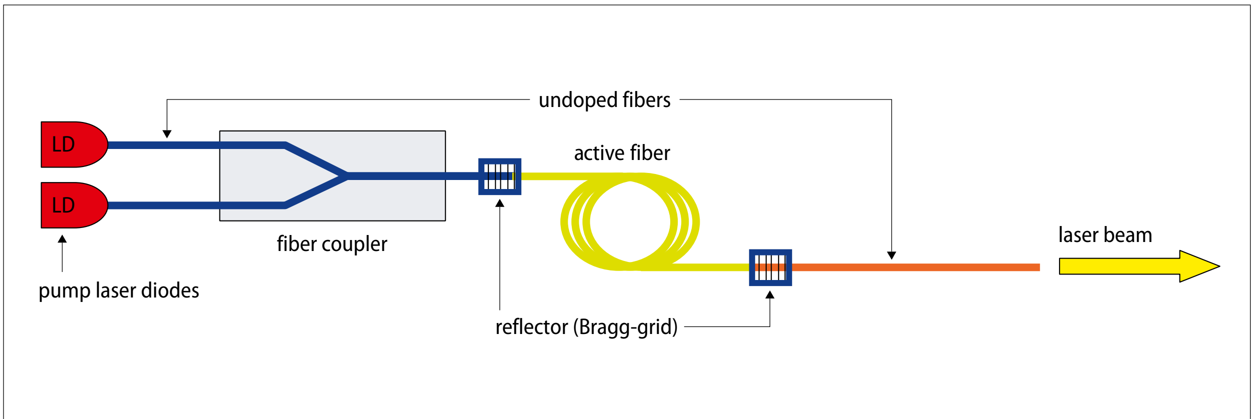


Figure 6: Structure of a fiber laser

The optical power of fiber laser can amount up to over 100 kW, which is why they are highly attractive for materials processing.

Another distinguishing feature among lasers is the ability to emit continuous or pulsed light. With semiconductor lasers this quality is used for data transmission through fiber optic cables. At pulse frequencies in the GHz-range data transmission rates of 100 Gbit/s can be achieved in morn fiber optic networks at a single wavelength. In case several lasers with different wavelengths are used, the transmission rate in a single fiber can be multiplied (one independent transmission channel per wavelength). This is called wavelength division multiplexing (CWCM or DWDM depending on channel spacing) with transmission rates of up to several Tbit/s.

1.6.2 Detectors

The detection of light at the end of a fiber optic cable usually is done with the help of a photodetector, in most cases made of an anorganic semiconductor material in the form of a diode. Depending on the application, different active materials (Si for visible and near IR light up to a wavelength of 1 µm, Ge or InGaAs for IR up to 1.8 µm, CdTe up to far IR) and set-ups are used.

A large number of diode designs have been developed with optimised features for the respective fields of application. Nevertheless, a detailed description would go beyond the scope of this overview.

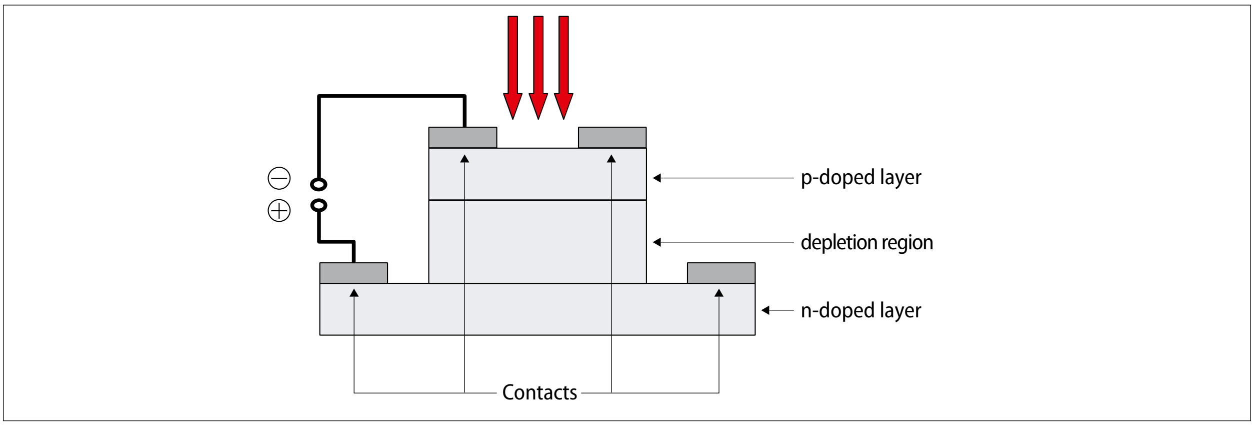


Figure 7: Structure of a photodiode for normal incidence of light

2. Fiber optic components

In LEONI's product portfolio, a basic distinction is made between four types of fiber optic components:

a) Components in which the light is guided by an isolated fiber
==> optical fibers, optical cables
b) Components in which the light is coupled into and guided by a bundle of fibers
==> fiber bundles, fiber bundle cables
c) Components in which the light is guided in a structured planar substrate
==> planar lightguide (PLC)
d) Components in which, within a hybrid structure, micro-optical/mircomechanichal elements are combined in a free space with components of the categories a) to c)
==> fiberoptic switches

2.1 Fiber types

2.1.1 Individual fibers

The illustration below shows the most important basic types of optical fibers:

- Multimode fiber with step-index profile
- Multimode fiber with graded-index profile
- Singlemode fiber

2.1.1.1 Singlemode fibers

In a singlemode fiber (also known as a mono-mode fiber) the signals are transferred by transmitting the light only in the fundamental mode (mono or single mode), as this is the only mode capable of being propagated and all other modes are not guided. Singlemode fibers are preferred for applications involving long distances and wide bandwidths. They provide the least amount of signal distortion and therefore the greatest transmission distance. The most commonly used singlemode fiber is the telecommunications fiber, which has a mode-field diameter typically of 9 to 10 µm and a cladding diameter of 125 µm. The light is guided primarily in the area of the optically more dense core, but with a small part being guided outside the actual core in an area of the optically less dense cladding close to the core. The mode-field distribution approximates a Gaussian curve, which is determined as an intensity distribution in a so-called near field measurement at the end of the fiber. The $1/e^2$-width of this distribution curve is called the mode field diameter. As the mode field expands with growing wavelengths, the respective wavelength should always be declared as well, when giving a value for the mode field. (e. g. $MFD_{1310\,nm}$ = 9.2 µm, $MFD_{1550\,nm}$ = 10.4 µm.) The actual core diameter of a standard telecommunications fiber is smaller and typically 8.2 µm, with a NA of 0.14. The singlemode transmission properties of such a fiber span a spectral range from 1280 to 1650 nm. The critical wavelength

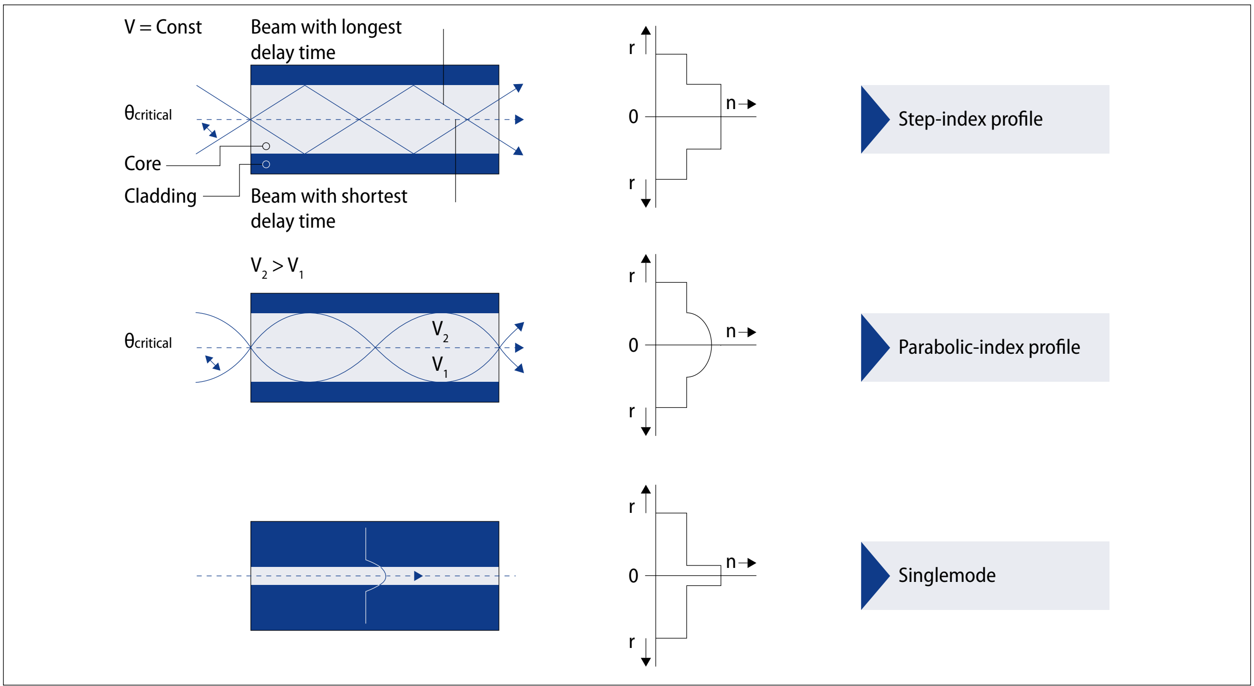


Figure 8: Basic types of optical fibers

from which on a second mode is capable of being propagated is called the cut-off wavelength and is approximately 1260 to 1280 nm for a standard telecommunications fiber.

Utmost cleanliness of the fiber material (fused silica glass/doped silica glass) is a priority during the manufacturing of standard telecommunications fibers in order to achieve maximum transmission. The maximum attenuation of a morn singlemode fiber for telecommunications is 1310 or 1550 nm at ≤0,3 dB/km, meaning that signals can be transmitted over distances of more than 100 km without amplification.
A further development of the standard singlemode fiber is the so-called 'low-water-peak fiber' (ITU-T G.652.C and G.652.D). With these fibers it is possible to transmit data in the wavelength range between 1360 and 1460 nm with low loss because special production methods have resulted in a particularly low water content of the fiber, which suppresses the substantial absorption due to OH vibrations in this wavelength range.

These fibers open up the E-band (extended band) for data transmission. This range is largely made available through CWDM technology (Coarse Wavelength Division Multiplexing), which makes it possible to use low-cost lasers for parallel transmission of light with several defined wavelengths due to the large wavelength spacings. Non-zero dispersion fibers are used as singlemode fibers for wide area networks (ITU-T G.655.C). They display very little attenuation and dispersion in the c-band around 1550 nm. Thus long distances can be achieved without dispersion compensation. A recent development for telecommunications are fibers with a minimum bending radius that has been remarkably reduced from 30mm to – depending on manufacturer and fiber design – less than 10mm without a noticeable increase of attenuation. Such fibers are described in the ITU-T G. 657 A and B standards.

Singlemode fibers for other wavelength ranges are also commercially available. The mode-field diameters of fibers for the near IR range and the visible wavelength range (VIS), in particular, are becoming smaller and smaller. These fibers are suitable for an array of special applications requiring transmission with an excellent beam quality. Generally speaking, the low attenuation over long distances is not a critical requirement for such applications.

At the moment, this new class of fibers, which are called photonic crystal fibers (Photonic Bandgap Fiber, PBF or PCF (not to be confused with the acronym for large core fibers with polymer coating)) is not yet economically significant. Still, in the future they will gain importance due to their special qualities. A fiber of this type follows a totally different approach to light guidance. Its design can consist of an optical fiber with an inner light guiding area that is surrounded by a multitude of tube-type microstructures. Optical waveguides of this kind have, inter alia, the ability to guide light through extremely tight bends with very little loss.

2.1.1.2 Multimode step-index fibers

With multimode step-index fibers many modes are guided in the core due to the larger core diameter and/or correspondingly high Δn between the core and the cladding compared with singlemode fibers. The range of variation of such fiber types is huge. The main types, which also are of corresponding industrial significance, are listed below:

Optical waveguide	Core material	Cladding material (Cladding)
POF	PMMA	Fluorinated PMMA
PCF	Fused silica glass	Plastic (Acrylate)
Silica fibers (low OH, high OH)	Fused silica glass	Fused silica glass
Glass fibers	Fused silica glass, Ge-doped fused silica glass	Fused silica glass, F-doped fused silica glass
Glass fibers	High refractive index composite glass	Low refractive index composite glass
MIR-fibers	Special glass optically more dense (fluoride glass, chalcogenide glass)	Special glass optically less dense (fluoride glass, chalcogenide glass)

Table 2: Stucture and composition of optical fibers

The modal dispersion of step-index multimode fibers is considerable due to the different delay times.

2.1.1.3 Multimode gradient-index fibers

A graded refractive index together with increasing doping (e.g. germanium) towards the centre of the core minimises the differences in delay times for all modes and thus provides a substantial improvement in the bandwidth. The profile of the refractive index in the core is almost parabolic. These fibers bring about improvements for greater bandwidths in certain wavelength ranges.

2.1.1.4 Spectral properties of low OH/high OH

Owing to the OH vibrations, the water content of the fiber determines the absorption behaviour. A low-OH fiber has low attenuation values in the near infrared range and is consequently used in that range. A high-OH fiber reduces the formation of imperfections for irradiation in the ultraviolet range. Low and high-OH fibers are available in particular in the form of step-index silica fibers. They are used for power transmission in laser applications as well as in the detection of radiation in sensor systems, for example.

2.1.1.5 Polarization-maintaining fibers

A polarization-maintaining fiber is a special type of singlemode fiber. Stress elements in the cladding create birefringence in the core for retaining the polarization of the light guided throughout the complete fiber length. This prevents changes of the polarization state coupled into the fiber by external influences. The polarization planes of the light guided in the fiber remain the same. There are three different types of polarization-maintaining fiber, which differ in terms of the shape of the stress elements in the fiber (see figure 9).

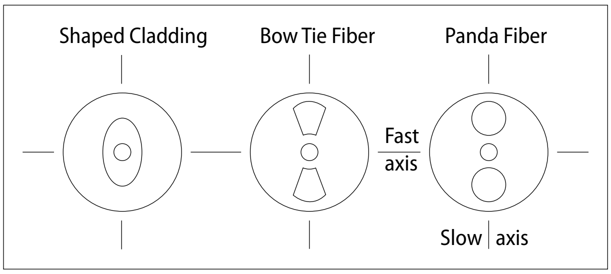


Figure 9: Structure of polarization maintaining fibers

The core diameters of the fibers correspond with the respective diameters of the standard fibers. Both 80 µm and 125 µm are standard cladding diameters, with the smaller cladding diameter having less influence on the polarization with small bending radii.

2.1.1.6 Coatings and buffers

Optical waveguides made from silica or plastic need to be protected mechanically and from moisture. Coatings and buffers are used for providing protection. Acrylates are usually applied as the coatings during the drawing of the fiber. For special applications, the fibers are coated with polyimide, PTFE, silicone rubber or high-temperature acrylate. Glass fibers for special applications can also be coated with a metal to make them suitable for soldering.

2.1.1.7 Bending radii

Fiber optic cables can only be bent by a certain amount before the fibers will break. When subjected to a specific mechanical load, the glass fibers may tear or rupture completely. For this reason manufacturers specify a minimum bending radius ($BR_{min.}$), which is likely to ensure a long service life if observed. The probability of a fiber breaking depends on the manufacturing parameters, composition, the cladding diameter and the dwell time. Its quality is tested by a proof test of the fiber bundle, in which the fiber is laid around a narrow radius and subjected to a specified force.

Generally speaking, the bending radius – the curvature of the individual fiber – should be no smaller than a factor of 300 x d fused silica glass. With a 600-µm-single fiber, the minimum bending radius is therefore 18 cm.

Roughly speaking, a rule for fused silica glass is: The bending radius (BR) – the curve of the individual fiber – should not be smaller than

$$BR_{min.} = 300 \times d_{\text{Fused silica glass}}. \quad [2\text{-}1]$$

In the case of a 600-µm-individual fiber the minimum bending radius is 18 cm. This rule does not apply to the influence of bending on the optical properties of the fiber.

2.1.2 Signal transmission in optical fibers

The transmission of signals containing large quantities of information (digital or analogue signals) requires the fiber to have particular transmission properties in order to achieve a transmission that is largely free of errors even over longer distances and with wide bandwidths

2.1.2.1 Dispersion and profiles

The quality of the optical transmission system is not only affected by the distance to be covered but also by the data rate that can be transmitted. High data rates require wide-band transmitter and receiver components but also wide-band optical fibers (not to be confused with the optical bandwidth, which defines the range of light wavelengths). The bandwidth of an optical fiber is limited by the dispersion, i.e. by the fact that a pulse that has been injected into an optical fiber broadens in the fiber while it is being transmitted.

With multimode fibers, the bandwidth-distance product of the particular fiber characterises the respective transmission property. The main effect on the transferable bandwidth is the delay difference of modes that cover different path lengths within the fiber. Therefore, with multimode fibers we speak of modal dispersion.

For a Gaussian-shaped pulse:

$B*L \approx 0.44 / \Delta t * L$ [2-2]

with B = Bandwidth [MHz], L = Fiber length [km],
Δt = Pulse broadening [10^{-6} sec]

With singlemode fibers, there is also a noticeable distortion of the optical signals caused by the scattering of the delay time (dispersion). In this case dispersion is caused by:

- different delay times for the two polarization states of the normal mode ==> Polarization mode dispersion (PMD)
- spectral bandwidth of the signal and the resulting delay differences depending on the wavelength of the light in the material glass ==> chromatic dispersion (CD) determined by material dispersion
- spectral bandwidth of the signal and the resulting delay differences depending on the variation of the effective refractive index for different wavelengths due to the waveguide structure ==> chromatic dispersion determined by waveguide structure

The coefficient D for chromatic dispersion in a singlemode fiber is given in [ps/nm*km]. Its value is a function of the wavelength and has a zero-crossing point at around 1310 nm, for example, depending on the design of the fiber.

The market offers a great number of fiber variations with deviating values!

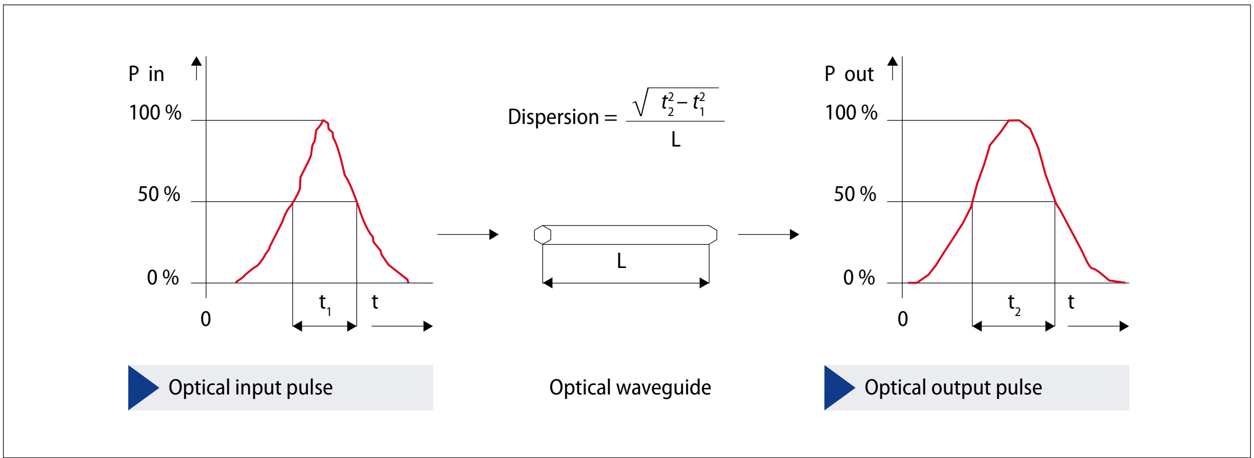


Figure 10: Pulse spreading (dispersion) in the optical waveguide

Table 3: The following table lists all typical signal transmission properties for common fibers:

	POF	PCF	Glass fiber		
Mode type	Multimode	Multimode	Multimode	Multimode	Singlemode
Fiber type	Step index	Step index	Gradient index	Gradient index	Step index
Core diameter [µm]	980	200	62.5	50	8
Cladding diameter [µm]	1000	230	125	125	125
Numerical aperture	0.5	0.37	0.27	0.20	0.13
Attenuation coefficient → 650 nm [dB/km]	160	10	10	10	–
Attenuation coefficient → 850 nm [dB/km]	2000	8	3.2	3.0	–
Attenuation coefficient → 1300 nm [dB/km]	–	6	1.0	0.9	0.35
Attenuation coefficient → 1550 nm [dB/km]	–	–	–	–	0.20
Typical wavelength used	650	650/850	850/1300	850/1300	1310/1550
Bandwidth distance product [MHz*km]					
→ 650 nm	1	17			
→ 850 nm	–	20	200	400	
→ 1300 nm	–	20	600	1200	
Coefficient for chromatic dispersion → 1310 nm					<3.5 ps/(nm*km)
Coefficient for chromatic dispersion → 1550 nm					<18.0 ps/(nm*km)

2.1.2.2 Attenuation and transmission

The optical power P decreases exponentially as it passes through an optical waveguide with length L. In fiber optics attenuation and transmission are the terms used to describe the performance of an optical waveguide.

Attenuation a

Attenuation describes the power loss of the light beam when passing through a fiber. Its amount depends on the applied wavelength and the length of the fiber. By default, the attenuation value of a fiber is given in dB/km.

Attenuation is typically presented in logarithmic notation and given in decibels (dB):

$$a = 10 \lg (P_0/P_1) \quad [2\text{-}3]$$

P_0 is the optical power in [mW] at the beginning of the waveguide and P_1 is the optical power at the end of the waveguide.

The equation for the attenuation coefficient α (kilometric attenuation) with

$$\alpha = a/L \quad [2\text{-}4]$$

yields dB/km as the measuring unit. The power, based on 1 mW, has the unit of measure of dBm, in accordance with the following definition:

$$P\,[\text{dBm}] = 10 \lg (P/1\,[\text{mW}]) \quad [2\text{-}5]$$

P is the optical power in [mW].

Transmission T

The transmission T describes the output power at the end of a waveguide with losses taken into consideration. It is given in percent and based on the injected power. Transmission too depends on the applied wavelength and the length of the fiber.

The transmission is the percentage of the light transmission in the fiber based on the injected power.

$T = 10^{(-\alpha \cdot L)/10dB)}$ [2-6]

T = Transmission
α = Attenuation coefficient (dB/km)
L = Fiber length (km)

As the values for the observed optical powers can cover several powers of ten, attenuation has established itself as the characteristic feature to describe fiber properties. Therefore, in the following the description the determination of transmission is neglected.

The causes for the attenuation of light in the waveguide are:

- Linear scattering at inhomogeneities in the molecular structure of the fiber core (Rayleigh scattering); a ~ $1/\lambda^4$, lowest value at $\lambda \approx 1{,}5$ µm and scattering effects at optical inhomogeneities in the magnitude range of the wavelength (Mie scattering); this part can be significantly reduced through technological measures,
- Non-linear scattering (Raman- and Brillouin-scattering); dependent on power and wavelength,
- Absorption as the result of excitation of the natural oscillation of molecules; OH groups cause problems in particular (water peaks) as do heavy metals occasionally
- Leakage of the optical power due to excessive bending of the fiber or due microscopic bends and turns (microbends)

Special manufacturing techniques can reduce the water peaks significantly so the usable wavelength range can be broadened (see chapter 2.1.1.1.).

2.1.2.3 Losses caused by bends

Bending a fiber creates a different combination of modes and some leakage of the higher-order modes out of the fiber. The smaller the bending radius is, the greater the losses are. Fibers with a low NA are generally more sensitive than fibers with a higher NA. With standard singlemode fibers for telecommunications, the NA at 0.14 is particularly low. Therefore a small part of the light is transmitted in the cladding due to the approximately Gaussian shaped mode field. As an effect singlemode fibers are especially sensitive to bending. This sensitivity increases with higher wavelengths, as the mode field reaches deeper into the cladding. The bend in the fiber can have a large cable curvature but can also be on a small scale, as can occur when stranding the optical cable for example. Such small-scale bends are called microbends, which also contribute to an increase in the losses (see chapter 3.1).

2.1.2.4 Connector loss or coupling loss

In addition to the length loss in the cable, loss occurs when connecting fibers with optical connectors. If the connector end faces touch or are less than a tenth of the light wavelength apart, the proportion of retroreflections from the interface between air and glass/glass and air, which occurs with connectors with an air gap, decreases by around 8 % for fused silica glass (depending on the refractive index). Such plug connections are known as connectors with physical contact. Absorption and scattering also occur as the result of surface flaws. Such flaws include scratches that were produced during the machining of the end faces as well as dirt resulting from improper handling of the connectors.

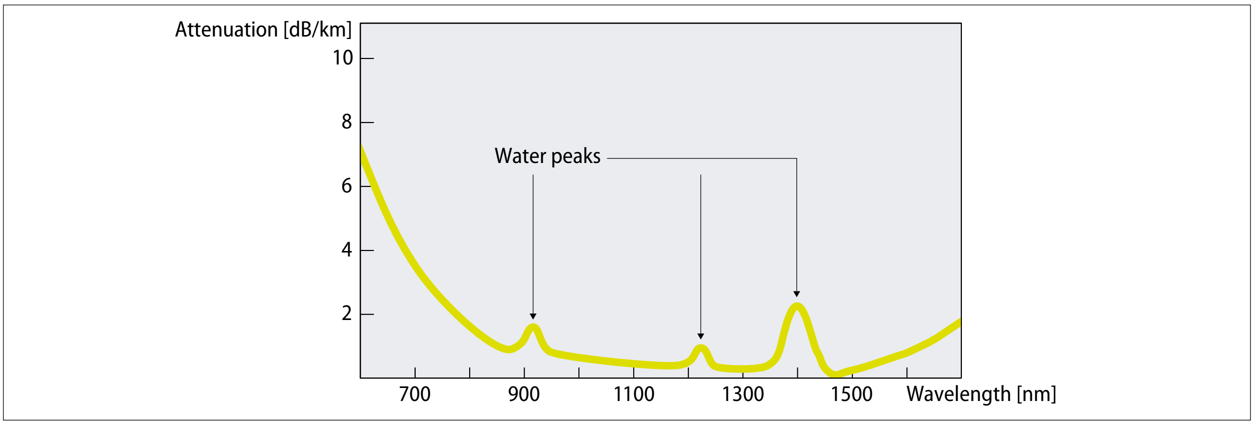


Figure 11: Attenuation curve of a fused silica glass fiber as a function of the wavelength

Connector types

- **Flat connectors with air gap**
  SMA 905, SMA 906, HP
  high attenuation 0.4 – 1.5 dB
  low return loss 14 dB

- **Connectors with physical contact (/PC)**
  ST, SC, DIN, FDDI, ESCON, E2000, MU, LC, FC, Opti-Jack, D4, Mini-BNC, Biconic
  low attenuation <0.1 – 0.7 dB
  medium return loss 20 to 50 dB

- **Angle-polished connectors with an air gap**
  VFO, HRL-11, EC/RACE
  high attenuation
  high return loss

- **Angle-polished connectors with physical contact(/APC)**
  DIN-APC, FC-APC, E2000-APC, SC-APC, FC
  low attenuation <0.1 – 0.7 dB
  highest return loss >55 db

- **Connectors with multiple fibers in one ferrule**
  MT, MP, MPO, MTRJ (SCDC, SCQC)
  up to 24 fibers in one ferrule
  medium attenuation <0.3 – 1.0 dB
  medium to high return loss 20 to >55 dB
  depending on angle of end face

- **Connector with ferrule Ø 1.25 mm**
  MU, LC, LX.5, F 3000
  quick assembly
  high packing density
  low attenuation
  medium to highest return loss
  20 to >55 dB (/PC or /APC design)

- **Connector without ferrule**
  VF-45-Volition (SG), Optoclip
  quick assembly
  guidance issues

- **Connectors with collimation optics**
  Lens connector
  Low sensitivity to dirt (e.g. installed in ICE train)

- **Optical fiber connectors with electrical plug connection within the same housing**
  hybrid connector
  application-specific design

2.1.3 Attenuation measurements (standards)

There are various standards for measuring attenuation which apply specifically to the most commonly used fibers and applications. The fiber loss is determined using either the direct-light method or the backscattering method. The basic properties of the two measurement techniques are explained in the chart below

Direct-light method	Backscattering method
POF, PCF + Glass	**PCF + Glass**
Total attenuation of a section	Total attenuation of a section
Spatial separation of the measuring instruments	Only connected at one end
Very accurate result	Technically tolerable result
No evaluation of interfaces	Evaluation of interfaces
No localisation of defects	Localisation of defects
	Distance measurement

Table 4: Comparison of direct-light method and backscattering method

2.1.3.1 Backscattering method

OTDR measuring instruments (Optical Time Domain Reflectometer), as are available commercially in various forms, are suitable for measuring a backscatter curve. Figure 13 schematically shows a measured curve alike to those that can be plotted for a section of fiber using such instruments.

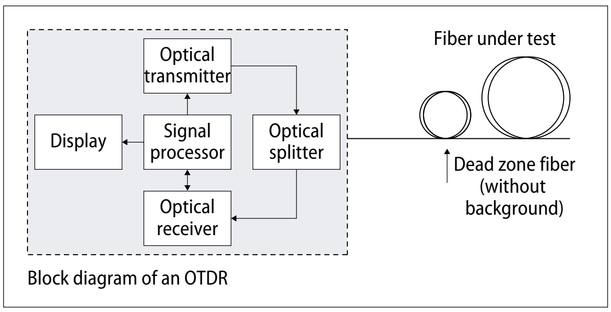


Figure 12: Set-up for the testing of attenuation in a fiber optic cable

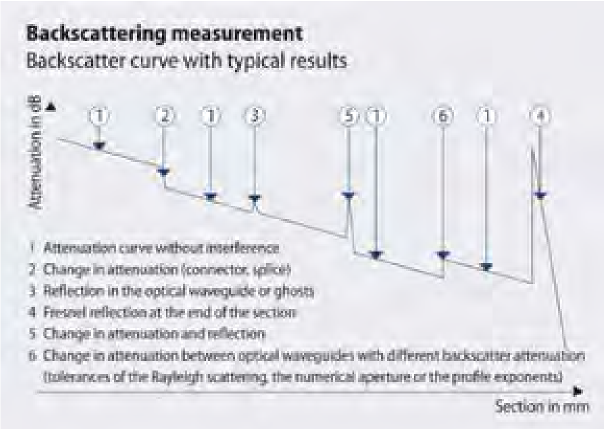


Figure 13: Typical curve of a backscatter measuring

2.1.3.2 Direct-light measurement

With the direct-light technique, an optical waveguide with a length L [m] is connected to a light source having a defined wavelength of power P_0 [dBm]. The optical power P_1 [dBm] at the end of the optical waveguide is then measured using a power meter. The power loss, i.e. the optical attenuation A [dB], is calculated from the difference between P_0 and P_1 :

$$a = P_0 - P_1 \quad [2\text{-}7]$$

If the path attenuation is much greater than the connector loss, the attenuation coefficient α [dB/m] can be calculated as follows:

$$\alpha = a/L = (P_0 - P_1)/L \quad [2\text{-}8]$$

The insertion loss method or cut-back method is usually used for measuring the optical power. The various techniques of the insertion loss method are targeted at specific applications or quality criteria. With patch cables that are connected directly to the transmitter and receiver, it is generally only necessary to compare these cables with a good reference cable of the same fiber, with the absorption value being calculated as follows

$$a = (P_{test} - P_{ref}) + a_{ref} \quad [2\text{-}9]$$

For this the transmitter should have the same radiation characteristics as in the application. The method is described in the IEC 60793-1-40. To minimise the influence of the transmitter, it is possible to work with a launching length, in which a mode scrambler generates a defined ray distribution in the fiber (IEC 61300-3-4 method B). The attenuation effect of the last connector is suppressed using these two methods. By contrast, if a lead-in and a lead-out length are used, as specified in IEC 61300-3-4 method C, the entire cable is tested by means of one single measurement. The different test set-ups can result in different values in the order of up to approx. 2 dB, depending on the type of fiber and connector.

2.1.3.3 Attenuation measurement for glass and PCF assemblies per IEC 61300-3-4 method B

The optical power P_0 at the end of the launching cable, which is directly connected to the level meter, is measured in a reference measurement

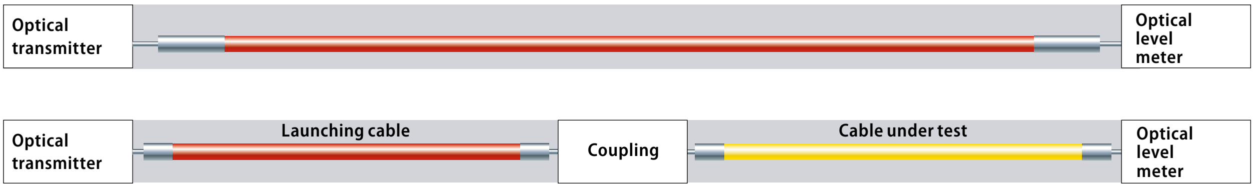


Figure 14: Diagram of the reference measurement and measurement per method B

For the actual measurement the cable under test is inserted between the launching cable and the level meter and the optical Power P_1 is determined. The measurement is executed twice with the cable under test rotated and measured in opposite direction for the second measurement, as only the attenuatin at one coupling of the cable under test is included each time. The worse value is to be used. In order to eliminate cladding modes as far as possible, the launching cable must be lead with 5 windings around a mandrel with a diameter of approx. 20 mm.
The attenuation in dB of the cable under test is given by formula [2-7].

During the evaluation, a comparison is made with the allowable limit value for attenuation. The relevant standards, such as IAONA, specify an attenuation of 0.75 dB with MM and SM glass (standard) for a coupled connector pair. The attenuation coefficient of the cable must be taken into account based on the length of fiber to be measured:

for glass MM 50/125	typ. 2.5 dB/km	at 850 nm
	typ. 0.7 dB/km	at 1300 nm
for glass MM 62.5/125	typ. 3.0 dB/km	at 850 nm
	typ. 0.8 dB/km	at 1300 nm
for PCF	typ. 10 dB/km	at 660 nm
	typ. 8 dB/km	at 850 nm

2.1.3.4 Attenuation measurement for glass and PFC assemblies per IEC 61300-3-4 method C

The reference measurement section consists of a launching cable and a reference cable which is directly connected to the level meter. Launching cable and reference cable are connected by a plug connection.The reference measurement determines the optical power P_{ref} in dBm at the end of the reference cable.

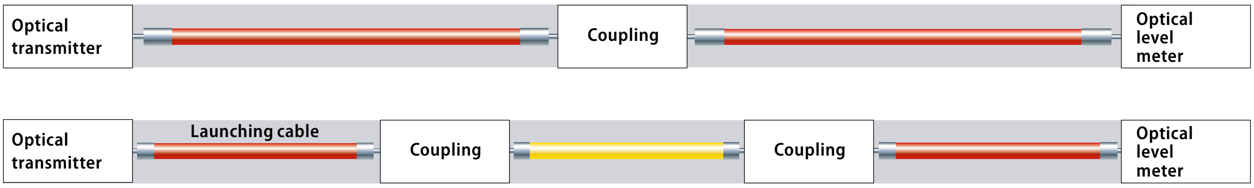


Figure 15: Diagram of the reference measurement per method C

For the measurement the cable to be tested is inserted between launching cable and reference cable and the optical power P_1 is determined. The measured value gives the total attenuation of the cable under test including the attenuation of both plug connectors. In order to largely eliminate cladding modes during the measurement, the launching cable and reference cable must have 5 windings around a mandrel with a diameter of approx. 20 mm.

During the evaluation, a comparison is made with the permitted limit value for attenuation. The relevant standards, such as IAONA, specify an attenuation of 0.75 dB with MM and SM glass (standard) for a coupled connector pair. The attenuation coefficient of the cable must be taken into account based on the length of fiber to be measured:

for glass MM 50/125	typ. 2.5 dB/km	at 850 nm
	typ. 0.7 dB/km	at 1310 nm
for glass MM 62.5/125	typ. 3.0 dB/km	at 850 nm
	typ. 0.8 dB/km	at 1310 nm
for PCF	typ. 10 dB/km	at 660 nm
	typ. 8 dB/km	at 850 nm

2.1.3.5 Attenuation measurement for POF and PCF assemblies per IEC 60793-1-40 B

The optical power P_0 in dBm is determined in a reference measurement at the end of the reference cable.

Figure 16: Diagram of the measurement and reference measurement per IEC 60793-1-40 B

After the reference cable has been replaced by the cable to be tested, the optical power P_1 is determined in an additional measurement.
This yields an attenuation $a = P_1 - P_0$ [dB].
The attenuation coefficient $\alpha = (P_1 - P_0) / L$ [dB/km] is derived from that. (L is for the length of the cable under test in km).

2.1.3.6 Comparison with the allowable limit value

The maximum allowable attenuation is given in the description of the system used. This must always be greater than the calculated attenuation a. You should always leave a safety margin of 3 dB.

Attenuation coefficient of cables

for POF typ. 230 dB/km at 660 nm

for PCF typ. 10 dB/km at 660 nm
typ. 8 dB/km at 850 nm

Order number	Connector type	Cable type
KXST-XST 11001m	ST (BFOC)	POF
KSMA-SMA 11001m	FSMA	POF
KF05-F0511001m	F05	POF
KHPS-HPS11001m	HP	POF
KXST-XST72001m	ST (BFOC)	PCF
KSMA-SMA72001m	FSMA	PCF
KF05-F0572001m	F05	PCF
KHPS-HPS72001m	HP	PCF

Table 5: Reference cables for attenuation measurement

The described attenuation measurement is a straightforward method for everyday use. Apply this method if the assemblies are to be utilised for direct transmitter/receiver connections or the couplings are unsuitable for measurements.

Tip
If PCF fibers are used in systems for POF (660 nm) and the system is not explicitly specified for PCF, the procedure is as follows:

- A POF cable is used as reference cable instead of a PCF cable
- Attenuation:
  $a = P_1$ (PCF cable) – P_0 (POF reference cable)
  During the evaluation, the maximum allowable attenuation for which the system is specified with POF must be greater than the attenuation determined in this way.

Experience has proved this method to be one of the most reliable, but the attenuation coefficient cannot be determined this way. It is better to use the transmitter that is built into the system (and not the transmitter described above).

2.1.3.7 Comparison of attenuation and transmission

As described above (chapter 2.1.2.2.), attenuation is mostly used in fiber optics to describe the power of an optical waveguide. Nevertheless, for specific applications it is necessary to indicate the transmission instead.

The following examples demonstrate the conversion of attenuation values into transmission values.

Examples of converting attenuation to transmission
The attenuation value of a PMMA fiber is 150 dB/km.
You need the transmission value of the fiber at a length of 35 m.

$$T = 10^{(-a*L)/10}$$
$$T = 10^{(-150\text{ dB/km}*0.035\text{ km})/10}$$
$$T = 0.29 \equiv 29\ \%$$

The attenuation value of a fiber of 6 dB/km signifies a transmission of 25 % for 1 km of fiber.

$$T = 10^{(-a*L)/10}$$
$$T = 10^{(-6\text{ dB/km}*1\text{km})/10}$$
$$T = 0.25 \equiv 25\ \%$$

T = transmission
α = attenuation coefficient (dB/km)
L = fiber length (km)

2.1.4 Ageing

The ageing of fibers is usually associated with deterioration in the transmission properties. In addition to the fiber ageing described here, signs of fatigue and wear also occur at the connecting systems.

2.1.4.1 Ageing of glass fibers

Material and environmental effects determine how quickly fibers age. As the polymers wrapping the glass fiber do not entirely suppress water diffusion, water molecules can attach to the glass surface and there lead to chemical reactions that noticeably influence the fiber properties. In addition, for process reasons, material inhomogeneities or flaws are present in fused silica glass and on the fiber surface. For example, mechanical stress from bending produces microfissures in the fused silica glass, which grow over time, possibly resulting in the rupture of the fiber. The development of the cracks is a statistically distributed process corresponding with the distribution of the occurring defects. Mathematically, the probability of a breakage is a function of the optical fiber length L, the mechanical stress σ and time t is described by the Weibull distribution of fracture probability F

$$F = 1\text{-}\exp\{-L/L_0 \cdot (\sigma/\sigma_0)^a \cdot (t/t_0)^b\} \quad [2\text{-}10]$$

The values with the index 0 denote the parameters for the reference test that was conducted. Parameters a and b must be determined by experiment.
During manufacture, the mechanical strength of the silica fibers is tested by the proof or screen test, whereby a specified mechanical stress is created by a weight on the fiber.

A further degradation process can be observed with fibers that have been exposed to ultraviolet light or X-rays. This causes colour centers or defects which can lead to a marked increase of attenuation and even blackening. Special doped fibers with reduced sensitivity to high-energy radiation available for radiation-intensive applications.

2.1.4.2 Ageing of POF

Temperature and moisture induce defects in plastic optical fibers, which manifest themselves through a rise in attenuation. With POF, the increase in absorption has been proven through the accumulation of OH ions, which causes an increase in attenuation as a function of the wavelength. Statistical statements can be deduced from test series, based on which the attenuation characteristic is measured over time at a particular ambient humidity (usually less than 95%) and temperature. The Arrhenius or William-Landel-Ferry theory is used for extrapolating the service life or the maximum continuous operating temperature. Based on all of these studies, it can be expected that a POF will last for 20 years at an operating temperature of 80 °C.

2.1.5 Fields of application

Optical fibers are now used in almost all areas of technology. The field of telecommunications has undoubtedly had a pioneering role and this sector and driven on by the ever growing demand for transmission capacity over the last three decades, has made considerable efforts to bring fiber optic technologies to industrial maturity. In chapter 3 the great variety of technical solutions based on optical fibers and fiber optic components will be illustrated by a selection of application examples.

2.1.5.1 Fiber selection for fields of application

When used as a transmission medium, the different types of fibers are selected based on their properties and depending on the application.

	POF	PCF	Glass-LWL
Electromagnetic compability (EMC)	++	++	++
Safety from interception	+	+	+
Risk in explosion hazardous environments	++	++	++
Light weight	+	+	+
Flexibility	+	–	–
Small bending radii	+	0	–
Ease of assembly	++	+	– –
Bandwidth	+	+	++
Optical signal attenuation	–	+	++
Cost	++	++	– – to ++

Table 6: Comparison of properties of different fiber types

In the simplest scenario, a transmission link of optical fibers comprises:

- optical transmitter
- optical waveguide
- optical receiver

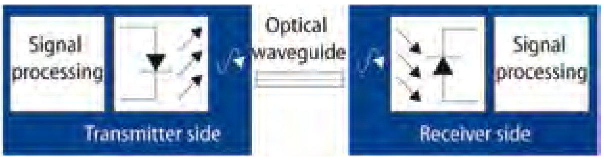


Figure 17: Schematic diagram of optical signal transmission

In telecommunications, the optical transmitter typically emits a power of less than 0 dBm. The receivers are usually sensitive in the range from –20 to –30 dBm.

The wavelength range, in which a fiber type exhibits particularly low absorption (attenuation), is called the optical window. The table below lists the optical windows for POF and glass fibers with the respective semiconductor materials used for the opto-electronic components. The windows are wavelength ranges around the central wavelength given in the table.

	Silicon (Si)	Germanium (Ge)	InGaAs
λ = 520 nm 1st opt. window POF	x	–	–
λ = 570 nm 2nd opt. window POF	x	–	–
λ = 650 nm 3rd opt. window POF	x	–	–
λ = 850 nm 1st opt. window, glass fiber	x	x	x
λ = 1300 nm 2nd opt. window, glass fiber	–	x	x
λ = 1550 nm 3rd opt. window, glass fiber	–	x	x
λ = 1625 nm 4th opt. window, glass fiber	–	–	x

Table 7: Optical windows for light transmission in fibers with the respective central wavelength

A few application examples demonstrate the criteria for the choice of the suitable fiber. For instance, in an optical bus system in a car, the most important factor is that the garage technicians are able to perform simple repairs on the fiber system used without first having to undertake extensive specialist training. For this reason and because of the cost, the POF is the preferred fiber for this application.

However, the exceptional ray quality at the output of a PM fiber for the visible range of light is utilised for the precision illumination of a cell for examination under a fluorescence microscope.

Fibers with a morate to large core diameter made from very pure fused silica glass are used in the transmission of power for material processing to ensure that there is no degradation of the fiber due to the high energy density.

2.2 Cables

The fibers described in Chapter 2.1 (fiber types) respond very sensitively to mechanical stress such as tensile, bending and torsional stress with large increases in attenuation. In many applications they are unable to cope with harsh environmental conditions, such as weathering, chemical stress and abrasion. It is therefore absolutely essential to protect the fibers by means of a suitable cable structure.

2.2.1 Buffered fibers

A first protective layer – the coating or more precisely the primary coating – is applied when the glass fibers are manufactured. The primary coating usually consists of a two-layer UV-hardened acrylate. It protects the fibers, preventing them from absorbing moisture and thus becoming brittle until cabling takes place.

The fibers with the primary coating are provided with a further protective coating in a first cabling stage. By analogy with copper cables, this intermediate product is called a buffered fiber. Buffered fibers are therefore the basic component of a fiber optic cable, which can then be combined, by stranding, to form a cable core. The protective coating applied to the intermediate product or buffered fiber is known as the secondary coating. According to VDE 0888 there are four distinct types of buffered fiber construction: multi-fiber loose tubes, plastic tubes, tight buffered fibers and ribbons.

2.2.1.1 Multi-fiber loose tubes

Multi-fiber loose tubes are buffered fibers in which multiple fibers are all surrounded by one secondary coating. The secondary coating around the buffered fibers is applied as a loose tube which is filled with a gel. The purpose of the gel is to gently embed the fibers and provide the maximum freedom of movement for the fibers when the cable is bent or pulled. For this reason, the buffer gels have to display a viscosity behaviour that is as constant as possible over the cable's entire Operating temperature range so that they do not harden or leak out. The fibers must be colour-coded in order to identify them. Multi-fiber loose tubes are usually made with 2, 4, 6, 8, 10, 12, 16, 20 and 24 fibers. The buffer tube surrounding a multi-fiber loose tube may be manufactured in a single layer of plastic or two layers of different plastics. At present, single-layer multi-fiber loose tubes are primarily made from polyester. Two-layer buffer tubes have the advantage that mating materials can be chosen which more or less combine the advantages of two plastics and offset the disadvantages in the properties of an individual plastic.

The combination of polyamide/polyester or the combination of polycarbonate/polyester (inner layer/outer layer, respectively) is used for manufacturing two-layer multi-fiber loose tubes. Two-layer loose tubes have lower thermal coefficients of linear expansion and are significantly more resistant to kinking than multi-fiber loose tubes having a single layer.

One important production parameter during the manufacture of multi-fiber loose tubes is the ratio of the length of fiber to the length of the buffer tube. In order to mechanically isolate the fibers, the multi-fiber loose tube must be constructed in such a way that the fiber is always slightly longer than the buffer tube. This is known as the fiber excess length. It is achieved by introducing the fibers helically into the loose tube. The fiber excess length must be kept constant along the entire length of the loose tube and within a very narrow tolerance of a fraction of a thousandth. This is to protect the fibers against the tensile forces acting on the buffer tube and also to prevent unacceptably small bending radii of the fibers when the buffer tube contracts at low temperatures.

2.2.1.2 Plastic tubes

Plastic tubes are buffered fibers in which just one fiber is surrounded by a buffer tube. In general they have the same design features as multi-fiber loose tubes. They provide the fiber with a large interior space which enables the fiber to embed itself loosely in a gel, ensuring a specific fiber excess length. This makes the plastic tube ideal for constructing cables for a wide range of operating temperatures, resulting in almost no increase in the attenuation of the fiber. A special type of tube consists of a stainless steel tube during the manufacturing of which the fiber is inserted in a u-shaped stainless steel profile. The profile is then bent to tube and the seam is welded. The result is as hermetically sealed fiber wrapping that efficiently protects the fiber from water and aggressive chemicals.

2.2.1.3 Tight buffered fibers

Tight buffered fibers are buffered fibers in which just one fiber is surrounded by a buffer tube. Compared to plastic tubes, the buffer tube has a much smaller outside diameter, which is adapted specifically to commercial connectors. Standard dimensions of these are, for example, 0.9 ± 0.1 mm or 0.6 ± 0.1 mm. There are many different types of tight buffered fibers: With a tight jacketed fiber the buffer tube is applied directly onto the fiber's primary coating, without providing the fiber with any space or room to move. It is also possible to apply a buffer, made of a UV-hardened acrylate, for example, between the fiber's primary coating and the thermoplastic buffer tube. The structure of a tight jacketed fiber usually permits only relatively short stripping lengths of up to a few centimetres. It is primarily used when assembling with machines, as the fiber cannot be pulled out of the jacket when it is being stripped automatically.

Another type is the compact or semi-tight buffered fiber. With this design, there is still a small space between the fiber and the inside diameter of the buffer tube. The gap can be filled with gel or simply left hollow, i.e. filled with air. The advantage of this type of buffered fiber is that it is possible to strip extremely long sections of the buffer tube from the fiber, up to 2 m at once. For this reason, the design is usually used for manufacturing pigtails; these have one pre-assembled end and are spliced onto another installed cable by the other end of the fiber which is placed in a splice tray. Another advantage is that they are easy to work with when assembling manually. As tight buffered fibers have a small outside diameter, there is very little or no excess fiber length compared to the length of the buffer tube, which means they are very sensitive to tensile stress and thermal contraction and respond to these with increases in attenuation.

Multi-fiber loose tubes for stranded cable designs with 2 fibers	2.0 mm
Multi-fiber loose tubes for stranded cable designs with 4 to 12 fibers	2.4 mm
Multi-fiber loose tubes for stranded cable designs with 2 to 12 fibers	3.5 mm
Multi-fiber loose tubes for stranded cable designs with 16 to 24 fibers	4.0 mm
Plastic tubes	1.4 mm
Tight buffered fibers	0.9 mm
Mini tight-buffered fibers for small form factor connectors	0.6 or 0.5 mm

Table 8: Standard diameters of buffered fibers

2.2.1.4 Ribbons

In addition to the round buffered fibers described above, another type of structure is the ribbon cable design. Between 2 and 12 fibers are joined together in parallel in one flat jacket. This design, which is used predominantly in American and Asian countries, frequently makes use of UV-hardened acrylates for the jacket material. The ribbon cables can sometimes cause difficulties when laying in tight installation casings as they are relatively rigid in the transverse direction. There is also a danger that the coating will be damaged when separating the fibers.

2.2.2 Cable structure

The buffered fibers described above represent the basic components of cable constructions. The design of the cable must take into account the individual requirements of the cable's field of application. In other words, it must ensure that the fibers are protected from tensile forces and other mechanical stresses, chemical media in the environment and thermal stresses.

First of all, round cables are split into two different designs: cables with a central buffered fiber, and stranded cables. Central cables have just one buffered fiber directly in the centre of the cable. Stranded cables have multiple buffered fibers and possibly also buffer or dummy elements which have been stranded in layers around a central element to achieve better cable flexibility. The stranding also prevents the buffered fibers or fibers from bunching up on one side of the central axis when the cable is bent, which would cause them to become compressed or stretched. Instead, the buffered fibers can slip and move slightly in the stranded structure in relation to the longitudinal direction along the helix of the stranding. This minimises or even completely compensates any tensile or compression stress caused by bending the cable. The size of the cable lay, i.e. the length corresponding to precisely one 360° turn of the strand elements, is particularly important. A large lay length permits only large bending radii of the cable. However, if the lay length is too small, the radii of curvature of the strand elements in the helix will be too small and generate attenuation losses. A suitable compromise must be chosen between these two effects.

A distinction is made between two types of stranding: continuous stranding (lang lay counter clockwise "S", lang lay clockwise "Z"), where the stranding direction of the buffered fibers does not change; and SZ stranding, when the direction of stranding reverses at short intervals. SZ stranding is used as an energy-saving and cost-effective process for permanent cable installations and continuous stranding is preferred for cables that are constantly moving.
A GRP element (glass-fiber reinforced plastic) is used as the central element for the stranding. The GRP element serves as a strength and support member and prevents the cable from contracting too greatly in the event of low ambient temperatures, thus also preventing an increase in the fiber attenuation. Film or fleece tape can be applied around the central buffered fiber or the stranded structure to stabilise the structure or to provide better separation between the outer jacket and the strain relief elements. This complete structure, without the outer jacket, is

called the cable core. The cable core usually also contains a manufacturer's tracer thread for identifying the manufacturer of the cable and a length measuring tape for accurately determining the length of the cable.

A distinction is made between indoor cables (which are designed specifically for the requirements of installing in buildings), outdoor cables (which are constructed specifically for use outdoors) and universal cables (which satisfy the requirements both for buildings and for outdoors) based on the installation site or the type of cable. For outdoor applications, the core of the cable is often made longitudinally watertight by means of core fillers in the cavities or swellable threads or ribbons. Consequently, if the cable jacket is damaged, any water that seeps into the cable is prevented from spreading along the length of the cable.

The choice and size of the cable jacket are crucial. The jacket must enclose the cable core to keep it watertight and, as the boundary layer to the environment, it must be able to withstand all environmental influences. There is no jacketing material that can withstand all conceivable environmental influences. For this reason, the choice of jacketing material must be tailored to the specific conditions in which the cable is to be used.

The following materials are used as a jacket for fiber optic cables:

- Halogen-free, flame-retardant materials with the type designation H, which above all have to comply with stringent fire prevention requirements, are preferred for network cables in buildings. These materials are generally less effective at protecting the cable core from moisture and chemical media, but this is less important in buildings.

- Polyethylenee (PE) with the type abbreviation 2Y is used as a jacketing material for cables that are used outdoors, i.e. underground, underwater or overhead. This material offers the best protection against moisture and, when combined with a carbon filler, against the destructive effects of UV radiation. However, this type of material does not meet fire prevention requirements.

- Polyvinyl chloride (PVC) with the type abbreviation Y for cables with greater requirements with regard to resistance to chemical media in industrial settings.

- Polyurethane (PUR) with the type abbreviation 11Y for cables that are designed for continuous movement, e.g. in drag chains, and are subject to extreme mechanical stresses, such as abrasion and crushing pressure, and are resistant to oil.

- Polyamide (PA) with the type abbreviation 4Y if the cable requires a very hard jacket that can slide easily or needs to be designed to be very rigid. A polyamide jacket also serves as protection against termites and rodents.

- Fluoropolymers (e.g. PTFE) with the type abbreviation 7Y, if the cable has to be designed for particularly high temperatures or chemical resistance

- Various other jacketing materials that are based on the chemicals listed above and have been improved through additives or stabilisers for specific stresses or resistances. Nowadays the chemical industry is continually developing new custom-made plastics for special applications. Generally, however, these new developments have some shortcoming or other (even if it is just the price) which will limit their use to certain fields of application.

Fiber optic cables are frequently installed in ducts or in buildings where they are likely to be damaged by rodents. Therefore a number of different technical solutions are available for protecting them from rodent damage. Non-metallic types of rodent protection have the advantage that they are usually cheaper, lighter in weight, more flexible and require no special precautions against accidental energization when installing the cable. One of the simplest designs of non-metallic rodent protection is to apply glass rovings under the jacket. The glass rovings (spun optical fiber tissue) provide two different functions: strain relief and rodent protection.

Another type of rodent protection is a hard polyamide jacket or encasing in GFR elements. Metal forms of rodent armouring are much more effective. These include, for example, designs with smooth, loosely wound, zinc-coated steel tapes or corrugated steel tapes provided under the jacket. Undisputedly, these solutions provide the best protection for the cable, but make it thick and heavy at the same time. Besides, with metal elements the cable is no longer galvanically isolated.

For underwater and mine applications, much more sophisticated armouring is used to protect the cable from harsh stresses. For example, the cables are wrapped in zinc-coated steel round wires, which are in turn encased in another protective plastic coating. Shark attacks were a frequent cause for malfunctions of insufficiently protected sea cables.

For effective protection against the ingress of water into the cable core, a film of aluminium at least 0.15 mm thick can be provided under the jacket as a diffusion barrier. This film is permanently bonded to the jacket.

2.2.3 Tests on cables
The standards listed below are relevant for testing the properties of fiber optic cables:

2.2.3.1 IEC 60793-1-40
(corresponding German standard: VDE0888 part 240)
Measurement methods and test procedures – Attenuation
Method C, the backscattering method, is usually used for all glass fibers in a cable factory. An optical time domain reflectometer (OTDR; see chapter 2.1.3.1) is used in this method. The advantage of this test is that only one end of the cable is required. The device under test is connected to the measuring instrument by means of a launching fiber.

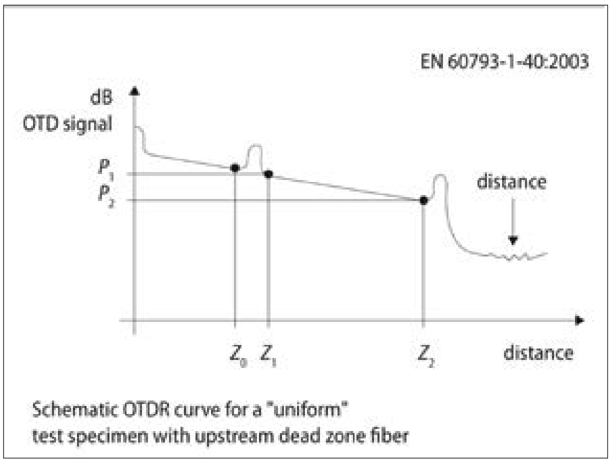


Figure 18: Schematic OTDR curve for cable

2.2.3.2 IEC 60794-1-2
(corresponding German standard: VDE0888 part 100-2)
For the testing of mechanical properties and environmental tests

Method E1: Tensile test
The test procedure investigates the attenuation of the fibers in the cable in the event of tensile forces which can occur while installing or operating the cable. Alternatively, the fiber extension can also be tested (see fig. 19).

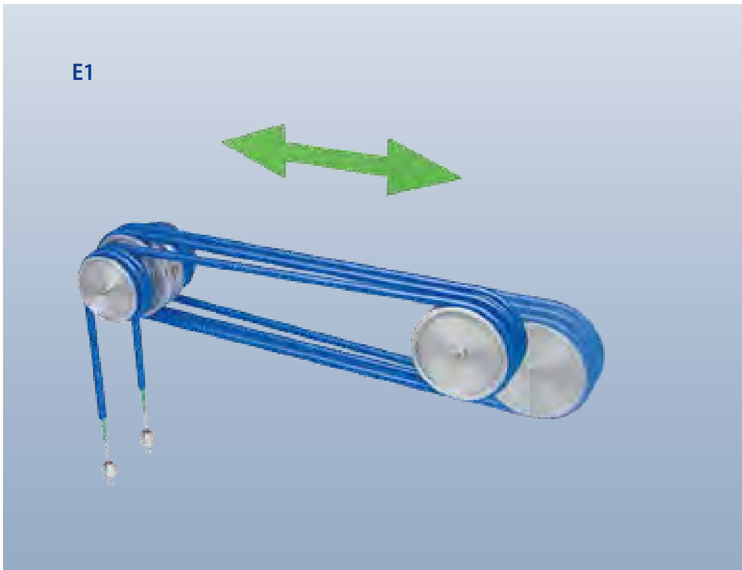


Figure 19: Tensioning mechanism for tensile test procedures

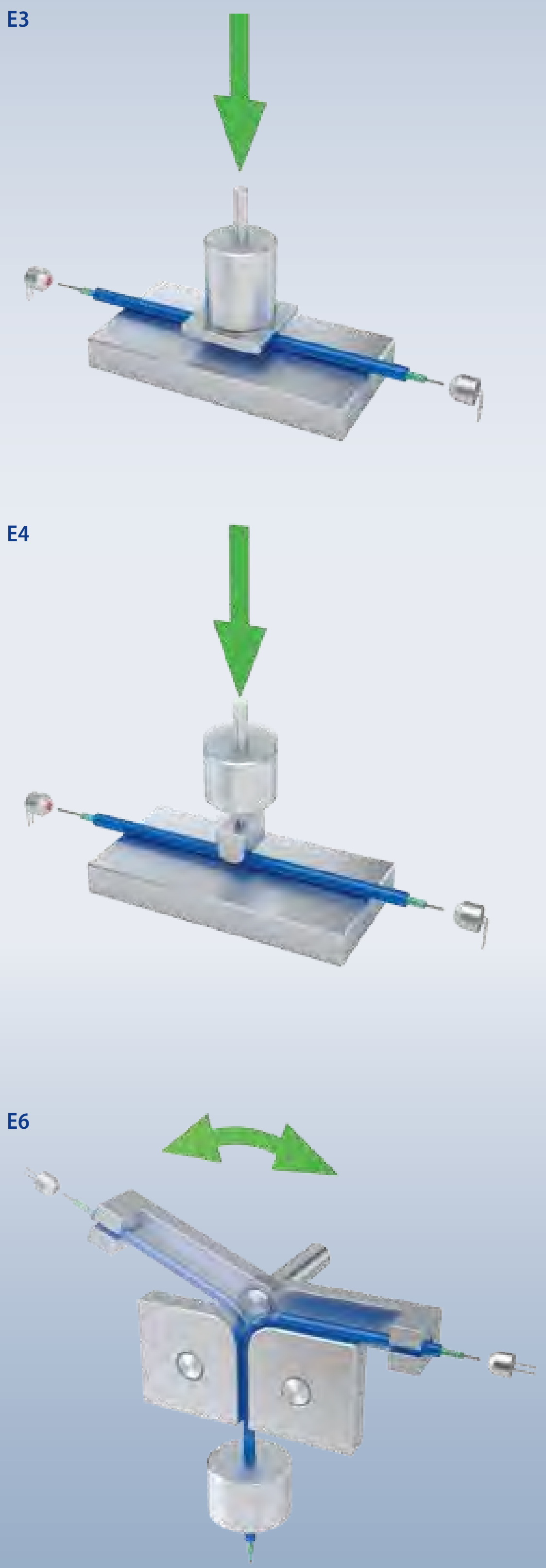


Figure 20: Experimental setup for the characterization of mechanical properties

Method E3: Cable crush test

This test determines the behaviour of a fiber optic cable under pressure. To do this, the test object is crushed for a specified time under a predetermined force between a flat steel base plate and a moving steel plate that is 100 mm long plus an edge radius of 5 mm (see fig. 20 top).

Alternatively, one or more steel mandrels 25 mm in diameter can be inserted at right angles into the specimen. The optical transmission of the fiber(s) (breakage) of the device under test is monitored or the change in attenuation is recorded during and after the test.

Method E4: Cable impact test

The test determines the behaviour of a fiber optic cable when exposed to one or more impacts. The device under test is placed on a flat steel plate and subjected to a specified (can be determined via mass and height of drop) drop energy (see fig. 20 middle).
The following must be specified for the test:

- Drop energy
- Radius of the drop hammer
- Number of impacts
- Temperature during the test
- Frequency of impacts

The optical transmission of the fiber(s) (breakage) of the device under test is monitored or the change in attenuation is recorded during and after the test.

Method E6: Repeated Bending

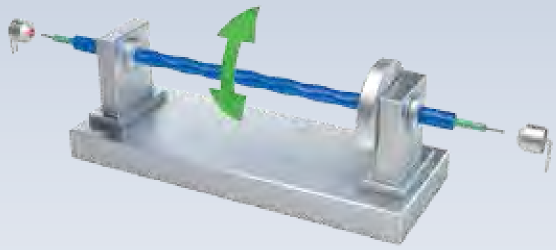
The test determines the behaviour of a fiber optic cable when exposed to repeated bending. During this test, the device under test is bent by ±90° gebogen (see fig. 20 bottom).

The following must be specified for the test:

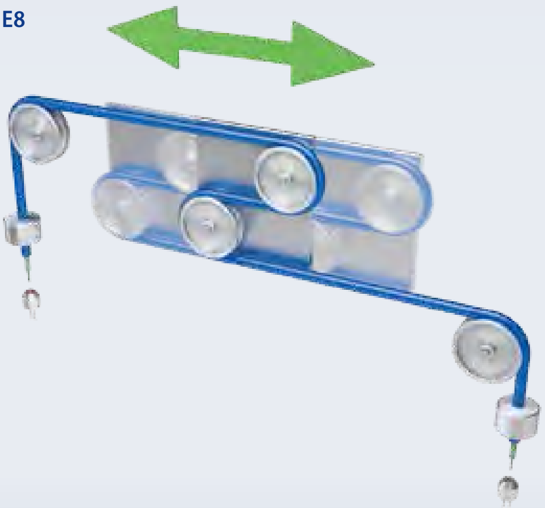
- Number of cycles
- Bend radius
- Tensile load

The optical transmission of the fiber(s) (breakage) of the device under test is monitored or the change in attenuation is recorded during and after the test.

E7



E8



E11A

Figure 21: Experimental setup for the characterization of mechanical properties

Method E7: Torsion

The test determines the behaviour of a fiber optic cable when exposed to mechanical twisting. The device under test is clamped by two clamps and twisted by ±180° (see fig. 21 top).

The following must be specified for the test:

- Twisted length
- Number of cycles
- Tensile load applied

The optical transmission of the fiber(s) (breakage) of the device under test is monitored or the change in attenuation is recorded during and after the test.

Method E8: Flexing test

The test determines the behaviour of a fiber optic when exposed to repeated bending during operation (e.g. in the case of an elevator cable. The device under test is guided over two pulleys in the shape of an S and loaded by a weight on both sides. The pulleys are located on a moving carriage, which carries out an alternating translational movement (see fig. 21 middle).

The following must be specified for the test:

- Diameters of the pulleys A and B
- Length of the displacement path of the carriage
- Number of cycles
- Mass of the weights attached (tensile load applied)

The optical transmission of the fiber(s) (breakage) of the device under test is monitored or the change in attenuation is recorded during and after the test.

Method E11A: Cable bend

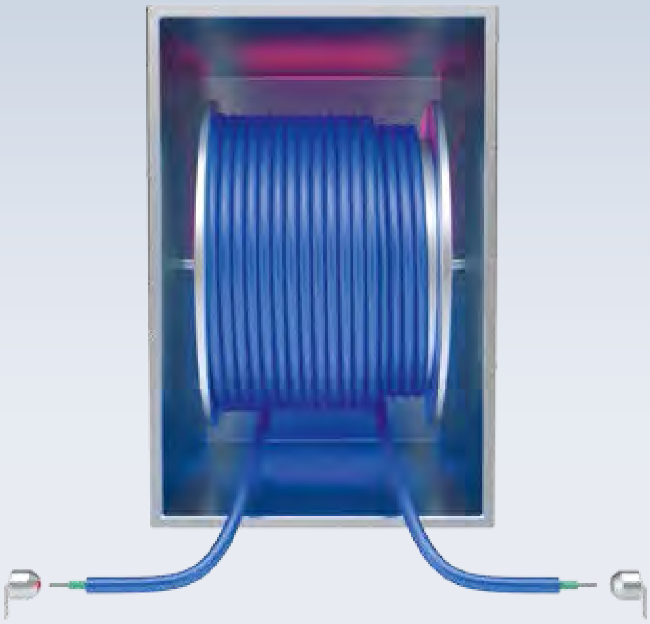
The purpose of this test is to determine the behaviour of fiber optic cable when bent about a test mandrel. The device under test is wound tightly in a coil around a mandrel and then unwound (see fig. 21 bottom).

The following must be specified for the test:

- Diameter of the test mandrel
- Number of cycles
- Number of windings
- Test temperature

The optical transmission of the fiber(s) (breakage) of the device under test is monitored or the change in attenuation is recorded during and after the test.

F1



F5

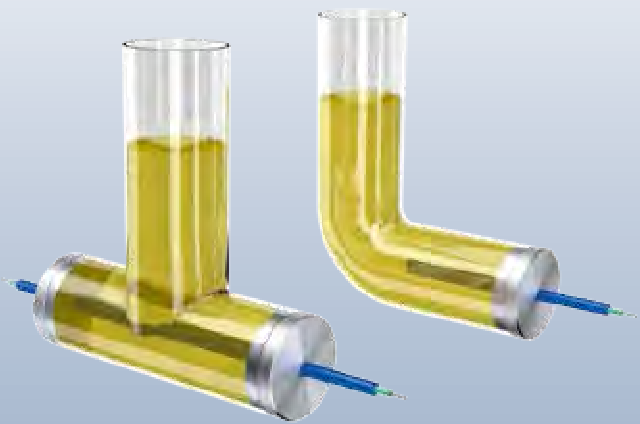


Figure 22: Experimental setup for the characterization of environmental stability and longitudinal watertightness

Method F1: Temperature cycling

This test procedure examines the stability of fiber attenuation of a fiber optic cable over the permitted temperature range for its particular use and also for its storage and transport.

Because of the different coefficients of expansion of the structural cable materials as well as certain shrinkage effects of the plastics under thermal stress, the fibers are subjected to compression or tensile stress which can cause considerable increases in attenuation if the cable design is not ideal.

The test is usually carried out in a large temperature chamber on an entire factory length as a loose coil or wound up on a reel (see fig. 22 top). Loose coils are preferred where possible, as this avoids the influences due to the coefficients of expansion of the reel. In practice, however, with rather thick cables it is often not possible to wind suitably long lengths as a loose coil.

The following must be specified for the test:

- Number of cycles
- Limit temperatures to be approached
- Dwell times at the temperature
- Rate of change in temperature

Any changes in attenuation in the device under test are monitored during and after the test.

Method F5: Longitudinal watertightness

This test determines whether a cable is capable of stemming the migration of water along a defined length in case the cable jacket is damaged.

The test specification differentiates between test procedure A, in which the water is able to penetrate into the cable core radially through a section of removed jacket and test procedure B, in which the water is able to penetrate into the entire cross-sectional area of the cable (see fig. 22 bottom).

The following must be specified for the test:

- Sample length
- Duration of the test
- Method used, A or B

Standard test parameters are:

- Exposure time 24 hours
- Cable length 3 m
- Height of water column 1 m

2.2.4 Fire prevention

Consideration of application and fire prevention criteria: The jacket around the buffered fiber or cable is designed to protect the fiber(s) from the effects of mechanical, thermal and chemical action as well as the ingress of moisture. In the event of a fire, however, the cable jacket should prevent a fire from spreading and stop toxic and corrosive gases from being produced.

All fiber optic cables for indoor cabling in this catalogue are listed in the FRNC (LSFROH) version.

FR Flame Retardant
NC Non Corrosive
LS Low Smoke
OH Zero Halogen

Summary of the advantages of FRNC cables:

➔ cables themselves do not propagate the fire
➔ combustion gases have relatively low toxicity
➔ combustion gases have no corrosive effect
➔ no dioxins in the fire residue
➔ minimum smoke

Figure 23: Testing of burning behaviour of fiber optic cables

The use of non-halogen, flame-retardant materials is advisable in order to protect equipment and buildings but above all to protect people. In harsh industrial environments, PUR and PVC (see chapter 2.2.2.), in particular, are used owing to their high resistance to oils and their abrasion resistance.
PE is also commonly used as a jacketing material for outdoor applications. However, it is often extremely difficult to meet all the requirements using just one jacketing material. To best satisfy the prevailing local operating conditions, LEONI offers the user a choice of four standard materials. If the criteria for a particular application are not met by the cable structures in this catalogue, an expert consultation is recommendable. Additional requirements can often be met through customised measures when making the jacket (e.g. installation of aluminium tape or use of special blends of materials).

While in theory the cables will last a lifetime, in day-to-day operation they may be destroyed by malfunctions or outside influences. Destruction by fire is a particularly critical situation. In addition to the loss of the cable functions, toxic and/or corrosive substances may be released when any non-metallic cable components, such as the insulation, jacket and films, start to burn. Toxic substances will immediately affect anybody in the vicinity of the fire, whereas corrosive by-products of a fire and their effects cannot always be detected immediately. It often takes weeks or even months before such by-products of the fire, dissolved in the extinguishing water or in the atmospheric moisture, start to corrode metals. Thus, fire damage can occur even at sites located some distance from the source of the fire itself. Fire testing and determining the combustion products resulting from a fire are therefore crucial in cable technology. They provide information about the propagation of fire through the cables and about the potential hazards for man and material in the event of a cable fire.
The corresponding tests investigate:

- the flammability of non-metallic cable components
- the toxicity of the fire by-products, particularly the combustion gases
- the propagation of the fire along a cable
- the smoke density in the event of a fire
- the corrosiveness of the combustion gases

The main fire tests are listed below. It should also be noted that these tests are conducted under standardised conditions and do not reflect the individual fire behaviour of cables and bunched cables at the particular installation site.

German and international fire standards		
German standard	International standard	Content
DIN EN 60332-1-1 to 3	IEC 60332-1-1 to -3	Flame propagation for single cables
(DIN VDE 0472 Part 804 C)	IEC 60332-3-##	Flame spread along bundled cables
(DIN VDE 0472 Part 813)	IEC 60754-1 and 2	Corrosiveness of combustion gases (abscence of halogen)
(DIN VDE 0472 Part 816)	IEC 61034-1 and -2	Measurement of smoke density
DIN VDE 0472 Part 814	IEC 60331-11 and -25	Insulation integrity under fire conditions
DIN EN 50200	EN 50200	Insulation integrity under fire conditions
DIN 4102-12	—	Function integrity of electric cables

Table 9: Standards for fire prevention properties of cables

The following subchapters present test procedures for the determination of fire behaviour and fire propagation.

Flammability and fire propagation

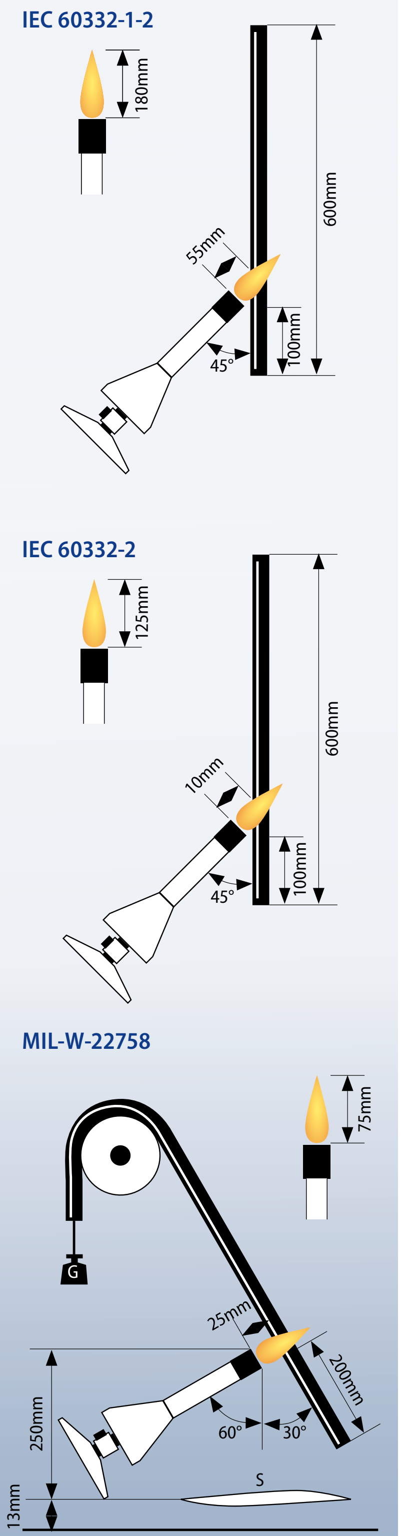


Figure 24: Test setups for the characterization of the burning behaviour of cables.

2.2.4.1IEC 60332-1-2 / EN 50265-2-1 / VG 95218-2 Method 1 / BS 4066 Part 1

Test setup and parameters:
The single cable under test ist secured vertically and flamed with a Bunsen burner at an angle of 45° to the vertical (see fig. 24 top). The flame temperature is determined by the stipulated setting of the Bunsen burner flame. The test duration for a cable with a diameter ≤ 25 mm is 60s, for cables with diameters 25 < D < 50 mm it is 120 s.

Compliance criteria:
The fire damage must end at least 50 mm below the upper fixing clamp. The cable must be self-extinguishing.

2.2.4.2 IEC 60332-2 / EN 50265-2-2 / VG 95218-2 Method 2 / BS 4066 Part 2

Test setup and parameters:
The single cable under test is secured vertically and flamed with a Bunsen burner at an angle of 45° to the vertical (see fig. 24 middle). The flame temperature is determined by the stipulated setting of the Bunsen burner flame. The test duration is 20s.

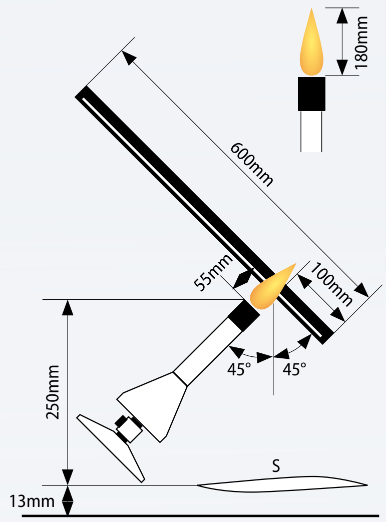
Compliance criteria:
The fire damage must end at least 50mm below the upper fixing clamp. The cable must be self-extinguishing.

2.2.4.3 MIL-W-22758 / MIL-W-8104 / VG 95218-2 Method 4

Test setup and parameters:
The single cable under test is weighted over a pulley at an angle of 30° to the vertical, in order to keep the sample stretched out during the test. The Bunsen burner flame is directed at the cable from below under an angle of 60° to the vertical. 250 mm below the point of heat application on the sample, a tissue paper (S) is spread horizontally at least 13 mm above the chamber floor. A Bunsen burner flame is adjusted to a height of 75 mm with an inner flame cone of 25 mm. The flame is applied to the sample 200 mm above the clamping point at a right angle (see fig. 24 bottom). The flame temperature must be at least 950 °C.
The test duration is 30 s.

Compliance criteria:
It is only permitted for the sample to continue burning for at most 30 seconds after the flame has been removed. Overall the fire damage to the cable must not exceed 76 mm. The tissue paper (S) spread out underneath must not be ignited by dripping material.

VG 95218-2



UL 1581

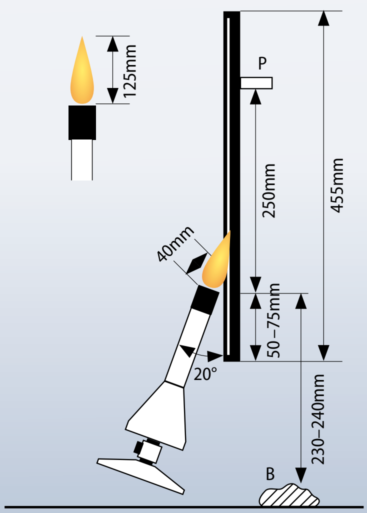


Figure 25: Test setups for the characterization of the burning behaviour of cables

2.2.4.4 VG 95218-2 Method 3

Test setup and parameters:
The single cable under test is weighted over a pulley and secured at an angle of 45° to the vertical. The Bunsen burner flame is directed at the cable from below under an angle of 45° to the vertical. 25 mm below the point of heat application on the sample, tissue paper (S) is spread out horizontically underneath the sample, at least 13 mm above the chamber floor (see fig. 25 top).
The flame temperature is determined by the stipulated setting of the Bunsen burner flame. The test duration is 60 s for cables with a diameter ≤ 25 mm and 120 s for cables with a diameter 25 < D < 50 mm.

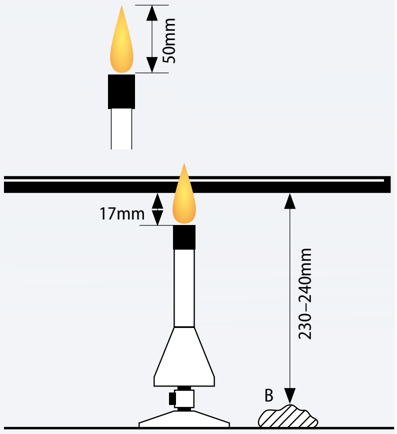
Compliance criteria:
It is only permitted for the sample to continue burning for at most 30 seconds after the flame has been removed. Overall the fire damage to the cable must not exceed 76 mm. The tissue paper (S) spread out underneath must not be ignited by dripping material.

2.2.4.5 UL 1581 UL 1581 Section 1060 (FT1) / Section 1061 (Cable Flame) / Section 1080 (VW-1)

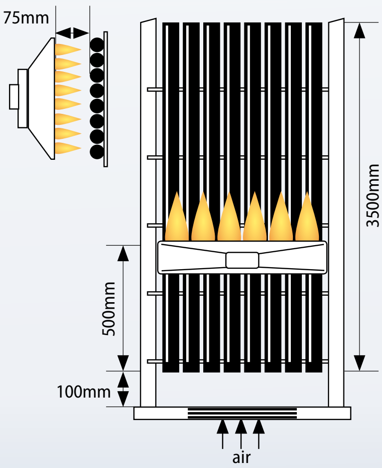
Test setup and parameters:
The cable is secured vertically and provided with a paper indicator flag (P, 10 x 20 mm). A Bunsen burner is used to apply the flame and it is secured at an angle of 20° to the vertical (see fig. 25 bottom).
The flame temperature is determined by the stipulated setting of the Bunsen burner flame. The test duration covers 5 cycles of 15 s of flame application with a break of 15 s each cycle per Section 1060, 3 cycles of 60 s of flame application with a break of 30 s each cycle per section 1061 and 5 cycles of 15 s of flame application with a break of 15 s each cycle per section 1080 (max. 60 s break in total).

Compliance criteria:
It is only permitted for the sample to continue burning for at most 60 seconds after the flame has been removed and for at most 25% of the paper indicator flag (P) to be burned. The cotton wadding (B) must not be ignited by dripping material.

UL 1581



IEC 60332-3



UL 1685

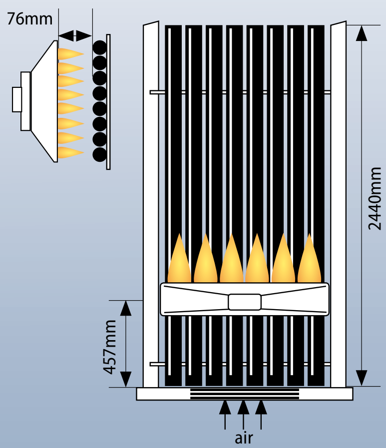


Figure 26: Test setups for the characterization of the burning behaviour of cables

2.2.4.6 UL 1581 Section 1090 (H) / Section 1100 (FT2)

Test setup and parameters:
The cable is secured horizontally and vertically and flamed with a Bunsen burner (the bur ner is tilted at an angle of 20° for the FT2 test). Cotton wadding (B) is placed next to the Bunsen burner (see fig. 26 top). The flame temperature is determined by the stipulated setting of the Bunsen burner flame. Test duration is 30 s.

Compliance criteria:
The cotton wadding (B) must not be ignited by dripping material. According to section 1090, the propagation speed of the flame must not exceed 25 mm/min, according to section 1100, the length of the charred section on the sample must not exceed 100 mm.

2.2.4.7 IEC 60332-3 / EN 50266-2

Test setup and parameters:
The cables are secured to a ladder, close together or spaced apart depending on the type of fire. The cables can be secured in several layers (see fig. 26 middle). The flame temperature is determined by the stipulated quantity of propane gas and air. Depending on the test specification the following test durations are required:
IEC Part 21/EN Part 1: Category A F/R only for special applications
IEC Part 22/EN Part 2: Category A (7 l flammable material/m): 40 min
IEC Part 23/EN Part 3: Category B (3.5 l flammable material/m): 40 min
IEC Part 24/EN Part 4: Category C (1.5 l flammable material/m): 20 min
IEC Part 25/EN Part 5: Category D (0.5 l flammable material/m): 20 min

Compliance criteria:
The visible area of fire damage to the cables must not exceed 2.5 m in height from the bottom edge of the burner.

2.2.4.8 UL 1685 Vertical Tray

Test setup and parameters:
The cables are secured to a ladder in a single layer (quantity depends on the diameter of the cable). The length of each sample is 2.44 m (see fig.26 bottom. The flame temperature is determined by the stipulated quantity of propane gas and air. The power equals 20.5 kW (70,000 Btu/hr). The test duration is 20 min each test. 2 tests have to be performed.

Compliance criteria:
The area of fire damage to the cables must be less than 2.44 m
(measured from the bottom of the ladder).

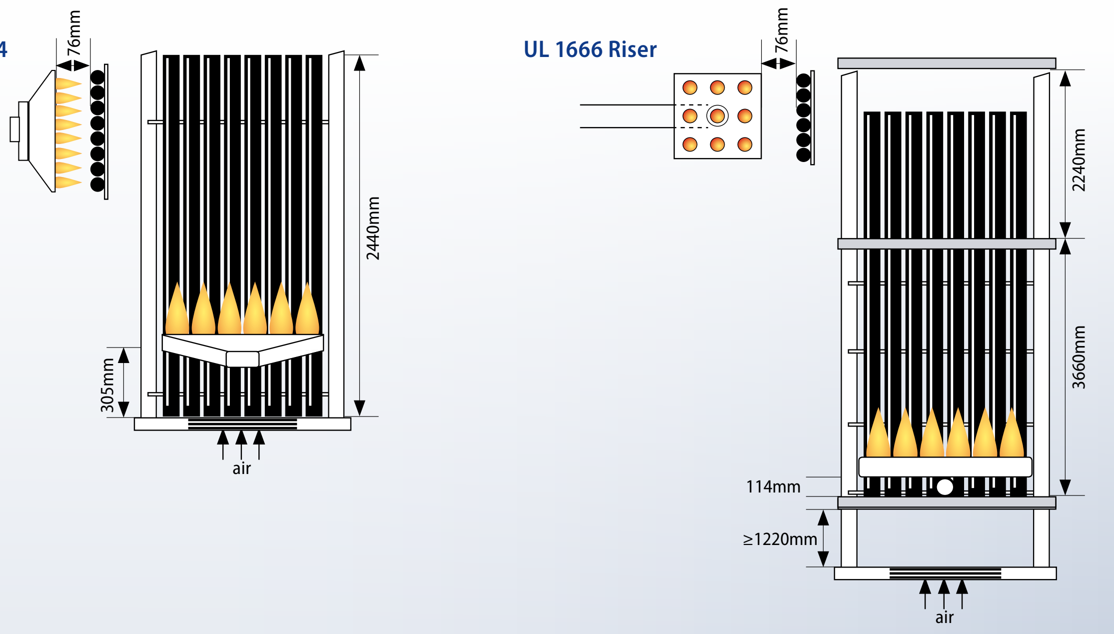


Figure 27: Test setups for the characterization of the burning behaviour of cables

2.2.4.9 UL1685 FT4 / IEEE 1202

Test setup and parameters:
The cables are secured to a ladder in a single layer (quantity depends on the diameter of the cable). The length of each sample is 2.44 m. Cables with a diameter of <13 mm are secured to the ladder in bundles. The burner is tilted at an angle of 20° (see fig. 27 left).
The flame temperature is determined by the stipulated quantity of propane gas and air. The power equals 20.5 kW (70,000 Btu/hr). The test duration is 20 min (2 tests have to be performed)

Compliance criterion:
The area of fire damage to the cables must be less than 1.5 m (measured from the bottom edge of the burner nozzle).

2.2.4.10 UL 1666 Riser

Test setup and parameters:
The cables are secured to a ladder in a single layer (quantity depends on the diameter of the cable). The length of each sample is 5.33 m. The flame is applied using a burner diffuser plate (see fig. 27 right). The flame temperature is determined by the stipulated quantity of propane gas and air. The power equals 154.5 kW (527,500 Btu/hr).
The test duration is 30 min (2 tests have to be performed).

Compliance criteria:
The area of fire damage to the cables must be less than 3.66 m (measured from the bottom of the ladder) and the temperature of any of the thermocouples (at a height of 3.66 m) must not exceed 454.4 °C. A third test must be carried out if the difference in propagation height for the two tests is greater than 1.52 m.

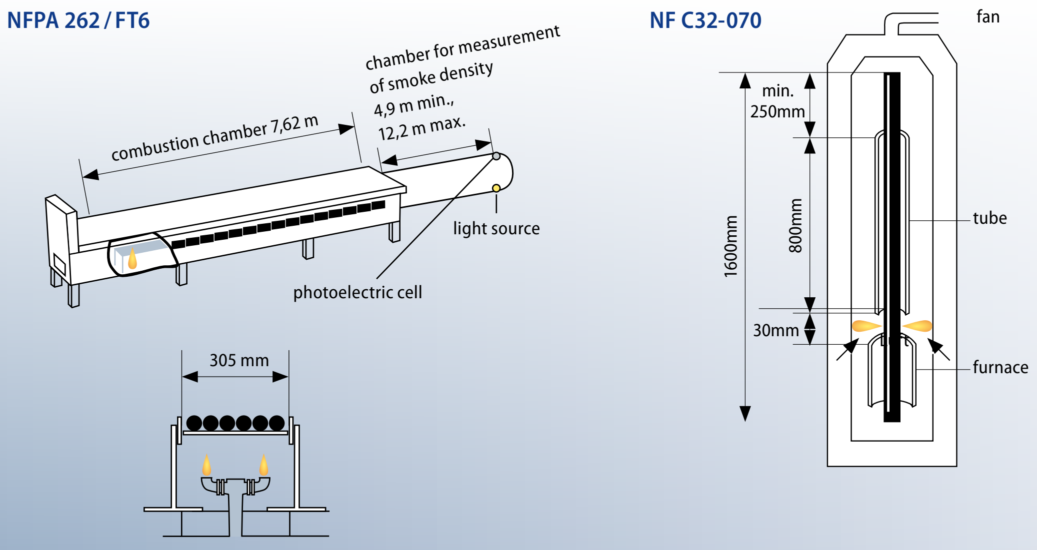


Figure 28: Test setups for the characterization of the burning behaviour of cables

2.2.4.11 NFPA 262 / FT6 Steiner-tunnel (UL 910 withdrawn)

Test setup and parameters:
The cables are secured to a horizontal ladder in a single layer (quantity depends on the diameter of the cable). The length of each sample is 7.32 m. A device for measuring the smoke density is placed behind the combustion chamber (see fig. 28 left). The flame temperature is determined by the stipulated quantity of propane gas and air. The power equals 86 kW (294,000 Btu/hr). The test duration is 20 min (2 tests have to be performed).

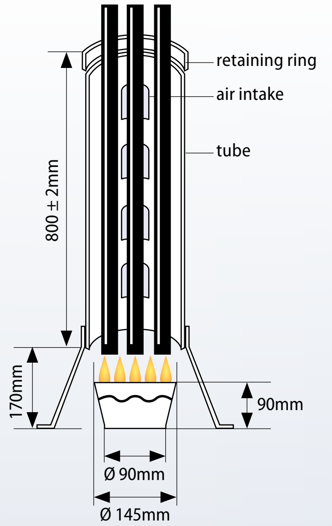
Compliance criteria:
The area of fire damage to the cable must be less than 1.52 m. The mean optical density of the smoke produced must not exceed a value of 0.15. The maximum optical smoke density should not exceed 0.5 (light transmission of 32%).

2.2.4.12 NF C32-070 Test 2 / UIC 895 VE Appendix 7

Test setup and parameters:
The cable is secured vertically in a furnace with a subsequent tube (Ø 125 mm, see fig. 28 right). The flame temperature is 830 °C ± 50 °C, with a test duration of 30 min.

Compliance criterion:
The end of the cable protruding from the top of the tube must not be damaged.

Def.-St. 02-641



UL 1666 Riser

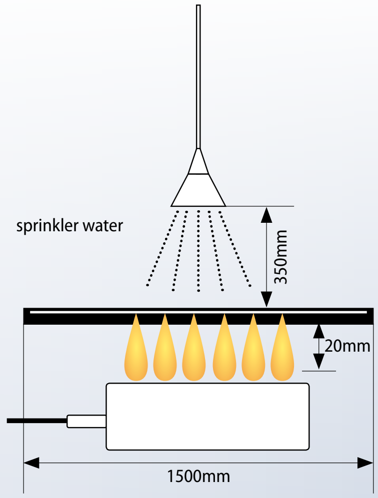


Figure 29: Test setups for the characterization of the burning behaviour of cables

2.2.4.13 Def.-St. 02-641 (formerly NES 641)

Test setup and parameters:
Three cables are secured vertically in a tube ("Swedish chimney"). A flame is applied by burning liquid, which is in a dish underneath the tube (see fig. 29 left). The flame temperature is determined by the flammable liquid.
Test duration: until the liquid is totally consumed.

Compliance criterion:
The visible area of fire damage to the cables must not exceed 250 m down from the top edge of the cable.

2.2.4.14 BS 6387 Category W

Test setup and parameters:
The cable is laid horizontally. The buffered fibers and shielding must be connected to a power supply with a voltage of U_0/U (see fig. 29 right). The flame is applied across a width of 1500 mm. After 15 minutes a sprinkler is turned on. The flame temperature is 650 °C ± 40 °C, with a test duration of 30 min (2 tests have to be performed).

Compliance criteria:
While the flame is applied, it must still be possible to transmit power or signals via all conductors. There must be no short circuit between the conductors or to the shielding.

2.2.4.15 DIN VDE 0472-814 / BS 6387 Category C

Test setup and parameters:
The cable is laid horizontally. The buffered fibers and shielding must be connected to a power supply having the following voltages:

- for data cables: 110 V
- for high power cables 0.6/1 kV: 230/400 V
- BS: all cables U_0/U

The flame is applied from below across a width of 1200 mm. The flame is directed at the cable (see fig. 30).
The flame temperature is min. 750 °C; BS:
950 °C ± 40 °C, with a test duration of 180 min.

Compliance criteria:
While the flame is applied and during a cooling period of an additional 12 hours, it must still be possible to transmit power or signals via all conductors. There must be no short circuit between the conductors or to the shielding and no break in the conductors.

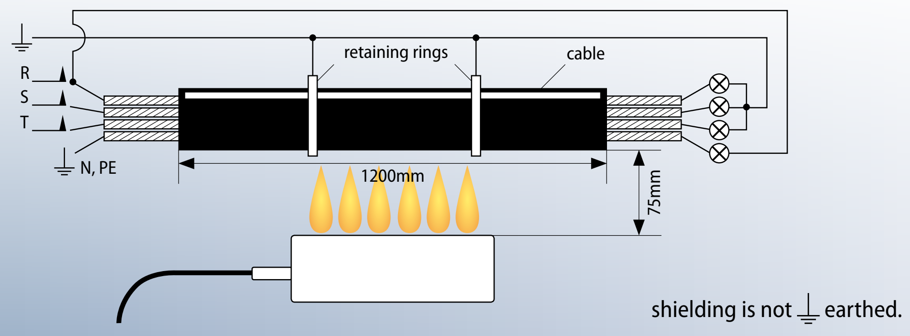


Figure 30: Setup for the testing cable behaviour in a fire

2.2.4.16 IEC 60331-21/IEC 60331-23

Test setup and parameters:
The cable is laid horizontally. The buffered fibers and shielding must be connected to a power supply having the following voltages:

- for high power cables 0.6/1 kV: U_0/U min 100 V
- for data cables: 110 V

The flame is applied under the cable from a horizontally offset position across a width of 1200 mm. The test setup is widely conform with figure 30. Flame temperature is at least 750 °C (equipment IEC 60331-11), with a test duration of 90 min (recommended).

Compliance criteria:
While the flame is applied and during a cooling period of an additional 15 minutes, it must still be possible to transmit power or signals via all conductors. There must be no short circuit between the conductors or to the shielding and no break in the conductors.

2.2.4.17 IEC 60331-25

Test setup and parameters:
The fiber optic cable is laid horizontally and the optical fibers must be connected. The flame is applied under the cable from a horizontally offset position across a width of 1200 mm. The test setup is widely conform with figure 30. The flame temperature is at least 750 °C (equipment IEC 60331-11), with a test duration of 90 min.

Compliance criteria:
While the flame is applied and during a cooling period of an additional 15 minutes, it must still be possible to transmit signals via the optical fibers.

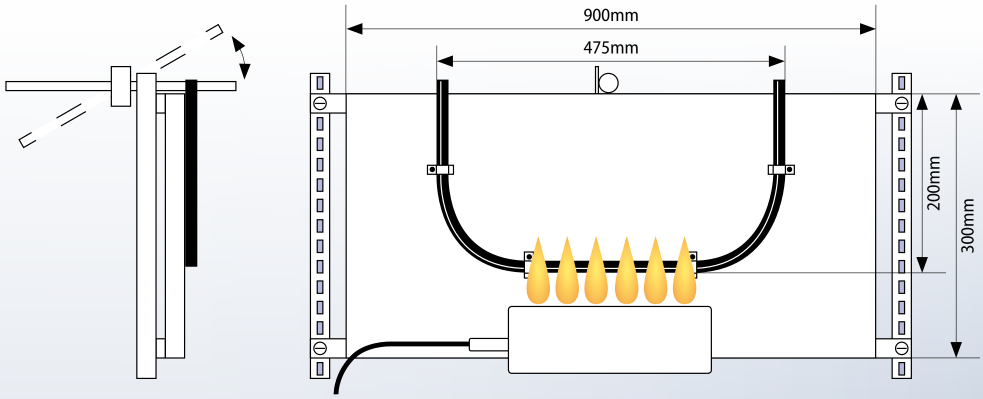


Figure 31: Setup for the testing of cable behaviour in a fire with added mechanical load

2.2.4.18 IEC 60331-31

Test setup and parameters:
The cable is secured onto a positioning board and a flame is applied from the front (see fig. 31). The positioning board is subjected to shocks every 5 minutes during the combustion period. The flame temperature is at least 830 °C (equipment IEC 60331-12), with a test duration of 120 min (recommended).

Compliance criteria:
While the flame is applied, it must still be possible to transmit power or signals via all conductors. There must be no short circuit between the conductors or to the shielding.

2.2.4.19 EN 50200

Test setup and parameters:
The cable (maximum diameter 20 mm) is secured onto a positioning board and a flame is applied from the front (see fig. 31). The positioning board is subjected to shocks every 5 minutes during the combustion period. The flame temperature is 842 °C, with a test duration of 90 min.

Compliance criteria:
- For cables and cords with a rated voltage of up to 600/1000 V: There must be no short circuit between the conductors and no break in the conductors.
- For data and communication cables without a rated voltage: There must be no short circuit between the conductors and no break in the conductors.
- For fiber optic cables: The increase in attenuation must not exceed the values defined in the relevant design standards.

2.2.4.20 BS 6387 Category Z

Test setup and parameters:
The cable is secured onto a positioning board and a flame is applied from below. The positioning board is subjected to two shocks/min. during the combustion period. The test setup is widely conform with figure 31. Flame temperature is 950 °C ± 40 °C, with a test duration of 15 min.

Compliance criteria:
While the flame is applied, it must still be possible to transmit power or signals vial all conductors. There must be no short circuit between the conductors and the shielding.

Smoke density

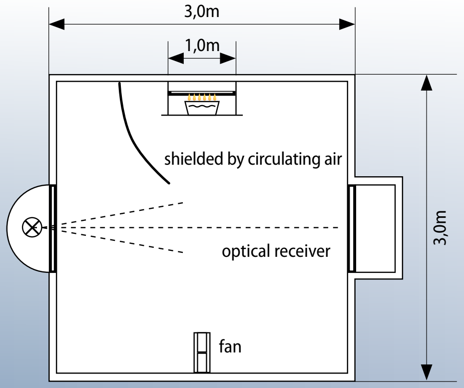


Figure 32: Setup for the testing of smoke density with a flammable liquid (or with a gas burner for Def.-St. 02 711)

2.2.5 Test procedures for the determination of smoke density

2.2.5.1 IEC 61034-2/EN 50268-2

Test setup and parameters:
A cable specimen is burnt in a closed chamber using a flammable liquid. The light transmittance of the resulting smoke is measured optically (see fig. 32).
The flame temperature is determined by the quantity and composition of the fuel. The test duration is 40 min.

Compliance criterion:
At the end of the test the light transmittance of the smoke must be at least 60%, unless stated otherwise in the individual specifications.

2.2.5.2 Def.-St. 02-711 (formerly NES 711)

Test setup and parameters:
The cables under test are burnt in test chamber using gas burners. Light transmittance is measured optically. The test setup is widely conform with figure 32. The flame temperature is not spedified. The cables under test must be fully burnt.
Test duration is 20 min.

Compliance criterion:
At the end of the test the light transmittance of the smoke must be at least 70 % / 40 % / 10 % depending on the product category, unless stated otherwise in the individual specifications.

Toxicity of the combustion gases

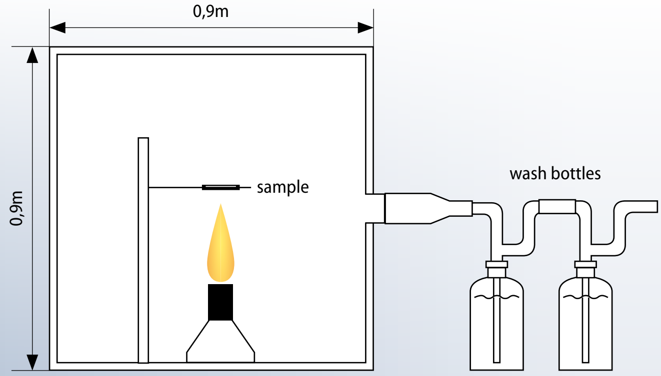


Figure 33: Toxicity test

2.2.6 Test procedures for the determination of the toxicity of the combustion gases

2.2.6.1 IEC 60695-7-1

Content:
This standard covers the general aspects of toxicity of smoke and combustion gases as well as the potential hazard (general guidelines).

2.2.6.2 Def.-St. 02-713 (formerly NES 713) / VG 95218-2 Method

Test setup and parameters:
The individual non-metallic materials of the cables are burnt in a test chamber (see fig. 33). The toxicity of the combustion gas is determined analytically for 14 substances. The flame temperature is 1150 °C ± 50 °C, with a test duration of 5 min.

Compliance criteria:
The toxicity values for the individual non-metallic materials of the cable are added according to their proportion of the total volume. The toxicity index for the overall cable must not exceed a value of 5.

Corrosiveness of combustion gases (absence of halogen)

Principles

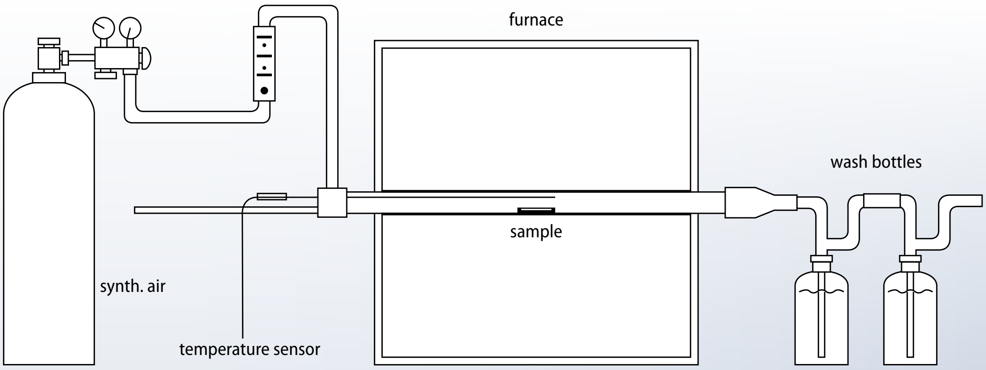


Figure 34: Test of the combustion gases on absence of halogen

2.2.7 Test procedure for the determination of the corrosiveness of the combustion gases (absence of halogen)

2.2.7.1 IEC 60754 / EN 50267

Content:
This standard covers the general aspects of corrosiveness of smoke and combustion gases dissolved in water or atmospheric moisture as well as the potential hazard (general guidelines).

2.2.7.2 IEC 60754-1 / EN 50267-2-1

Test setup and parameters:
A sample of between 0.5 g and 1.0 g is heated in a tube. The resulting gases are dissolved and tested for their halogen content (see fig. 34). The flame temperature is 800 °C ± 10 °C, with a test duration of 40 ± 5 min in total, thereof at least 20 min. at maximum temperature.

Compliance criterion:
The halogen content of all non-metallic materials must not exceed 0.5% or 5 mg/g.

2.2.7.3 IEC 60754-2 / EN 50267-2-2

Test setup and parameters:
A sample of 1 g of all non-metallic cable components is burnt in a furnace. The pH value and the conductivity of the combustion gases dissolved in water are measured (see fig. 34). The flame temperature is at least 935 °C, at a test duration of 30 min.

Compliance criteria:
The pH value of the washing water must be at least 4.3, the conductivity of the washing water must be at most 10 μS/mm.

2.2.8 Abbreviations of Standards

IEC	International Electrotechnical Commission
EN	European Norm
UIC	Union Internationale des Chemins de Fer (International Union of Railways)
VG	Verteidigungsgerätenorm (German Defence Equipment Standards)
MIL	Military Standard (USA)
BS	British Standard (GB)
Def.-St.	Defence Standard (GB)
NES	Naval Engineering Standard (GB)
UL	Underwriters Laboratories Inc. (USA)
NF	Norme Française (National Standard France) (F)
DIN VDE	Deutsche Industrienorm Verband der Elektroingenieure (D) (German Industrial Standard, Association of Electricians)

All dimensions given in mm.

2.3 Fiber bundles

In order to achieve narrower bending radii it is common to use fiber bundles consisting of fibers having small individual diameters. It is also possible to design receptacles having different cross-sectional areas or multi-branched optical waveguides. Sensor technology uses fiber bundles that radiate light via one part of the bundle and detect light via the other part.

2.3.1 Filling factor

Individual fibers are not able to fill the space at the ends of the receptacles completely and this results in losses in relation to the overall cross-sectional area of the receptacle because not all of the cross-sectional area is optically active. The fill factor η_{FF} describes the ratio of the optically active cross-sectional area to the total cross-sectional area of the bundle.

$$\eta_{FF} = N \times \pi \times (d_{core}/2)^2 / \pi \times (d_{bundle}/2)^2 \quad [2\text{-}11]$$

N is the number of individual fibers, d_{core} the diameter of one core and d_{bundle} is the total diameter of the bundle. If, for example, a bundle consists of 30 fibers each with an individual diameter of 80 µm, the optically active cross-section is calculated using the equation:

$$A = 30 \times \pi \times (80/2)^2 = 150796.45\ \mu m^2$$

Assuming that the bundle diameter is 500 µm, the total area is consequently equal to 196349.54 μm^2. This gives a fill factor of 0.77. The geometric losses based on this fill factor are therefore around 23 %. This loss is avoided with glass and plastic fibers by hot fusing the ends of the fiber bundle. As a result, the optically active cross-sectional area of the ends of the fibers is virtually 100 %.

2.3.2 Tapers and cones

A cone is a light-conducting rod or fiber rod having cross-sectional areas of different sizes at either end. Like a cross-section converter, this changes the aperture of a light ray. Using a cone, light from a larger optical waveguide can be launched into a smaller waveguide (application in endoscopy). Fiber cones can also be used as a magnifying or demagnifying image guide. A taper is an optical waveguide with a tapered cone.

When specifying the bending radii for cables, two limit bending radii are given: short-term and long-term. The short-term value is higher and intended for the installation of the cable. For the reasons given above it is known that the fiber can be bent further for a brief period and consequently this is specified as higher than the value given for permanent loading. In addition to the forces caused by bending during installation, it is assumed that other forces may act on the fiber as the result of torsion and tensile load and therefore considerably increase the total load.

2.3.3 Multi-branched fiber optic cables and splitters

Using bundle technology, a bundle of fibers can be split into two or more fiber bundles. This enables the light output to be split into partial light currents. The size of the partial currents is calculated from the number of individual fibers.

2.3.4 Cross-section converters

For some applications it will be necessary to convert a circular light ray into a rectangular light ray (spectrometry). Using bundle technology, this too can be achieved elegantly by providing one end of the bundle with a circular receptacle, with the other end being glued into a rectangular receptacle.

2.3.5 Image guides

Provided that the fibers are held in a particular order and are assigned a specific and identical location in the cross-section at both ends of the receptacle, it is possible to transmit images by means of these fiber optic cables. The number and diameter of the individual fibers determine the resolution of the image. In practice, such image guides are produced by drawing fibers bundles simultaneously. This then fixes the geometric position of each individual fiber.

2.3.6 Customised fiber optic cables

The diversity of optical fibers permits optical waveguides to be tailored to the customer's particular requirements. Numerous parameters can be modified over a wide range to meet the respective requirements resulting from a specific application. This covers not only geometrical-constructive parameters but also optical and material-specific parameters. Based on a brief technical description and a sketched diagram, a first suggestion for a solution is made which then serves as a basis for the detailed construction. These cables are then designed and produced in close collaboration with the customer.

2.3.7 Light-conducting rods and homogenisers

In principle, a light-conducting rod is a cylinder which is built in analogy to an individual fiber, where the diameter is so large that is has no bending properties anymore. A common application for this is the homogenising of the light transmitted through the fiber bundle. Diameters of about 10 mm are typical. The maximum length is limited to 1 m due to the production technique.

2.3.8 Fiber rods

Fiber rods are stiff fiber components that can be used as image guides. They are used whenever the image guide does not need to be flexible. The individual fiber rod comprises a number of fused individual fibers.

2.3.9 Length of fiber bundles

The length of a bundle of optical fibers can vary greatly. Light guide cones for instance are very short components that are used in endoscopy or as homogenisers. The maximum length of a bundle of fiber optic cables is limited by the transmission losses in the core on the one hand and by the production techniques on the other. The transmission properties depend on material and wavelength. The current limitations by production technique are at about 20 m for small fiber diameters (Fused silica glass fiber bundles) and at about 10 for large fiber diameters (multicomponent glass fibers; consult data sheets for details).
The transmission loss is described adequately by the so-called exponential equation [2-6] mentioned in chapter 2.1.2.2 (Beer's law):

$$T = 10^{(-\alpha \cdot L)/10\mathrm{dB})} \quad [2\text{-}12]$$

2.3.10 Temperature behaviour

Generally speaking, the fibers are glued into the end receptacles. The adhesive in this case is the limiting factor for the thermal stability of the optical waveguide. Ceramic-based adhesives are already in use nowadays for high-temperature applications of up to 400 °C. Higher application temperatures are also made possible through the use of hot-fused fiber ends.

2.3.11 Pressure

Pressure is important with respect to liquid, vacuum and pressure vessel applications. The receptacles and bonding processes are particularly important in this regard. In addition, the end of the bundle which is exposed to mechanical or chemical stress, can be protected by an optical window made of e.g. silica or sapphire which is built into a sleeve at the end of the bundle. AR coatings for the wavelength range of the application can be necessary in order to avoid unwanted effects caused by reflections at the interface.

2.3.12 Corrosion

The standard materials used in optical waveguides are resistant to many different liquids and gases. This is particularly true of silica. On the other hand, the right material must be chosen for the receptacles and the protective tubes to ensure good resistance to corrosion. Some cases require the window technique as described above.

2.3.13 Materials and bundle manufacturing

The possible materials for fiber optic cables must have certain physical properties. In particular, the material itself has to feature low transmission losses for specific wavelengths. The refractive index of the basic glass is another important criterion as it defines the numerical aperture of the fiber optic bundle.

Flexible fiber optic cables have a bundle structure that is created by drawing a rod-shaped preform and then wound sorted in a single layer on a large reel. The length of an individual fiber within the bundle corresponds with the circumference of the reel. The number of fibers within a bundle corresponds with the number of windings on the reel.

2.3.14 Glas

Glass is commonly used as the basis material for optical fibers. The term glass covers a wide range of materials (inorganic materials that are in a solid, amorphous state). For this reason, we will confine ourselves here to oxide glasses, like those used in numerous optical components, for example.
A general distinction is made between silica glass with optional doping (e.g. GeO_2) and fluoride glasses or compound glasses. The main constituent of such compound glasses is typically SiO_2. Further components are for example boric oxide and phosphorous oxide as glass formers as well as a number of glass modifiers such as the metal oxides Na_2O, K_2O, CaO, Al_2O_3, PbO, La_2O_3 etc.Glass modifiers are substances that are built into the surrounding glass network during the melting process and that can largely modify its material properties. The optical properties such as refractive index and transmission as well as mechanical properties such as thermal expansion can be specifically determined by these additives. Thus, the difference between the

2.4 Planar waveguides

refractive indices of core and cladding and therefore the numerical aperture of the waveguide can be adjusted. Values of 0.57 and above are possible.
The morate melting temperatures of composite glass permit low-cost production methods to be employed. Individual fiber diameters of between 30 and 100 µm are used for flexible fiber bundles. Even smaller diameters are used for image guiding. The minimum bending radius is obtained by multiplying the individual fiber diameter by a factor of 400–600.
Standard glass optical waveguides transmit light in a wavelength range from around 400 to 1700 nm. References to this are given in the data sheets LIR 120.3, LA1, LB60 and LW2

With a single optical fiber, initially the light can be guided from point A to point B. However, more complex optical functional elements will be required if additional optical functions are to be integrated into such a transmission link. It is better to stay with wave-conducting systems and not switch to the conventional field of free-space optics. Integrated optics offer a whole range of possibilities.

Wafer 1×16

Wafer 1×32

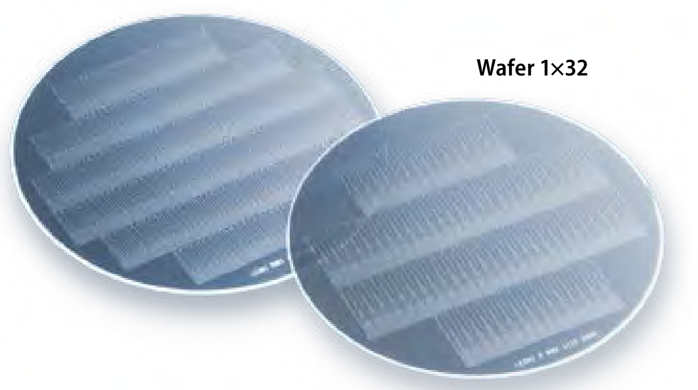


Figure 35: Masked wafer

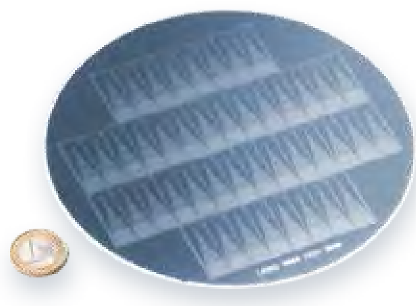
2.4.1 Planar optical splitter components

More complex waveguide structures can be integrated into a planar substrate using a variety of methods (optical chip, similar to an electronic chip). For this LEONI uses an ion exchange process in which the sodium ions of a special glass are substituted with silver ions. Thus, precise, structured variations in refractive index and hence precise waveguide structures can be created. The ion exchange takes place through openings in a metal film mask having a photolithographic structure. Structural details in the submicrometer range can be achieved in this way.
Standard components are singlemode waveguides for the near IR range as well as the telecommunications wavelength range. On request, LEONI also offers planar multimode waveguides with core diameters of up to 400 µm. These can be suited to a large number of fiber types.

Monolithic splitter components with up to 64 channels on the output side and 1 or 2 input channels are available, but designs with more than 2 input channels are possible.

The special properties listed below characterise the planar technique using ion exchange in glass:

- Miniature construction
- Lowest attenuation
- Wide bandwidth
- Lowest polarization dependence
- Good structural flexibility
- Highly reliable and environmentally stable



Wafer 1×64

2.4.2 Optical properties

The planar waveguide structures that have been optimised for use in telecommunications are suitable for transmitting over the entire standard spectral range from 1260 to 1650 nm and have very smooth spectral attenuation curves. The excess loss is less than 1 to 2 dB, depending on the splitting ratio. For specialised applications (e.g. in optical metrology) LEONI also offers customised planar waveguide components for wavelengths below the standard telecommunication range, right down to 450 nm.

2.4.3 Design of waveguide chips

An integrated optical chip with complex functionality can be designed with a small number of optical functional elements. The basic structures for singlemode waveguides (fig. 36) are the straight waveguide, the curved waveguide, the symmetric Y-splitter, the asymmetric Y-splitter, the 2x2 coupler, the 3x3 coupler, the star coupler and the multi-branched waveguide.

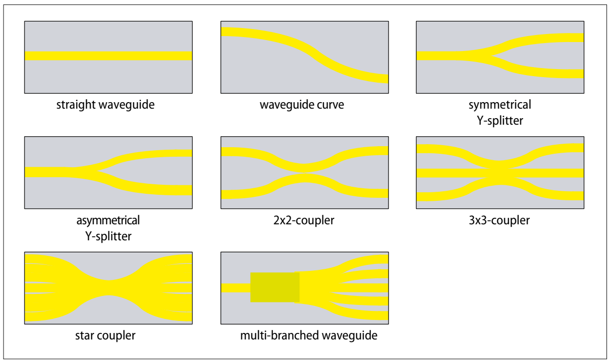


Figure 36: Basic structures of singlemode waveguides

Waveguide structures are designed with special software tools, which are attuned for the specific production process. The desired functional elements are connected in a design scheme. In a corresponding simulation program, the optical properties of the structure are calculated and the structural parameters are fitted in a series of optimization cycles until the desired functionality is achieved. The result of this calculation is a mask-type design which is used as a basis for the manufacturing of waveguide chips.

2.4.4 Structure of integrated optical components

The solid connection of input and output fibers with the pla nar optical waveguide chip requires a highly precise joining technology. As the cross-section of a singlemode fiber covers only 0.012 mm^2, the gluing of the individual fiber to the end face of the chip does not achieve sufficient mechanical stability. Therefore the fiber(s) are fixed between two carrier plates with one of the plates having precise V-shaped grooves for the neat adjustment of the fibers. Figure 37 shows a schematic diagram of such a V-groove fiber array. The V-groove material can be either photolithographically masked, anisotropically etched monocrystalline silicon or the same glass that has been used for the chip, with the V-grooves sawn out with a precision saw.

With the fibers laid into the V-groove array and the individual parts glued together, a mechanically stable block with a high-precision fiber arrangement is achieved. The displacement of the single fiber from the ideal position is < 1 µm even for large fiber arrays with up to 64 individual fibers. Finally, the end face is ground and polished, with the end surface at an angle of 8° to the fiber axis. The chip, too, is given a 8° angle at the end face so the compontent displays a return loss of ≥ 55 dB. The input and output array are positioned actively in front of the respective side of the chip and the end faces are glued together. With a suitable choice of adhesive a long-term-stable and environmentally stable component is obtained, as is shown in relevant tests, e.g. according to Telcordia 1209 and Telcordia 1221 standards.

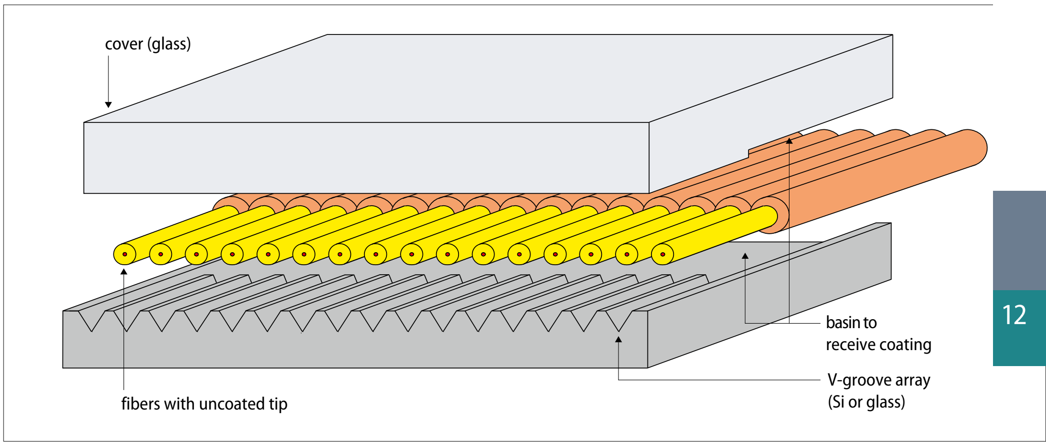


Figure 37: Structure of the fiber array for coupling into the chip

2.5 Switchable fiber components

For a number of applications a fixed lightguide path is not sufficient. Instead it is necessary to switch the light within the waveguide system. There are different approaches for the realization of such fiber optic switches. For very fast optical switches in the GHz-range, integrated optical waveguide switches have been developed based on electro-optical materials (e.g. lithium niobate monocrystal).

The optical properties of a waveguide structure such as a coupler (see chapter 2.4.3, fig. 36) can be modified by applying an electrical field to the effect that the guided light can be switched from one output channel to another. Still, electro-optical switches of this type are limited to a very small field of applications and fiber types (e.g. standard SM telecommunications fiber) and therefore are not described in this chapter.

In contrast, fiber switches based on micromechanical, micro-optical concepts can be fitted to the employed fiber a lot more flexibly. In the three following chapters three different switch designs covering more or less the complete bandwidth of available fiber types are introduced.

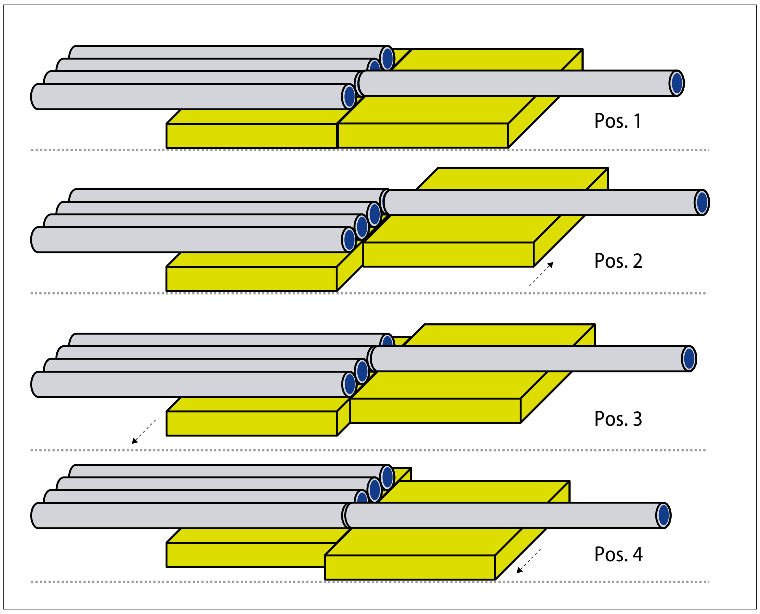


Figure 38: Switching principle of a fiber optic multimode switch

2.5.1 Switches for optical fibers with large fiber diameter (≥125 µm)

Fibers with large core diameters of 100 µm and above are suited for direct switching by the precise shifting of the fiber channels to be switched. Figure 38 shows the switching principle of such a 4-channel switch. (mol series).

The input fiber is mounted on a platform that is movable in a straight line in a right angle to the fiber direction. It resides on the same plane with the four output fibers that are likewise mounted on a platform parallel to each other and with the same optical axis as the input fiber.
By shifting the platforms, the input fiber can be positioned in front of each of the output fibers. Very small transition losses from the input to one of the output fibers can be achieved by limiting the gap between them to a few µm. In case switches with very low loss are used, additional AR-coatings of the fiber end faces can reduce coupling losses even more. The platforms carrying the fibers are moved to their positions using piezo benders. Piezo benders are designed similar to bimetallic elements and ensure that the shifting takes place only in the desired direction. The platform with the output fibers is hoisted exactly one fiber diameter (pitch) and the platform with the input fiber is hoisted exactly 2 fiber diameters (double pitch). The precise positions are ensured with the help of end stops. Insertion losses of such multimode switches are below 1 dB, typically at about 0.7 dB.

Fiber stiffness increases with the diameter. Therefore the mechanical components require a more solid design in order to handle the higher forces. This leads to an increase of switching time from about 5 ms for fiber diameters of 200 µm to about 20 ms for 800 µm.

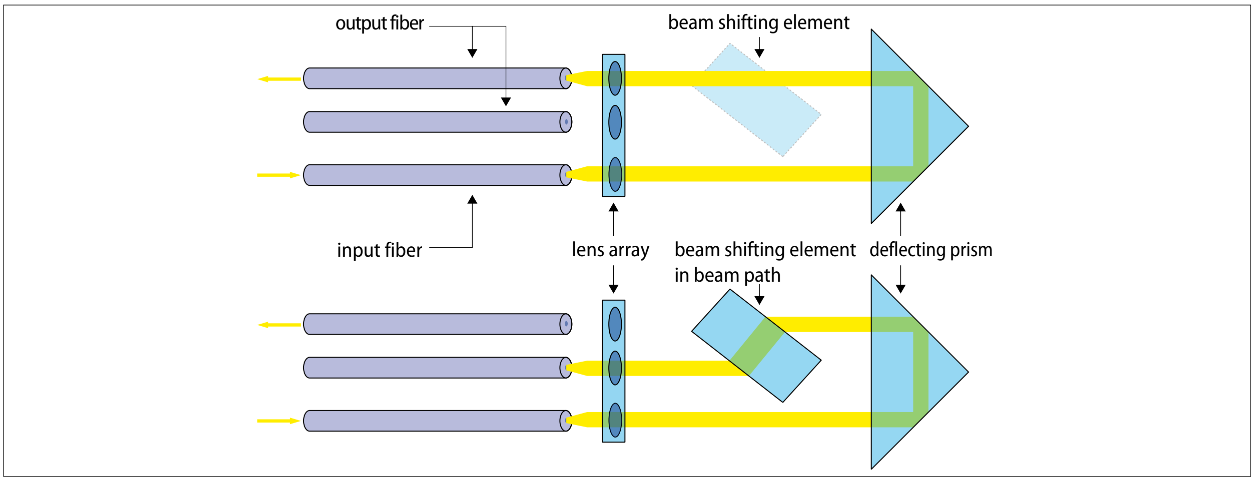


Figure 39: Switching principle of a switch for fibers with small diameter

2.5.2 Switches for optical fibers with small fiber diameter (≤ 125 µm)

Direct switching of fibers by axial shifting is less apt for fibers with small fiber or core diameters, as the needed precision can only be achieved with elaborate and expensive mechanics. For these fibers a different switching concept has been developed (eol series), in which the divergent light excited by the fiber is translated into a widened parallel beam with the help of a collimation lens. The actual switching takes place within the free space with the help of micro-optical elements.

Figure 39 shows the basic setup and the beam path of such a switch. As the figure shows, input and output fibers are located on the same side and are already fixed in a V-groove array (see chapter 2.4.4 and fig. 37) with high precision. In front of the fiber array a lens array is placed for the collimation/focusing onto the fiber core. The widened beam is led back via the deflecting prism, focused by one of the lens element of the lens array and coupled into one of the output fibers. If a beam shifting element is moved into the beam path using a piezo bender, the widened beam is correspondingly shifted into a parallel path and guided into a different output fiber. Up to four beam shifting elements can be combined in this kind of switch design, addressing up to 16 output channels.

In order to achieve the lowest possible loss, all optical surfaces within the free space receive AR coatings. Standard values for the insertion loss are below 1dB.

This switching principle is not only suited for standard but also for special fibers such as polarization maintaining fibers. In the case of PM fibers these must also be aligned within the array according to their polarization properties. This reduces the coupling of the two polarization modes capable of propagating through the fiber to a minimum. The polarization extinction ratio (PER) describes to which extent the polarization coupled into the fiber is maintained. Depending on fiber type and wavelength it ranges from 18 to 25 dB.

2.5.3 Fiber optic switches for large channel numbers

Fiber switches with large channel numbers can generally be obtained by cascading switches of the two design principles describes above. Unfortunately these cascaded switches feature the disadvantage that with increased cascading the attenuation values quickly rise and the size of the fiber guiding between the individual switches becomes noticeably larger.

An alternative switching principle developed by LEONI, which eliminates the drawbacks mentioned above, can be described with the help of an adjustable mirror driven by piezo-electronic actuators. The structure of such a switch is shown schematically in figure 40. Input and output fibers are arranged in a 2-dimensional array with a matrix-like structure. The end face of each fiber is permanently connected to a gradient-index lens (GRIN-lens) in a way that fiber and lens share the same optical axis.

Within the free space the light beam leaving the GRIN-lens is led to an adjustable mirror via a lens system, reflected and led back through the same lens system into the array of GRIN-lenses and fibers. The mirror can be tilted over the axes that are at a right angle to the optictal axis, so the reflected beam can be pointed at any fiber within the array. The tilting axes of the mirror are moved exactly to their respective position by piezo actuators, so that the adjustment of the tilt angle ensures efficient coupling of light with maximum precision into one of the output channels.
Switches with several 100 output channels can be realized with the above design. Compared to cascaded switches, fiber switches of this type show – within certain limits – next to no influence of the number of channels on the insertion loss.
For example, the insertion loss for a multimode switch with 100 channels (fiber type SI 100/125) is specified with ≤ 1.0 dB.

Application fields for this type of switches with a high channel number are sensor systems with a large number of measuring points that are sequentially read as for example in power plants or in the quality monitoring of optoelectronic components.

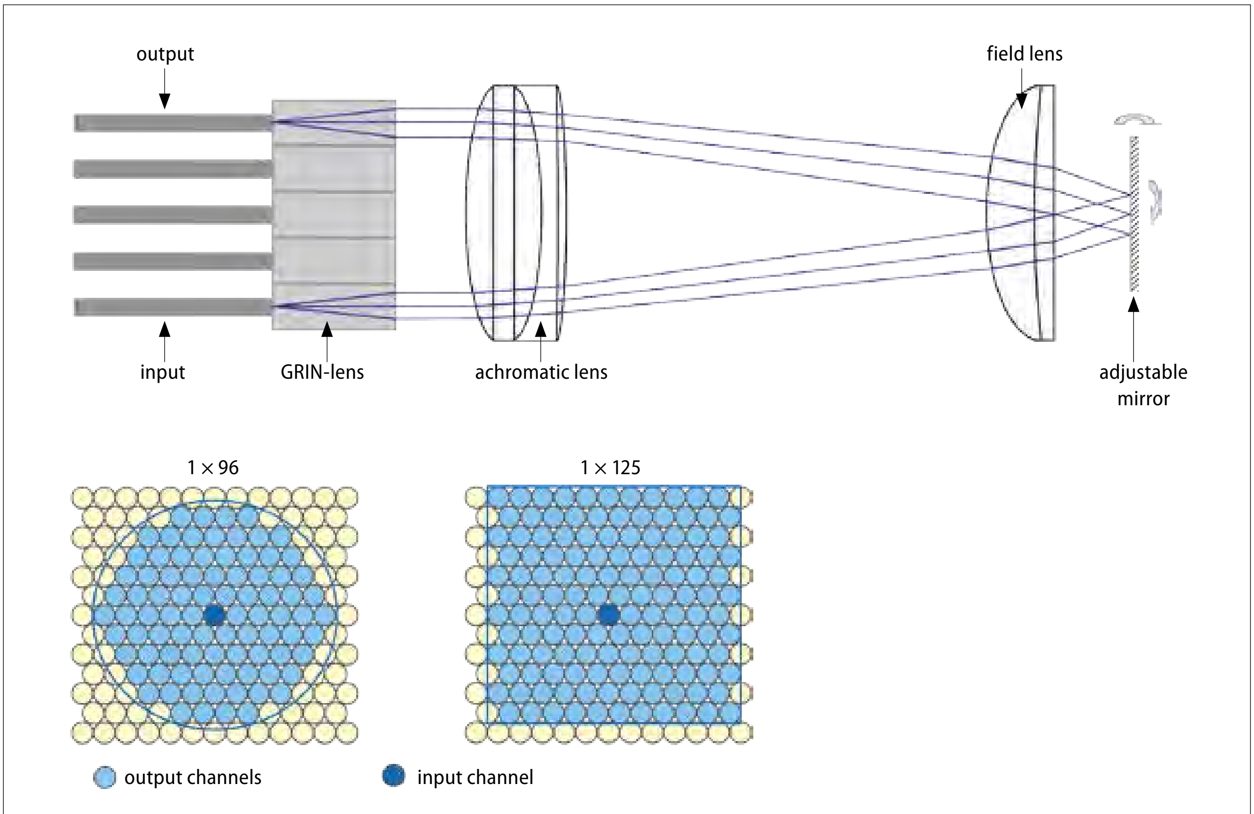


Figure 40: Fiber optic 4-channel switch a) schematic diagram b) fiber/GRIN-lens array

3. Selected application examples

The following chapter describes a few application examples in order to illustrate the diversity of technical solutions using optical fibers and waveguide components. Nevertheless, a detailed description of all examples would go beyond the scope of this overview on the one hand while on the other hand some aspects require confidentiality with respect to our clients.

3.1 Multimode cables for industrial data transmission

In optical telecommunications, cables with singlemode fibers prevail in the market and have by now developed into a global network with enormous transmission capacities. Still, for the transmission of data and information in the industrial sector, these singlemode fibers are often not optimally suited. The requirements for this kind of application have led to better customized cables with notably different features. As the distances to be covered are relatively short the amounts of data to be transferred are in a medium to high range, cables with multimode gradient-index fibers are a good solution. Standard applications are data connections between control units/rooms and production systems or energy facilities (see fig. 41)
Due to the sometimes extreme environmental conditions such as high temperature, corrosive vapours or liquids, strong electromagnetic fields or strong mechanical impacts or vibrations, it is necessary to operate sensitive electronics at an appropriate distance from sources of disturbances and in separated locations.

The fiber optic cables and optical components needed for transmission must meet the following requirements:

- high transmission capacity (up to 500 MHz – km at 1300 nm)
- flexible and easily modifiable cable laying
- simple cable assembly on the spot
  (high quality of the fiber end face without optical elaborate finishing, only by carving and breaking with a cleaver)
- use of standard plug connectors
  (e.g. SMA, ST, or SCRJ)
- single or multicore cable designs, fitted for the environmental requirements (flexibility, chemical resistance, temperature resistance, stable under high mechanical stress etc.)

These requirements can be met by a new type of fibers (product name FAST). Different from the PCF fibers used for such application in the past, this new fiber features a gradient-index profile with a core diameter of 62.5 µm enclosed with a pure silica cladding with 200 µm and a polymer-based coating material with a 230 µm diameter. Compared to the PCF fiber a notably higher transmission capacity is achieved without losing the positive handling properties of the PCF fiber. The cross-sections of FAST and PCF fibers are compared in figure 42.

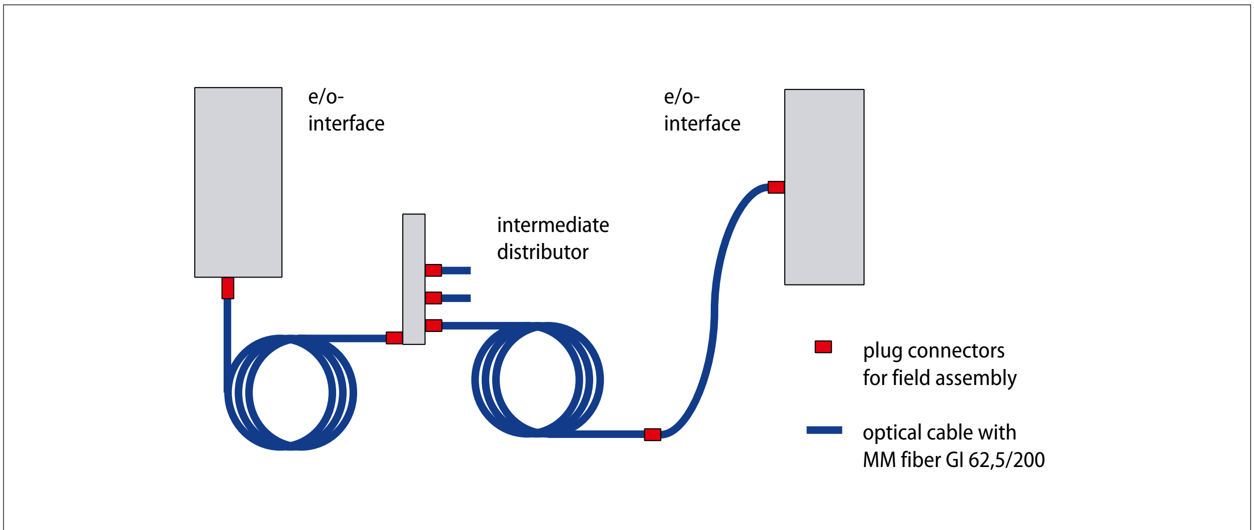


Figure 41: Optical data connection between control room and production system

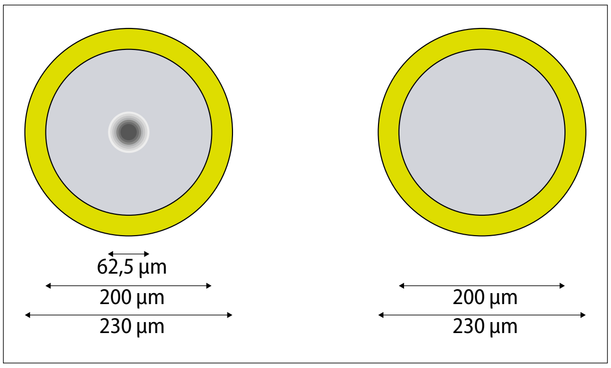


Figure 42: Comparison of the cross-sections of the FAST and PCF fiber types

With optical cables using the FAST fiber signals at 850 nm can still be transmitted with 1 Gbit/s over a distance of more than 350 m. This is about 10 times the value achieved with standard PCF. As the attenuation per km is significantly lower as well, the relatively large losses resulting from the use of the cleaving technique for connectors are more than compensated for.

3.2 Fiber optic probes for ophthalmic surgery

These days many surgeries for eye diseases are executed with the help of lasers. A distinction is made between surgeries at the surface and inside the eye. With surgical interventions inside the eye in particular the laser light has to be guided close to the affected area. This can be for example the retina or macula in the back of the eye. Surgery inside the eye is called vitrectomy.

Lasers with the wavelengths 532 nm, 577 nm or 810 nm are suited for intraocular interventions. For transscleral applications (using a suited cannula inserted through the sclera) a diode laser with 810 nm is required.

With the help of optical fibers the light energy needed for cutting and coagulating damaged tissue can be guided to the affected area inside the eye with pinpoint precision (laser spot). As the glass fiber itself does not have the afforded mechanical stability, handpieces are needed in which the fiber is fixed within a rigid metal cannula. Thus it can be led with high precision to the respective area inside the eye. These handpieces are called endoprobes. The laser fiber of an endoprobe ends flush with the tip of the front of the handpiece inserted into the eye. The tip consists of a polished metal tube that is needed in different diameters. The outer diameter is given in Gauge. (➔ dimension of the outer diameter of cannulae).

The laser spots generated with the endoprobe allow:

- sealing off retina holes or cracks, so that fluid cannot enter below the retina and loosen it;
- reattaching loosend retina to the tissue underneath or
- prophylactically coagulating the retina with the choroid after the removal of the vitreous body.

For the treatment of heavy eye injuries or after the removal of foreign objects that have penetrated the eye, endoprobes with 20G are used. For the excision of the vitreous body, the treatment of pull onto the retina or the removal of membranes endoprobes with 23G of 25G can be applied. Figure 43 show a schematic presentation of an intra-ocular surgery.

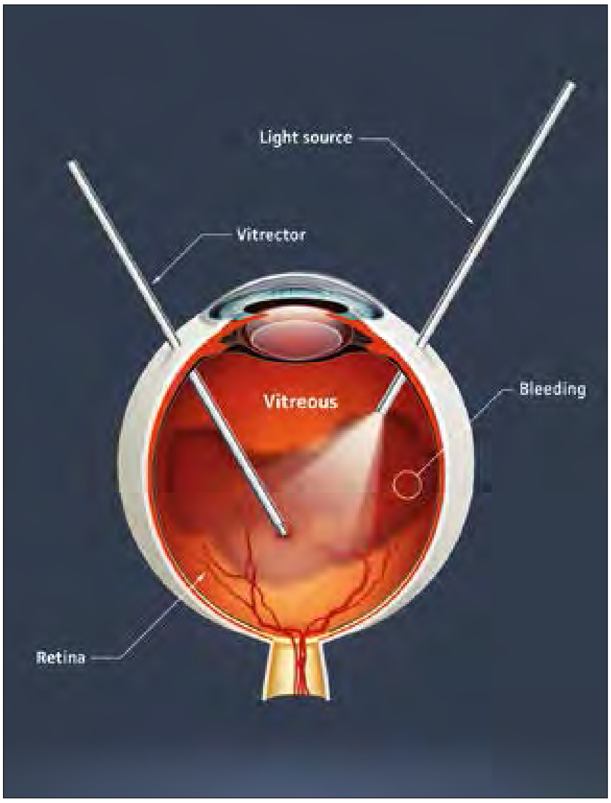


Figure 43: Schematic presentation of a vitreoretinal operation (vitrectomy with laser cannula and illumination cannula)

The handpiece (endoprobe) enabling the surgeon to precisely move the glass fiber(s) during the surgery has to be optimized for the different surgery types (see fig. 44). In this respect the correct combination of the materials used (sterilisability), the optical properties concerning light transmission and the well defined light guiding at the output end of the fiber are just as important as the ergonomic design. Where appropriate, a micro-optical element can be inserted for beam shaping (e.g. focusing or broadening) at the end of the fiber.
Endoprobes are produced with straight or bent tips. Adjustable endoprobes can be employed for surgery in the area of the peripheral fundus, mostly with 23G (see fig. 44: retracted with straight cannula for insertion into the eye with a so-called port; ejected with bent cannula for reaching into the peripheral fundus).

Figure 44: Adjustable endoprobes for intraocular laser surgery at the peripheral fundus

Next to the semiconductor lasers mentioned above, infrared solid-state lasers (NdYAG) are often used as surgery lasers. Suitable fibers are step-index fibers with core diameters between 100 and 600 µm and a low OH content. The thinner fibers in particular allow probe designs with a small outer diameter of 0.5 mm (25 Gauge [G]*), meaning only a small opening is necessary and the part of the sclera injured by the surgery will close itself without needing a suture. For the patient this means reduced stress and lowest complications during the healing process.

*) Gauge ➔ Measuring unit for the outer diameter of cannulae

diameter [mm]	**0.9**	0.8	0.7	**0.6**	0.55	**0.5**	0.45	0.4
diameter [G]	**20**	21	22	**23**	24	**25**	26	27

Standard diameters in ophthalmology are in **bold print**.
The measuring unit Gauge originally describes the diameter of a wire and is derived from the number of passes through the wire drawing machine.

3.3 Measuring system for the controlling of wind power stations

Optical fibers are not only used for the transmission of light signals. Certain properties of the fibers or of adequately modified fibers can be used for creating sensor elements or measuring probes. Fiber optic probes or sensors differ from conventional sensors especially because of their insensitivity to strong electromagnetic fields. This means they can be applied in situations where other sensors or probes would suffer from strong disturbances induced by such fields. In addition, many measuring procedures can be miniaturized and reduced in cost by using fiber optic or waveguide components.

A clear example for the superior properties of a fiber optic sen sor system can be given with the strain measuring system for the monitoring of mechanical stress on the rotor blades of wind turbines. With the help of this sensor system the rotor position as a function of wind pressure can be optimized in a way that highest power output can be achieved while at the same time high safety concerning mechanical overload is provided and mechanical damage can be identified at an early stage.

Specially prepared fibers with an optical grid inscribed into the core are the basis for the measurement of mechanical tension in the rotor blades. These sensor elements are called Fiber-Bragg-Gratings (FBG). A very elegant method of creating such a grating in a singlemode fiber is a writing procedure using an Excimer laser and a special light exposure apparatus to inscribe a highly precise grid into the fiber core. A pulsed laser beam is focused in a way that the light reaches maximum intensity exactly in the core and thereby alters the refractive index of the core material. The complete fiber is exposed to the light without the coating having to be removed.

By repeatedly shifting the fiber by one grid period the desired structure is achieved. This method provides gratings with highest precision while at the same time the mechanical stability is identical with that of the original fiber. Figure 45 illustrates the functioning of a FBG used as strain measurement probe.

In this equation n_1 is the refractive index of the fiber core, n_2 he refractive index of the core modified by the laser exposure and Λ is the grating constant. If the grating constant is altered through compressing or stretching, the wavelength of the reflected light is changed (see fig. 45).

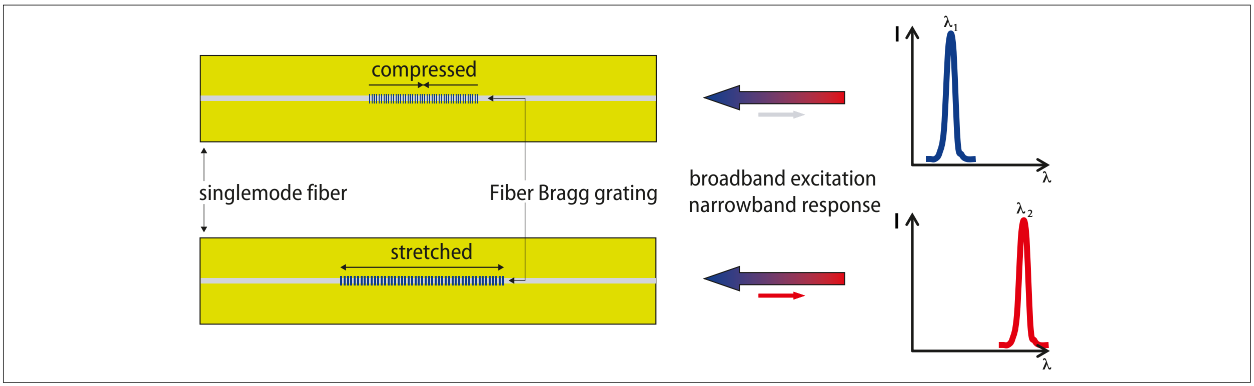


Figure 45: Functioning of an FBG sensor for the measurement of mechanical tension

The grating inscribed with a defined grating constant reflects the light of a single wavelength according to the grating constant. The remaining light passes the grating without significant interaction. The central wavelength λ_{Bragg} of the light reflected by the grating is described as follows:

$$\lambda_{Bragg} = (n_2 + n_1)/2 \cdot 2\Lambda \quad [3\text{-}1]$$

Figure 46 shows an FBG measuring system for a rotor blade of a wind turbine. Five or six of the FBG pads applied onto a carrier film are connected with each other by an optical cable. They are firmly fixed on the inside surface of the rotor blade or directly embedded into to the blade wall during the laminating procedure. Thus, a direct transfer of mechanical tension onto the grating is ensured.

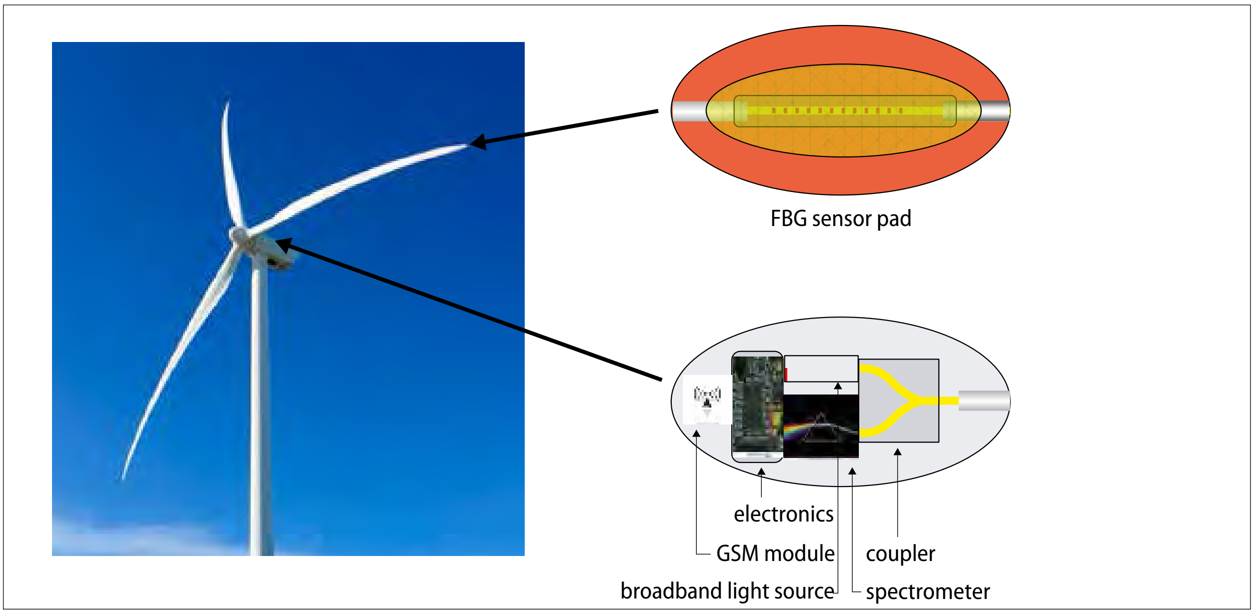


Figure 46: Measuring system for monitoring and controlling rotor blades

Principles

Each of these FBG pads shows a different grating constant, so the reflected light of each FBG is spectrally coded. The FBG fiber section of a pad is designed galvanically isolated to the effect that stretching and compressing depend only on thermic expansion and its signal is used for temperature compensation. At the end of the FBG sensor conductor an interrogator featuring a broadband light source, a spectrally resolving detector, an electronic signal evaluation and a signal transmitting element (e.g. GPS module) is placed.

The system monitors the deflection of the rotor blades and transmits the measured values to the control unit, that adjusts the rotor position to the wind pressure or triggers an alert if limiting values are exceeded and fixing is required. Analog systems also serve for the monitoring of the wind power plant's foundations and of the towers that reach heights up to 150 m.

3.4 In-house information and data transmission

In many housing complexes with a large number of rental units or in condominiums, cable distribution systems for the transmission of TV-channels from satellite trackings or from the house connection are installed. Yet copper-based cables have limited transmission capacities and no longer fulfil morn demands. By substituting copper cables with glass fiber cables, transmission capacities can be highly increased and thus be adapted to the increased demand.

In order keep the fiber system as close as possible to the traditional transmission structure, the copper-based system is translated almost identically into an optical system. The result is shown schematically in figure 47.

Figure 47: Fiber optic building distribution

In the future, FBG systems will be applied in numerous application fields, as they show considerable advantages compared to conventional electronic strain measurement systems. Particularly important features are: excellent EMC, serial system design and high stability in aggressive environments.

It is crucial that all users receive the signal with nearly equal optical power levels. The splitter components installed on every floor play a key role in this. As shown in figure 47, the light signal of the optical power I0 is distributed to 16 local loops via four distribution levels to the result that every participant receives 1/16 of the original power minus the usual power loss. Special asymmetrical splitter components have been developed for this. The structure of the first three splitters consists of a Y-splitter from which one channel is guided to the next splitter stage while the other is again branched into the four user ports.

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The first splitter divides the optical power in a 75/25 ratio approximately, with the channel with the higher power leading to the next distribution level. There the ratio is 66.66/33.33 approximately with a corresponding passing of the higher power and distribution of the remaining power to the user ports. At the third stage, about half of the available power is passed on to the last level, which consists of a symmetric 1:4 splitter distributing the remaining power to the four user ports of this stage.

The design of the asymmetrical Y-splitters in the first three sta ges also considers the attenuation losses within the subsequent cascade levels, so that at the first stage not exactly 75% are passed on but a slightly higher percentage in order to compensate for the high additional losses caused by the the following distribution levels. In correspondence to that the next two distribution levels show a likewise adjusted distribution ratio.

The fiber cables as well as the splitter components are of broad-band spectral design so future capacity increases can be transmitted not only at one wavelength but in a broad wavelength window with a number of individual wavelengths. A network of this type is called a transparent optical network; it offers high flexibility for future development.

3.5 Application fields for planar multimode waveguides

The manufacturing procedure for planar waveguides is particularly flexible regarding the adjustment of the waveguide's cross-section and numerical aperture. With single mode waveguides, about four areas are of interest concerning the waveguides cross-section:

- infrared 1250 nm – 1650 nm
- near infrared 760 nm – 980 nm plus the
- visible ranges 600 nm – 760 nm and 450 nm – 580 nm.

The planar waveguide's geometrical cross-section must be fitted for these wavelengths by using lithographic mask design. For the fiber areas mentioned above, the following approximate geometrical cross-sections arise: 9 µm, 5 µm, 4 µm or 3.5 µm. A numerical aperture < 0.12 must be observed for this. As the waveguides produced by ion diffusion diffuse into the glass substrate virtually stress-free, they are equally suited for the coupling with polarization-maintaining fibers. The waveguides do not influence the polarization of the guided light.

The variety of optical fibers with different cross-sections and numerical apertures is greater for planar multimode waveguides. Prototypes and small batches have already been produced for specific frequently requested fibers types.

	Diameter of the waveguiding layer [µm]	Fiber diameter [µm]	Numerical aperture
Step- and graded-index	50	125	0.22
Step- and graded-index	62.5	125	0.22
Graded-index	100	140	0.20
Step-index	105	125	0.20
Step-index	200	240	0.22
Step-index	200	230	0.37

Table 10: List of common multimode fiber types

For example, the fibers listed in table 10 are among these. The choice of the fiber type is typically associated with a certain application. 50µm and 62.5µm for instance are mainly used in datacom applications for in-house cabling of fast data connections (e.g. data centers). Fibers with 100µm diameter often occur as launch fibers in context with high-power applications, when the task is the production of laser combiners. The output side is frequently coupled to a larger cross-section, e.g. a 200 µm fiber. Other applications for 200µm fibers with high numerical apertures (e. g. PCF 0.37) can be found in sensor and measurement technology whenever the largest possible optical cross-section is needed in order to gather the light back into an evaluation unit. Generally speaking, a number of further fiber types can receive appropriate geometrical cross-sections and numerical apertures using the procedure of ion diffusion in glass. In addition to that the flexibility of lithographic design allows the manufacturing of diverse input and output combinations.

Based on the familiar approach the process of ion diffusion was modified in a way that in the first stage of diffusion an electric field is applied immediately. Part of the procedure is shown in figure 48. A glass wafer is coated with a metal mask using photolithographic structuring. .

By contacting the opposite wafer surfaces with galvanically isolated molten salts and applying an electric field, the silver ions of the molten salt on the masked side diffuse through the mask openings, thus creating areas inside the glass corresponding with the mask in which the sodium ions of the glass are replaced by silver ions. These modified areas feature a higher refraction index compared to the original glass and thereby create a lightwave guiding. The created refractive index profile corresponds with a gradient index profile.

The cross-section of the waveguide profile is, unlike that of a monomode planar waveguide chip, semicircular. To achieve circular cross-sections, two mirror symmetrical chips must be glued together.

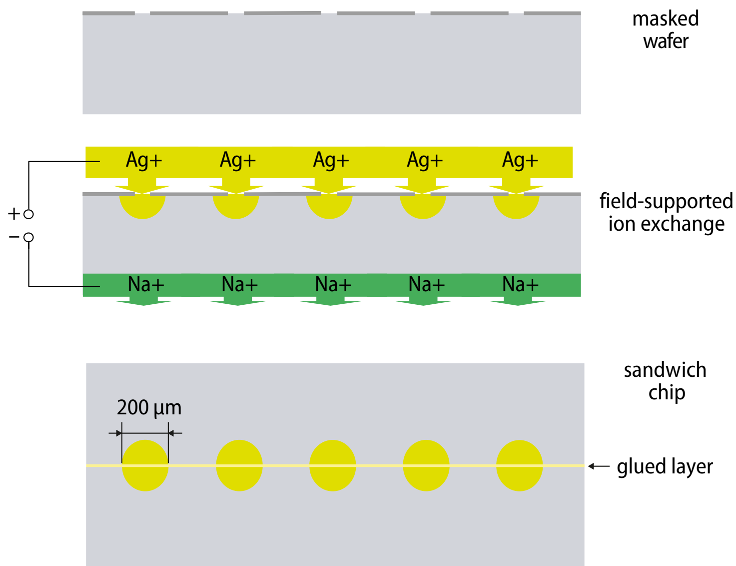

Figure 48: manufacturing process of multimode planar waveguides

4. Symbols and units of measure

Symbols/units of measure	Definition
a	attenuation in decibels
a′	attenuation in neper
a_{12} / a_{21}	levels in a backscatter diagram in decibels
B	bandwidth in GHz
BLP	bandwidth-length product in MHz km
CR	coupling ratio
d	radial misalignment in µm
D	directivity: cross-talk attenuation in decibels
D	chromatic dispersion in ps/nm
D_{CD}	coefficient of chromatic dispersion in ps/(nm·km)
D_{MAT}	coefficient of material dispersion in ps/(nm·km)
D_{WAV}	coefficient of wavelength dispersion in ps/(nm·km)
dB	decibel
dBm	unit of logarithmic power based on a milliwatt
dB/km	unit of attenuation coefficient
EL	excess loss in decibels
f	frequency in hertz
g	profile exponent
Gbit	gigabit
GHz	gigahertz
HWB	full width at half maximum
Hz	hertz
I	isolation in decibels
IL	insertion loss in decibels
km	kilometre
L	length in kilometres
m	metre
mW	milliwatt
n	refractive index
n_0	refractive index of the medium between the end faces
n_K	core refractive index
n_M	cladding refractive index
NA	numerical aperture
nm	nanometre

P	power in mW
P_0	injected power
PMD_1	first-order PMD coefficient
ps	picoseconds
r_K	core radius in µm
R	bit rate in Gbit/s
R	reflection
RL	return loss: reflection attenuation in decibels
s	axial misalignment in µm
S	increase in the coefficient of chromatic dispersion in ps/ (nm²·km)
S_0	increase in the coefficient of chromatic dispersion at the zero-dispersion wavelength
S_{0max}	maximum increase in the coefficient of chromatic dispersion at the zero-dispersion wavelength
T	pulse width
T	transmission
U	uniformity in decibels
v	propagation velocity in km/s
V	V number
V_C	normalised critical frequency
w	mode-field radius
Z	number of modes that can be propagated
α	attenuation coefficient in dB/km
α	angle between incident ray and perpendicular
α_{Grenz}	critical angle of total internal reflection
γ	tilt angle
η	coupling efficiency
λ	wavelength in nm
λ_0	zero-dispersion wavelength in nm
λ_{0max}	maximum zero-dispersion wavelength
λ_{0min}	minimum zero-dispersion wavelength
λ_C	cut-off wavelength in nm
$\Delta\lambda$	spacing between adjacent wavelengths
µm	micrometre
$\theta_{critical}$	maximum allowable angle of inclination to the optical axis
τ	group delay per unit of length in ps/km
$\Delta\tau_{CD}$	pulse spreading due to chromatic dispersion in ps
$\langle\Delta\tau\rangle$	PMD delay in ps

5. Physical definitions and formulae

5.1 General

Velocity of light in vacuum: c = 299,792.458 km/s

Velocity of light in any medium: $v = \frac{c}{n}$

Typical refractive index n ≈ 1.5: Propagation velocity in an optical fiber v ≈ 200,000 km/s.

5.2 Light propagation in a fiber

Snell's refraction law: $n_1 \cdot \sin(\alpha_1) = n_2 \cdot \sin(\alpha_2)$

Critical angle of total internal reflection: $\alpha_{critical} = \arcsin\left(\frac{n_M}{n_k}\right)$ with $n_K > n_M$

Numerical aperture: $NA = \sin(\theta_{critical}) = \sqrt{n_K^2 - n_M^2}$

Relative refractive index difference: $\Delta = \frac{(n_K^2 - n_M^2)}{2n_M^2} \Rightarrow NA = n_K\sqrt{2\Delta}$

5.3 Attenuation in waveguides

Drop in power along the optical fiber:

$P(L) = P_0 \cdot e^{-a'(L)}$ a´: attenuation in neper

$P(L) = P_0 \cdot 10^{-a(L)/10dB}$ a: attenuation in decibels

Power in dBm: $P = 10 \cdot \log\left(\frac{P[mW]}{1[mW]}\right)[dB]$

Attenuation in the optical fiber in decibels: $a = 10 \cdot \log\left(\frac{P_0}{P(L)}\right) = P_0 - P(L)[dBm]$

Attenuation coefficient in dB/m: $\alpha = \frac{a}{L}$

5.4 Coupling losses

Coupling efficiency: Ratio of the power P2 guided in optical fiber 2

to the power P1 provided by optical fiber 1 when coupling two optical fibers: $\eta = \frac{P_2}{P_1}$

Attenuation at the coupling: $a = 10 \cdot \log\left(\frac{P_1}{P_2}\right) = -10 \cdot \log(\eta)[dB]$

5.5 Intrinsic losses between multimode fibers (uniform mode distribution, step index profile or gradient index profile)

Mismatch of the core radii:

$$\eta = \left(\frac{r_{K2}}{r_{K1}}\right) \text{ for } r_{K1} \geq r_{K2};\ \eta = 1 \text{ for } r_{K1} \leq r_{K2}$$

$$a = 20 \cdot \log\left(\frac{r_{K1}}{r_{K2}}\right)[\text{dB}] \text{ for } r_{K1} \geq r_{K2};\ a = 0[\text{dB}] \text{ for } r_{K1} \leq r_{K2}$$

Mismatch of the numerical apertures:

$$\eta = \left(\frac{NA_2}{NA_1^2}\right)^2 \text{ for } NA_1 \geq NA_2;\ \eta = 1 \text{ for } NA_1 \leq NA_2$$

$$a = 20 \cdot \log\left(\frac{NA_1}{NA_2}\right)[\text{dB}] \text{ for } NA_1 \geq NA_2;\ a = 0[\text{dB}] \text{ for } NA_1 \leq NA_2$$

Mismatch of the refractive index profiles:

$$\eta = \frac{g_2(g_1+2)}{g_2(g_1+2)} \text{ for } g_1 \geq g_2;\ \eta = 1 \text{ for } g_1 \leq g_2$$

$$a = 10 \cdot \log\frac{g_2(g_1+2)}{g_2(g_1+2)}[\text{dB}] \text{ for } g_1 \geq g_2;\ a = 0[\text{dB}] \text{ for } g_1 \leq g_2$$

5.6 Extrinsic losses between multimode fibers (uniform mode distribution, step index profile or gradient index profile)

Radial misalignment, transverse misalignment or lateral misalignment d:

$$\eta = 1 - \frac{g+2}{g+1} \cdot \frac{2d}{\pi \cdot r_K};\ a = 2.76 \cdot \frac{g+2}{g+1} \cdot \frac{d}{r_K}\ [\text{dB}]$$

Step index fiber (g = ∞): $\eta = 1 - \frac{2d}{\pi \cdot r_K};\ a = 2.76 \cdot \frac{d}{r_K}\ [\text{dB}]$

Parabolic index fiber (g = 2): $\eta = 1 - \frac{8d}{3\pi \cdot r_K};\ a = 3.68 \cdot \frac{d}{r_K}\ [\text{dB}]$

Tilting about angle γ (in radian measure):

$$\eta = 1 - \frac{g+2}{g+1} \cdot \frac{2n_0 \cdot \gamma}{\pi \cdot NA};\ a = 2.76 \cdot \frac{g+2}{g+1} \cdot \frac{2n_0 \cdot \gamma}{NA}\ [\text{dB}]$$

Step index fiber (g = ∞): $\eta = 1 - \frac{2n_0 \cdot \gamma}{\pi \cdot NA};\ a = 2.76 \cdot \frac{n_0 \cdot \gamma}{NA}\ [\text{dB}]$

Parabolic index fiber (g = 2): $\eta = 1 - \frac{8n_0 \cdot \gamma}{3\pi \cdot NA};\ a = 3.68 \cdot \frac{n_0 \cdot \gamma}{NA}\ [\text{dB}]$

Axial misalignment, longitudinal misalignment s:

$$\eta = 1 - \frac{2(1-K)\cdot s\cdot NA}{r_K\cdot n_0}; a = 8.69\cdot\frac{(1-K)\cdot s\cdot NA}{r_K\cdot n_0}[dB]$$

Step index fiber (K = 1 – 2/3π) : $\eta = 1 - \frac{4\cdot s\cdot NA}{3\pi\cdot r_K\cdot n_0}; a = 1.84\cdot\frac{(1-K)\cdot s\cdot NA}{r_K\cdot n_0}[dB]$

Parabolic index fiber (K = 0,75): $(K = 0.75){:}\ \eta = 1 - \frac{s\cdot NA}{r_K\cdot n_0}; a = 2.17\cdot\frac{s\cdot NA}{r_K\cdot n_0}[dB]$

5.7 Intrinsic losses between singlemode fibers

Mismatch of the mode field radii:

$$\eta = \left(\frac{2w_1\cdot w_2}{w_1^2 + w_2^2}\right)^2; a = 20\cdot\log\left(\frac{w_1^2 + w_2^2}{2W_1\cdot w_2}\right)$$

$\eta = 1$ or $a = 0$ dB only if $w_1 = w_2$, otherwise there are always coupling losses!

5.8 Extrinsic losses between singlemode fibers

Radial misalignment d: $\eta = e^{-\frac{d^2}{w^2}}; a = 4.34\cdot\frac{d^2}{w^2}[dB]$

Tilting about angle γ (in radian measure): $\eta = e^{-\left(\frac{\pi\cdot n_0\cdot W\cdot\gamma}{\lambda}\right)}; a = 42.9\cdot\left(\frac{n_0\cdot w}{\lambda}\right)^2[dB]$

Axial misalignment s: $\eta = \frac{1}{1 + \left(\frac{\lambda\cdot s}{2\cdot\pi\cdot n_0\cdot w^2}\right)^2}; a = \left(\frac{\lambda\cdot s}{3\cdot n_0\cdot w^2}\right)^2[dB]$

5.9 Reflections

Reflection at a change in refractive index with normal incidence: $R = \left(\frac{n_1 - n_0}{n_1 + n_0}\right)^2$

Return loss: $RL = 10\cdot\log\left(\frac{P_1}{P_R}\right) = 10\cdot\log\left(\frac{1}{R}\right) = -10\cdot\log(R)[dB]$

Insertion loss due to reflection: $a = -10\cdot\log(1 - R)[dB]$

5.10 Levels in a backscatter diagram

Level at the transition from fiber 1 (w_1, n_1) to fiber (w_2, n_2):

$$a_{12} = 20 \cdot \log\left(\frac{w_1^2 + w_2^2}{2w_1 \cdot w_2}\right) + 10 \cdot \log\left(\frac{n_2}{n_1}\right) + 10 \cdot \log\left(\frac{w_2}{w_1}\right) [\mathrm{dB}]$$

Level at the transition from fiber 2 (w_2, n_2) to fiber 1 LWL 1 (w_1, n_1):

$$a_{21} = 20 \cdot \log\left(\frac{w_1^2 + w_2^2}{2w_1 \cdot w_2}\right) + 10 \cdot \log\left(\frac{n_1}{n_2}\right) + 10 \cdot \log\left(\frac{w_1}{w_2}\right) [\mathrm{dB}]$$

5.11 Fibers

Number of modes that can propagate: $Z \approx \frac{V^2}{2} \cdot \frac{g}{g+2}$

Normalized frequency: $V = 2 \cdot \pi \cdot NA \cdot \frac{r_K}{\lambda}$

Cut-off wavelength in a singlemode fiber: $\lambda_c = \frac{2 \cdot \pi \cdot r_K \cdot NA}{V_c}; V_c = 2{,}405$ if step index profile

The following applies to the mode field radius under standard operating conditions: $w \approx r_K \cdot \frac{2.6}{V} \approx \frac{1.3}{\pi} \cdot \frac{\lambda}{NA}$

Coefficient of chromatic dispersion:

$$\frac{\lambda \cdot S_{0max}}{4} \cdot \left[1 - \left(\frac{\lambda_{0max}}{\lambda}\right)^4\right] \leq D_{CD}(\lambda) \leq \frac{\lambda \cdot S_{0max}}{4} \cdot \left[1 - \left(\frac{\lambda_{0min}}{\lambda}\right)^4\right]$$

Coefficient of chromatic dispersion per **G.655.C-LWL:**

$$1 \left[ps/(nm \cdot km)\right] \leq |D_{CD}| \leq 10{,}0 \left[ps/(nm \cdot km)\right]$$

Coefficient of chromatic dispersion per **G.655.D-LWL**:

$$\frac{7.00}{90} \cdot (\lambda - 1460) - 4.20 \left[ps/(nm \cdot km)\right] \leq D_{CD}(\lambda) \leq \frac{2.91}{90} \cdot (\lambda - 1460) + 3.29 \left[ps/(nm \cdot km)\right]$$

for 1460 [nm] ≤ λ ≤ 1550 [nm]

$$\frac{2.97}{75} \cdot (\lambda - 1550) + 2.8 \left[ps/(nm \cdot km)\right] \leq D_{CD}(\lambda) \leq \frac{5.06}{75} \cdot (\lambda - 1460) + 6.20 \left[ps/(nm \cdot km)\right]$$

for 1550 [nm] ≤ λ ≤ 1625 [nm]

Coefficient of chromatic dispersion per **G.655.E-LWL**:

$$\frac{5.2}{90}\cdot(\lambda-1460)+0.64\left[\mathrm{ps/(nm\cdot km)}\right]\le D_{CD}(\lambda)\le\frac{4.65}{90}\cdot(\lambda-1460)+4.66\left[\mathrm{ps/(nm\cdot km)}\right]$$

for 1460 [nm] ≤ λ ≤ 1550 [nm]

$$\frac{3.30}{75}\cdot(\lambda-1550)+6.06\left[\mathrm{ps/(nm\cdot km)}\right]\le D_{CD}(\lambda)\le\frac{4.12}{75}\cdot(\lambda-1460)+9.31\left[\mathrm{ps/(nm\cdot km)}\right]$$

for 1550 [nm] ≤ λ ≤ 1625 [nm]

Coefficient of chromatic dispersion per **G.656-LWL**:

$$\frac{2.60}{90}\cdot(\lambda-1460)+1.00\left[\mathrm{ps/(nm\cdot km)}\right]\le D_{CD}(\lambda)\le\frac{4.68}{90}\cdot(\lambda-1460)+4.60\left[\mathrm{ps/(nm\cdot km)}\right]$$

for 1460 [nm] ≤ λ ≤ 1550 [nm]

$$\frac{0.98}{75}\cdot(\lambda-1550)+3.60\left[\mathrm{ps/(nm\cdot km)}\right]\le D_{CD}(\lambda)\le\frac{4.72}{75}\cdot(\lambda-1460)+9.28\left[\mathrm{ps/(nm\cdot km)}\right]$$

for 1550 [nm] ≤ λ ≤ 1625 [nm]

5.12 Bandwidth

Bandwidth-length product: BLP ≈ B·L.

Maximum achievable bandwidth: $B\approx\frac{0.4}{T}$ (T: pulse width)

5.13 Chromatic dispersion

• Coefficient of chromatic dispersion:

$$D_{CD}(\lambda)=D_{MAT}(\lambda)+D_{WEL}(\lambda)=\frac{d\tau(\lambda)}{d\lambda}[\mathrm{ps/(nm^2\cdot km)}]$$

Chromatic dispersion: $D(\lambda)=D_{CD}(\lambda)\cdot L[\mathrm{ps/nm}]$

Zero crossing point of chromatic dispersion: $D_{CD}(\lambda_0)=0$

Increase in the coefficient of chromatic dispersion:

$$S(\lambda)=\frac{dD_{CD}(\lambda)}{d\lambda}=\frac{d^2\tau(\lambda)}{d\lambda^2}[\mathrm{ps/(nm^2\cdot km)}]$$

Principles

Increase in the coefficient of chromatic dispersion at the zero-dispersion wavelength

$\lambda_0 : S_0 = S(\lambda_0)[ps/(nm^2 \cdot km)]$

Pulse spreading due to chromatic dispersion: $\Delta\tau_{CD} = HWB \cdot L \cdot D_{CD}$

Dispersion-limited length for externally modulated lasers with conventional modulation methods (Marcuse):

$$L \approx \frac{100{,}000}{R^2 \cdot D_{CD}}[km]; (R\,[Gbit/sec], D\,[ps(nm \cdot km)])$$

Dispersion tolerance: $DT = L \cdot D_{CD}$

5.14 Polarisation mode dispersion

First-order PMD coefficient with weak mode coupling: $PMD_1 = \frac{\langle\Delta\tau\rangle}{L}[ps/km]$

First-order PMD coefficient with strong mode coupling: $PMD_1 = \frac{\langle\Delta\tau\rangle}{\sqrt{L}}[ps/\sqrt{km}]$

Dispersion-limited length with strong mode coupling and conventional NRZ modulation:

$$L \approx \frac{1}{100 \cdot R^2 \cdot PMD_1^2}D$$

Series connection of numerous sections of sufficient length with strong mode coupling:

PMD value: $\langle\Delta\tau\rangle_{length} = \sqrt{\sum \langle\Delta\tau_i\rangle^2}$

PMD Coefficient: $PMD_{1length} = \sqrt{\frac{\sum [L_i \cdot (PMD_1^i)^2]}{\sqrt{L}}}$ with $\sum L_i = L$

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5.15 Couplers

Excess loss: $EL = 10 \cdot \log\left(\frac{P_1}{P_3+P_4}\right)[dB]$

Insertion loss: $IL = 10 \cdot \log\frac{P_1}{P_3}$ or $IL = 10 \cdot \log\frac{P_1}{P_4}[dB]$

Coupling ratio: $CR = \frac{P_4}{P_3+P_4} \cdot 100[\%]$

Return loss: $RL = 10 \cdot \log\frac{P_1}{P_{1r}}\ [dB]$

Cross-talk attenuation: $D = 10 \cdot \log\frac{P_1}{P_2}\ [dB]$

Uniformityt: $U = IL_{max} - IL_{min}\ [dB]$

Insulation: $I = 10 \cdot \log\frac{P_{3,\lambda_1}}{P_{3,\lambda_2}}$ bzw. $I = 10 \cdot \log\frac{P_{4,\lambda_2}}{P_{3,\lambda_1}}\ [dB]$

5.16 Dense wavelength division multiplexing

Connection between light frequency and wavelength in vacuum:

$$f(\lambda) = \frac{c}{\lambda}$$

Spacing between adjacent light frequencies Δf and adjacent wavelengths Δλ:

$|f(\lambda)| = \frac{c \cdot |\Delta\lambda|}{\lambda^2} => \Delta f = 100[GHz]$ corresponds with $\Delta\lambda \approx 0.8[nm]$ in the third optical window.

Standardised wavelength grid for a channel spacing of 100 GHz:

$$f_n = 193.1 + n \cdot 0.1[THz]$$

with n being a positive or negative integer (including zero).

Principles

Definition of terms

Term	Definition
Absorption	Loss of light radiation when passing through matter as the result of conversion into other forms of energy, e.g. heat energy. With photodiodes, the absorption is the process that destroys a photon as it arrives and through its energy elevates an electron from the valence band to the conduction band.
Acceptance angle	The largest possible angle within which light in the area of the fiber core can impinge on the end face, thus enabling it to be guided along the fiber core.
Add-Drop-Multiplexer	Functional module that makes it possible to add and drop partial signals to/from a multiplex signal.
Amplified spontaneous emission	Amplification of spontaneous events in an optical amplifier when the input signal is missing. Causes the characteristic noise of the fiber amplifier.
Analyser	Component for checking the state of polarisation of the light. Differs from a polariser only with regard to its function in the selected optical design. The analyser is located on the observer side.
APC connector	➔ HRL connector
Arrayed waveguide grating	Integrated, optical component that functions as a multiplexer/demultiplexer. Different input wavelengths cause differences in phase, permitting a channel separation similar to the classic diffraction grating.
Attenuation	Reduction in the optical signal power in a fiber due to scattering, absorption, mode conversion or at a coupling point (connector, splice). Attenuation is a dimensionless variable and is usually given in decibels.
Attenuation coefficient	Is the attenuation based on the length of the fiber. The attenuation coefficient is expressed in dB/km and is an important parameter for characterising a fiber.
Attenuation dead zone	Minimum spacing from a reflecting event in order to be able to measure the attenuation of a following event (OTDR measurement).
Attenuation-limited operation	Limitation of the achievable transmission link due to the effects of attenuation.
Avalanche photodiode	Receiver component that is based on the avalanche effect: the photoelectric current is amplified through carrier multiplication.
Backscatter attenuation	Ratio of incident optical power to the optical power scattered in the fiber, this optical power being capable of propagating in the reverse direction. Usually expressed in decibels (positive values).
Band gap	Energy gap between the valence band and the conduction band of a semiconductor. The band gap defines the operating wavelength of a semiconductor laser.
Bandwidth of the optical amplifier	Spectral range that is optically amplified (usually based on a 3-dB drop).
Bandwidth-length product	The bandwidth of an optical fiber is approximately inversely proportional to its length with negligible mode mixing and changing processes. The bandwidth multiplied by the length is therefore almost constant. The BLP is an important parameter for characterising the transmission properties of multimode fibers. With increasing length, the bandwidth decreases to a lesser extent. Consequently, a modified relationship applies to the BLP, in which a gamma factor is introduced.
Bend loss	Additional loss caused by micro- or macro-bending. An increased bend loss may be caused by the manufacture of the cable or by poor cable routing.
Bending radius	Two different definitions: 1. Minimum radius of curvature by which a fiber can be bent without breaking. 2. Minimum radius of curvature by which a fiber can be bent without exceeding a certain predetermined attenuation value.
Bidirectional	Propagation of optical signals in opposing directions along one optical waveguide.
Birefringence	Property by which the effective propagation velocity of the light wave in a medium depends on the orientation of the light's electrical field (state of polarisation).
Bit	Basic unit of information in digital transmission systems. The bit is equivalent to the decision between two states, 1 and 0. Bits are represented as pulses. A group of eight bits is equal to one byte.
Bit error rate	The ratio of the number of bit errors occurring on average in digital signal transmission over a relatively long period of time to the number of bits transmitted during this period. The bit error rate is a system-specific index of error probability. The standard requirement is a BER < 10–9. In modern SDH systems, a BER < 10–12 is required. The bit error rate can be reduced using forward error correction (FEC).
Bit rate	Transmission rate of a binary signal, also called the bit repetition rate.
CCDR	Cladding-to-core diameter ratio
Channel gain	The amplification of a signal with a specific wavelength in a DWDM system. It differs in general for different wavelengths.
Channel spacing	Frequency spacing or wavelength spacing between adjacent channels in a wavelength division multiplex system.
Chirp	Change in frequency (change in wavelength) of the laser diode as the result of modulation across the laser current.

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Term	Definition
Chirped fiber Bragg grating	Fiber Bragg grating with different distances between the reflecting sections. Is suitable for compensating dispersion.
Chromatic dispersion	Pulse spreading in the optical waveguide arising from differences in the propagation velocity of light at different wavelengths. Is the dominant type of dispersion in singlemode fibers and consists of material and waveguide dispersion.
Circulator	➔ Optical circulator
Cladding	The entire, optically transparent material of a fiber, except the core.
Coarse wavelength division multiplex	Wavelength division multiplexing method with channel spacings of 20 nm.
Coherence	Property of light of having fixed phase and amplitude relationships at a different time and space. A distinction is made between spatial and temporal coherence.
Coherent light source	Light source which emits coherent waves
Core	The central area of an optical fiber which serves as a waveguide.
Core-to-cladding eccentricity	Parameter for fibers which states how far the centre of the fiber core is from the centre of the overall fiber.
Coupler	Passive, optical component having multiple input and output ports for combining or dividing optical power or wavelengths.
Coupling efficiency	The ratio of optical power downstream of a coupling point to the power upstream from this coupling point.
Coupling length	Length of a fiber that is required to achieve an equilibrium mode distribution. It may be a few hundreds to a few thousands of metres.
Coupling loss	Loss that occurs when two fibers are joined. There is a distinction between fiber-related (intrinsic) coupling losses, which occur owing to various fiber parameters, and mechanically related (extrinsic) losses, which stem from the joining technique.
Coupling ratio	The percentage of power emerging from a certain output with respect to the total amount of emerging power in a coupler.
Critical angle	The angle of incidence of a light ray when passing from one substance with a higher refractive index into another substance with a lower refractive index, the angle of refraction being 90°. The critical angle separates the area of totally reflected rays from the area of refracted rays, i.e. the portion of rays guided along the fiber from those rays that are not guided.
Critical wavelength	➔ Cut-off wavelength

Cross-talk attenuation *Directivity*	Ratio of the injected power to the power emerging from the dark input on the same side of a coupler.
Crosstalk	Undesirable signals in a communication channel caused by the overcoupling of other channels.
Cut-back technique	Method for measuring attenuation in which the fiber to be measured is cut back.
Cut-off wavelength	Shortest wavelength at which the fundamental mode of a fiber is the only mode capable of being propagated. To ensure singlemode operation, the cut-off wavelength must be smaller than the wavelength of the light to be transmitted.
Decibel	Logarithmic power ratio of two signals
Demultiplexer	➔ Multiplexer
Dense wavelength division multiplex	Wavelength division multiplexing method with a very small channel spacing (typically: 0.8 nm).
DFB laser *Distributed feedback laser*	Laser diode with a spectral full width at half maximum of <<1 nm, by which very specific light wavelengths can be reflected by means of a series of undulating bumps on the semiconductor surface but with just one single resonance wavelength being amplified.
Dielectric thin-film filter	Optical filter which only allows a small wavelength range to pass through and all other wavelengths are reflected.
Differential mode delay	Difference in delay between the mode groups in a multimode fiber
Dispersion	Scattering of the group delay in a fiber. As a result of the dispersion, the light pulses spread out over time and thereby restrict the bit rate and/or the length of cable.
Dispersion compensation	The reversal of effects causing pulse spreading, e.g. chromatic dispersion or polarisation-mode dispersion.
Dispersion tolerance	Measure of the spectral properties of a transmitter. Permits the dispersion-limited length to be determined, provided the coefficient of chromatic dispersion of the fiber is known.
Dispersion-compensating fiber	Special fiber that can compensate for any dispersion that occurs, e.g. with a large negative coefficient of chromatic dispersion.
Dispersion-limited operation	Limitation of the achievable transmission link due to the effects of dispersion.
Dispersion-shifted fiber	Singlemode fiber with a shifted zero-crossing point of the coefficient of chromatic dispersion (as per ITU-T G.653). This fiber has minimum chromatic dispersion as well as minimum attenuation at 1550 nm.
Dopant	Material with which the refractive index can be changed.

Term	Definition
Doping	Intentionally adding small quantities of a different substance to a pure substance in order to alter its properties. For example, the increased refractive index of a fiber core is achieved by doping the basic substance (silicon dioxide) with germanium dioxide.
Double heterostructure	Sequence of layers in an optoelectronic semiconductor component, in which the active semiconductor coating is sandwiched by two jacket layers with a larger band gap. With laser diodes, the double heterostructure confines the charge carriers and creates a fiber in the active zone.
Increase in dispersion coefficient *Zero-dispersion slope*	Increase in the coefficient of chromatic dispersion at a particular wavelength, e.g. at the dispersion zero-crossing point.
Insertion loss	Loss of power that results from inserting a component into the previously continuous path.
Insertion loss technique	Method for measuring attenuation in which the measurement object is inserted into a reference section.
Electroabsorption modulator	Component which blocks an optical signal or allows it to pass, depending on whether or not a voltage is applied. Used for the amplitude modulation of an optical signal.
Electromagnetic wave	Periodic change of state of an electromagnetic field. In the range of optical frequencies these are called light waves.
Emitter	Semiconductor component in which an applied electric current generates an emission in the visible or near infrared range of light. A distinction is made between an edge emitter and a surface emitter.
Equilibrium mode distribution	Energy distribution in a multimode fiber which stops changing after passing along a sufficient length (coupling length) and is independent of the original mode distribution at the coupling point. Higher-order modes have a comparatively lower power than lower-order modes. Reproducible attenuation measurements are only possible if equilibrium mode distribution prevails in a multimode fiber.
Equipment dead zone	Distance from the base to the end of the falling edge at the start of the section to be measured (OTDR measurement).
Er^+ fibers	Fibers with an erbium-doped core for use in optical amplifiers
Event dead zone	Minimum spacing between two reflecting events in order to be able to measure the location of the second event (OTDR measurement).
Excess loss	Sum of the optical power leaking out of all ports of a coupler in relation to the input power in dB.
External modulation	Modulation of a light carrier outside the actual light source (e.g. laser) using a special modulator (e.g. a Mach-Zehnder modulator). Thus, the light source itself remains unaffected by the signal and can be constant in terms of its frequency and power or regulated independently of the modulated signal.
Fabry-Perot laser	Simple type of semiconductor laser that makes use of the Fabry-Perot resonator effect. Has a relatively large spectral full width at half maximum (a few nm).
Fabry-Perot resonator	Space defined on two sides by flat, parallel mirrors. A flat wave injected perpendicularly to the mirror faces travels back and forth multiple times between the mirrors. A standing wave of high intensity forms in the resonator (resonance) if twice the distance between the mirrors is equal to a multiple of the light's wavelength.
Faraday effect	The plane of oscillation of linearly polarised light is twisted if a magnetic field is applied in the direction of the light. The proportionality constant between the magnetic field and the angle of rotation per light path travelled in the field is the Verdet constant. The Faraday effect is used in the design of a Faraday rotator.
Fiber	Term for a round optical waveguide.
Fiber amplifier	Uses a laser-like amplification effect in a fiber, whose core is highly doped with erbium, for example, and is stimulated with an optical pump power of a specific wavelength.
Fiber bandwidth	The frequency at which the value of the transfer function (based on the optical power) of a fiber decreases to half its value.
Fiber Bragg grating	A spectral filter that is based on the change in refractive index in the fiber core. A key element of components such as optical multiplexers/demultiplexers, dispersion compensators or EDFAs with a flattened amplifier curve.
Fiber buffer	Consists of one or more materials that are used for protecting the individual fibers from damage and provide mechanical isolation and/or mechanical protection.
Fiber curl	Inherent curvature of a fiber
Ferrule	Guide pin for fiber connectors in which the fiber is secured.
Field diameter	➔ Mode field diameter
Four-wave mixing	Formation of combination frequencies (totals, differences) of optical signals through nonlinear optical effects. Occurs as interference in a fiber (consequence: nonlinear crosstalk in DWDM systems) and is used for shifting the frequency of optical signals.
Fresnel loss	Attenuation as the result of Fresnel reflection
Fresnel reflection	Reflection as the result of a change in the refractive index

Term	Definition
Full width at half maximum	Width of a distribution curve (time, wavelength) at which the power drops to half its maximum value.
Fundamental mode	Lowest order mode in a fiber with an approximately Gaussian field distribution. Identified by LP01 or HE11.
Fused fiber splice	Is the connection of two fibers by melting the ends.
Fused silica glass	A synthetically produced glass with a silicon dioxide content >99 %, base material for glass fibers.
Gain	Ratio between the mean output power and input power, omitting the contributions made by amplified spontaneous emission.
Gamma factor	Describes the relationship between the bandwidth and distance that can be spanned.
Germanium dioxide GeO_2	A chemical compound that is the most common substance used in the manufacture of optical fiber for doping the fiber core.
Ghosts	Interference in the backscatter diagram as the result of multiple reflections on the fiber link
Gradient index profile	Refractive index profile of a fiber that continually decreases across the cross-sectional area of the fiber core from the inside outwards.
Gradient index fiber	Fiber with a gradient index profile
GRIN lens	Glass rod a few millimetres in diameter which has a refractive index curve like that of a parabolic index fiber (profile exponent ≈ 2). The light propagates in an approximately sinusoidal shape. In fiber optic technology, GRIN lenses are used imaging elements or in beam splitters.
Group index	Quotient from velocity of light in vacuum and propagation velocity of a wave group (group velocity), of a light pulse in a medium.
Group velocity	Propagation velocity of a wave group, e.g. of a light pulse, which is composed of waves having different wavelengths.
HCS, HPCS, PCF, PCS	Fibers with a silica/silica or plastic core and hard or normal polymer cladding, which is tightly bonded to the core.
Hertz	Unit of measure for frequency or bandwidth; corresponds to one oscillation per second.
High-power connector	Special connector design which permits the transmission of very high power densities, which can occur particularly in DWDM systems.
HRL connector	Connector with very high reflection attenuation, which is ensured through physical contact in combination with angled polishing.
Immersion	Medium with a fluid adapted approximately to the refractive index of the fiber core. The immersion is suitable for reducing reflections.
Infrared radiation	Range of the spectrum of electromagnetic waves from 0.75 µm to 1000 µm (near infrared: 0.75 µm to 3 µm, medium infrared: 3 µm to 30 µm, far infrared: 30 µm to 1000 µm). Infrared radiation is invisible to the human eye. The wavelengths for optical communications are in the near infrared range (0.85 µm, 1.3 µm, 1.55 µm).
Intensity	Power density (power per unit area) on the radiating area of a light source or on the cross-sectional area of a fiber (unit of measure: mW/µm²).
Interference	Overlapping of waves: addition (constructive interference) or cancellation (destructive interference)
Isolation	Ability to suppress undesirable optical energy that occurs in a signal path.
Isolator	➔ Optical isolator
Kerr effect	Non-linear effect when subject to high intensities: the refractive index changes as a function of the power.
Laser	Acronym for Light Amplification by Stimulated Emission of Radiation. A light source that generates coherent light through stimulated emission.
Laser chirp	Displacement of the central wavelength of a laser during one single pulse.
Laser diode	Transmitter diode based on semiconductor materials which emits a threshold current of coherent light (stimulated emission).
Launch angle	Angle between the propagation direction of incident light and the optical axis of the fiber. For the light to be guided in the fiber core, the launch angle must not exceed the acceptance angle.
Launch conditions	Conditions under which light is injected into an optical waveguide. They are important for the further dispersion of the optical power in the optical waveguide.
Launch efficiency	Indicates how efficiently an optical transmitter can be coupled onto an optical waveguide. The launch efficiency is the ratio between the optical power conducted by the fiber and the optical power output by the transmitter.
Launching fiber	Fiber connected upstream of the fiber to be measured.
Lead-out fiber	Fiber connected downstream of the fiber to be measured.
Leaky mode	Type of wave that is attenuated through radiation along the fiber and is in the marginal area between guided modes of a fiber and the non-propagatable light waves.
Light-emitting diode	A semiconductor component that emits incoherent light by means of spontaneous emission.
Light injection and detection	System for adjusting fibers in splicers using bending couplers.

Term	Definition
Limited phase space method	Method to reduce the phase space volume in a multimode fiber with the aim of achieving an approximate equilibrium mode distribution.
Low-water-peak fiber	Singlemode fiber with a low attenuation coefficient in the wavelength range between the 2nd and 3rd optical window by reducing the OH peak at the wavelength of 1383 nm.
Mach-Zehnder interferometer	A device that splits the optical signal into two optical paths of different, generally variable path lengths and joins them together again. The two rays are then able to interfere. The Mach-Zehnder interferometer is often used as an external intensity modulator.
Macrobending	Macroscopic axial deviations in a fiber from a straight line (e.g. on a delivery spool). Can lead to local attenuation, particularly in singlemode fibers if certain radii of curvature are exceeded.
Material dispersion	Pulse spreading due to the dependence of the wavelength on the refractive index. The light from the transmitter, which is injected into the fiber, always has an infinite spectral width. Each portion of wavelength corresponds to a different refractive index of the glass and thus also to a different propagation velocity. Material dispersion is usually negligible in a multimode fiber.
Microbending	Microscopic bends or unevenness in the fiber which give rise to losses by injecting light that is guided in the core into the cladding.
Microelectromechanical system	Component that contains moving mechanical parts to guide light. Two-dimensional and three-dimensional configurations are possible.
Modal dispersion	The dispersion in a fiber caused by the superimposition of modes having different delay times at the same wavelength. Dominant type of dispersion in a multimode fiber.
Mode field diameter	Measure of the width of the approximate Gaussian light distribution in a singlemode fiber. It is the distance between the points at which the field distribution drops to the value 1/e ≈ 37 %. Since the eye records the intensity of the light, the mode field diameter corresponds to a drop in intensity, with respect to the maximum value, to 1/e2 ≈ 13.5 %.
Mode filter	Component for implementing an approximate equilibrium mode distribution. It causes radiation of higher-order modes.
Mode mixing	Gradual energy exchange between the various modes during the propagation along the multimode fiber.
Mode scrambler	Component for implementing an equilibrium mode distribution in a multimode fiber.
Modes	Solutions to Maxwell's equations, taking into account the constraints of the waveguide. They correspond to the possible propagation paths in the fiber.
Modulation	A selective change in a parameter (amplitude, phase or frequency) of a harmonic or discontinuous carrier in order to transmit a message by this carrier.
Mono-mode fiber	➔ Singlemode fiber
Multimode fiber	Fiber whose core diameter is large compared with the wavelength of the light. Numerous modes can be propagated in it.
Multipath interference	Interference as a result of multiple reflections on one optical path. These reflections are phase-shifted within the detected signal, which results in pulse spreading and a deterioration of the system properties.
Multiplexer	Functional unit that receives a series of transmission channels and bundles the signals for transmitting in a common channel. At the end of a section, a demultiplexer separates them back into the original signals. A distinction is made between various multiplexing methods, e.g. time-division multiplexing or wavelength-division multiplexing.
Noise due to multiple reflection	Noise of the optical receiver caused by interference of delayed signals through multiple reflections at points along the length of the fiber.
Noise figure	Ratio of the signal-to-noise ratio at the input to the signal-to-noise ratio at the output of the optical amplifier. As each amplifier always adds its own noise, the noise figure is always >1. It is a power ratio and is given in decibels. At best, the noise figure is equal to 3 dB.
Nonlinear optical effect	The dielectric material properties change with a high energy density in the fiber core (generally speaking, in a strong electromagnetic field). The effects, which are weak per se, increase as a result of the generally long sections that the optical signals travel in fiber.
Nonlinearities	Collective term for nonlinear optical effects: FWM, SBS, SPM, SRS and XPM.
Non-return to zero	Method for modulating amplitudes in which the on and off levels are maintained for an entire bit interval.
Non-uniformity of amplification	Change in the amplification as a function of the wavelength. The slope of the amplification profile is expressed in dB/nm.
Non-zero dispersion shifted fiber	Fiber with a small, non-zero coefficient of chromatic dispersion in the wavelength range of the 3rd optical window. This fiber is used in multichannel (DWDM) systems and is suitable for reducing the effect of four-wave mixing.

Term	Definition
Numerical aperture	The sine of the acceptance angle of a fiber. The numerical aperture is dependent on the refractive index of the core and of the cladding. An important parameter for characterising a fiber.
Optical add-drop multiplexer	Component which drops one of the signals from a signal burst (consisting of multiple wavelengths), which is travelling along a fiber, and injects a new signal of the same wavelength.
Optical amplifier	Component which permits direct amplification of numerous wavelengths at the same time. Is particularly important in DWDM systems.
Optical attenuator	Component that attenuates the intensity of the light passing through the component.
Optical axis	Axis of symmetry of an optical system
Optical channel	Optical wavelength band for optical wavelength-division multiplex transmission.
Optical circulator	Non-reciprocal, passive optical component which guides an optical signal from port 1 to port 2, another signal from port 2 to port 3 and successively to all other ports. The circulator operates like an isolator but in the opposite direction.
Optical communications	Method of transmitting messages using light.
Optical cross-connect	Optical switch with N inputs and N outputs. It can guide an optical signal, which enters at any input port, to any output port.
Optical glass	Composite glass with a silicon dioxide content of approx. 70% and additional components, such as boric oxide, lead oxide, calcium oxide, etc.
Optical isolator	Non-reciprocal, passive optical component with low insertion loss in the forward direction and high insertion loss in the reverse direction. The optical isolator is capable of greatly suppressing power return loss. The main part of an optical isolator is the Faraday rotator, which makes use of the magneto-optic effect.
Optical return loss	➔ Return loss
Optical time domain reflectometer	A measuring instrument which measures light scattered and reflected in the fiber and consequently provides information about the properties of the section installed. The optical time domain reflectometer permits the measurement of attenuation, attenuation coefficients, defects (connectors, splices, interruptions), their attenuation and return loss as well as their locations in the fiber.
Optical waveguide *fiber, fibre*	Dielectric waveguide whose core is made of optically transparent material of low attenuation and whose cladding is made of optically transparent material with a lower refractive index than that of the core. It is used for transmitting signals by means of electromagnetic waves in the range of the optical frequencies.
Optoelectronic circuit	Functional module that technically combines electronic, optical and optoelectronic components on a shared substrate (GaAs, InP).
Optoelectronic regenerator	Intermediate amplifier in fiber sections which amplifiers the signal using optoelectronic conversion, regenerates it in terms of time, pulse shape and amplitude and converts it back to an optical signal (3R regenerator: retiming, reshaping, reamplification). 2R function at low bit rates (no retiming). 1R function: signal amplification only.
Outer modulation	➔ External modulation
Parabolic index fiber	Fiber with a parabolic refractive index profile across the cross-section of the core
PC connector	Connector with physical contact at the connector end face
Phase refractive index	Quotient from velocity of light in vacuum and phase velocity
Phase velocity	Propagation velocity of a flat (monochromatic) wave
Photodiode	Component that absorbs light energy and produces a photoelectric current
Photon	Quantum of an electromagnetic field, 'light particle'
Photonic crystal fibers	Special two-dimensional shape of a photonic crystal. Fiber with a plurality of microscopic holes parallel to the optical axis of the fiber. The mode guidance is achieved by deliberately installing 'defects'.
Photonic crystals	Periodic structures with dimensions in the order of magnitude of the wavelength of light or below. Area of research of (nano-)optics, where considerable impetus is expected for the development of future, signal-processing functional elements.
Pigtail	Short section of a fiber optic cable having a connector for coupling optical components to the transmission link.
Plastic optical fiber	Optical fiber consisting of a plastic core and cladding with a comparatively large core diameter and a large numerical aperture. Inexpensive alternative to a glass fiber for applications with low requirements with regards to length and bandwidth.
PIN photodiode	Receiver diode with predominant absorption in a space-charge region (i-zone) within its pn junction. Such a diode has a high defective quantum efficiency, but unlike avalanche photodiodes no internal current amplification.
Planar waveguide	Waveguide structure that is created on or at the surface of substrates.
Polarisation	Property of a transversal wave of retaining certain oscillating states. Polarisation is proof of the transversal nature of an electromagnetic wave.

Term	Definition
Polarisation-dependent attenuation	The difference (in dB) between maximum and minimum attenuation values as the result of a change in the state of polarisation of the light propagating through the component.
Polarisation mode dispersion	Dispersion arising from delay differences between the two modes which are oscillating orthogonally to each other. Polarisation mode dispersion only occurs in singlemode fibers. It only has any significance at high bit rates and with a drastic reduction in the chromatic dispersion.
Polariser	Component for producing linearly polarised light (polarising filter, polarising prism). Differs from an analyser only with regard to its function in the selected optical design. The polariser is located on the side of the light source.
Power-law index profile	Refractive index profile whose radial characteristic is described as a power of the radius.
Polymer optical fiber	➔ Plastic optical fiber
Preamplifier	Optical amplifier that is used directly upstream of the receiver.
Preform	Glass rod comprising core glass and cladding glass which can be drawn to form a fiber.
Primary coating	Is the coating applied directly to the cladding surface when manufacturing the optical fiber. It may comprise a number of layers. This preserves the integrity of the surface.
Principal states of polarisation	The two most orthogonal polarisation states of a mono-chromatic light ray, which are injected into a fiber (input PSP) and propagate along the fiber without any pulse spreading or distortion.
Profile aligning system	System for aligning fibers in splicers with the aid of an image of the fiber structure on a CCD line.
Profile dispersion	Dispersion arising from an unsatisfactory adaptation of the profile exponent of a parabolic index fiber to the spectral properties of the optical transmitter.
Profile exponent	Parameter with which the shape of the profile is defined for power-law index profiles. Particularly important profile exponents in practice are $g \approx 2$ (parabolic index fiber) and g ➔ ∞ (step index fiber).
Quantum efficiency	In a transmitter diode, the ratio of the number of emitted photons to the number of charge carriers transported across the pn junction. In a receiver diode, the ratio of the number of electron-hole pairs produced to the number of incident photons.
Raman amplifier, amplification	Makes use of an amplification effect that is produced in a long optical fiber when a relatively high pump optical power (a few 100 mW) is injected. The difference between the frequency of the pumping wave and the frequency of the amplified signal wave is called the Stokes frequency. Unlike optical fiber amplifiers and semiconductor amplifiers, Raman amplification is not tied to a specific optical frequency range.
Rayleigh scattering	Scattering caused by fluctuations in density (inhomogeneities) in a fiber which are smaller than the wavelength of the light. Rayleigh scattering is largely responsible for the attenuation in a fiber and it decreases with the fourth power of the wavelength.
Receiver	A component (part of a terminal device) in optical communications for converting optical signals into electrical signals. It comprises a receiver diode (PIN photodiode or avalanche photodiode) that can be coupled to an optical fiber, a low-noise amplifier and electronic circuits for processing the signal.
Receiver sensitivity	The minimum optical power required by the receiver for low-noise signal transmission. With digital signal transmission, the mean optical power in mW or dBm is specified, with which a particular bit error rate, e.g. 10^{-9}, is achieved.
Receptacle	Connecting element of the active optical component and the fiber connector. The component is accommodated in a rotationally symmetrical guide. The optical path can be guided by an optical system. The ferrule in the connector is centred by a sleeve which is aligned with the optically active surface area of the component. The housing is formed by the connector's locking mechanism.
Reflectance	Reciprocal value of return loss. Expressed as a negative value in decibels.
Reflection	Return of rays (waves) at a boundary between two media having different refractive indices, the angle of incidence being equal to the angle of reflection.
Reflection loss	Ratio of incident optical power to reflected optical power; usually given in decibels (positive values).
Reflectometer method	Method for the space-resolved measurement of power return loss (➔ Optical time domain reflectometer).
Refraction	The change in direction experienced by a ray (wave) when it passes between different materials having different refractive indices.
Refractive index	Ratio of the velocity of light in a vacuum to the propagation velocity in the respective medium. The refractive index is a function of the material and the wavelength.

Term	Definition
Refractive index difference	Difference between the maximum refractive index occurring in the core of a fiber and the refractive index in the cladding. The refractive ndex difference defines the size of the numerical aperture of the optical fiber.
Refractive index profile	Characteristic of the refractive index over the cross-sectional area of the fiber core.
Relaunch efficiency	Proportion of the light in relation to the total scattered light that is in the reverse direction within the acceptance range and is guided in the fiber.
Resolution	Spacing between two events at which the optical time domain reflectometer is still able to recognise the second event precisely and measure its attenuation.
Resolution bandwidth	The ability of an OSA to plot two closely adjacent wavelengths separately. The resolution bandwidth is usually determined by the spectral properties of the optical filter in the OSA.
Return loss	Ratio of the incident optical power to the returned optical power (reflected and scattered light), which is caused by a specific length of a fiber section (usually expressed in decibels: positive values). Sometimes the returned optical power means just the reflected light.
Return to zero	Method for modulating amplitudes in which the on and off levels are not maintained for an entire bit interval.
Ribbon cable design	Design in which the optical fibers are arranged in the form of ribbons. The fibers in a ribbon cable can all be spliced together at the same time.
Ribbon fiber	Interconnection of several fibers with a primary coating which are held together by means of an additional shared jacket (similar to a flat cable).
Safety margin	Attenuation or attenuation coefficient which is taken into account when planning fiber optic systems. The safety margin is necessary because of a potential increase in the attenuation in a transmission link during operating due to component ageing or repairs.
Scattering	Main reason for losses in a fiber. It is caused by microscopic fluctuations in density in the glass, which thereby change the direction of some of the guided light so that it is no longer in the fiber's acceptance range in the forward direction and consequently the signal is lost. The main component of scattering is Rayleigh scattering.
Self-phase modulation	Effect that occurs in the core due to the nonlinear optical effect in a fiber with a high energy density in the core. As a result, a light pulse with a frequency (wavelength) that was originally constant undergoes a phase modulation proportional to its instantaneous intensity.

Side-mode suppression	Ratio of the power of the dominant mode to the power of the maximum side mode in decibels.
Signal-to-noise ratio	Ratio of useful signal to interference signal within the frequency band that is used for the transmission.
Silica/silica fiber	Optical waveguide comprising a core material (synthetic silica) having a higher refractive index and a cladding material having a lower refractive index. The refractive indices are modified by doping the material (fluorine, germanium).
Single-longitudinal mode laser	Laser diode which has one dominant longitudinal mode. The side-mode suppression is at least 25 dB.
Singlemode fiber	Waveguide in which just one single mode, the fundamental mode, is capable of being propagated at the operating wavelength.
Small-signal gain	Gain with small input signals (preamplifier), if the amplifier is not yet operating in saturation.
Snell's law	Describes the relationship between the angle at which light enters and emerges when it undergoes refraction.
Soliton	State of oscillation of one solitary wave in a nonlinear medium, which remains unchanged as it propagates despite the dispersive properties of the medium. Pulse power, pulse shape and dispersion properties of the transmission medium must be in specific proportions.
Spectral efficiency, bandwidth efficiency, spectral density	Ratio of transmitted bit rates of all channels in the DWDM system to the bandwidth capacity of a singlemode fiber within the respective wavelength range.
Spectral width	Measure of the range of wavelengths in the spectrum
Splice	Adhesive joint between fibers
Splicing	Bonding or splicing of two fiber ends
Spontaneous emission	Emitted radiation if the internal energy of a quantum-mechanical system reverts back from a stimulated state to a lower state, without stimulated emission being present. Examples: Emission from an LED, radiation from a laser diode below the lasing threshold or some of the emission of an optical amplifier.
State of polarisation	Orientation of the electric field vector of a propagating optical wave. Generally, this vector takes the path of an ellipse. Special cases: linearly polarised light, circularly polarised light.
Step index profile	Refractive index of a fiber that is characterised by a constant refractive index within the core and by a stepped drop at the core-cladding boundary.

Term	Definition
Stimulated emission	It occurs when photons in a semiconductor stimulate available excess charge carriers into radiant recombination, in other words to emit photons. The emitted light is identical, in terms of wavelength and phase, to the incident light; it is coherent.
Substitution method	Method for measuring attenuation in which a reference fiber is substituted by the measurement object in a measurement section.
Surface-emitting laser	A laser that emits light perpendicular to the layer structure of the semiconductor material. Emits a circular ray of low divergence, has a relatively low spectral full width at half maximum and is particularly important for the transmission of high bit rates over multimode fibers at 850 nm.
Switch	Component which transmits light from one or more input ports to one or more output ports.
System bandwidth	Bandwidth of a section of fiber, measured from the transmitter to the receiver.
Taper	Optical adapter that creates a gradual transition from one optical waveguide to another.
Threshold current	The minimum current at which the amplification of the light wave in a laser diode is greater than the optical losses, with the result that stimulated emission starts. The threshold current is greatly dependent on the temperature.
Time division multiplex	Multiplex system in which the time on one transmission channel is assigned to different sub-channels in succession.
Total internal reflection	Reflection at the boundary between a more optically dense medium and a less optically dense medium, the light propagating in the more optically dense medium. The angle of incidence at the boundary must be greater than the critical angle of total internal reflection.
Transceiver	Compact component having one electrical and two optical interfaces (transmitter and receiver). Contains an optical transmitter (e.g. laser diode) with an exciter for operating the light source and an optical receiver (e.g. PIN diode) with a receiver circuit for operating the diode.
Transmission	Light transmission in the fiber as a percentage based on the injected power.
Transmitter	A component in optical communications for converting electrical signals into optical signals. The transmitter comprises a transmitter diode (laser diode or LED), an amplifier as well as other electronic circuits. For laser diodes in particular, a monitor photodiode with an automatic gain control amplifier is required to monitor and stabilise the radiated power. A thermistor and Peltier cooling are often used to help stabilise the Operating temp..
Transponder	Wavelength converter (O/E/O converter). Implements the wavelength conversion and 2R or 3R regeneration.
Tunable Laser	Laser that is able to change its peak intensity wavelength to optimise it for any given application.
Unidirectional	Propagation of optical signals in the same direction along one fiber.
Uniform mode distribution	Mode distribution in which the power is distributed uniformly across all modes.
Uniformity	Difference in insertion losses from the best and worst ports (in decibels) with multi-port couplers
V number	Dimensionless parameter that is dependent on the core radius, the numerical aperture and the wavelength of the light. The number of guided modes is determined by the V number.
Water peak	Increase in attenuation of the fiber in the region of the wavelength of 1383 nm caused by hydroxyl ion impurities in the glass.
Waveguide	A dielectric or conductive medium in which electromagnetic waves can propagate.
Waveguide dispersion	Typical type of dispersion in a singlemode fiber. Is caused by the wavelength dependence of the light distribution of the fundamental mode on the core and cladding glass.
Wavelength	Spatial period of a flat wave, i.e. the length of one complete oscillation. In optical communications, the wavelengths used are in the range from 650 nm to 1625 nm. Velocity of light (in the particular medium) divided by the frequency.
Wavelength division multiplex	Method for increasing the transmission capacity of a fiber by simultaneously transmitting different light wavelengths.
Zero-dispersion wavelength	Wavelength at which the chromatic dispersion of the fiber is zero.

Abbreviations

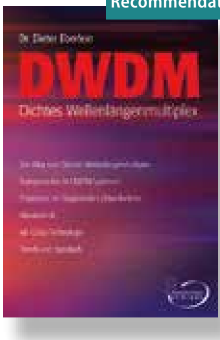
Abbreviation	Eplanation
3R	3R-Regeneration: Re-Amplification, Re-Shaping, Re-Timing
A/D	Analog/Digital
A-DCM	Adaptive Dispersion-Compensating Module
ADM	Add-Drop-Multiplexer
ADSL	Asymmetric Digital Subscriber Line
AEL	Accessible Emission Limit
AN	Access Node
AON	All Optical Network oder Agile Optical Network
APC	Angled Physical Contact
APD	Avalanche Photodiode
APON	Asynchronous Transfer Mode PON
AR	Antireflection
ARPU	Average Revenue Per User
ASE	Amplified Spontaneous Emission
ASON	Automatically Switched Optical Network
ASTN	Automatical Switched Transport Network
ATM	Asynchronous Transfer Mode
AutoCAD/ CAD	Computer Aided Design
AWG	Arrayed Waveguide Grating
BER	Bit Error Rate
bit	Binary digit
bit rate	Binary digit rate
BoM	Bill of Material
BoQ	Bill of Quantity
BOTDR	Brillouin-OTDR
BPON	(Broadband PON) is a standard based on APON
Bps	Bits per second
C & C	Crimp & Cleave
CATV	Cable Television
C-Band	Conventional Band (1530 nm up to 1565 nm)
CCDR	Clad Core Diameter Ratio
CD	Chromatic dispersion
CDM	Code Division Multiplex
CECC	CENELEC Electronic Components Committee
CLEC	Competitive Local Exchange Carries
COST COTDR	European co-operation in the field of scientific and technical research
CPE	Customer Premises Equipment
CPR	Coupled Power Ratio
CSO	Composite Second-Order Beat Noise
CTB	Customer Termination Box
CVD	Chemical Vapour Deposition
CW	Continuous Wave
CWDM	Coarse Wavelength Division Multiplex
D2B	Domestic Digital Bus
DA	Dispersion Accommodation
DBA	Dynamic Bandwidth Allocation
DBFA	Double Band Fiber Amplifier
DBR-Laser	Distributed Bragg Reflector Laser
DCD	Dispersion Compensation Device
DCF	Dispersion Compensating Fiber
DCM	Dispersion Compensation Module
DFB-Laser	Distributed Feedback Laser
DFF	Dispersion Flattened Fiber
DGD	Differential Group Delay
DIN	Deutsches Institut für Normung [German standards institute]
DMD	Differential Mode Delay
DML	Directly Modulated Laser
DMS	Dispersion Managed Soliton
DMUX	Demultiplexer
DN	Distribution Node
DOCSIS	Data Over Cable Service Interface Specification
DOP	Degree of Polarization
DP	Distribution Point
DSF	Dispersion Shifted Fiber
DSLAM	Digital Subscriber Line Access Multiplexer
DST	Dispersion Supported Transmission
DTF	Dielectric Thin Film Filter
DUT	Device under Test
DWDM	Dense Wavelength Division Multiplex
E/O	Electrical to Optical Conversion
EA	Electro Absorption
EBFA	Extended Band Fiber Amplifier
EDFA	Erbium Doped Fiber Amplifier
EDWA	Erbium Doped Waveguide Amplifier
EFM	Ethernet in the First Mile in IEEE 802.3ah
EIC	Expanded Wavelength Independent Coupler
EMB	Effective Modal Bandwith, laser bandwith
EMD	Equilibrium Mode Distribution
EML	Externally Modulated Laser
EN	European Norm
EP2P	Ethernet over P2P in IEEE 802.3ah
EPON	Ethernet Passive Optical Network
ESLK	Earth wire overhead cable
ETDM	Electrical Time Division Multiplex
FA	Fixed Analyser
FBG	Fiber Bragg Grating
FBT	Fused Biconic Taper
FC	Fiber Connector
Fccn	Fiber cross connect node
Fcp	Fiber concentration point
Fcpm	Fiber concentration point minor
Fd box	Floor Distribution box
FDDI	Fiber Distributed Data Interface
FDF	Fiber Distribution Field
FDM	Frequency Division Multiplex
FEC	Forward Error Correction
FIC	Full Range Wavelength Independent Coupler
FITH	Fiber In The Home
FM	Frequency Modulation
FP	Fabry-Perot
FSAN	Full Service Access Network
FSC	Factory Standard Cost
FSO	Free Space Optics
FTTB	Fiber to the Building
FTTC	Fiber to the Curb
FTTD	Fiber to the Desk
FTTH	Fiber to the Home
FTTM	Fiber to the Mast
FTTN	Fiber to the Node
FTTO	Fiber to the Office
FTTP	Fiber to the Premises
FTTX	Fiber To The X
FTU	Fiber Termination Unit
FWA	Fixed Wireless Access
FWHM	Full Width at Half Maximum

Abbreviation	Eplanation
FWM	Four Wave Mixing
Gbps	Gigabit per second (Gbit/s)
Ge	Germanium
GeO_2	Germanium dioxide
GFF	Gain guided laser
GINTY	General Interferometric Analysis
GPON	Gigabit Passive Optical Network
GRIN	Graded Refractive Index
GZS	Accessible Emission Limit
HC	Homes Connected
HCS fiber	HardClad Silica Fiber
HDPE	High Density Polyethylene
HFC	Hybrid Fiber Coax
HFC+	Hybrid fiber-coaxial plus
HP	Homes Passed
HRL	High Return Loss
IDP	Indoor Distribution Point
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGL	Index Guided Laser
IL	Insertion Loss
ILEC	Incumbent local exchange carries
IM	Intensity Modulation
IMP	Indoor Manipulation Point
InGaAs	Indium Gallium Arsenide
InGaAsP	Indium Gallium Arsenide Phosphide
IOC	Integrated Optoelectronic Circuit
IP	Internet Protocol
IPA	Isopropyl Alcohol
IR	Infrared
ISDN	Integrated Service Digital Network
ISO	International Organization for Standardization
ISP	Internet Service Provider
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Sector
IVD	Inside Vapour Deposition
JME	Jones Matrix Eigenanalysis
LAN	Local Area Network
L-Band	Long Band
LD	Laser Diode
LEAF	Large Effective Area Fiber
LED	Light Emitting Diode
LI	Local Interface
LID	Light Injection and Detection
LMDS	Local Multipoint Distribution Service
LP	Linearly Polarised
LSA	Least-Squares Averaging, Least-Squares Approximation
LSZH	Low Smoke, Zero Halogen
LWP	Low Water Peak
M/U	Municipality/Utility
MAN	Metropolitan Area Network
Mbits/s	unit of measure for the bit rate
Mbps	Megabit per second (Mbit/s)
MCVD	Modified Chemical Vapor Deposition
MDU	Multi-Dwelling Units
MEMS	Micro Electro Mechanical System
MFD	Mode Field Diameter
MM	Multimode
MMDS	Multichannel Multipoint Distribution Service
MMF	Multimode Fiber
MN	Main Node
MPE	Maximum Permissible Exposure
MPI	Multipath Interference
MPI	Main Point of Interest
MTU	Multi-Tenant Units
MUX	Multiplexer
MZB	see MPE
MZI	Mach-Zehnder-Interferometer
NA	Numerical Aperture
NF	Near Field
NGA	Next Generation Access Network
NGN	Next Generation Network
NIR	Near Infrared
NRZ	Non Return to Zero
NTU	Network Termination Unit
nVoD	Near Video on Demand
NZDSF	Non-Zero Dispersion Shifted Fiber
O/E	Optical to Electical Conversion
O/E/O	Optical to Electrical to Optical Conversion
OADM	Optical Add-Drop-Multiplexer
OB	Optical Booster
OC	Optical Carrier or Optical Channel
OCDM	Optical Code Division Multiplex
OCWR	Optical Continous Wave Reflectometer
OD	Optical Demultiplexer
ODF	Optical Distribution Frame
ODFM	Optical Frequency Division Multiplex
ODP	Optical Distribution Point
OE	Optical Ethernet
OEIC	Opto Electronical Integrated Circuit
OFA	Optical Fiber Amplifier
OFL	Overfilled Launch
OH	Hydroxide ion, negatively charged ion in water
OLCR	Optical Low Coherence Reflectometry
OLT	Optical Line Terminal
OM	Optical Multiplexer
OMP	Optical Manipulation Point
ONT	Optical Network Terminal
ONU	Optical Network Unit
OP	Optical Preamplifier
OPAL	Optical connection line
OPGW	Optical Ground Wire
ORD	Optical Reflection Discrimination
ORL	Optical Return Loss
ORR	Optical Rejection Ratio
OSA	Optical Spectrum Analyser
OSC	Optical Supervisory Channel
OSNR	Optical Signal to Noise Ratio
OTDM	Optical Time Division Multiplex
OTDR	Optical Time Domain Reflectometry
OTN	Optical Transport Network
OVD	Outside Vapor Deposition
OWG	Optical Waveguide
OXC	Optical Cross Connect
P	Failure Probability
P2MP	Point-To-Multi-Point
P2P	Point-to-Point

Abbreviation	Eplanation
PAS	Profile Aligning System
PBG	Photonic Bandgap
PC	Physical Contact
PCF	Polymer Cladded Fiber
PCF	Photonic Crystal Fiber
PCH	Prechirp
PCM	Pulse Code Modulation
PCS fiber	Polymer Cladded Silica Fiber
PCVD	Plasma Activated Chemical Vapor Deposition
PD	Photodiode
PDC	Passive Dispersion Compensator
PDF	Probability Density Function
PDFA	Praseodymium Doped Fiber Amplifier
PDG	Polarization-Dependent Gain
PDH	Plesiochronous Digital Hierarchy
PDL	Polarization-Dependent Loss
PIN-Diode	Positivly-Intrinsic-Negativly Doped Diode
PLC	Planar Lightwave Circuit
PM	Polarization Maintaining
PMD	Polarization Mode Dispersion
PMMA	Polymethyl Methacrylate
PMSMF	Polarization Maintaining Single Mode Fiber
POF	Plastic Optical Fiber/Polymer Optical Fiber
PON	Passive Optical Network
PoP	Point of Presence
POTDR	Polarization Optical Time-Domain Reflectometer
PSA	Poincaré Sphere Analysis
PSP	Principal State of Polarization
P-t-MP	Point-to-Multi-Point
P-t-P	Point-to-Point
QDST	Quaternary Dispersion Supported Transmission
QoS	Quality of Service
RBW	Resolution Bandwidth
RC	Reduced Cladding
RDS	Relative Dispersion Slope
RFA	Raman Fiber Amplifier
RIN	Relative Intensity Noise
RL	Return Loss
RML	Restricted Mode Launch
RMS	Root Mean Square
RNF	Refracted Nearfield Method
ROADM	Reconfigurable Optical Add/Drop-Multiplexer
RoW	Right-of-Way
RU	Rack unit, 1RU=50mm
RX	Receiver
RZ	Return to Zero
S/N	Signal-to-noise ratio / noise ratio
SAN	Storage Area Network
SatCom	Satellite Communications
S-Band	Short Band (1460 nm up to 1530 nm)
SBS	Stimulated Brillouin Scattering
SDH	Synchronous Digital Hierarchy
SDM	Space Division Multiplex
SDSL	Symmetric Digital Subscriber Line
SERCOS	Serial Realtime Communication System
SFF	Small-Form-Factor
SFU	Single Family Unit
Si	Silicone
SI	Step-index
SiO_2	Silicone Dioxide
SLA	Semiconductor Laser Amplifier
SLED	Super-Luminescencediode (LED)
SLM	Single-Longitudinal Mode Laser
SM	Singlemode
SMF	Singlemode Fiber
SMSR	Side Mode Suppression Ratio
SNR	Signal-to-Noise-Ratio
SOA	Semiconductor Optical Amplifier
SONET	Sychronous Optical Network
SOP	State of Polarization
SPE	Stokes Parameter Evaluation
SPM	Self Phase Modulation
SRS	Stimulated Raman Scattering
SSC	Standard Singlemode Coupler
SSMF	Standard Singlemode Fiber
STM	Synchronous Transport Module
STS	Synchronous Transport Signal
STU	Single-Tenant Units
TCO	Total Cost of Ownership
TDFA	Thulium Doped Fiber Amplifier
TDM	Time Division Multiplex
TDMA	Time Division Multiplex Access
TINTY	Traditional Interferometry Analysis
TODC	Tunable Optical Dispersion Compensator
TX	Transmitter
ULH	Ultra Long-Haul
UDWDM	Ultra-Dense Wavelength Division Multiplex
UMD	Uniform Mode Distribution
UPC	Ultra Polished Connector
UPS	Uninterruptible Power System
UTP	Unshielded Twisted Pair
UV	Ultraviolet
VLH	Very Long-Haul
VAD	Vapour Phase Axial Deposition
VCSEL	Vertical Cavity Surface Emitting Laser
VCSOA	Vertical Cavity Semiconductor Optical Amplifier
VDSL	Very High Bit Rate Digital Subscriber Line
VOA	Variable Optical Attenuator
VoD	Video on Demand
VSR	Very Short Reach
WAN	Wide Area Network
WDM	Wavelength Division Multiplex
WFC	Wavelength Flattened Coupler
WG	Waveguide
WIC	Wavelength Independent Coupler
WLAN	Wireless LAN
WWDM	Wideband Wavelength Division Multiplex
XPM	Cross-Phase Modulation
ZWP	Zero-Water-Peak

Reference literature

Recommendation 1



Dr. Dieter Eberlein
DWDM – Dichtes Wellenlängen-multiplex
Dr. M. Siebert GmbH

Berlin 2003 / 1st edition / 231 pages
ISBN-13: 978-3-00-010819-8
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Lichtwellenleiter-Technik
expert verlag GmbH

Renningen 2013 / 9. Auflage / 364 pages
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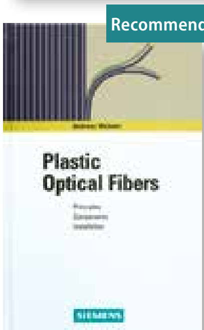

Andreas Weinert
Plastic Optical Fibers
Publicis MCD Verlag

Erlangen and Munich
154 pages
ISBN: 3-89578-135-5

Recommendation 4

Olaf Ziemann, Werner Daum,
Jürgen Krauser, Peter E. Zamzow
POF-Handbuch
Springer-Verlag Berlin Heidelberg

2nd revised and supplemented
edition 2007 / 884 pages
ISBN: 978-3-540-49093-7

Recommendation 5

Dr. Dieter Eberlein
Leitfaden Fiber Optic
Dr. M. Siebert GmbH

Berlin 2012 / 2nd edition / 336 pages
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Price: 55 €
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Recommendation 1

DWDM – Dichtes Wellenlängen-multiplex

Following an introduction to the problems of dense wavelength-division multiplexing, the book discusses important components that are required for wavelength-division multiplexing. This is followed by an explanation of the dispersion effects and measures to control them. Measurements performed on DWDM systems are described in another chapter. Finally, the book concludes with a look ahead to future developments.

Topics covered

- From conventional to dense wavelength-division multiplexing
- Components in DSDM systems (laser diodes, optical waveguides, optical amplifiers, nonreciprocal components, multiplexers/demultiplexers, etc.)
- Dispersion in singlemode fibers (chromatic dispersion, polarisation-mode dispersion)
- Measuring techniques
  (spectral measurement, measurement of polarisation-mode dispersion, measurement of chromatic dispersion, measurement of bit error rates, Q-factor measurement)
- 40-Gbit/s technology
- Trends (CWDM, Solitons, components, design of morn networks, planning and installation)
- Standardisation
- Appendix (abbreviations, symbols, units of measure, glossary)

Recommendation 2

Lichtwellenleiter-Technik

The book offers an introduction to fiber optics. The discussion of the subject matter is based on sound theory, which is then expanded into concrete practical examples and applications. This enables readers to apply the topics directly to their own situations The 9th edition additionally explores a range of new aspects, such as current standards, new fiber types, Fiber-to-the- Home/Building, particular requirements for the realization 40/100 Gigabit ethernet over multimode fibers and new aspects of temporary and permanent joining techniques.

Topics covered

- Principles of fiber optics
- Temporary joining techniques
- Permanent joining techniques
- Fiber optic measuring techniques, focusing particularly on backscattering measurements
- Optical transmission systems

Recommendation 3

Plastic Optical Fibers

In recent years there has been a meteoric rise in the use of plastic fiber optic cables, e.g. for data transmission on short to medium-length transmission paths. The reason for this is that plastic fiber optic cables can be connected to the relevant transmission components at low cost and using simple tools. This book offers an introduction to the physical principles of the new technology and describes the materials and manufacturing process of plastic fibers as well as the construction of plastic fiber optic cables. It describes various types of cable, as well as transmitting and receiving components in the transmission path and it provides useful tips on the processing and installation of plastic fiber optic cables. Reference is also made to important national and international standards.

This book is intended for anyone involved in the development, planning or installation of plastic fiber optic cable systems. The fundamental structure of the book also makes it suitable for university lecturers and students.

Recommendation 4

POF-Handbuch

POF (polymer optical fibers) are still in their infancy but are gaining popularity in communication technology. The advantages are considerable, but how are they used? Different systems of innovative and important technologies are described. The reader is given an introduction and a general overview. The book covers point-to-point systems, in other words the transmission of one channel from the transmitter to the receiver, and wavelength division multiplexing systems, i.e. the transmission of multiple channels over one fiber having different light wavelengths. The excellent descriptions of the subject-matter in the book are complemented with a high-quality, full-colour presentation.

Recommendation 5

Leitfaden Fiber Optic

The guidebook provides an outline of key topics of fiber optics in the form of short descriptions, explanatory illustrations, summarising tables and references to current standards. It enables engineers, technicians and students alike to learn quickly about a topic, without having to explore the subject area in depth. This makes the guidebook an important tool for any specialist working in the field of fiber optics.

Topics covered

- General information
- Principles of fiber optics
- Coupling of optical components
- Optical fiber connectors
- Splicing techniques
- Optical fibers
- Fiber optic cables
- Dispersion
- Transmitters for optical communications
- Receivers for optical communications
- Fiber optic measuring techniques
- Couplers
- Optical amplifiers
- Fiber optic components
- Wavelength division multiplexing
- Fiber to the user
- Optical transmission systems

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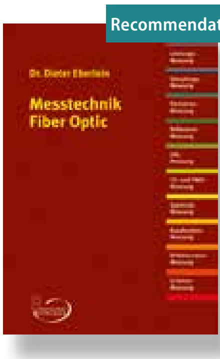
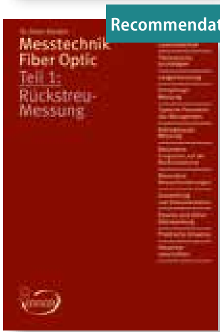


Dr. Dieter Eberlein
Messtechnik Fiber Optic
Dr. M. Siebert GmbH

Berlin 2006 / 1st edition / 170 pages
ISBN-13: 978-3-00-018278-5
Price: 30 €

Recommendation 7



Dr. Dieter Eberlein and four co-authors
Messtechnik Fiber Optic
Part 1 **Rückstreumessung**
Dr. M. Siebert GmbH

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ISBN-13: 978-3-00-022129-3
Price: 13.50 €

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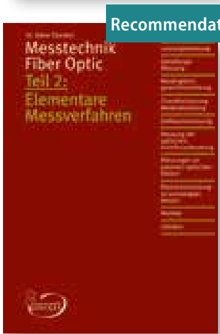

Dr. Dieter Eberlein
Messtechnik Fiber Optic
Part 2 **Elementare Messverfahren**
Dr. M. Siebert GmbH

Berlin 2008 / 1st edition
ISBN-13: 978-3-00-024216-8
Price: 13.50 €

Recommendation 9

Dr. Dieter Eberlein
Messtechnik Fiber Optic
Part 3 **Dispersionsmessungen an Singlemode-LWL**

Berlin 2009 / 1st edition / 96 pages
ISBN-13: 978-3-00-028124-2
Price: 13.30 €

Recommendation 10

Dr. Dieter Eberlein
Messtechnik Fiber Optic
Part 4 **Morne Messverfahren**
Dr. M. Siebert GmbH

Berlin 2010 / 1st edition / 96 pages
ISBN-13: 978-3-00-032451-2
Price: 13.30 €

Recommendation 6

Messtechnik Fiber Optic

This book explains basic methods of fiber optic measuring techniques. It focuses specifically on characterising installed fibers. In addition to conventional methods, such as attenuation and backscattering measurements, it also examines measurements that are required for morn fiber sections (spectral measurements, CD and PMD measurements). Lesser known, but equally useful measuring techniques, such as the space-resolved measurement of fiber expansion or temperature, are also discussed.

Topics covered

- Power measurements
- Attenuation measurements
- Backscattering measurements
- Reflection measurements
- Measurement of chromatic dispersion (CD)
- Measurement of polarisation-mode dispersion (PMD)
- Spectral measurements
- Bandwidth measurements
- Bit error rate measurements
- Q-factor measurements

Recommendation 7

Messtechnik Fiber Optic
Part 1 **Rückstreumessung**

This booklet is the first in a series of four on fiber optic measuring techniques. The first booklet concentrates on the theoretical and practical aspects of backscattering measurements. Current developments and standards are also described and new products are presented.

Topics covered

- General information
- Backscattering measurements – theoretical principles
- Linear measurements and attenuation measurements
- Parameters of the optical time domain reflectometer
- Bidirectional measurements
- Specific events on the backscatter curve
- Particular measurement requirements
- Evaluation and documentatin of measurement results
- Passive and active monitoring of fiber sections
- Practical aspects
- Acceptance specifications
- Abbreviations, symbols, units of measure

Recommendation 8

Messtechnik Fiber Optic
Part 2 Elementare Messverfahren

This booklet is the second in a series of four on fiber optic measuring techniques. It describes elementary measurement techniques for characterising fiber sections. It covers power measurements and attenuation measurements as well as special measuring techniques for passive optical networks.

Topics covered
- Measuring aids
- Power measurements
- Attenuation measurements
- Reflection measurements
- ORL measurements
- Measurements on passive optical networks

Recommendation 9

Messtechnik Fiber Optic
Part 3 Dispersionsmessungen an Singlemode-LWL

This booklet is the third in a series of four on fiber optic measuring techniques. It describes the methods of dispersion measurement in singlemode optical waveguides.

Topics covered
- Principles of dispersion
- Measurement of chromatic dispersion
- Measurement of polarization-mode dispersion
- Space-resolved PMD-measurement
- Practical advice

Recommendation 10

Messtechnik Fiber Optic
Part 4 Morne Messverfahren

This booklet is the last in the series of four on fiber optic measuring techniques. It describes morn measurement methods on optical waveguides.

Topics covered
- Optical spectrum analysis
- Spectral attenuation measurement
- Space-resolved fiber elongation measurement
- Space-resolved temperature measurement
- Bit error rate measurement
- Bandwidth measurement

CHAPTER 13

Service & Index

Quality and environmental management, distribution network

We provide our customers with extensive system expertise and exceptional service, from the initial consultation by experienced engineering teams, to problem analyses, project planning, technical documentation, individual and integration tests right through to complete fiber optic systems.

In dialog with our customers we develop application-optimized systems for a variety of industrial sectors, meeting the respective requirements in every way.

We are constantly striving to provide quality and service at a competitive price. To increase efficiency, we make good use of our various production sites throughout and outside of Germany.


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Quality and environmental management

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Our ISO 9001- and ISO 13485-certified quality management systems enable us to communicate our product and competence portfolios in a clear and transparent manner and to adjust our manufacturing procedures to our customers' expectations. Thus, we control the entire production process from planning to completion.

Environmental management – We do not regard financial success and environmental responsibility as a contradiction in terms. We acknowledge our special co-responsibility as a global industrial company in protecting the world's natural resources. We are endeavouring to strike a balance between environmental issues and the interests of our company. Protecting the environment is therefore an intrinsic element of our corporate activitie.

We encourage our partners to operate by the same environmental guidelines as we do and advise our customers on how to use and dispose of our products in an environmentally responsible manner. Our cable production has successfully implemented an environmental management system in line with ISO 14001.


ZERTIFIKAT

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ISO 14001:2004

Quality assurance

Cables · Fibers · Medical devices

We have the human resources to meet the demands of our quality management system in all divisions:

Business Unit **Fiber Optics**	**Head of quality and environmental manager regulatory affairs (medical devices)**
For all production sites	Quality management officer (QMO) Environmental officer Safety officer for medical devices Product testing / quality assurance

Cables

Every cable that leaves our factory is subjected to a full inspection to ensure it satisfies its attenuation values. We are one of a few manufacturers in the world to use a method that enables attenuation measurements to be carried out on POF over a factory length of 500 m, for example. This not only reduces measuring errors, it also permits longer factory lengths. Furthermore, the combination of production order number and drum number printed onto the cable provides complete traceability throughout the entire manufacturing process, from the receiving inspection of the fibers to the delivery of the cable. Years later we can still ascertain the measured parameters of a particular cable, for example.

Fibers

During the production of our fibers, we constantly monitor online the complete spectrum of requirements for fiber and coating geometry for the entire drawing process. This is also true when it comes to extruding fibers using a wide variety of materials. To verify that our fibers satisfy the stipulated strength requirements, every length of fiber produced in its entirety undergoes a screen test.

Measured values for the transmission and numerical aperture are available for every fiber batch. All the requirements stipulated for the various fibers are monitored 100% for the entire manufacturing process. No single metre of fiber leaves the factory without being tested first.

Medical devices

Our top priority when manufacturing our medical products is to ensure compliance with the fundamental requirements of RL 93 / 42 / EEC and thus the safety of patients, users, third parties and the environment. This is documented by the CE marking on our medical products. CE mark approval is verified every year by our notified body.

To this end, we have implemented a comprehensive QA system in line with the requirements of EN ISO 13585. This standard contains the same basic requirements as EN ISO 9001, but also goes a lot further.

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Switches, spitters, arrays, probes

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