Fiber Optics

Light switching, Light transportation, Light distribution

The Quality Connection

LEONI

The Fiber Optics business unit of the LEONI Group is one of the leading suppliers of optical fiber technology for communication and for special applications in a host of industrial sectors as well as in science and medicine. As a vertically integrated business unit, we offer a unique product portfolio at every stage in the value chain.

This distinguishes us from other suppliers:
From preform production through cable manufacturing with different fibers, lengths, bundles, connectors and special plug systems to optical switches and splitters, we offer a unique portfolio comprising more than 8,000 products.

We bring together heterogeneous technologies for heterogeneous applications. The result: complete fiber optic systems. We manufacture products individually in series and piece production, just-in-time and quality assured. We develop the desired product design in accordance with the customers' individual requirements. We analyse our customers' requests, study the environment of the respective application and combine these insights with our know-how. We invest well over € 1.5 million each year in research and development.

We're there for you, along with our 300 employees. The result speaks for itself…

Andreas Weinert   Philipp Dehn, Ph.D.

Vice Presidents Fiber Optics

FiberConnect® Light Guide Cable Solutions

We offer you cables with optical fibers made from glass (singlemode and multimode), plastic optical fibers (POF), plastic cladded fibers (PCF) and large-core fibers (silica/silica). All fiber types are also available in a radiation-resistant version. We manufacture different cable designs from central core cables to breakout cables with all buffered fiber types and specific inner and outer jacketing materials, customised according to your needs. We use all fiber types to produce hybrid cables with optical fibers and electrical conductors.

FiberTech® Special Optical Fiber Technologies

We manufacture multimode and singlemode fibers and fiber bundles with different numerical apertures, coatings and claddings. We specialise in special fibers and special coatings. Our company has four optical fiber drawing towers as well as corresponding screeners and extruders. All fibers can be assembled to the customer's specific needs for high-performance laser cables or, for example, spectroscopic applications. We manufacture medical fibers for laser energy transmission and also offer series production of surgical, ophthalmological, urological, dental and endovascular laser probes with biocompatible materials.

FiberSwitch® 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 visible 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.

FiberSplit® 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 customised modules or systems 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 16 years. We also produce customer-specific chips, components and modules, for example optical waveguide structures for wavelength ranges between 600 and 1700 nm with various waveguide properties and functions including optical chips and fiber arrays.

Up-to-date information on LEONI Fiber Optics products, developments, research projects and trade fairs can also be found on the Internet:

www.leoni-fiber-optics.com

www.us-fibertech.com

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Page

LEONI
Cable expertise for the most various 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 45,000 people in 34 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, fiber optic cables as well as special cables, cable harnesses, wiring systems components and fully assembled systems for applications in various industrial markets.

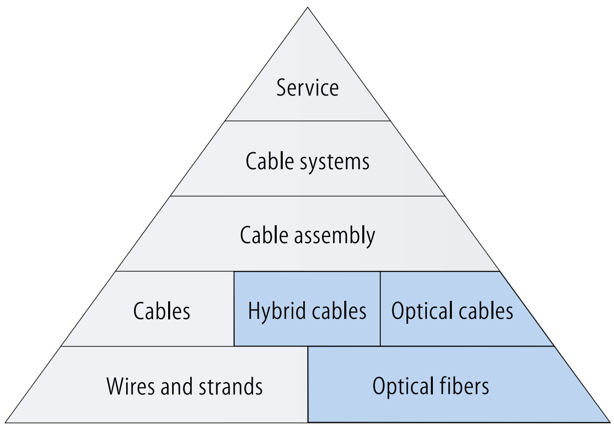
Your markets – our strength

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

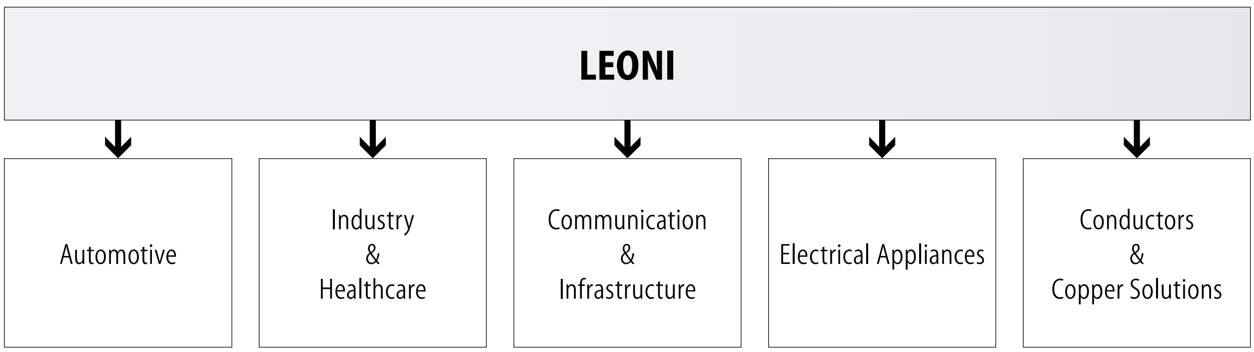
We are among the leading European suppliers in the Industry & Healthcare market to which at LEONI as a cable manufacturer also belong activities in the fields of aerospace, telecommunication systems, fiber optics, industrial solutions and healthcare. Customers of our Fiber Optics business unit benefit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

LEONI – we create the best connection for your future.

Products and services portfolio at a glance



LEONI's core markets



Fiber Optics business unit
Our areas of expertise.

Cross-sectional technology and key technology
Optical technologies are innovative and in great demand in many markets. That is why fiber optic products are manufactured for a wide variety of industrial sectors for an equally wide array of applications.

In order to be able to persist in these markets and to give our customers a competitive edge, the Fiber Optics business unit stands for:
Innovation
Quality
Service
Process Control.

Our products and technologies epitomise market competence in the following sectors:

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

Value chain
– from the preform to the complete fiber optic system.

Design and development

- Development of customer-specific system solutions and prototypes
- Industrial research projects on materials science and technology development

Preform and fiber production

- Production of multimode fibers with a core diameter of 10 to 2000 µm
- Manufacturing of customer-specific IR and UV preforms

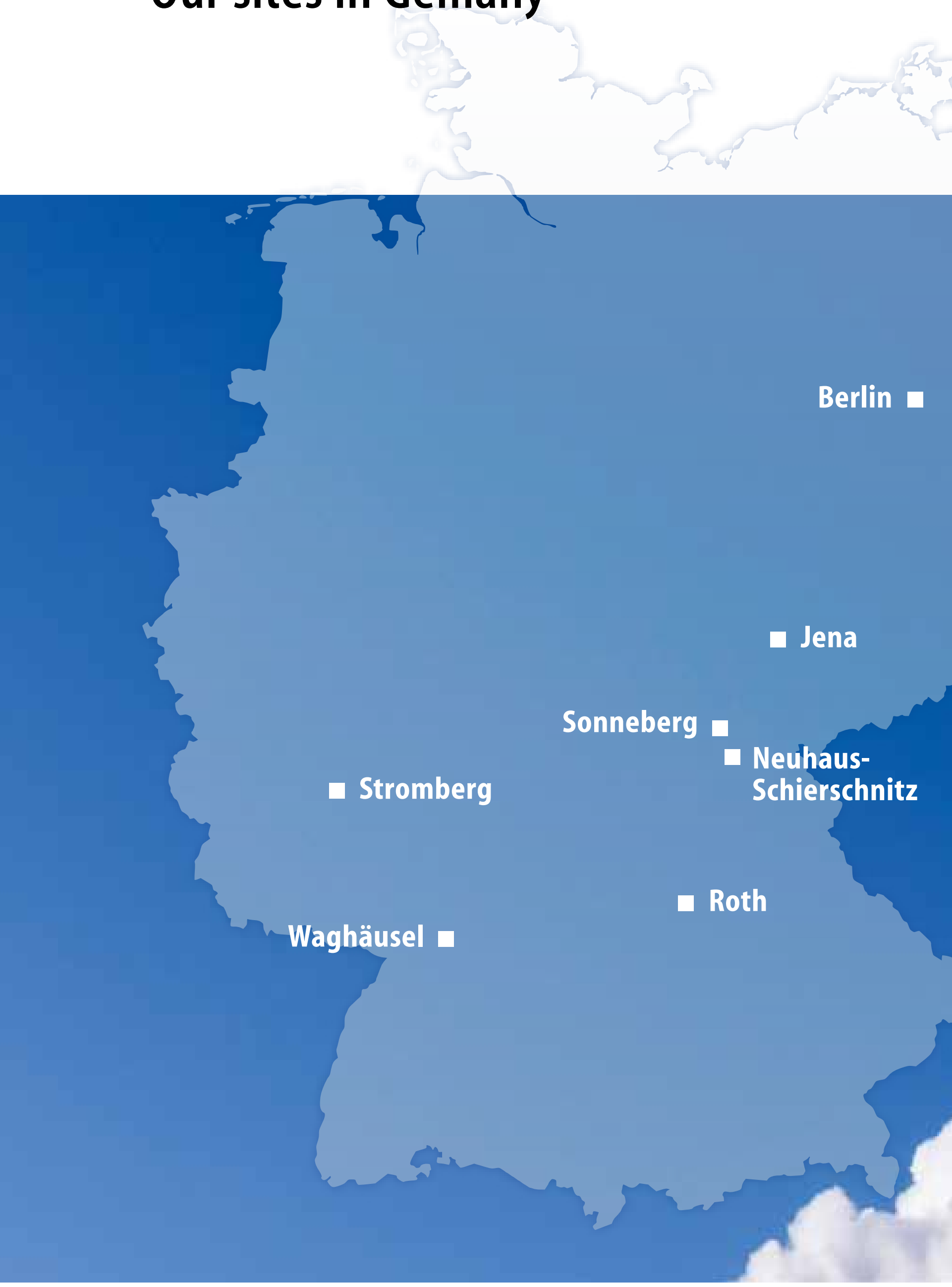
Fiber optic cable production

- Production from standard and self-drawn special fibers (glass, silica, POF, PCF)
- Hybrid cables with electrical and optical waveguides

Customised assembly and special components

- Assembly of fiber optical systems for applications in industry, medicine and science
- Manufacturing of planar optical fibers as optical splitters
- Manufacturing of fiber optical switches

Our sites in Gemany



To LEONI, customer focus not only means to identify and satisfy our customers' needs but it also refers to customer proximity in the true sense of the world. You can rely on us – anywhere, anytime.

Our range of services:

- **Comprehensive production and service network**
- **High product availability**
- **Process monitoring**
- **Process and product optimisation**
- **Customer-specific logistics solutions**
- **On-site installation**
- **Spare-parts management**

Seven sites in Germany

LEONI Fiber Optics GmbH, Neuhaus-Schierschnitz
LEONI Fiber Optics GmbH, Roth
LEONI Fiber Optics, Stromberg
LEONI Fiber Optics GmbH, Jena
LEONI Fiber Optics GmbH, Waghäusel
LEONI Fiber Optics GmbH, Sonneberg
FiberTech GmbH, Berlin

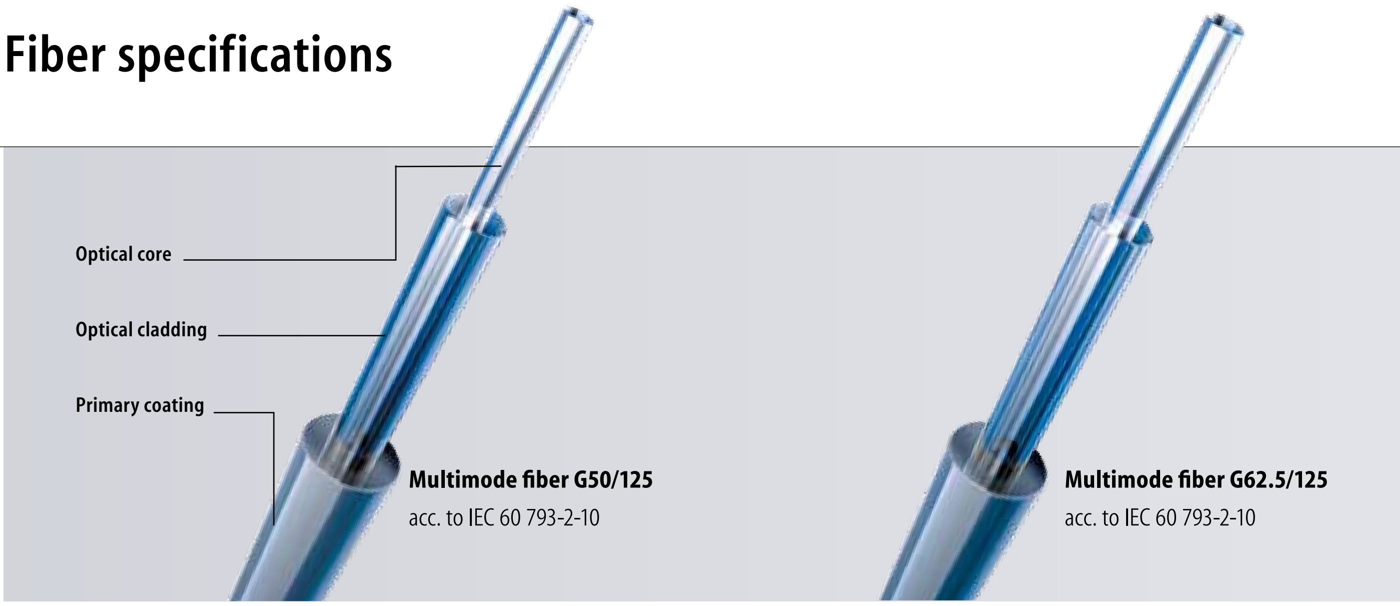
We are where you need us to be:
Our sites and offices in Europe, Asia and North America can be found on page 308.

Fiber Optic Cables

singlemode/multimode fibers

Fast and trouble-free communications are taken for granted nowadays. The Fiber Optics business unit 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 because they allow not only high rates of data transmission with extensive spare capacity, but also the highest possible degree of operating security.

Fiber specifications



G50/125 **Multimode fiber G50/125** acc. to IEC 60 793-2-10

Geometric/mechanical properties

Core diameter (µm)	50 ± 2.5	Cladding non-circularity (%)	< 1
Cladding diameter (µm)	125 ± 2	Core/cladding concentricity error (µm)	< 1.5
Coating diameter (µm)	245 ± 10	Eccentricity of coating (µm)	< 10
Core non-circularity (%)	< 5	Screen test	1% expansion for 1 s (≙ 100 kpsi)

Transmission properties	Fiber type F		Fiber type G		Fiber type H		Fiber type I		Fiber type J	
	(OM2)		(OM2+)		(OM2++)		(OM3)		(OM4)	
Wavelength (nm)	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
Bandwidth min. OFL (MHz · km)	500	500	500	1000	600	1200	1500	500	3500	500
Bandwidth min. EMB (MHz · km)							2000		4700	
Effective group of refraction	1.483	1.478	1.483	1.478	1.483	1.478	1.483	1.478	1.483	1.475
Numerical aperture	0.200 ± 0.020		0.200 ± 0.015		0.200 ± 0.015		0.200 ± 0.015		0.200 ± 0.015	

G62.5/125 **Multimode fiber G62.5/125** acc. to IEC 60 793-2-10

Geometric/mechanical properties

Core diameter (µm)	62.5 ± 3	Cladding non-circularity (%)	< 1
Cladding diameter (µm)	125 ± 2	Core/cladding concentricity error (µm)	< 1.5
Coating diameter (µm)	245 ± 10	Eccentricity of coating (µm)	< 10
Core non-circularity (%)	< 5	Screen test	1% expansion for 1 s (≙ 100 kpsi)

Transmission properties	Fiber type L (OM1)		Fiber type M (OM1+)	
Wavelength (nm)	850	1300	850	1300
Attenuation max. (dB/km)	3.2	0.9	3.0	0.8
Bandwidth min. OFL (MHz · km)	200	500	300	800
Effective group of refraction	1.497	1.493	1.497	1.493
Numerical aperture	0.275 ± 0.015		0.275 ± 0.015	

Singlemode fiber E9/125
(matched cladding type)
acc. to ITU-T Rec. and IEC 60 793-2-50

Radiation resistance

All fiber types are also available in a radiation-resistant versionor with approval according to MIL-PRF-49291C (6B MMF 62.5/125, 1B MMF 50/125, 7C SMF 9/125).

E9/125 **Singlemode fiber E9/125 (matched cladding type)** acc. to ITU-T Rec. G.652.D, ITU-T Rec. G657.A and IEC 60 793-2-50

Other fiber types e.g. ITU-T G.655 or ITU-T G.657.B on request

Geometric/mechanical properties

Cladding diameter (μm)	125 ± 0.7	Mode field/cladding concentricity error (μm)	< 0.5
Coating diameter (μm)	245 ± 10	Eccentricity of coating (μm)	< 12
Cladding non-circularity (%)	< 1	Screen test	1% expansion for 1 s (≙ 100 kpsi)

Transmission properties	Fiber type A		Fiber type B		Fiber type E	
	acc. to ITU-T G.652.D and ISO 11801 type OS 2		acc. to ITU-T G.652.D and ISO 11801 type OS 2		acc. to ITU-T G.657.A	
	for semi-tight and tight buffered fibers		for loose tubes			
Wavelength (nm)	1310	1550	1310	1550	1310	1550
Attenuation max. (dB/km)	0.38	0.28	0.36	0.22	0.36	0.22
Dispersion coefficient max. (ps/nm · km)	3.5	18	3.5	18	3.5	18
Zero dispersion wavelength (nm)	1302 – 1322		1302 – 1322		1302 – 1322	
Dispersion slope (ps/nm2 · km)	≤ 0.090		≤ 0.090		≤ 0.092	
Cut-off wavelength (cabled) (nm)	≤ 1260		≤ 1260		≤ 1260	
Polarisation mode dispersion (ps/$\sqrt{\text{km}}$)	≤ 0.2		≤ 0.2		≤ 0.2	
Effective group of refraction	1.4695	1.4701	1.4695	1.4701	1.4695	1.4701
Mode field diameter at 1310 μm (μm)	9.2 ± 0.4		9.2 ± 0.4		8.9 ± 0.4	

Applications and link lengths

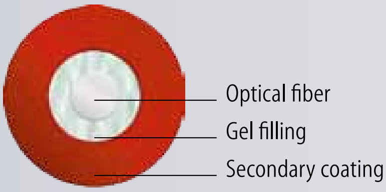
	G50/125					G50/125	
	F	G	H	I	J	L	M
Type acc. to ISO 11801: 09/2002	OM2	OM2+	OM2++	OM3	OM3+	OM1	OM1+
Gigabit Ethernet 1000BASE-SX (850 nm)	500 m	525 m	525 m	1000 m	1500 m	350 m	400 m
Gigabit Ethernet 1000BASE-LX (1300 nm)	550 m	1000 m	2000 m	550 m	550 m	550 m	1000 m
10 Gigabit Ethernet 10GBASE-SX (850 nm)				300 m*	550 m		
10 Gigabit Ethernet 10GBASE-LX4 (1310 nm WDM)				300 m	300 m**		

* 10 GE Link length acc. to ISO 11801.2
** Radiation resistance

Buffered optical fibers

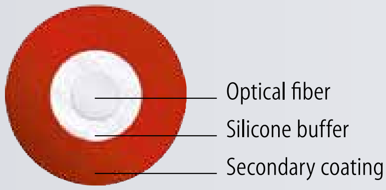
Buffered fibers for the modular structure of the tight buffered fiber cables

STB900 – Semi-tight buffered fiber



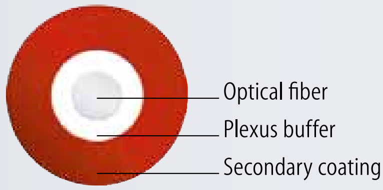
V-...

TB900 – Tight buffered fiber



V-...

LB900 – Superstrip buffered fiber



V-...

Properties/application

- 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 (STB900U)
- Ease of installation and assembly (2000 mm and more can be stripped in one piece)
- Primary and secondary coatings available in 12 colours

Properties/application

- In equipment and distributor cabinets as two-sided ready assembled cable
- Resistant to temperature fluctuations
- High resistance to external mechanical loads such as bending or transverse pressures and environmental influences
- Easy consistent stripping of buffered fiber (up to 80 mm in one piece)
- Ease of installation, because of no gel filling

Properties/application

- For splicing as pigtail
- For indoor cables in equipment and distribution cabinets as well as on cable trays
- High flexibility
- Very good kink resistance
- Ease of installation, because of no gel filling
- Ease of installation and assembly (1000 mm and more can be stripped in one piece)
- Primary and secondary coatings available in 12 colours

Thermal properties

Transport and storage	–20°C to +50°C
Installation	+5°C to +40°C
Operation	–10°C to +60°C

Mechanical properties

min. bending radius	30 mm
max. pull force, long-term	5 N
max. crush resistance, long-term	200 N

The right buffered fiber for every application
Alternative constructions

Buffered fiber	Ø [µm]	Type	Order no.	Stripable in one piece	Flexibi-lity	Resist-ance to tem-perature cycling	Ease of instal-lation	Suit-able for splicing	Note
TB500A	500	Mini tight buffered fiber, upcoated	8499998Z	Up to 50 mm	+++	+++	++	No	Miniaturised optical cables suitable for SFFC (Small Form Factor Connector, e.g. MT-RJ), high temperature stability, ideal for stripping machines
TB600	600	Mini tight buffered fiber	84950116	Up to 80 mm	++	++	+	No	Suitable for SFFC (Small Form Factor Connector, e.g. MT-RJ)
TB600A	600	Mini tight buffered fiber, upcoated	8499998Y	Up to 50 mm	+++	+++	++	No	Suitable for SFFC (Small Form Factor Connector, e.g. MT-RJ), high temperature stability, ideal for stripping machines
TB900A	900	Tight buffered fiber, upcoated	8499998X	Up to 50 mm	+++	+++	++	No	All indoor cables for connector assembly at both ends, high temperature stability, ideal for stripping machines
STB900U unfilled	900	Semi-tight buffered fiber, dry core	84998009	Up to 2000 mm	++	+	+++	Yes	Pigtail assembly, primary and secondary coatings available in 12 colours
STB900H	900	Semi-tight buffered fiber, dry core, flame retardant (FRNC)	84998007	Up to 1000 mm	++	++	+++	Yes	All indoor cables, pigtail assembly, primary and secondary coatings available in 12 colours
Plastic tube	1400	Plastic tube, gel-filled	84997101	Up to 2000 mm	++	++	+	Yes	Suitable for cables in harsh industrial environments, drag chain cables
TB900L	900	Tight buffered fiber, flexible, with Hytrel®	8499800L	Up to 50 mm	+++	+++	+	No	Flexible buffered fiber, high temperature stability
TB900R	900	Tight buffered fiber, rigid	84988004	Up to 50 mm	+	++	+	No	More rigid buffered fiber, high temperature stability, ideal for stripping machines
STB900RF	900	Semi-tight buffered fiber, rigid, gel-filled	84998005	Up to 2000 mm	+	++	++	Yes	More rigid buffered fiber, high temperature stability, ideal for manual assembly
STB900RU	900	Semi-tight buffered fiber, rigid, dry core	84998008	Up to 2000 mm	+	++	+++	Yes	More rigid buffered fiber for pigtail assembly

Handling and safety notices
when using optical 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 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 optical 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
for optical 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 Fiber Optics business unit 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 aging	+	+	+	+
Halogen-free	+	+	– –	+
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	+	– –	+	++
Alkaline solutions	+	– –	+	+
Saline solutions		–	+	+

++ excellent
\+ good
● depends 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, 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 the effect of extreme swelling

4) Swelling in aliphatic and aromatic hydrocarbons and in chlorinated hydrocarbons

5) Not resistant to chlorinated hydrocarbons, resistant to hydrocarbons and aliphatic and aromatic solvents

Note: Instead of FRNC (flame retardant non corrosive), the expression LSOH or LSZH (low smoke zero halogene) is often used.

Type designations for optical cables

I – V (ZN) H H 4G50/125 STB900 2.5

Field of application	
Indoor cable	**I**
Universal cable	**U**
Outdoor cable	**A**
Splittable outdoor cable	**AT**
Buffered fiber type	
Tight buffered fiber	**V**
Gel-filled loose tube	**D**
Gel-filled plastic tube	**W**
Constructional composition	
Dry core, longitudinally watertight	**Q**
Grease-filled	**F**
Optical cable with copper elements	**S**
Non-metallic strain relief	**(ZN)**
Aluminium sheath	**(L)**
Steel strain relief	**(ZS)**
Armour	**B**
Corrugated steel cladding	**W**
Inner jacket mixtures	
PVC (polyvinyl chloride)	**Y**
PE (polyethylene)	**2Y**
PA (polyamide)	**4Y**
ETFE (tetrafluoroethylene)	**7Y**
PP (polypropylene)	**9Y**
PUR (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 under inner jacket mixtures	E.g. H
Fiber number or fiber bundling	
Number of fibers	**n**
Number of multi-fiber loose tubes x number of fibers per multi-fiber loose tube	**nxm**
Fiber type/fiber core diameter/fiber cladding diameter	
Singlemode fiber (glass/glass)	**E**
Multimode graded-index fiber (glass/glass)	**G**
Multimode step-index fiber (glass/glass)	**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 as well as buffered fiber types	
a) Fiber attenuation / wave range / bandwidth (only with PCF and POF fibers) xx Attenuation (dB/km) z Wave range (nm), A = 650 nm, B = 850 nm, F = 1300 nm, H = 1550 nm yy Bandwidth (MHz x km with PCF) (MHz x 100 m with POF)	**xx z yy**
b) Buffered fiber type (only with glass/glass fibers)	
Miscellaneous, e.g. plant-specific details	
▪ Diameter of single element or cable outer diameter ▪ Dimension with flat cables (e.g. 2.2 x 4.5 mm) ▪ Data on copper buffered fibers with hybrid cables (e.g. 4 x 0.75 mm²) ▪ Data on strain relief (e.g. 2500 N)	E.g. 2.5

Other examples:

Indoor cable (glass/glass)
I–V (ZN) H H 4G50/125 STB900 2.5
➔ Indoor cable (breakout) with tight buffered fibers
Single elements 2.5 mm with non-metallic 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 (glass/glass)
A–D Q (ZN)2Y W 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 cable (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 at 650 nm
Bandwidth 17 MHz x km
Attenuation: 8 dB/km at 850 nm
Bandwidth 20 MHz x 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 at 650 nm
Bandwidth 10 MHz x 100 m
Total diameter of cable: 6.0 mm

Fiber colour code for multi-fiber loose tubes

Standard code of the Fiber Optics business unit acc. to IEC 60304

Fiber no.	Fiber colour code
1	red
2	green
3	blue
4	yellow
5	white
6	grey
7	brown
8	violet
9	turquoise
10	black
11	orange
12	pink

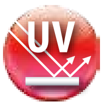
Fiber no.	Fiber colour code with ring marking
13	red
14	green
15	blue
16	yellow
17	white
18	grey
19	brown
20	violet
21	turquoise
22	transparent (no ring marking)
23	orange
24	pink

Standards

Optical cables from Fiber Optics fulfil one or more of the following standards:

- DIN VDE 0888
- DIN VDE 0899
- DIN VDE 0472
- DIN VDE 0473
- EN 50 173
- EN 187 000 to 187 105
- EN 188 000
- ITU-T Rec G.651 to G.657
- IEC 60793
- IEC 60794

Pictograms

	**Flame-retardant and halogen-free jacket** The outer jacket of the cable is self-extinguishing and does not propagate fire. The halogen-free jacket material forms neither toxic nor corrosive combustion gases in the event of fire.
	**Non-retardant jacket** The cable meets certain fire prevention standards.
	**Oil resistance** Generally good resistance to oil, petrol, acids and alkaline solutions.
	**Rodent proof** The cable core is protected or safe from damage caused by rodents.
	**Suitable for use with drag chains** The cable composition is tested and approved for use in drag chains.
	**UV resistance** Cable outer jacket is UV-resistant.
	**Transversely waterproof** Diffusion of water at right angles to the cable core is prevented.
	**Longitudinally waterproof** Water in the cable core cannot spread out in longitudinal direction.

Industrial Cables

In industry, one frequently comes up against a wide variety of technical requirements that cannot be met with conventional cables. The Fiber Optics business unit is the specialist for application-optimised optical cables in industrial settings.

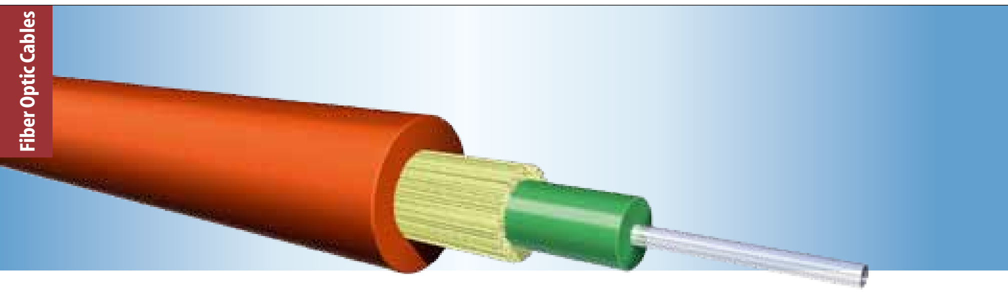
Extensive know-how, many years of experience and a highly flexible production setup enable us to design and produce the right cable for even the most demanding areas.

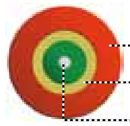
We offer

- cables with oil-resistant jacket materials
- cables for mobile use in drag chains
- cables for the greatest bending stresses, such as in component placement machines in the electronics industry, for example
- 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. If necessary, we can develop and produce the cable solution for your application.

Simplex cable PUR

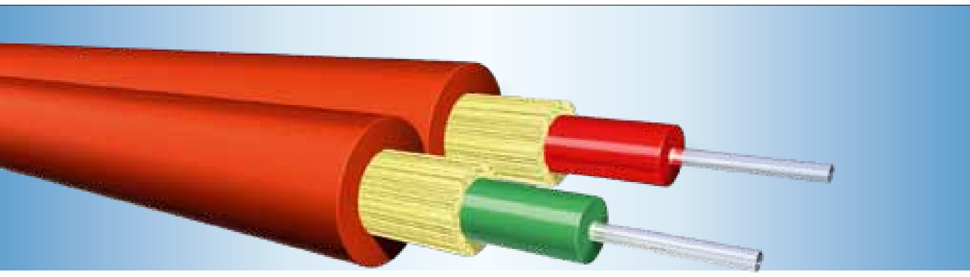


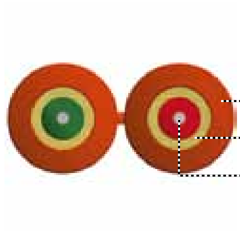


FiberConnect® I-V(ZN)11Y 1…

Order no.	**84 006 00 ☐ ☐**		
Standardisation	IEC 60 794-2		
Application	Oil-resistant patch cable in distribution systems as well as for connecting terminals in harsh industrial environments		
Construction	Cable core	Tight buffered fiber (TB), semi-tight buffered fiber (STB) or superstrip (LB)	
	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 and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–10°C to +70°C	
Mechanical properties	Outer dimensions	2.8 mm	
	Weight	6 kg/km	
	min. bending radius	static dynamic	30 mm 45 mm
	max. pull force	long-term	400 N
	max. crush resistance	500 N/dm	
	Resistance to impact	3 impacts/1 Nm	
Chemical properties	Very good resistance to oil, petrol, acids and alkaline solutions		
Fire performance	The cable is halogen-free and self-extinguishing		

Duplex cable PUR

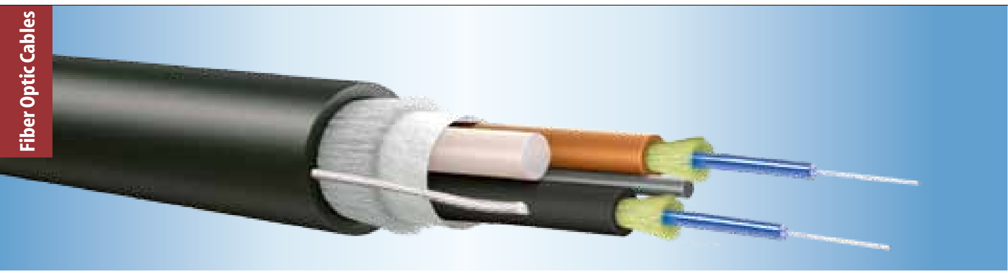


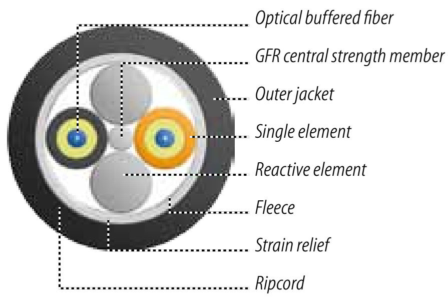


FiberConnect® I-V(ZN)11Y 2x1

Order no.	**84 007 01 ☐ ☐**		
Standardisation	IEC 60 794-2		
Application	Oil-resistant patch cable in distribution systems as well as for connecting terminals in harsh industrial environments		
Construction	Cable core	Tight buffered fiber (TB), semi-tight buffered fiber (STB) or superstrip (LB)	
	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 and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–10°C to +70°C	
Mechanical properties	Outer dimensions	3.0 x 6.0 mm	
	Weight	15 kg/km	
	min. bending radius	static dynamic	30 mm 60 mm
	max. pull force	long-term	600 N
	max. crush resistance	500 N/dm	
	Resistance to impact	3 impacts/1 Nm	
Chemical properties	Very good resistance to oil, petrol, acids and alkaline solutions		
Fire performance	The cable is halogen-free and self-extinguishing		

Breakout cable with rodent protection

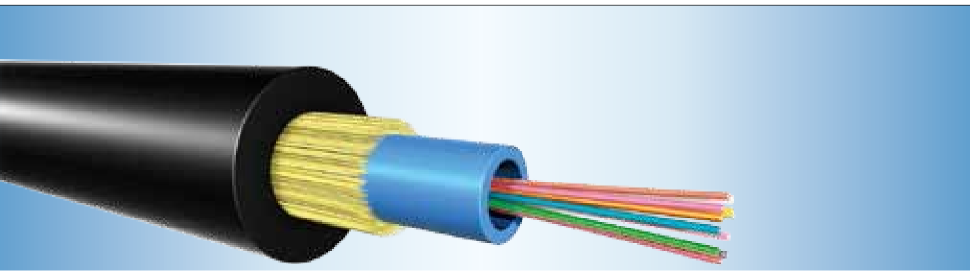


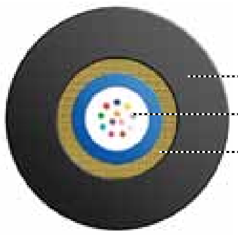


FiberConnect® AT-V(ZN)H(ZN)B2YFR 2… 2.1 mm

Order no.	**84 215 017 ☐**		
Standardisation	IEC 60794-3, DIN VDE 0888 Part 5		
Application	Breakout cable for fixed installation indoors and outdoors with non-metallic rodent protection. Suitable for direct connector assembly. Jacket material with very low water absorption suitable for running directly in the ground.		
Construction	Breakout single element	Tight buffered fiber or semi-tight buffered fiber with non-metallic strain relief elements (aramid) and halogen-free, flame-retardant subcable jacket, Ø 2.1 mm, colours: orange and black	
	Cable core	Glass fiber-reinforced central strength member in the core, over that two breakout single elements and two reactive elements stranded in one layer	
	Tape	1 layer of fleece	
	Armour	Multi-functional E-glass yarn as non-metallic strain relief elements and rodent protection	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Black	
Thermal properties	Transport and storage	−40°C to +80°C	
	Installation	−5°C to +50°C	
	Operation	−40°C to +80°C	
Mechanical properties	Outer dimensions	7.8 mm	
	Weight	55 kg/km	
	min. bending radius	static	80 mm
		dynamic	120 mm
	max. pull force	short-term	2000 N
		long-term	600 N
	max. crush resistance	2000 N/dm	
	Resistance to impact	5 impacts/2 Nm	
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		
Note	UV-resistant outer jacket		

Mobile camera cable (universal cable) with central loose tube



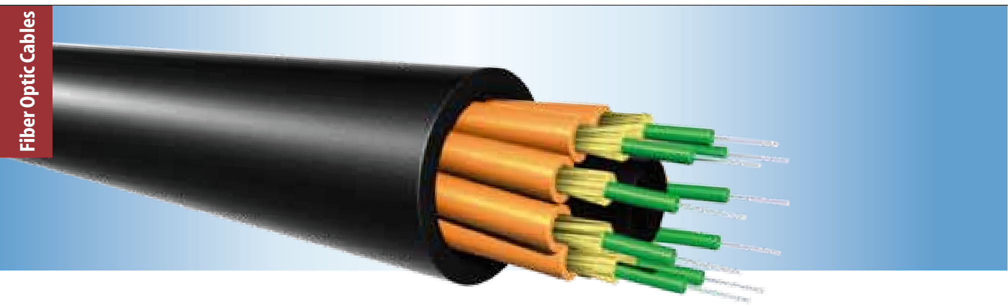


LEONI U-DQ(ZN)11Y n…

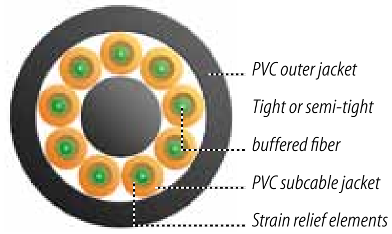
Order no.	**84 023** ☐ ☐ ☐		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Light, flexible and non-metallic cable that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits. Suitable for fixed and flexible use in harsh industrial environments.		
Construction	Cable core	Loose tube, gel-filled	
	Strain relief	Aramid yarns	
	Cable jacket	Polyurethane (PUR)	
	Colour of jacket	Black	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–25°C to +50°C	
	Operation	–25°C to +70°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	3000 N/dm
	Resistance to impact	5 impacts/3 Nm	
Fire performance	Cable is self-extinguishing		
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		
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

Breakout cable suitable for drag chains



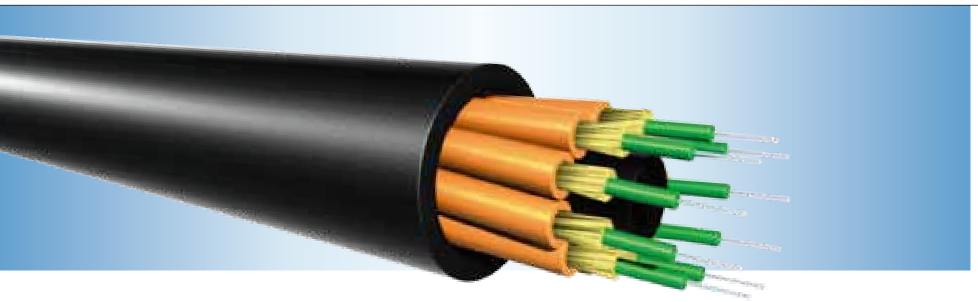
FiberConnect® AT-V(ZN)YY…



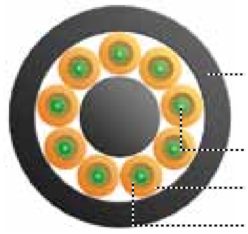
Order no.	**84 206 ☐☐ ☐ ☐**	
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2	
Application	Rugged breakout cable suitable for drag chains that can be used both inside and outside buildings and in harsh industrial environments. For direct connector assembly.	
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as tight buffered or semi-tight buffered 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	Polyvinyl chloride (PVC)
	Colour of jacket	Black
Thermal properties	Transport and storage	–25°C to +80°C
	Installation	–5°C to +50°C
	Operation	–20°C to +80°C
Mechanical properties	max. crush resistance	long-term 800 N/dm
	Resistance to impact	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	145	235	1200	1.84

Breakout cable suitable for drag chains, oil resistant



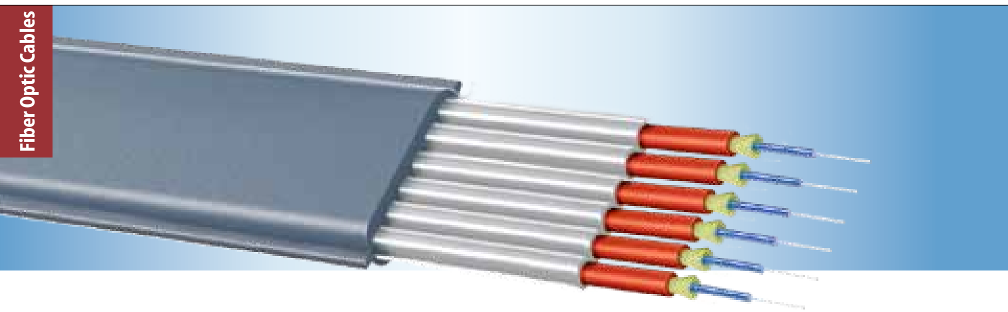
FiberConnect® AT-V(ZN)Y11Y…



Order no.	**84 207 ☐☐ ☐ ☐**	
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2	
Application	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.	
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as tight buffered or semi-tight buffered 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 and storage	–25°C to +80°C
	Installation	–5°C to +50°C
	Operation	–20°C to +80°C
Mechanical properties	max. crush resistance	long-term 800 N/dm
	Resistance to impact	10 impacts/2 Nm
	Drag chain test	5,000,000 cycles
Chemical properties	Very good resistance to oil, petrol, acids and alkaline solutions	
Note	Cable jacket with high abrasion resistance	

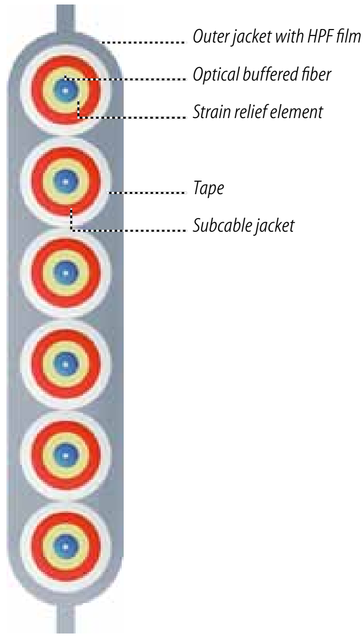
Number of fibers	Outer Ø	Weight	Min. bending radius static	Min. bending radius dynamic	Max. pull force	Fire load
	mm	kg/km	mm	mm	N	MJ/m
2	9.5	80	95	140	800	1.20
4	9.5	85	95	140	800	1.20
6	10.5	110	105	155	1200	1.36
8	12.3	150	125	185	1200	1.52
10	13.8	170	140	205	1200	1.68
12	15.6	210	145	235	1200	1.84

High-performance flex flat cable



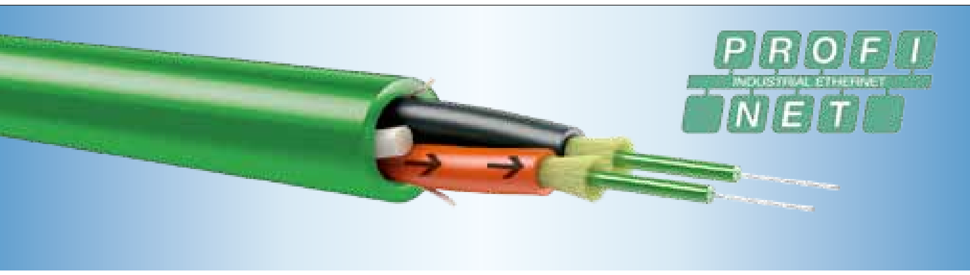
FiberConnect® HPF-FO-Cable n…

Order no.	**See table**		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Drag cable with maximum flexibility, low friction and low abrasion for applications in industrial clean rooms and in medical technology		
Construction	Cable core	Several single-fiber cables arranged in parallel beside each other with buffered fiber type TB600, non-metallic strain relief elements (aramid) and subcable jacket made from TPE taped with ePTFE, diameter 1.6 mm	
	Cable jacket	HPF film	
	Colour of jacket	Grey	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	+5°C to +50°C	
	Operation	–10°C to +60°C	
Mechanical properties	min. bending radius	dynamic	50 mm (over flat side)
Fire performance	No requirement		



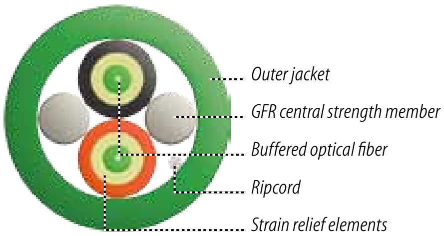
Number of tubes	Total width	Weight	Order no.
	mm	kg/km	
4	10.0	20	**84950772** ☐
6	14.0	30	**84950773** ☐
8	19.0	40	**84950774** ☐
12	27.0	60	**84950776** ☐

Profinet type B duplex indoor cable

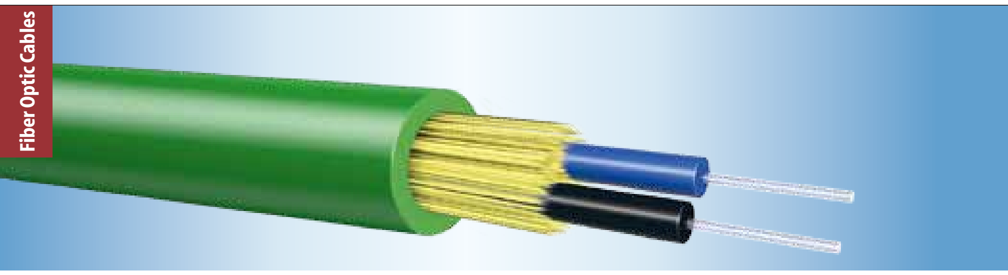


FiberConnect® B AT-W(ZN)YY Z…

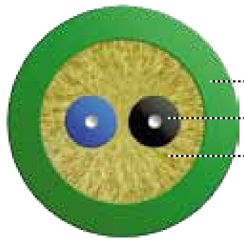
Order no.	**84950544** ☐			
Standardisation	DIN VDE 0888, Part 6 and PROFINET standard			
Application	Bus cable for PROFINET applications in industrial settings for fixed installation in cable ducts and conduits			
Construction	Cable core	Stranding consisting of two PVC single cables with buffered fibers 1.4 mm and with non-metallic strain relief elements (aramid) (Ø 2.9 mm)		
	Cable jacket	Flame-retardant polyvinyl chloride (PVC)		
	Colour of jacket	Black and orange (with printed arrows)		
Thermal properties	Transport and storage	–20°C to +70°C		
	Installation	–5°C to +50°C		
	Operation	–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	short-term	600 N	
	max. crush resistance	short-term	500 N/dm	
Fire performance	Flame retardancy	IEC 60332-1-2		
Note	The cable is also available with a polyurethane (PUR) jacket			



ETFE high-temperature cable
Duplex cable

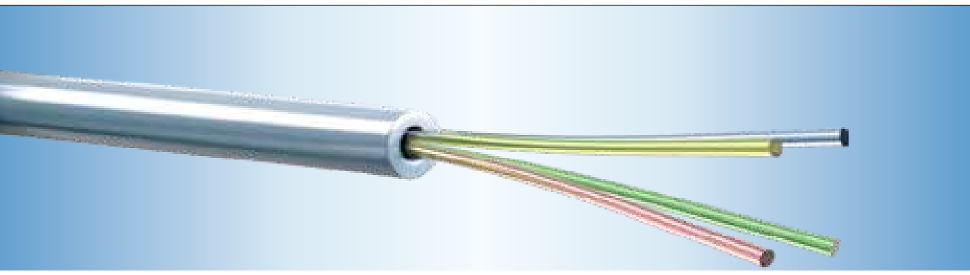


FiberConnect® I-V(ZN)7Y 2G50/125 TB9007Y 3.0 HAT 150



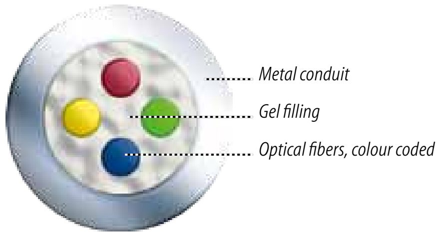
Order no.	**84 950 686** ☐		
Standardisation	IEC 60794-2		
Application	For use at higher temperatures, such as in engines and smelting plants for example, as well as for environments with aggressive media in the chemical industry For direct connector assembly		
Construction	Cable core	Fiber with special coating, type HTC 200 for continuous temperatures up to 150°C and ETFE buffer with Ø 0.9 mm	
	Strain relief elements	Non-metallic (aramid)	
	Cable jacket	Ethylene tetrafluorethylene (ETFE)	
	Colour of jacket	Green	
Thermal properties	Transport and storage	–40°C to +150°C	
	Installation	–5°C to +50°C	
	Operation	–40°C to +150°C	
Mechanical properties	Outer diameter	3.0 mm	
	Weight	11 kg/km	
	min. bending radius	static	30 mm
		dynamic	45 mm
	max. pull force	long-term	500 N
	max. crush resistance	200 N/dm	
	Resistance to impact	3 impacts/1 Nm	
Chemical properties	Very good resistance to oil, petrol, acids and alkaline solutions		
Fire performance	IEC 60332-1-2		

Stainless steel conduit with optical fibers



FiberConnect® stainless steel conduit x mm n…

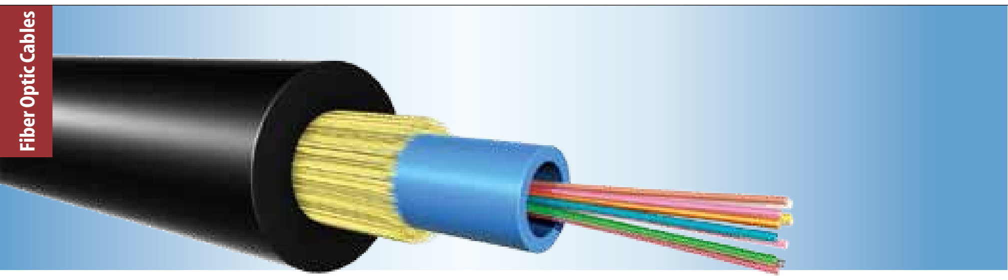
Order no.	**See table**	
Standardisation	IEC 60794-4	
Application	For use in optical ground wires (OPGW) as well as for environments with aggressive media and high mechanical loads	
Construction	Optical fibers, colour coded	
	Gel filling	
	Longitudinally welded, hermetically sealed metal conduit made from stainless steel	
	DIN 17441, type 1.4301 and ASTM 304	
	Thickness: 0.2 mm; diameter: see table	
Thermal properties	Transport and storage	−40°C to +80°C
	Installation	−20°C to +80°C
	Operation	−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	

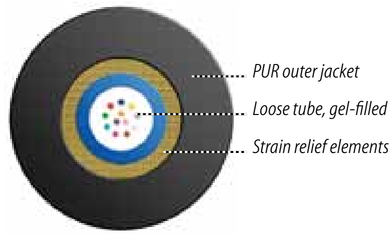


The optimum solution for protecting the fibers against oil and water

Number of fibers	Conduit Ø	Weight	Bending radius min.	Pull force max.	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** ☐

Central loose tube cable with leak-proof, cross-linked gel





FiberConnect® U-DQ(ZN)11Y n… CJ

Order no.	**84 057 □□ □ □**		
Standardisation	IEC 60794-2		
Application	Especially suited as a longitudinally waterproof optical universal cable for mobile use for constant reeling in and out as well as in drag chains		
Construction	Cable core	Loose tube, filled with cross-linked two-component gel	
	Strain relief	Aramid yarns	
	Cable jacket	Polyurethane (PUR)	
	Colour of jacket	Black	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–25°C to +50°C	
	Operation	–25°C to +70°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	3000 N/dm
	Resistance to impact	5 impacts/2 Nm	
Fire performance	Cable is self-extinguishing		
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	36	0.55
24	7.7	50	0.76

2-component gel cables

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.

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.

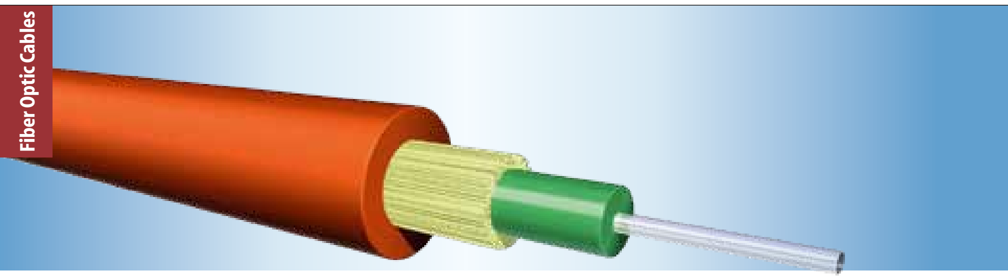
FiberConnect® optical indoor cables are ideally suited to the manufacturing of assembled connection cables for all conceivable cabling structures and network topologies. Either multimode fibers with different specifications or singlemode fibers are used for these cables, depending on the required data rate and the distance to be covered.

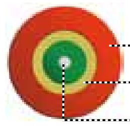
Optical indoor cables with a halogen-free and flame-retardant jacket are required in order to fulfil the strict fire prevention requirements for indoor installations, since they are guaranteed not to propagate fire and not to produce corrosive and toxic gases.

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.

Simplex cable





FiberConnect® I-V(ZN)H 1…

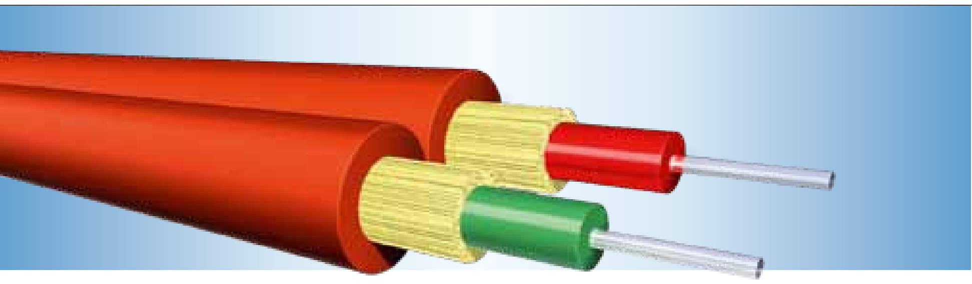
Order no.	**84 003 ☐☐ ☐ ☐**		
Standardisation	DIN VDE 0888, Part 4 and IEC 60 794-2		
Application	Ideal for use as a patch cable in distribution systems as well as for connecting terminals due to the high flexibility and small diameter		
Construction	Cable core	Tight buffered fiber (TB), semi-tight buffered fiber (STB) or superstrip (LB)	
	Strain relief elements	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 and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–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	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

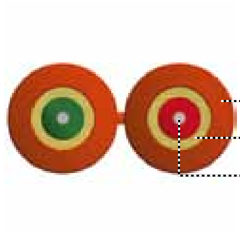
Outer Ø	Type	Weight	Max. pull force long-term	Max. crush resistance long-term	Fire load
mm		kg/km	N	N/dm	MJ/m
1.6	I-V(ZN)H 1…	2.9	200	100	0.09
1.8	I-V(ZN)H 1…	3.7	200	100	0.10
2	I-V(ZN)H 1…	5.0	300	100	0.11
2.1	I-V(ZN)H 1…	5.1	300	100	0.12
2.4	I-V(ZN)H 1…*	5.7	400	150	0.16
2.8	I-V(ZN)H 1…	7.9	400	150	0.18
2.9	I-V(ZN)H 1…	8.0	400	150	0.20
3	I-V(ZN)H 1…	8.1	400	150	0.21
3.4	I-V(ZN)H 1…*	12.0	400	150	0.32

* acc. to TS 0011/96 Deutsche Telekom

All simplex cables available with TB, STB and LB buffered fibers. Order no. on request.

Duplex cable





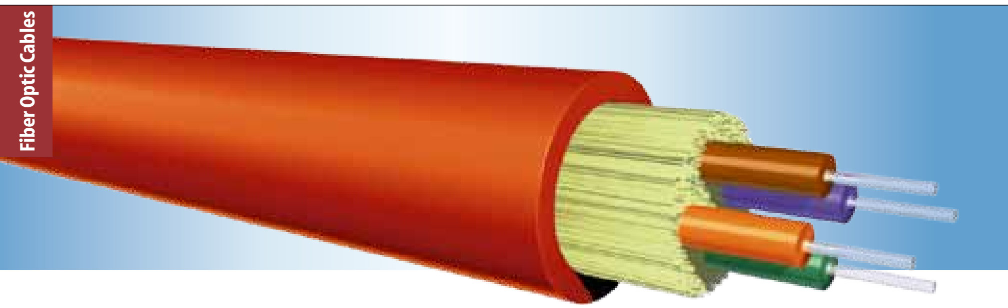
FiberConnect® I-V(ZN)H 2x1…

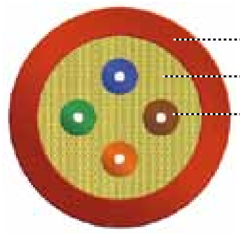
Order no.	**84 005 ☐☐ ☐ ☐**	
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2	
Application	Ideal for use as a patch cable in distribution systems as well as for connecting terminals due to the high flexibility and small diameter	
Construction	Cable core	Tight buffered fiber (TB), semi-tight buffered fiber (STB) or superstrip (LB)
	Strain relief elements	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 and storage	–25°C to +70°C
	Installation	–5°C to +50°C
	Operation	–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
	Halogen-free	IEC 60754-2
	No corrosive and toxic fumes	

Outer Ø	Type	Weight	Max. pull force long-term	Max. crush resistance long-term	Fire load
mm		kg/km	N	N/dm	MJ/m
1.6 x 3.3	I-V(ZN)H 2x1…	5.8	400	200	0.18
1.8 x 3.7	I-V(ZN)H 2x1…	7.4	400	200	0.20
2.0 x 4.1	I-V(ZN)H 2x1…	9.0	400	200	0.22
2.1 x 4.3	I-V(ZN)H 2x1…	9.0	400	400	0.24
2.4 x 4.9	I-V(ZN)H 2x1…	12.6	400	400	0.32
2.8 x 5.7	I-V(ZN)H 2x1…	15.8	600	600	0.36
3.0 x 6.1	I-V(ZN)H 2x1…	17.5	600	600	0.42

All duplex cables available with TB, STB and LB buffered fibers. Order no. on request.

Mini breakout cable





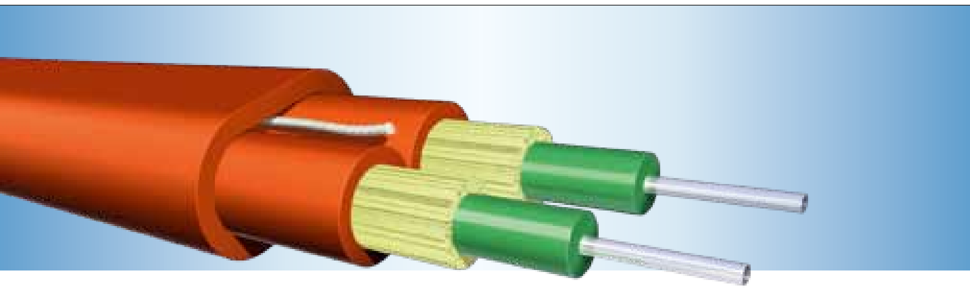
FiberConnect® I-V(ZN)H n…

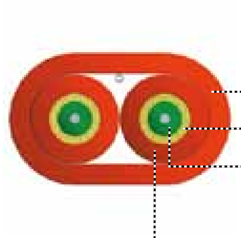
Order no.	**84 026 ☐☐ ☐ ☐**		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Ideal for workstation cabling due to the high flexibility and small dimensions. Non-metallic indoor cable for direct connector assembly.		
Construction	Cable core	Tight buffered fiber (TB), semi-tight buffered fiber (STB) or superstrip (LB)	
	Strain relief elements	Non-metallic (aramid)	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Orange for multimode, yellow for singlemode	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–10°C to +70°C	
Mechanical properties	max. pull force	long-term	800 N
	max. crush resistance	long-term	300 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

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, STB and LB buffered fibers. Order no. on request.

Breakout cable, flat





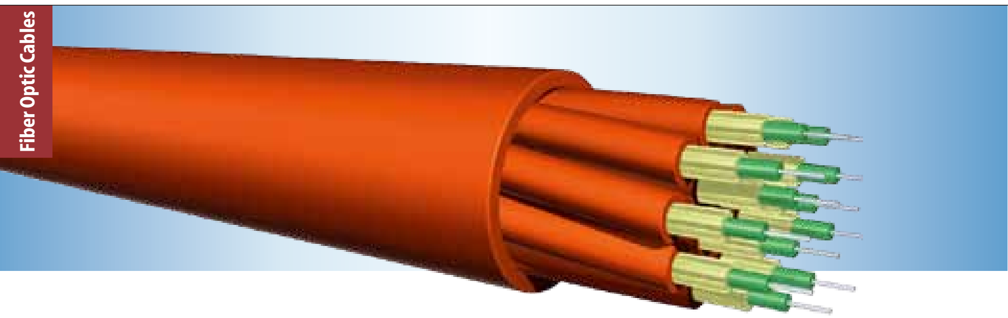
FiberConnect® I-V(ZN)HH 2x1…

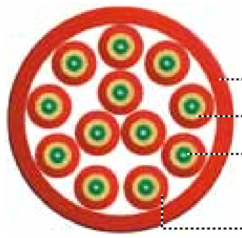
Order no.	**84 011 □□ □ □**		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Light, thin and rugged indoor cable for use as a patch cable in distribution systems, as connection cable for terminals as well as for workstation cabling. For direct connector assembly.		
Construction	Cable core	Two single-fiber cables (TB, STB or LB) arranged in parallel beside each other with non-metallic strain relief elements (aramid) and halogen-free, flame-retardant subcable jacket (Ø see table)	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Orange for multimode, yellow for singlemode	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–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	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

Single element	Cable outer dimensions	Type	Weight	Max. pull force long-term	Max. crush resistance long-term	Fire load
mm	mm		kg/km	N	N/dm	MJ/m
1.7	2.8 x 4.5	I-V(ZN)HH 2x1…	16.5	400	400	0.58
1.8	2.9 x 4.7	I-V(ZN)HH 2x1…	17.5	400	400	0.60
2.0	3.1 x 5.2	I-V(ZN)HH 2x1…	19.0	600	400	0.63
2.1	3.1 x 5.2	I-V(ZN)HH 2x1…	19.0	600	400	0.63
2.5	3.7 x 6.2	I-V(ZN)HH 2x1…	26.0	600	600	0.65
2.8	4.0 x 6.8	I-V(ZN)HH 2x1…	32.0	600	600	0.83

All flat breakout cables available with TB, STB and LB buffered fibers. Order no. on request.

Breakout cable





FiberConnect® I-V(ZN)HH n…

Order no.	**See table**	
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2	
Application	Non-metallic, rugged cable for installation in the rising and horizontal indoor area. For direct connector assembly.	
Construction	Cable core	Stranded single elements designed as tight buffered fiber (TB), semi-tight buffered fiber (STB) or superstrip (LB) with non-metallic strain relief elements (aramid) and halogen-free, flame-retardant subcable jacket (Ø see table)
	Cable jacket	Halogen-free and flame-retardant material
	Colour of jacket	Orange for multimode, yellow for singlemode
Thermal properties	Transport and storage	–25°C to +70°C
	Installation	–5°C to +50°C
	Operation	–10°C to +70°C
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A
	Smoke density	IEC 61034
	Halogen-free	IEC 60754-2
	No corrosive and toxic fumes	
Note	The cable is alternatively available with non-metallic rodent protection (B).	

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

Single cable with 2.0 mm Ø, tight buffered fiber, semi-tight buffered fiber or superstrip fiber with 900 µm

Order no. **84 054 ☐☐ 0 ☐ (TB) | 84 054 ☐☐ 1 ☐ (STB) | 84 054 ☐☐ 6 ☐ (LB)**

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	14.6	200	150	225	1000	1000	2.23

Single cable with 2.1 mm Ø, tight buffered fiber, semi-tight buffered fiber or superstrip buffered fiber with Ø 900 µm

Order no. **84 013** ☐☐ **0** ☐ (TB) | **84 013** ☐☐ **1** ☐ (STB) | **84 013** ☐☐ **6** ☐ (LB)

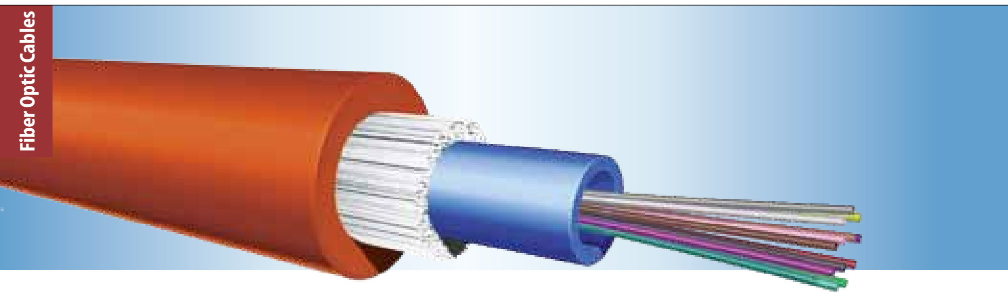
Number of fibers	Outer Ø	Weight	Min. bending radius static	Min. bending radius dynamic	Max. pull force long-term	Max. crush resistance long-term	Fire load
	mm	kg/km	mm	mm	N	N/dm	MJ/m
2	7.0	40	70	105	800	1000	1.10
4	7.0	45	70	105	800	1000	1.10
6	8.2	65	80	120	1000	1000	1.18
8	9.6	95	95	145	1000	1000	1.31
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, buffered fiber: TB900 or STB900, tight buffered fiber, semi-tight buffered fiber or superstrip buffered fiber with Ø 900 µm

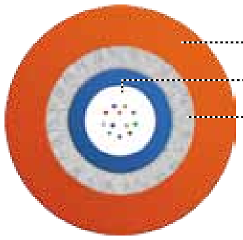
Order no. **84 010** ☐☐ **0** ☐ (TB) | **84 010** ☐☐ **1** ☐ (STB) | **84 010** ☐☐ **6** ☐ (LB)

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

Indoor cable with central, gel-free loose tube



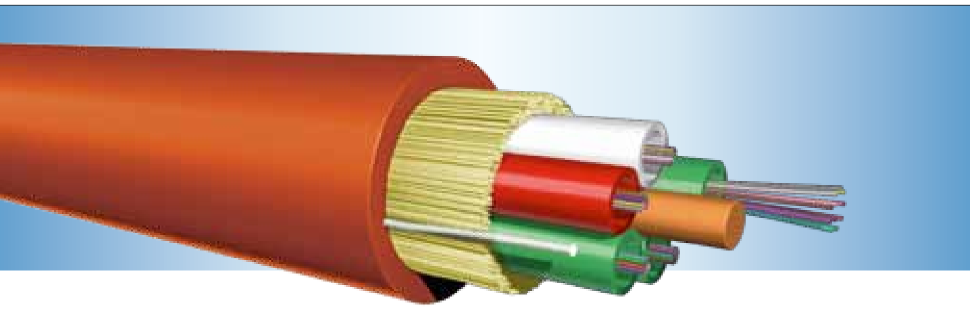
FiberConnect® I-D(ZN)BH n… JF

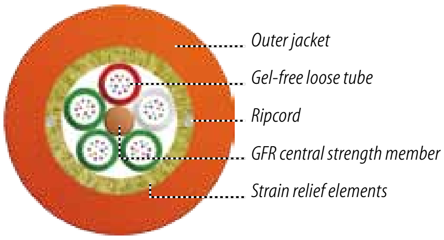


Order no.	**84 050** ☐☐ ☐ ☐		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Light and flexible cable, can be used inside buildings. Gel-free loose tubes mean the fibers do not need to be cleaned. Installation in cable ducts, on cable trays or in cable conduits. Especially suited for rising areas.		
Construction	Cable core	Gel-free loose tubes with max. 24 fibers	
	Armour	Multi-functional E-glass yarn, water-absorbent as strain relief and rodent protection	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Orange for multimode, yellow for singlemode	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–10°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	600 N
	max. crush resistance	long-term	1500 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

Number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	6.3	44	0.68
24	6.8	49	0.76

Indoor cable with stranded, gel-free loose tubes





FiberConnect® I-D(ZN)H nxm… JF

Order no.	84 048 □□ □ □		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Cable for use inside buildings. Gel-free loose tubes mean the fibers do not need to be cleaned. Installation in cable ducts, on cable trays or in cable conduits. Especially suited to rising areas.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as gel-free loose tubes and if applicable bundle elements	
	Strain relief elements	Non-metallic (aramid)	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Orange for multimode, yellow for singlemode	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–10°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	1000 N
	max. crush resistance	long-term	2000 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

Number of tubes	Number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	10.5	95	2.00
2 x m	**24**	10.5	95	2.00
3 x m	**36**	10.5	95	2.00
4 x m	**48**	10.5	95	2.00
5 x m	**60**	10.5	95	2.00
6 x m	**72**	11.6	115	2.36
8 x m	**96**	13.1	135	2.48
10 x m	**120**	14.8	175	3.12
12 x m	**144**	16.3	215	3.76

You will find universal cables for use inside and outside buildings with loose tube construction or tight buffered fiber construction in the next chapter on outdoor cables.

Fiber Optic Cables

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 Fiber Optics business unit 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 (polyethylene) is halogen-free and UV-resistant. LEONI outdoor cables are certified according to the symbol test in accordance with DIN VDE 0888, Part 3.

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.

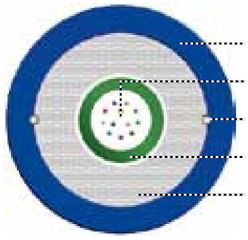
Universal cables with an integrated metallic humidity barrier are also offered for this as appropriate to the environment and installation conditions. Universal cables with an aluminium jacket or corrugated steel jacket are suitable for running directly in the ground, doing away with the need to use a HDPE protective conduit.

The halogen-free and flame-retardant cable jackets of the FiberConnect® optical universal cables guarantee adherence with the strict fire prevention requirements for cables for indoor use.

Universal cable with system integrity

Rodent-protected universal cable
with central loose tube (2500 N)
and system integrity in the event of fire

FiberConnect® U-D(ZN)BH n…2500 N

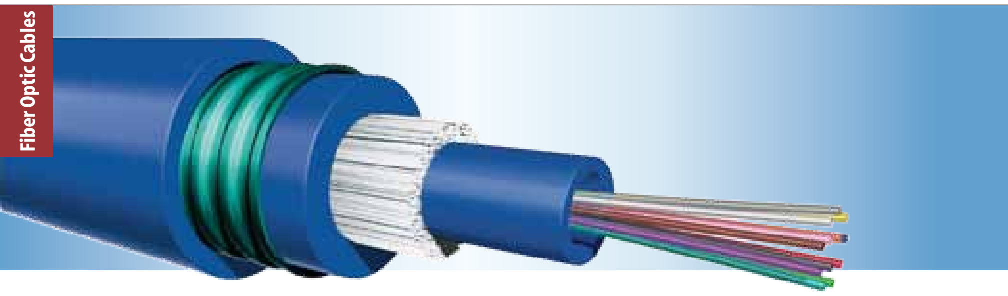


Order no.	**84 040** □□ □ □		
Standardisation	DIN VDE 0888, Part 6		
Application	Non-metallic, light and flexible cable with increased tensile strength that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.		
Construction	Cable core	Loose tube, gel-filled	
	Inner fire protection tape		
	Armour	Multi-functional, strengthened E-glass yarn, water-absorbent as non-metallic strain relief elements and rodent protection	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Blue	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	3000 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		
System integrity test (VDE test report)	Acc. to IEC 60 331-11, IEC 60 331-25 and EN 50200 90 min		

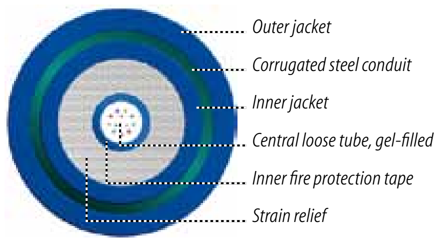
System integrity for at least 90 minutes in the event of fire

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

Universal cable with system integrity



Rodent-protected universal cable with central loose tube (2500 N) and system integrity in the event of fire



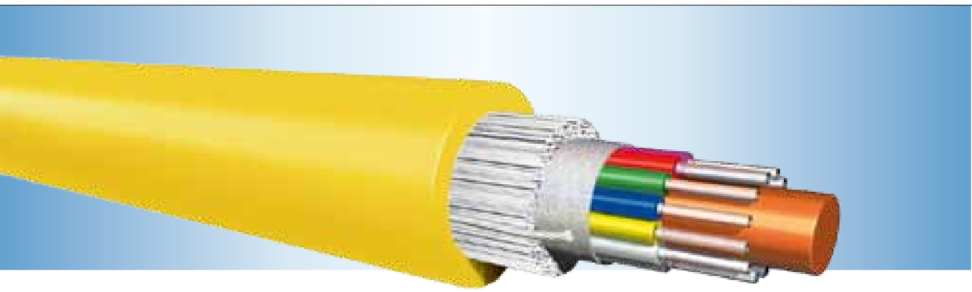
FiberConnect® U-DQ(ZN)HWH n…

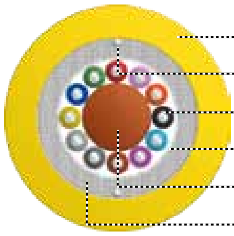
Order no.	**84 047** ☐☐ ☐ ☐		
Standardisation	DIN VDE 0888, Part 6		
Application	Mechanically rugged cable with increased tensile strength that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.		
Construction	Cable core	Loose tube, gel-filled	
	Inner fire protection tape		
	Strain relief elements	Non-metallic (E-glass yarn), water-absorbent	
	Inner jacket	Halogen-free and flame-retardant	
	Corrugated steel conduit	As outer fire barrier and rodent protection	
	Outer jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Blue	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	2500 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		
System integrity test (VDE test report)	Acc. to IEC 60 331-11, IEC 60 331-25 and EN 50200 120 min		

System integrity for at least 120 minutes in the event of fire

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

Rodent-protected universal cable with stranded tight buffered fibers



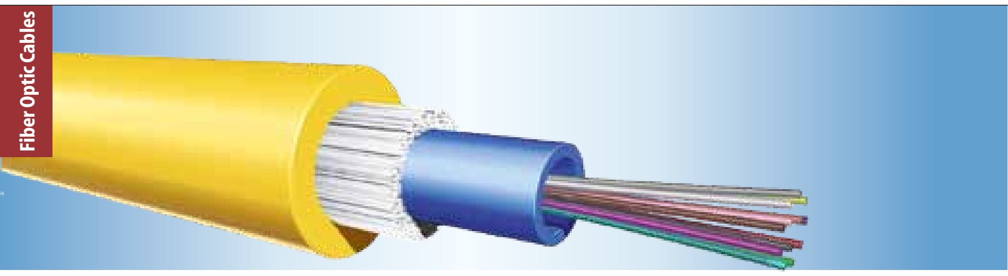


FiberConnect® U-VQ(ZN)BH n…

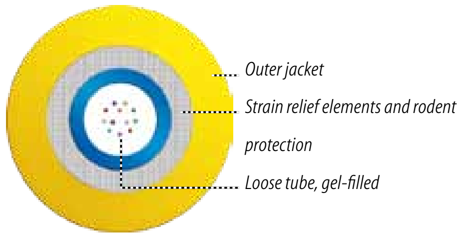
Order no.	**84 950 165** ☐		
Standardisation	DIN VDE 0888, Part 6		
Application	Cable for use both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits. Non-metallic universal cable for direct connector assembly. Suitable for all types of installation in protective conduits.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as tight buffered fibers (TB) and if applicable dummy elements	
	Armour	Multi-functional, strengthened E-glass yarn, water-absorbent as non-metallic strain relief elements and rodent protection	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Yellow	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	1000 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

Number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
4	9.4	130	1.03
6	9.4	130	1.03
8	9.4	130	1.03
10	9.8	145	1.21
12	9.8	145	1.21
16	10.8	150	1.37
20	10.8	150	1.37
24	11.1	155	1.44

Rodent-protected universal cable with central loose tube (1750 N)



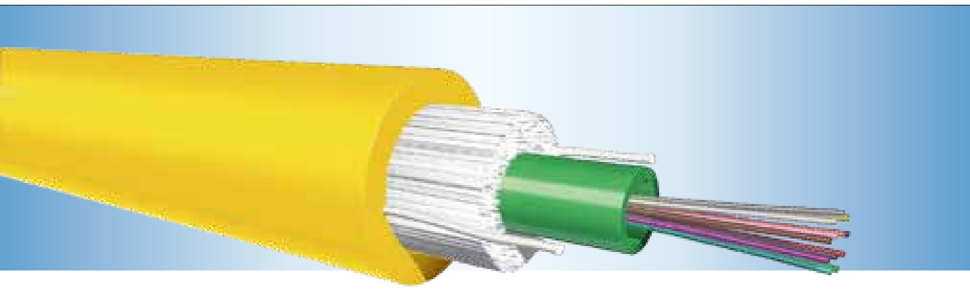
FiberConnect® U-DQ(ZN)BH n… 1750 N

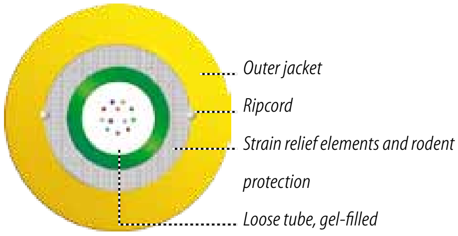


Order no.	**84 025 □□ □ □**		
Standardisation	DIN VDE 0888, Part 6		
Application	Non-metallic, light and flexible cable that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.		
Construction	Cable core	Loose tube, gel-filled	
	Armour	Multi-functional E-glass yarn, water-absorbent as non-metallic strain relief elements and rodent protection	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Yellow	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	1750 N
	max. crush resistance	long-term	1500 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-24 Cat. C	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

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

Rodent-protected universal cable with central loose tube (2500 N)



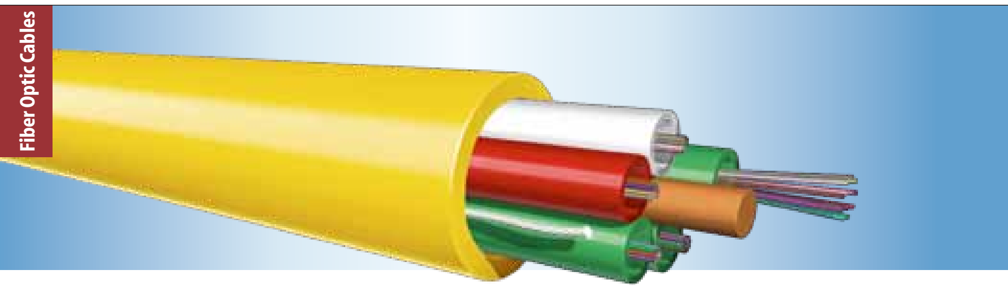


FiberConnect® U-DQ(ZN)BH n… 2500 N

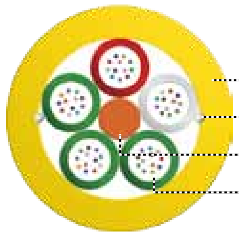
Order no.	**84 032** □□ □ □		
Standardisation	DIN VDE 0888, Part 6		
Application	Non-metallic, light and flexible cable with increased tensile strength that can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.		
Construction	Cable core	Loose tube, gel-filled	
	Armour	Multi-functional, strengthened E-glass yarn, water-absorbent as non-metallic strain relief elements and rodent protection	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Yellow	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	3000 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

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

Universal cable with stranded loose tubes



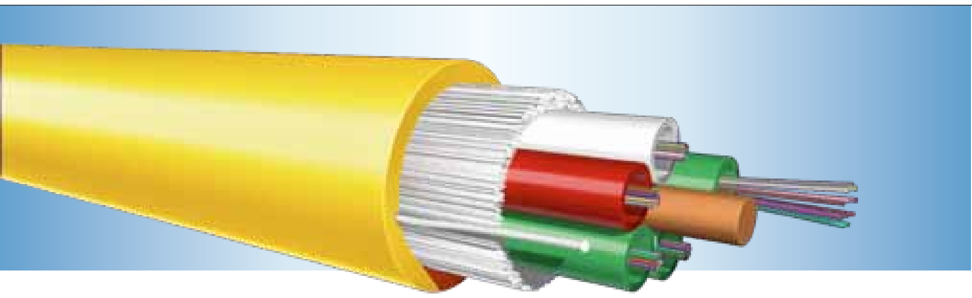
FiberConnect® U-DH nxm…

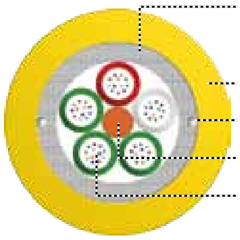


Order no.	**84 029** □□ □ □		
Standardisation	DIN VDE 0888, Part 6		
Application	Non-metallic cable, can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as loose tubes and if applicable dummy elements	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Yellow	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–25°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	1500 N
	max. crush resistance	long-term	2000 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	10.5	105	2.2
2 x m	**24**	10.5	105	2.2
3 x m	**36**	10.5	105	2.2
4 x m	**48**	10.5	105	2.2
5 x m	**60**	10.5	105	2.2
6 x m	**72**	11.0	125	2.6
7 x m	**84**	11.7	130	2.9
8 x m	**96**	12.4	145	3.0

Rodent-protected universal cable with stranded loose tubes



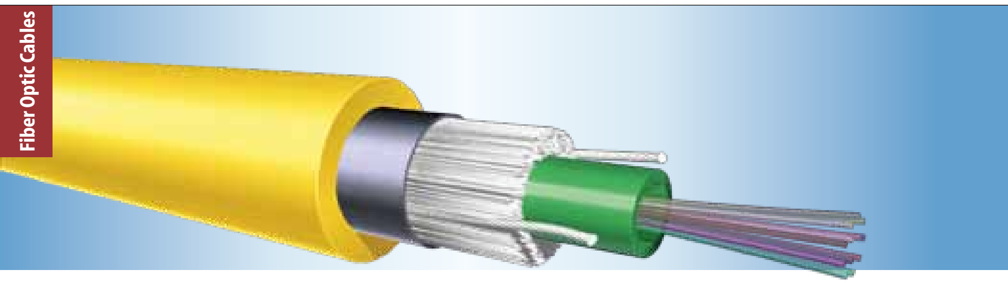


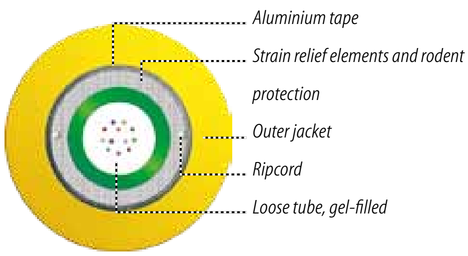
FiberConnect® U-DQ(ZN)BH nxm…

Order no.	**84 033** ☐☐ ☐ ☐		
Standardisation	DIN VDE 0888, Part 6		
Application	Non-metallic cable, can be used both inside and outside buildings. Installation in cable ducts, on cable trays or in cable conduits.		
Construction	Cable core	Glass fiber-reinforced support elements with strand elements, designed as loose tubes and if applicable dummy elements	
	Armour	Multi-functional, strengthened E-glass yarn, water-absorbent as non-metallic strain relief elements and rodent protection	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Yellow	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–25°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	6000 N
	max. crush resistance	long-term	3000 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	12.5	185	3.1
2 x m	**24**	12.5	185	3.1
3 x m	**36**	12.5	185	3.1
4 x m	**48**	12.5	185	3.1
5 x m	**60**	12.5	185	3.1
6 x m	**72**	13.4	200	3.2
8 x m	**96**	14.4	225	3.4
10 x m	**120**	15.9	250	3.7
12 x m	**144**	17.7	305	4.5

Transversely waterproof universal cable with central loose tube



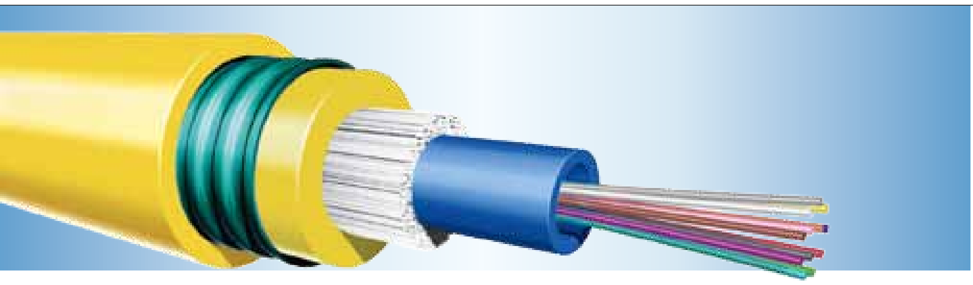


FiberConnect® U-DQ(ZN)(L)H n…

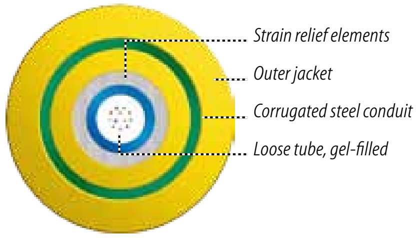
Order no.	**84 034** ☐☐ ☐ ☐		
Application	Can be used both inside and outside buildings. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.		
Construction	Cable core	Loose tube, gel-filled	
	Strain relief elements	Non-metallic (E-glass yarn), water-absorbent	
	Aluminium tape	For transversal water resistance	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Yellow	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	1000 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

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

Rodent-protected, transversely waterproof universal cable with central loose tube



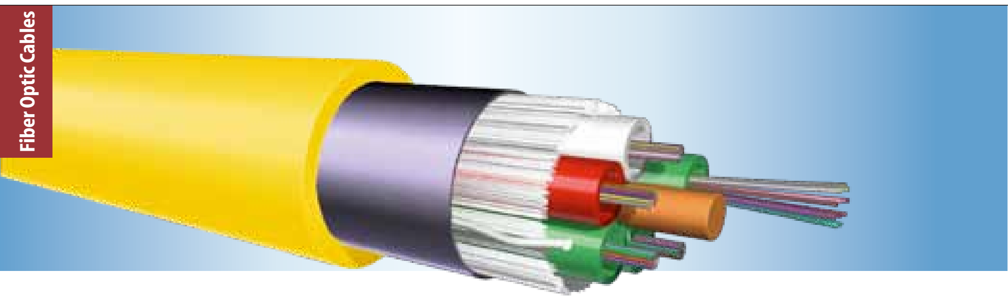
FiberConnect® U-DQ(ZN)HWH n…



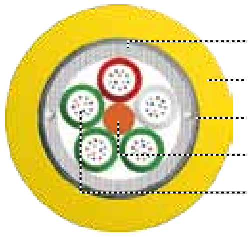
Order no.	**84 030** ☐☐ ☐ ☐		
Application	Can be used both inside and outside buildings. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.		
Construction	Cable core	Loose tube, gel-filled	
	Strain relief elements	Non-metallic (E-glass yarn), water-absorbent	
	Inner jacket	Halogen-free and flame-retardant	
	Corrugated steel conduit	As highly effective rodent protection	
	Outer jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Yellow	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	2500 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

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

Transversely waterproof universal cable with stranded loose tubes



FiberConnect® U-DQ(ZN)(L)H nxm…

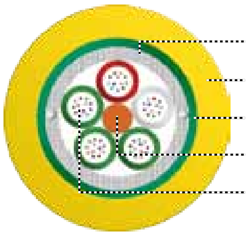


Order no.	**84 035** ☐☐ ☐ ☐		
Application	Can be used both inside and outside buildings. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as gel-filled loose tubes and if applicable dummy elements	
	Strain relief elements	Non-metallic (E-glass yarn), water-absorbent	
	Aluminium tape	For transversal water resistance	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Yellow	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	3000 N
	max. crush resistance	long-term	1500 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	12.1	170	2.73
2 x m	**24**	12.1	170	2.73
3 x m	**36**	12.1	170	2.73
4 x m	**48**	12.1	170	2.73
5 x m	**60**	12.1	170	2.73
6 x m	**72**	13.0	190	3.13
8 x m	**96**	14.4	230	3.28
10 x m	**120**	15.9	270	3.60
12 x m	**144**	17.7	320	4.39

Rodent-protected, transversely waterproof universal cable with stranded loose tubes

FO Cables

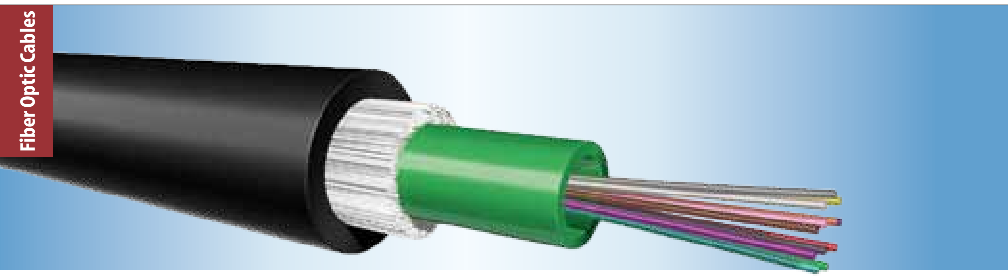


FiberConnect® U-DQ(ZN)WH nxm…

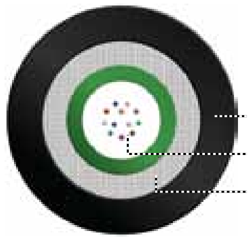
Order no.	**84 037** ☐☐ ☐ ☐		
Application	Can be used both inside and outside buildings. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as gel-filled loose tubes and if applicable dummy elements	
	Strain relief elements	Non-metallic (E-glass yarn), water-absorbent	
	Corrugated steel conduit	As highly effective rodent protection	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Yellow	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	3000 N
	max. crush resistance	long-term	2000 N/dm
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	12.7	200	3.45
2 x m	**24**	12.7	200	3.45
3 x m	**36**	12.7	200	3.45
4 x m	**48**	12.7	200	3.45
5 x m	**60**	12.7	200	3.45
6 x m	**72**	16.5	305	4.05
8 x m	**96**	16.5	305	4.05
10 x m	**120**	16.5	305	4.05

Rodent-protected outdoor cable with central loose tube (1750 N)



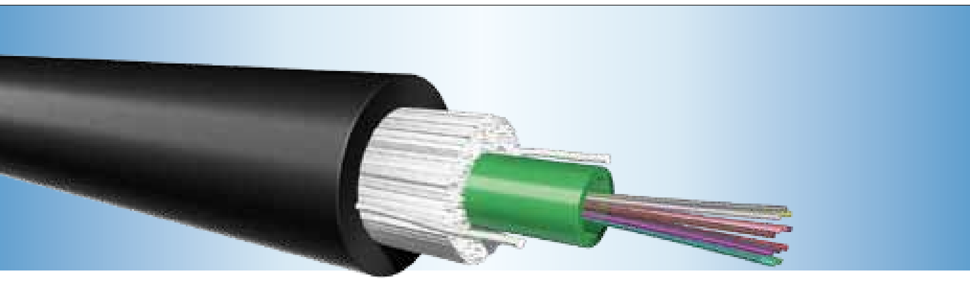
FiberConnect® A-DQ(ZN)B2Y n… 1750 N



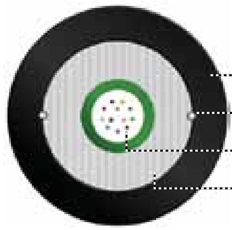
Order no.	**84 305** ☐☐ ☐ ☐		
Standardisation	IEC 60 794-3		
Application	Light, flexible and non-metallic outdoor cable for primary cabling and the backbone area. For pulling into conduits, installation on cable trays or directly in the ground.		
Construction	Cable core	Loose tube, gel-filled	
	Armour	Multi-functional E-glass yarn, water-absorbent as strain relief and rodent protection	
	Cable jacket	PE jacket with imprint	
	Colour of jacket	Black	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	1750 N
	max. crush resistance	long-term	1500 N/dm
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		
Note	The jacket material PE 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	1.11
24	7.5	47	1.20

Rodent-protected outdoor cable with central loose tube (2500 N)



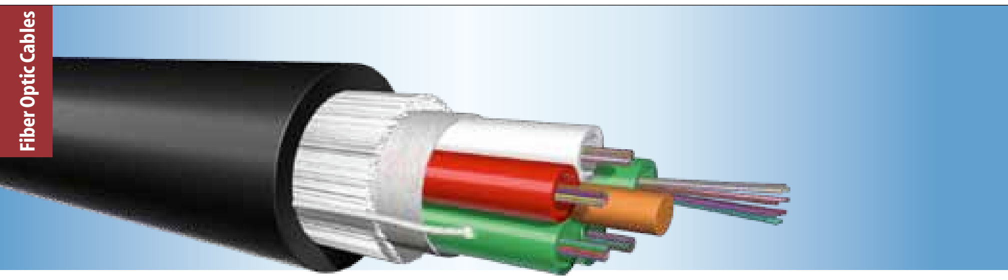
FiberConnect® A-DQ(ZN)B2Y n… 2500 N



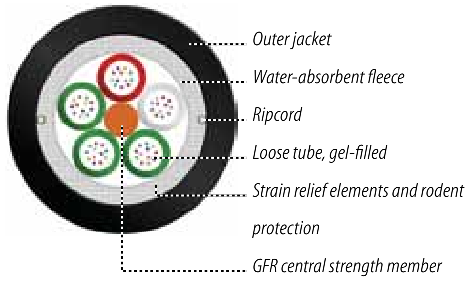
Order no.	**84 321 ☐☐ ☐ ☐**		
Standardisation	IEC 60 794-3		
Application	Non-metallic construction for primary cabling and the backbone area. For pulling into conduits, installation on cable trays or directly in the ground.		
Construction	Cable core	Loose tube, gel-filled	
	Armour	Multi-functional, strengthened E-glass yarn, water-absorbent as strain relief and rodent protection	
	Cable jacket	PE jacket with imprint	
	Colour of jacket	Black	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	3000 N/dm
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		
Note	The jacket material PE offers good protection against transversal water ingress.		

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

Rodent-protected, dry-core outdoor cable with stranded loose tubes



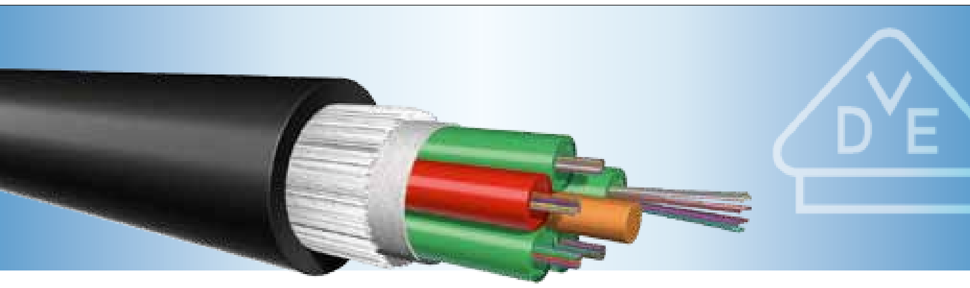
FiberConnect® A-DQ(ZN)B2Y nxm…

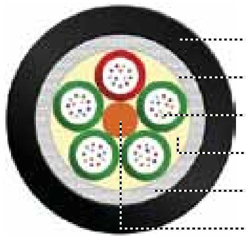


Order no.	**84 316**□□ □ □		
Standardisation	DIN VDE 0888, Part 3 and IEC 60 794-3		
Application	Non-metallic, rugged outdoor cable. Installation-friendly because of the cable core kept free of grease. Installation in conduits, on cable trays or directly in the ground.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as gel-filled loose tubes and if applicable dummy elements	
	Water-absorbent fleece		
	Armour	Multi-functional, strengthened E-glass yarn as non-metallic strain relief elements and rodent protection	
	Cable jacket	PE jacket with hot-stamped marking	
	Colour of jacket	Black	
Thermal properties	Transport and storage	–40°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–40°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	4000 N
	max. crush resistance	long-term	3000 N/dm
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		
Note	The jacket material PE offers good protection against transversal water ingress.		
	Higher fiber numbers and pull forces on request.		
	Also available with aluminium or corrugated steel tape.		

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	11.4	115	4.1
2 x m	**24**	11.4	115	4.1
3 x m	**36**	11.4	115	4.1
4 x m	**48**	11.4	115	4.1
5 x m	**60**	11.4	115	4.1
6 x m	**72**	12.3	135	4.5
8 x m	**96**	13.7	160	5.0
10 x m	**120**	15.2	190	5.5
12 x m	**144**	17.0	230	6.2

Grease-filled outdoor cable with stranded loose tubes



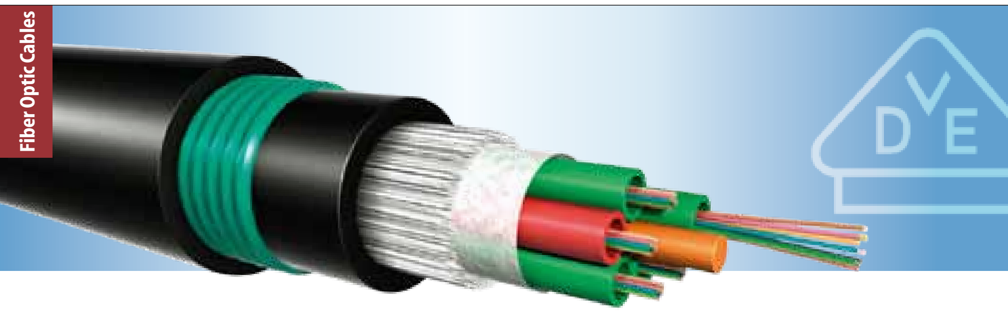


FiberConnect® A-DF(ZN)2Y nxm…

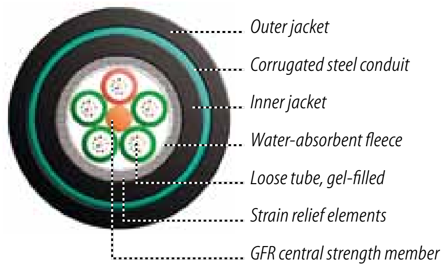
Order no.	**84 300** ☐☐ ☐ ☐		
Standardisation	DIN VDE 0888, Part 3 and IEC 60 794-3		
Application	Non-metallic, rugged outdoor cable for primary cabling and the backbone area. Installation in conduits, on cable trays or directly in the ground.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as gel-filled loose tubes and if applicable dummy elements. Cable core filled with water-blocking gel.	
	Strain relief element	E-glass yarn	
	Cable jacket	PE jacket with hot-stamped marking	
	Colour of jacket	Black	
Thermal properties	Transport and storage	−40°C to +70°C	
	Installation	−5°C to +50°C	
	Operation	−40°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	≤ 7 strand elements 3000 N
			> 7 strand elements 4000 N
	max. crush resistance	long-term	3000 N/dm
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		
Note	The jacket material PE offers good protection against transversal water ingress.		
	Also available with aluminium or corrugated steel tape and copper elements.		

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	11.4	120	4.3
2 x m	**24**	11.4	120	4.3
3 x m	**36**	11.4	120	4.3
4 x m	**48**	11.4	120	4.3
5 x m	**60**	11.4	120	4.3
6 x m	**72**	12.3	135	4.6
8 x m	**96**	13.7	170	5.1
10 x m	**120**	15.2	200	5.7
12 x m	**144**	17.0	240	6.5
16 x m	**192**	16.8	255	7.4

Rodent-secure, grease-filled outdoor cable with stranded loose tubes



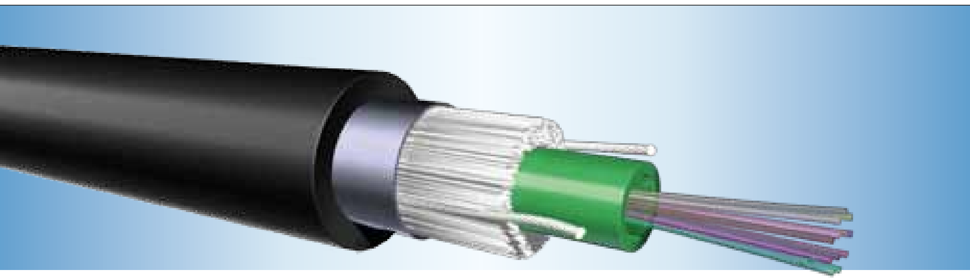
FiberConnect® A-DF(ZN)2YW2Y nxm…



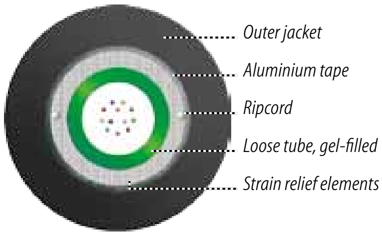
Order no.	**84 310** ☐☐ ☐ ☐		
Standardisation	DIN VDE 0888, Part 3 and IEC 60 794-3		
Application	Rugged outdoor cable for primary cabling and the backbone area. Installation in conduits, on cable trays or directly in the ground.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as gel-filled loose tubes and if applicable dummy elements. Cable core filled with water-blocking gel.	
	Strain relief element	E-glass yarn	
	Inner jacket (black)	PE jacket	
	Corrugated steel conduit	As highly effective rodent protection	
	Cable jacket	PE jacket with hot-stamped marking	
	Colour of jacket	Black	
Thermal properties	Transport and storage	–40°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–40°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	≤ 7 strand elements 3000 N
			> 7 strand elements 4000 N
	max. crush resistance	long-term	3000 N/dm
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	16.7	275	10.4
2 x m	**24**	16.7	275	10.4
3 x m	**36**	16.7	275	10.4
4 x m	**48**	16.7	275	10.4
5 x m	**60**	16.7	275	10.4
6 x m	**72**	18.8	335	12.0
8 x m	**96**	18.8	335	12.0
10 x m	**120**	21.8	335	12.5
12 x m	**144**	21.8	370	13.1
16 x m	**192**	21.8	380	13.8

Transversely waterproof outdoor cable with central loose tube



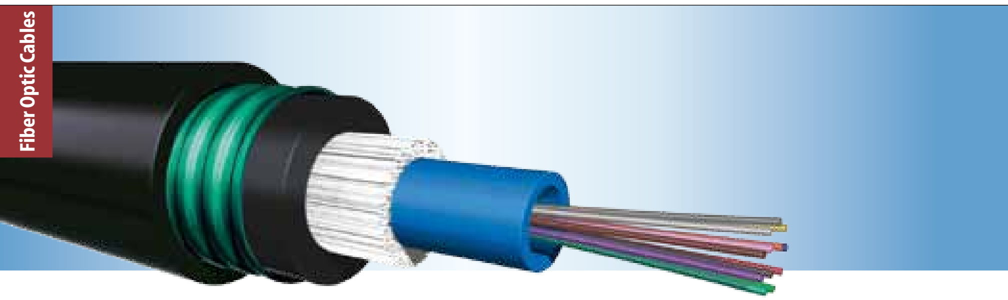
FiberConnect® A-DQ(ZN)(L)2Y n…



Order no.	**84 333** □□ □ □		
Standardisation	DIN VDE 0888, Part 3 and IEC 60 794-3		
Application	Light outdoor cable with diffusion barrier. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.		
Construction	Cable core	Loose tube, gel-filled	
	Strain relief element	Non-metallic (E-glass yarn), water-absorbent	
	Aluminium tape	For transversal water resistance	
	Cable jacket	PE jacket with imprint	
	Colour of jacket	Black	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	1000 N/dm
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		

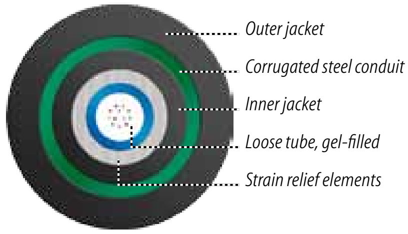
Max. number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	10.8	128	1.42
24	11.3	135	1.62

Rodent-protected, transversely waterproof outdoor cable with central loose tube



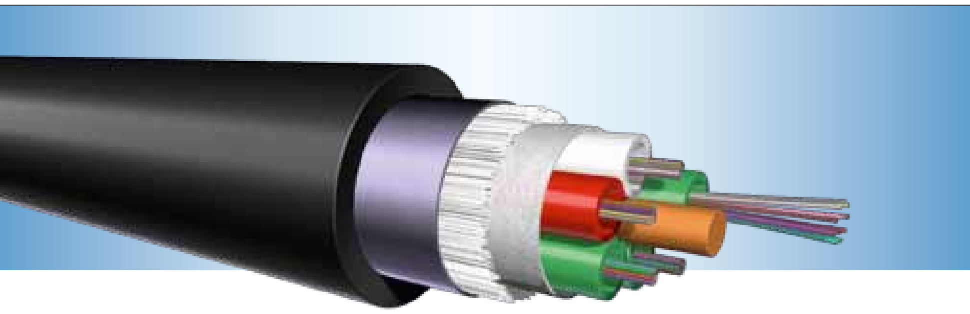
FiberConnect® A-DQ(ZN)2YW2Y n…

Order no.	**84 331** □□ □ □		
Standardisation	DIN VDE 0888, Part 3 and IEC 60 794-3		
Application	Rugged outdoor cable for installation in cable ducts, on cable trays, in conduits or directly in the ground		
Construction	Cable core	Loose tube, gel-filled	
	Strain relief element	Non-metallic (E-glass yarn), water-absorbent	
	Inner jacket (black)	PE jacket	
	Corrugated steel conduit	As highly effective rodent protection	
	Outer jacket	PE jacket with imprint	
	Colour of jacket	Black	
Thermal properties	Transport and storage	–40°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–40°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	2500 N/dm
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		

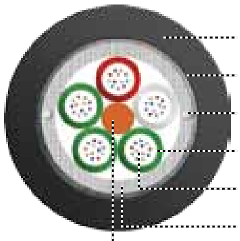


Number of fibers	Outer Ø	Weight	Fire load
	mm	kg/km	MJ/m
12	12.5	160	1.8
24	12.5	160	1.8

Transversely waterproof outdoor cable with stranded loose tubes



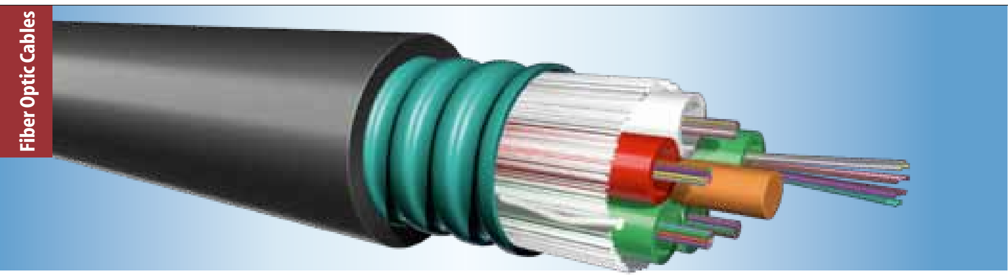
FiberConnect® A-DQ(ZN)(L)2Y nxm…



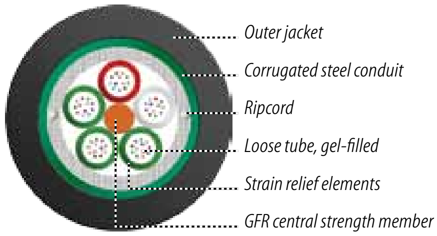
Order no.	**84 326** ☐☐ ☐ ☐		
Standardisation	DIN VDE 0888, Part 3 and IEC 60 794-3		
Application	Rugged outdoor cable with diffusion barrier. Installation in cable ducts, on cable trays, in cable conduits or directly in the ground.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as gel-filled loose tubes and if applicable dummy elements	
	Strain relief element	Non-metallic (E-glass yarn), water-absorbent	
	Aluminium tape	For transversal water resistance	
	Cable jacket	PE jacket with hot-stamped marking	
	Colour of jacket	Black	
Thermal properties	Transport and storage	−40°C to +70°C	
	Installation	−5°C to +50°C	
	Operation	−40°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	3000 N
	max. crush resistance	long-term	1500 N/dm
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	12.1	140	4.9
2 x m	**24**	12.1	140	4.9
3 x m	**36**	12.1	140	4.9
4 x m	**48**	12.1	140	4.9
5 x m	**60**	12.1	140	4.9
6 x m	**72**	13.0	160	5.6
8 x m	**96**	14.4	200	5.9
10 x m	**120**	15.9	240	6.4
12 x m	**144**	17.7	280	7.2

Rodent-protected, transversely waterproof outdoor cable with stranded loose tubes

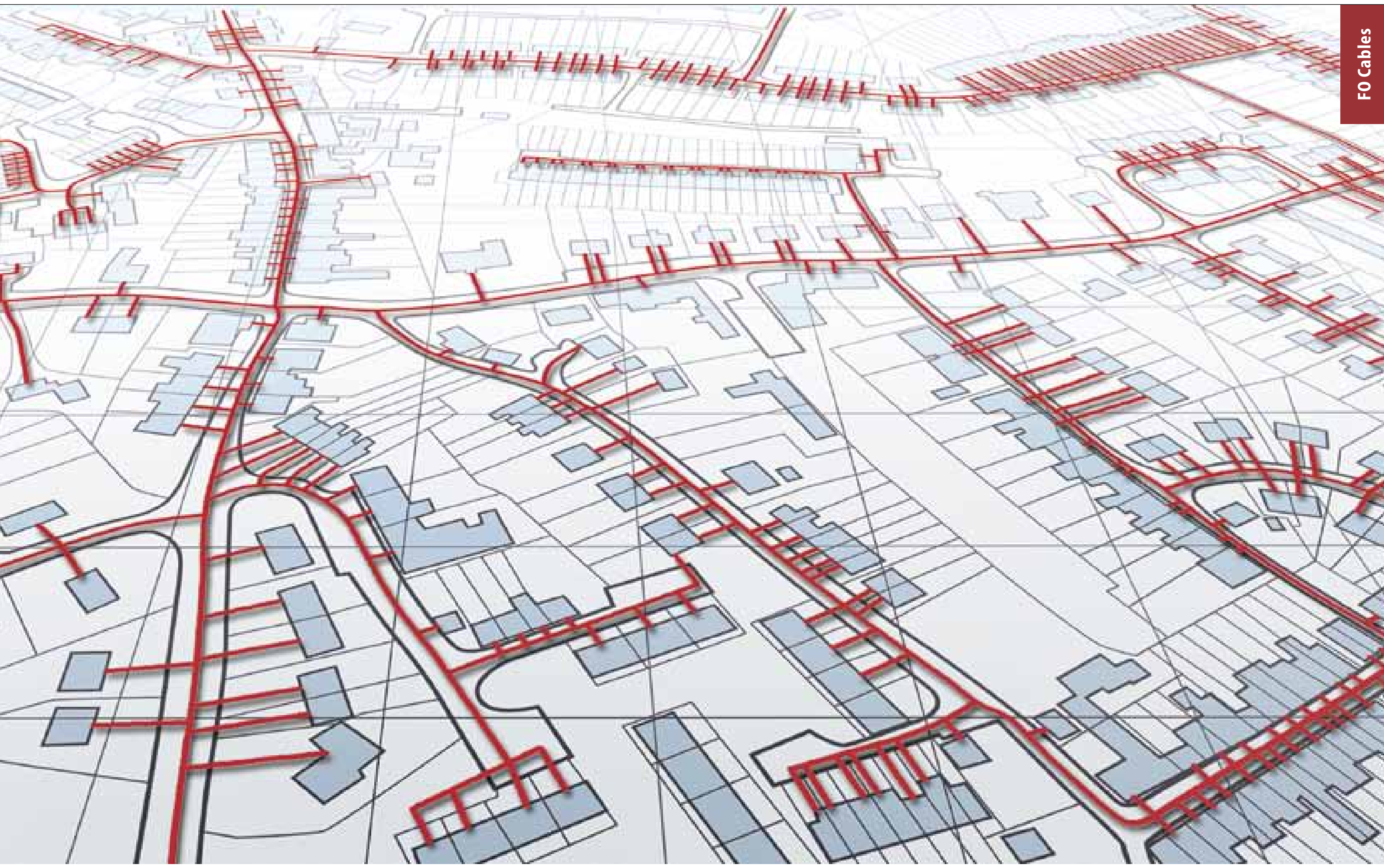


FiberConnect® A-DQ(ZN)W2Y nxm...



Order no.	**84 334** ☐☐ ☐ ☐		
Standardisation	DIN VDE 0888, Part 3 and IEC 60 794-3		
Application	Rugged outdoor cable for installation in cable ducts, on cable trays, in conduits or directly in the ground		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as gel-filled loose tubes and if applicable dummy elements	
	Strain relief element	Non-metallic (E-glass yarn), water-absorbent	
	Corrugated steel conduit	As highly effective rodent protection	
	Cable jacket	PE jacket with hot-stamped marking	
	Colour of jacket	Black	
Thermal properties	Transport and storage	−40°C to +70°C	
	Installation	−5°C to +50°C	
	Operation	−40°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	3000 N
	max. crush resistance	long-term	2000 N/dm
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		

Number of tubes	Max. number of fibers	Outer Ø	Weight	Fire load
		mm	kg/km	MJ/m
1 x m	**12**	12.7	165	4.6
2 x m	**24**	12.7	165	4.6
3 x m	**26**	12.7	165	4.6
4 x m	**48**	12.7	165	4.6
5 x m	**60**	12.7	165	4.6



FTTH applications

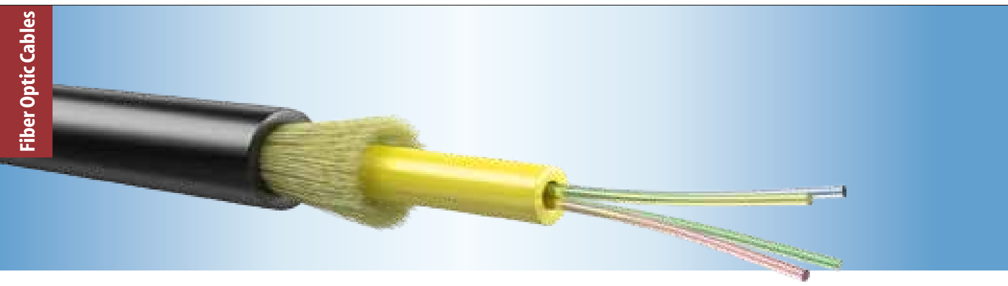
Modern households are demanding higher and higher data rates for communication via the Internet and for the wide range of services offered by providers of broadband applications such as television stations and providers of video-on-demand.

That is why the DSL connections based on copper cables used in households are increasingly yielding to a modern high-speed network based on glass fiber cables, called Fiber To The Home (FTTH).

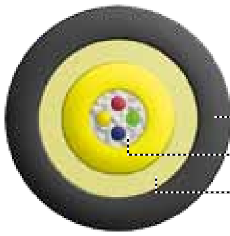
LEONI has a wide range of cable products specifically tailored to this application. The cables are run directly in the ground or blown into empty conduits installed underground, depending on the method of installation. Blowing cables into empty conduits offers the greatest advantages and has established 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 schemes and lowers costs. The cables must be especially thin and light for blowing in. The surface must exhibit 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 use outdoors, 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.

Micro duct cable with central loose tube



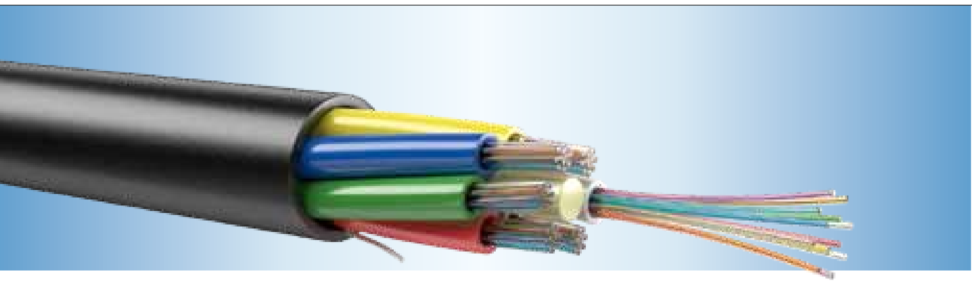
FiberConnect® A-D(ZN)2Y n… MDC



Order no.	**84 344** □□ □ □			
Standardisation	IEC 60 794-5			
Application	Mini cable for blowing or pulling into micro ducts. The outdoor cable is light and flexible and can be installed with minimal bending radii.			
Construction	Cable core	Mini loose tube, gel-filled		
	Strain relief elements	Non-metallic (aramid)		
	Cable jacket	HDPE with imprint		
	Colour of jacket	Black		
Thermal properties	Transport and storage	–25°C to +70°C		
	Installation	–5°C to +50°C		
	Operation	–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 bending-resistant fibers G657A; bending radii up to 15 mm			
Fire performance	Jacket is halogen-free			
	No corrosive and toxic fumes			

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	2.5	4.6	300	200	0.26
12	2.5	4.6	300	200	0.26
24	3.9	12.7	450	200	0.51

Loose tube mini cable with stranded loose tubes

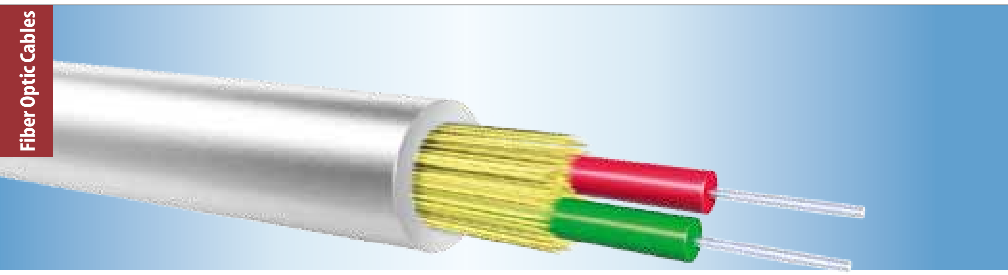


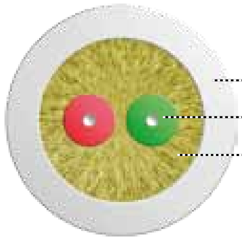
FiberConnect® A-DQ2Y n… LMTC

Order no.	**84 345** □□ □ □		
Standardisation	IEC 60 794-5		
Application	Mini cable for blowing or pulling into micro ducts. The outdoor cable is light and flexible and can be installed with minimal bending radii.		
Construction	Cable core	Glass fiber-reinforced central strength member with strand elements, designed as gel-filled loose tubes and if applicable dummy elements	
	Cable jacket	HDPE with imprint	
	Colour of jacket	Black	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–25°C to +70°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	20 x outside diameter
	max. pull force	long-term	500 N
	max. crush resistance	long-term	500 N/dm
	Resistance to impact	3 impacts/2 Nm	
Fire performance	Jacket is halogen-free		
	No corrosive and toxic fumes		

Number of tubes	Max. number of fibers	Outer Ø	Weight
		mm	kg/km
1 x m	**12**	5.8	26
2 x m	**24**	5.8	26
3 x m	**36**	5.8	26
4 x m	**48**	5.8	26
5 x m	**60**	5.8	26
6 x m	**72**	5.8	26
8 x m	**96**	6.8	39
10 x m	**120**	7.8	52
12 x m	**144**	8.8	68

FTTH indoor cable, duplex cable





FiberConnect® I-V(ZN)H 2…. TB600 2.8

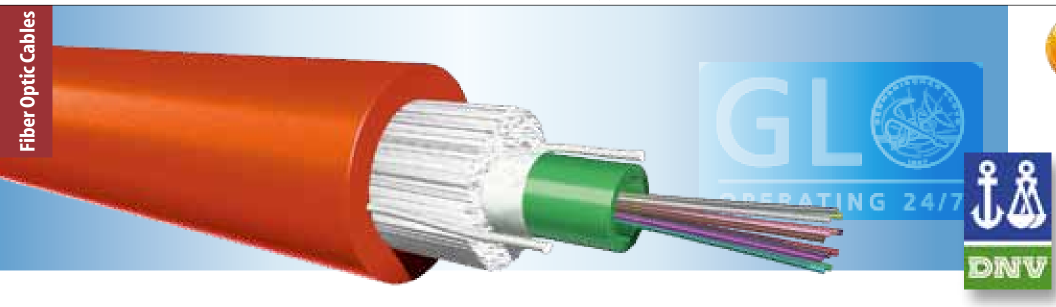
Order no.	**84 950 120 ☐**		
Standardisation	IEC 60794-2 and DIN VDE 0888 Part 6		
Application	For fixed installation inside buildings in cable ducts and conduits as well as for shunting purposes. Suitable for direct connector assembly.		
Construction	Cable core	Buffered fiber type TB600, diameter 0.6 mm one buffered fiber red, other buffered fibers yellow (E9/125), green (G50/125) or blue (G62.5/125)	
	Strain relief elements	Non-metallic (aramid)	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	White	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–5°C to +70°C	
Mechanical properties	Outer diameter	2.8 mm	
	Weight	7.5 kg/km	
	min. bending radius	static	30 mm
		dynamic	60 mm
	with fiber type G657A	static	15 mm
	max. pull force	long-term	300 N
	max. crush resistance	100 N/dm	
	Resistance to impact	3 impacts/1 Nm	
Fire performance	IEC 60332-1-2 IEC 60332-3-22 Cat A IEC 61034 IEC 60754-2 No corrosive and toxic fumes.		

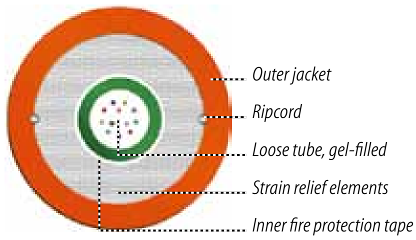
Marine cables

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 optical cables for a verified period (system integrity).

Rodent-protected universal cable with system integrity (90 min)





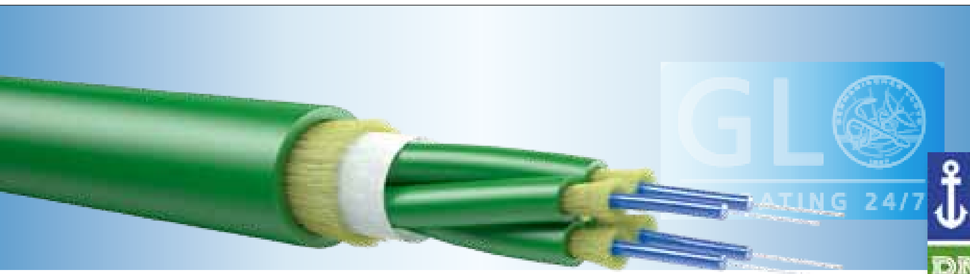
FiberConnect® GL U-D(ZN)BH n…

Order no.	**84040 ☐☐☐ ☐ 222 ZGELO**		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	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.		
Construction	Cable core	Loose tube, gel-filled Inner fire protection tape	
	Armour	Multi-functional, strengthened E-glass yarn as non-metallic strain relief elements and rodent protection	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Orange	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +60°C	
Mechanical properties	min. bending radius	static	15 x outside diameter
		dynamic	15 x outside diameter
	max. pull force	long-term	2500 N
	max. crush resistance	long-term	3000 N/dm
	max. resistance to impact	10 impacts/2 Nm	
Fire performance	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		
System integrity test (VDE test report)	Acc. to IEC 60 331-11, IEC 60 331-25 and EN 50200 90 min		

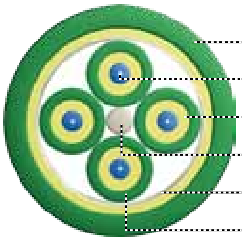
System integrity for at least 90 minutes in the event of fire

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

Breakout cable



FiberConnect® GL AT-V(ZN)H(ZN)H n…



Order no.	**See table**		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	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 central strength member with strand elements, designed as semi-tight buffered fiber, gel filled with non-metallic strain relief elements (aramid) and halogen-free, flame-retardant subcable jacket (Ø 2.9 mm)	
	Strain relief	Aramid yarns	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Mint green	
Thermal properties	Transport and storage	–25°C to +80°C	
	Installation	–5°C to +50°C	
	Operation	–20°C to +80°C	
Mechanical properties	min. bending radius	static	10 x outside diameter
		dynamic	15 x outside diameter
	max. pull force	long-term	1200 N
	max. crush resistance	long-term	1000 N/dm
	max. resistance to impact	10 impacts/2 Nm	
Fire performance	Non-flammability	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	No corrosive and toxic fumes		

Max. number of fibers	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**

Military cables

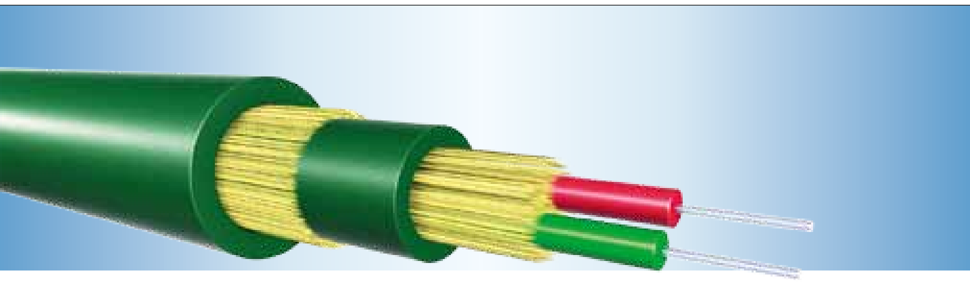
The military frequently uses optical cables in mobile use for connecting command posts due to their protection against tapping.

These cables must be resistant to abrasion, reelable at all temperatures and 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.

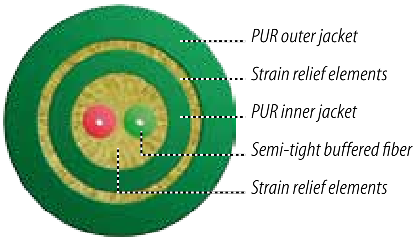
Regardless of whether you need cables for tactical field use or for other special applications – we have the solution.

Mobile field cable



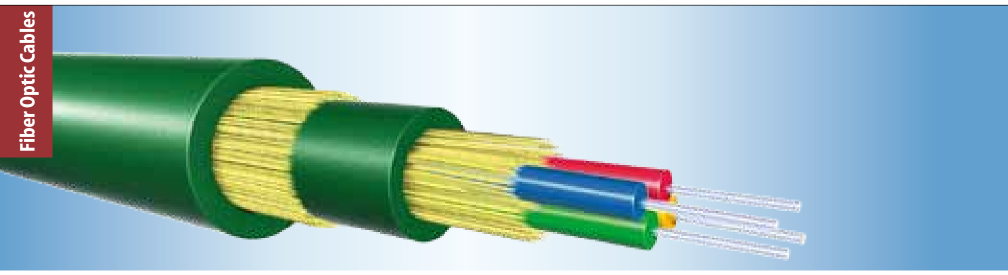
Approved by the German Federal Office of Defence Technology and Procurement (BWB).

FiberConnect® A-V(ZN)11Y(ZN)11Y 2…



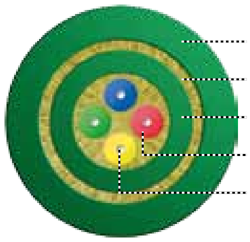
Order no.	**84 950 003** ☐		
Standardisation	BWB TL 6020-0001 certified and prEN 177000		
Application	For military tactical field use and inside buildings. For direct connector assembly.		
Construction	Cable core	2 semi-tight buffered fibers, gel-filled	
	Strain relief elements	Non-metallic (aramid)	
	Inner and outer jacket	Polyurethane (PUR)	
	Colour of jacket	Green or customer-specific	
Thermal properties	Transport and storage	–55°C to +80°C	
	Installation	–5°C to +50°C	
	Operation	–40°C to +70°C	
Mechanical properties	Outer diameter	6.0 mm	
	Weight	30 kg/km	
	min. bending radius	static	25 mm
		dynamic	25 mm
	max. pull force	long-term	2000 N
	max. crush resistance	long-term	1000 N/dm
	Resistance to impact	30 impacts/2 Nm	
Fire performance	Flame retardancy	IEC 60332-1-2	
Chemical properties	Very good resistance to oil, petrol, acids and alkaline solutions		

Mobile field cable



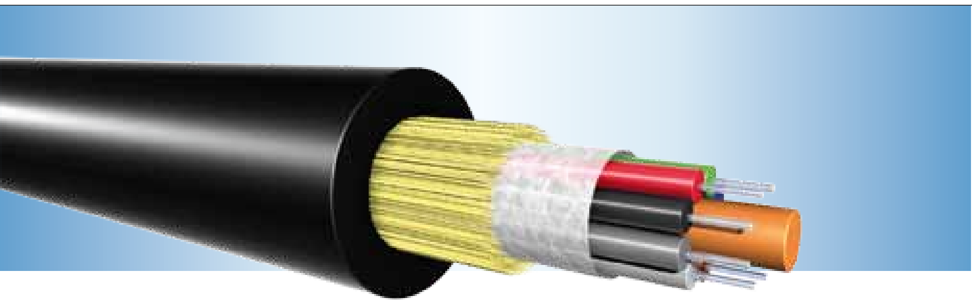
Approved by the German Federal Office of Defence Technology and Procurement (BWB).

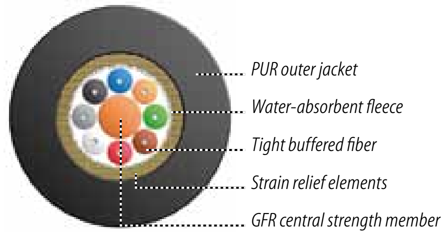
FiberConnect® A-V(ZN)11Y(ZN)11Y 4…



Order no.	**84 950 042** ☐		
Standardisation	BWB TL 6020-0001 certified and prEN 177000		
Application	For military tactical field use and inside buildings. For direct connector assembly.		
Construction	Cable core	4 semi-tight buffered fibers, gel-filled	
	Strain relief elements	Non-metallic (aramid)	
	Inner and outer jacket	Polyurethane (PUR)	
	Colour of jacket	Green or customer-specific	
Thermal properties	Transport and storage	−55°C to +80°C	
	Installation	−5°C to +50°C	
	Operation	−40°C to +70°C	
Mechanical properties	Outer diameter	6.0 mm	
	Weight	33 kg/km	
	min. bending radius	static	90 mm
		dynamic	120 mm
	max. pull force	long-term	2000 N
	max. crush resistance	long-term	1000 N/dm
	Resistance to impact	30 impacts/2 Nm	
Fire performance	Flame retardancy	IEC 60332-1-2	
Chemical properties	Very good resistance to oil, petrol, acids and alkaline solutions		

Mobile outdoor cable





FiberConnect® A-V(ZN)11Y n…

Order no.	See table below		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	For mobile and flexible use outdoors, inside buildings and in harsh industrial environments. Suitable for use in drag chains. For direct connector assembly.		
Construction	Cable core	GFR central strength member with strand elements, designed as tight buffered fiber and if necessary dummy elements	
	Strain relief	Aramid yarns	
	Cable jacket	Polyurethane (PUR)	
	Colour of jacket	Black	
Thermal properties	Transport and storage	−55°C to +80°C	
	Installation	−5°C to +55°C	
	Operation	−40°C to +70°C	
Mechanical properties	min. bending radius	static dynamic	10 x outside diameter 15 x outside diameter
	max. pull force	long-term	2000 N
	max. crush resistance	long-term	1000 N/dm
	Resistance to impact	50 impacts/2 Nm	
	Drag chain test	1,000,000 cycles	
Fire performance	Cable is halogen-free		
Chemical properties	Very good resistance to oil, petrol, acids and alkaline solutions		

Max. number of fibers	Outer Ø	Weight	Order no.
	mm	kg/km	
4	6.0	32	**84950232** ☐
6	6.0	32	**84950403** ☐
8	7.5	52	**84950285** ☐
10	8.8	67	**84950399** ☐
12	8.8	67	**84950314** ☐

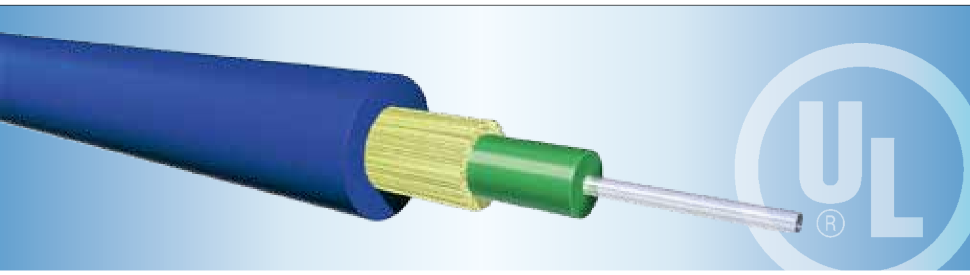
Optical cables with UL approval

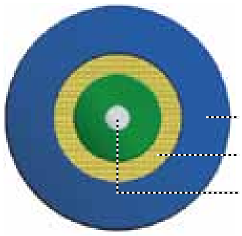
Cables with UL (Underwriter Laboratories) Approval
Cables with UL approval guarantee safety and reliability in the intended application areas. They are specifically tailored to the requirements of the North American market, however demand for them is increasing in Asia and Europe, where they are being 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). UL cables have to meet very high requirements for fire performance in particular, including generation of smoke gas.

Simplex indoor cable

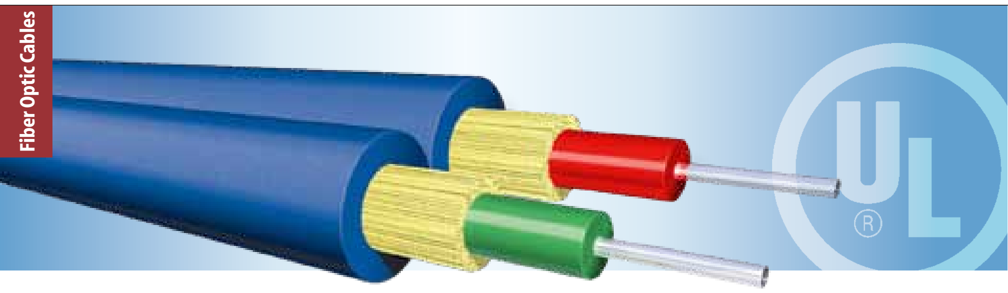


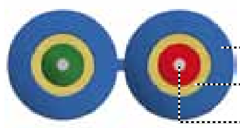


FiberConnect® I-V(ZN)H 1… UL OFNR

Order no.	**84950407** ☐		
Standardisation	DIN VDE 0888, Part 4 and IEC 60 794-2		
Application	Indoor cable with UL approval type OFNR (riser) for USA and Canada. Ideal for use in distribution systems as well as for connecting terminals.		
Construction	Cable core	Flame-retardant semi-tight buffered fiber (STB900H)	
	Strain relief elements	Non-metallic (aramid)	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Blue	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–10°C to +70°C	
Mechanical properties	Outer dimensions	2.9 mm	
	Weight	10.0 kg/km	
	min. bending radius	static	30 mm
		dynamic	60 mm
	max. pull force	long-term	400 N
	max. crush resistance	long-term	150 N/dm
Fire performance	UL approval type	OFNR (NEC Article 770, UL 1651), c(UL)us	
	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	Fire load	0.18 MJ/m	
	No corrosive and toxic fumes		

Duplex indoor cable

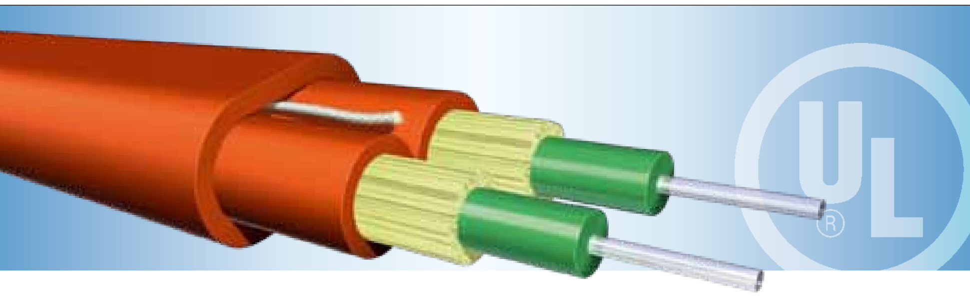


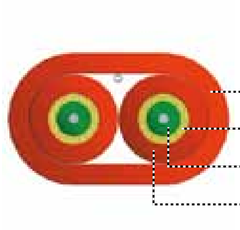


FiberConnect® I-V(ZN)H 2x1 UL OFNR

Order no.	**84005017 □ □□□ ZULOO**		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Indoor cable with UL approval type OFNR (riser) for USA and Canada. Ideal for use in distribution systems as well as for connecting terminals.		
Construction	Cable core	2 flame-retardant tight buffered fibers (STB 900H)	
	Strain relief elements	Non-metallic (aramid)	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Blue	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–10°C to +70°C	
Mechanical properties	Outer dimensions	2.8 mm x 5.7 mm	
	Weight	15.8 kg/km	
	min. bending radius	static	30 mm
		dynamic	60 mm
	max. pull force	long-term	600 N
	max. crush resistance	long-term	600 N/dm
Fire performance	UL approval type	OFNR (NEC Article 770, UL 1651), c(UL)us	
	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	Fire load	0.36 MJ/m	
	No corrosive and toxic fumes		

Duplex indoor cable

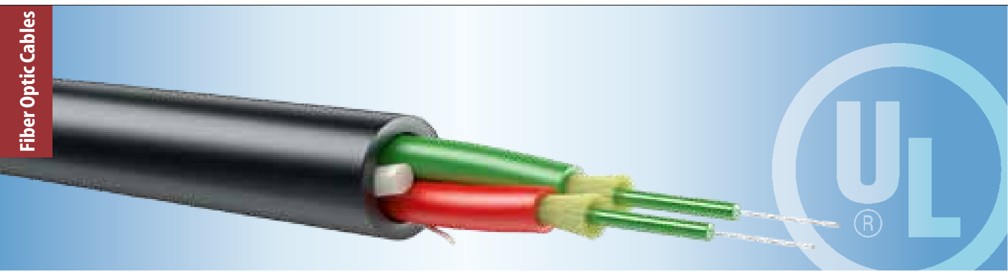




FiberConnect® I-V(ZN)HH 2x1… UL OFNR

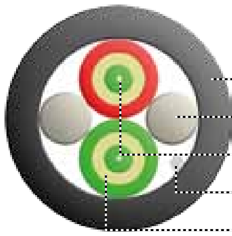
Order no.	**84011011 ☐ ☐☐☐ ZUL00**		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Indoor cable with UL approval type OFNR (riser). Ideal for use in distribution systems, for connecting terminals as well as for fixed installation.		
Construction	Cable core	Two single-fiber cables (STB900) arranged in parallel beside each other with non-metallic strain relief elements (aramid) and halogen-free, flame-retardant subcable jacket (Ø 2.5 mm)	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Orange for multimode, yellow for singlemode	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–10°C to +70°C	
Mechanical properties	Outer dimensions	3.7 x 6.2 mm	
	Weight	26.0 kg/km	
	min. bending radius (over flat side)	static dynamic	35 mm 65 mm
	max. pull force	long-term	600 N
	max. crush resistance	long-term	600 N/dm
Fire performance	UL approval type	OFNR (NEC Article 770, UL 1651)	
	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	Fire load	0.65 MJ/m	
	No corrosive and toxic fumes		

Duplex outdoor cable

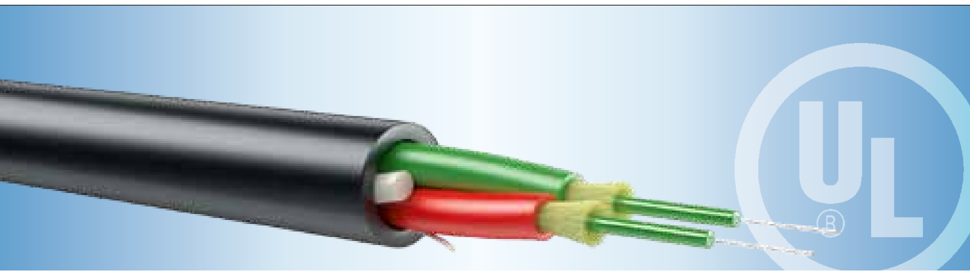


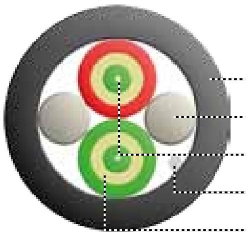
FiberConnect® AT-V(ZN)YY 2… UL AWM Style

Order no.	**84950504** ☐		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Extremely temperature-stable and UV-resistant outdoor cable, tested acc. to UL VW-1 Flame Test. Ideal for use in harsh environments such as mobile base stations.		
Construction	Cable core	Stranding consisting of two PVC single cables (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 and storage	–55°C to +85°C	
	Installation	–20°C to +60°C	
	Operation	–40°C to +85°C	
Mechanical properties	Outer dimensions	7.0 mm	
	Weight	44.0 kg/km	
	min. bending radius	static	70 mm
		dynamic	105 mm
	max. pull force	long-term	800 N
	max. crush resistance	long-term	800 N/dm
Fire performance	UL-AWM Style 5432, VW-1 Flame Test		
	Flame retardancy	IEC 60332-1-2	



Duplex outdoor cable

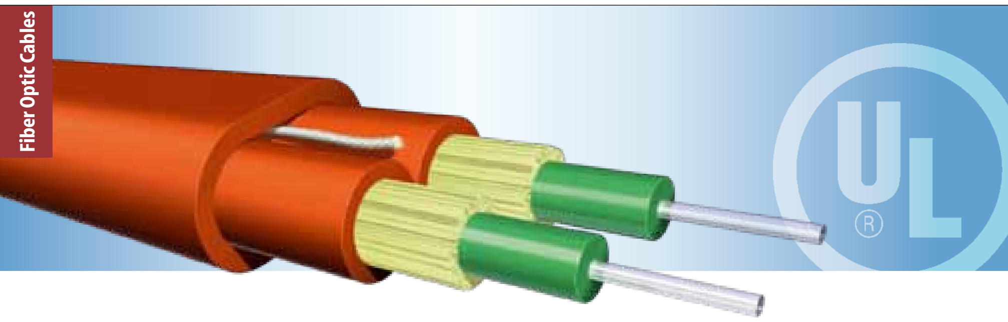


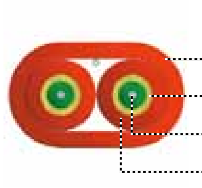


FiberConnect® AT-V(ZN)YY 2… UL OFNR

Order no.	**84950632** ☐		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	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.		
Construction	Cable core	Stranding consisting of two PVC single cables (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 and storage	–55°C to +85°C	
	Installation	–20°C to +60°C	
	Operation	–40°C to +85°C	
Mechanical properties	Outer dimensions	7.0 mm	
	Weight	44.0 kg/km	
	min. bending radius	static	70 mm
		dynamic	105 mm
	max. pull force	short-term	1000 N
		long-term	600 N
	max. crush resistance	short-term	220 N/dm
		long-term	800 N/dm
Fire performance	UL approval type OFNR (NEC Article 770, UL 1651)		
	Flame retardancy	IEC 60332-1-2	

Duplex indoor cable





FiberConnect® I-V(ZN)HH 2x1 UL OFN

Order no.	**84950500** ☐		
Standardisation	DIN VDE 0888, Part 6 and IEC 60 794-2		
Application	Indoor cable with UL approval type OFN (general purpose) for USA and Canada. Ideal for use in distribution systems, for connecting terminals as well as for fixed installation.		
Construction	Cable core	Two single-fiber cables (STB900FR) arranged in parallel beside each other with non-metallic strain relief elements (aramid) and halogen-free, flame-retardant subcable jacket (Ø 2.0 mm)	
	Cable jacket	Halogen-free and flame-retardant material	
	Colour of jacket	Orange for multimode, yellow for singlemode	
Thermal properties	Transport and storage	–25°C to +70°C	
	Installation	–5°C to +50°C	
	Operation	–10°C to +70°C	
Mechanical properties	Outer dimensions	3.0 x 5.0 mm	
	Weight	18.5 kg/km	
	min. bending radius (over flat side)	static dynamic	30 mm 60 mm
	max. pull force	long-term	600 N
	max. crush resistance	long-term	1000 N/dm
Fire performance	UL approval type	OFN (NEC Article 770, UL 1651), c(UL)us	
	Flame retardancy	IEC 60332-1-2 and IEC 60332-3-22 Cat. A	
	Smoke density	IEC 61034	
	Halogen-free	IEC 60754-2	
	Fire load	0.62 MJ/m	
	No corrosive and toxic fumes		

Order number scheme

Cable construction	No. of fibers in the cable	Buffered fiber type	Fiber type
☐☐☐☐☐	☐☐	☐	☐

Cable construction: See product page

No. of fibers in the cable:

- **00** = 1 fiber
- **01** = 2 fibers
- **02** = 4 fibers
- **03** = 6 fibers
- **04** = 8 fibers
- **xx** = 2 x XX fibers

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 fiber, gel-filled, type STB900
- **4** = Tight buffered fiber type TB900R
- **5** = Semi-tight buffered fiber type TB900RF
- **6** = Semi-tight buffered fiber type LB900
- **7** = Semi-tight buffered fiber type STB900H
- **8** = Semi-tight buffered fiber type STB900RU
- **9** = Semi-tight buffered fiber type STB900U
- **L** = Tight buffered fiber type TB900L
- **X** = Tight buffered fiber type TB900A

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
- **L** = 3.2B200/0.9F500 OM1
- **M** = 3.0B300/0.8F800 OM1+

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

Glass fiber assembly

Almost all connectors can be combined with the cables listed on pages 18–76.

Lengths ≥ 100 m are supplied on plywood reels as standard, smaller lengths as a ring.

In the case of multi-fiber loose tube cables, the assembly can be equipped with the economical "Easy Pull" cabling system (see page 130/131) or the extremely rugged "Heavy Trunk" cabling system (see page 81).

Customer-specific requirements for pulling tool, connector protection, identification, 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 slot 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 II/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	≤ 0.2 dB	≤ 0.3 dB	≥ 35 dB	According to IEC 61300-3-15 IEC 61300-3-16 IEC 61300-3-23
MM/UPC	≤ 0.2 dB	≤ 0.3 dB	≥ 40 dB	
MM/APC	≤ 0.2 dB	≤ 0.3 dB	≥ 50 dB	
SM/SPC	≤ 0.2 dB	≤ 0.3 dB	≥ 35 dB	
SM/UPC	≤ 0.2 dB	≤ 0.3 dB	≥ 50 dB	
SM/APC	≤ 0.2 dB	≤ 0.3 dB	≥ 70 dB	
MTRJ SM	≤ 0.3 dB	≤ 0.3 dB	≥ 35 dB	
MTRJ MM	≤ 0.3 dB	≤ 0.3 dB	≥ 20 dB	
LC-uniboot MM/SPC	≤ 0.3 dB	≤ 0.5 dB	≥ 35 dB	
LC-uniboot MM/UPC	≤ 0.3 dB	≤ 0.5 dB	≥ 40 dB	
LC-uniboot MM/APC	≤ 0.3 dB	≤ 0.5 dB	≥ 50 dB	
LC-uniboot SM/SPC	≤ 0.5 dB	≤ 0.6 dB	≥ 35 dB	
LC-uniboot SM/UPC	≤ 0.5 dB	≤ 0.6 dB	≥ 50 dB	
LC-uniboot SM/APC	≤ 0.5 dB	≤ 0.6 dB	≥ 70 dB	

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.

Heavy trunk
Divider for multi-fiber loose tube cables

Applications
Building cabling, computer 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 same colour as the fiber
- Bundle marking close to the divider head
- Water and dust-tight acc. 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 divider 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

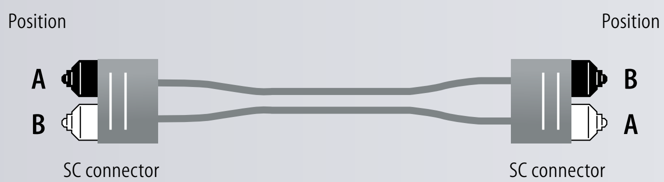
Lengths
Nominal length between the connectors of the two longest whips

Length tolerances

< 30m	±50 cm
30–100 m	±100 cm
> 100 m	±2 %

Delivery format
- 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)



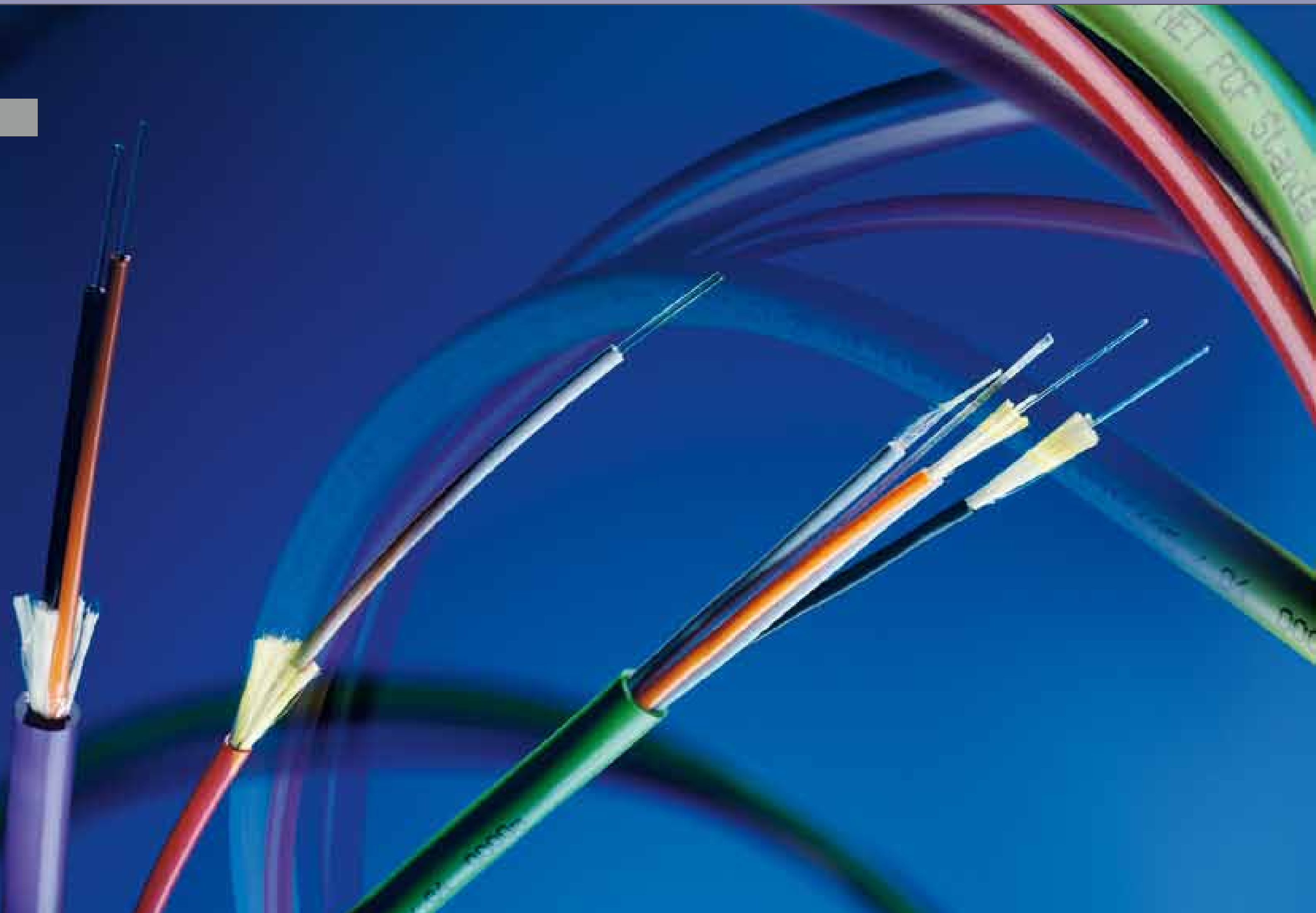
Note on polarity

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).

POF

Polymer optical fibers



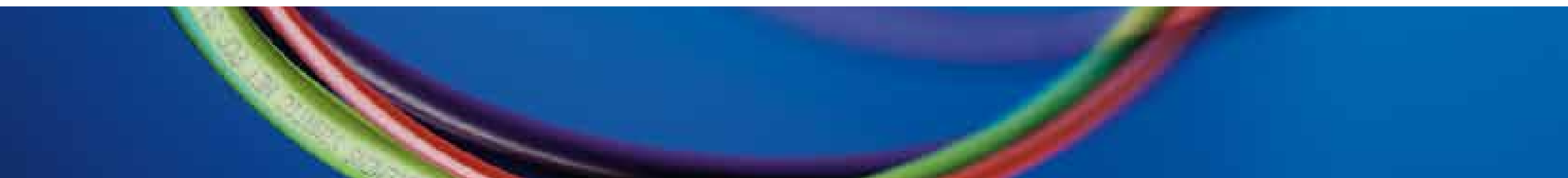
Polymer optical fibers (POF) have been on the market for many years. Both the fiber core and the cladding are made of polymer. Key advantages of polymer optical fibers are high flexibility (high alternate bending resistance with smaller bending radii) as well as more economical connecting and transmission 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, etc.**

POF can by now be used to bridge distances up to 70 metres, 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 metres by selecting suitable active components.

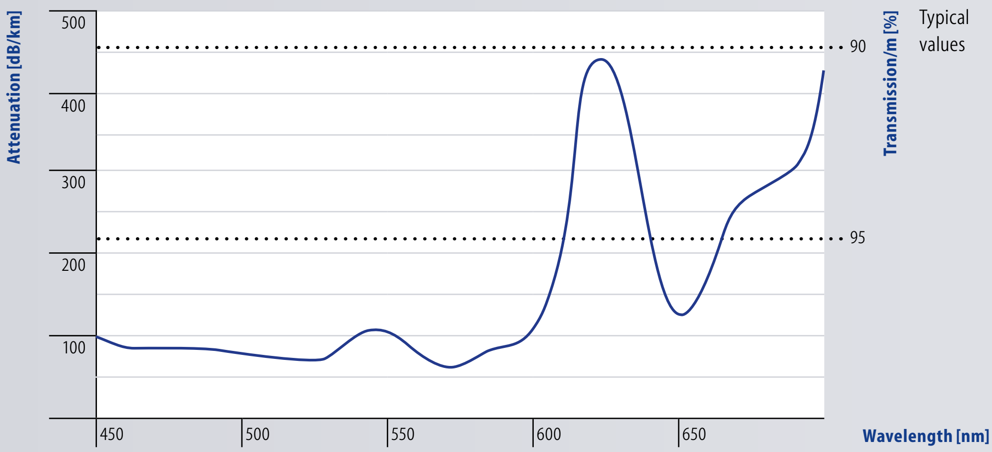
Globally unparalleled quality assurance

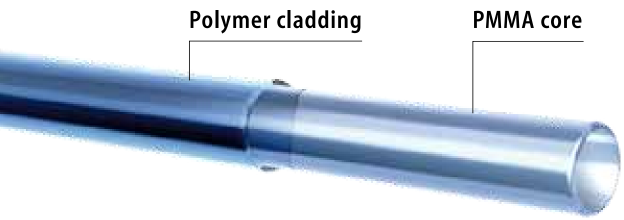
LEONI performs a 100% final check of optical attenuation on all POF cables in series production. This enables us to guarantee first-class quality for our products. Attenuation measurements on entire cable drums (250 and 500 m) represent a particular challenge due to the high optical attenuation of the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



POF fiber specifications

Fiber type
Standard



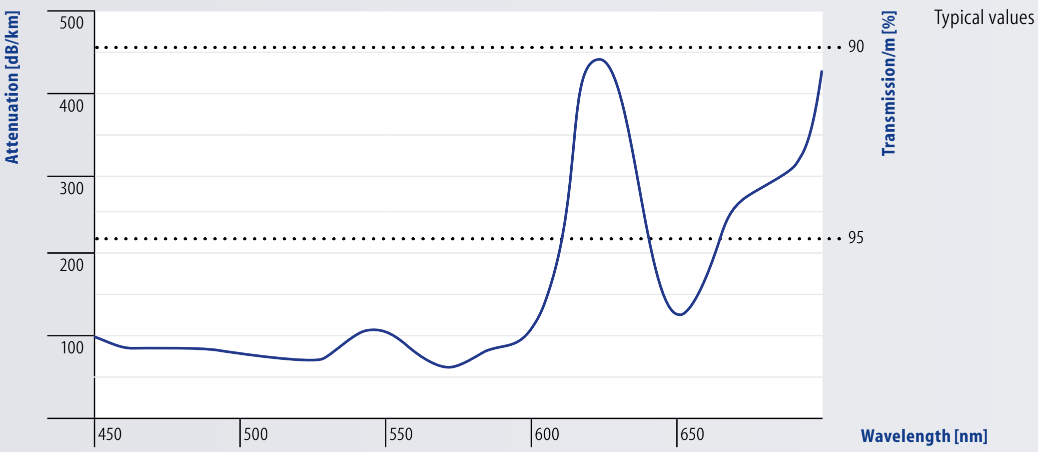


Standard POF is made of a super pure polymethylmethacrylate (PMMA) fiber core, which is cladded with a fluoropolymer jacket. The large fiber core facilitates coupling to transmitter and receiver elements and allows the use of low-cost connector systems, some of which have been specially developed for 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 to IEC 60793-2		A4c	A4b	A4a		
Geometric/thermal properties						
Core diameter	240 ± 23 µm	486 ± 30 µm	735 ± 45 µm	980 ± 60 µm	1470 ± 90 µm	1960 ± 120 µm
Jacket diameter	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
Transmission 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

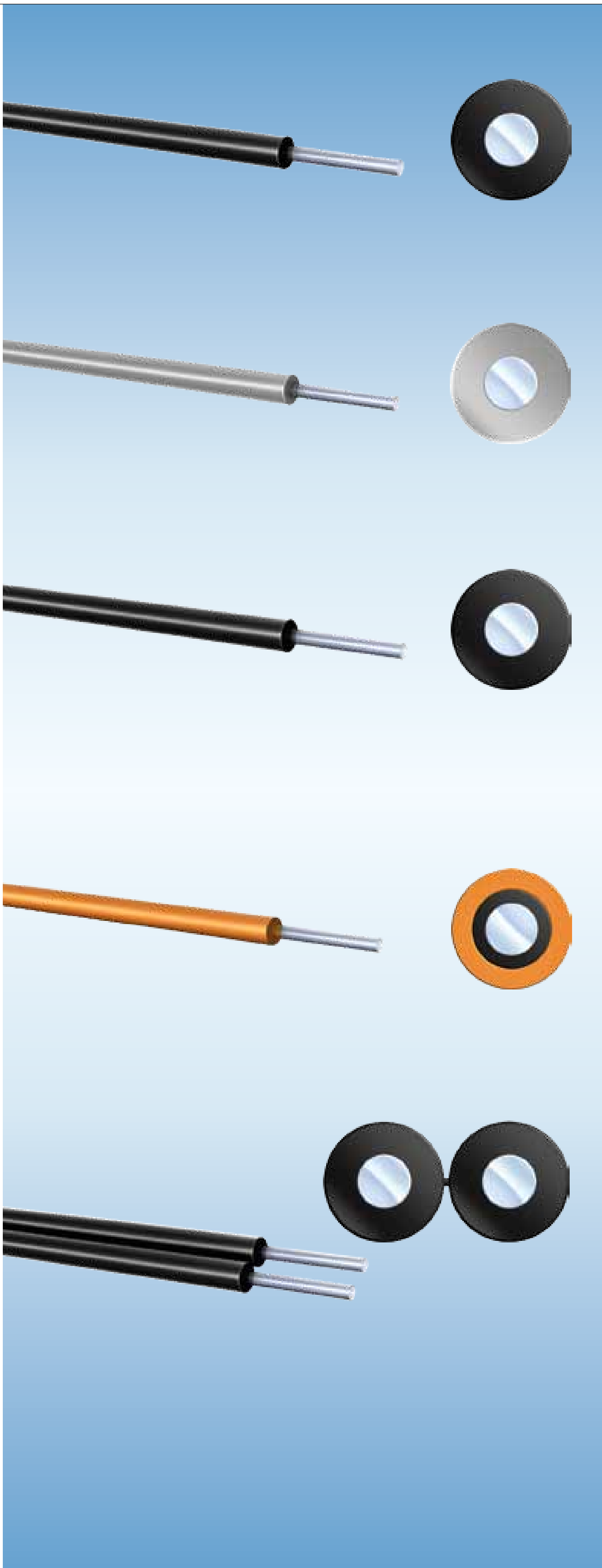


The numerical aperture of the fiber as well as the temperature resistance can be changed by using different cladding materials. High NA POF (fibers with a higher numerical aperture) permit higher power coupling in the fiber. However increasing the NA results in a lower bandwidth.

POF fibers are subject to natural aging (see the chapter Principles of fiber optics from page 190). 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.

	High NA POF	High-temperature POF	
Order no.	**84860115B**	**84860131B**	**84860130B**
Designation	P980/1000 high NA	P980/1000 high-temperature POF	P485/500 high-temperature POF
Designation to IEC 60793-2			
Geometric/thermal properties			
Core diameter	980 ± 60 µm	980 ± 60 µm	485 ± 30 µm
Jacket diameter	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
Transmission properties			
Wavelength	650 nm	650 nm	650 nm
max. attenuation	160 dB/km	200 dB/km	200 dB/km
min. bandwidth (MHz × 100 m)			
Numerical aperture	0.6	0.58	0.58

POF cables



V-2Y 1P980/1000

Order no.	84A00100S000
Code no.	11
Application	Light mechanical stress
Assembly	Direct connector assembly
Length	2100 m

V-Y 1P980/1000

Order no.	84A00200S777
Code no.	14
Application	Light mechanical stress
Assembly	Direct connector assembly
Length	500 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	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

V-2Y 2x1P980/1000

Order no.	84B00100S000
Code no.	13
Application	Light mechanical stress
Assembly	Direct connector assembly
Length	500 m

POF

POF cables in colour

POF cables from the 84A00100SXXX series are now 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.

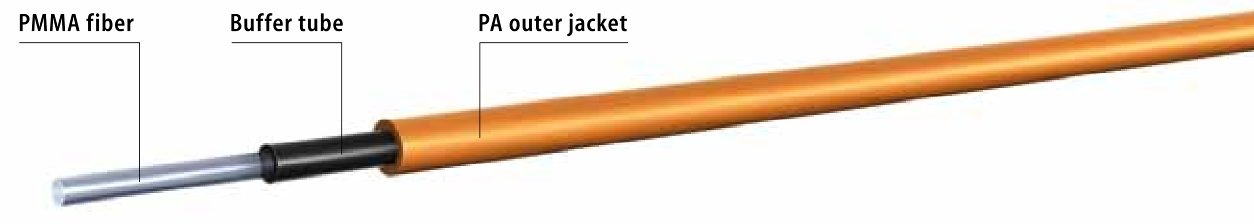
Order table for colours

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

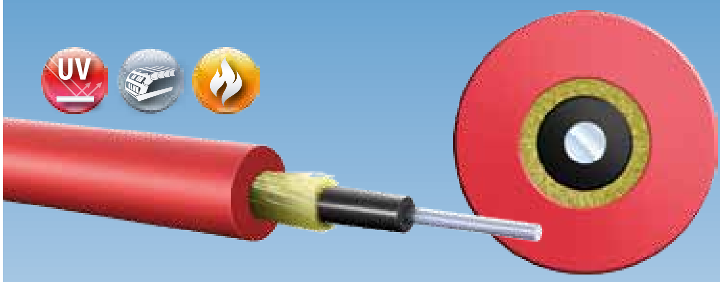
POF cable specifications

POF cable specifications			V-2Y 1P980/1000	V-Y 1P980/1000	V-4Y 1P980/1000	V-4Y 1P980/1000	V-2Y 2x1P980/1000
Order no.			84A00100S000	84A00200S777	84A00300S000	84A00300S262	84B00100SXXX (see table)
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

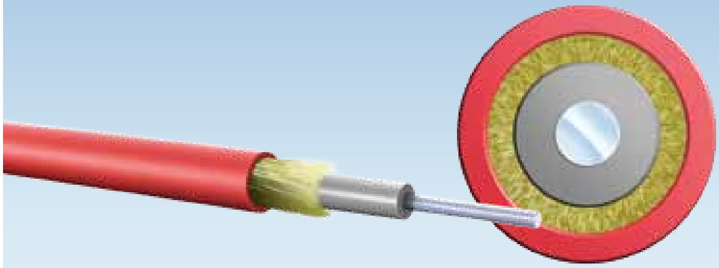


POF



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

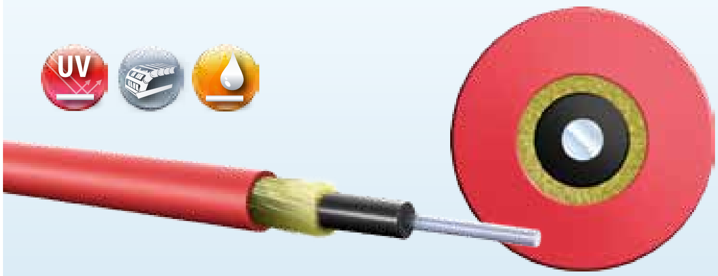


I-VY(ZN)Y 1P980/1000

Order no.	84C00200S333
Code no.	26
Application	Flexible applications with low dynamic stress
Assembly	Direct connector assembly
Length	500 m

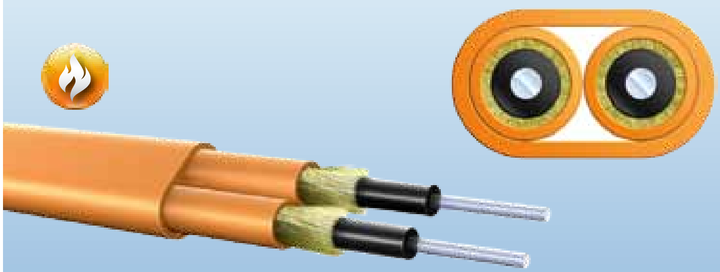
I-V2Y(ZN)11Y 1P980/1000

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

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 2x1P980/1000

Order no.	84D00900S222
Code no.	32
Application	Flexible applications with low dynamic stress, for fixed installation
Assembly	Direct connector assembly
Length	500 m

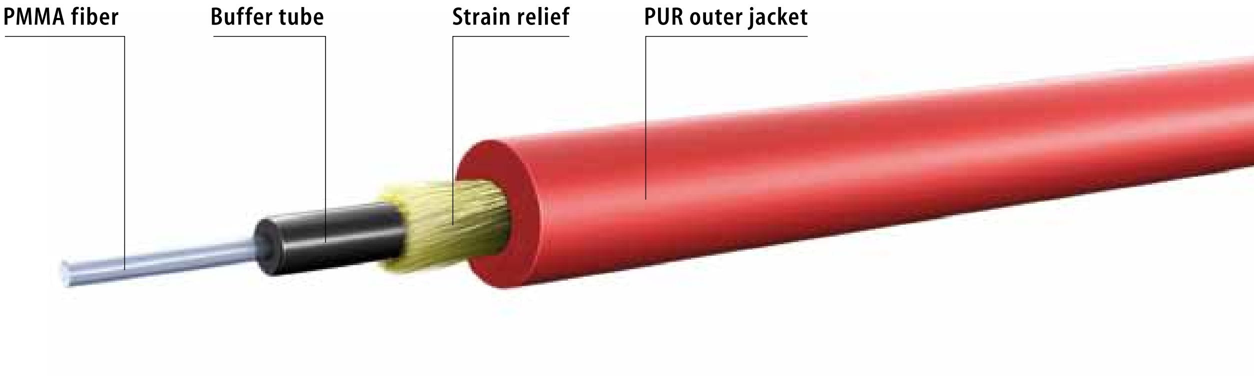
POF cables are divided into the following fiber groups:

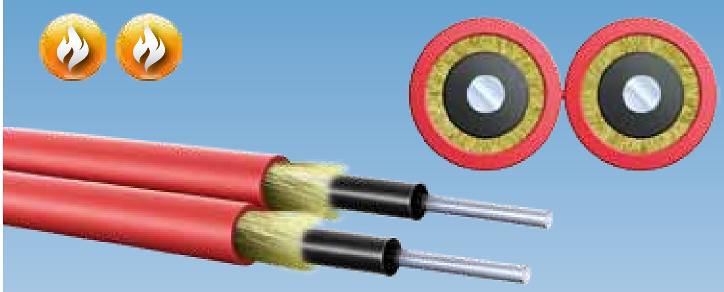
POF buffered fibers:
- Step index standard
- Step index POF with low/high NA
- Step index for high temperature
- Step index for fast Ethernet
- Gradient index

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	I-V2Y(ZN)11Y 1P980/1000	I-V2Y(ZN)HH 2x1P980/1000
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

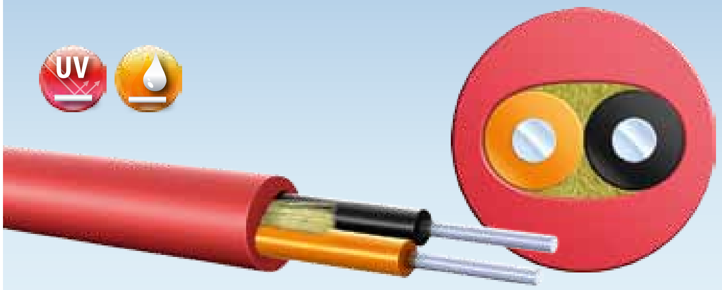
* over flat side





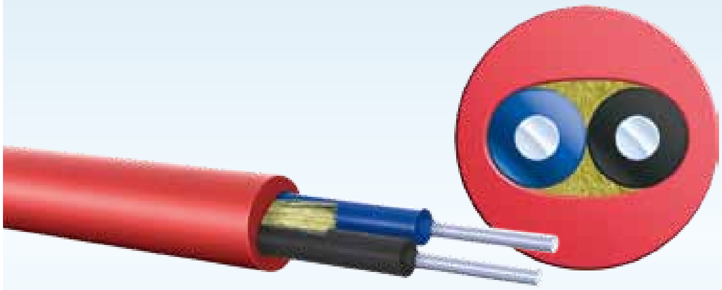
I-V2Y(ZN)H 2x1P980/1000

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



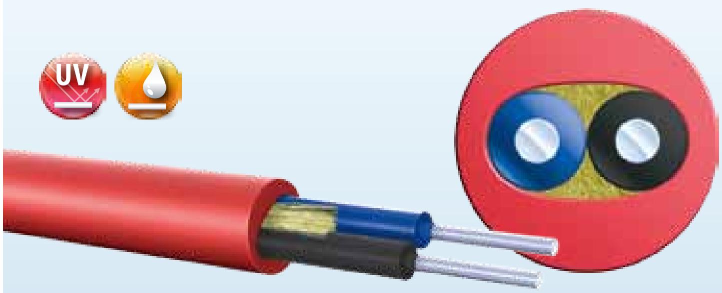
I-V4Y(ZN)11Y 2P980/1000 HEAVY

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



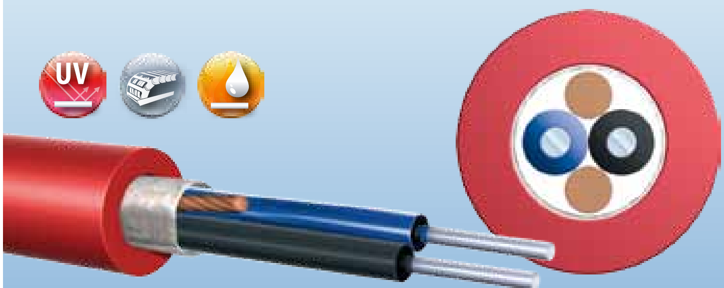
I-V2Y(ZN)Y 2P980/1000

Order no.	84D01600S333
Code no.	33
Application	Flexible applications 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

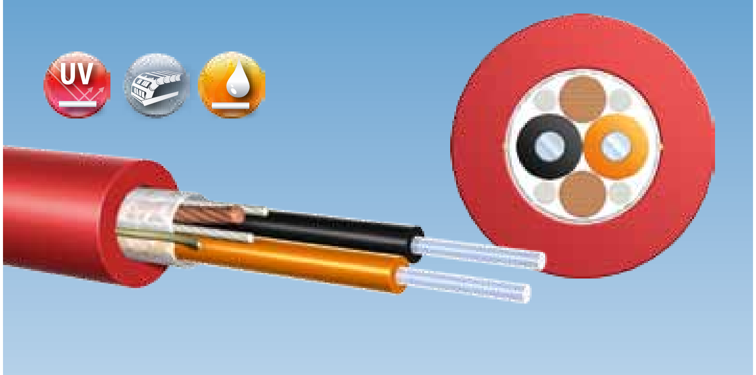


I-V2Y(ZN)11Y 2P980/1000 FLEX

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 2x1P980/1000	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 x 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

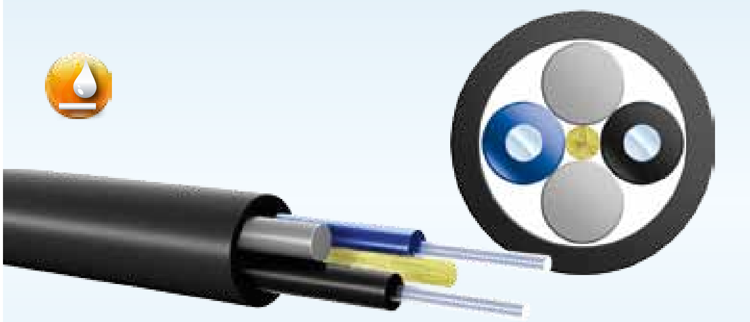


I-V4Y(ZN)11Y 2P980/1000 FLEX

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

I-(ZN)V2Y11Y 2P980/1000+2x1.0qmm

Order no.	84D00600S333
Code no.	29
Application	in harsh industrial environments, suitable for drag chains
Assembly	Direct connector assembly
Length	500 m

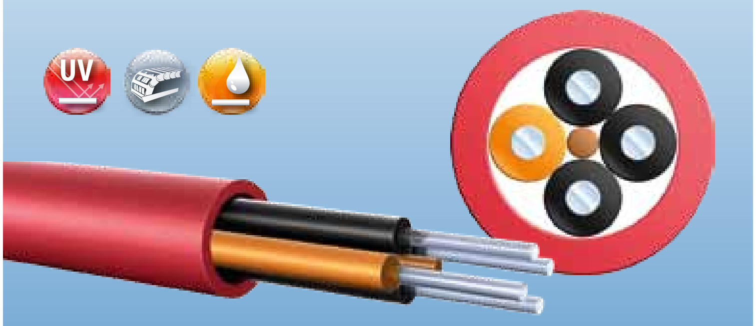


AT-(ZN)V2Y2Y 2P980/1000

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

I-(ZN)V4Y11Y 2P980/1000+2x1.0qmm

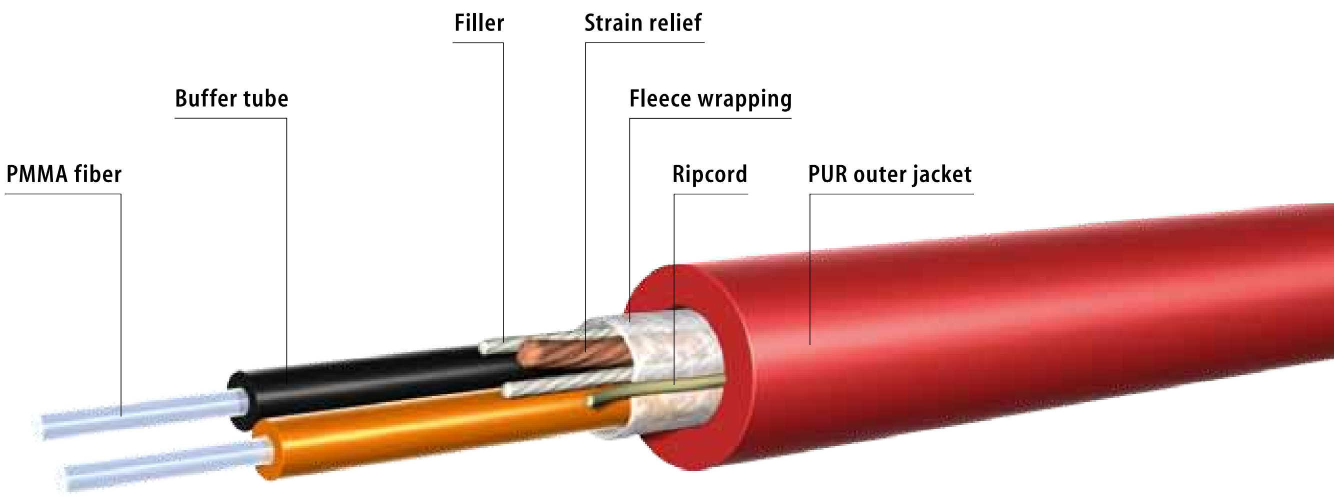
Order no.	84D02800S333
Code no.	38
Application	in harsh industrial environments, suitable for drag chains
Assembly	Direct connector assembly
Length	500 m

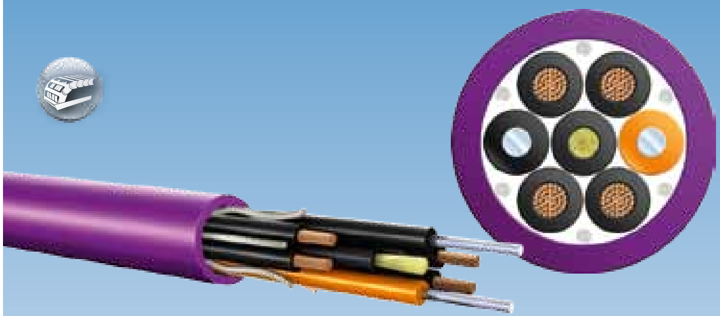


I-V4Y11Y 4P980/1000

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

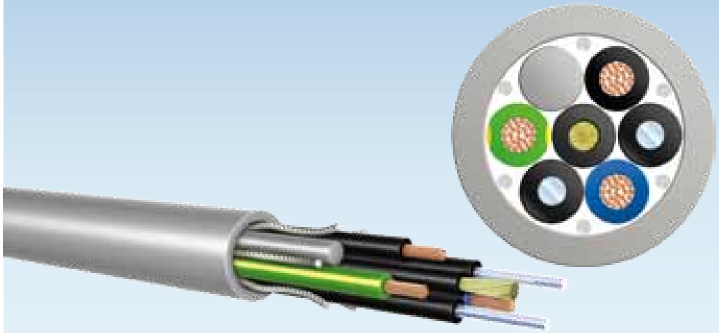
POF cable specifications			I-V4Y(ZN)11Y 2P980/1000 FLEX	I-(ZN)V2Y11Y 2P980/1000 +2x1.0qmm	AT-(ZN)V2Y2Y 2P980/1000	I-(ZN)V4Y11Y 2P980/1000 + 2x1.0qmm	I-V4Y11Y 4P980/1000
Order no.			84D00300S383	84D00600S333	84D02500S000	84D02800S333	84E00200S333
Composition	Buffer tube material		PA	PE	PE	PA	PA
	Outer jacket material		PUR	PUR	PE	PUR	PUR
	No. of POF elements (980/1000 µm)		2	2	2	2	4
	No. of copper elements		–	2	–	2	–
	Outer Ø [mm]		8.0	7.5	7.0	7.5	7.5
Mechanical properties	min. bending radius [mm]	during installation	60	90	90	70	70
		long-term	40	60	60	50	50
	max. pull force [N]	short-term	400	200	200	400	500
		long-term	100	100	100	100	200
	Approx. cable weight [kg/km]		55	62	33	42	42
Thermal properties	Operating temperature [°C]		–20 to +70	–20 to +70	–25 to +70	–20 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (laser)		<190	<220	<220	<190	<190
	[dB/km] at 660 nm (LED)		<290	<350	<350	<290	<290





I-(ZN)V4Y11Y 2P980/1000+4x1.5qmm

Order no.	84D01400S444
Code no.	41
Application	in harsh industrial environments, suitable for drag chains
Assembly	Direct connector assembly
Length	500 m



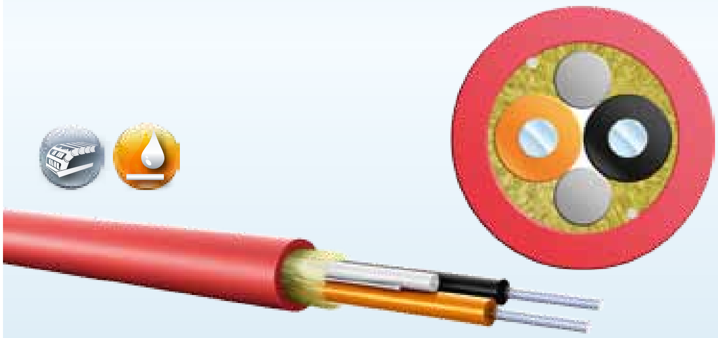
I-(ZN)V4YY 2P980/1000+3x1.5qmm

Order no.	84D01800S707
Code no.	42
Application	Flexible applications with low dynamic stress
Assembly	Direct connector assembly
Length	500 m

POF cable specifications			I-(ZN)V4Y11Y 2P980/1000 +4x1.5qmm	I-(ZN)V4YY 2P980/1000 +3x1.5qmm
Order no.			84D01400S444	84D01800S707
Composition	Buffer tube material		PA	PA
	Outer jacket material		PUR	PVC
	No. of POF elements (980/1000 µm)		2	2
	No. of copper elements		4	3
	Outer Ø [mm]		10.6	10.7
Mechanical properties	min. bending radius [mm]	during installation	110	110
		long-term	70	70
	max. pull force [N]	short-term	400	200
		long-term	100	100
	Approx. cable weight [kg/km]		146	132
Thermal properties	Operating temperature [°C]		–20 to +70	–20 to +70
Attenuation	[dB/km] at 650 nm (laser)		<230	<230
	[dB/km] at 660 nm (LED)		<330	<330
Flame test	Tested acc. to UL VW-1		–	–

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.	84D03500S333
Code no.	1A
Application	in harsh industrial environments, suitable for drag chains
Assembly	Direct connector assembly
Length	500 m

POF

Info

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

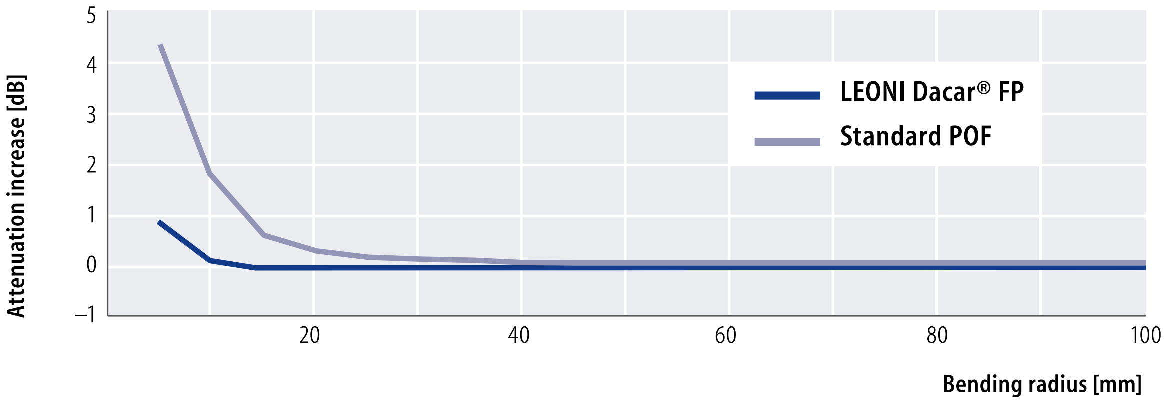
Cables with UL (Underwriter Laboratories) approval
Cables with UL approval guarantee safety and reliability in the intended application areas. They are specifically tailored to the requirements of the North American market, however demand for them is increasing in Asia and Europe, where they are being 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.

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	84D03500S333
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
Flame test	Tested acc. to UL VW-1		For harsh industrial environments	Suitable for flexible applications in areas with low dynamic stress	For harsh industrial environments

LEONI **Dacar**® **FP** – Automotive cables

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



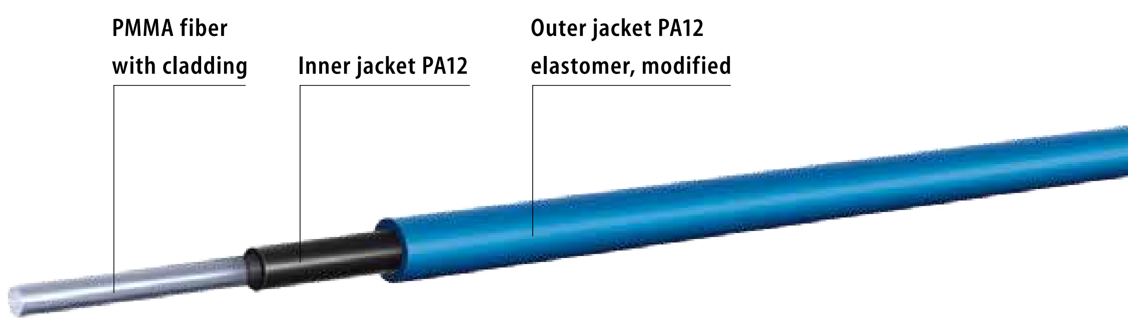
LEONI Dacar® FP
– Optical fibers for use in vehicles
Electronic systems are increasingly being used instead of mechanical components in automotive development to realise more and more comfort and safety functions. This means ever increasing complexity of the vehicle electronics with a fast-growing number 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.



LEONI Dacar® FP

Order no.	See table
Application	For data communication within the vehicle, for heavy mechanical stress and highly flexible applications with small bending radii
Assembly	Direct connector assembly
Length	5000 m

Order table for LEONI Dacar® FP

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

MOST-Insert Pin POF

Order no.	SMIP-SM0-25-0010
Colour	Metallic
Fiber Ø	1000 µm
Cable Ø	2.3 mm
Assembly	Crimping/cutting
Ferrule	Metal
Incl. dust cap	

MOST-Insert Socket POF

Order no.	SMIS-SM0-25-0010
Colour	Metallic
Fiber Ø	1000 µm
Cable Ø	2.3 mm
Assembly	Crimping/cutting
Ferrule	Metal
Incl. dust cap	

Info

POFs have been used for years for data communication between audio devices and for the airbag management system in the vehicle. Easy and cost-effective assembly of the POF, insusceptibility to interference from electromagnetic radiation, low weight and high bandwidths speak in favour of using these fibers instead of copper cables.

LEONI Dacar® FP assembly available in following designs

Order no.	See table
Design	Pin – pin, pin – socket, with MOST-Inserts in metal or plastic at both ends.
Length	xxx in the order number must be replaced by the required length (in mm or cm) in three digits.

Order table

Colour	Pin – pin		Pin – socket	
	Plastic	Metal	Plastic	Metal
orange	KMIP-MIP-17xxxcm-K	KMIP-MIP-17xxxcm-M	KMIP-MIS-17xxxcm-K	KMIP-MIS-17xxxcm-M
green	KMIP-MIP-C7xxxcm-K	KMIP-MIP-C7xxxcm-M	KMIP-MIS-C7xxxcm-K	KMIP-MIS-C7xxxcm-M
blue	KMIP-MIP-C8xxxcm-K	KMIP-MIP-C8xxxcm-M	KMIP-MIS-C8xxxcm-K	KMIP-MIS-C8xxxcm-M
yellow	KMIP-MIP-C9xxxcm-K	KMIP-MIP-C9xxxcm-M	KMIP-MIS-C9xxxcm-K	KMIP-MIS-C9xxxcm-M

LEONI Dacar® FP Golden Fiber

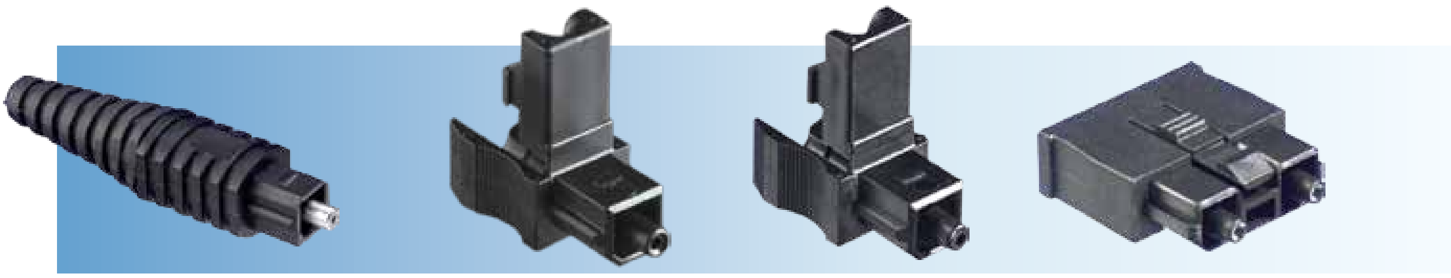
Order no.	KMIP-MIP17001M pin – pin KMIP-MIS17001M pin – socket
Application	For matching the setup for attenuation measurements in MOST cables. Fiber end faces are inspected using the microscope and the pictures archived. Each fiber end face can be assigned via the ident. number/label. The label is attached directly to the Golden Fiber (side A) and contains the following information: ident. number / date of manufacture / attenuation / measured length.
Packaging	The assembled buffered fibers are individually packaged in sealable PE pouches, the connectors are fitted with dust caps. A certificate is enclosed with each Golden Fiber.
Accessories	Appropriate interchangeable adapters for the optical power meter (page 236)

Order table

Designation	Order no.
Active interchangeable adapter for MOST-Insert pin, 650 nm	ZMIS-Ts0-650
Interchangeable adapter for MOST-Insert connector	ZMIP-TX0

POF connectors

POF

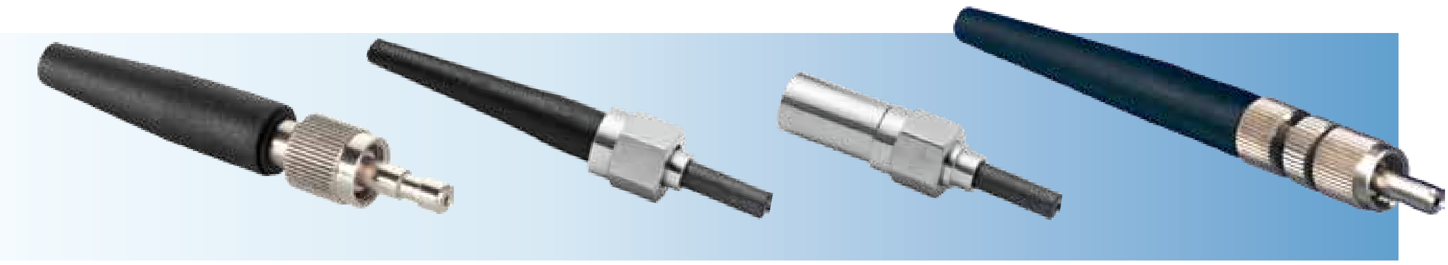


	F05 connector POF			F07 connector POF
Order no.	SF05-SS0-20-0010	SF05-SG0-02-0010	SF05-SV0-02-0010	SF07-DG0-08-0010
Compatibility	TOCP155/TOCP155P/ TOCP172	TOCP155/TOCP155P/ TOCP173	TOCP155/TOCP155P/ TOCP174	TOCP200/TOCP200P/ TOCP255/TOCP255P
Fiber Ø	1000 µm	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	2.2 mm	2.2 mm
Assembly	Crimping/polishing	Clamping/hot plate	Clamping/polishing	Clamping/hot plate
Ferrule	Metal	Plastic	Plastic	Plastic
Reference cable	KF05-F0511050cm for attenuation measurement of 0.5 m	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	Incl. dust cap
Stripping	A2 / A6	A2 / A6	A2 / A6	A2 / A6
Crimping	C3	–	–	–
Polishing	P2 / P3 / P7	P10	P2 / P3 / P7	P10

	FSMA connector POF			
Order no.	SSMA-SH0-02-0010	SSMA-SH0-02-0020	SSMA-SS0-02-0020	SSMA-SS0-02-0030
Fiber Ø	1000 µm	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	6.0 mm	6.0 mm	3.6 mm
Assembly	Crimping/hot plate	Crimping/hot plate	Crimping/polishing	Crimping/polishing
Ferrule	Metal	Metal	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. black boot and dust cap	Incl. crimping sleeve, 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

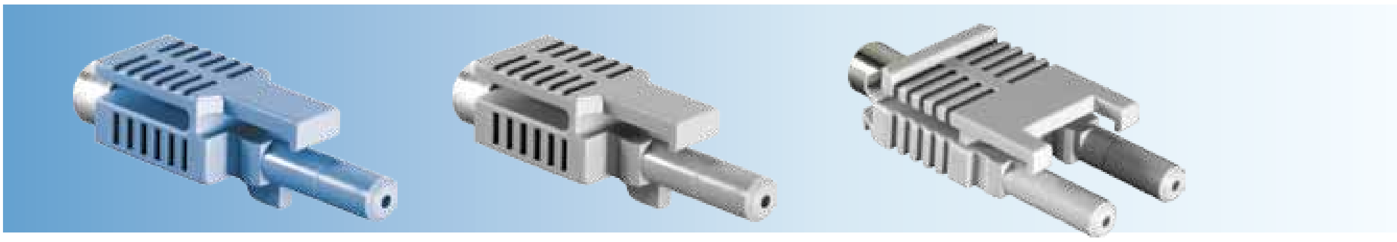
Info

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.



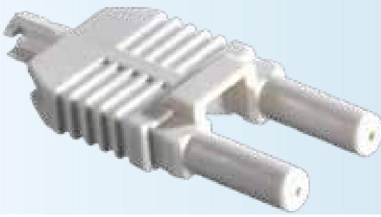
	FSMA connector POF			
Order no.	SSMA-SS0-02-0050	SSMA-SS0-02-0060	SSMA-SS0-02-0070	SSMA-SV0-02-0010
Fiber Ø	1000 µm	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	6.0 mm	2.2 mm
Assembly	Crimping/polishing	Crimping/polishing	Crimping/polishing	Clamping/polishing
Ferrule	Metal	Plastic	Plastic	Metal
Reference 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

	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-SV0-02-0010
Compatibility	HFBR 4531	–
Fiber Ø	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm
Assembly	Clamping/polishing	Clamping/polishing
Ferrule	Plastic	Plastic
Reference cable	KHPS-HPS11050cm for attenuation measurement 0.5 m	KHPS-HPS11050cm for attenuation measurement 0.5 m
Features	Incl. dust cap	Without dust cap
Stripping	A2 / A6	A2 / A6
Crimping	C3	C3
Polishing	P1 / P2 / P3 / P8	P1 / P2 / P3 / P8

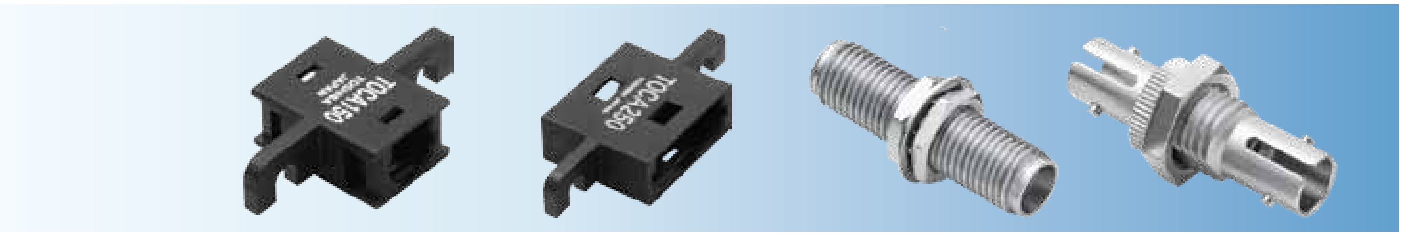


	HP connector duplex POF	Anti-kink protecting sleeve for HP connectors
Order no.	SXHP-DS0-19-0010	SKNS-CZ0-20-0010 **in blue** SKNS-GZ0-20-0010 **in grey**
Compatibility	HFBR 4506	HFBR 4501, 4503, 4511 and 4513
Fiber Ø	1000 µm	
Cable Ø	2.2 mm	
Assembly	Crimping/polishing	
Ferrule	Plastic	
Reference cable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

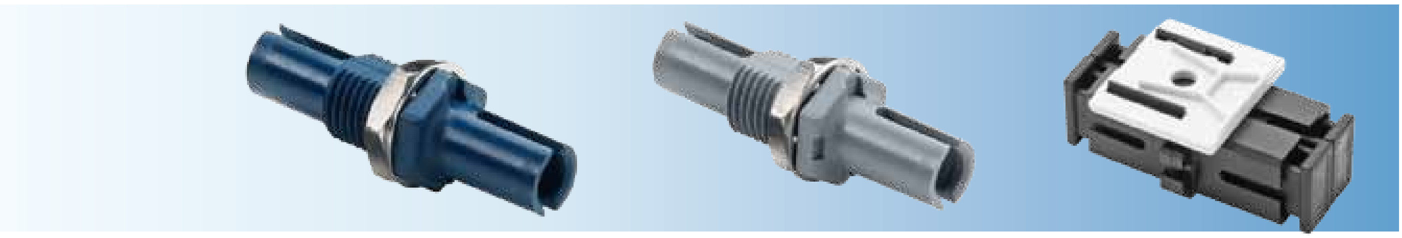
	ST connector (BFOC) POF		SC connector POF
Order no.	SXST-SS0-22-0010	SXST-SV0-02-0010	SXSC-SS0-02-0010
Fiber Ø	1000 µm	1000 µm	1000 µm
Cable Ø	2.2 mm	2.2 mm	2.2 mm
Assembly	Crimping/polishing	Clamping/polishing	Crimping/polishing
Ferrule	Metal	Metal	Metal
Reference cable	KXST-XST11050cm for attenuation 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	Incl. 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

	MIP connector POF	MIS connector POF	SCRJ connector duplex IP20
Order no.	SMIP-SM0-25-0010	SMIS-SM0-25-0010	SSCR-DV0-02-0010
Fiber Ø	1000 µm	1000 µm	1000 µm
Cable Ø	2.3 mm	2.3 mm	2.2 mm
Assembly	Crimping/cutting	Crimping/cutting	Clamping/polishing
Ferrule	Metal	Metal	Metal
Reference cable	KMIP-MIP17050cm for attenuation measurement 0.5 m	KMIS-MIS17050cm for attenuation measurement 0.5 m	KSCR-SCR13050cm for attenuation measurement 0.5 m
Features	Incl. dust cap	Incl. dust cap	Incl. black boot and dust cap
Stripping	A2 / A6	A2 / A6	A2 / A6
Crimping	On request	On request	–
Polishing	On request	On request	P2 / P3 / P6

POF couplings



	Coupling for F05 POF	Coupling for F07 POF	Coupling for FSMA POF	Coupling 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

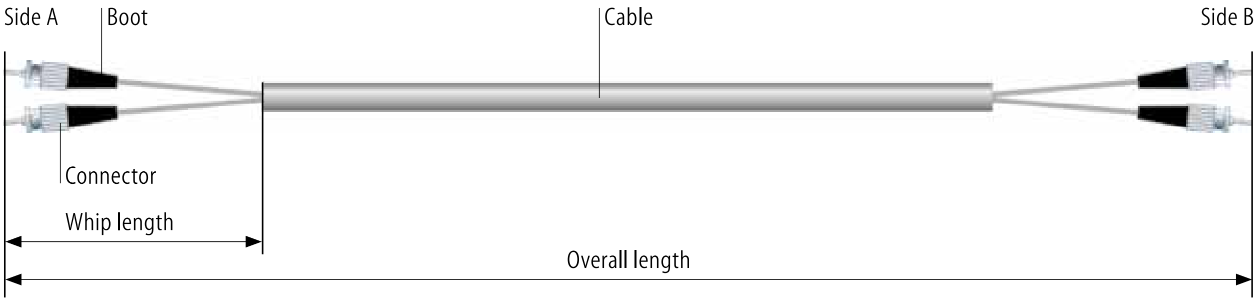


	Coupling for HP POF	Coupling for HP POF	Coupling for SCRJ POF
Order no.	SKUP-2XHPS-0020	SKUP-2XHPS-0030	SKUP-2XSCR-0010
Compatibility	HFBR 4515	HFBR 4505	–
Fiber Ø	1000 µm	1000 µm	1000 µm
Ferrule	Plastic without separate metal insert	Plastic without separate metal insert	Plastic with ceramic insert

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, engineering and consulting.

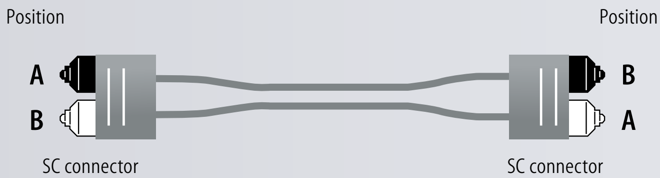
Service features

- 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
- Delivery possible within 24 hours
- 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).

POF position switch

Position switch IP67	
Order no.	H01x0015500AS0X900
Design	1S/1OE snap-action contacts, swivel drive adjustable on right/left, stainless steel lever, 27 mm in length, with 19 mm plastic roller
Fiber type	POF 980/1000 µm
Insertion loss	POF switching mechanism 4 to 6 dB (650 nm) POF cable (84D052SIS) AT-V4YQ(ZN)B2Y 2P980/1000 650 nm (laser) max. 190 dB/km 660 nm (LED) typ. 290 dB/km
Housing	Metal
Protection class	IP66/67 in enclosed system with appropriate cable gland in the housing
Operating temperature	−40°C to +85°C (depending on cable type)
Scope of delivery	POF switching insert with 1x N/O contact and 1x N/C contact

Order number scheme for POF cable assembly

K XST – 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**
MIP (Most Insert Pin)	**MIP**
MIS (Most Insert Socket)	**MIS**
SMI	**SMI**
Connector type Side B (see above)	E.g. XST
POF cable code no.	
E.g. I-V2Y(ZN)HH	**32**
AT-(ZN)V2Y2Y 2P980	**37**
Length	
128, 010, etc.	E.g. 325
Unit	
mm, cm, m, etc.	E.g. cm
Variants	
Customer-specific	

Order example:

K XST-XST 32 325 cm

3.25 m, duplex connection cable (cable type: I-V2Y(ZN) HH2X1P980/1000, PMMA fiber with PE buffer tube and FRNC outer jacket) assembled with ST connectors

PCF

Polymer cladded fibers

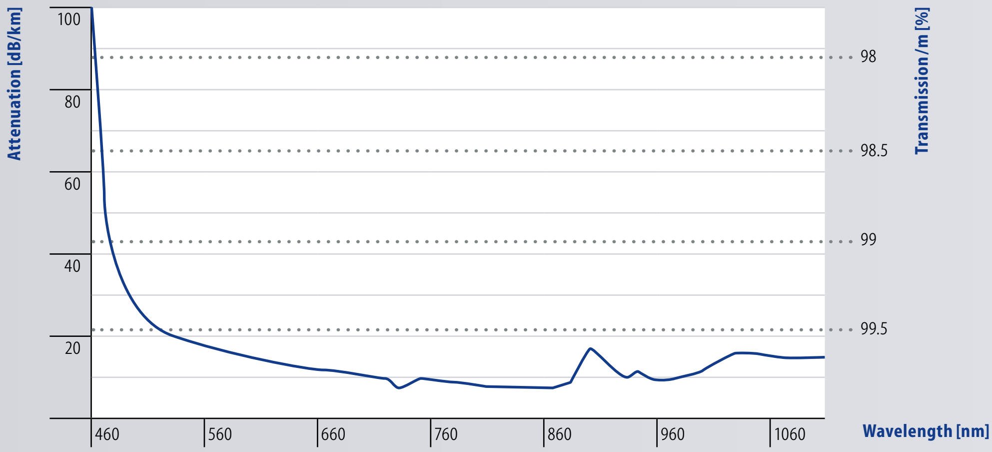
Polymer cladded fibers (PCF) have been on the market for many years, standing out by being very robust and easy to assemble.

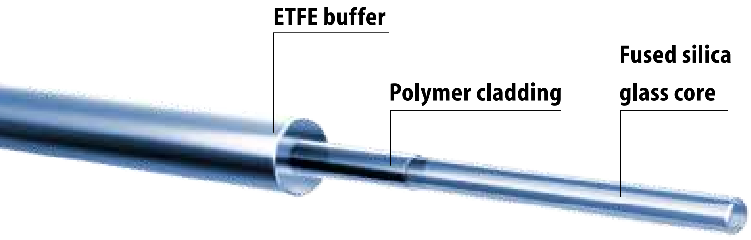
PCF consists of a glass core with polymer cladding. What is especially important here is good adhesion of the cladding material to the glass core, which does not go without saying because of the different expansion coefficients especially at high temperatures. That is where many products on the market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

It is also why there are a vast number of different abbreviations for PCF such as PCS, HCS and HPCF. LEONI uses a fiber with NA = 037, which shows especially low attenuation at 650 and 850 nm, as its standard PCF. The low attenuation makes it possbile to bridge distances of up to 500 m in systems designed for POF with 650 nm and distances of up to 4 km in systems with 850 nm.

PCF fiber specifications

Fiber type
Standard



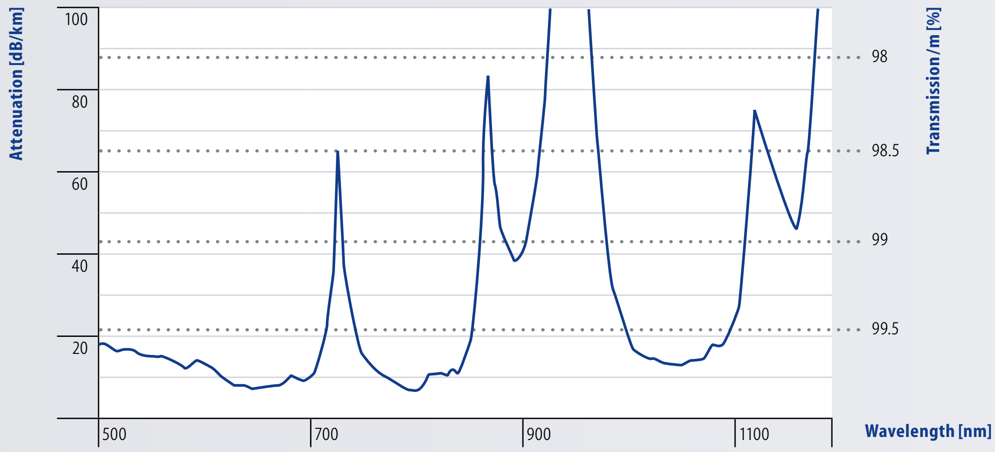


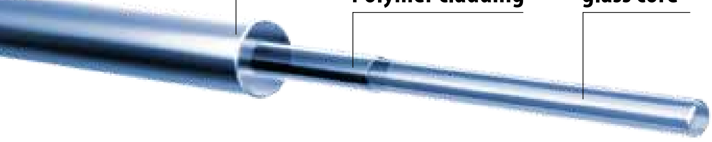
The combination of the PCF consisting of a fused silica glass core and a polymer cladding offers the optimum blend of advantages of POF and glass fibers.
A Tefzel® layer is additionally applied as a buffer to improve the mechanical and thermal properties. The same transmitter and receiver components 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**
Transmission 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 [nm]	15	16	24	47	94	94	118	295

Gradient 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.

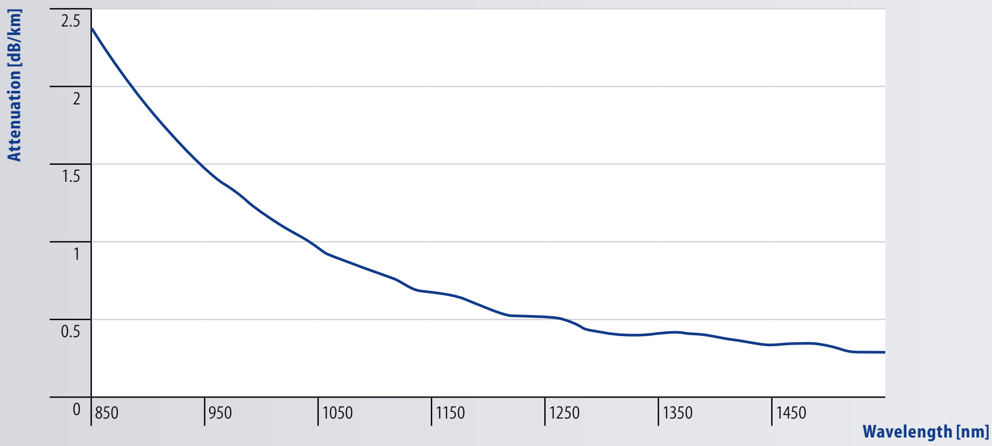
The bandwidth of optical fibers with step-index profile such as standard PCF is drastically restricted by the modal dispersion. The use of gradient-index fibers is the best solution to this problem.

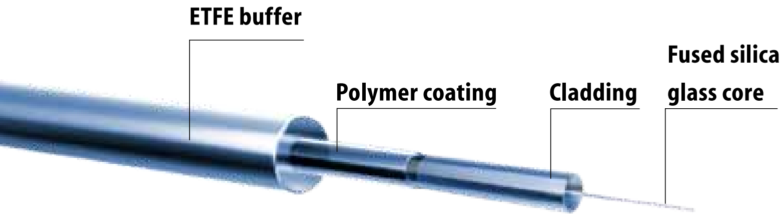
Please inform us of your special requirements.

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

FiberConnect® 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.

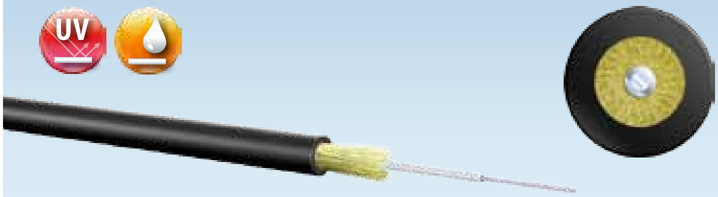
	GK 62.5/200/230
Order no.	**84850043F**
Transmission properties	
Core [µm] (±2%)	62.5
Cladding [µm] (±2%)	200
Coating [µm] (±2%)	230
Buffer (µm) (+-5%)	500
Attenuation at 850 nm	3.2
Attenuation at 1300 nm	0.9
Bandwidth [MHz×km] at 850 nm	200
Bandwidth [MHz×km] at 1300 nm	500
NA	0.275
Mechanical properties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

- High bandwidth
- Faster, more efficient assembly technology in comparison with SM or MM glass fibers
- Compatibility with PCF cleaving technique and thus reduced overall costs during installation
- High resilience: flexible, resistant to aging, low susceptibility to temperature and humidity
- Compatible transmitter elements: LEDs, laser diodes, VCSELs, RCLEDs

PCF cables

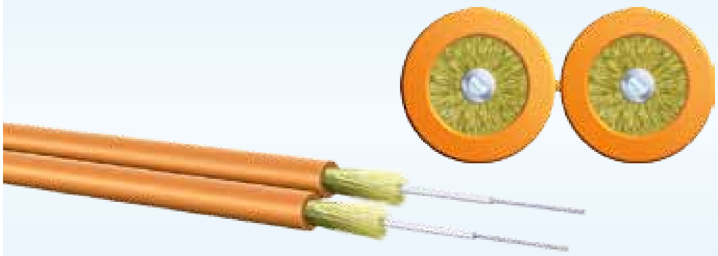
I-V(ZN)Y 1K200/230

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



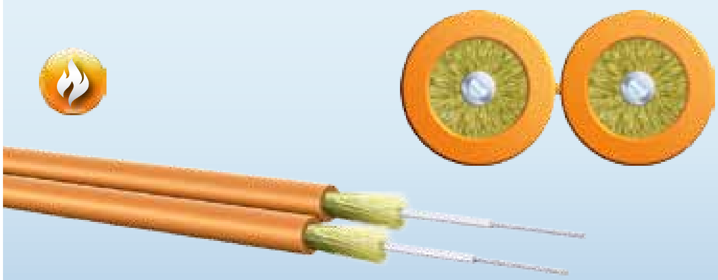
A-V(ZN)11Y 1K200/230

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



I-V(ZN)Y 2X 1K200/230

Order no.	84Q00300T222
Code no.	61
Application	Flexible applications with low dynamic stress
Assembly	Direct connector assembly
Length	2100 m



I-V(ZN)H 2X 1K200/230

Order no.	84Q01000T222
Code no.	66
Application	Flexible applications with low dynamic stress
Assembly	Direct connector assembly
Length	2100 m

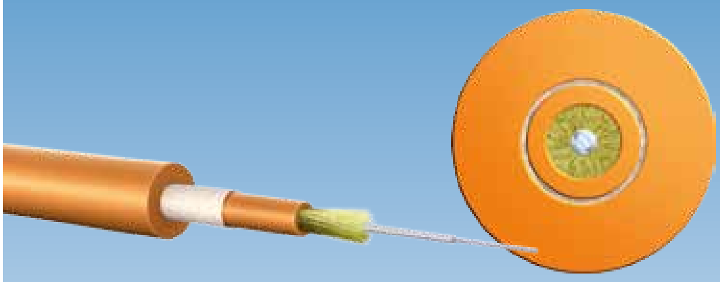
Info

PCF cables are available for both indoor and outdoor applications. 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.

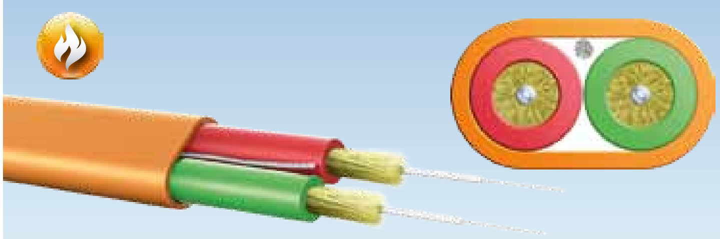
PCF cable specifications			I-V(ZN)Y 1K200/230	A-V(ZN)11Y 1K200/230	I-V(ZN)Y 2X 1K200/230	I-V(ZN)H 2X 1K200/230
Order no.			84P00300T222	84P00600T000	84Q00300T222	84Q01000T222
Composition	Inner jacket material		–	–	–	–
	Outer jacket material		PVC	PUR	PVC	FRNC
	No. of PCF elements (200/230)		1	1	2	2
	Buffered fiber Ø [mm]		–	–	–	–
	Outer Ø [mm]		2.2	3.0	2.2 x 4.5	2.2 x 4.5
Mechanical properties	min. bending radius [mm]	during installation	60	60	60*	60*
		long-term	30	30	30	30
	max. pull force [N]	short-term	300	800	300	300
		long-term	100	400	100	100
	Approx. cable weight [kg/km]		5	6.5	10	11
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

* over flat side



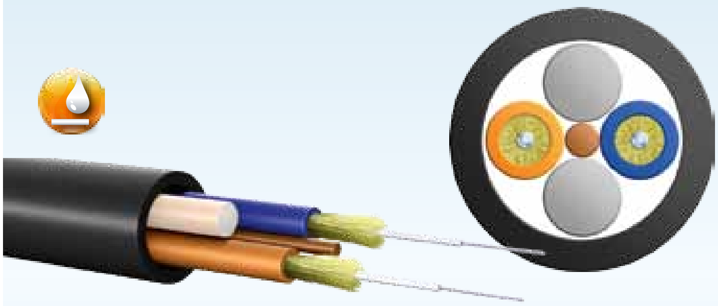
I-V(ZN)YY 1K200/230

Order no.	84P00900T333
Code no.	71
Application	Flexible applications with low dynamic stress
Assembly	Direct connector assembly
Length	2000 m



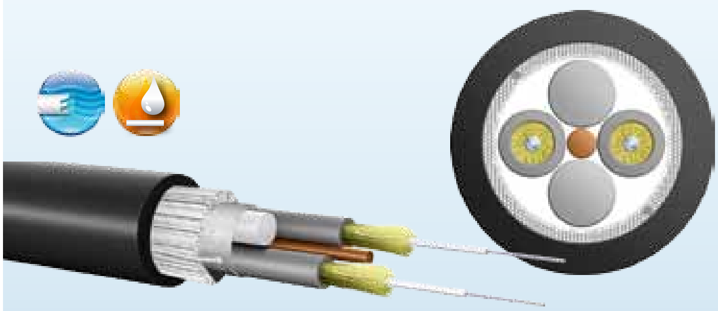
I-V(ZN)HH 2X 1K200/230

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



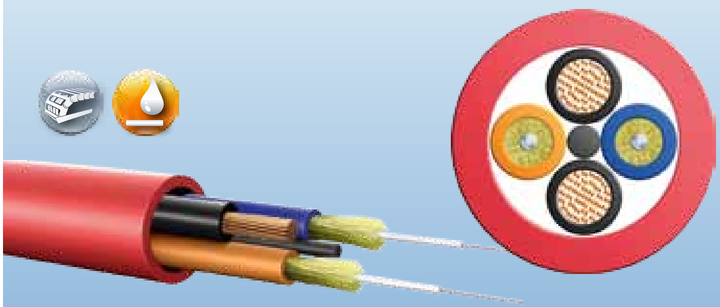
I-V(ZN)H2Y 2K200/230

Order no.	84Q00400T000
Code no.	63
Application	Splittable cable for fixed indoor and outdoor installation
Assembly	Direct connector assembly
Length	2000 m



AT-VQ(ZN)HB2Y 2K200/230

Order no.	84Q00200T000
Code no.	75
Application	Splittable cable for fixed installa-tion, longitudinally waterproof
Assembly	Direct connector assembly
Length	2000 m



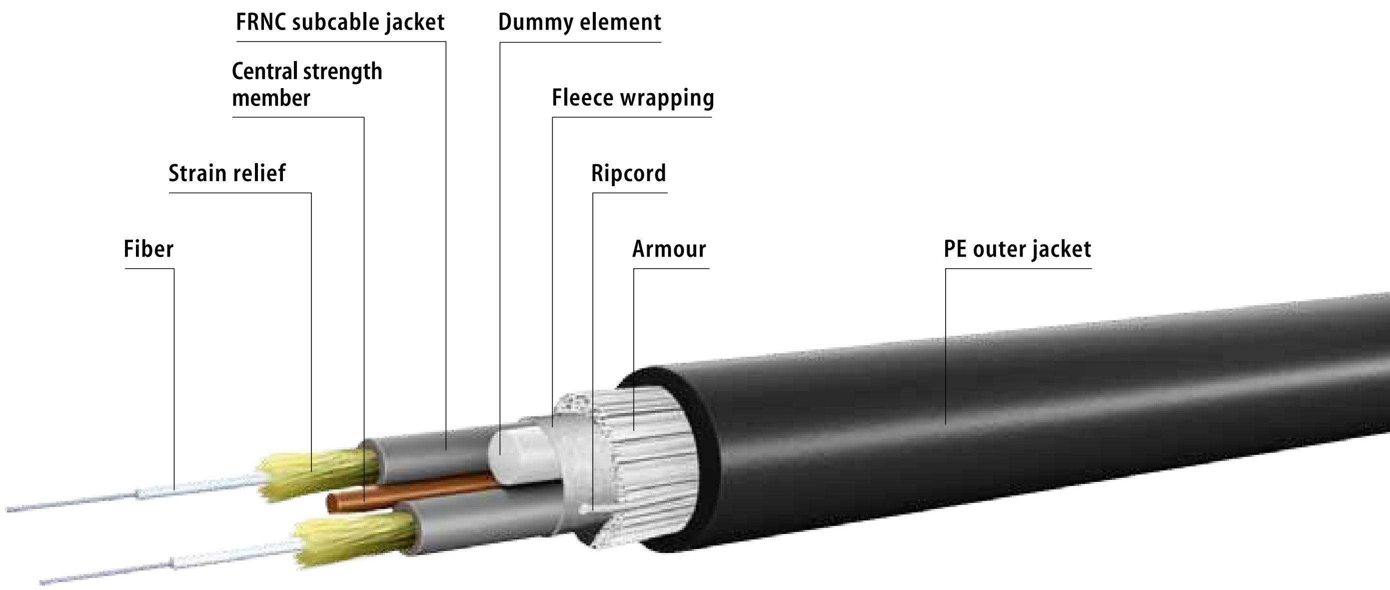
I-V(ZN)Y11Y 2K200/230+2x1qmm

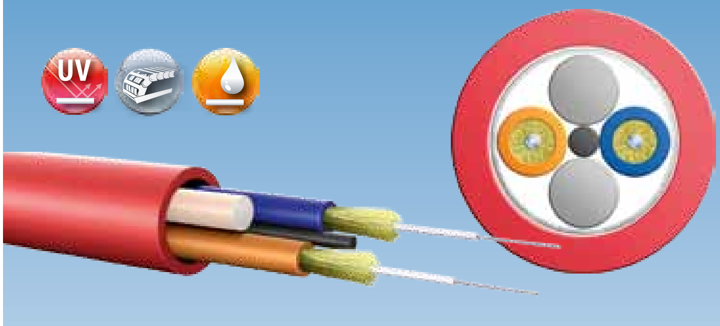
Order no.	84Q03000T333
Code no.	62
Application	Splittable indoor cable for harsh industrial environments, for fixed installation, suitable for drag chains
Assembly	Direct connector assembly
Length	2000 m

PCF cable specifications			I-V(ZN)YY 1K200/230	I-V(ZN)HH 2X 1K200/230	I-V(ZN)H2Y 2K200/230	AT-VQ(ZN)HB2Y 2K200/230	I-V(ZN)Y11Y 2K200/230 2x1qmm
Order no.			84P00900T333	84Q00700T222	84Q00400T000	84Q00200T000	84Q03000T333
Composition	Inner jacket material		PVC	FRNC	FRNC	FRNC	PVC
	Outer jacket material		PVC	FRNC	PE	PE	PUR
	No. of PCF elements (200/230)		1	2	2	2	2
	No. of copper elements		–	–	–	–	2
	Buffered fiber Ø [mm]		2.2	2.9	2.2	2.9**	2.2
	Outer Ø [mm]		5.0	3.9 x 6.8	7.0	10.5	7.6
Mechanical properties	min. bending radius [mm]	during installation	60	50*	70	150	70
		long-term	40	30	50	200	50
	max. pull force [N]	short-term	300	800	800	1500	800
		long-term	100	200	200	500	200
	Approx. cable weight [kg/km]		28	31	38	90	65
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

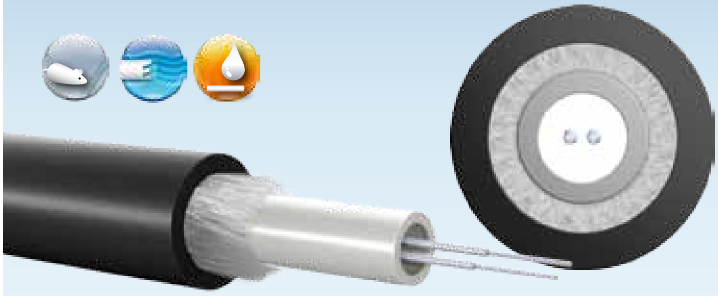
* over flat side

** also special size with Ø 2.2 mm



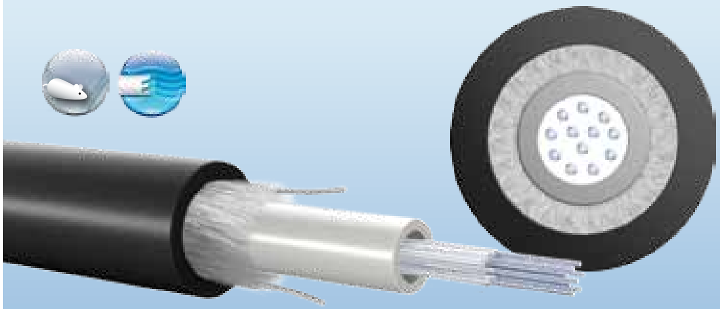


AT-V(ZN)Y11Y 2K200/230	
Order no.	84Q04700T333
Code no.	D6
Application	Abrasion-resistant PU jacket, suitable for drag chains, for fixed indoor and outdoor installation
Assembly	Direct connector assembly
Length	2000 m



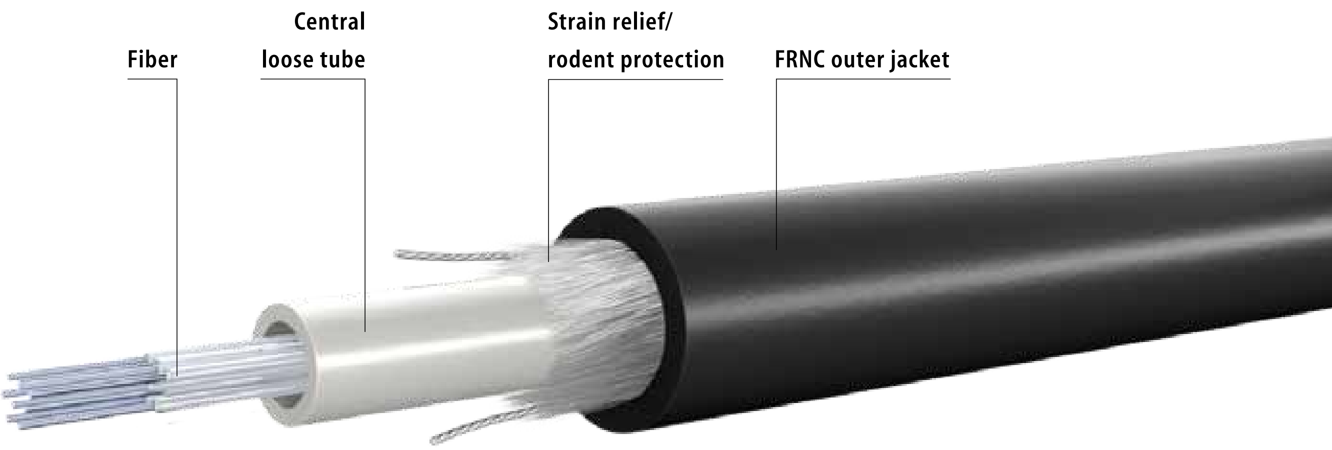
A-DQ(ZN)B2Y 2K200/230	
Order no.	84S00400T000
Code no.	76
Application	Longitudinally waterproof cable with non-metallic rodent protection, for fixed installation outdoors, for running directly in the ground
Length	2000 m

A-DQ(ZN)B2Y 4K200/230	
Order no.	84S00800T000
Code no.	D7
Application	Longitudinally waterproof cable with non-metallic rodent protection, for fixed installation outdoors, for running directly in the ground
Assembly	Direct connector assembly
Length	2000 m

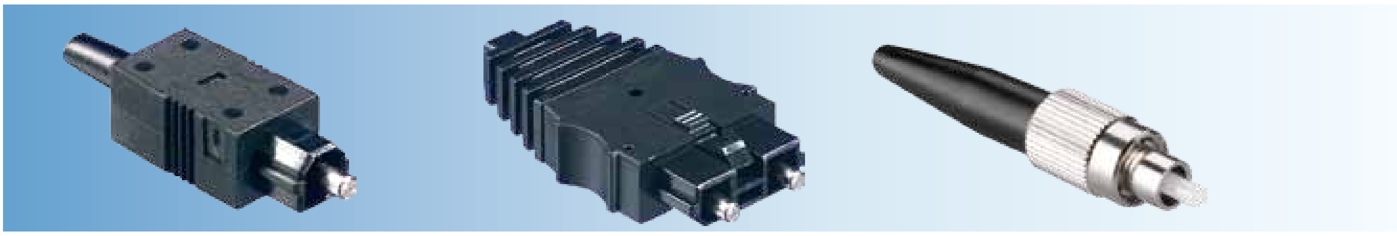


A-DQ(ZN)BH 12K200/230	
Order no.	84S00200T000
Code no.	79
Application	Longitudinally waterproof cable with non-metallic rodent protection, for fixed installation indoors and outdoors
Length	2000 m

PCF cable specifications			AT-V(ZN)Y11Y 2K200/230	A-DQ(ZN)B2Y 2K200/230	A-DQ(ZN)B2Y 4K200/230	A-DQ(ZN)BH 12K200/230
Order no.			84Q04700T333	84S00400T000	84S00800T000	84S00200T000
Composition	Inner jacket material		PVC	–	–	–
	Outer jacket material		PUR	PE	PE	FRNC
	No. of PCF elements (200/230)		2	2	4	12
	Buffered fiber Ø [mm]		2.2	3.5	4.5	4.5
	Outer Ø [mm]		7.4	7.5	8.5	8.5
Mechanical properties	min. bending radius [mm]	during installation	110	150	170	170
		long-term	70	110	130	130
	max. pull force [N]	short-term	800	1500	1500	1500
		long-term	200	1200	1200	1200
	Approx. cable weight [kg/km]		45	47	76	82
Thermal properties	Operating temperature [°C]		–40 to +85	–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



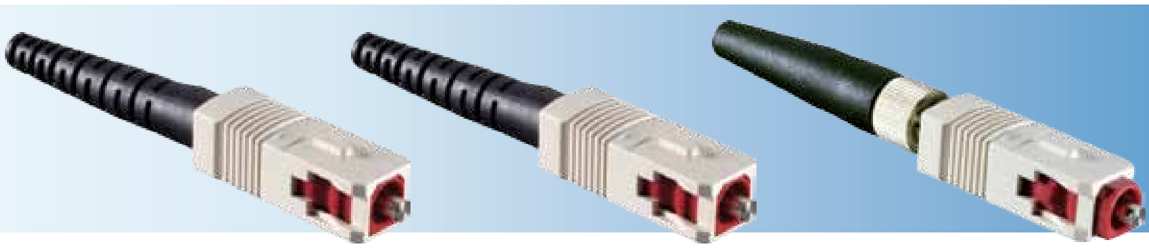
PCF connectors



	F05 connector PCF	F07 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	HP connector PCF	HP connector housing PCF
Order no.	SXHP-SC0-32-0010	SXHP-SC0-32-0020	SGEH-DC0-10-0010
Compatibility	HFBR 4521, V-PIN 2005	HFBR 4521, V-PIN 2005	BP 04703
Fiber Ø	230 µm	230 µm	–
Cable Ø	2.2 mm	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	

Special note:
The HP connectors (see left) with the order no. SXHP-SC0-32-0010 must be ordered separately.



	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	Incl. black boot and dust cap
Assembly	On request	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.

PCF connectors

	LC connector PCF	LC duplex clamp PCF
Order no.	SXLC-SK0-01-0030	SKLA-DU0-01-0010
Fiber Ø	230 µm	–
Cable Ø	3.0 mm	–
Assembly	Crimping/gluing/polishing	Clipping
Ferrule	Metal	
Reference cable	KXLC-XLC 72050cm for attenuation measurement 0.5 m	
Features	Incl. crimping sleeve, white boot and dust cap	
Assembly	On request	

	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

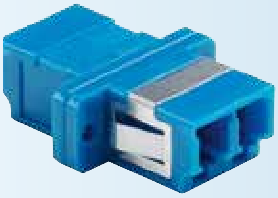
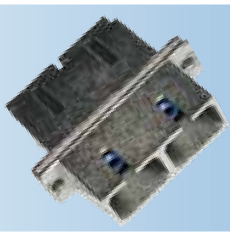
	FSMA connector PCF		
Order no.	SSMA-SW0-02-0020	SSMA-SK0-04-0020	SSMA-SK0-04-0030
Fiber Ø	230 µm	230 µm	230 µm
Cable Ø	3.0 mm	3.0 mm	2.2 mm
Assembly	Clamping/cleaving	Crimping/gluing/polishing	Crimping/gluing/polishing
Ferrule	Metal	Ceramic	Ceramic
Reference cable	KSMA-SMA 72050cm for attenuation measurement 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

PCF connectors

	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			E2000 connector PCF
Order no.	SXST-SW0-02-0010	SXST-SW0-02-0020	SXST-SW0-02-0030	SE2K-SC0-45-0010
Fiber Ø	230 µm	230 µm	230 µm	230 µm
Cable Ø	2.2 mm	2.5 mm	3.0 mm	2.2 – 3.0 mm
Assembly	Clamping/cleaving	Clamping/cleaving	Clamping/cleaving	Crimping/cleaving
Ferrule	Metal	Metal	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	KE2K-E2K72050cm 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	Incl. boot and dust cap
Assembly	K2	K2	K2	On request

PCF couplings


	Coupling for LC duplex PCF	Coupling for SC duplex PCF	Coupling 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



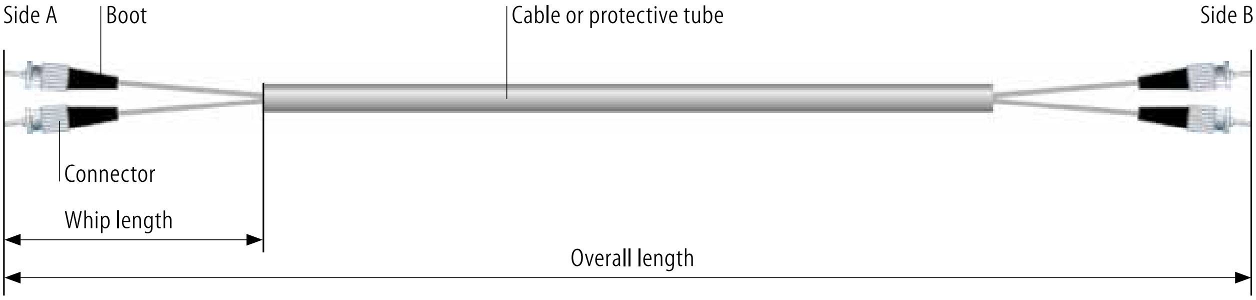
	Coupling for SCRJ PCF	Coupling for FCPC PCF	
Order no.	SKUP-2XSCR-0010	SKUP-2XFCP-0010	SKUP-2XFCP-0020
Fiber Ø	230 µm	230 µm	230 µm
Housing	Plastic with ceramic insert	Metal with metal insert	Metal with ceramic insert


	Coupling for FSMA PCF	Coupling for ST PCF
Order no.	SKUP-2XSMA-0010	SKUP-2XXST-0010
Fiber Ø	230 µm	230 µm
Housing	Metal without separate insert	Metal without separate insert

Pre-assembled PCF cables

Description of the structure of pre-assembled PCF indoor cables

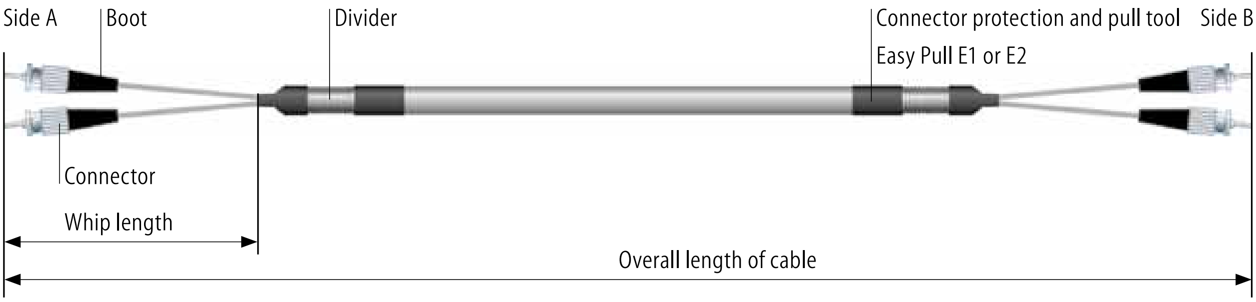
- Standard whip lengths 20 ±4 cm
- Overall length tolerances ±2%



Description of the structure of pre-assembled PCF outdoor cables

- Whip lengths 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 cabling 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 customer-specific assembly as well as engineering and consulting.

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
- Delivery possible within 24 hours
- 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.

Order number scheme
for PCF cable assembly

K XST – XST 64 325 cm (example)

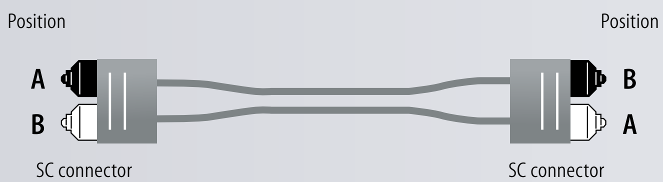
Cable assembly	**K**
Connector type Side A	
BFOC (ST®)	**XST**
FSMA	**SMA**
HP simplex	**HPS**
HP duplex	**HPD**
F05, TOSLINK-compatible	**F05**
F07, TOSLINK-compatible	**F07**
SC	**XSC**
SCRJ	**SCR**
E2000	**E2K**
LC	**XLC**
FC/PC	**FCP**
Connector type Side B (see above)	E.g. XST
PCF cable code no.	
z. B. I-V(ZN)HH 2X1K200/230	**64**
A-V(ZN)11Y 1K200/230	**74**
Length	
128, 010, etc.	E.g. 325
Unit	
mm, cm, m, etc.	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).

Easy Pull cabling system

Easy Pull E1

The pull tool system can be used for assemblies with up to 4 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 pull tool can be easily removed and the connectors can be joined to the couplings or transceivers as usual at the destination. Gauging the assembly in the plant is an integral part of the delivery package.

Easy Pull 1 – no. of fibers n	2	4
min. bending radius of cable	Acc. to cable data sheet	
min. bending radius of buffered fiber/whip	30 mm	30 mm
Minimum hole Ø for through-feeds with cabinets and walls	30 mm	30 mm
max. pull force on pull tool	500 N	600 N

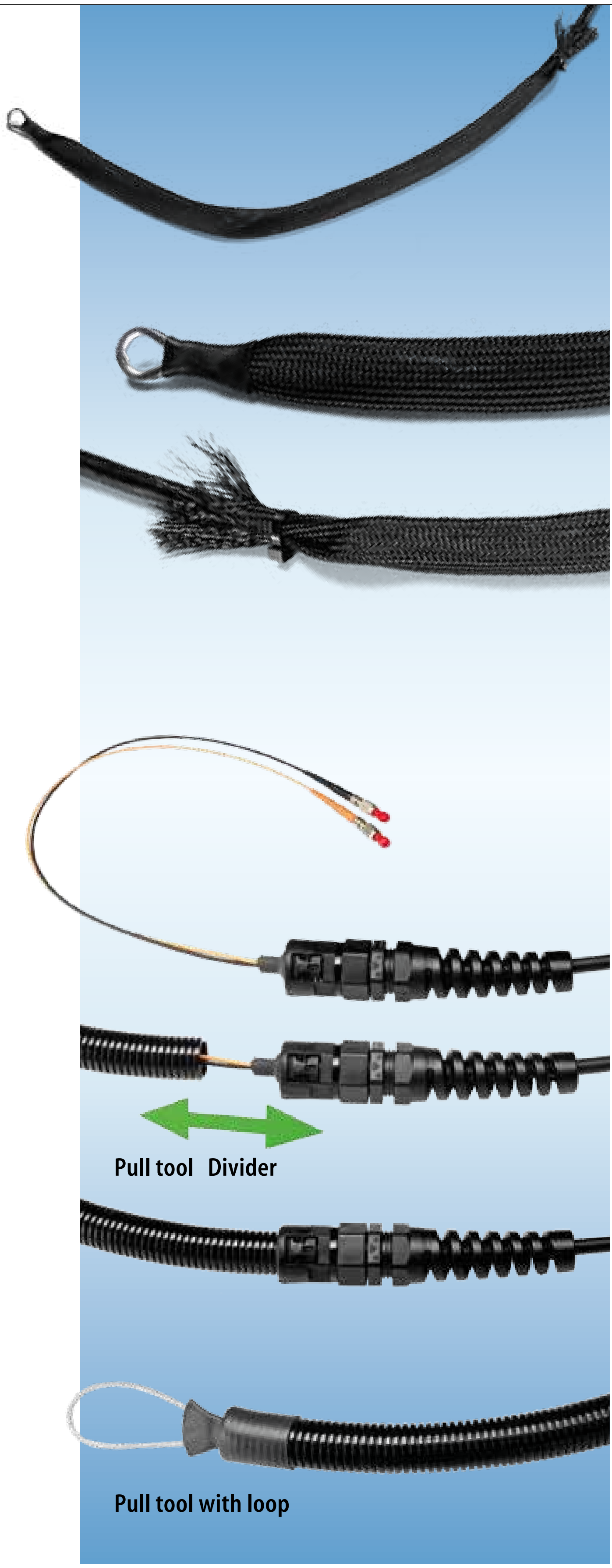
You will find the corresponding cables in the chapters on glass fiber cables and PCF cables.

Easy Pull E2

This pull tool 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 couplings or transceivers as normal. Gauging the assembly in the plant is an integral part of the delivery package.

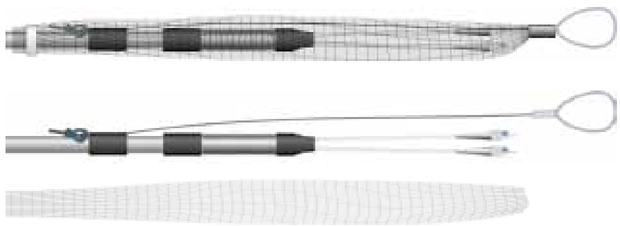
Easy Pull 2 – no. of fibers n	2	4	5 to 12	13 to 32
min. bending radius of cable	Acc. to cable data sheet			
min. bending radius of buffered fiber/whip	30 mm	30 mm	30 mm	30 mm
Outer Ø of divider element	14 mm	14 mm	21 mm	30 mm
Resistance to apex pressure (protective conduit)	350 N	350 N	350 N	350 N
max. pull force on pull tool	500 N	500 N	600 N	600 N
PG cable gland	M20 (PG13.5)	M25 (PG21)	M25 (PG21)	M50 (PG36)
Outer Ø of protective conduit	20 mm	30 mm	30 mm	55 mm
Minimum hole Ø for through-feeds with cabinets and walls	35 mm	40 mm	45 mm	60 mm
Material (protective conduit)	PA 6 (flame-retardant/halogen-free/UV-stable)			



Divider for Easy Pull E1

The divider specially developed for the Easy Pull E2 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 pull tool is a sharp knife and a cutting pliers.



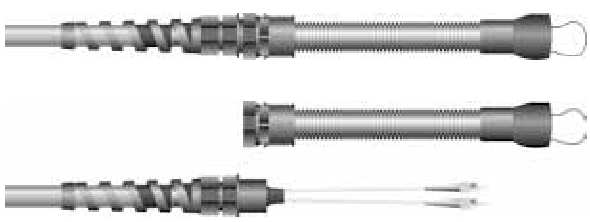
Divider for Easy Pull E2

The divider specially developed for the Easy Pull E2 system contains no metal and is especially sturdy despite its low weight.

The divider is splashproof and offers good protection against mechanical damage. The high flexibility permits trouble-free installation, even under difficult conditions. The pull tool can be removed without any tools.

Properties

- Sturdy, watertight, flexible and UV-resistant protective conduit made from PA 6, with pull tool
- 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



Large Core

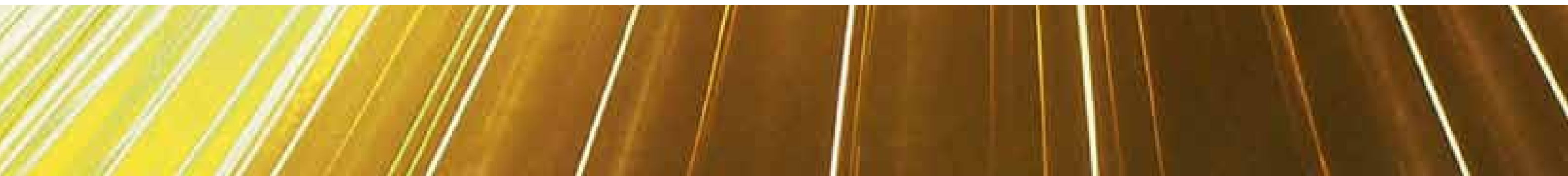
Special fibers – fused silica glass, sapphire, non-oxidic glasses

Fibers made from super pure silica are used for optimum light transmission from the ultra-violet range (UV) to the infrared range (IR).

We have drawing systems on which large-diameter UV-conductive silica/silica fibers (high-OH), IR-conductive silica/silica fibers (low-OH) or capillaries and tapers are drawn.

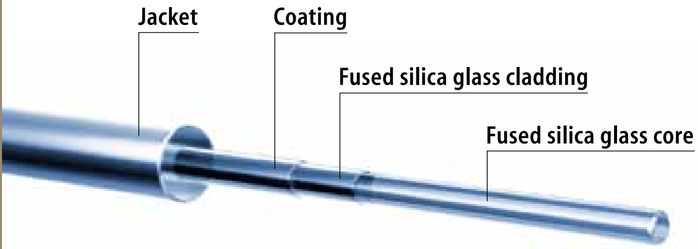
The fibers are available individually or in different buffered fiber and cable constructions. We supply core diameters from 3 µm to 10 µm for singlemode applications and from 20 µm to 2 mm for multimode applications such as spectroscopy, medical technology, energy transmission (laser technology) and sensor technology.

Silica fibers are covered with a coating consisting of acrylate, dual acrylate, high-temperature dual acrylate, silicone or polyimide. The fibers are covered with a further buffer, made from Nylon® or Tefzel® for example, so that they can be used in different temperature ranges and chemical environments. The apertures of the silica optical fibers can vary from 0.1 to 0.49.



UV-VIS fiber specifications Silica/silica

Step-index multimode
UV-VIS

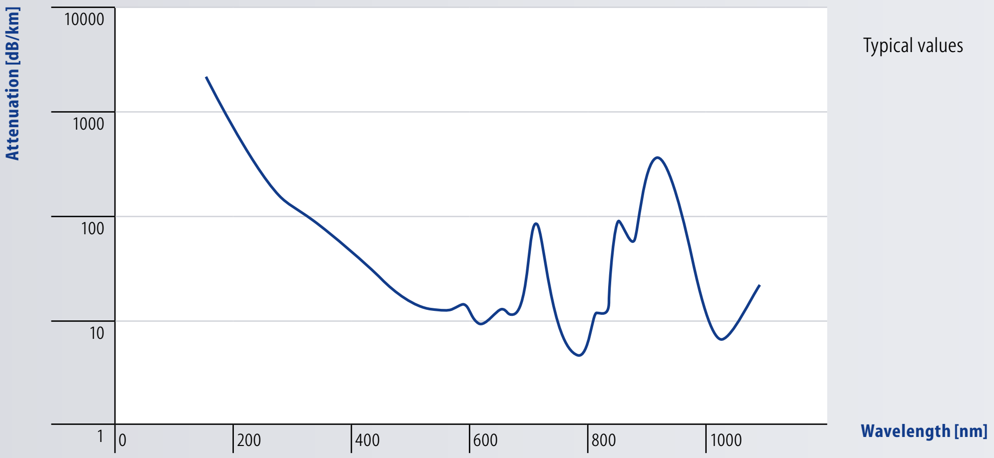


With these step-index fibers, the core and cladding consist of pure fused silica glass with high OH content. The fibers are used in a wavelength range from 190 nm to 1100 nm (UV-VIS). The fibers themselves are covered with a coating either consisting of acrylate, silicone or polyimide.

The 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	200	300	300
Jacket Ø [µm] (±5%)	55	125	110	125	125	220	240	330	360
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%)	125	200	200	200	200	350	400	500	500
Order no.	84800002N	84800003N	84800004N	84800005N	84800006N	84800007N	84800008N	84800009N	84800010N
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%)	180	245	245	245	245	350	400	550	550
Order no.	84800031N	84800032N	84800033N	84800034N	84800035N	84800036N	84800037N	84800038N	84800039N
Coating – silicone	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –40°C to 150°C								
Coating Ø [µm] (±3%)	245	245	245	400	450	550			
Order no.	84800071N	84800072N	84800073N	84800074N	84800075N	84800076N			
Coating – polyimide	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –190°C to 50°C (briefly up to 400°C)								
Coating Ø [µm] (±3%)		150	125	150		240	280	360	
Order no.		84800191N	84800192N	84800193N		84800194N	84800195N	84800196N	
Fibers with coating and jacket									
Coating – acrylate / jacket – Nylon®	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –30°C to 70°C								
Jacket Ø [µm](±5%)		500	500	500		700	700	700	
Order no.	84800101N	84800102N	84800103N	84800104N	84800105N	84800106N	84800107N	84800108N	84800109N
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		700	700	700	
Order no.		84800161N	84800162N	84800163N		84800164N	84800165N	84800166N	

Short-term bending radius: 100 x jacket radius
Long-term bending radius: 600 x jacket radius



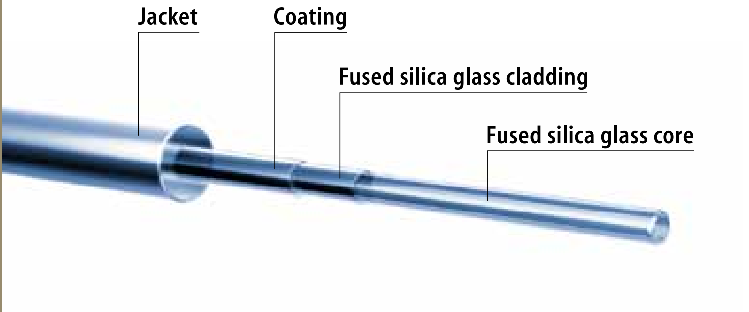
	Step-index multimode: UV-VIS								
Core Ø [µm] (±2%)	365	400	400	500	600	800	910	1000	1500
Jacket Ø [µm] (±5%)	400	440	480	550	660	880	1000	1100	1650
Fibers with coating									
Coating – single acrylate	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –40°C to 85°C (optionally 150°C)								
Coating Ø [µm](±3%)	550	550	660	700	900	1000	1200	1250	1800
Order no.	84800011N	84800012N	84800013N	84800014N	84800015N	84800016N	84800017N	84800018N	84800019N
Coating – silicone	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –40°C to 150°C								
Coating Ø [µm] (±3%)	600	650	700	750	850	1100		1300	
Order no.	84800077N	84800078N	84800079N	84800080N	84800081N	84800082N		84800083N	
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%)	440	480	520	590	710	1100			
Order no.	84800197N	84800198N	84800199N	84800200N	84800201N	84800202N			
Fibers with coating and jacket									
Coating – acrylate / jacket – Nylon®	Numerical aperture 0.22 (0.1 to 0.28 on request) Temperature range –30°C to 85°C								
Jacket Ø [µm](±5%)	900	900		1000	1000	1300		1500	2000
Order no.	84800110N	84800111N	84800112N	84800113N	84800114N	84800115N	84800116N	84800117N	84800118N
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%)	900	900		1000	1000	1300		1500	2000
Order no.	84800167N	84800168N	84800169N	84800170N	84800171N	84800172N		84800173N	

Short-term bending radius: 100 x jacket radius
Long-term bending radius: 600 x jacket radius

VIS-IR fiber specifications

Step-index multimode
VIS-IR

Large Core

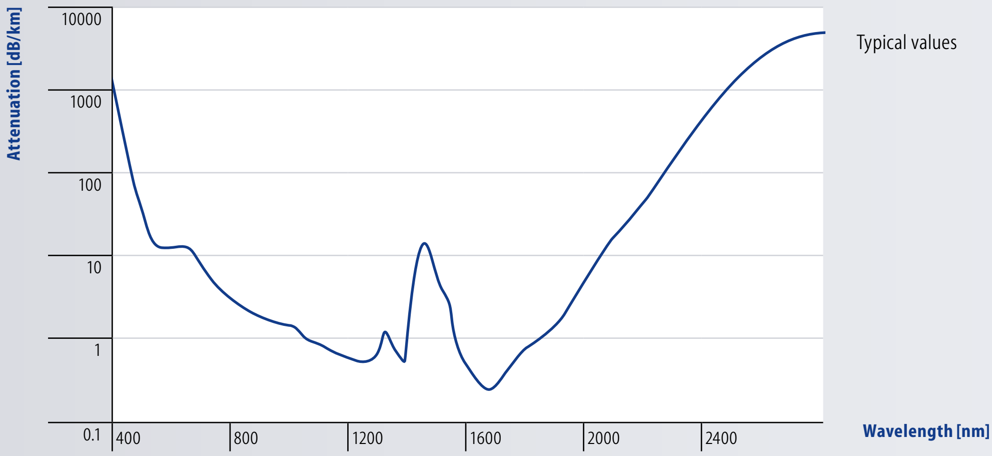


The core of glass fibers for IR consists of pure fused silica glass with low OH content and uniform refractive index across the entire diameter. The fibers are used in a wavelength range from 400 nm to 2400 nm (VIS-IR). The fibers themselves are covered with a coating either consisting of acrylate, silicone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

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

	Step-index multimode: VIS-IR								
Core Ø [µm] (±2%)	40	50	60	90	100	100	100	105	200
Jacket Ø [µm] (±5%)	125	125	125	125	110	120	140	125	220
	Fibers with coating								
	Coating – single acrylate			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –30°C to 70°C					
Coating Ø [µm](±3%)	200	200	200	200	200	200	200	205	350
Order no.	84810001N	84810003N	84810004	84810005N	84810006N	84810007N	84810008N	84810009N	848100010N
	Coating – dual acrylate			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –30°C to 70°C					
Coating Ø [µm](±3%)	245	245	245	245	245	245	245	245	400
Order no.	84810041N	84810043N	84810044N	84810045N	84810046N	84810047	84810048N	84810049N	84810050N
	Coating – silicone			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –40°C to 150°C					
Coating Ø [µm](±3%)	245	245	245	245	245	245	245	245	400
Order no.	84810071N	84810072N	84810073N	84810074N	84810075N	84810076N	84810077N	84810078N	84810079N
	Coating – polyimide			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –190°C to 385°C					
Coating Ø [µm] (±3%)	150	150	150	150	125	140	170	150	240
Order no.	84810191N	84810193N	84810194N	84810195N	84810196N	84810197N	84810198N	84810199N	84810200N
	Fibers with coating and jacket								
	Coating – acrylate / jacket – Nylon®			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –30°C to 70°C					
Jacket Ø [µm](±5%)	500	500	500	500	500	500	500	700	700
Order no.	84810101N	84810103N	84810104N	84810105N	84810106N	84810107N	84810108N	84810109N	84810109N
	Coating –silicone / jacket – Tefzel®			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –40°C to 150°C					
Jacket Ø [µm](±5%)	500	500	500	500	500	500	500	500	700
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

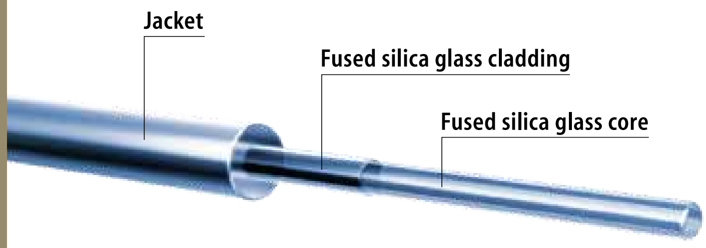


	Step-index multimode: VIS-IR									
Core Ø [µm] (±2%)	200	200	365	400	400	500	600	800	1000	1500
Jacket Ø [µm] (±5%)	240	280	400	440	480	550	660	880	1100	1650
	Fibers with coating									
	Coating – single acrylate			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –30°C to 70°C						
Coating Ø [µm](±3%)	400	440	550	550	660	700	800	1000	1250	1800
Order no.	84810011N	84810012N	84810014N	84810015N	84810016N	84810017N	84810018N	84810020N	84810022N	84810024N
	Coating – dual acrylate			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –30°C to 70°C						
Coating Ø [µm](±3%)	400	500	600	650	700	750	900	1100	1300	1800
Order no.	84810051N	84810052N	84810054N	84810055N	84810056N	84810057N	84810058N	84810060N	84810062N	84810064N
	Coating – silicone			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –40°C to 150°C						
Coating Ø [µm] (±3%)	450	500	600	650	700	750	850	1100	1300	1800
Order no.	84810080N	84810081N	84810083N	84810084N	84810085N	84810086N	84810087N	84810089N	84810091N	84810093N
	Coating – polyimide			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –190°C to 385°C						
Coating Ø [µm] (±3%)	280	310	440	480	520	590	710	1100		
Order no.	84810201N	84810202N	84810204N	84810205N	84810206N	84810207N	84810208N	84810209N		
	Fibers with coating and jacket									
	Coating – acrylate / jacket – Nylon®			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –30°C to 85°C						
Jacket Ø [µm](±5%)	700	700	900	900	900	1000	1000	1300		2000
Order no.	84810110N	84810111N	84810113N	84810114N	84810115N	84810116N	84810117N	84810118N		84810060N
	Coating – silicone / jacket – Tefzel®			Numerical aperture 0.22 (0.1 to 0.40 on request) Temperature range –40°C to 150°C						
Jacket Ø [µm](±5%)	700	700	900	900	900	1000	1000	1300		2000
Order no.	84810170N	84810171N	84810173N	84810174N	84810175N	84810176N	84810177N	84810178N		84810179N

Short-term bending radius: 100 x jacket radius
Long-term bending radius: 600 x jacket radius

VIS-IR fiber specifications

Graded-index multimode
VIS-IR

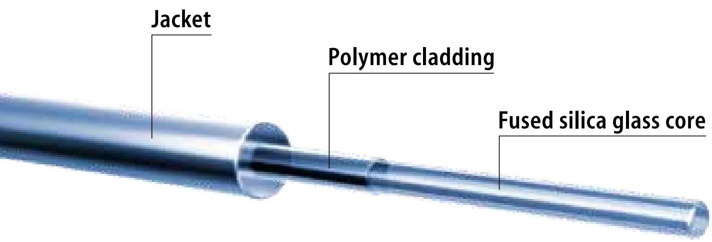


The gradient-index multimode fiber is a glass fiber possessing a reduced mode dispersion compared to a normal step-index multimode fiber. The optical density of the core material decreases continuously in a gradient fiber from the middle to the borders. Because of this, the mode 0 along the optical axis, which possesses the shortest path in the fiber, will diffuse in the densest medium. Higher modes with longer paths will diffuse mostly in the less dense medium. Thus, the diffusion velocity and the dispersion will be reduced. A bandwidth of up to 1 GHz × km is reached.

Due to the core profile the light does not spread in zigzag but bended paths. The pulse form in the gradient-index fiber remains more stable compared to the pulse form observed at the end of a step-index fiber. If the gradient-index fiber is for example not completely illuminated, the diameter of the beam will be almost kept to the end of the fiber. There are gradient-index fibers designed for power delivery and data transfer.

	Gradient-index multimode: VIS-IR						
Core Ø [µm] (±2%)	50	62.5	85	100	200	400	600
Jacket Ø [µm] (±5%)	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						
Coating Ø [µm](±3%)	250	250	250	200	450	700	1000
Order no.	84810501N	84810502N	84810503N	84810504N	84810505N	84810506N	84810507N
	Coating – polyimide						
Coating Ø [µm] (±3%)	140	140	140	155	300	580	
Order no.	84810511N	84810512N	84810513N	84810514N	84810515N	84810516N	84810517N

HPCS and PCS 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.

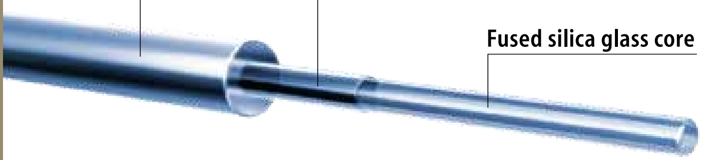
The special properties of this fiber are defined by the special material combination. The mechanical and thermal properties usually differ greatly depending on the manufacturer and polymer used, while the optical properties are often identical. The use of this type of fiber must therefore be agreed with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

The PCF fibers (see page 110) 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.

HPCS 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.

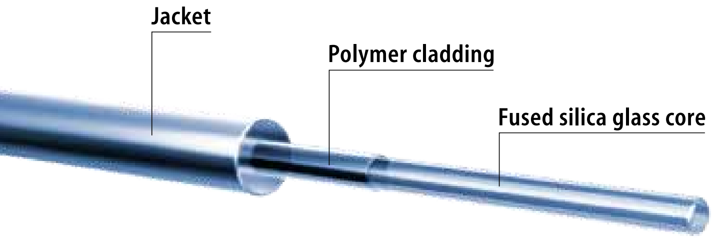
This fiber type can be used to transport low to medium power ratings over short distances with relatively low losses. A Tefzel® or Nylon® layer is additionally applied as a jacket (as a buffer function) to improve the mechanical, chemical and thermal properties.

	Hard plastic clad silica (HPCS)							
Core Ø [µm] (±2%)	110	125	200	300	400	600	800	1000
Cladding Ø [µm] (±3%)	125	150	230	330	430	630	840	1050
Jacket Ø [µm] (±5%)	600	500	500	500	730	950	1000	1400
	HPCS-IR fibers with Nylon® jacket							
Fiber type	HPCS110IRN	HPCS125IRN	HPCS200IRN	HPCS300IRN	HPCS400IRN	HPCS600IRN	HPCS800IRN	HPCS1000IRN
Order no.	84890103N	84890105N	84890107N	84890111N	84890114N	84890117N	84890118N	84890101N
	HPCS-IR fibers with Tefzel® jacket							
Fiber type	HPCS110IRT	HPCS125IRT	HPCS200IRT	HPCS300IRT	HPCS400IRT	HPCS600IRT	HPCS800IRT	HPCS1000IRT
Order no.	84890121N	84890120N	84890109N	84890112N	84890115N	84890116N	84890119N	84890102N
	HPCS-UV fibers with Nylon® jacket							
Fiber type	HPCS110UVN	HPCS125UVN	HPCS200UVN	HPCS300UVN	HPCS400UVN	HPCS600UVN	HPCS800UVN	HPCS1000UVN
Order no.	84890220N	84890218N	84890204N	84890208N	84890213N	84890211N	84890215N	84890201N
	HPCS-UV fibers with Tefzel® jacket							
Fiber type	HPCS110UVT	HPCS125UVT	HPCS200UVT	HPCS300UVT	HPCS400UVT	HPCS600UVT	HPCS800UVT	HPCS1000UVT
Order no.	84890219N	84890217N	84890207N	84890209N	84890210N	84890212N	84890216N	84890214N

Find out about other possible specifications.

PCS fiber specifications

NA 0.38
Alternative PCS



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.

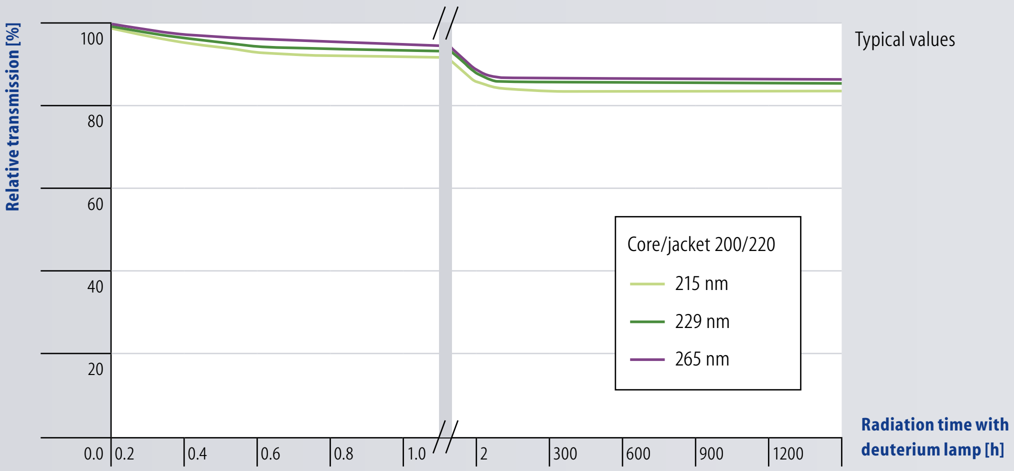
A Tefzel® or Nylon® layer is additionally applied as a jacket (as a buffer function) to improve the mechanical, chemical and thermal properties.

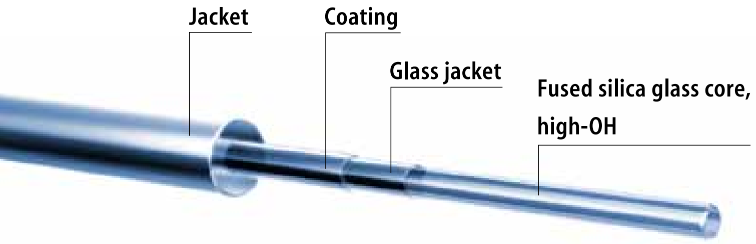
	Plastic clad silica (PCS)							
Core Ø [µm] (±2%)	110	125	200	300	400	600	800	1000
Cladding Ø [µm] (±3%)	190	200	350	450	550	800	950	1250
	PCS-IR fibers with Nylon® jacket							
Fiber type	PCS100IRN	PCS125IRN	PCS200IRN	PCS300IRN	PCS400IRN	PCS600IRN	PCS800IRN	PCS1000IRN
Order no.	84880302N	84880312N	84880305N	84880314N	84880307N	84880308N	84880416N	84880318N
Jacket Ø [µm] (±5%)	400	400	500	650	850	1000	1300	1650
	PCS-IR fibers with Tefzel® jacket							
Fiber type	PCS110IRT	PCS125IRT	PCS200IRT	PCS300IRT	PCS400IRT	PCS600IRT	PCS800IRT	PCS1000IRT
Order no.	84880310N	84880311N	84880306N	84880313N	84880315N	84880309N	84880417N	84880301N
Jacket Ø [µm] (±5%)	400	400	500	650	850	950	1300	1650
	PCS-UV fibers with Nylon® jacket							
Fiber type	PCS110UVN	PCS125UVN	PCS200UVN	PCS300UVN	PCS400UVN	PCS600UVN	PCS800UVN	PCS1000UVN
Order no.	84880420N	84880418N	84880406N	84880416N	84880409N	84880411N	84880414N	84880309N
Jacket Ø [µm] (±5%)	400	400	500	650	850	1000	1300	1650
	PCS-UV fibers with Tefzel® jacket							
Fiber type	PCS110UVT	PCS125UVT	PCS200UVT	PCS300UVT	PCS400UVT	PCS600UVT	PCS800UVT	PCS1000UVT
Order no.	84880419N	84880417N	84880407N	84880408N	84880410N	84880412N	84880415N	84880402N
Jacket Ø [µm] (±5%)	400	400	500	650	850	950	1300	1650

Find out about other possible specifications.

ASB fibers (solarisation-stable fibers)

Also available as a fiber bundle with single-fiber core Ø from 30 µm.





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.

The relative transmission is shown in the graph. A deuterium light source was used for the measurement.

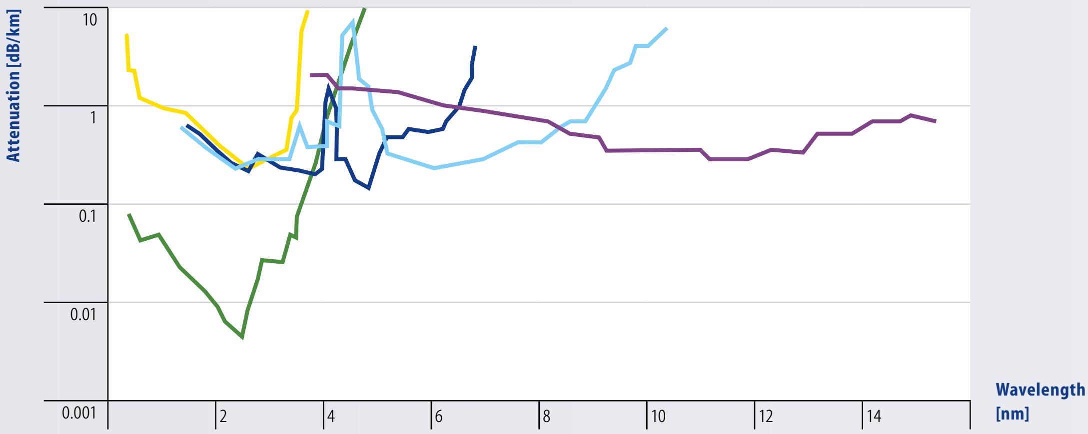
	Step-index multimode: UV-VIS							
Core Ø [µm] (±2%)	100	200	300	400	500	600	800	1000
Jacket Ø [µm] (±2%)	110	220	330	440	550	660	880	1100
	Coating – single acrylate							
Coating Ø [µm] (±3%)	160	270	400	520	630	740	980	1200
Order no.	84808 011N0000	84808 012N0000	84808 013N0000	84808 014N0000	84808 016N0000	84808 017N0000	84808 018N0000	84808 019N0000
	Coating – silicone							
Coating Ø [µm] (±3%)	240	340	440	550	680	780	990	1230
Order no.	84808 020N0000	84808 021N0000	84808 022N0000	84808 023N0000	84808 025N0000	84808 026N0000	84808 027N0000	84808 028N0000
	Coating – polyimide							
Coating Ø [µm] (±3%)	135	245	355	465	575	685		
Order no.	84808 003N0000	84808 004N0000	84808 005N0000	84808 006N0000	84808 008N0000	84808 009N0000		

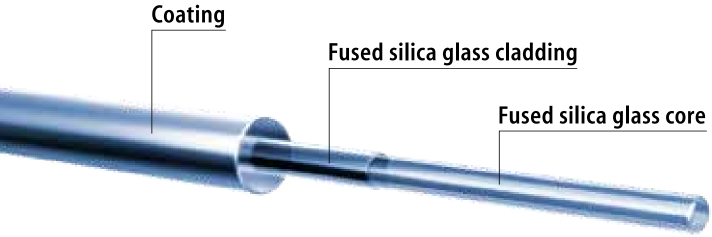
Jacket: Nylon® or Tefzel®
Further specifications (including CCDR) are possible

MIR and FIR fibers

Step-index multimode
MIR & FIR

Attenuation curves of the MIR and FIR fibers





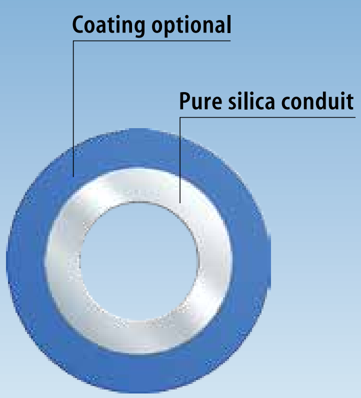
Optical fibers absorb very strongly starting from a wavelength range of approximately 2500 nm. Therefore special fibers, which work within the middle infrared range, were developed.

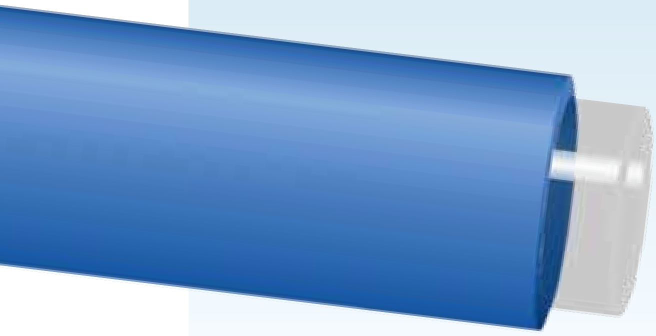
Differently doped glass fibers, polycrystalline or crystalline waveguides are used in the medium to far infrared range. Typical applications are endoscopy and spectroscopy.

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
Cladding	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 8483000xx	On request 8483002xx	On request SM 8483006xx MM 8483004xx	On request	On request

Capillaries

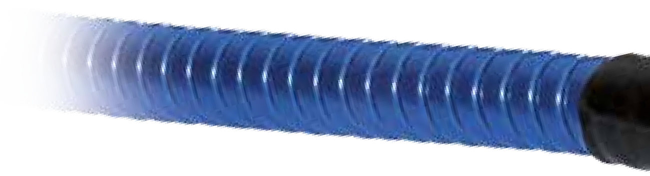




Capillaries

- 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 optical components	
	■ High-pressure miniature conduits	
	■ Beam optics	
Properties	■ Inner diameter	50–2000 µm
	■ Wall thickness	30–1000 µm
	■ Diameter tolerance	On request
	■ Length (dependent on Ø)	1 m–10 km
	■ End face processing	Cut or broken
Optional properties	■ Polyimide coating	–190 to 385°C
	■ Acrylate coating	–40 to 85°C
	■ High-temperature acrylate coating	–40 to 200°C
	■ Silicone coating	–40 to 180°C



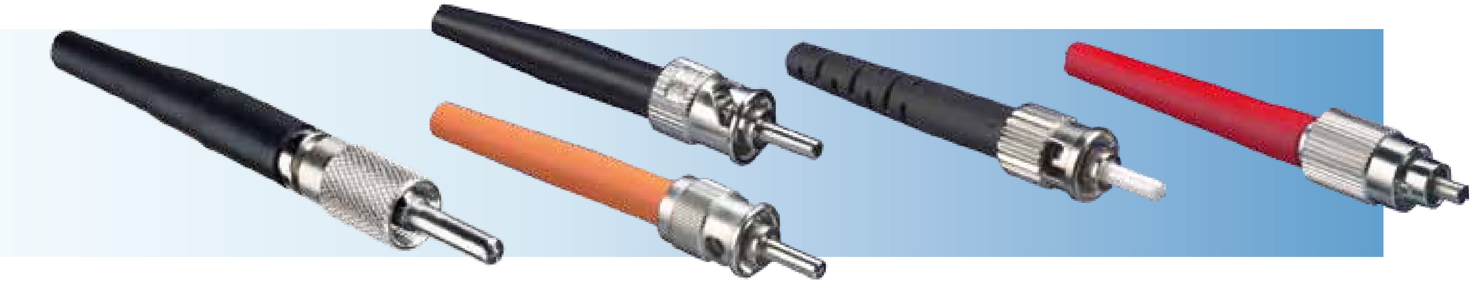
Connectors for large-core fiber assemblies

	Standard SMA connector	High-power SMA connector LC 100
Order no.	SSMA-M-F	SSMA-HP100-M-F-short/long
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 Hexagonal or knurled union nut	Free-standing fiber Adhesive-free assembly Long or short design available

	High power LC 1000	Special high power connector
Order no.	S-HP1000-M-F-10(15)	S-SHP-4x10-M-F
Hole	480 – 1100 µm	480 – 1500 µm
Assembly	Clamping/polishing	Clamping/polishing
Ferrule	Metal Length 57 mm, Ø 10 or 15 mm	Metal Length 10 mm, Ø 4 mm
Features	Mode stripper Free-standing fiber Adhesive-free assembly compatible with standard laser systems	Free-standing fiber in ceramic insert, adhesive-free assembly

High power LC 1000
High-power laser connector
for a medium power rating
of up to 1 kW

Connectors with standard ferrules in metal or ceramic

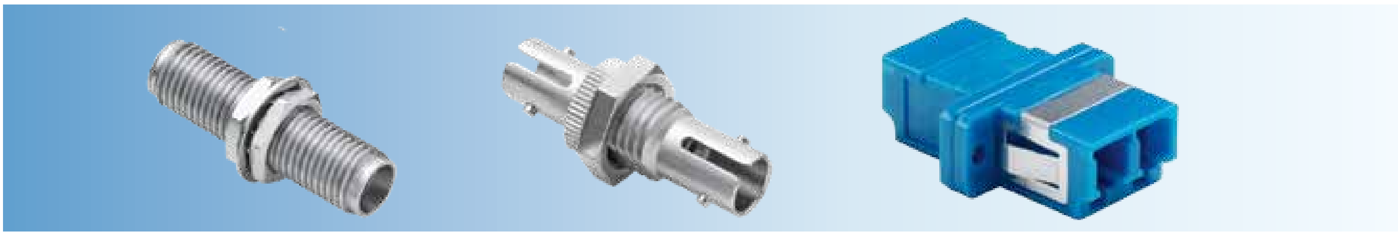


	DIN connectors	ST connector (BFOC)		FC PC connector
Order no.	SDIN-M	SXST-SK0-M	SXST-SK0-C	SFCPC-SK0-M
Hole	128 – 1500 µm	125 µm – 1000 µm	125 µm – 600 µm	125 µm – 1000 µm
Assembly	Crimping/gluing/polishing	Crimping/gluing/polishing	Crimping/gluing/polishing	Crimping/gluing/polishing
Ferrule	Metal	Metal	Ceramic	Metal, ferrule with spring or fixed
Features	Anti-twist protection, 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.	SFCP-SK0-C	SFCA-SK0-C	SSMA-SK0-M	SSMA-SK0-C
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

Couplings

	Coupling for FCPC PCF		Coupling for SC PCF
Order no.	SKUP-2XFCP-0010	SKUP-2XFCP-0020	SKUP-2XSCR-0010
Fiber Ø	SM, MM	SM, MM	MM
Housing	Metal and metal insert	Metal and ceramic insert	Plastic and ceramic insert



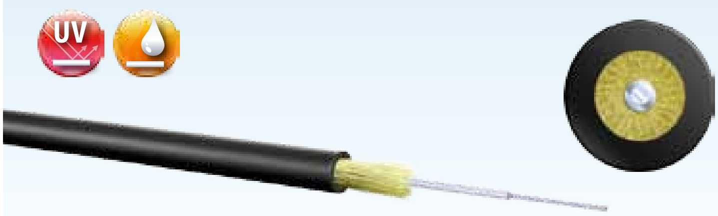
	Coupling for FSMA PCF	Coupling for ST PCF	Coupling for LC PCF
Order no.	SKUP-2XSMA-0010	SKUP-2XXST-0010	SKUP-2XXLC-0010
Fiber Ø	MM	MM	SM, MM
Housing	Metal without separate insert	Metal with metal insert	Metal with ceramic insert

	DIN coupling
Order no.	SKUP-2xDIN-0010
Housing	Metal and metal insert
Feature	Hexagonal fitting

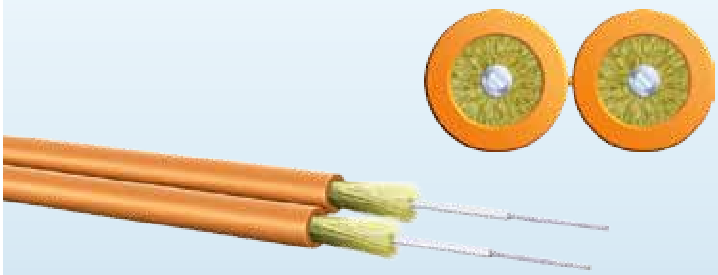
Examples of cable constructions

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

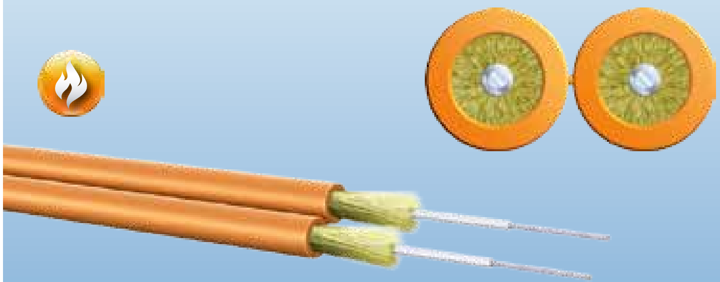
I-V (ZN) Y	
Order no.	Depends on fiber, on request
Application	For indoor installation
Length	500 m and above



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



I-V (ZN) Y 2x1	
Order no.	Depends on fiber, on request
Application	For indoor installation
Length	500 m and above



I-V (ZN) H 2x1	
Order no.	Depends on fiber, on request
Application	For indoor installation
Length	500 m and above

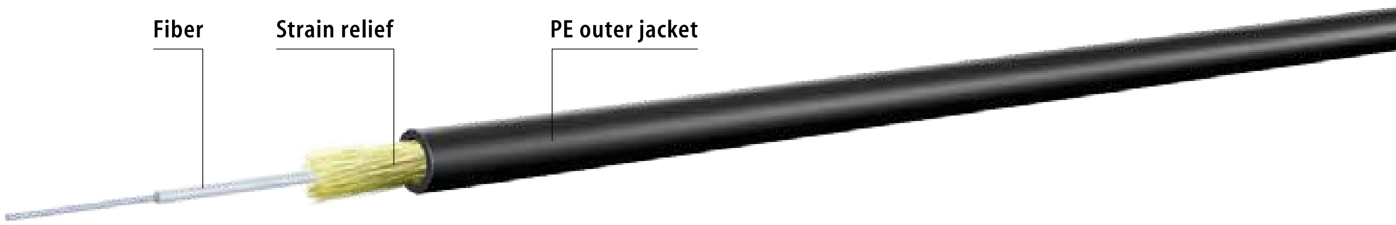
Info

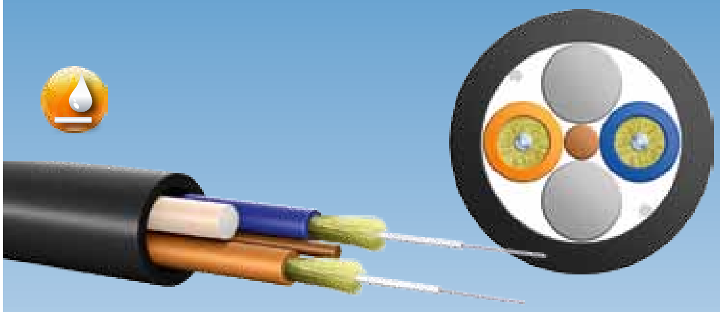
An increase of up to 2 dB/km in the fiber attenuation value is to be expected when fibers are combined into cables.

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

For smaller lengths (<500 m), we offer a range of different protective tubes from the simple PVC tube to the costly metal corrugated tube (see chapter on tubes). The fibers are pulled into the tube. For longer lengths (>500 m) it is possible to manufacture a cable.

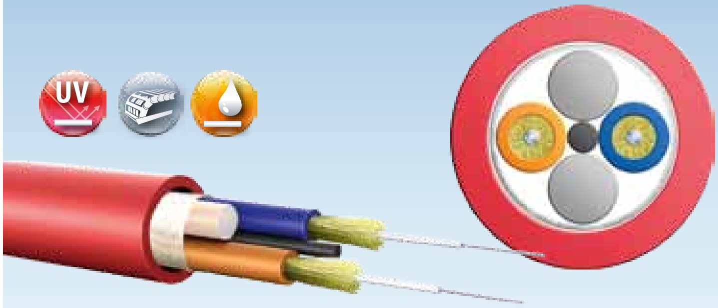
Large-core fiber cable specifications		I-V (ZN) H 1	I-V (ZN) Y	A-V (ZN) 11Y	I-V (ZN) Y 2x1	I-V (ZN) H 2x1
Order no.		Depends on fiber, on request				
Composition	Outer jacket material	FRNC	PVC	PUR	PVC	FRNC
	Buffer tube material	–	–	–	–	–
	No. of fibers	1	1	1	2	1
	Outer Ø [mm]	2.2	2.2	3.0	2.2 x 4.5	2.2 × 4.5
Mechanical properties	min. bending radius [mm]	Depends on fiber, on request				
	max. pull force [N]	Depends on fiber, on request				
Thermal properties	Operating temperature [°C]	Depends on fiber, on request				





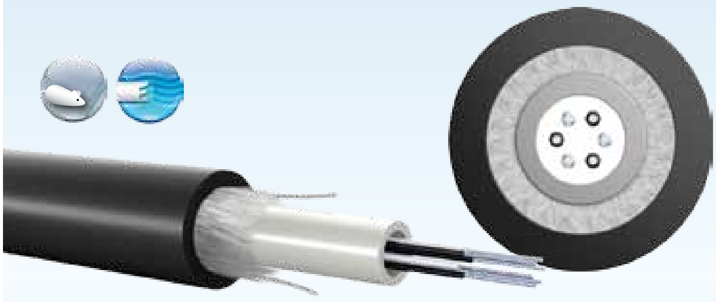
I-V (ZN) H 2Y

Order no.	Depends on fiber, on request
Application	For outdoor installation
Length	500 m and above



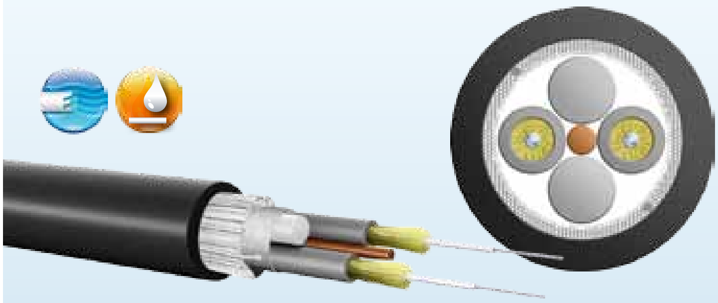
AT-V(ZN)Y 11Y

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



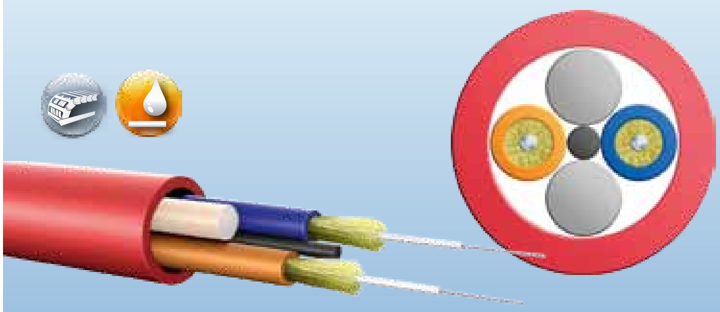
ADQ(ZN) BH

Order no.	Depends on fiber, on request
Application	For outdoor installation
Length	500 m and above



AT-VQ (ZN) HB 2Y

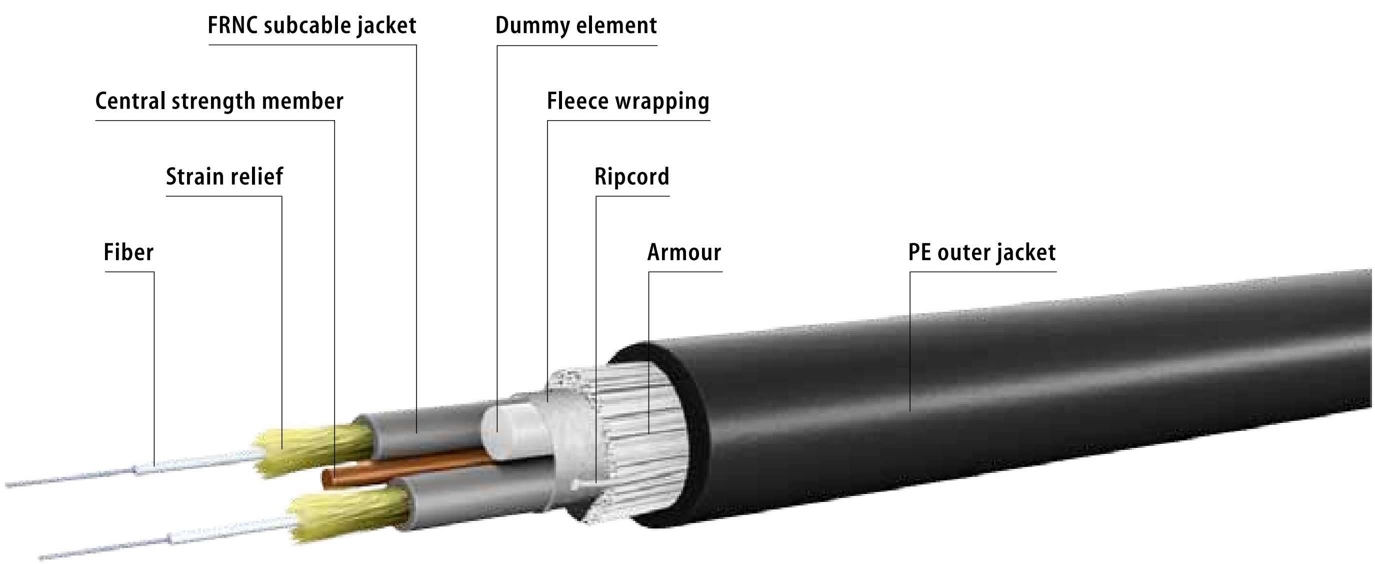
Order no.	Depends on fiber, on request
Application	For outdoor installation
Length	500 m and above



I-V (ZN) H 11Y

Order no.	Depends on fiber, on request
Application	For indoor installation
Length	500 m and above

Large-core fiber cable specifications		I-V (ZN) H 2Y	AT-V(ZN)Y 11Y	ADQ(ZN) BH	AT-VQ (ZN) HB 2Y	I-V (ZN) H 11Y
Order no.		Depends 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]	Depends on fiber, on request				
	max. pull force [N]	Depends on fiber, on request				
Thermal properties	Operating temperature [°C]	Depends on fiber, on request				



Assembling Large-core special 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
- Semi-conductor production
- Measuring instruments
- Defense technology
- Mode-mixing designs for all fibers and fiber bundle types
- Non-linear optics
- Optical pyrometers
- Quality control

You will find pre-assembled products in the chapter "Optical Components" (page 203).

Assembly

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

Service features

- All fiber and cable types (including hybrid cables) as well as protective tube types
- All connector types
- Every attenuation grade for different customer requirements
- Every length, even for small order sizes
- Delivery possible within 24 hours
- 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 large-core fibers** for all fiber diameters; for various 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 on tubes)

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

Quality assurance

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

Type designation for pre-assembled large core fibers

CM 003 x A01 – 08 / 4.4 gy 03 x 02 / 03 x 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	**03**
SMA – free-standing	**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 …**
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

Singlemode

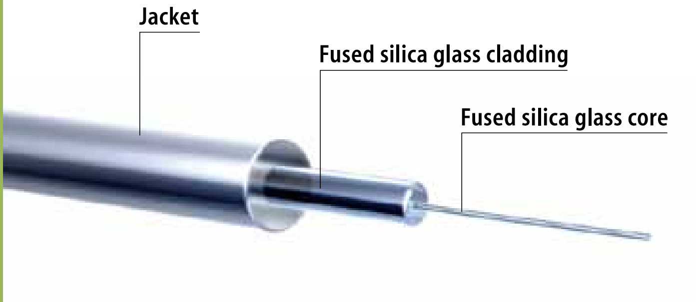
Special fibers

In addition to the standard singlemode fibers, there is an entire range of fibers whose cut-off wavelength is adapted to specific wavelength ranges.

Polarisation-maintaining (PM) fibers are another group of singlemode fibers. With PM fibers, the required polarisation behaviour of the fibers is produced through a direction-dependent disparity in the distribution of the refractive index.

If polarised light is launched into this type of fiber, this polarisation alignment is maintained over the entire fiber length.

Fiber specifications



The Select-Cut-off-Fibers are optimised for a specific wavelength in the range from 400 nm to 1600 nm, in which these fibers display a singlemode characteristic.

It is usually the mode field diameter that is mentioned with singlemode fibers and not the core diameter. This is because with singlemode fibers, a certain percentage of the light diffuses through the cladding (this is dependent on the wavelength). With singlemode fibers, the cut-off wavelength is specified. It describes the wavelength range in which the fiber functions as singlemode.

Standard applications include sensor technology and data transmission in LANs/MANs/WANs. With well over 1GHz x km, higher bandwidths are achieved and the values of the multimode fiber thus exceeded.

A large numerical aperture produces lower sensitivity to attenuation during bending. A large core diameter offers advantages during launching of light. The 125 µm cladding diameter is compatible with telecommunications connectors.

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
Transmission 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.	84820001G	84820002E	84820003G	84820004E	84820005G	84820006G	84820007E	84820008E

Claddings and assemblies available on request.

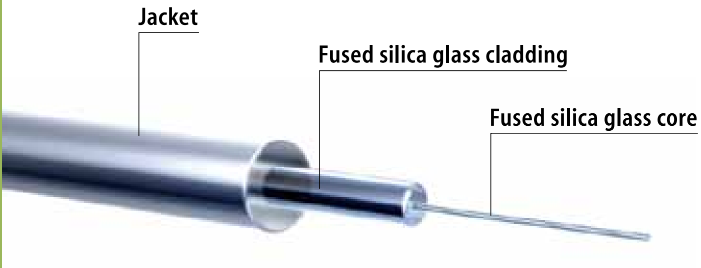
Select-Cut-off-Singlemode-Fibers: VIS-IR								
Mode field Ø [µm]	2.6 at 1100 nm	5.8 at 980 nm	4.2 at 980 nm	4.2 at 980 nm	5.9 at 980 nm	3.3 at 1100 nm	2.6 at 1100 nm	9 at 1310 nm
Jacket Ø [µm]	125	125	125	80	125	125	125	80
Transmission properties								
Wavelength range [nm]	960–1600	970–1210	980–1600	980–1600	980–1600	1100–1600	1100–1600	1250–1610
Cut-off wavelength [nm]	900	920	920	920	920	1000	1000	1200
Attenuation [dB/km]	20 at 1550 nm	3 at 980 nm	3.5 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	0.2	0.14	0.28	0.35	0.11–0.13
Coating – acrylate								
Coating Ø [µm]	245	245	245	165	245	245	245	165
Order no.	84820009G	84820010E	84820011G	84820012E	84820013G	84820014G	84820015G	84820016E

Claddings and assemblies available 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
Transmission 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 1550 nm	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.	84820017E	84820018G	84820019G	84820020G	84820021G	84820022E	84820023F	84820024G

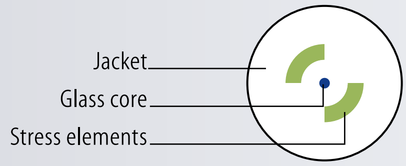
Claddings and assemblies available on request.

Polarisation-maintaining fiber specifications

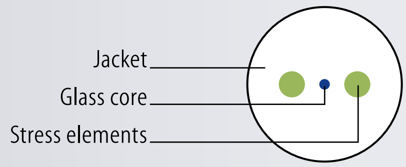


Polarisation-maintaining fibers are special singlemode fibers that maintain the polarisation of the light in the fiber. Stress elements embedded in the cladding exert mechanical stresses on the fiber core, which leads to birefringence in the fiber core. The stress elements can have different designs. These fibers are used in networks with optical fibers, for pump lasers and for microscopic applications.

Bow Tie



Panda



	Polarisation-maintaining fibers: VIS-IR						
Mode field Ø [µm]	3.3 at 515 nm	3.2 at 488 nm	4.0 at 515 nm	3.6 at 488 nm	4.0 at 515 nm	3.2 at 630 nm	4.0 at 630 nm
Jacket Ø [µm]	125	125	125	125	125	125	125
Transmission properties							
Wavelength range [nm]	460–630	470–630	480–540	480–540	480–540	600–675	620–675
Cut-off wavelength [nm]	410	420	435	410	570	550	560
Attenuation [dB/km]	30 at 460 nm	100 at 488 nm	30 at 480 nm	100 at 488 nm	30 at 480 nm	15 at 630 nm	12 at 630 nm
Fiber type	Panda	Bow tie	Panda	Bow tie	Panda	Bow tie	Bow tie
Numerical aperture	0.12	0.13	0.1	0.11	0.1	0.16	0.14
	Coating – acrylate						
Coating Ø [µm]	245	245	245	245	400	245	245
Order no.	84821001G	84821002K	84821003H	84821004E	84821005H	84821006E	84821007K

Claddings and assemblies available on request.

Polarisation-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
Transmission 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

Claddings and assemblies available on request.

Polarisation-maintaining fibers: VIS-IR								
Mode field Ø [µm]	4.5 at 820 nm	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	7.0 at 1300 nm	8.4 at 1300 nm
Jacket Ø [µm]	80	125	125	125	125	125	80	80
Transmission properties								
Wavelength range [nm]	800–880	950–1080	950–1080	970–1170	1020–1130	1270–1390	1290–1450	1290–1450
Cut-off wavelength [nm]	725	875	875	920	930	1150	1190	1190
Attenuation [dB/km]	4 at 820 nm	2.5 at 980 nm	2.5 at 980 nm	3 at 980 nm	3 at 1064 nm	2 at 1300 nm	2 at 1300 nm	2 at 1300 nm
Fiber type	Bow tie	Panda	Panda	Bow tie	Bow tie	Bow tie	Bow tie	Bow tie
Numerical aperture	0.17	0.12	0.12	0.14	0.16	0.16	0.16	0.13
Coating – acrylate								
Coating Ø [µm]	165	245	400	245	245	245	165	165
Order no.	84821015K	84821016H	84821017H	84821018E	84821019E	84821020E	84821021K	84821022K

Claddings and assemblies available on request.

Polarisation-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	10.5 at 1550 nm	7.8 at 1550 nm
Jacket Ø [µm]	125	125	125	125	125	125	125	80
Transmission properties								
Wavelength range [nm]	1290–1485	1290–1485	1380–1560	1380–1560	1450–1620	1450–1620	1500–1620	1500–1620
Cut-off wavelength [nm]	1195	1195	1290	1290	1370	1370	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	1 at 1550 nm	2 at 1550 nm
Fiber type	Panda	Panda	Panda	Panda	Panda	Panda	Bow tie	Bow tie
Numerical aperture	0.11	0.11	0.11	0.11	0.12	0.12	0.13	0.17
Coating – acrylate								
Coating Ø [µm]	245	400	245	400	245	400	245	165
Order no.	84821023H	84821024H	84821025H	84821026H	84821027H	84821028H	84821029K	84821030K

Claddings 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. 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 1510 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:

Radius of the ferrule

Too small	➔ Ferrule and fiber end face pointed
Too big	➔ Ferrule and fiber end face flat
Possible consequence	➔ Incomplete contact between the end faces and fibers and as a result possibly
	➔ glass-air-glass transitions in individual areas.

Highest point of the ferrule to centre 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 centre of the fiber. This offset is also called the apex and is measured from the fiber axis to the centre. A perfectly ground PC connector exhibits no eccentricity, which means that the highest point of the polish (ferrule) coincides with the centre of the fiber.

Consequence of an apex that is too big:

- ➔ Axial offset between the coupled fibers
- ➔ Glass-air-glass transition – no 100% overlapping of the fibers

Fiber cavity – fiber sitting above or below the ferrule

Fiber sitting above ferrule:

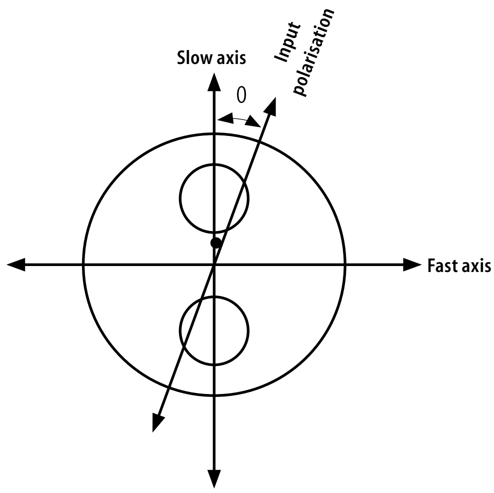
- ➔ Damage to the fiber end faces
- ➔ Stress on the fiber – impairment of the long-term behaviour

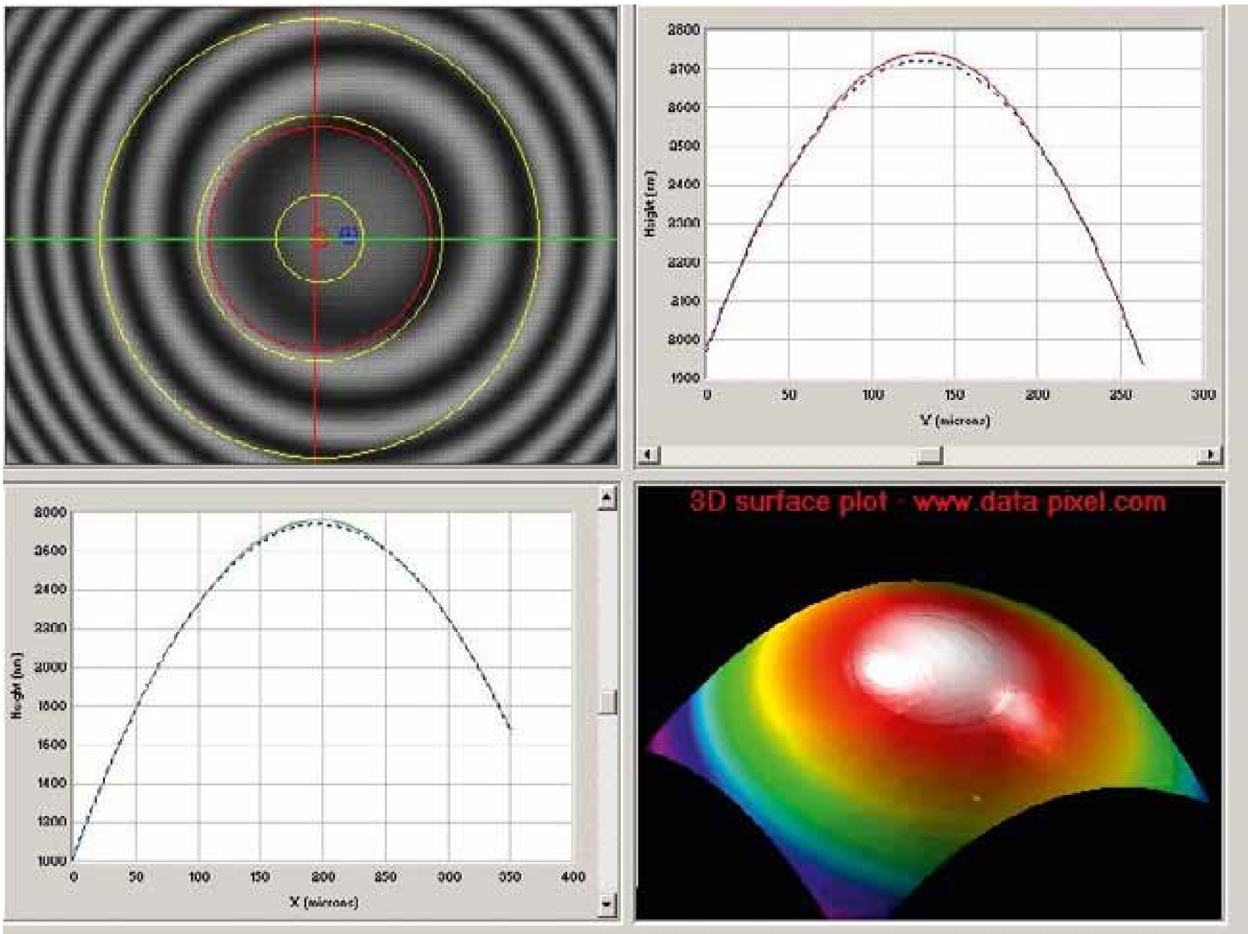
Fiber sitting below ferrule:

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

ER (extinction ratio) measurement

Measuring the quality of the polarised light beam is only important for polarisation-maintaining fibers (PM). This value is specified in the form of the extinction ratio (ER). The most important factor for a high ER value is the alignment of the polarised light relative to the slow axis of the PM fiber. To achieve an ER of >20 dB, for example, the deviation must not exceed 6°.



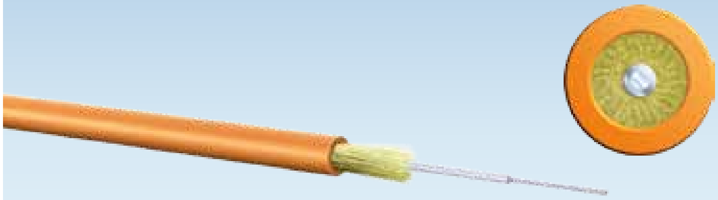


Measurements on singlemode special fibers: fiber cavity – fiber sitting above or below the ferrule

Cables with singlemode special fibers

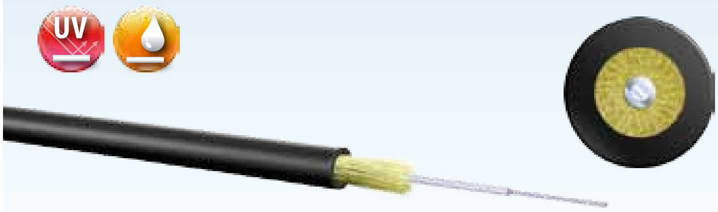
I-V (ZN) H 1

Order no.	Depends on fiber, on request
Application	For fixed indoor installation
Length	500 m and above



I-V (ZN) Y

Order no.	Depends on fiber, on request
Application	For indoor installation
Length	500 m and above

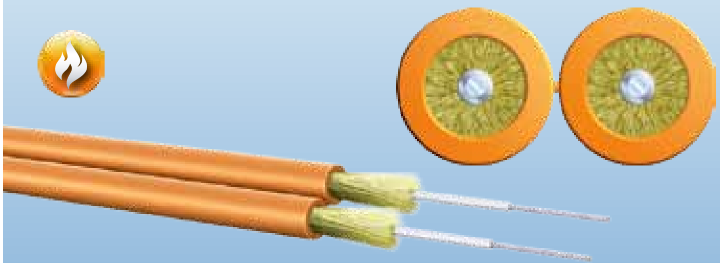


A-V (ZN) 11Y

Order no.	Depends on fiber, on request
Application	For outdoor installation
Length	500 m and above

I-V (ZN) Y 2x1

Order no.	Depends on fiber, on request
Application	For indoor installation
Length	500 m and above



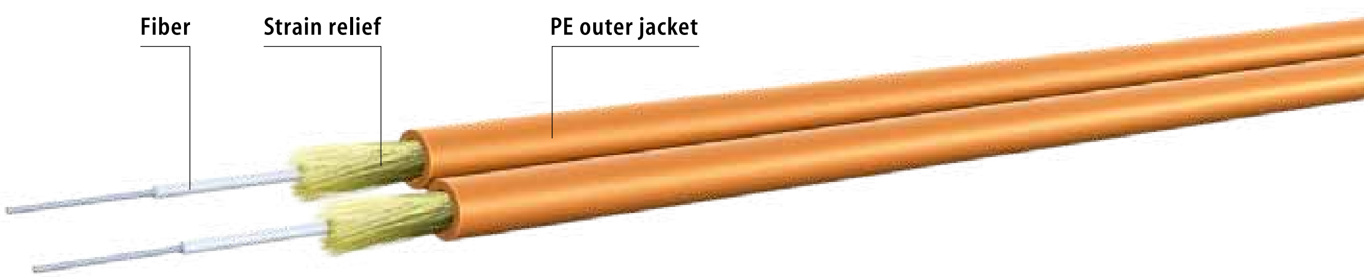
I-V (ZN) H 2x1

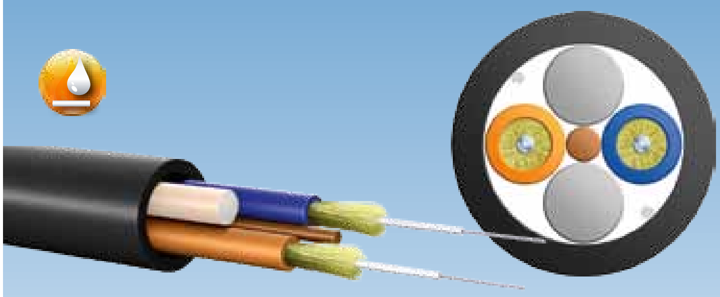
Order no.	Depends on fiber, on request
Application	For indoor installation
Length	500 m and above

Step-index singlemode
VIS-IR

Polarisation-maintaining fibers
VIS-IR

Specifications for singlemode special fibers		I-V (ZN) H 1	I-V (ZN) Y	A-V (ZN) 11Y	I-V (ZN) Y 2x1	I-V (ZN) H 2x1
Order no.		Depends 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 x 4.5	2.2 × 4.5
Mechanical properties	min. bending radius [mm]	Depends on fiber, on request				
	max. pull force [N]	Depends on fiber, on request				
Thermal properties	Operating temperature [°C]	Depends on fiber, on request				



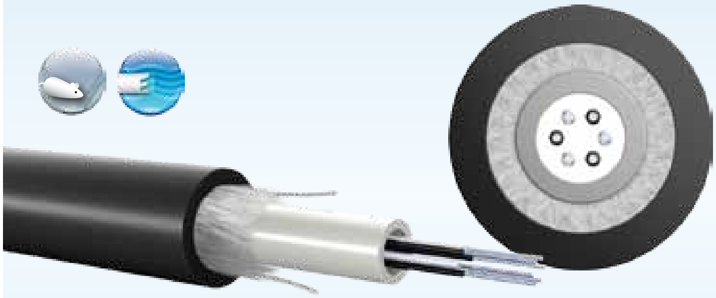


I-V (ZN) H 2Y

Order no.	Depends on fiber, on request
Application	For outdoor installation
Length	500 m and above

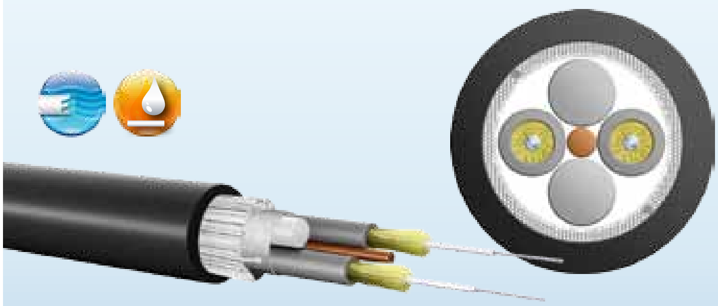
AT-V(ZN)Y 11Y

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



ADQ(ZN) BH

Order no.	Depends on fiber, on request
Application	For outdoor installation
Length	500 m and above



AT-VQ (ZN) HB 2Y

Order no.	Depends on fiber, on request
Application	For outdoor installation
Length	500 m and above

I-V (ZN) H 11Y

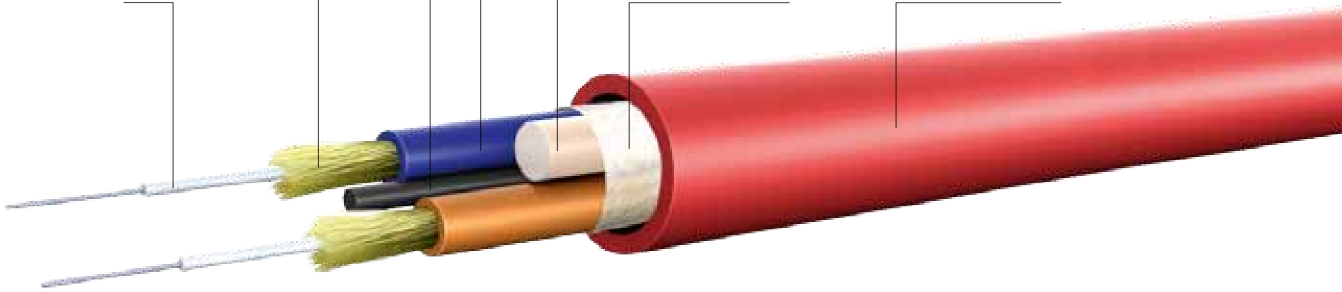
Order no.	Depends on fiber, on request
Application	For indoor installation
Length	500 m and above

Step-index singlemode
VIS-IR

Polarisation-maintaining fibers
VIS-IR

Singlemode

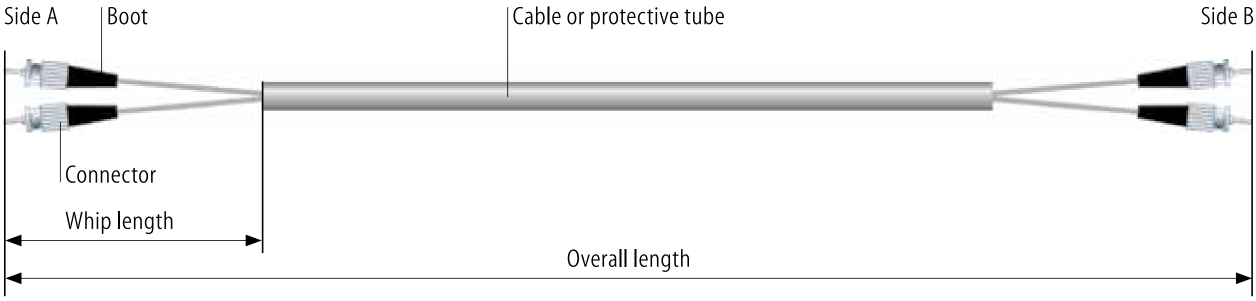
Singlemode special fiber specifications		I-V (ZN) H 2Y	AT-V(ZN)Y 11Y	ADQ(ZN) BH	AT-VQ (ZN) HB 2Y	I-V (ZN) H 11Y
Order no.		Depends on fiber, on request				
Composition	Outer jacket material	PE	PUR	PE	PUR	FRNC/PE
	Buffer tube material	FRNC	PVC	FRNC	PVC	PVC
	No. of fibers	2	2	2	2	2
	Outer Ø [mm]	7.0	7.0	7.0	7.0	7.5
Mechanical properties	min. bending radius [mm]	Depends on fiber, on request				
	max. pull force [N]	Depends on fiber, on request				
Thermal properties	Operating temperature [°C]	Depends on fiber, on request				



Pre-assembled cables with singlemode special fibers

Description of the structure of pre-assembled singlemode special 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



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 as well as engineering and consulting.

Service features

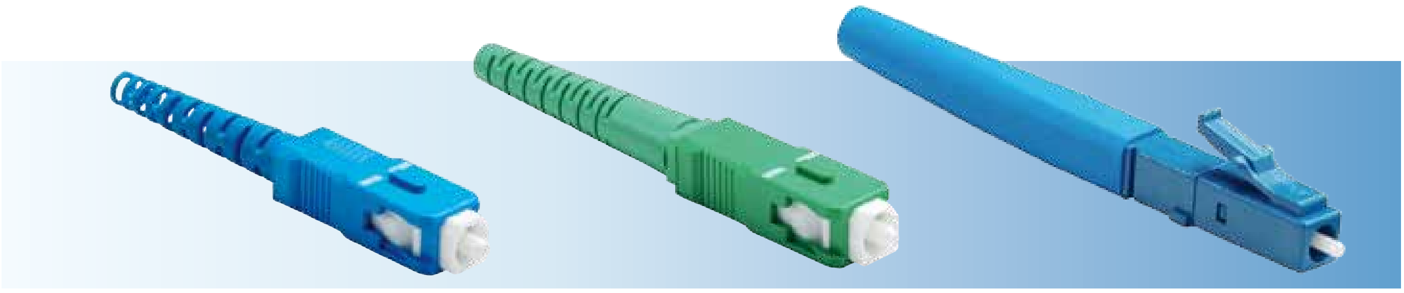
- All fiber and cable types (including hybrid cables)
- All connector types
- Every attenuation grade for different customer requirements
- Every length, even for small order sizes
- Delivery possible within 24 hours
- Customer-specific assembly
- Customer-specific cable printing
- Additional selective printing of the cable jacket during the process of cutting to length

Quality assurance

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

Connectors for singlemode special fibers

	FCPC connector UV-IR	FC-APC connector UV-IR	ST connector (BFOC) UV-IR	SMA connector UV-IR
Order no.	SFCP-SK0-C	SFCA-SK0-C	SXST-SK0-C	SSMA-SK0-C
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 UV-IR	SC-APC connector UV-IR	LC-PC connector UV-IR
Order no.	SXSC-SK0-C	SSCA-SK0-C	SXLC-SK0-C
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

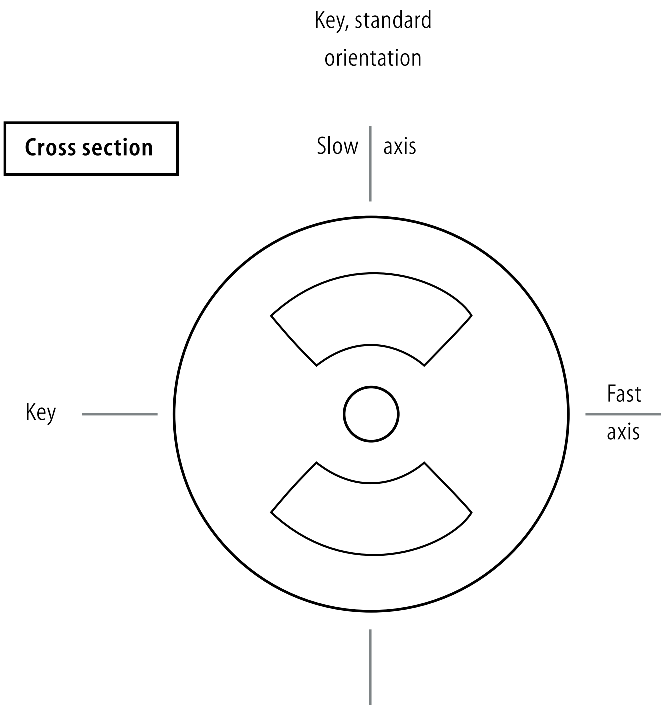
Couplings for singlemode special fibers

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

The fact that LEONI produces, assembles and develops its own fibers and cables enables it to achieve superior properties and maximum reliability. In addition to standard products, we offer a range of special product functionalities as well as customer-specific assembly, engineering and consulting.

The order numbers for pre-assembled cables are dependent on the fiber and are generated in response to customer requests. Additional information is required for the assembly of PM cables or PM pigtails:

- Alignment of the fiber axis relative to the connector key; a differentiation is made here between
  – orientation parallel to slow axis (standard orientation) and
  – orientation relative to the fast axis
- The extinction rate should also be specified (see the chapter "Measurements on special singlemode fibers")
- The required angular tolerance relative to the axis alignment must also be specified if necessary



Fiber Bundles

Fused silica glass and optical glass

LEONI produces customer-specific fiber 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 bundles vary between 4, 5, 10 and 20 m. The bundle diameters are individually produced according to the customer's wishes.

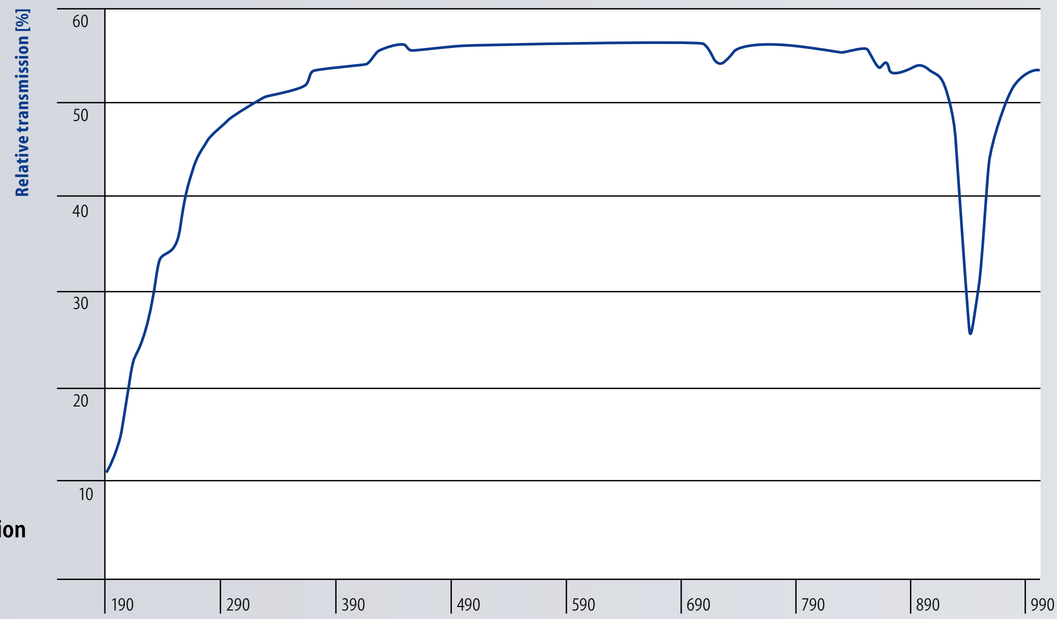
The fiber bundles are available specifically for endoscopic applications in different radiation angles of 67° (LB type), 83° (LA type), 90° (LW2 type) and ≥100° (L120.3 type) for optimum illumination.

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.

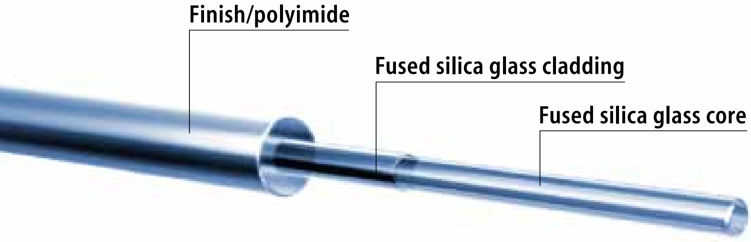
Fiber bundles (silica/silica)

Fiber bundles
UV-VIS



Spectral transmission (length 1 m)

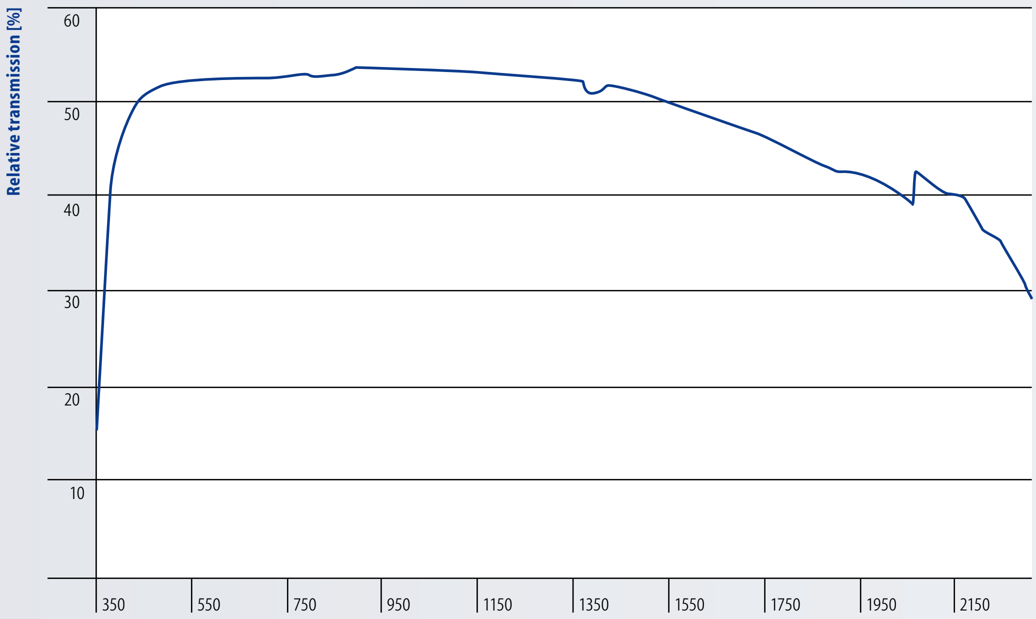
The transmission graph includes material and geometric loss irrespective of the individual and bundle fiber diameters.



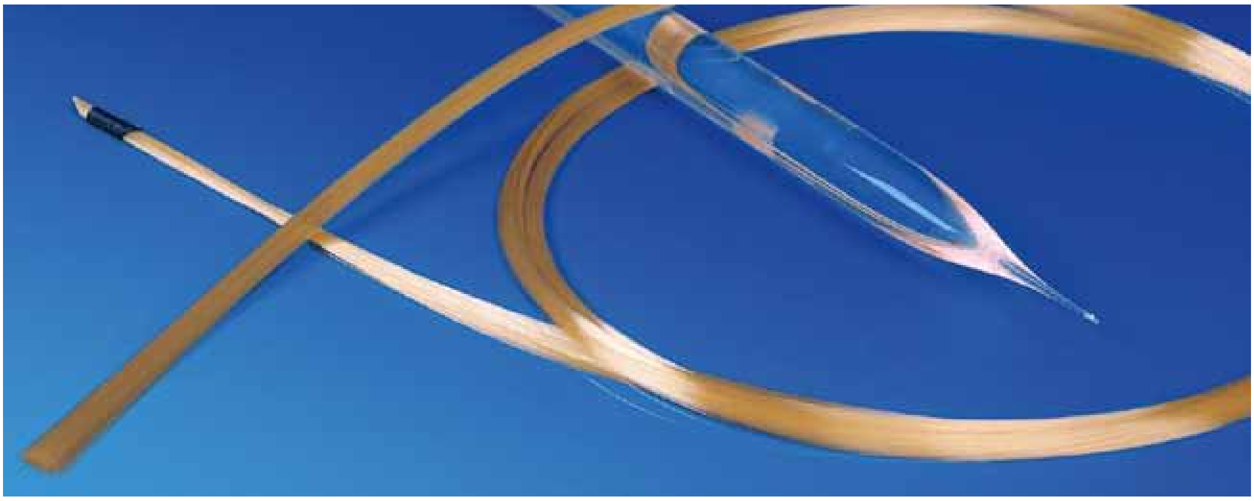
	Properties of individual fibers UV-VIS			
Fiber diameter (incl. cladding and coating) [µm]	**30**	**50**	**80**	**105**
CCDR	1.1			
Acceptance angle	25°			
Numerical aperture	0.22 ± 0.02 (0.1 or 0.26 on request)			
Temperature resistance with finish [°C]	200°C			
Temperature resistance with polyimide [°C]	300°C			
	Properties of fiber bundles			
Bundle Ø [mm]	0.3 – 6 (other dimensions on request)			
Bending radius [mm]	40 – 60 depending on bundle Ø			

Fiber bundles
VIS-IR

Spectral transmission (length 1 m)



The transmission graph includes material and geometric loss irrespective of the individual and bundle fiber diameters.

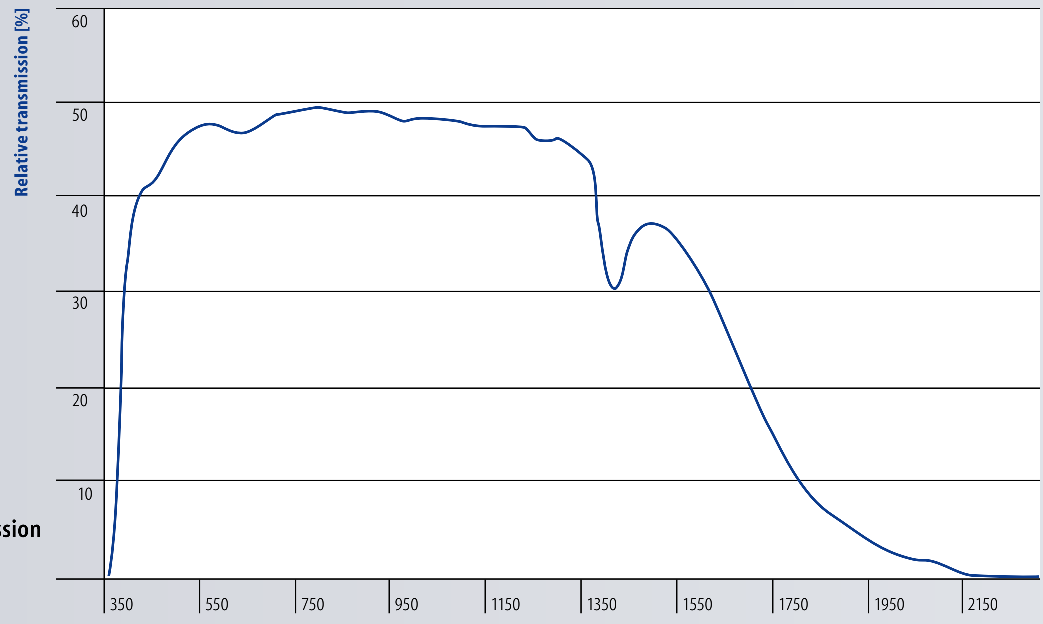


	Properties of individual fibers VIS-IR				
Fiber diameter (incl. cladding and coating) [µm]	**30**	**50**	**70**	**80**	**105**
CCDR	1.2				
Acceptance angle	25°				
Numerical aperture	0.22 ± 0.02 (0.1 or 0.36 on request)				
Temperature resistance with finish [°C]	200°C				
Temperature resistance with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

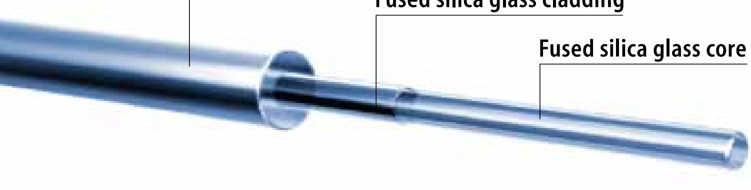
Fiber bundles (optical glass/optical glass)
LB type

Fiber bundles
VIS

Spectral transmission (length 1 m)



The transmission graph includes material and geometric losses irrespective of the individual and bundle fiber diameters.

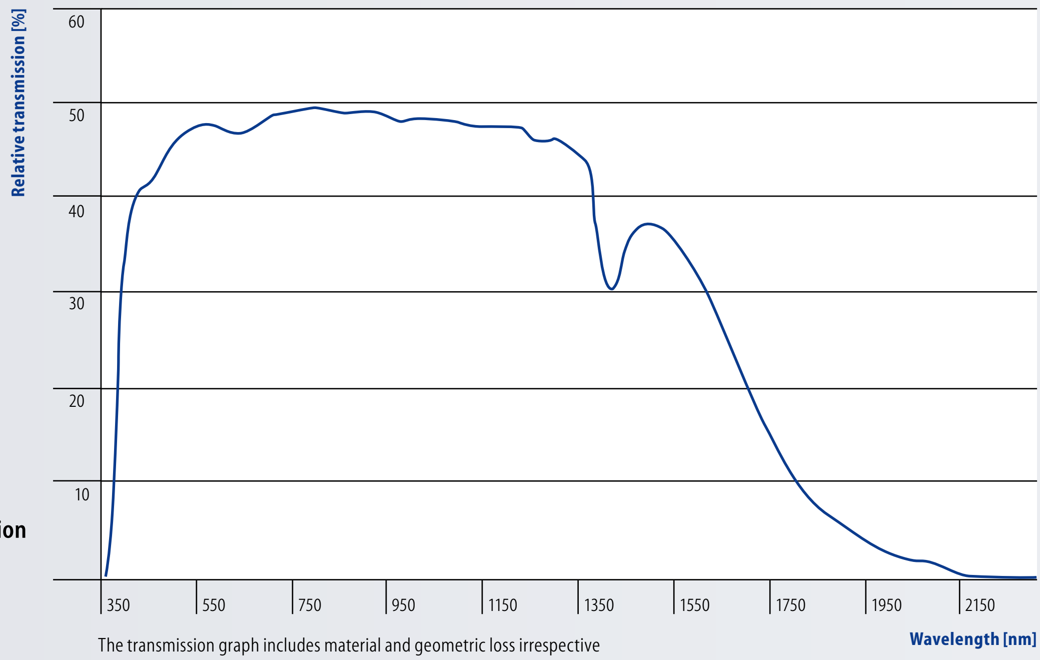


	Properties of individual fibers LB type			
Fiber diameter (incl. cladding and coating) [µm]	**30**	**50**	**60**	**70**
CCDR	1.1			
Acceptance angle	67°			
Numerical aperture	0.56			
Temperature resistance with finish [°C]	200°C			
Temperature resistance with polyimide [°C]	300°C			
	Properties of fiber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

Fiber bundles (optical glass/optical glass)
LA type

Fiber bundles
VIS

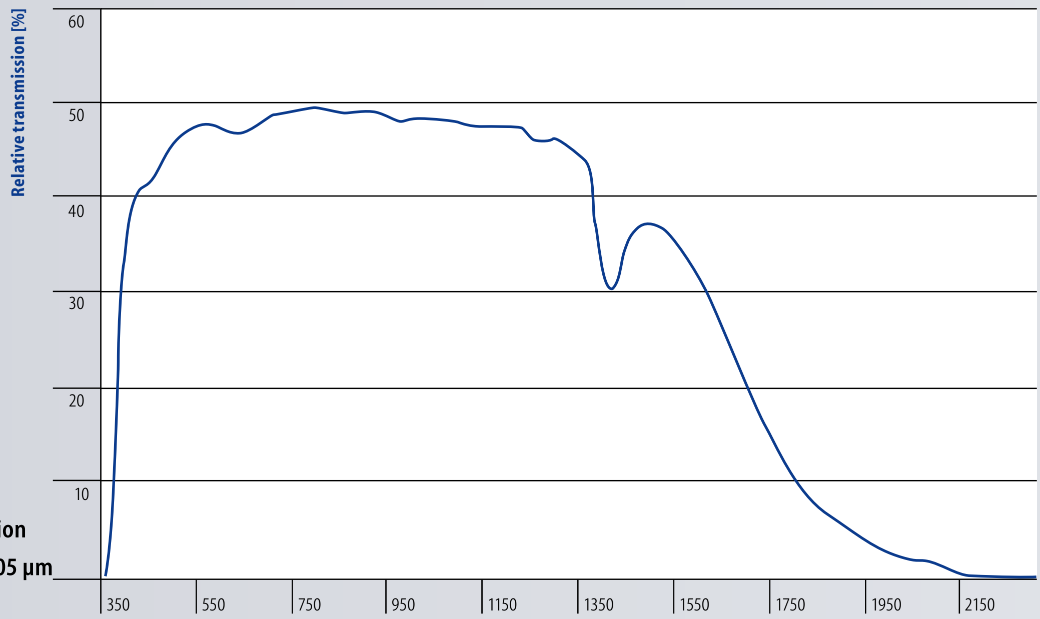
Spectral transmission (length 1 m)



The transmission graph includes material and geometric loss irrespective of the individual and bundle fiber diameters.

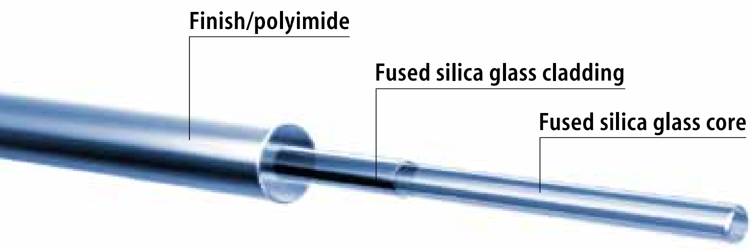
	Properties of individual fibers LA1 type			
Fiber diameter (incl. cladding and coating) [µm]	**30**	**50**	**60**	**70**
CCDR	1.1			
Acceptance angle	83°			
Numerical aperture	0.66			
Temperature resistance with finish [°C]	200°C			
Temperature resistance with polyimide [°C]	300°C			
	Properties of fiber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

Fiber bundles (optical glass/optical glass)
LW2 type



Spectral transmission (length 2 m) LUV 105 µm

The transmission graph includes material and geometric loss irrespective of the individual and bundle fiber diameters.

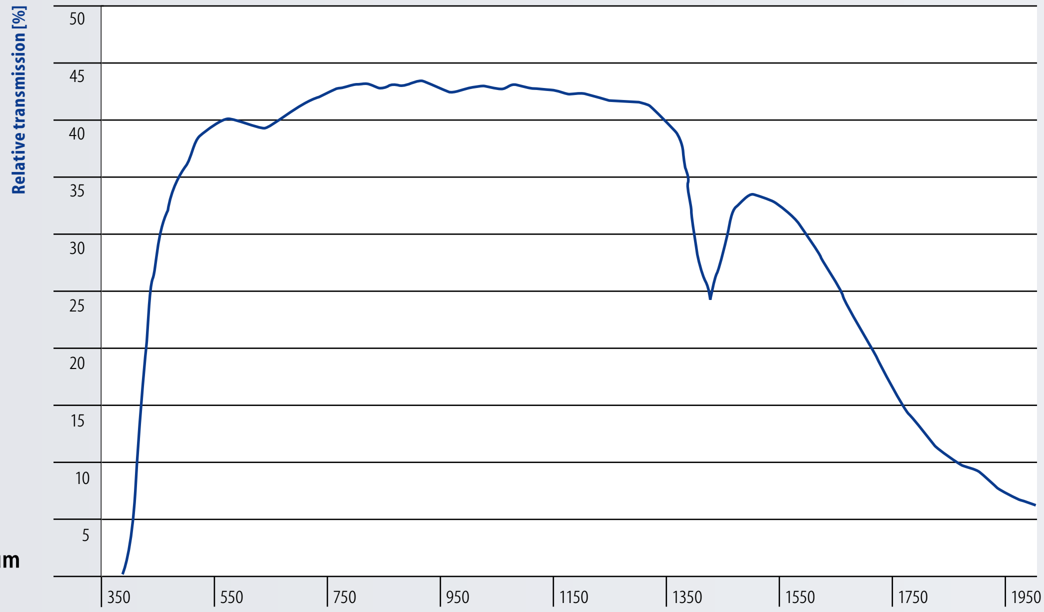


	Properties of individual fibers LW2 type			
Fiber diameter (incl. cladding and coating) [µm]	**30**	**50**	**60**	**70**
CCDR	1.1			
Acceptance angle	93°			
Numerical aperture	0.72			
Temperature resistance with finish [°C]	200°C			
Temperature resistance with polyimide [°C]	300°C			
	Properties of fiber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

Fiber bundles (optical glass/optical glass)
L120.3 type

Fiber bundles
VIS

Spectral transmission (length 1 m) 120.3 30 µm



The transmission graph includes material and geometric losses irrespective of the individual and bundle fiber diameters.

	Properties of individual fibers L120.3-VIS		
Fiber diameter (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 bundles		
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.

Advantages

- The fibers and cables used 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 the chapter on tubes.
- 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, SZ, ST connectors or tailor-made ferrules.

Info

Assembly examples can be found in the chapter “Optical Special Components”.

Laser Probes

for pulsed and high-performance CW lasers for medical applications

Over 22 years of experience, innovation and high quality as well as the cost effectiveness of our products enable us to offer a wide selection of medical probes.

Applications
- Arthroscopy
- General surgery
- Dentistry
- Dermatology
- Gastroenterology
- Gynaecology
- Endovascular applications
- Laser lipolysis
- Lithotripsy
- Ophthalmology
- Urology

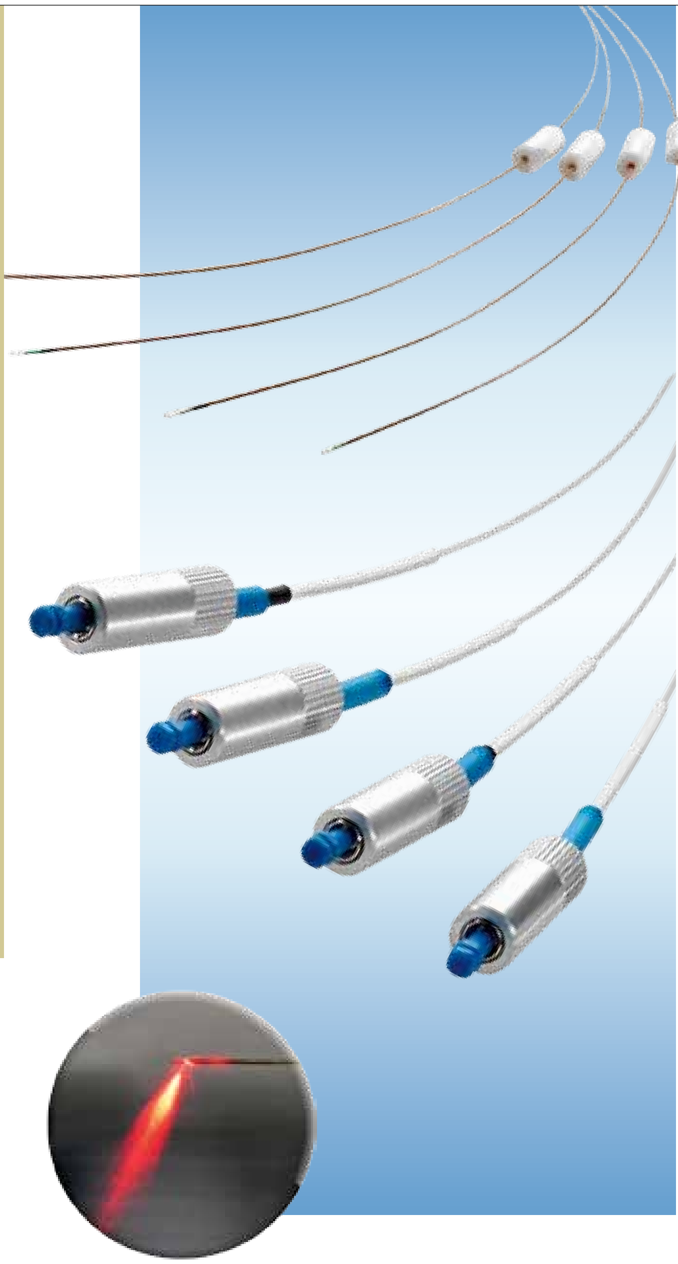
Note

Versions with customer-specific adaptations such as different colours, diameters and lengths, for example, are possible for all products and designs.

Services

- Development of a customer-oriented product design
- Fibers for different wavelengths with different numerical apertures (NA) as well as particularly low OH content are available
- Manufacturing of medical probes for the laser energy transmission of argon, Nd:YAG, excimer, holmium, KTP and diode lasers
- Series production of surgical, ophthalmological, urological, dental and endovascular probes with biocompatible materials
- Manufacturing of medical fibers for laser energy transmission primarily in the wavelength range from 266 nm to 2200 nm
- **ISO 9001, ISO 13485 and FDA certified**
- **CE marking for medical devices**

Laser probes



SideFiring fibers

Fiber optic cable 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 well-regarded in clinics around the world.

Certification	All products are EN ISO 13485 and FDA certified and bear the CE marking.
Properties	■ Suitable for UV 532 nm and IR up to 2200 nm ■ Capillary Ø 1750 or 2050 µm ■ Handling aid and capillaries with beam direction marking ■ High-power F-SMA905 connector (free-standing) ■ Max. output up to 250 W CW ■ Adapters available ■ Optimisation for customer-specific laser devices possible
Recommended for the indications	■ BPH (benign prostatic hyperplasia) ■ Bladder tumours ■ Urethral stenoses ■ Vaporisation of urethral warts ■ Meatotomy etc.

Wavelength	Core Ø [µm]	Capillary Ø [µm]	Length [m]	Colour	Type designation
UV	600	1750	3	Transparent	**FT UV600/720HCN-3/SL-SF-1750**
UV	600	2050	3	Transparent	**FT UV600/720HCN-3/SL-SF-2050**
IR	600	1750	3	Transparent	**FT IR600/720HCN-3/SL-SF-1750**
IR	600	2050	3	Transparent	**FT IR600/720HCN-3/SL-SF-2050**

Laser probes for diode, Nd:YAG, KTP and holmium lasers (BareFiber)

With a wide range of application options.

Certification	All products are EN ISO 13485 and FDA certified and bear the CE marking.
Properties	■ Available as a sterile disposable item or an autoclavable reusable item ■ F-SMA extension sleeve available in various colours, laser inscription possible ■ Can be used for UV 532 nm and IR up to 2200 nm ■ Standard (SM) or high-power (SL) F-SMA905 connectors ■ Customer-optimised designs on request ■ Can be used with holmium laser devices ■ Various accessories available (strippers, cleavers, etc.)
Recommended for the indications	■ Urology ■ Gastroenterology ■ Gynaecology ■ General surgery

Type	Core Ø [µm]	Fiber Ø [µm]	Length [m]	Colour	NA	Type designation
200	272	600	3	Blue	0.22	**FT IR272/300ST-3/SL-F**
365	365	700	3	Blue	0.22	**FT IR 365/400ST-3/SL-F**
550	550	900	3	Blue	0.22	**FT IR 550/605ST-3/SL-F**
1000	1000	1500	3	Blue	0.22	**FT IR1000/1100ST-3/SL-F**
200 1.1	200	500	3	Blue	0.22	**FT IR200/220ST-3/SL-F**
200 1.2	200	520	3	Blue	0.22	**FT IR 200/240 ST-3/SL-F**
300 1.1	300	600	3	Blue	0.22	**FT IR 300/330 ST-3/SL-F**
400 1.1	400	750	3	Blue	0.22	**FT IR 400/440 ST-3/SL-F**
500 1.1	500	850	3	Blue	0.22	**FT IR 500/550 ST-3/SL-F**
600 1.1	600	1000	3	Blue	0.22	**FT IR 600/660 ST-3/SL-F**

Laser probes with HPCS fibers (BareFiber)

Fiber optic cable with increased NA (NA = 0.37) and excellent beam quality. A disposable product – high quality and economical.

Certification	All products are EN ISO 13485 and FDA certified and bear the CE marking.
Properties	■ EtO-sterilised, double packed (pouch in pouch) ■ Male/female LuerLock for catheter connection available (with L in the product code) ■ F-SMA extension sleeve available in various colours, laser inscription possible ■ IR fibers, low OH ■ F-SMA905 connectors, customer-specific connectors can be assembled ■ Cost-efficient ■ Various accessories available (strippers, cleavers, etc.)
Recommended for the indications	■ Varices ■ Spider veins (varicose veins) ■ Laser lipolysis ■ Coagulation, ablation ■ Contact cutting and interstitial coagulation

Type	Core Ø [µm]	Fiber Ø [µm]	Length [m]	Colour	NA	Type designation
200	200	500	3	Transparent	0.37	**FT IR200T-3/SM-F**
300	300	650	3	Transparent	0.37	**FT IR300T-3/SM-F**
400	400	750	3	Transparent	0.37	**FT IR400T-3/SM-F**
600	600	980 / 750	3	Transparent	0.37	**FT IR600T-3/SM-F**
800	800	1100	3	Transparent	0.37	**FT IR800T-3/SM-F**
200L	200	500	3	Transparent	0.37	**FT IR200T-3/SM-F-L**
300L	300	650	3	Transparent	0.37	**FT IR300T-3/SM-F-L**
400L	400	750	3	Transparent	0.37	**FT IR400T-3/SM-F-L**
600L	600	980 / 750	3	Transparent	0.37	**FT IR600T-3/SM-F-L**
800L	800	1100	3	Transparent	0.37	**FT IR800T-3/SM-F-L**

Ophthalmological laser probes

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

Certification	All products are EN ISO 13485 and FDA certified and bear the CE marking.
Properties	■ Excellent mechanical and optical quality ■ Fibers centric in the cannula, minimal adhesive gap ■ EtO-sterilised, double packed (pouch in pouch) ■ IR fibers, low OH ■ Many connector types available (F-SMA, FC/PC, ceramic ferrules, etc.) ■ F-SMA extension sleeve available in various colours ■ Laser inscription possible (handpiece and/or extension sleeve) ■ Endoprobes available in 20, 23, 25 gauge ■ Cycloprobe with ball made from fiber material, Ø 900 µm ■ Retinopexy probe with laterally decoupling laser beam ■ Many bending radii and bending shapes available

Type	Core Ø [µm]	Length [m]	Colour	NA	Type designation
Endo 20 S	210	2.5	White/blue	0.22	**FT IR210/220A-2.5/SM-ES20**
Endo 20 C	210	2.5	White/blue	0.22	**FT IR210/220A-2.5/SM-EC20**
Endo 23 S	210	2.5	White/blue	0.22	**FT IR210/220A-2.5/SM-ES23**
Endo 23 C	210	2.5	White/blue	0.22	**FT IR210/220A-2.5/SM-EC23**
Endo 25 S	210	2.5	White/blue	0.22	**FT IR210/220A-2.5/SM-ES25**
Endo 25 C	210	2.5	White/blue	0.22	**FT IR210/220A-2.5/SM-EC25**
Cyclo 900	600	2.5	White/blue	0.22	**FT IR600/900AN-2.5/SM-CS**
Retinopexi	600	2.5	White/blue	0.22	**FT IR600/630A-2.5/SM-ER**
Illuminated	210	2.5	White/blue	0.22	**FT IR210/220A-2.5/SM-EIS20**

Laser probes with polyimide fibers for dentistry

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

Certification

All products are EN ISO 13485 and FDA certified and bear the CE marking.

Properties

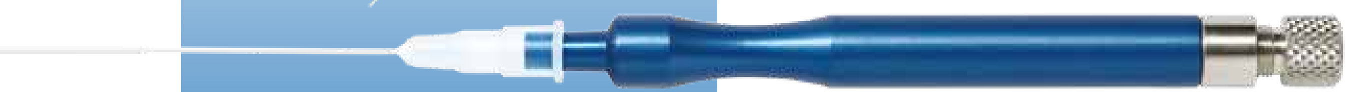
- F-SMA905 connectors, customer-specific connectors can be assembled
- IR fibers, low OH
- Available with germanium-doped silica/silica fibers (NA = 0.37/0.40)
- Sterilisable, autoclavable
- Polyimide coating
- C-Flex® or silicone tube with 2.00 mm outer diameter
- Distal 10 cm of fibers free-standing
- Laser-inscribed handpieces available

Accessories

Dental handpiece HPD1

- Autoclavable
- Connection for Luer cannulae
- Single-part fiber clamping system

Dental handpiece (see page 189)



Type	Core Ø [µm]	Fiber Ø / tube Ø [µm / mm]	Length [m]	Colour	NA	Type designation
200	200	270 / 2	3	Opaque	0.22	**FT IR200/240PI-3/SM-F-C2**
320	320	415 / 2	3	Opaque	0.22	**FT IR320/385PI-3/SM-F-C2**
400	400	470 / 2	3	Opaque	0.22	**FT IR400/440PI-3/SM-F-C2**
600	600	690 / 2	3	Opaque	0.22	**FT IR600/660PI-3/SM-F-C2**
Dental handpiece				Blue		**HPD1**

Gas or liquid-cooled optical fibers

Especially interesting for the gastroenterological discipline.

Certification	All products are EN ISO 13485 and FDA certified and bear the CE marking.
Properties	■ F-SMA905 connectors, customer-specific connectors can be assembled ■ IR fibers, low OH, NA = 0.37 ■ EtO-sterilised, double packed (pouch in pouch) ■ Luer adapters for rinsing medium ■ F-SMA extension sleeve available in various colours ■ Laser inscription possible ■ Also available: silica/silica fibers, NA = 0.22

Type	Core Ø [µm]	Outer Ø [µm]	Length [m]	Colour	NA	Type designation
400/1.8	400	1.8 mm	3 m	Transparent	0.37	**FT IR400N-3/SM-GLC-1800**
600/2.1	600	2.1 mm	3 m	Transparent	0.37	**FT IR600N-3/SM-GLC-2100**

Handpieces for laser probes

Handpieces for laser probes

Surgical handpieces with cannulae made from stainless steel.

Properties

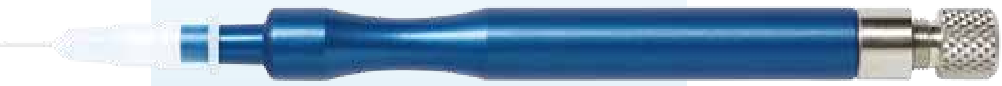
- Autoclavable
- Single-part fiber clamping system
- Many needle shapes/lengths/diameters available
- Handpieces for ENT
- Handpieces with variable spot diameter (1x to 3x fiber core diameter)
- Dermatological handpieces with spacers (30 and 50 mm focal distance)
- Handpieces with connected assembled fiber in the protective tube
- Bleaching handpieces

Surgical handpieces	Length [mm]	Type designation	
		for core Ø 400 µm	for core Ø 600 µm
Short curved (45°)	20	**HPS1-20-400**	**HPS1-20-600**
	40	**HPS1-40-400**	**HPS1-40-600**
	60	**HPS1-60-400**	**HPS1-60-600**
Offset (ENT)	60	**HPS2-60-400**	**HPS2-60-600**
	80	**HPS2-80-400**	**HPS2-80-600**
	100	**HPS2-100-400**	**HPS2-100-600**
	120	**HPS2-120-400**	**HPS2-120-600**
Curved	50	**HPS3-50-400**	**HPS3-50-600**
	75	**HPS3-75-400**	**HPS3-75-600**
	100	**HPS3-100-400**	**HPS3-100-600**
	125	**HPS3-125-400**	**HPS3-125-600**
Straight	20	**HPS4-20-400**	**HPS4-20-600**
	40	**HPS4-40-400**	**HPS4-40-600**
	60	**HPS4-60-400**	**HPS4-60-600**
	80	**HPS4-80-400**	**HPS4-80-600**
	100	**HPS4-100-400**	**HPS4-100-600**
	120	**HPS4-120-400**	**HPS4-120-600**
	140	**HPS4-140-400**	**HPS4-140-600**
	160	**HPS4-160-400**	**HPS4-160-600**
	180	**HPS4-180-400**	**HPS4-180-600**
	200	**HPS4-200-400**	**HPS4-200-600**

Focusing handpiece, 30 mm and 50 mm

Focusing handpiece, manually adjustable

Bleaching handpiece



Dental handpiece for Luer cannula
(cannula shown not included)

SMA fiber checktool

Handpieces for dermatology and dentistry

Designation	Product code
Bleaching handpiece with 600 µm fibers, length 3 m and SMA905 connector	**HPD-B-600**
Handpiece with clamping device and Luer tip	**HPD-1**

Designation	Product code
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**

Accessories

Designation	Product code
Ceramic scissors – cleave tool	**CS1**
Fiber stripper 0.12 to 0.40 mm	**FS1**
Fiber stripper 0.30 to 1.00 mm	**FS2**
SMA-Fiber checktool	**FC1**

Type designations for laser probes

FT IR 600/660 S T - 3.5/S L - F - C2 (example)

Manufacturer	
FiberTech 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	E.g. 600
Cladding diameter	E.g. 660
Coating	
Acrylate	**A**
Silicone	**S**
Polyimide	**PI**
Hard clad	**HC**
Buffer/jacket	
Teflon	**T**
Nylon®	**N**
Product length [m]	E.g. 3.5
Connector type	
F-SMA905	**S**
FC/PC	**F**
DIN	**F**
BST	**B**
Special connector	**X**
Connector design	
Standard	**M**
High power	**L**
Programmable	**P**
Distal tip	
Flat	**F**
Tapered	**T**
Ball	**B**
Orb	**O**
Spherical	**S**
Side fire	**SF**
Gas/liquid-cooled	**GLC**
Special designs	
Capillary	E.g. C2
Protective tube	

Tubes

Tubes are used to protect various optical fiber arrangements against damage from longitudinal and lateral forces as well as a wide range of 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 permissible 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

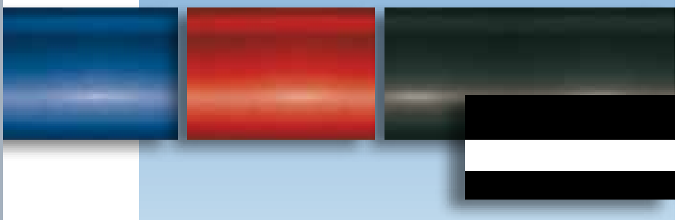
Affixing of warning and safety notices
Affixing warning markings is very helpful in ensuring proper handling of the cables during installation and maintenance work.

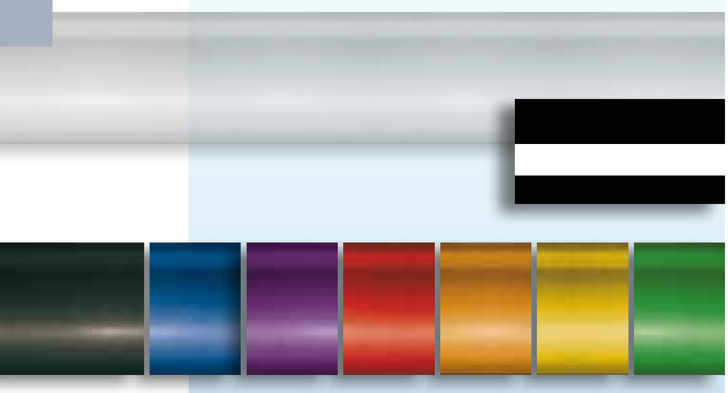
Options:

1. Printed shrink-fit tubes
in signal colours and variable intervals and lengths

2. **Direct printing of the tubes**
with warning notices

Tubes





PVC tube

Cost-effective construction for lightweight indoor and outdoor cables

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 permissible 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.
Other diameters on request.

PTFE tube

For vacuum applications, in the medium temperature range, good gliding quality (cable inner constructions)

Protection class	IP68
Operating temperature	–60°C to +260°C
Colours	transparent / black / blue / violet / red / orange / yellow / green
Composition	Smooth tube
Material	PTFE
Properties	Bondability: none / resistance to lateral compression: medium to good

Order no.	Inner Ø approx.	Outer Ø approx.	Weight ±10%	Minimum permissible 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.
Other diameters on request.

PEEK tube

Vacuum applications, wide temperature range, good gliding quality

Protection class	IP68
Operating temperature	–40°C to +220°C
Colours	Beige
Composition	Smooth tube
Material	PEEK
Properties	Bondability: good / resistance to lateral compression: medium to good

Order no.	Inner Ø approx.	Outer Ø approx.	Weight ±10%	Minimum permissible 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.
Other diameters on request.

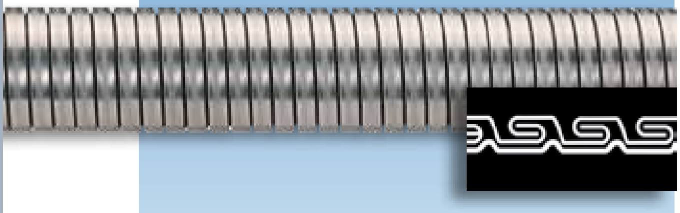
Metal tube (single-interlocked metal profile)

Tube for moderately heavy cables with very wide temperature operating range

Protection class	IP40
Operating temperature	Up to +600°C
Composition	Metal convoluted tube with single-interlocked profile
Material	Stainless steel
Properties	Bondability: good / resistance to lateral compression: good

Order no.	Inner Ø approx.	Outer Ø approx.	Weight ±10%	Minimum permissible 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.
Other diameters on request.



Metal tube (double-interlocked metal profile, Agraff)

Tube for moderately heavy cables with very wide temperature operating range and improved tensile and torsional strength

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: very good

Order no.	Inner Ø approx.	Outer Ø approx.	Weight ±10%	Minimum permissible 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

* Applies to the tube only and is influenced by the fiber and cable inner composition used.
Other diameters on request.

Metal/plastic tube (single-interlocked metal profile)

Leakproof tube for moderately heavy indoor and outdoor cables

Protection class	IP68
Colours	Black (other colours on request)
Composition	Metal convoluted tube with single-interlocked profile, covered with plastic tube
Properties	Bondability: good / resistance to lateral compression: good

<table>
<tr><th>Order no.</th><th>Inner Ø approx.</th><th>Outer Ø approx.</th><th>Weight ±10%</th><th>Minimum permissible bending radius*</th><th>Material</th><th>Operating tempera-ture</th></tr>
<tr><td></td><td>mm</td><td>mm</td><td>kg/m</td><td>mm</td><td></td><td>°C</td></tr>
<tr><td>Z10107</td><td>4</td><td>7</td><td>0.05</td><td>17</td><td rowspan="6">Galva-nised iron/PVC</td><td rowspan="6">–25 to +80</td></tr>
<tr><td>Z20457</td><td>4.8</td><td>8</td><td>0.06</td><td>20</td></tr>
<tr><td>Z10108</td><td>6</td><td>9</td><td>0.08</td><td>25</td></tr>
<tr><td>Z10109</td><td>8</td><td>10.2</td><td>0.085</td><td>40</td></tr>
<tr><td>Z10110</td><td>10</td><td>14</td><td>0.138</td><td>40</td></tr>
<tr><td>Z10111</td><td>12</td><td>16</td><td>0.161</td><td>44</td></tr>
<tr><td>Z20604</td><td>7</td><td>10</td><td>0.085</td><td>40</td><td>Galvanised iron/ polyamide</td><td>–50 to +115</td></tr>
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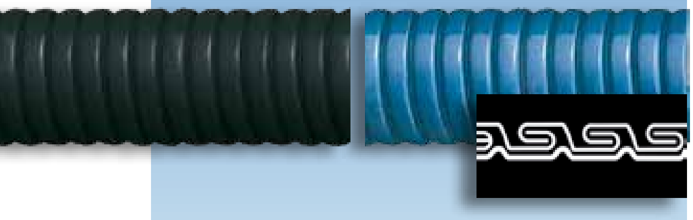
* Applies to the tube only and is influenced by the fiber and cable inner composition used.
Other diameters on request.



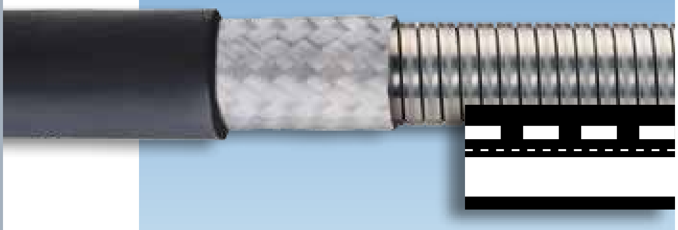
Metal/plastic tube (double-interlocked metal profile, Agraff)

Leakproof tube for moderately heavy indoor and outdoor cables with improved tensile and torsional strength

Protection class	IP68
Colours	See table (other colours on request)
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 permissible bending radius*	Material	Operating temperature
	mm	mm	kg/m	mm		°C
Z20846	4.5	8.4	0.11	40	Brass/ black silicone	–60 to +260
Z20865	6	9.6	0.115	40	Stainless steel/black silicone	
Z20610	7	10	0.13	44	Galvanised iron/blue PUR	–40 to +80

* Applies to the tube only and is influenced by the fiber and cable inner composition used.
Other diameters on request.



Metal/silicone tube

As a protective tube for fiber bundles in medical and industrial technology

Protection class	IP68
Operating temperature	–60°C to +260°C
Colours	Grey / black
Composition	Wound flattened wire coil with braid made from 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.	Outer Ø approx.	Weight ±10%	Minimum permissible bending radius*
	mm	mm	kg/m	mm
Z10093	1.0	3.0	0.016	11
Z10092	1.5	4.0	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 strong design.
Other diameters on request.

Fabric tube

As a protective tube for fiber bundles in medical and industrial technology

Protection class	IP30
Composition	Braided fiber materials
Properties	Bondability: good / resistance to lateral compression: none

Order no.	Diameter approx.	Weight ±10%	Material	Operating temperature
	mm	kg/m		°C
Z10018	1.5	0.001	Glass fiber yarn	Up to +400
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	Up to +150
Z10061	20	0.010	Polyamide	Up to +115

Other diameters on request.

Properties of selected tube materials

Material properties	PE	PA	PVC	TPE-O (FRNC)	TPE-U (PUR)	PVC	PE
Resistance to aging	+	+	+	+	+	+	+
Halogen-free	+	+	– –	+	+	– –	+
Non-flammability	– –/●	–	+	+	+	+	– –/●
Elasticity	–	+	●	–	+	●	–
Abrasion resistance	+/–	+	+	–	++	+	+/–
Low smoke gas generation	– –/●	+	–	++	●	–	– –/●
Low emission of corrosive gases	+/●	++	– –	++	●	– –	+/●
Low smoke gas toxicity	+/●	++	– –	++	●	– –	+/●
No toxicological risk	+/●	++	–	++	●	–	+/●

General resistance to	PE	PA	PVC	TPE-O (FRNC)	TPE-U (PUR)	PVC	PE
UV light	1)	+	+	1)	1)	1)	1)
Water absorption	+	– –	+	–	–	+	+
Gas diffusion	●			–	2)		●
Fuels	+/–	+	+	–	+	+/–	+
Petroleum/lubricants	+	+	●	–	++	●	+
Organic solvents	+ 4)	+ 5)	–	–	+ 3)	–	+ 4)
Alcohol	+	+	+	–	–	+	+
Oxidants	–	–	+	–	–	+	–
Acids	++	–	+	+	– –	+	++
Alkaline solutions	+	+	+	+	– –	+	+
Saline solutions	+	–	+		–	+	+

++ excellent
\+ good
● depends 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, O_2 low gas permeation, CO_2, H_2, He higher gas permeation

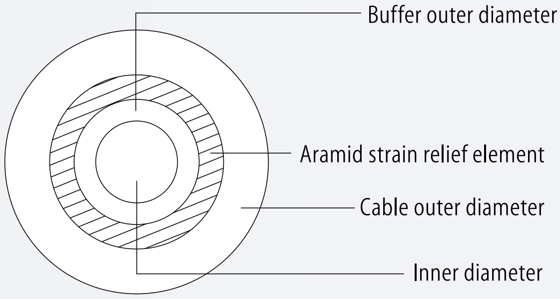
3) Low swelling in saturated hydrocarbons; significant swelling in aromatic hydrocarbons, aliphatic esters cause swelling, highly polar organic solvents dissolve under the effect of extreme swelling

4) Swelling in aliphatic and aromatic hydrocarbons and in chlorinated hydrocarbons

5) Not resistant to chlorinated hydrocarbons, resistant to hydrocarbons and aliphatic and aromatic solvents

Loose tubes/cable for cable dividers

Loose tubes/cable are designed for the direct assembly of multi-fiber loose tube cables with divider elements for mechanical protection of the fibers.



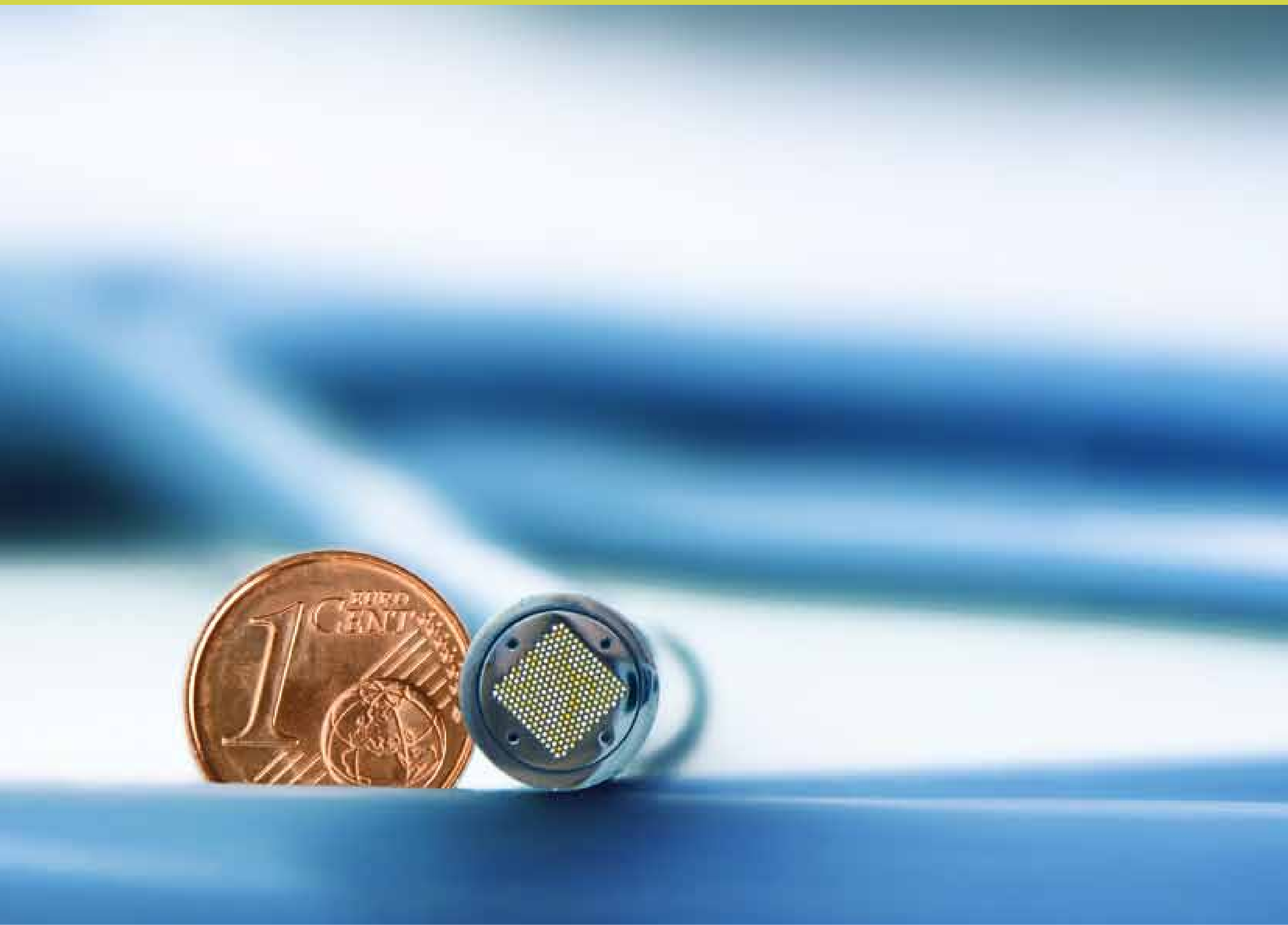
Assembly	Direct connector assembly
Buffer tube material	FRNC
Min. delivery quantity	2000 m
Makeup	Disposable drum

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 number	84950139X111	84950139X222	84950220X000	84950220X222
Colour	Rape yellow	Pastel orange	Jet black	Pastel orange
RAL	1021	2003	9005	2003
Cable outer diameter	2.1 mm	2.1 mm	2.2 mm	2.2 mm
Buffer outer diameter	0.9 mm	0.9 mm	1.1 mm	1.1 mm
Inner diameter	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 number	84950139X666ZIF01	84950139X666ZIF12	84950132X222	84950132X666
	Digit 1	Digit 12		
Colour	Yellow green	Yellow green	Pastel orange	Yellow green
RAL	6018	6018	2003	6018
Cable outer diameter	2.1 mm	2.1 mm	2.8 mm	2.8 mm
Buffer outer diameter	0.9 mm	0.9 mm	0.9 mm	0.9 mm
Inner diameter	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
	–5°C to +70°C	–5°C to +70°C	–5°C to +70°C	–5°C to +70°C

Optical Components

Probes, switches, splitters, arrays



Components for splitting, switching or shaping the beam of the light are needed in many applications within medicine and industry. We offer a variety of components, for example:

- Light-guide cones
- Light-guide rods
- Light-guide fiber rods
- Splitters for fiber bundles
- Optical fibers with endo-optics
- Cross-section converters
- Vacuum feed-through assemblies
- Splitters for singlemode FTTX and special applications
- Optical switches for singlemode and multimode applications

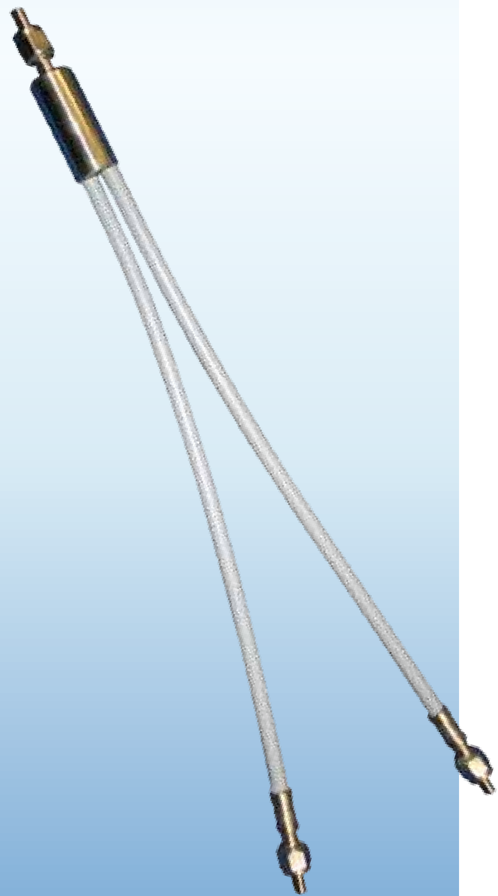
Optical components

Light-guide cones

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, without major losses in the transition.

Application	Endoscopy
Composition	Mono or fiber cones possible ■ Mono cone with core and cladding ■ Fiber cone consisting of several hundred individual fibers ➔ enlarging or reducing photographic-grade line possible
Diameter	0.1 mm to ≥10 mm
Receptacles	Stainless steel housing, as per medical standard



Fiber bundles – optical fibers with endo-optics

Single-branched and multi-branched optical fibers with endo-optics 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

Fiber matrix with fiber row and defined fiber arrangements

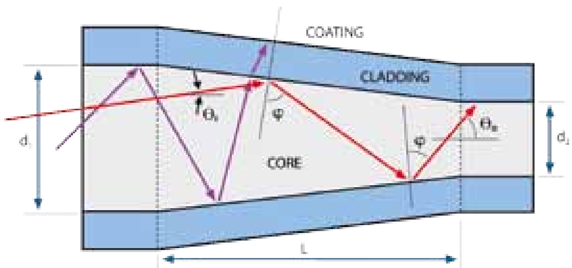
Optical fiber assembly with multiple thick-core fibers with specific and high-precision arrangement of the fibers.

Application	Analytical and sensor technology (spectroscopy in the chemical industry, mechanical engineering and construction, astrophysics)
Composition	■ Optical fibers made from fused silica glass ■ Flexurally rigid assembly ■ Polished finish of fiber end faces also for use on high-performance lasers
Length	Up to 200 m

Fiber tapers

Optical fiber made from fused silica glass with different input and output core diameters and NA converters.

Application	Laser applications for working material and spectroscopy
Composition	■ Ratio of input to output diameter: up to 1:5 ■ Can be assembled with various tubes, standard and special connectors
Length	Up to 25 m

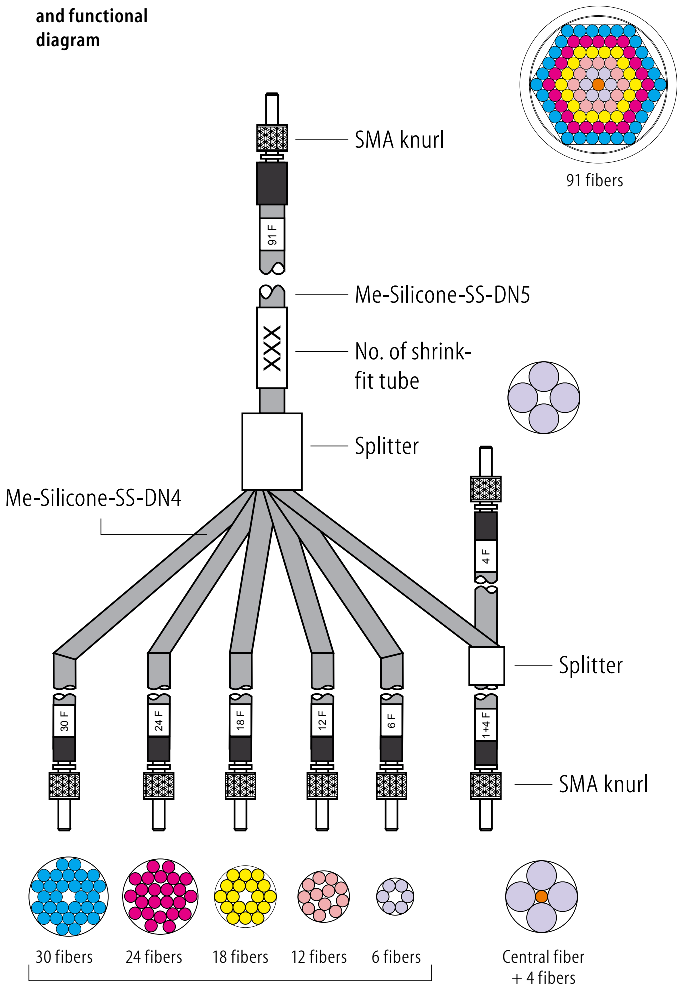


Reflection probes

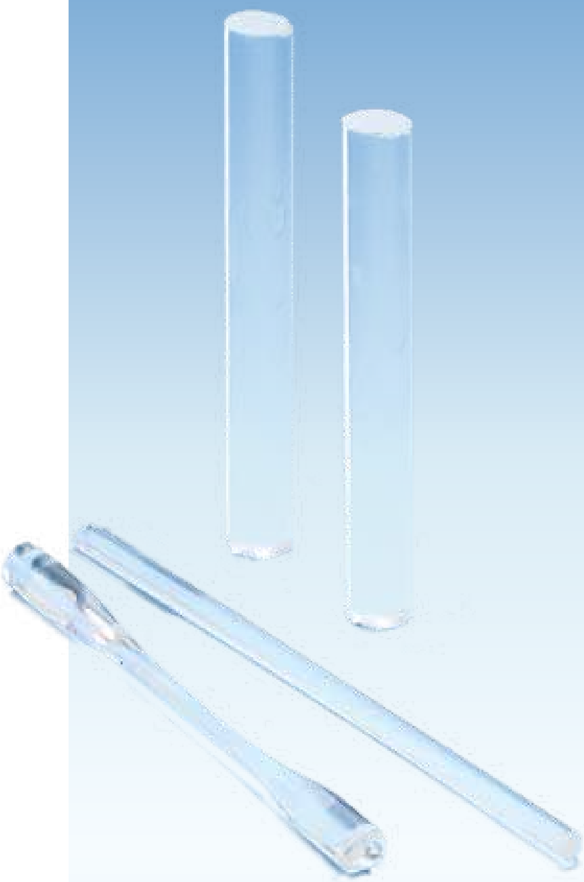
Optical fiber for the spectroscopic analysis of liquid and solid materials.

Application	Spectroscopic examinations of liquid, gaseous or solid matter
Composition	■ One reflection probe consists of at least two optical fibers ■ These are assembled together in a measuring head at one end ■ The other end consists of several outgoing and incoming lines for connection to spectroscopy systems ■ Can be assembled with various tubes, standard and special connectors
Length	Up to 200 m

Construction and functional diagram



Arrangement of the fibers in these individual connectors can differ



Light-guide rods

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.
Diameter	0.1 mm to ≥10 mm
Receptacles	Customer-specific: Also tapered if required (tapering across specific areas of the cross-sectional area of the light-guide rod)

Light-guide fiber rods

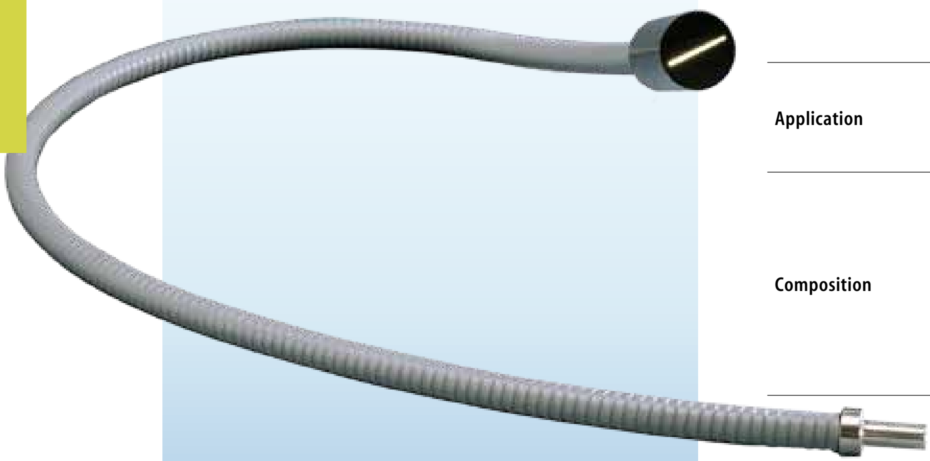
Optical fiber made from silica, optical glass or plastic with large cross-sectional area consisting of several hundred individual fibers.

Application	In applications where a picture or impression is to be transmitted in addition to light and the optical and image guide do not have to be flexible. The number and diameter of the individual fibers determine the resolution of the picture.
Diameter	0.1 mm to ≥10 mm
Receptacles	Customer-specific: Also tapered if required (tapering across specific areas of the cross-sectional area of the fiber rod)

Multi-branched fiber bundles – optical fibers

Incoming light is directed to the required different positions via various individual arms (= splitter).

Application	Spectrometry, analytical technology, sensor technology. With glass or plastic fibers also for lighting and decoration.
Composition	■ One common fiber bundle and several individual fiber bundles as passive light-guide channels ■ Individual fibers made from optical glass (when transmitting visible light) or quartz (when transmitting UV/IR light) ■ Protective tubes, receptacles and adhesives as appropriate to temperature and ambient conditions
Length	Up to 100 m



Fiber bundles – cross-section converters

For converting a circular light beam into a slot-shaped light beam

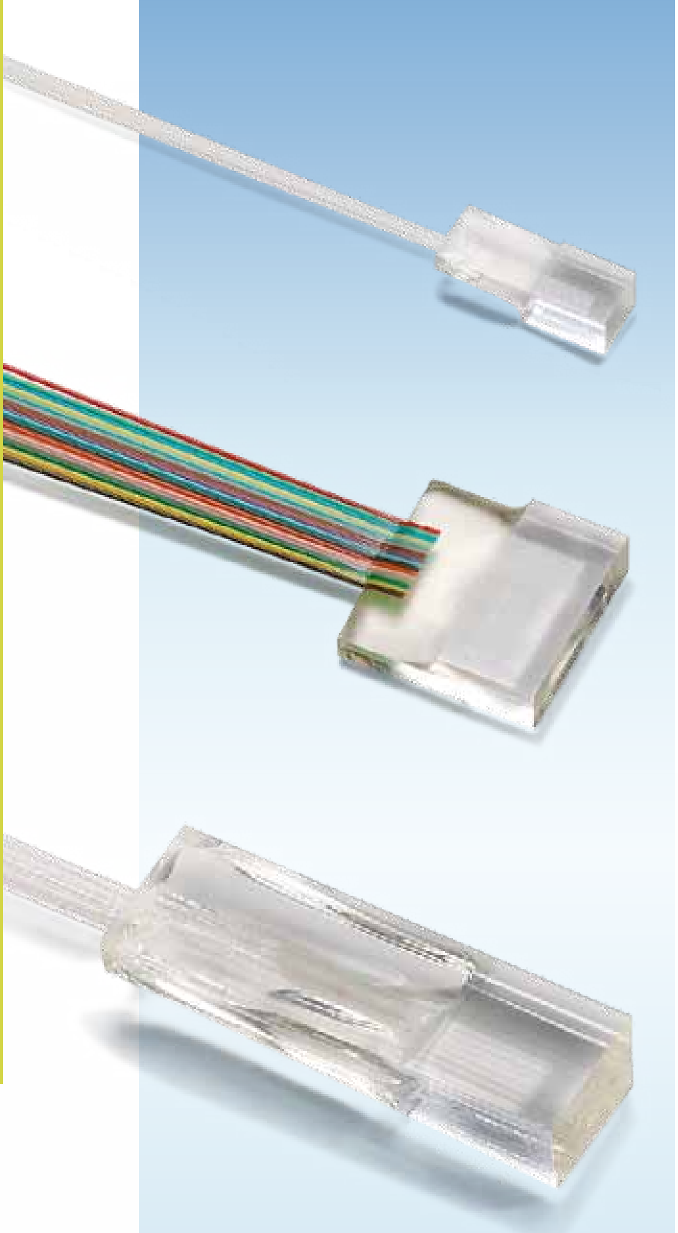
Application	Spectrometry, analytical technology, sensor technology, e.g. for optimum illumination of linear arrays
Composition	■ Individual fibers made from optical glass (when transmitting visible or UV light) or quartz (when transmitting IR light) ■ Protective tubes, receptacles, adhesives and endo-optics as appropriate to temperature and ambient conditions

Vacuum feed-through assemblies

Optical components that create a transition from atmospheric areas to 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.
Application	Spectrometry, analytical technology and optical sensing in vacuum areas

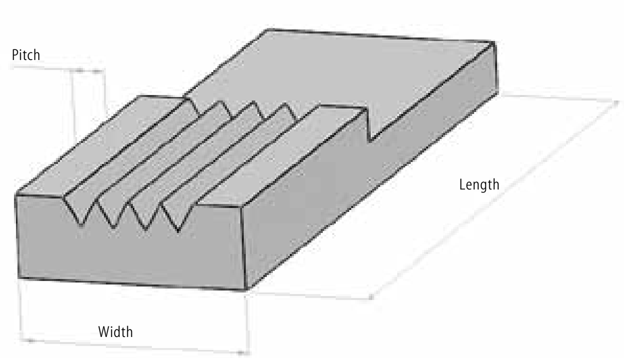
Fiber arrays
for singlemode and multimode applications



Fiber arrays

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 thick-core 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 PC and APC 8° polish. The fiber end faces can also be given an anti-reflective 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 or 250 µm are available for the SM telecommunications fibers ■ Positional accuracy of the fiber cores in the array better than 1 µm ■ 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)
Special design	Two-dimensional arrays (customer-specific) have already been realised.



Fiber arrays for singlemode applications

Number of fibers	Dimensions	125 µm AD	125 µm AD
1	l x w x h [mm]	10.0x3.7x2.5	10.0x3.7x2.5
	pitch [µm]	–	–
2	l x w x h [mm]	10.0x3.7x2.5	10.0x3.7x2.5
	pitch [µm]	250	127
4	l x w x h [mm]	10.0x3.7x2.5	10.0x3.7x2.5
	pitch [µm]	250	127
8	l x w x h [mm	10.0x3.7x2.5	10.0x3.7x2.5
	pitch [µm]	250	127
16	l x w x h [mm]	10.0x10.0x2.5	10.0x3.7x2.5
	pitch [µm]	250	127
32	l x w x h [mm]		15.0x11.6x2.5
	pitch [µm]		127
64	l x w x h [mm]		15.0x11.6x2.5
	pitch [µm]		127

Fiber arrays for multimode applications

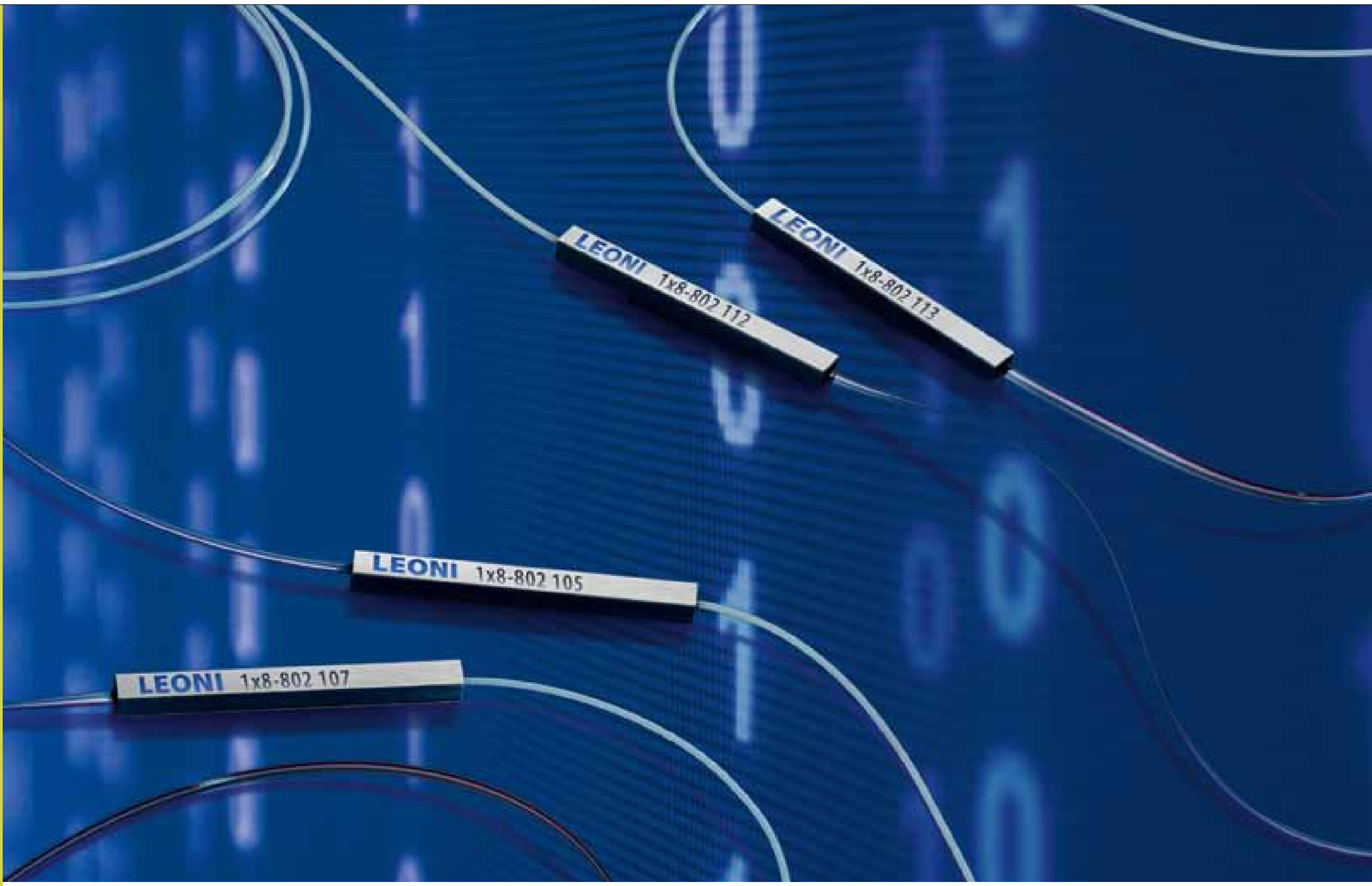
Number of fibers	Dimensions	125 µm AD	125 µm AD	200–280 µm AD	400–480 µm AD	600–680 µm AD	800–880 µm AD
1	l x w x h [mm]	10.0x3.7x2.5	10.0x3.7x2.5	12.5x5.0x3.05	12.5x5.0x3.05	12.5x5.0x3.05	12.5x5.0x3.05
	pitch [µm]	–	–	–	–	–	–
2	l x w x h [mm]	10.0x3.7x2.5	10.0x3.7x2.5	13.0x5.0x3.05	16.5x5.0x3.05	18.5x5.0x3.05	18.5x5.0x3.05
	pitch [µm]	250	127	300	500	700	1000
4	l x w x h [mm]	10.0x3.7x2.5	10.0x3.7x2.5	16.0x5.0x3.05	21.5x5.0x3.05	23.5x5.0x3.05	23.5x5.0x3.05
	pitch [µm]	250	127	300	500	700	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	E.g. 08
Chip	
MM 4-channel v-groove 125 µm, glass, 0.25 mm pitch, 10x3.5x2.5 mm	**13**
SM 16-channel v-groove 125 µm, glass, 0.25 mm pitch, 10x3.5x2.5 mm	**33**
MM 4-channel v-groove 830 µm, glass, 1 mm pitch, 23.5x5x3.05 mm	**24**
Others on request	**...**
Variants	

Order example:
AR00483H208-1300
Array with 4 GI100/140/250 NA 0.29 fibers,
FC/PC connector,
0.9 mm Hytrel tube,
length 80 cm,
MM 4-channel v-groove 125 µm chip,
glass,
pitch 0.25 mm,
dimensions 10 x 3.5 x 2.5 mm (l x w x h)



Singlemode splitters for FTTX and special applications

LEONI splitters are based on a unique planar waveguide technology that offers maximum performance and exceptional long-term stability. The standard products are low-loss and broadband singlemode splitters for the entire telecommunications wavelength range with splitting rates of 1x2 to 1x64, including splitters such as 1x5 or 1x10.

Planar waveguide components for the near infrared (NIR) and visible (VIS) wavelength range are in development. LEONI offers alternative micro-optical splitters and couplers for special applications (e.g. multimode fiber optical systems).

The splitters are above all characterised by

- Very low insertion losses
- High uniformity
- High extinction rate
- Lowest PDL
- Widest wavelength range (1260 to 1650 nm)
- Small, rugged metal housing
- Any fiber assembly
- Own connectors
- Exceptional long-term stability – tested to Telcordia GR 1209 and 1221

1xN ultra broadband splitter series

Planar waveguide splitters:
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 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 **1x2, 1x4, 1x8, 1x10, 1x16 and 1x32** Customer-specific designs (on request), e.g. 1xN with N≠2^n, asymmetrical splits, splitters for lower wavelengths are available on request.	
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 various connector types e.g. LGX, Corning CCH	
Slots	19" slots with connector panels 1, 2 or 3 HU	
Fiber type	SMF 28 (9/125/250 µm) (other types on request)	
Fiber length	≥1 m	
Housing size	40 x 4 x 4 mm for 1x8 splitter (other shapes on request)	
Temperature range	Operating temperature Storage temperature	−40 to +85°C −40 to +85°C

Splitter type	**1x2**	**1x4**	**1x8**	**1x10**	**1x16**	**1x32***
Max. insertion loss [dB]**	3.9	7.4	10.8	12.0	14.1	17.3
Max. uniformity [dB]	0.5	0.9	1.0	1.2	1.3	1.6
Return loss	≥55 dB					
Directivity	≥55 dB					
Polarisation-dependent losses	≤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 polarisation states
** Value is up to 0.3 dB higher for the extended wavelength range from 1360–1480 nm

2xN ultra broadband splitter series

Planar waveguide splitters:
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 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 **2x4 and 2x8** Customer-specific designs 2x2, 2x16, 2x32 and 2xN with e.g. 2xN with $N \neq 2^n$, asymmetrical splits, splitters for lower wavelengths are available on request.
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 various connector types, e.g. LGX, Corning CCH	
Slots	19" slots with connector panels 1, 2 or 3 HU	
Fiber type	SMF 28 (9/125/250 µm) (other types on request)	
Fiber length	≥1 m	
Housing size	40 x 4 x 4 mm (other shapes on request)	
Temperature range	Operating temperature Storage temperature	–20 to +60°C –40 to +85°C

Splitter type	**2x4**	**2x8**
Max. insertion loss [dB]*	7.8	11.2
Max. uniformity [dB]	1.5	1.8
Return loss	≥55 dB	
Directivity	≥55 dB	
Polarisation-dependent losses	≤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 polarisation states.
Value is up to 0.3 dB higher for the extended wavelength range from 1360–1480 nm.

1x2 broadband PM splitter series

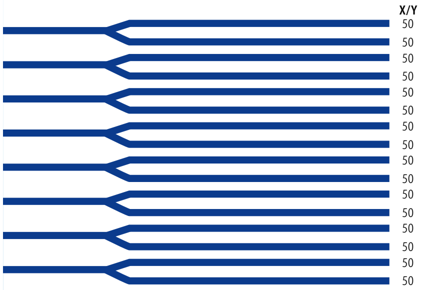
Planar PM splitters:

Planar PM splitters 1x2 from LEONI are developed for special applications involving high polarisation retention. The special ion exchange process for manufacturing the extremely stress-free waveguide structures on planar chips results in excellent and stable polarisation properties even under extreme conditions.

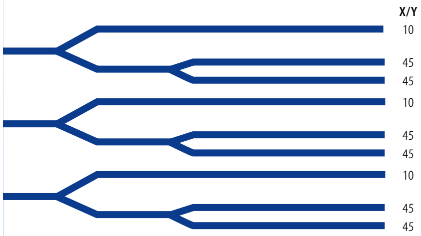
Composition		
Connectors	UPC or APC: SC, FC, LC, MU, E2000, ST, MPO, DIN	
Trays	"Plug & play" for various connector types, e.g. LGX, Corning CCH	
Slots	19" slots with connector panels 1, 2 or 3 HU	
Fiber type	Fujikura Panda SM 13-P/SM 15-P	
Fiber length	1 m	
Housing size	40 x 4 x 4 mm for 8-fold 1x2 splitter (other shapes on request)	
Temperature range	Operating temperature Storage temperature	–40 to +60°C –40 to +85°C

Splitter type	**1x2**	
Quality grade	ST (Standard)	HQ (High quality)
Max. insertion loss [dB]*	4.2	4.0
Max. uniformity [dB]	0.6	0.5
Return loss	≥55 dB	
Directivity	≥55 dB	
Extinction rate of polarisation [dB]	≥20	≥25
Wavelength ranges	1260–1650 nm	

* 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.



8-fold 1x2 splitter



Customer-specific 3-fold 1x2 splitter
with additional monitor channel

Multiple 1x2 ultra broadband splitter series

Planar multi waveguide splitters M-fold 1x2:
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 **1x2 M-fold (where M = 2 to 8)** Customer-specific designs, other combinations and splitters for lower wavelengths available on request.
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 various connector types, e.g. LGX, Corning CCH	
Slots	19" slots with connector panels 1, 2 or 3 HU	
Fiber type	SMF 28 (9/125/250 µm) (other types on request)	
Fiber length	≥1 m	
Housing size	69 x 10 x 5.6 mm (other shapes on request)	
Temperature range	Operating temperature Storage temperature	–40 to +85°C –40 to +85°C

Splitter type	**M-fold 1x2* (M = 1 to 8)**					
Splitting rate	50 / 50	60 / 40	70 / /30	80 / 20	90 / 10	95 / 5
Max. insertion loss [dB]**	3.9	3.0	2.1	1.6	0.9	0.7
Max. uniformity [dB]	3.9	4.8	6.1	7.8	10.9	14.5
WDL* channel 1 (max.) [dB]**	0.5	0.5	0.5	0.5	0.5	0.5
WDL* channel 2 (max.) [dB]**	0.5	0.5	0.6	0.7	0.8	0.9
Return loss	≥55 dB					
Directivity	≥55 dB					
Polarisation-dependent losses	≤0.15 dB					
Wavelength ranges	1260–1360 nm					

* Other multi-splitter types (e.g. 1x3, 1x4) on request
** Applies across the entire wavelength and temperature range as well as for all polarisation states
*** WDL: wavelength-dependent loss between 1260 and 1650 nm (uniformity of the IL)

Order number scheme for optical splitters

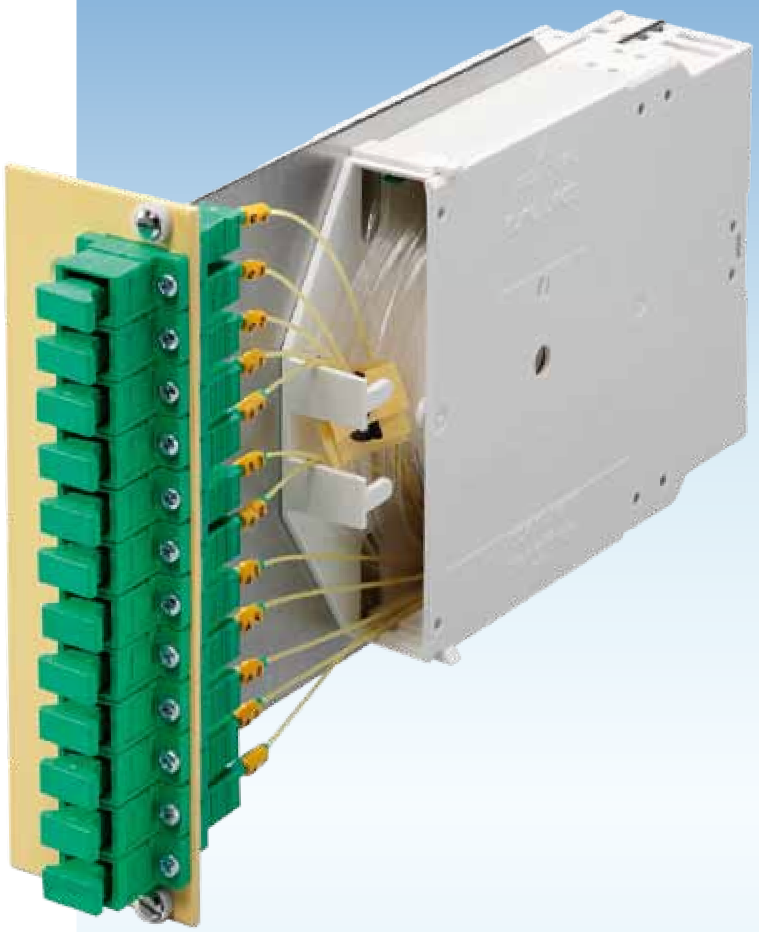
V 1x02 10 10-10 10-ST (example)

Optical splitter	**V**
Input channel number N	**Code**
2	**2**
4	**4**
8	**8**
…	**etc.**
Output channel number N	
(see input channel number)	E.g. 2
Input fibers	
250 µm individual fiber	**10**
900 µm individual fiber (tight buffered)	**20**
900 µm individual fiber (loose tube)	**30**
N-f. ribbon cable	**40**
Output fibers	
(see input fibers)	E.g. 10
Input connectors	
No connector	**NV**
FC	**10**
SC	**20**
ST	**30**
LC	**40**
E2000	**50**
MU	**60**
DIN	**70**
SMA	**80**
MPO N fibers (nn = 04, 08 or 12)	**1nn**
End face polish PC	**+A**
End face polish APC	
Output connectors	
See input connectors	E.g. 10
Variants (e.g. quality grades)	
Standard	**ST**
High quality	**HQ**
Customer specification	**CU**

Order example:

V 1x02 10 10-10 10-ST
means 1x2 splitter with 250 µm input fibers,
250 µm output fibers,
FC/APC connector,
standard specification

Splitter modules, slots and trays



Splitter modules, slots and trays

Based on the described splitter components, LEONI offers a wide range of further assemblies in modules, slots and trays that are suitable for direct installation in closures, 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 proposals on request

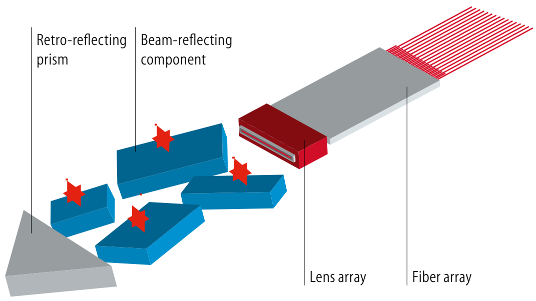
Example	Vertical slots (3 HU) in which one 3-fold 1x4 splitter component with 12 output fibers with connectors (SC/APC) and three input fibers placed in one splice tray have been installed.

Optical switches for singlemode and multimode applications

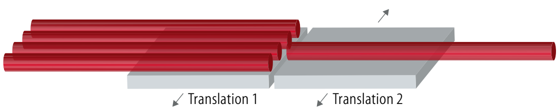
Application and technology

LEONI's eol and mol series have been developed 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 (mol series), laser scan microscopy, multi-channel optical performance monitoring, fiber Bragg sensors, testing of fiber optical cables and environmental trace analysis.



Schematic diagram of a fiber optical switch 1x16



Schematic diagram of a fiber optical multimode switch 1x4

LEONI's 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 visible to the infrared and for a wide variety of fiber types, including PM fibers with the eol series. Switches with a higher specified number of channels can also be developed and produced on request.

Optical properties

- Low insertion loss
- Low polarisation losses (eol series)
- Excellent repeatability
- High optical isolation
- Extremely low back reflection (eol series)
- Wide to ultrawide (mol series) spectral range
- Short switching times

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

Reliability

- Excellent long-term reliability, tested to Telcordia GR-1073
- Lifetime >100 million switching cycles

Fiber optical switch
eol 1x2 · eol 1x4 · eol 2x2

For requests please specify:

■ Number of channels	1x2, 1x4 or 2x2
■ Spectral range	Operating wavelength range
■ Fiber type	E.g. Corning SMF 28 type
■ Pigtail length	In metres
■ Connector type(s)	E.g. LC, FC, SC, ST, MU, E2000
■ Electronic interface	E.g. TTL, RS-232, I^2C (Ethernet, USB on request)
■ Special requirements	

Switch version		**IR**	**NIR**	**VIS**	**PM**
Specifications					
Operating wavelength	[nm]	1260 – 1360 1480 – 1630	700 – 1100	400 – 690	VIS-IR
Max. insertion loss (typical)	[dB]	1.0 (0.7)	1.4 (0.9)	1.4 (0.9)	1.4 (0.9)
Return loss	[dB]	≥65	≥55	≥55	≥55
Crosstalk	[dB]	≥55			
Repeatability	[dB]	≤0.005	≤0.01	≤0.01	≤0.01
Polarisation-dependent losses	[dB]	≤0.05	≤0.05	≤0.05	–
Polarisation-dependent crosstalk (typical)	[dB]	–	–	–	≤20 (≤22)
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 to +60			
Storage temperature	[°C]	–40 to +80			
Housing dimensions	[mm]	75 x 50 x 13	75 x 50 x 13	124 x 56 x 13	75 x 50 x 13

Fiber optical switch
eol 1x8 · eol 1x12 · eol 1x16

For requests please specify:

■ Number of channels	1x8, 1x12 or 1x16
■ Spectral range	Operating wavelength range
■ Fiber type	E.g. Corning SMF 28 type
■ Pigtail length	In metres
■ Connector type(s)	E.g. LC, FC, SC, ST, MU, E2000
■ Electronic interface	E.g. TTL, RS-232, I²C (Ethernet, USB on request)
■ Special requirements	

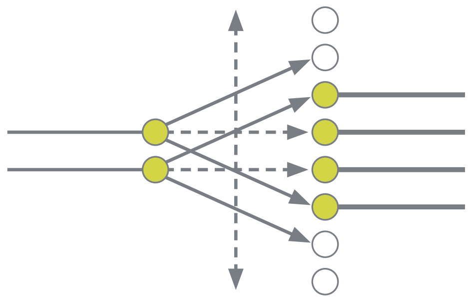
Switch version		**IR**	**NIR**	**VIS**
Specifications				
Operating wavelength	[nm]	1260 – 1360 1480 – 1630	700 – 1100	400 – 690
Max. insertion loss (typical)	[dB]	1.0 (0.7) *)	1.5 (0.9)	1.5 (0.9)
Return loss	[dB]	≥60	≥55	≥55
Crosstalk	[dB]		≥55	
Repeatability	[dB]	≤0.005	≤0.01	≤0.01
Polarisation-dependent losses	[dB]		≤0.1	
Polarisation-dependent crosstalk (typical)	[dB]	–	–	–
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 to +60	
Storage temperature	[°C]		−40 to +80	
Housing dimensions	[mm]		124 x 56 x 13	

*) Fiber optical switch 1x16 eol: max. insertion loss for the IR version is 1.2 dB

Fiber optical switch
eol 2x4 · eol 2x8

For requests please specify:

■ Number of channels	2x4, 2x8
■ Spectral range	Operating wavelength range
■ Fiber type	E.g. Corning SMF 28 type
■ Pigtail length	In metres
■ Connector type(s)	E.g. LC, FC, SC, ST, MU, E2000
■ Electronic interface	E.g. TTL, RS-232, I²C (Ethernet, USB on request)
■ Special requirements	Specify configuration



Switch version		IR	NIR	VIS
Specifications				
Operating wavelength *)	[nm]	1260 – 1360 1480 – 1630	700 – 1100	400 – 690
Max. insertion loss (typical)	[dB]	1.0 (0.7)	1.5 (0.9)	1.5 (0.9)
Return loss	[dB]	≥60	≥55	≥55
Crosstalk	[dB]		≥55	
Repeatability	[dB]	≤0.005	≤0.01	≤0.01
Polarisation-dependent losses	[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 to +60	
Storage temperature	[°C]		–40 to +80	
Housing dimensions	[mm]		124 x 56 x 13	

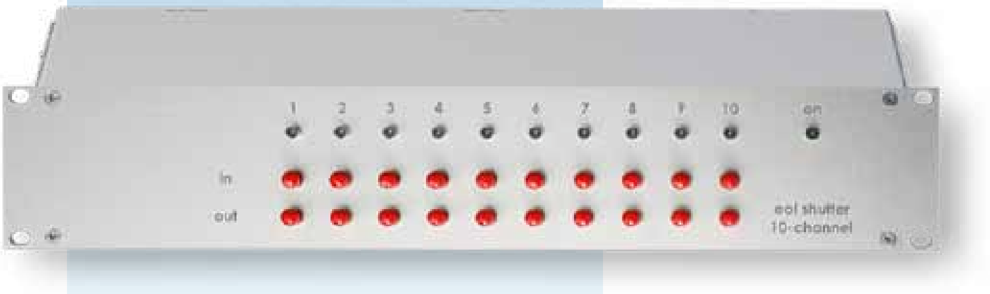
*) Detailed information about the different wavelength ranges can be found in separate data sheets.

Fiber optical multimode switch
mol 1x2 · mol 1x4 · mol 2x2 · mol 2x4

For requests please specify:

- Number of channels — 1x2, 1x4, 2x2 or 2x4
- Spectral range — Operating wavelength range
- Fiber type — E.g. MM50/125 GI
- Pigtail length — In metres
- Connector type(s) — E.g. LC, FC, SC, ST, MU, E2000
- Electronic interface — E.g. TTL, RS-232, I²C (Ethernet, USB on request)
- Special requirements

Switch version		Core diameter 50 µm to < 200 µm	Core diameter 200 µm to 400 µm	Core diameter 600 µm to 800 µm
Specifications				
Operating wavelength	[nm]		Dependent on the transmission range	
Max. insertion loss (typical)	[dB]	≤1.0 (0.7)	≤1.0 (0.5)	≤1.0 (0.5)
Low return loss			Optional	
Crosstalk	[dB]	< –55	< –45	< –40
Repeatability	[dB]		0.03	
Switching times	[ms]	≤5	≤10	≤20
Guaranteed lifetime	[cycles]		$>10^8$	
Switching frequency	[s^{-1}]		≤50	
Operating voltage	[V]		5	
Power consumption	[mW]		<450	
Operating temperature	[°C]		0 to +60	
Storage temperature	[°C]		–40 to +80	
Fiber core diameter	[µm]		50 up to 800	
Housing			Different housing types from compact to tabletop housings. Minimum size dependent on type of fiber used.	



Fiber optical multi-channel shutter eol N (N = 1 to 16, mol shutters on request)

For requests please specify:

■ Number of channels	N = 1, 2, 3 … 16
■ Spectral range	Operating wavelength range
■ Fiber type	E.g. Corning SMF 28 type
■ Pigtail length	In metres
■ Connector type(s)	E.g. LC, FC, SC, ST, MU, E2000
■ Electronic interface	E.g. TTL, RS-232, I²C (Ethernet, USB on request)
■ Special requirements	

Switch version		**IR**	**NIR**	**VIS**
Specifications				
Operating wavelength	[nm]	1260 – 1650	700 – 1100	400 – 690
Max. insertion loss (typical)	[dB]	1.0 (0.7)	1.5 (0.9)	1.5 (0.9)
Low return loss	[dB]	≥60	≥55	≥55
Crosstalk	[dB]		≥55	
Repeatability	[dB]	≤0.005	≤0.01	≤0.01
Guaranteed lifetime	[cycles]		$>10^8$	
Polarisation-dependent losses	[dB]		≤0.1	
Switching times	[ms]		≤2	
Switching frequency	[s^{-1}]		≤50	
Operating voltage	[V]		5	
Power consumption	[mW]		<450	
Operating temperature	[°C]		0 to +60	
Storage temperature	[°C]		–40 to +80	
Housing (standard) *)			19" slot 1–3 HU	

*) Customer-specific housing on request.

Order number scheme for optical switches

M 01 x 004 61 2 B 10 A 1 (example)

	Code
Switch type	Code
SM	**S**
MM	**M**
Shutter	**H**
Number of fibers, input	**01**
Number of fibers, output	**004**
Fiber type 50/125/250 NA 0.22 9/125/250/900 µm tight buffer, others on request	E.g. 61
Connector type	
All fibers with FC/APC	**1**
All fibers with FC/PC	**2**
All fibers with FC/AFC	**3**
All fibers with E2000/PC	**4**
All fibers with SC/APC	**5**
All fibers with LC/PC	**7**
All fibers with ST/PC	**8**
All fibers with E2000/PC	**B**
All fibers with SC/PC	**E**
All fibers with LC/APC	**I**
Others on request	
Secondary coating	
None	**A**
With metal corrugated tube 3 mm	**B**
With metal corrugated tube 5 mm	**C**
900 µm buffer + metal corrugated tube 3 mm	**D**
900µm buffer Hytrel loose tube	**J**
Others on request	
Length in dm	E.g. 10
Housing	
Standard compact large 124 x 56 x 13	**A**
Standard compact small 75 x 50 x 13	**B**
Others on request	**C**
Electrical activation	
RS232, I²C, TTL (without strobe)	**1**
RS232, I²C, parallel (with strobe)	**2**
Ethernet	**3**
Others on request	
Variants	

Order example:
M 01x004 61 2 B 10 A 1
means 1x4 MM switch
with 50/125/250 NA 0.22 fibers,
FC/PC connector,
metal corrugated tube 3 mm od,
1 m pigtail length,
standard compact large 124x56x13
and S232, I2C,TTL activation.

Support

Tools, measuring devices and accessories

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.

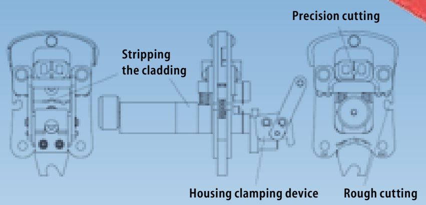
Suitable tools are available for the process steps from stripping through crimping and end face processing to final checking.

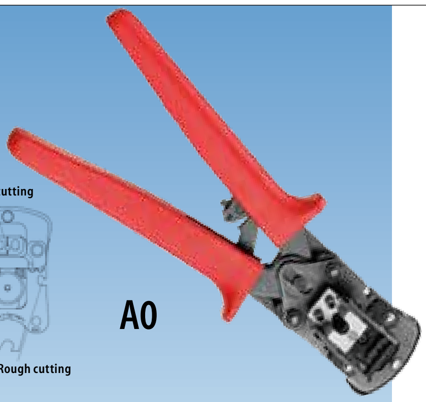
This makes the assembly of POF in particular a cinch.
These assembly tools for PCF and POF are specially tailored to LEONI's cable constructions and connectors.

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.

Strippers





A0

Universal assembly tool POF SCRJ

Order no.	On request
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

A1

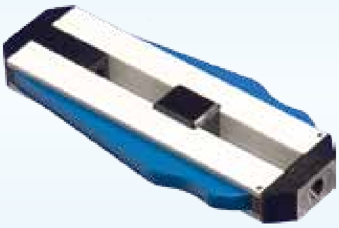
Stripper

Order no.	Z012-SA0-3.6-6.0
Application	For Ø 6.0 + Ø 3.6 mm Simplex cables

A2

Stripper

Order no.	Z010-SA0-2.2
Application	For cables with Ø 2.2 mm specially for PCF and PA buffered fibers



A3

Buffer stripper

Order no.	Z004-TA0-0.5
Application	For 230 µm PCF fibers

A4

Cutter

Order no.	ZXXX-TD0
Application	For POF buffered fibers and fibers up to Ø 2.3 mm

A5

Stripper

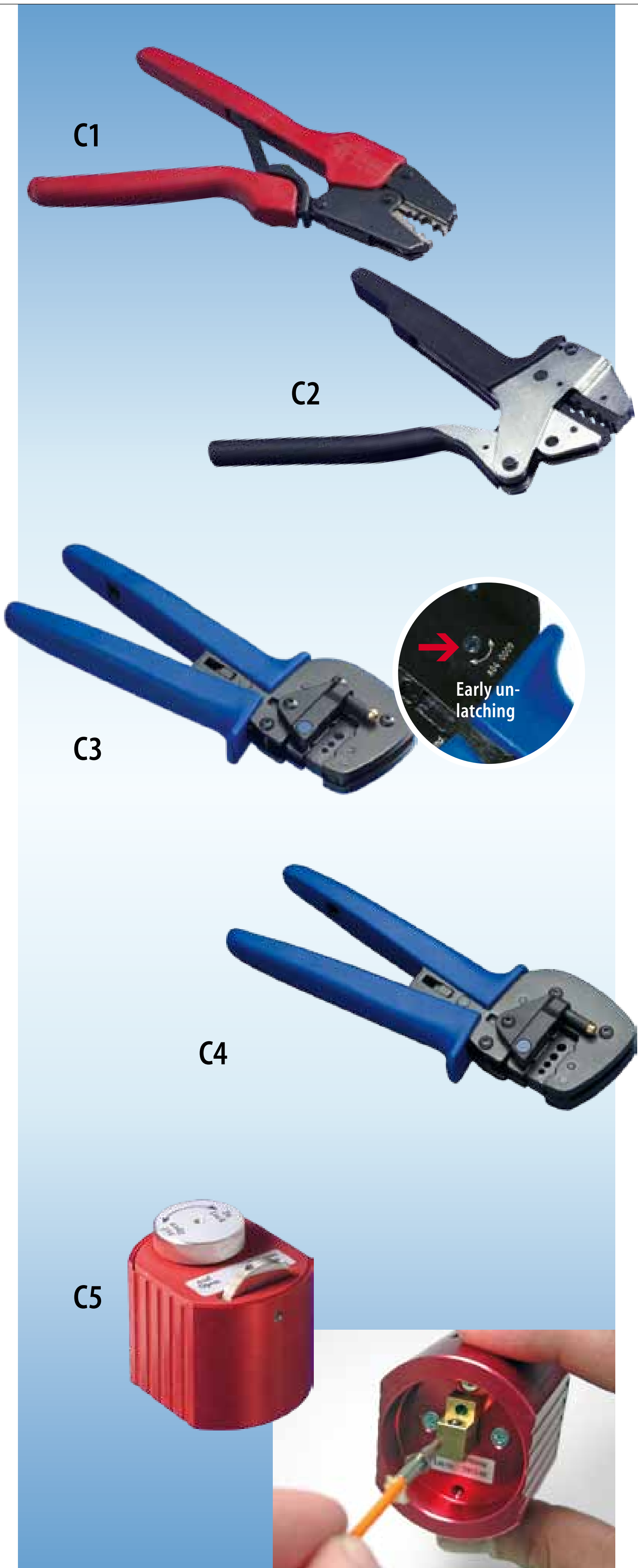
Order no.	Z004-TA0-0.5-2.2
Application	For PCF buffered fiber cladding and fiber buffers

A6

Precision stripper

Order no.	Z011-SA0-2.2
Application	For Ø 2.2 mm PE buffered fibers

Crimp and cleave tools



Crimp tool POF

Order no.	ZSMA-CC0
Application	For FSMA connectors POF with Ø 2.2 / 3.6 / 6.0 mm

Crimp tool POF

Order no.	ZXST-CC0
Application	For ST connectors POF

Universal crimp tool POF

Order no.	ZXXX-CB0, see table
Application	For ST / FSMA / V-PIN (HP) connectors

Order table

Connector type	**Order no.**	**Crimp dimen-sions** [mm]
V-PIN	SHP-SV0-19-0010	5.0
V-PIN	SHP-DS0-19-0010	5.0
V-PIN metal	SHP-SS0-20-0010	3.0
F05 metal	SF05-SS0-20-0010	5.0
FSMA	SSMA-SS0-02-0050	3.0
FSMA	SSMA-SH0-02-0010	3.0
ST	SXST-SS0-22-0010	3.5

Universal crimp tool PCF

Order no.	ZXXX-CC0, see table
Application	For PCF buffered fiber cladding and fiber buffers

Order table

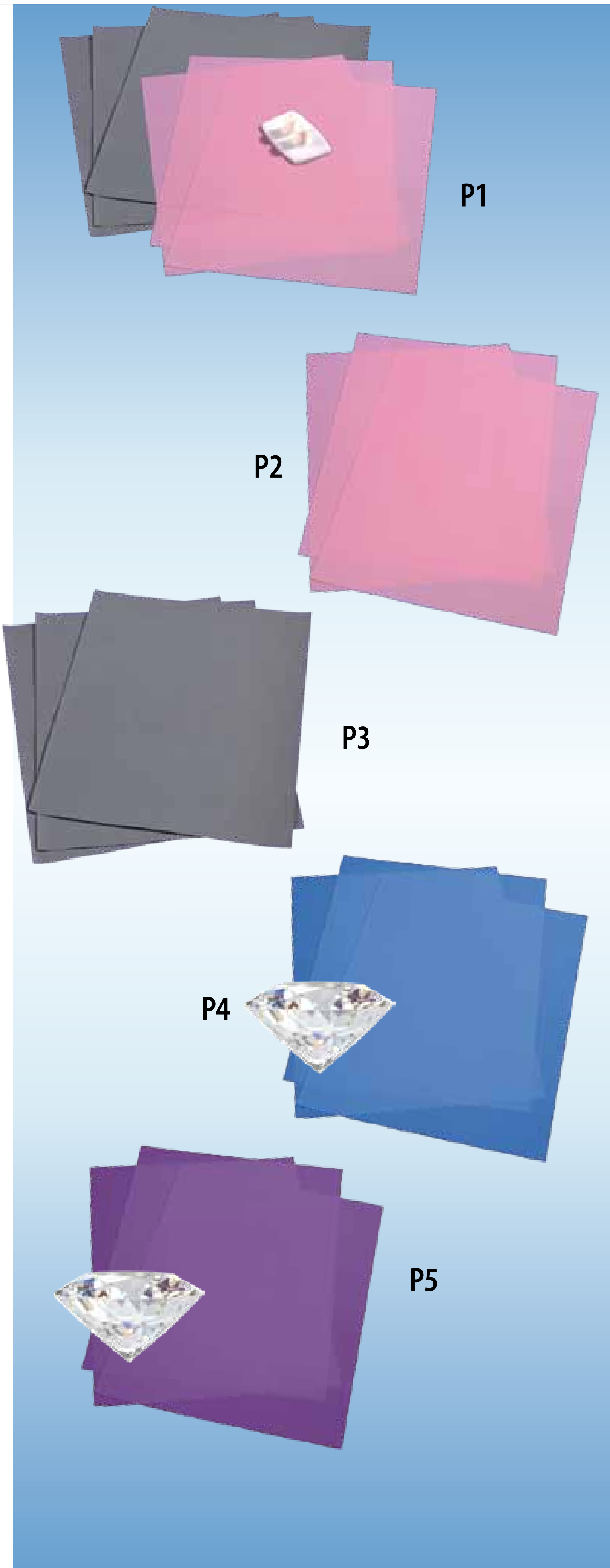
Connector type	**Order no.**	**Crimp dimen-sions** [mm]
FSMA	SHP-SV0-19-0010	Anchor 3.3
ST	SXST-SK0-01-0020	Anchor 4.5
ST	SXST-SK0-01-0030	Anchor 4.5

Cleave tool PCF

Order 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-PIN) PCF (crimp and cleave version)	ZSHP-TW0
For F05 / F07 connectors	ZF07-TW0
For SC connectors (clamp version)	ZXSC-TW0

Tools for fiber end face treatment



Polishing set	
Order no.	ZHP-PS0
Contents	Lapping film 600 Polishing film 3µm Polishing disc
Quantity	1 sheet of each
Sheet size	100 × 100 mm

Polishing film 3 µm	
Order no.	ZHP-PS0
Grain	3 µm
Material	Al2O3
Quantity	10 sheets
Sheet size	216 × 279 mm

Lapping film 600	
Order no.	ZHP-PS0
Grain	600
Material	Al2O3
Quantity	10 sheets
Sheet size	230 × 280 mm

Diamond polishing film, 9 µm grain	
Order no.	Z005-PS1
Grain	9 µm
Material	C (diamond)
Quantity	15 sheets
Sheet size	230 × 280 mm

Diamond polishing film, 1 µm grain	
Order no.	Z007-PS1
Grain	1 µm
Material	C (diamond)
Quantity	10 sheets
Sheet size	230 × 280 mm

P6

P7

P8

P9

P10

Polishing disc ZSMA	
Order no.	ZSMA-SP0
Application	For FSMA connectors (metal)

Polishing disc F05	
Order no.	ZF05-SP0-
Application	For F05 connectors (metal)
Description	With wear indicator

Polishing disc HP	
Order no.	ZHP-TP0
Application	For HFBR connectors, Ø 2.2 mm

Universal polishing disc, 2.5 mm	
Order no.	ZXXX-SP0-2.5
Application	For ST, FSMA and V-PIN (HP) connectors

Polishing disc ST	
Order no.	ZXST-SPO
Application	For PCF buffered fiber cladding and fiber buffers

P11

Hot plate incl. power supply unit POF

For assembling plastic fiber optic cables. The hot plate method is an alternative to the lapping and polishing technique for finishing the POF fiber end face. It is characterised in particular by its high reproducibility and ease of handling. With this method, the fiber end faces are fused at a temperature of approx. 140°C and moulded into their final shape. Almost all POF connectors are available for this special assembly technique.

Operating voltage	24 V / 1 A power supply unit
Power consumption	24 W
Input	220 V AC / 50 Hz / 38 W
Temperature	Approx. 140°C
Output	24 V DC / 1 A / 24 W
Connector	DIN connector

Order table

Connector type	Order no.
With guide for FSMA and F05/F07 connectors	ZSMA-TH0
With guide for ST (BFOC) connectors	ZXST-TH0

Measuring devices


ST (BFOC)


HP


FSMA


HP


F05


FCPC

Optical power meter with digital display

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.

Optical detector	Silicone PIN diode
Detector area	2.65 x 2.65 mm
Optical connection	Interchangeable adapter, screw-in
Display range	–50.0 to +3 dBm

Order table

Wavelength meter	Order no.
660 / 850 nm	ZXXX-TM0
1300 / 1550 nm	ZXXX-TM0_1300
520 / 660 / 850 / 940 nm	ZXXX-TM0-4W

Interchangeable adapter, receiver side

The connector type and required wavelength are defined by means of simple push-in adapters. The basic device remains the same.

Order table

Connector type	Order no.
ST (BFOC)	ZXST-TX0
FSMA	ZSMA-TX0
F05	ZF05-TX0
HP	ZHP-TX0
HP	ZHPD-TX0
FCPC	ZFCPC-TX0

Optical transmitter – wavelength dependent on adapter

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). 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.

Order table

Wavelength transmitter	Order no.
520 to 940 nm	ZXXX-TS0
1300 nm	ZXXX-TS0-1300
1550 nm	On request

Active interchangeable adapter

The connector type and required wavelength are defined by means of simple push-in adapters. The basic device remains the same.

Order table

Connector type	Order no.
ST (BFOC)	ZXST-TS0-660
FSMA	ZSMA-TS0-660
F05	ZF05-TS0-660
HP	ZHP-TS0-650
HP	ZHPD-TS0-650

Other types on request.

Measuring devices

Microscope

Microscopes with 100x magnification are used to check the quality of the finished fiber faces of the POF and of cleaved PCF connectors.

Our camera-based microscope supplies better results. The newly developed device 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.

Order no.	ZXXX-TF0-V1
Magnification	100x

Golden Fiber – pre-assembled reference cable with MOST inserts at both ends

Length	1 m
Design	Pin – pin Pin – socket

Order table

Connector type		Order no.
ST (BFOC)	Pin – pin	KMIP-MIP17001M
FSMA	Pin – socket	KMIP-MIS17001M

Measurement kit

With transmitter and power meter – with various adapters

Contents of the measurement kit

Optical power meter with digital display
Optical transmitter, basic device with BNC connection
Transmitter adapter
Receiver adapter
2 power supply units for worldwide use
Reference cable

Order table

Measurement kit suitable for connector type	Order no.
ST (BFOC)	ZXST-KM0
FSMA	ZSMA-KM0
F05	ZF05-KM0
HP	ZXHP-KM0

Fiber optic assembly kits

K1 + K2

Fiber optic assembly kit for FSMA connectors PCF (K1)

The fiber optic assembly kits K1 and K2 are the same except for the cleave tool and microscope adapter.

Order no.	Contents of the fiber optic assembly kit
Z004-TA0-0,5-2,2	Stripper for 230 µm PCF conductors
ZXXX-TN0	Kevlar scissors
ZSMA-TW0	Cleave tool – FSMA
00405402	Container for fiber off-cuts
ZXXX-TL0	Card cleaner
ZXXX-TF0-V1	Microscope, 100x magnification
ZSMA-AF0-V1	Microscope adapter

Order table

Suitable for Simplex FSMA connectors	Order no.
For PCF cables with buffered fiber Ø 2.2 mm	SSMA-SW0-02-0010
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)

The fiber optic assembly kits K1 and K2 are the same except for the cleave tool and microscope adapter.

Order no.	Contents of the fiber optic assembly kit
Z004-TA0-0,5-2,2	Stripper for 230 µm PCF conductors
ZXXX-TN0	Kevlar scissors
ZXST-TW0	Cleave tool – PCF ST
00405402	Container for fiber off-cuts
ZXXX-TL0	Card cleaner
ZXXX-TF0-V1	Microscope, 100x magnification
ZXST-AF0-V1	Microscope adapter

Order table

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

Fiber optic assembly kit for SC connectors PCF

Order no.	Contents of the fiber optic assembly kit
Z004-TA0-0,5-2,2	Stripper for 230 µm PCF conductors
ZXXX-TN0	Kevlar scissors
ZXSC-TWO	Cleave tool – PCF
00405402	Container for fiber off-cuts
ZXXX-TL0	Card cleaner
ZXXX-TF0-V1	Microscope, 100x magnification
ZXST-AF0-V1	Microscope adapter

Order table

Suitable for Simplex SC connectors	Order no.
For PCF cables with buffered fiber Ø 2.2 mm	SXSC-SW0-02-0010
Fiber optic assembly kit	ZXSC-KW0

Fiber optic assembly kits

Fiber optic assembly kit for F05/F07 connectors PCF

Fiber optic assembly kit with crimp tool

Order no.	Contents of the fiber optic assembly kit
Z004-TA0-0,5-2,2	Stripper for 230 µm PCF conductors
ZXXX-TN0	Kevlar scissors
ZF0507-CC0-REN	Crimp tool for F05/F07 connectors – PCF
ZF07-TW0	Cleave tool – PCF F05/F07
00405402	Container for fiber off-cuts
ZXXX-TL0	Card cleaner
ZXXX-TF0-V1	Microscope, 100x magnification
ZXST-AF0-V1	Microscope adapter for F05 connectors

Order table

Suitable for 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
Fiber optic assembly kit	ZF0507-KC0

Fiber optic assembly kit for HP connectors PCF

Fiber optic assembly kit with crimp tool

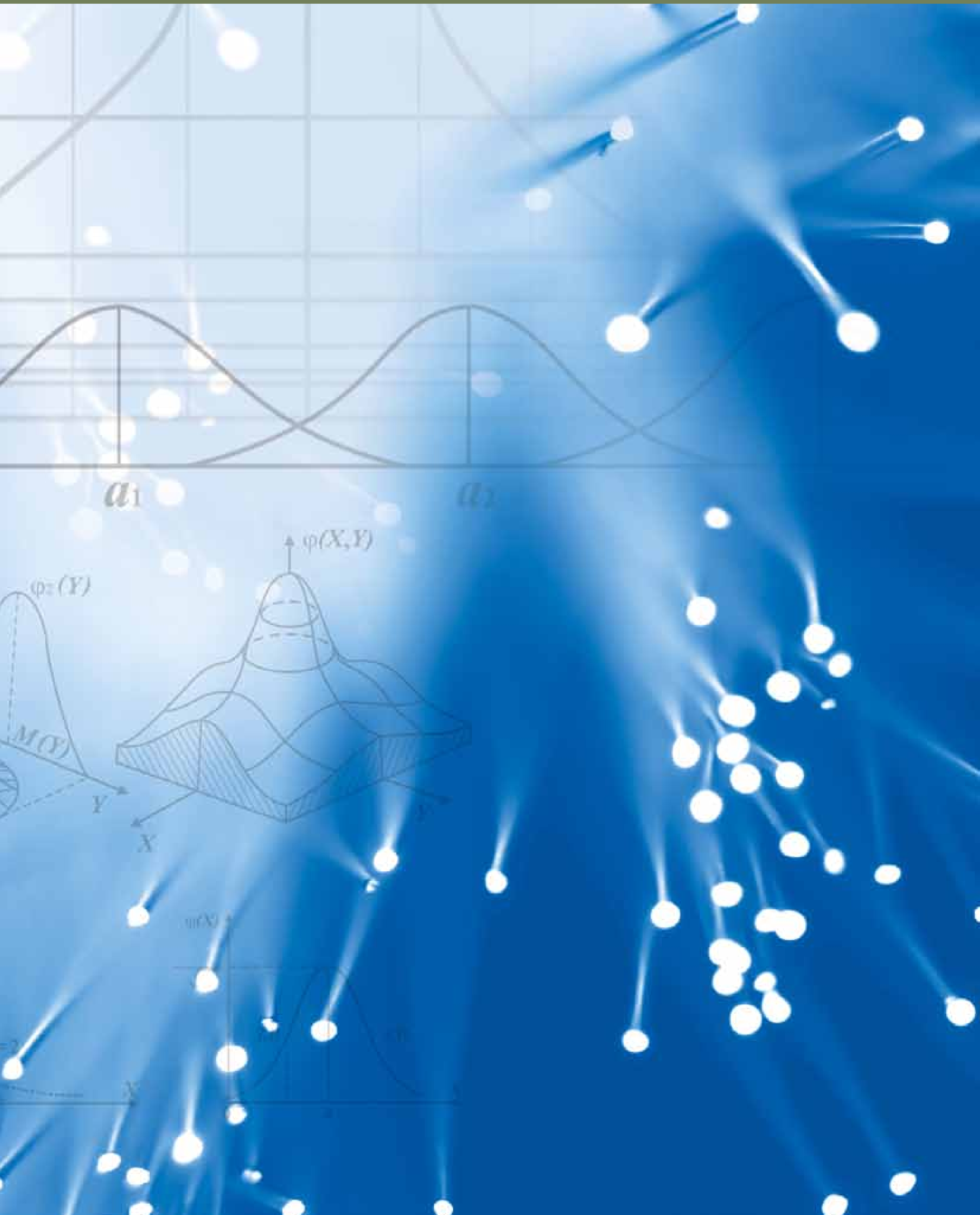
Order no.	Contents of the fiber optic assembly kit
Z004-TA0-0,5-2,2	Stripper for 230 µm PCF conductors
ZXXX-TN0	Kevlar scissors
ZXHP-CC0	Crimp tool for HP connector V-Pin, PCF
ZXHP-TW0	Cleave tool – PCF HP
00405402	Container for fiber off-cuts
ZXXX-TL0	Card cleaner
ZXXX-TF0-V1	Microscope, 100x magnification
ZXHP-AF0-V1	Microscope adapter for HP connectors

Order table

Suitable for following connectors	Order no.
Simplex HP connector 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
Fiber optic assembly kit	ZXHP-KW0

Principles

of fiber optics technology

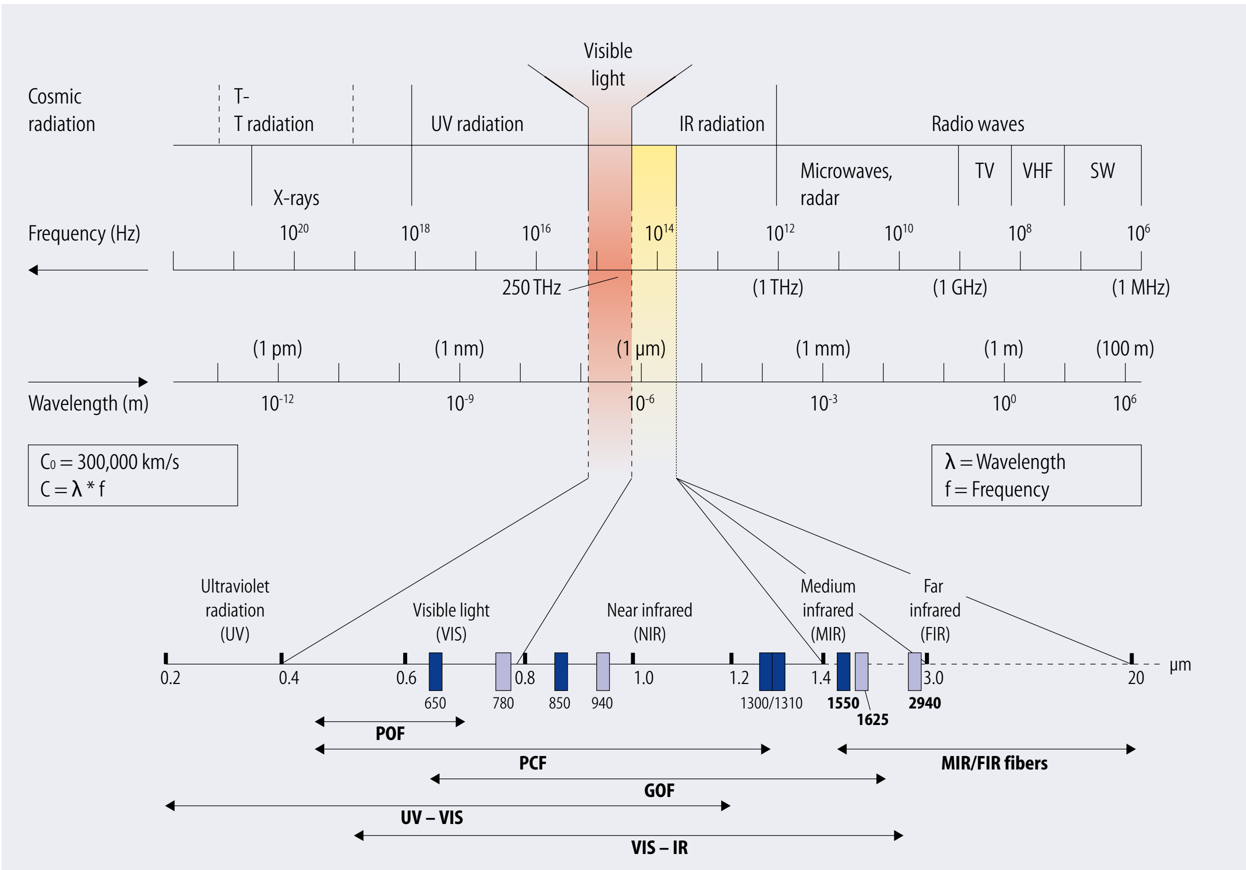


1. Optical waveguides in general

1.1. Spectrum of light

Light travels as an electromagnetic wave through a vacuum 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 infrareds (IR) (λ = 200 mm), although visible light only occupies the range from 380 nm to 780 nm. Different types of optical waveguides are used at different wavelengths depending on their transmission properties. The majority of waveguide applications extends from the near UV (300 nm and above) to the low IR range.

In a homogeneous medium, light travels in a straight line and is described by the laws of geometric optics. Geometric optics can also be used to explain the propagation behaviour in large waveguide structures, where there are many possible directions in which the light can travel (see Chapter 1.2.). However, as waveguide structures become ever smaller, the propagation of light can only be explained in terms of wave theory. The following chapters will describe the fundamental physical properties of those waveguide components manufactured by LEONI.



Principles

1.2. Propagation of light in an optical waveguide

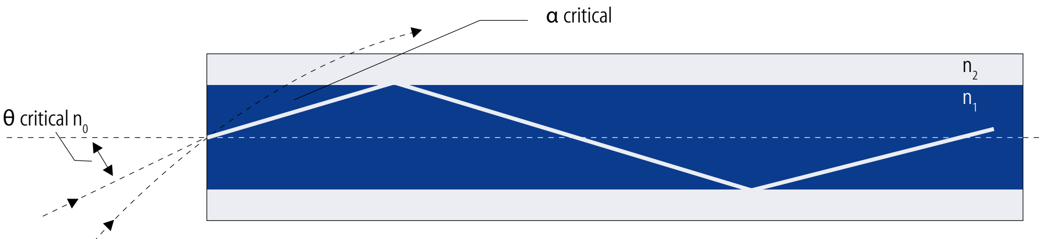
The basic principle of transmission in an optical waveguide is based on total internal reflection. When a light ray hits the boundary surface between a more optically dense medium with the refractive index n_1 and a less optically dense medium with the refractive index n_2, the ray is either refracted or totally reflected, depending on the angle of incidence α.

$$\sin \alpha / \sin \beta = n_1 / n_2$$

(α = angle of incidence, β = angle of reflection, n_1 = refractive index of the more optically dense medium, n_2 = 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 ray of light strikes the boundary is, the closer the refracted ray 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 ray of 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.

Total reflection in step-index profile - optical waveguide



1.3. Numerical aperture

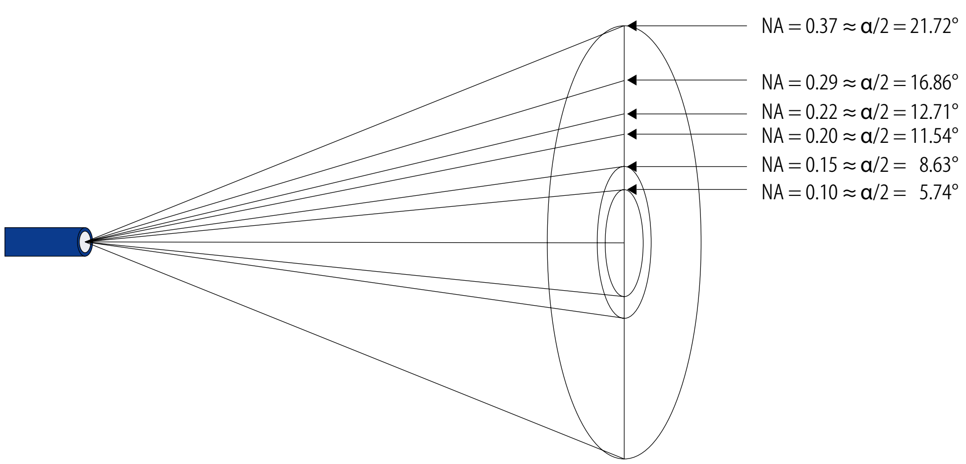
The numerical aperture is a crucial variable for the coupling of light into an optical waveguide. It is calculated from the difference between the refractive indices for the core and the cladding.

The numerical aperture *NA* is calculated using the sine of the critical angle $\theta_{critical}$ as follows:

$$NA = \sin \theta_{critical} = \sqrt{(n_1^2 - n_2^2)}$$

Only those rays of light that enter the fiber within a certain range of angles $\leq \theta_{critical}$ are guided along the fiber.

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°.



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 been 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.

2. Fiber types

In LEONI's product portfolio, a basic distinction is made between two types of fiber optic component: a) components in which the light is guided by an isolated fiber, and b) components in which the light is guided by a bundle of fibers. Individual fiber components also include components in which multiple buffered fibers are assembled in one cable. Individual fibers will be described first in the following sections, although certain fundamental properties also apply to fiber bundles. This will be followed by a specific description of the properties of fiber bundles.

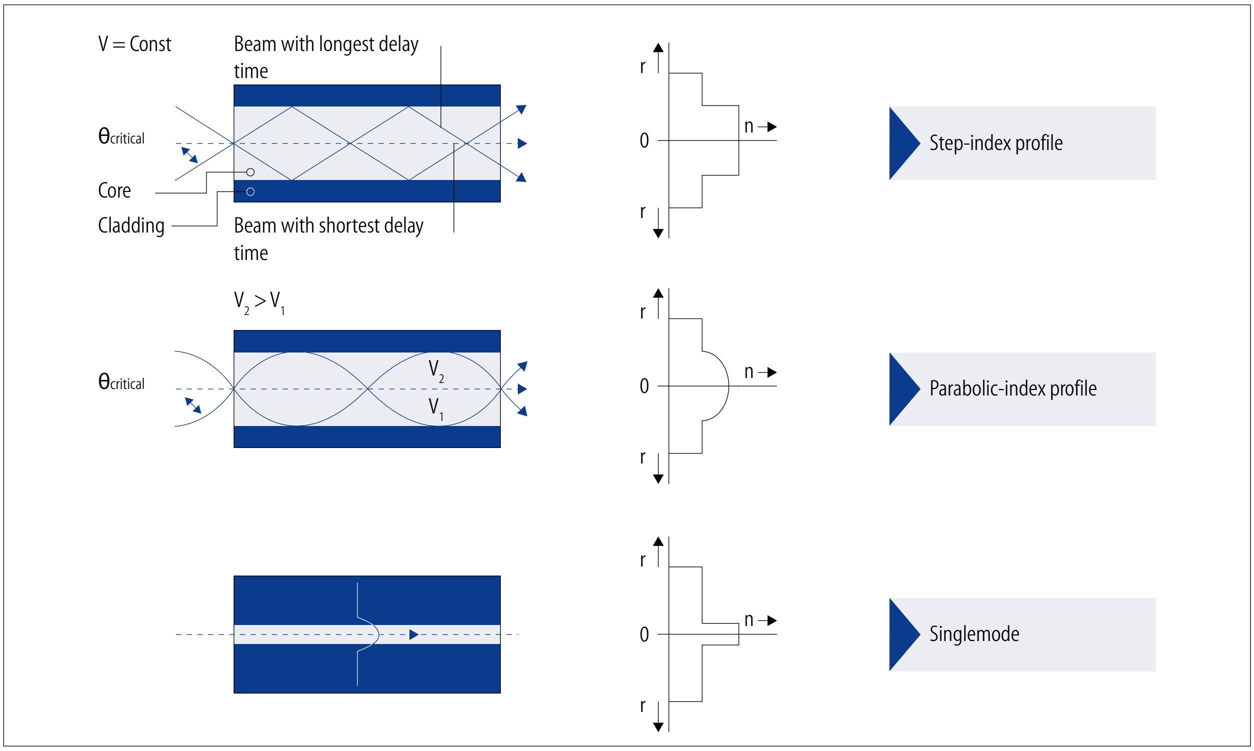
2.1. Individual fibers

The illustration below shows the most important basic types of optical fiber:

- Multimode fiber with step-index profile
- Multimode fiber with gradient-index profile
- Singlemode fiber

The most commonly used singlemode fiber is the telecommunication 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 mode-field diameter, but with a small part being guided outside the actual core in an area of the cladding close to the core. The mode-field distribution corresponds to a Gaussian curve. The actual core diameter is usually 8.2 µm with a NA of 0.14. The singlemode transmission properties of a standard telecommunication fiber span a spectral range from 1280 to 1650 nm. The critical wavelength 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 telecommunication fiber.

Utmost cleanliness of the fiber material (fused silica glass/doped silica glass) is a priority during the manufacture of standard telecommunication fibers in order to achieve maximum transmission. The typical attenuation of a modern singlemode fiber for telecommunications is 1310 or 1550 nm at <0.05 dB/km, meaning that signals can be transmitted over distances



2.1.1. 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 guided.

Singlemode fibers are preferred for applications involving long distances and wide bandwidths, as they provide the least amount of signal distortion.

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 1310 and 1550 nm without 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 transmission due to the large wavelength spacings.

The singlemode fibers used for wide area networks are non-zero-dispersion fibers (ITU-T G.655.C). They have a very low attenuation and dispersion in the C-band around 1550 nm. This permits longer lengths without the need for dispersion compensation.

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 ray quality. Generally speaking, the low attenuation over long distances is not a critical requirement for such applications.

2.1.2. 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
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 or composite glass	Doped silica or composite glass
MIR fibers	Special glass (fluoride glass, chalcogenide glass)	Special glass

The modal dispersion of step-index multimode fibers is considerable due to the different delay times.

2.1.3. Multimode gradient-index fibers

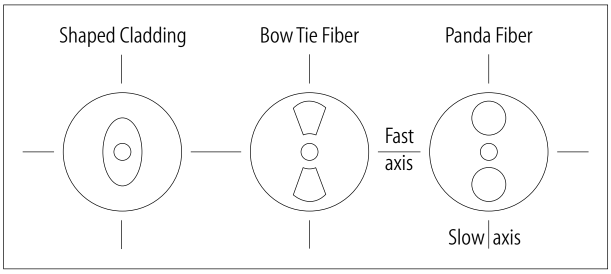
A graded refractive index together with increasing germanium doping towards the centre of the core minimises the differences in delay times for all modes and thus provides a substantial improvement in the bandwidth. The profile of the refractive index in the core is almost parabolic. These fibers bring about improvements for greater bandwidths in certain wavelength ranges.

2.1.4. 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.

2.1.5. Polarisation-maintaining fibers

A polarisation-maintaining fiber is a special type of singlemode fiber. Stress elements in the cladding create birefringence in the core for retaining the polarisation of the light guided in the fiber. There are three different types of polarisation-maintaining fiber, which differ in terms of the shape of the stress elements in the fiber.



The core diameters of the fibers correspond to 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 polarisation with small bending radii.

2.1.6. 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. For special applications, the fibers are coated with polyamide, 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.

Principles

2.1.7. 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, which is likely to ensure a long service life if observed. The probability of a fiber breaking depends on the manufacturing parameters, 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 600 x d_{core}. With a 600-µm single fiber, the minimum bending radius is therefore 36 cm.

2.2. 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.

2.2.1. 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.

The transmission property of a fiber is largely determined by the following parameters:

With multimode fibers, the bandwidth-length product of the particular fiber characterises the respective transmission property. For a Gaussian-shaped pulse:

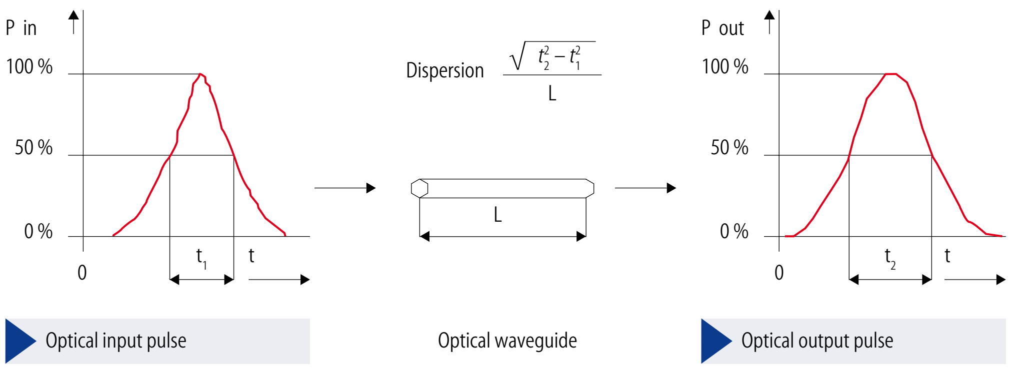
$$B*L \approx 0.44 / \Delta t * L$$

With singlemode fibers, there is also a noticeable distortion of the optical signals caused by the scattering of the delay time (dispersion). Dispersion is caused by:

- Reduction in the slope rate and overlapping of pulses increase the bit error rate and decrease the bandwidth
- Modal dispersion due to different delay times
- Material dispersion due to the frequency dependence of the refractive index (transmitter emits light at more than one wavelength); the various wavelengths propagate at different speeds (minimum approx. 1300 nm)
- Profile, waveguide, polarisation and chromatic dispersion.

Chromatic dispersion of a singlemode fiber is expressed in ps/nm*km. Its value is a function of the wavelength and has a zero-crossing point of around 1310, for example, depending on the design of the fiber.

Pulse spreading (dispersion) in the optical waveguide



The table below lists typical signal transmission properties for common fiber types:

	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
Typical wavelength used	650	650/850	850/1300	850/1300	1310/1550
Bandwidth-length product [MHz*km]					
→ 650 nm	1	17			
→ 850 nm	–	20	200	400	
→ 1300 nm	–	20	600	1200	
Chromatic dispersion →1310 nm					3.5 ps/km*nm
Chromatic dispersion →1550 nm					18.0 ps/km*nm

There is a wide variety of fibers available on the market with a correspondingly wide range of specifications.

2.2.2. Attenuation and transmission

The optical power P decreases exponentially as it passes through an optical waveguide with length L. The optical power surpasses many powers of ten, and for this reason it is common to use logarithmic notation and to specify the attenuation A in decibels (dB):

$$A = -10 \log P_0 / P_L$$

where P_0 is the optical power in mW at the beginning of an optical waveguide and P_L is the optical power in mW at the end of an optical waveguide. For the attenuation coefficient α (kilometric attenuation) where

$$\alpha = A / L$$

this yields dB/km as the unit of measure. The power, based on 1 mW, has the unit of measure of dBm, in accordance with the following definition:

$$P = -10 \log (P / 1\ \text{mW})$$

where P is the optical power in mW.

The transmission is the percentage of the light transmission in the fiber based on the injected power.

$$T = 10^{(-A*L)/10}$$

T = transmission
A = attenuation (db/km)
L = length of fiber (km)

Attenuation of the light in an optical waveguide is caused by:
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); these 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 (as do heavy metals occasionally)
- Leakage of the optical power due to excessive bending of the fiber or due to microbends – microscopic bends and turns

2.2.3. 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, the greater the losses. Fibers with a low NA are generally more sensitive than fibers with a higher NA. The bend in the fiber can have a large cable curvature but can also be on a small scale, as can occur when installing the optical cable for example. Such small-scale bends are called microbends, which also contribute to an increase in the losses.

2.2.4. Connector loss or coupling loss

In addition to the length loss in the cable, loss occurs in the area of the connectors, i.e. in the transition between the connectors at the couplings. 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 the air and the glass, which occurs with connectors with an air gap, decreases by around 8% (for fused silica glass, as a function of 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.

Connector types

- **Flat connectors with an air gap**
  SMA 905, SMA 906, HP
  high loss 0.4 – 1.5 dB
  high 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 loss 0.0 – 0.7 dB
  moderate return loss –20 to –50 dB

- **Angle-polished connectors with an air gap**
  VFO, HRL-11, EC/RACE
  high loss
  low return loss

- **Angle-polished connectors with physical contact (/APC)**
  DIN-APC, FC-APC, E2000-APC, SC-APC
  low loss
  lowest return loss < –55 db

- **Connectors with multiple fibers in one ferrule**
  MT, MP, MPO, MTRJ (SCDC, SCQC)
  up to 24 fibers in one ferrule
  high loss
  moderate to low return loss –20 to < –55 dB

- **Connectors with 1.25-mm ferrule**
  MU, LC, LX.5, F 3000
  quick assembly
  high packing density
  low loss
  moderate to lowest (/APC design)
  return loss –20 to <–55 dB

- **Connectors without a 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 in the same housing**
  hybrid connector
  application-specific design

2.3. 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.

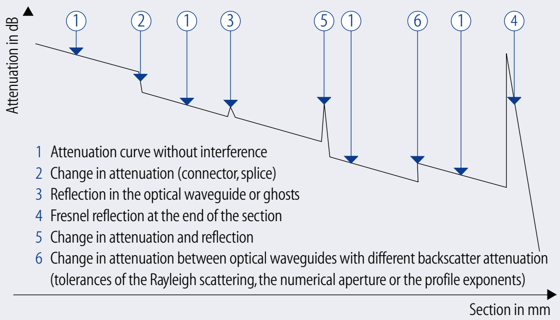
Direct-light method	Backscattering method
POF, PCF + Glass	**PCF + Glass**
Total attenuation of a section	Total attenuation of a section
Spatial separation of the measuring instruments	Only connected at one end
Very accurate result	Technically tolerable result
No evaluation of interfaces	Evaluation of interfaces
No localisation of defects	Localisation of defects
No distance measurement	Distance measurement

2.3.1. Backscattering method

OTDR measuring instruments, as are available commercially in various forms, are suitable for measuring a backscatter curve. The diagram below schematically shows a measured curve like those that can be plotted for a section of fiber using such instruments.

Backscattering measurement

Backscatter curve with typical results



2.3.2. 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_L [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_L:

$$A = P_0 - P_L$$

If the path attenuation is much greater than the connector loss, the attenuation coefficient α [dB/m] can be calculated as follows:

$$\alpha = A/L = (P_0 - P_L)/L$$

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:

$$A = -P_{test} - P_{ref}$$

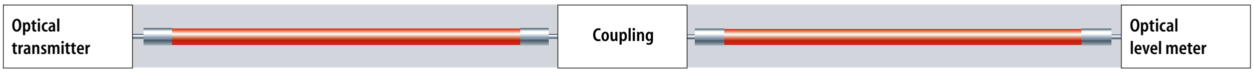
In this case, the transmitter should have radiation characteristics typical of the application. This method is described in IEC 60793-1-40.

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 B, the entire cable is tested by means of one single measurement.

The different test set-ups could result in different values in the order of 0 to approx. 2 dB, depending on the type of fiber and connector.

2.3.3. Attenuation measurement of glass and PCF assemblies per IEC 61300-3-4 method B

The optical power Ps in dBm at the end of the reference cable is determinded in a reference measurement.



Basic device with adapter or existing transmitter with permanent light

The reference with 5 windings can be eliminated.

The cable to be tested is inserted between the reference cable and the optical level meter by means of a coupling. The optical power PL in dBm is determinded.

Basic device with adapter or existing transmitter with permanent light

Measurement 2 must be repeated after the cable under test has been rotated, as so far only the attenuation at the coupling has been calculated. The worse value of the two must be used. Attenuation A = PL – Ps [dBm].

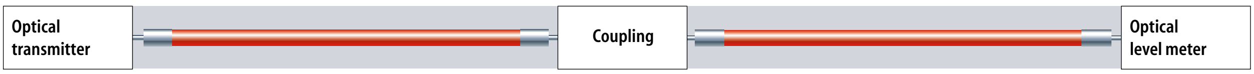
During the evaluation, a comparison is made with the allowable limit value for attenuation.
The relevant standards, such as IAONA, specify an attenuation of 0.75 dB with MM and SM glass (standard) for a coupled connector pair.

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 1310 nm
for glass MM 62.5/125	typ. 3.0 dB/km	at 850 nm
	typ. 0.8 dB/km	at 1310 nm
	typ. 10 dB/km	at 660 nm
	typ. 8 dB/km	at 850 nm

2.3.4. Attenuation measurement of glass and PCF assemblies per IEC 61300-3-4 method C

The optical power Ps in dBm at the end of the inserted reference cable is determinded in a reference measurement.



Basic device with adapter or existing transmitter with permanent light

In order to largely eliminate cladding modes during the measurement, the launching and lead-out reference must have 5 windings around a mandrel with a diameter of approx. 20 mm.

The coupling is opened and the cable under test is inserted. The measurement of the optical power PL (in dBm) is then carried out at the end of the section.

Basic device with adapter or existing transmitter with permanent light

The attenuation at A = PL – Ps [dBm].

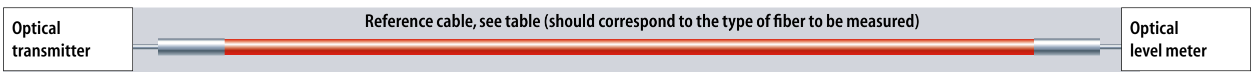
During the evaluation, a comparison is made with the permitted limit value for attenuation.
The relevant standards, such as IAONA, specify an attenuation of 0.75 dB with MM and SM glass (standard) for a coupled connector pair.

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
	typ. 10 dB/km	at 660 nm
	typ. 8 dB/km	at 850 nm
for PCF	typ. 10 dB/km	at 660 nm
	typ. 8 dB/km	at 850 nm

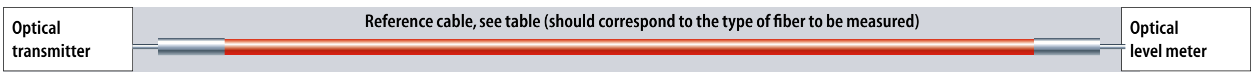
2.3.5. Attenuation measurement of POF and PCF assemblies per IEC 60793-1-40 B

The optical power Ps in dBm at the end of the reference cable is determinded in a reference measurement.



Basic device with adapter or existing transmitter with permanent light

The measurement of the optical power [PL] is carried out at the end of the cable to be tested having length L.



Basic device with adapter or existing transmitter with permanent light

This yields an attenuation at $A = P_L – P_S$ [dB].

From this you can derive the attenuation coefficient α = PL/PS [dB/km] (L is the length of the cable under test in km).

Comparison with the allowable limit value:

Attenuation

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

Reference cable for the attenuation measurement

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

Use this method if the assemblies are to be utilised for direct transmitter/receiver connections or the couplings are unsuitable for measurements.

Attenuation measurement – a straightforward method for use in practice

Tip

If you use PCF fibers in systems for POF (660 nm) and your system is not specified explicitly for PCF fibers, proceed as follows:

- Use a POF cable as the reference cable instead of a PCF cable
- Attenuation:
  $A = P_L$ (PCF cable) – P_S (POF reference)
  During the evaluation, the maximum allowable attenuation specified for the system with POF must be greater than the attenuation determined in this way.

Experience has shown this method to be one of the most reliable, but you cannot determine the attenuation coefficient in this way. It is better to use the transmitter that is built into the system (and not the transmitter described above).

2.3.6. Comparison of attenuation and transmission

In fiber optics, the terms attenuation and transmission are used when describing the power of an optical waveguide.

Attenuation

Attenuation describes the energy loss of the light ray as it passes along a fiber. Its value depends on the wavelength used and the length of the fiber. The attenuation value of a fiber is usually expressed in dB/km.

Transmission

Transmission describes the output power of an optical waveguide, taking the losses into consideration. It is given as a percentage of the injected power. The transmission is also dependent on the wavelength used and the length of the fiber. Transmission is expressed as a percentage.

Examples of converting attenuation into transmission

The attenuation value of a PMMA fiber is 150 dB/km. You need to work out the transmission value of this fiber at a length of 35m.

$$T = 10^{(-A \cdot L)/10}$$
$$T = 10^{(-150\ \mathrm{dB/km} \cdot 0.035\ \mathrm{km})/10}$$
$$T = 0.29 = 29\%$$

The attenuation value of a fiber of 6 dB/km signifies a transmission of 25% for 1 km of fiber.

$$T = 10^{(-A \cdot L)/10}$$
$$T = 10^{(-6\ \mathrm{dB/km} \cdot 1\mathrm{km})/10}$$
$$T = 0.25 = 25\%$$

A = attenuation [dB/km]
L = length of the fiber [km]
T = transmission

2.4. Ageing

The ageing of fibers is usually associated with a deterioration in the transmission properties. In addition to the fiber ageing described here, signs of fatigue and wear also occur at the connecting systems.

2.4.1. Ageing of glass fibers

Material and environmental effects determine how quickly fibers age. 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 cracks develop at a statistically distributed rate as these are defects with a statistical distribution. Mathematically, the probability of a breakage as 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:

$$F = 1-\exp\{-L/L_0\cdot(\sigma/\sigma_0)^a \cdot (t/t_0)^b\}$$

The values with the index 0 denote the parameters for the reference test that was conducted. Parameters a and b must be calculated through experimentation.

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.

For fibers that are radiated with ultraviolet light or X-rays, ageing causes colour centres or defects which could result in a marked increase in attenuation, even to the extent of blackening. Special doped fibers with low ageing characteristics are available for radiation-intensive applications.

2.4.2. 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.

2.5. 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.

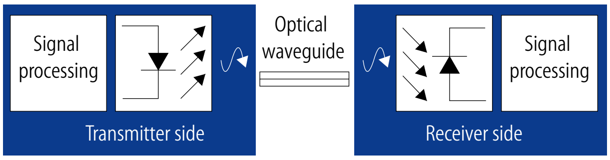
2.5.1. Applications

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 fiber
Electromagnetic compatibility (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 ++

In the simplest scenario, a transmission link of optical fibers comprises:
- optical transmitter
- optical waveguide
- optical receiver

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.

Typical components:
- optical transmitter: LEDs or laser diodes (VCSEL – advantage: little beam divergence, greater modulation rates compared with LED)
- optical receiver: PIN diodes or avalanche diodes

The wavelength ranges 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.

	Silicon (Si)	Germa-nium (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

The criteria by which the most suitable fiber is selected will be explained with reference to a few examples.

For example, 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 moderate 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.

3. Cables

The fibers described in Chapter 2 (physical principles) respond very sensitively to mechanical stress such as tensile, bending and torsional stress through large increases in attenuation. They are also not able 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.

3.1. 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. 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 three distinct types of buffered fiber construction:

A. 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 have a viscosity that is as constant as possible over the cable's entire operating temperature range so that they do not freeze 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.

B. Plastic tubes are buffered fibers in which just one fiber is surrounded by a buffer tube. Otherwise, in principle 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.

C. Tight buffered fibers are buffered fibers in which just one fiber is surrounded by a buffer tube. Unlike 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. Because 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.

D. 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.

Standard diameters of buffered fibers are:

Multi-fiber loose tubes for stranded cable constructions having 2 fibers	2.0 mm
Multi-fiber loose tubes for stranded cable constructions having 4 to 12 fibers	2.4 mm
Multi-fiber loose tubes for central constructions having 2 to 12 fibers	3.5 mm
Multi-fiber loose tubes for central constructions having 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

3.2. 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 twisted in layers around a central element to achieve better cable flexibility. The twisting 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. Furthermore, 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, when 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 a core filler 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 entire length of the cable.

The choice and size of the cable jacket are crucial. It 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 the jacket for fiber optic cables:

- Non-halogen, flame-retardant materials (type rating 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.

- Polyethylene (type rating 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, type rating Y) for cables with greater requirements with regard to resistance to chemical media in industrial settings.

- Polyurethane (type rating 11Y) for cables that are designed for continuous movement, e.g. in cable carriers, and are subject to extreme mechanical stresses, such as abrasion and crushing pressure, and are resistant to oil.

- Polyamide (type rating 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.

- Fluorines (type rating 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. There are therefore a number of different technical solutions 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 being accidentally energized when installing the cable.

One of the simplest designs of non-metallic rodent protection is glass rovings under the jacket. The glass rovings provide two different functions: a 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. Furthermore, the metal elements mean that 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.

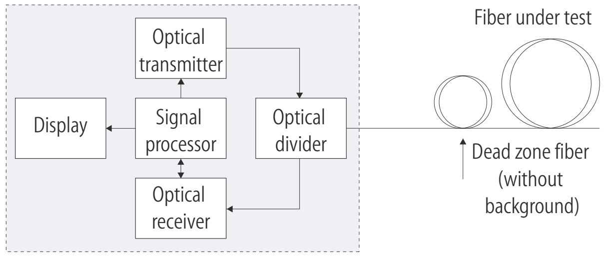
For effective protection against the ingress of water into the cable core, a film of aluminium at least 0.15 mm thick can be provided under the jacket as a diffusion barrier. This film is permanently bonded to the jacket.

3.3. Tests on cables

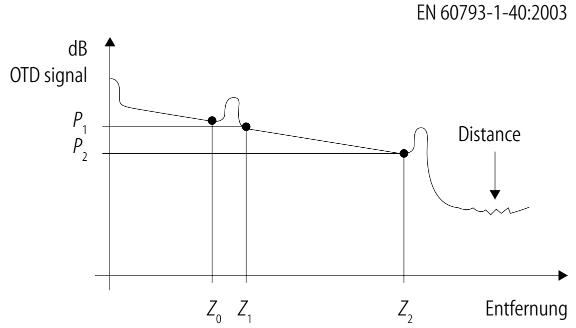
The standards listed below are relevant for testing the properties of fiber optic cables:

3.3.1. IEC 60793-1-40 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) 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.



Block diagram of an OTDR

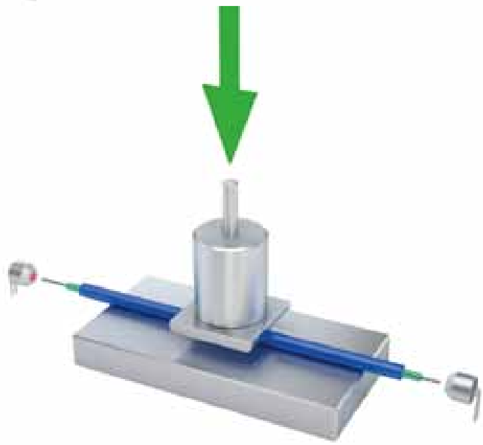


Schematic OTDR curve for a "uniform" test specimen with upstream dead zone fiber

3.3.2. IEC 60794-1-2
For testing 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.

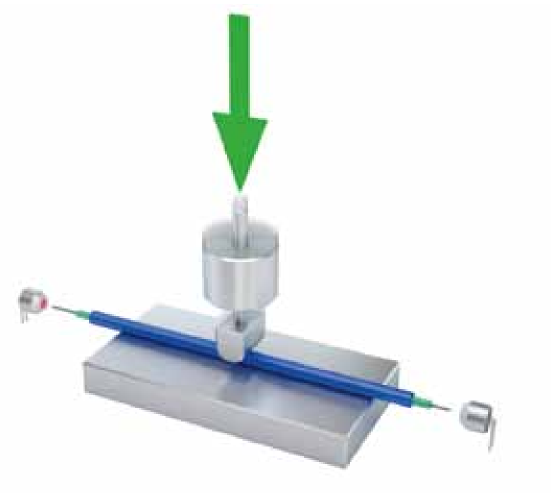


Method E3: Cable crush test

This test determines the ability of a fiber optic cable to withstand crushing 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.

Alternatively, one or more steel mandrels 25 mm in diameter can be inserted at right angles into the specimen. The optical transmission of the fibers (breakage) or the increase in attenuation of the device under test is monitored during and after the test.



Method E4: Cable impact test

The test determines the ability of a fiber optic cable to withstand one or more impacts. The device under test is placed on a flat steel plate and subjected to a specified drop energy (can be determined via mass and height of drop). 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 fibers (breakage) or the increase in attenuation of the device under test is monitored during and after the test.

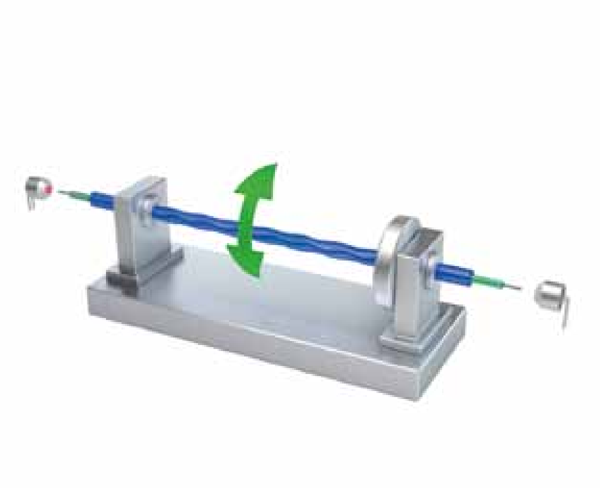
Method E6: Repeated bending

The test determines the ability of a fiber optic cable to withstand repeated bending.

During this test, the device under test is bent by ±90° (i.e. 180° from end position to end position).
The following must be specified for the test:

- Number of cycles
- Bending radius
- Tensile load

The optical transmission of the fibers (breakage) or the increase in attenuation of the device under test is monitored during and after the test.



Method E7: Torsion

The test determines the ability of a fiber optic cable to withstand mechanical twisting.

The device under test is clamped by two clamps and twisted by ±180° (i.e. by 360° from end position to end position).
The following must be specified for the test:

- Twisted length
- Number of cycles
- Tensile load applied

The optical transmission of the fibers (breakage) or the increase in attenuation of the device under test is monitored during and after the test.

Method E8: Flexing test

The test determines the ability of a fiber optic cable to withstand 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.

The following must be specified for the test:

- Diameter of the pulleys A and B
- Length of displacement path of the carriage
- Number of cycles
- Mass of the weights attached (tensile load applied)

The optical transmission of the fibers (breakage) or the increase in attenuation of the device under test is monitored during and after the test.

Method E11A: Cable bend

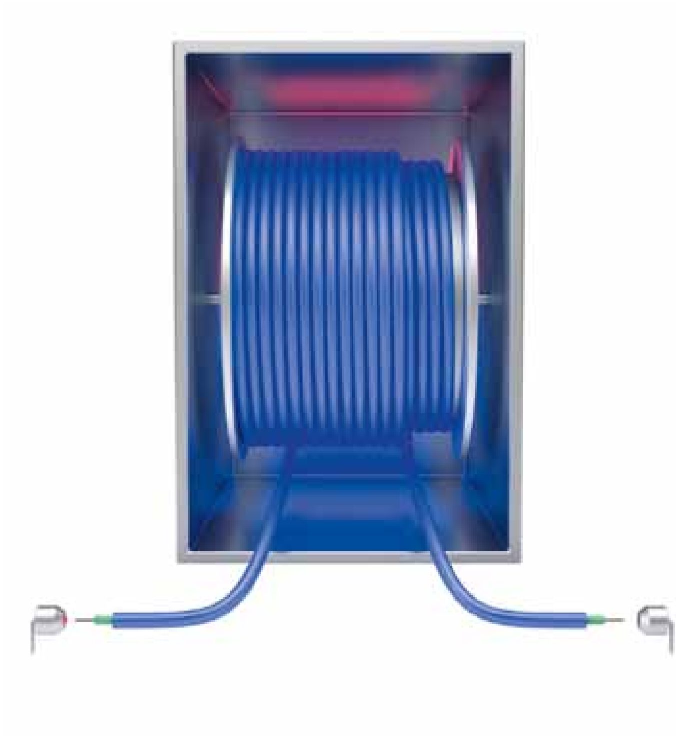
The purpose of this test is to determine the ability of a fiber optic cable to withstand bending about a test mandrel.

The device under test is wound tightly in a coil around a mandrel and then wound in the opposite direction.

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 fibers (breakage) or the increase in attenuation of the device under test is monitored during and after the test.



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. Loose coils are preferred where possible, as this avoids the influences due to the coefficients of expansion of the reel. In practice, however, it is often not possible to wind suitably long lengths of relatively thick cables 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 the 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 the event 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.

The following must be specified for the test:

- Sample length
- Duration of the test
- The method used, A or B

The standard test parameters are:
24 hours · 3 m of cable · 1 m water column

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

3.3.3. 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.

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, 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. Please contact us if the criteria for your particular application are not met by the cable structures in this catalogue. Additional requirements can often be met through customised measures when making the jacket (e.g. aluminium tape or 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. 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 how fires spread through cables and about the potential hazards for man and materials in the event of a cable fire.

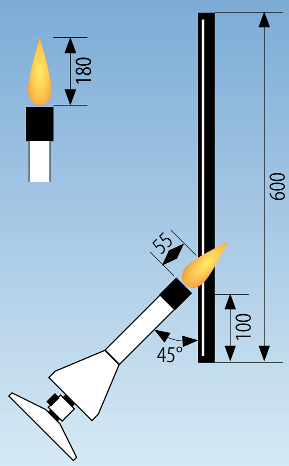
The corresponding tests investigate:
- the flammability of non-metallic cable components
- the toxicity of the fire by-products, particularly the combustion gases
- how a fire spreads along a cable
- the smoke density in the event of a fire
- the corrosiveness of the combustion gases

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.

3.3.3.1. Overview of the standards for fire tests on cables

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 bunched cables
(DIN VDE 0472 Part 813)	IEC 60754-1 and 2	Corrosiveness of gases evolving during combustion (absence of halogen)
(DIN VDE 0472 Part 816)	IEC 61034-1 and -2	Measurement of smoke density
DIN VDE 0472 Part 184	IEC 6033-11 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

Flammability and fire propagation



1.1 IEC 60332-1-2 / EN 50265-2-1 / VG 95218-2 Method 1 / BS 4066 Part 1

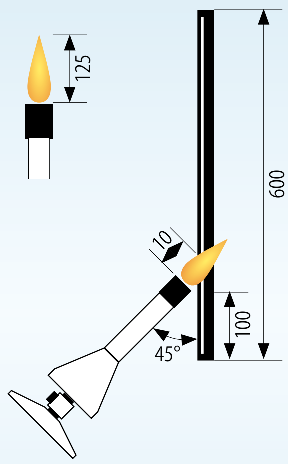
Test set-up The single cable under test is secured vertically and flamed with a Bunsen burner at an angle of 45° to the vertical.

Flame temperature Determined by the stipulated setting of the Bunsen burner flame.

Test duration

Cable with a diameter of ≤ 25 mm:	60 seconds
Cable with a diameter of 25 < D < 50 mm:	120 seconds

Compliance criterion The fire damage must end at least 50 mm below the upper fixing clamp. The cable must be self-extinguishing.



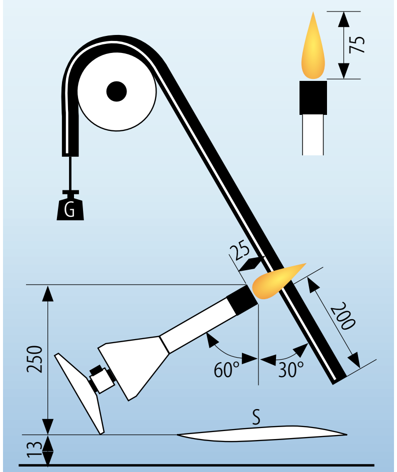
1.2 IEC 60332-2 / EN 50265-2-2 / VG 95218-2 Method 2 / BS 4066 Part 2

Test set-up The single cable under test is secured vertically and flamed with a Bunsen burner at an angle of 45° to the vertical.

Flame temperature Determined by the stipulated setting of the Bunsen burner flame.

Test duration 20 seconds

Compliance criterion The fire damage must end at least 50 mm below the upper fixing clamp. The cable must be self-extinguishing.



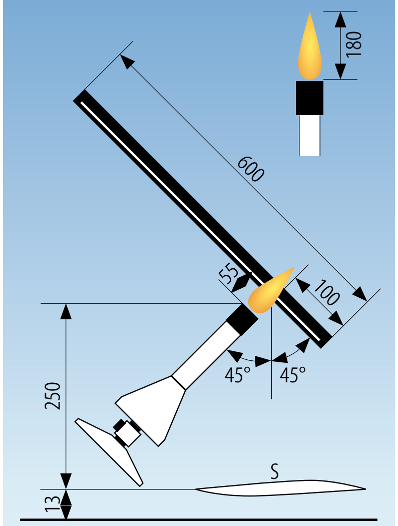
1.3 MIL-W-22758 / MIL-W-8104 / VG 95218-2 Method 4

Test set-up The single cable under test is weighted over a pulley and secured at an angle of 30° to the vertical. The Bunsen burner flame is directed at the cable from below at an angle of 60° to the vertical. Tissue paper (S) is spread out underneath the sample.

Flame temperature At least 950 °C

Test duration 30 seconds

Compliance criterion 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.



1.4 VG 95218-2 Method 3

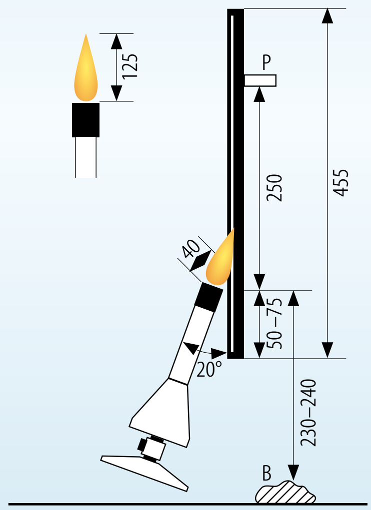
Test set-up
The single cable under test is weighted over a pulley and secured at an angle of 30° to the vertical. The Bunsen burner flame is directed at the cable from below at an angle of 60° to the vertical. Tissue paper (S) is spread out underneath the sample.

Flame temperature
Determined by the stipulated setting of the Bunsen burner flame.

Test duration

Cable with a diameter of ≤ 25 mm:	60 seconds
Cable with a diameter of 25 < D < 50 mm:	120 seconds

Compliance criterion
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.



1.5 UL 1581 Section 1060 (FT1) / Section 1061 (Cable Flame) / Section 1080 (VW-1)

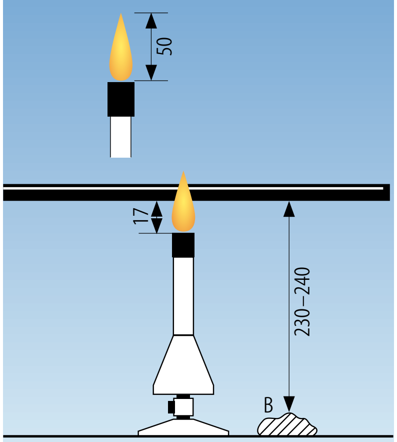
Test set-up
The cable is secured vertically and provided with a paper indicator flag (P, 10 x 20 mm). A Bunsen burner is used to apply the flame and it is secured at an angle of 20° to the vertical.

Flame temperature
Determined by the stipulated setting of the Bunsen burner flame.

Test duration

Section 1060:	5 cycles of flame application for 15 seconds with a break of 15 seconds
Section 1061:	3 cycles of flame application for 60 seconds with a break of 30 seconds
Section 1080:	5 cycles of flame application for 15 seconds with a break of 15 seconds and a maximum break of 60 seconds

Compliance criterion
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.



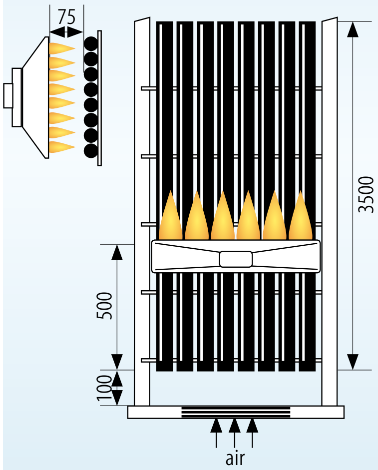
1.6 UL 1581 Section 1090 (H) / Section 1100 (FT2)

Test set-up
The cable is secured horizontally and vertically and flamed with a Bunsen burner (the burner is tilted at an angle of 20° for the FT2 test). Cotton wadding (B) is placed next to the Bunsen burner.

Flame temperature
Determined by the stipulated setting of the Bunsen burner flame.

Test duration
30 seconds

Compliance criterion
The cotton wadding (B) must not be ignited by dripping material.
Section 1090: The propagation speed of the flame must not exceed 25 mm/min.
Section 1100: The length of the charred section on the sample must not exceed 100 mm.



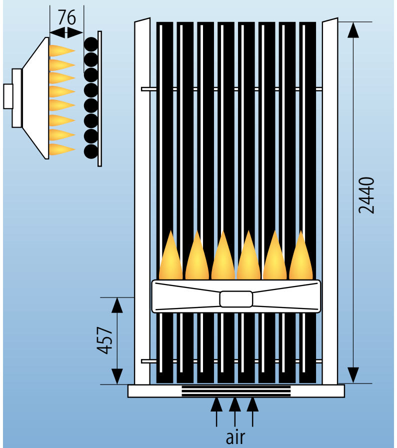
1.7 IEC 60332-3 / EN 50266-2

Test set-up
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.

Flame temperature
Determined by the stipulated quantity of propane gas and air.

Test duration
IEC Part 21/EN Part 1: Category A F/R for special applications only
IEC Part 22/EN Part 2: Category A (7 l flammable material/m): 40 minutes
IEC Part 23/EN Part 3: Category B (3.5 l flammable material/m): 40 minutes
IEC Part 24/EN Part 4: Category C (1.5 l flammable material/m): 20 minutes
IEC Part 25/EN Part 5: Category D (0.5 l flammable material/m): 20 minutes

Compliance criterion
The visible area of fire damage to the cables must not exceed 2.5 m in height from the bottom edge of the burner.



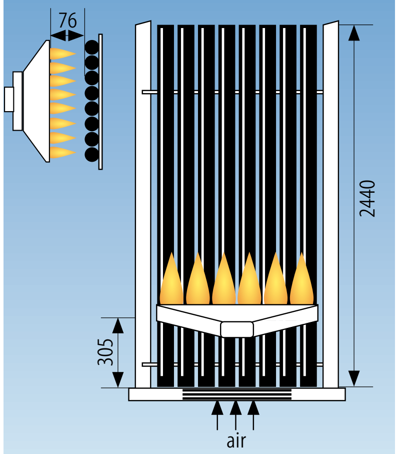
1.8 UL 1685 Vertical Tray

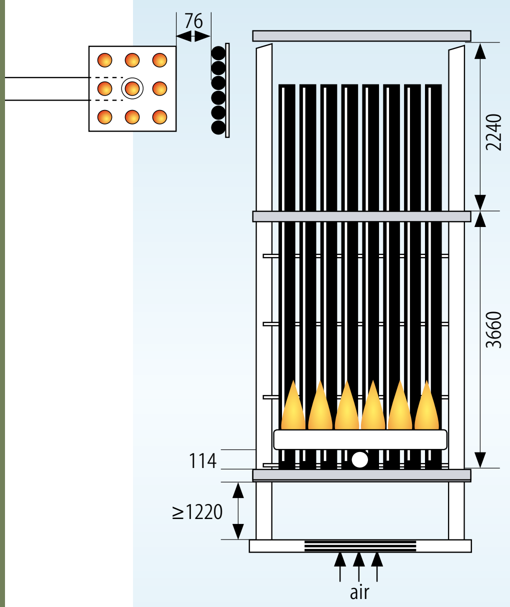
Test set-up
The cables are secured to a ladder in a single layer (quantity depends on the diameter of the cable). The length of each sample is 2.44 m.

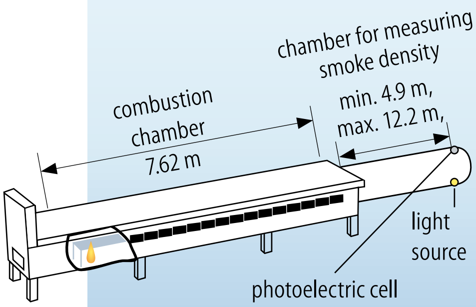
Flame temperature
Determined by the stipulated quantity of propane gas and air.
The power equals 20.5 kW (70,000 Btu/hr).

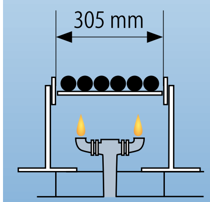
Test duration
20 minutes (2 tests to be performed)

Compliance criterion
The area of fire damage to the cables must be less than 2.44 m (measured from the bottom of the ladder).









1.9 UL1685 FT4 / IEEE 1202

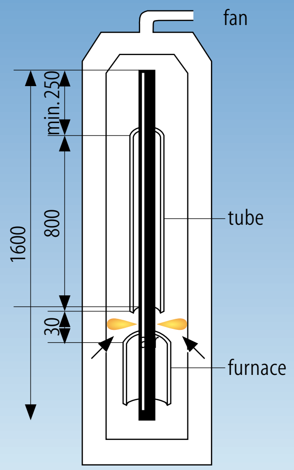
Test set-up	The cables are secured to a ladder in a single layer (quantity depends on the diameter of the cable). The length of each sample is 2.44 m. Cables with a diameter of <13 mm are secured to the ladder in bundles. The burner is tilted at an angle of 20°.
Flame temperature	Determined by the stipulated quantity of propane gas and air. The power equals 20.5 kW (70,000 Btu/hr).
Test duration	20 minutes (2 tests 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).

1.10 UL 1666 Riser

Test set-up	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.
Flame temperature	Determined by the stipulated quantity of propane gas and air. The power equals 154.5 kW (527,500 Btu/hr).
Test duration	30 minutes (2 tests to be performed)
Compliance criterion	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.

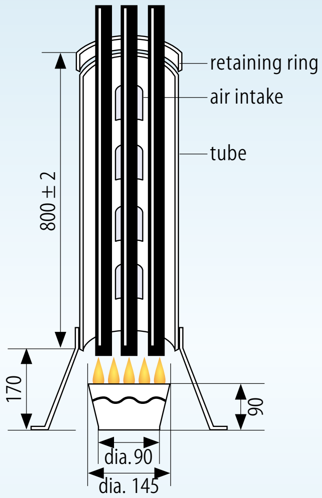
1.11 NFPA 262 / FT6 Steiner Tunnel (UL 910 withdrawn)

Test set-up	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.
Flame temperature	Determined by the stipulated quantity of propane gas and air. The power equals 86 kW (294,000 Btu/hr).
Test duration	20 minutes (2 tests to be performed)
Compliance criterion	The area of fire damage to the cables must not exceed 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%).



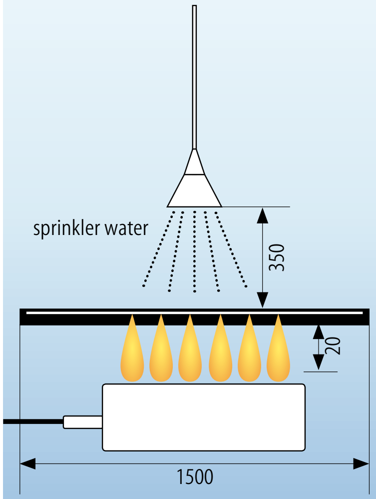
1.12 NF C32-070 Test 2 / UIC 895 VE Appendix 7

Test set-up	The cable is secured vertically in a furnace with a subsequent tube (125 mm in diameter).
Flame temperature	830 °C ± 50 °C
Test duration	30 minutes
Compliance criterion	The end of the cable protruding from the top of the tube must not be damaged.



1.13 Def. St. 02-641 (formerly NES 641)

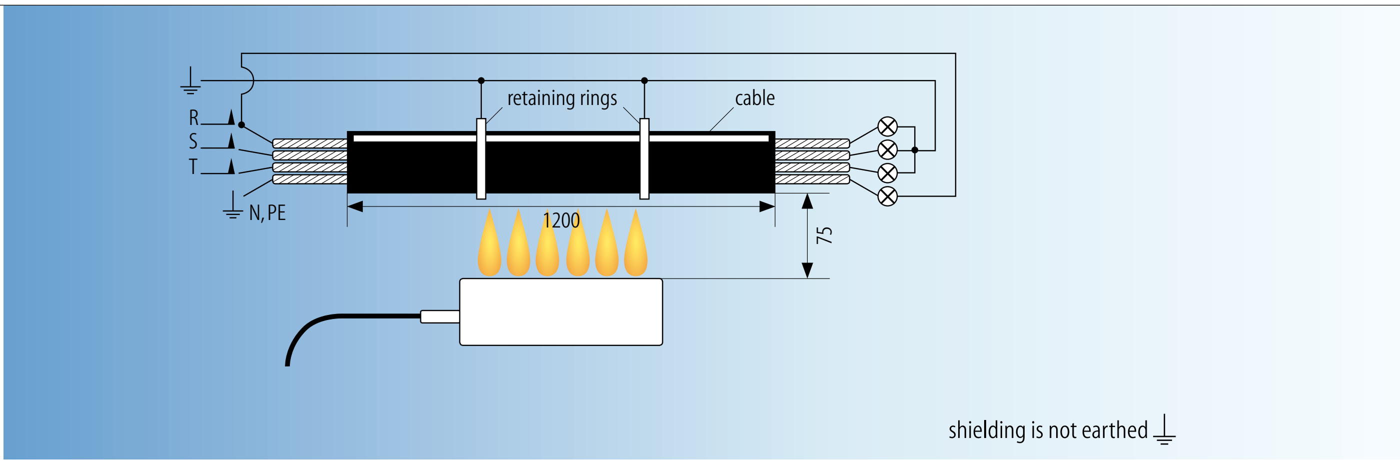
Test set-up	Three cables are secured vertically in a tube (“Swedish chimney”). A flame is applied by burning liquid, which is in a dish underneath the tube.
Flame temperature	Is determined by the flammable liquid.
Test duration	Until all the liquid has burned off.
Compliance criterion	The visible area of fire damage to the cables must not exceed 250 m down from the top edge of the cable.



1.14 BS 6387 Category W

Test set-up	The cable is laid horizontally. The buffered fibers and shielding must be connected to a power supply with a voltage of U_0/U. The flame is applied across a width of 1500 mm. After 15 minutes a sprinkler is turned on.
Flame temperature	650 °C ± 40 °C
Test duration	30 minutes (2 tests to be performed)
Compliance criterion	When 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.

Principles



1.15 DIN VDE 0472-814 / BS 6387 Category C

Test set-up The cable is laid horizontally. The buffered fibers and shielding must be connected to a power supply having the following voltages:

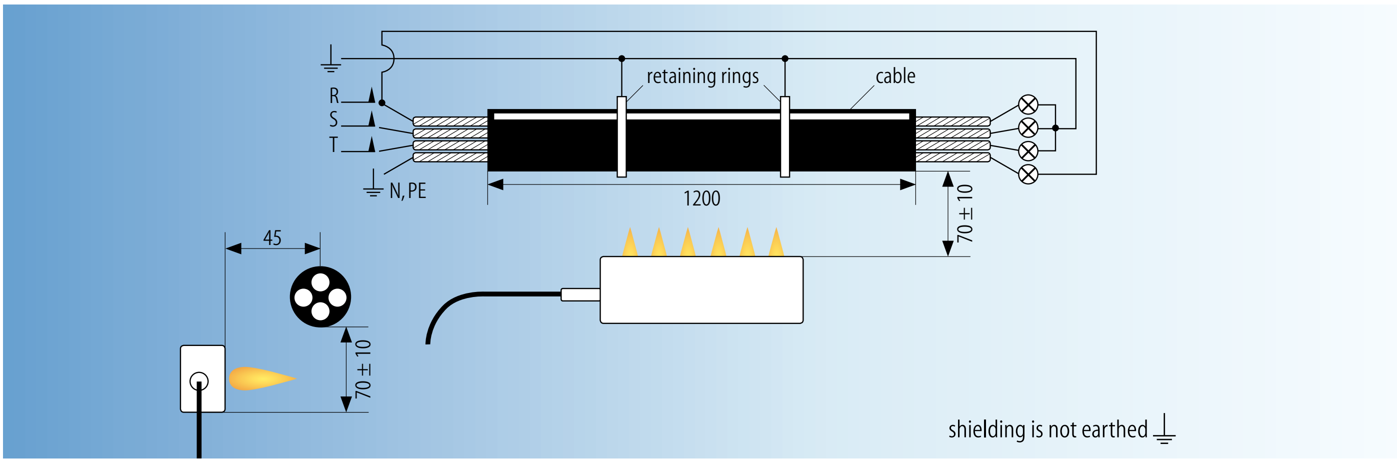
- Data cables: 110 V
- Power cables 0.6/1 kV: 230/400 V
- BS: all cables U_0/U

The flame is applied from below across a width of 1200 mm. The flame is directed at the cable.

Flame temperature Min. 750 °C
BS: 950 °C ± 40 °C

Test duration 180 minutes

Compliance criterion When 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.



1.16 IEC 60331-21/IEC 60331-23

Test set-up The cable is laid horizontally. The buffered fibers and shielding must be connected to a power supply having the following voltages:

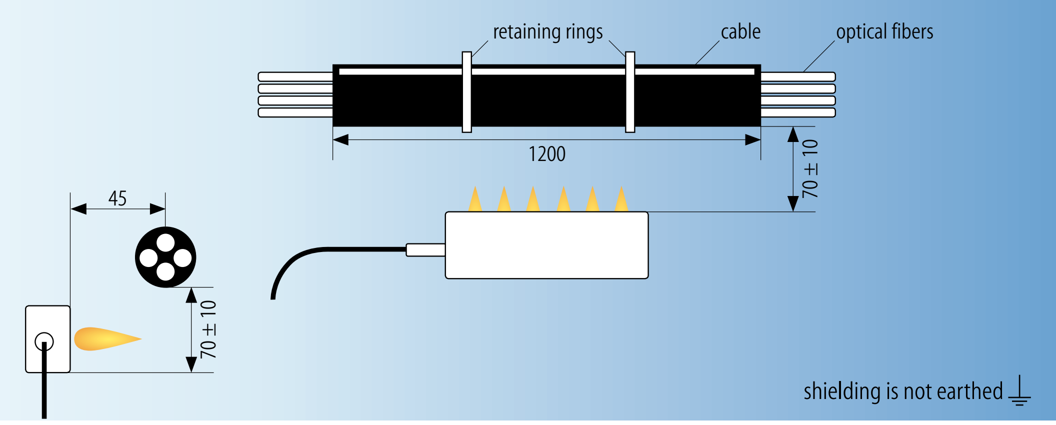
- Power cables 0.6/1 kV: U_0/U min. 100 V
- Data cables: 110 V

The flame is applied under the cable from a horizontally offset position across a width of 1200 mm.

Flame temperature At least 750 °C (equipment IEC 60331-11)

Test duration Recommended: 90 minutes

Compliance criterion When 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.



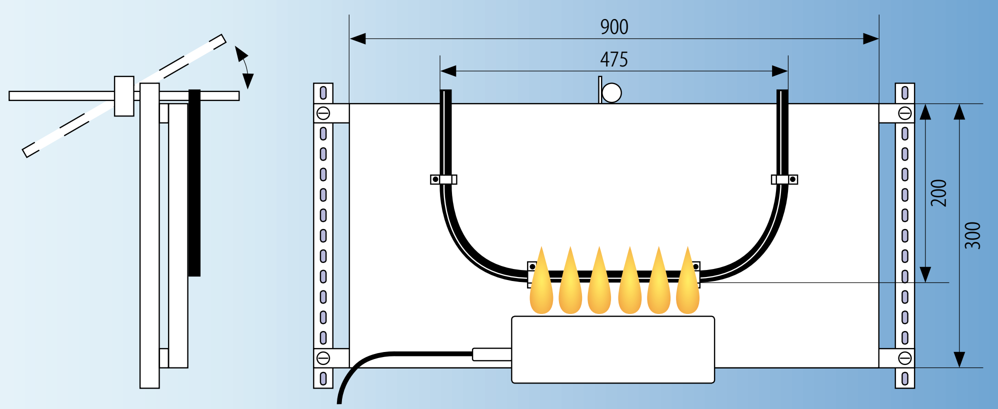
1.17 IEC 60331-25

Test set-up 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.

Flame temperature At least 750 °C (equipment IEC 60331-11)

Test duration 90 minutes

Compliance criterion When 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.



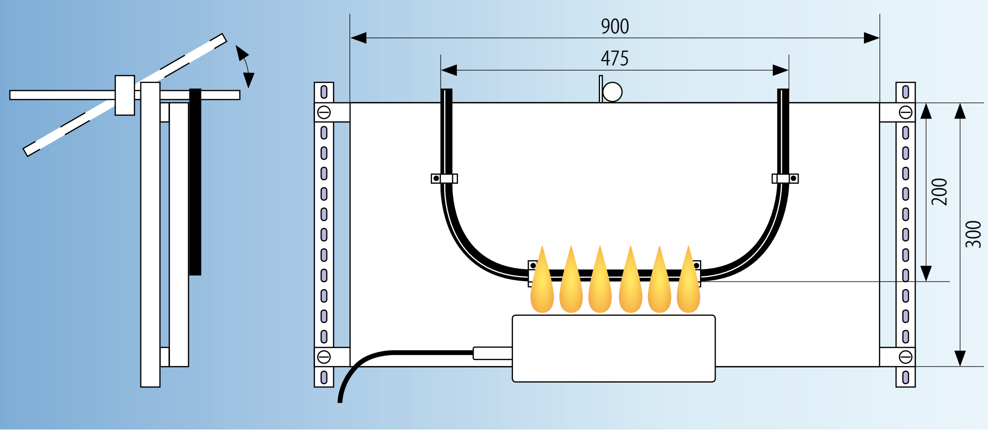
1.18 IEC 60331-31

Test set-up The cable is secured onto a positioning board and a flame is applied from the front. The positioning board is subjected to shocks every 5 minutes during the combustion period.

Flame temperature At least 830 °C (equipment IEC 60331-12)

Test duration Recommended: 120 minutes

Compliance criterion When 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.



1.19 EN 50200

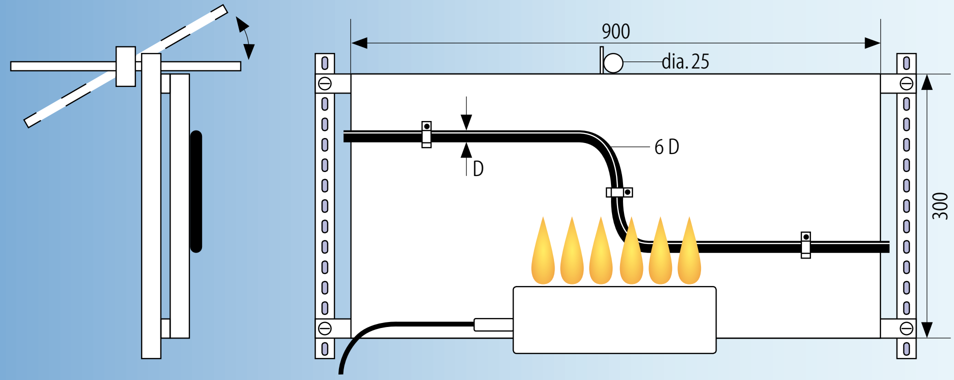
Test set-up The cable (max. 20 mm in diameter) is secured onto a positioning board and a flame is applied from the front. The positioning board is subjected to shocks every 5 minutes during the combustion period.

Flame temperature 842 °C

Test duration 90 minutes

Compliance criterion

- 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.



1.20 BS 6387 Category Z

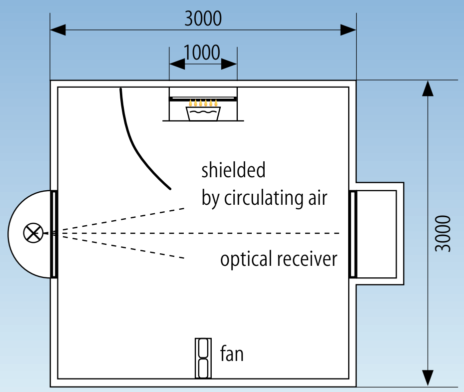
Test set-up The cable is secured onto a positioning board and a flame is applied from below. The positioning board is subjected to two shocks every minute during the combustion period.

Flame temperature 950 °C ± 40 °C

Test duration 15 minutes

Compliance criterion When 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.

Smoke density



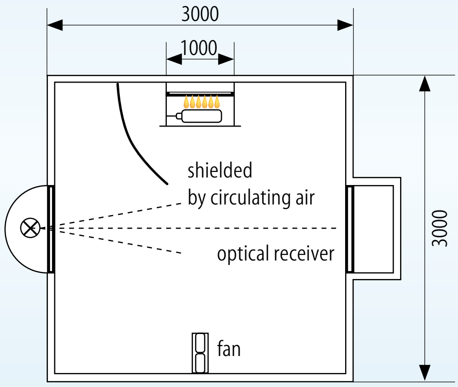
2.1 IEC 61034-2/EN 50268-2

Test set-up A cable specimen is burnt in a closed chamber using a flammable liquid. The light transmittance of the resulting smoke is measured optically.

Flame temperature Determined by the quantity and composition of the fuel.

Test duration 40 minutes

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 Def. St. 02-711 (formerly NES 711)

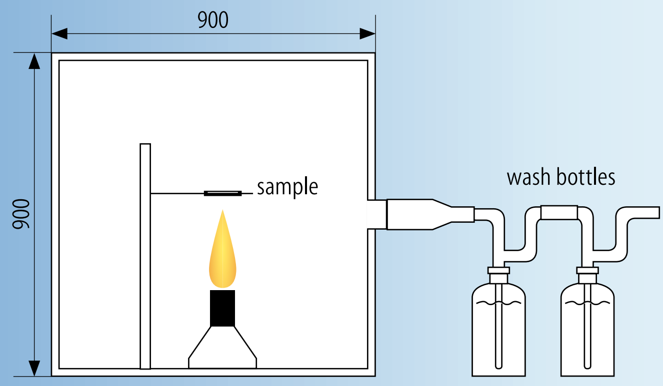
Test set-up The devices under test are burnt in a test chamber using gas burners. The light transmittance is measured optically.

Flame temperature Not specified (devices under test must be fully burnt).

Test duration 20 minutes

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



3.1 IEC 60695-7-1

Test set-up This standard covers the general aspects of toxicity of smoke and combustion gases as well as the potential hazard (general guidelines).

3.2 Def. St. 02-713 (formerly NES 713) / VG 95218-2 Method 1

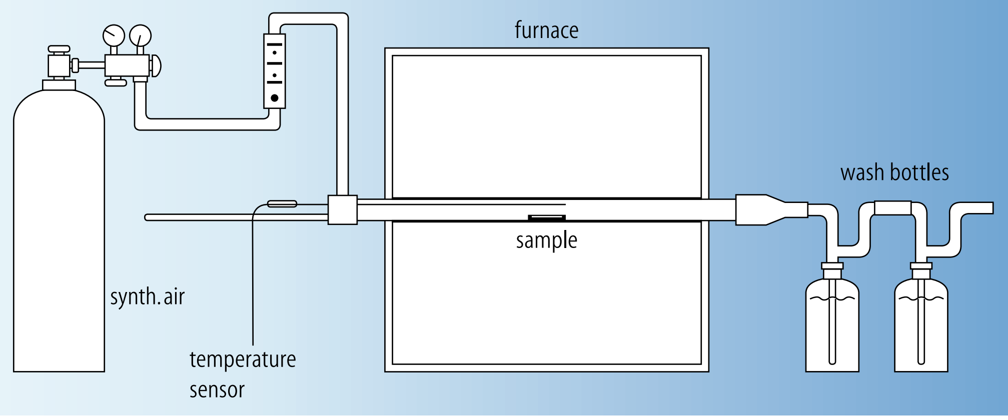
Test set-up The individual non-metallic materials of the cables are burnt in a test chamber. The toxicity of the combustion gas is determined analytically for 14 substances.

Flame temperature 1150 °C ± 50 °C

Test duration 5 minutes

Compliance criterion The toxicity values for the individual non-metallic materials of the cable are added together according to their proportion of the total volume. The toxicity index for the overall cable must not exceed a value of 5.

Corrosiveness of the combustion gases (absence of halogen)



4.1 IEC 60754 / EN 50267

Test set-up 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).

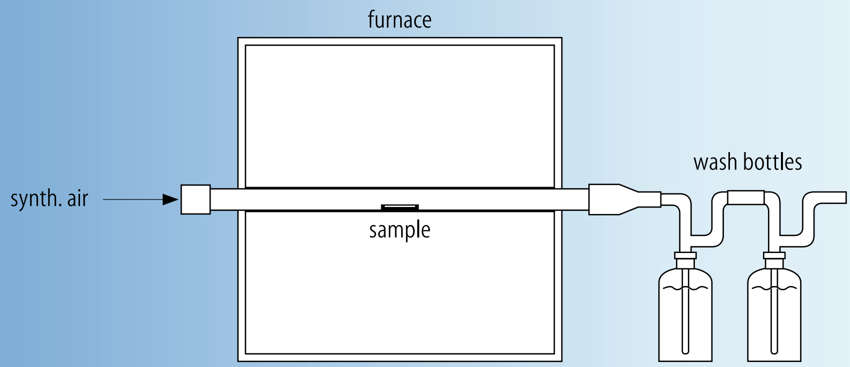
4.2 IEC 60754-1 / EN 50267-2-1

Test set-up 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.

Flame temperature 800 °C ± 10 °C

Test duration 40 ± 5 minutes in total, with at least 20 minutes at the maximum temperature

Compliance criterion The halogen content of all non-metallic materials must not exceed 0.5 % or 5 mg/g.



4.3 IEC 60754-2 / EN 50267-2-2

Test set-up	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.
Flame temperature	At least 935 °C
Test duration	30 minutes
Compliance criterion	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.

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 Standard)
MIL	Military Standard (USA)
BS	British Standard (UK)
Def. St.	Defence Standard (UK)
NES	Naval Engineering Standard (UK)
UL	Underwriters Laboratories Inc. (USA)
NF	Norme Française (National Standard France) (F)
DIN VDE	Deutsche Industrienorm Verband der Elektroingenieure (German Industrial Standard, Association of Electricians)

All dimensions given in mm.

4. Fiber bundles

Principles

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.

4.1. Fill 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 describes the ratio of the optically active cross-sectional area to the total cross-sectional area of the bundle.

$$\eta_{FF} = N \times \pi \times (d_{core} / 2)^2 / \pi \times (d_{bundle} / 2)^2$$

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 0.5 mm, 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%.

4.2. 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 (e.g. an endoscope).

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.

4.3. 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.

4.4. Cross-section converters

For some applications it will be necessary to convert a circular light ray into a slit light ray (spectrometry). Using bundle technology, too can be achieved elegantly by providing one end of the bundle with a circular receptacle, with the other end being stuck into a slotted receptacle.

4.5. 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.

4.6. Customised fiber optic cables

The diversity of optical fibers permits optical waveguides to be tailored to the customer’s particular requirements. A brief technical description or diagram is all that is required. These cables are then designed and produced in close collaboration with the customer.

4.7. Light-conducting rods and homogenisers

In principle, a light-conducting rod is a single fiber with a specific, relatively large diameter. These rods are used if the optical waveguide does not need to be flexible. One common application is for homogenising the light transmitted by the fiber bundle.

4.8. Fiber rods

Fiber rods are image guides with a larger diameter. They are used if the image guide does not need to be flexible. The individual fiber rod comprises a number of fused individual fibers.

4.9. Length of fiber bundles

The length of a bundle of optical fibers can vary greatly. Very short components include, for example, light-guide cones, which are used in endoscopy, and also homogenisers. The maximum length of a fiber optic cable is determined by the transmission losses in the core. These are dependent on the material and the wavelength. Lengths of up to 20 m are possible (see data sheets for details).

The transmission losses are accurately described by the following exponential equation (Beer's law):

$$I_{out} = I_{in} \times \exp(-\alpha \times l)$$

where I_{in} is the light intensity at the entry to the fiber, I_{out} is the light intensity at the exit of the optical waveguide, α is the wavelength-dependent absorption constant and l is the length of the optical waveguide.

4.10. Thermal 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.

4.11. Pressure

Pressure is important with respect to liquid, vacuum and pressure cylinder applications. The receptacles and bonding processes are particularly important in this regard.

4.12. 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.

4.13. Material

The possible materials for fiber optic cables must have certain physical properties. Flexible optical waveguides have a bundle structure that is created by drawing a rod-shaped preform. The transmission losses of the material itself must also be minimal for specific wavelengths.

4.14. Glass

Glass is commonly used as the base 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.

The main constituent of the glass used for conducting light is SiO_2. Additives include boric oxide and phosphorus oxide as well as a number of possible metal oxides, such as Na_2O, K_2O, CaO, Al_2O_3, PbO, La_2O_3 etc. The additives induce a change in the optical properties, e.g. the numerical aperture. Possible values in this case are 0.57 and above. The moderate 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. 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.

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5. Planar waveguides

With an 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.

5.1. 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 precise, structured variations in refractive index and hence precise waveguide structures can be created through localised substitution of sodium ions found in a special glass with silver ions. The ion exchange takes place through openings in a metal film mask having a photolithographic structure. Structural details in the submicrometre range can be achieved in this way. Currently its use is limited to singlemode waveguides for the near IR range as well as the telecommunication wavelength range.
Monolithic splitter components with up to 32 channels on the output side and 1 or 2 input channels are available.

The special properties listed below characterise the planar technique using ion exchange in glass:

- Miniature construction
- Lowest attenuation
- Wide bandwidth
- Lowest polarisation dependence
- Good structural flexibility
- Highly reliable and environmentally stable

5.2. 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 650 nm.

The illustration below shows the sequence of processes in the manufacture of planar waveguide splitters.

Principles

Physical definitions and formulae

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 $n \approx 1.5$: Propagation velocity in an optical fiber $v \approx 200{,}000$ km/s.

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: $\alpha_{Critical} = \arcsin\left(\frac{n_M}{n_K}\right)$ where $n_K > n_M$

Numerical aperture: $NA = \sin\theta_{Critical} = \sqrt{n_K^2 - n_M^2}$

Relative refractive index difference: $\Delta = \frac{n_K^2 - n_M^2}{2n_M^2} \Rightarrow NA = n_K\sqrt{2\Delta}$

Attenuation in an optical waveguide

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: $P/dBm = 10\lg\frac{P\,in\,mW}{1mW}$

Attenuation in the optical fiber in decibels: $a/dB = 10\lg\frac{P_0}{P(L)} = P_0/dBm - P(L)/dBm$

Attenuation coefficient in dB/km: $\alpha = \frac{a}{L}$

Transmission in an optical fiber

Light transmission in the fiber as a percentage of the injected power:

$T = 10^{(-A \cdot L)/10}$

Coupling losses

Coupling efficiency: Ratio of the power P_2 guided in optical fiber 2 to the power P_1 provided by optical fiber 1: $\eta = \frac{P_2}{P_1}$

Attenuation at the coupling: $a/dB = 10\lg\frac{P_1}{P_2} = 10\lg\frac{1}{\eta} = -10\lg\eta$

Intrinsic losses between multimode fibers (uniform mode distribution, step index profile or gradient index profile)

Mismatch of the core radii: $\eta = \left(\frac{r_{K2}}{r_{K1}}\right)^2$ for $r_{K1} \geq r_{K2}$ $\quad \eta = 1$ for $r_{K1} \leq r_{K2}$

$a = 20\lg\frac{r_{K1}}{r_{K2}}$ in dB for $r_{K1} \geq r_{K2}$ $\quad a = 0$ dB for $r_{K1} \leq r_{K2}$

Mismatch of numerical apertures: $\eta = \left(\frac{NA_2}{NA_1}\right)^2$ for $NA_1 \geq NA_2$ $\quad \eta = 1$ for $NA_1 \leq NA_2$

$a = 20\lg\frac{NA_1}{NA_2}$ in dB for $NA_1 \geq NA_2$ $\quad a = 0$ dB for $NA_1 \leq NA_2$

Mismatch of the refractive index profiles: $\eta = \frac{g_2(g_1+2)}{g_1(g_2+2)}$ for $g_1 \geq g_2$ $\quad \eta = 1$ for $g_1 \leq g_2$

$a = 10\lg\frac{g_1(g_2+2)}{g_2(g_1+2)}$ for $g_1 \geq g_2$ $\quad a = 0$ dB for $g_1 \leq g_2$

Extrinsic losses between multimode fibers (uniform mode distribution, step index profile or gradient index profile)

Radial misalignment, transverse misalignment or lateral misalignment d: $\eta = 1 - \frac{g+2}{g+1} \cdot \frac{2d}{\pi \cdot r_K}$ $a = 2.76 \cdot \frac{g+2}{g+1} \cdot \frac{d}{r_K}$ in dB

Step index fiber: $g = \infty$ $\eta = 1 - \frac{2d}{\pi \cdot r_K}$ $a = 2.76 \cdot \frac{d}{r_K}$ in dB

Parabolic index fiber: $g = 2$ $\eta = 1 - \frac{8d}{3\pi \cdot r_K}$ $a = 3.68 \cdot \frac{d}{r_K}$ in dB

Tilting about angle γ (in radian measure): $\eta = 1 - \frac{g+2}{g+1} \cdot \frac{2n_0 \cdot \gamma}{\pi \cdot NA}$ $a = 2.76 \cdot \frac{g+2}{g+1} \cdot \frac{n_0 \cdot \gamma}{NA}$ in dB

Step index fiber: $g = \infty$ $\eta = 1 - \frac{2n_0 \cdot \gamma}{\pi \cdot NA}$ $a = 2.76 \cdot \frac{n_0 \cdot \gamma}{NA}$ in dB

Parabolic index fiber: $g = 2$ $\eta = 1 - \frac{8n_0 \cdot \gamma}{3\pi \cdot NA}$ $a = 3.68 \cdot \frac{n_0 \cdot \gamma}{NA}$ in dB

Axial misalignment or longitudinal misalignment s: $\eta = 1 - \frac{2(1-K)s \cdot NA}{r_K \cdot n_0}$ $a = 8.69 \frac{(1-K)s \cdot NA}{r_K \cdot n_0}$ in dB

Step index fiber: $K = 1 - \frac{2}{3\pi}$ $\eta = 1 - \frac{4s \cdot NA}{3\pi \cdot r_K \cdot n_0}$ $a = 1.84 \frac{s \cdot NA}{r_K \cdot n_0}$ in dB

Parabolic index fiber: $K = 0.75$ $\eta = 1 - \frac{s \cdot NA}{2r_K \cdot n_0}$ $a = 2.17 \frac{s \cdot NA}{r_K \cdot n_0}$ in dB

Intrinsic losses between singlemode fibers

Mismatch of the mode-field radii: $\eta = \left(\frac{2w_1 \cdot w_2}{w_1^2 + w_2^2} \right)^2$ $a = 20\lg \frac{w_1^2 + w_2^2}{2w_1 \cdot w_2}$ in dB

$\eta = 1$ or $a = 0$ dB **only** if $w_1 = w_2$, otherwise there are always coupling losses!

Extrinsic losses between singlemode fibers

Radial misalignment d: $\eta = e^{-\frac{d^2}{w^2}}$ $a = 4.34 \cdot \frac{d^2}{w^2}$ in dB

Tilting about angle γ (in radian measure): $\eta = e^{-\left(\frac{\pi \cdot n_0 \cdot w \cdot \gamma}{\lambda} \right)^2}$ $a = 42.9 \left(\frac{n_0 \cdot w}{\lambda} \right)^2 \gamma^2$ in dB

Axial misalignment s: $\eta = \frac{1}{1 + \left(\frac{\lambda \cdot s}{2\pi \cdot n_0 \cdot w^2} \right)^2}$ $a = \left(\frac{\lambda \cdot s}{3n_0 \cdot w^2} \right)^2$ in dB

Reflections

Reflection at a change in refractive index with perpendicular incidence: $R = \left(\frac{n_1 - n_0}{n_1 + n_0} \right)^2$

Return loss: $RL = 10\lg \frac{P_1}{P_R} = 10\lg \frac{1}{R} = -10\lg R$ in dB

Insertion loss due to reflection: $a = -10\lg(1-R)$ in dB

Principles

Levels in a backscatter diagram

Level at the transition from fiber 1 (w_1, n_1) to fiber 2 (w_2, n_2): $a_{12} = 20\lg\frac{w_1^2+w_2^2}{2w_1\cdot w_2} + 10\lg\frac{n_2}{n_1} + 10\lg\frac{w_2}{w_1}$ in dB

Level at the transition from fiber 2 (w_2, n_2) to fiber 1 (w_1, n_1): $a_{21} = 20\lg\frac{w_1^2+w_2^2}{2w_1\cdot w_2} + 10\lg\frac{n_1}{n_2} + 10\lg\frac{w_1}{w_2}$ in dB

Fibers

Number of modes that can propagate: $Z \approx \frac{V^2}{2}\cdot\frac{g}{g+2}$

V number: $V = 2\pi\cdot NA\cdot\frac{r_K}{\lambda}$

Cut-off wavelength in a singlemode fiber: $\lambda_C = \frac{2\pi\cdot r_K\cdot NA}{V_C}$; $V_C = 2.405$ 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: $\frac{\lambda\cdot S_{0max}}{4}\left[1-\left(\frac{\lambda_{0max}}{\lambda}\right)^4\right] \le D_{CD}(\lambda) \le \frac{\lambda\cdot S_{0max}}{4}\left[1-\left(\frac{\lambda_{0min}}{\lambda}\right)^4\right]$

Bandwidth

Bandwidth-length product: $BLP \approx B\cdot L$.

Maximum achievable bandwidth: $B \approx \frac{0.335}{T}$ (T: pulse width)

Chromatic dispersion

Coefficient of chromatic dispersion: $D_{CD}(\lambda) = D_{MAT}(\lambda) + D_{WAV}(\lambda) = \frac{d\pi(\lambda)}{d\lambda}$ in ps/(nm·km)

Chromatic dispersion: $D(\lambda) = D_{CD}(\lambda)\cdot L$ in ps/nm

Zero-crossing point of chromatic dispersion: $D_{CD}(\lambda_0) = 0$

Increase in the coefficient of chromatic dispersion: $S(\lambda) = \frac{dD_{CD}(\lambda)}{d\lambda} = \frac{d^2\tau(\lambda)}{d\lambda^2}$ in ps/(nm²·km)

Increase in the coefficient of chromatic dispersion at the zero-dispersion wavelength λ_0: $S_0 = S(\lambda_0)$ in ps/(nm²·km)

Pulse spreading due to chromatic dispersion: $\Delta\tau_{CD} = HWB\cdot L\cdot D_{CD}$

Dispersion-limited length for externally modulated lasers and with conventional modulation methods (Marcuse):

$$L \approx \frac{100{,}000((Gbit/s)^2 ps/nm)}{R^2\cdot D_{CD}}$$

Dispersion tolerance: $DT = L\cdot D_{CD}$

Polarisation mode dispersion

First-order PMD coefficient with weak mode coupling: $PMD_1 = \frac{\langle \Delta\tau \rangle}{L}$ in ps/km

First-order PMD coefficient with strong mode coupling: $PMD_1 = \frac{\langle \Delta\tau \rangle}{\sqrt{L}}$ in $ps/\sqrt{km}$

Dispersion-limited length with strong mode coupling and conventional NRZ modulation: $L \approx \frac{1}{100 \cdot R^2 \cdot PMD_1^2}$

Series connection of numerous sections of sufficient length with strong mode coupling:

PMD delay: $\langle \Delta\tau \rangle_{Length} = \sqrt{\sum_i \langle \Delta\tau_i \rangle^2}$

PMD coefficient: $PMD_{1Length} = \frac{\sqrt{\sum_i \left[L_i \cdot \left(PMD_1^i \right)^2 \right]}}{\sqrt{L}}$ where $\sum_i L_i = L$

Coupler

Excess loss: $EL = 10 \lg \frac{P_1}{P_3 + P_4}$ in dB

Insertion loss: $IL = 10 \lg \frac{P_1}{P_3}$ or $IL = 10 \lg \frac{P_1}{P_4}$ in dB

Coupling ratio: $CR = \frac{P_4}{P_3 + P_4} \times 100$ in %

Return loss: $RL = 10 \lg \frac{P_1}{P_{1r}}$ in dB

Cross-talk attenuation: $D = 10 \lg \frac{P_1}{P_2}$ in dB

Uniformity: $U/dB = IL_{max}/dB - IL_{min}/dB$

Isolation: $I = 10 \lg \frac{P_{3,\lambda_1}}{P_{3,\lambda_2}}$ or $I = 10 \lg \frac{P_{4,\lambda_2}}{P_{4,\lambda_1}}$ in dB

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 $\Delta\lambda$:

$|\Delta f| = \frac{c \cdot |\Delta\lambda|}{\lambda^2}$ => Δf = 100 GHz corresponds to $\Delta\lambda \approx 0.8$ nm in the third optical window.

Standardised wavelength grid for a channel spacing of 100 GHz: f_n = 193.1 THz + n x 0.1 THz,

where n is a positive or negative integer (including zero).

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
P0	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/nm^2·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
$\alpha_{critical}$	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

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.
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.

Principles

Principles

Term	Definition
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.
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).

Term	Definition
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
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).

Principles

Term	Definition
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.
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.

Term	Definition
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.
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.

Term	Definition
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.
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 $g \rightarrow \infty$ (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.
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 index 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.

Term	Definition
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.
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.

Term	Definition
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 temperature.
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	Explanation
3R	3R regeneration: reamplification, reshaping, retiming
A/D	analogue/digital
A-DCM	adaptive dispersion-compensating module
ADM	add-drop multiplexer
AEL	accessible emission limit
ATM	asynchronous transfer mode
AON	all optical network or agile optical network or active optical network
APC	angled physical contact
APD	avalanche photodiode
ASE	amplified spontaneous emission
ASON	automatically switched optical network
ASTN	automatically switched transport network: see ASON
AWG	arrayed waveguide grating
BER	bit error rate
BOTDR	Brillouin OTDR
C & C	crimp & cleave
CATV	cable television
C-band	conventional band (1530 nm to 1565 nm)
CCDR	cladding-to-core diameter ratio
CD	chromatic dispersion
CDM	code division multiplex
CECC	CENELEC Electronic Components Committee
COST COTDR	European co-operation in the field of scientific and technical research
CPR	coupled power ratio
CSO	composite second-order beat noise
CVD	chemical vapour deposition
CW	continuous wave
CWDM	coarse wavelength division multiplex
D2B	domestic digital bus
DA	dispersion accommodation
DBFA	double band fiber amplifier: fiber amplifier for the C- and L-band
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 (caused by PMD)
DIN	Deutsches Institut für Normung [German standards institute]
DMD	differential mode delay
DML	directly modulated laser
DMS	dispersion managed soliton
DMUX	demultiplexer
DOP	degree of polarisation
DSF	dispersion shifted fiber
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	electroabsorption
EBFA	extended band fiber amplifier: fiber amplifier for the L-band
EDFA	erbium doped fiber amplifier
EDWA	erbium doped waveguide amplifier
EIC	expanded wavelength independent coupler
EMB	effective modal bandwidth, laser bandwidth
EMD	equilibrium mode distribution
EML	externally modulated laser
EN	European Norm
ESLK	earth wire overhead cable [Erdseil-Luftkabel]
ETDM	electrical time division multiplex
FA	fixed analyser
FBG	fiber Bragg grating
FBT	fused biconic taper
FC	fiber connector
FDDI	fiber distributed data interface
FDM	frequency division multiplex
FEC	forward error correction
FIC	full range wavelength independent coupler
FM	frequency modulation
FOC	fiber optic cable, fiber
FP	Fabry-Perot
FSAN	full service access network
FTTC	fiber to the curb
FTTD	fiber to the desk
FTTH	fiber to the home
FTTM	fiber to the mast
FTU	fiber termination unit
FWHM	full width at half maximum
FWM	four wave mixing
Ge	germanium
GeO_2	germanium oxide
GFF	gain guided laser
GINTY	general interferometric analysis
GRIN	graded refractive index
GZS	accessible emission limit
HCS fiber	hard-clad silica fiber
HRL	high return loss
IEC	International Electrotechnical Commission
IGL	index guided laser
IM	intensity modulation
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
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 extended transmission band (1565 nm to 1625 nm)
LD	laser diode
LEAF	large effective area fiber
LED	light emitting diode
LID	light injection and detection
LP	linearly polarised
LSA	least-squares averaging, least-squares approximation
LWP	low water peak

Abbreviation	Explanation
MAN	metropolitan area network
Mbits/s	unit of measure for the bit rate
MCVD	modified chemical vapour deposition
MEMS	micro-electro-mechanical system
MFD	mode field diameter
MM	multimode
MMF	multimode fiber
MPE	maximum permissible exposure
MPI	multipath interference
MPI	main point of interest
MUX	multiplexer
MZ	Mach-Zehnder
MZB	see MPE
NA	not applicable
NF	near field
NGN	next generation network
NIR	near infrared
NRZ	non-return to zero
NZDSF	non-zero dispersion shifted fiber
OADM	optical add-drop multiplexer
OB	optical booster
OC	optical carrier or optical channel
OCDM	optical code division multiplex
OCWR	optical continuous wave reflectometer
OD	optical demultiplexer
ODFM	optical frequency division multiplex
ODF	optical distribution frame
O/E	optical to electrical conversion
OEIC	opto-electronic integrated circuit
O/E/O	optical to electrical to optical conversion
OFA	optical fiber amplifier
OFL	overfilled launch
OLCR	optical low coherence reflectometry
OH	hydroxide ion, negatively charged ion in water
OLT	optical line terminal
OM	optical multiplexer
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 vapour deposition
OWG	optical waveguide
OXC	optical cross connect
P	failure probability
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 vapour deposition
PD	photodiode
PDC	passive dispersion compensator
PDF	probability density function
PDFA	praseodymium doped fiber amplifier
PDG	polarisation-dependent gain
PDH	plesiochronous digital hierarchy
PDL	polarisation-dependent loss
PIN diode	positive-intrinsic-negative diode
PLC	planar lightwave circuit
PM	polarisation maintaining
PMD	polarisation mode dispersion
PMMA	polymethyl methacrylate
PMSMF	polarisation-maintaining single mode fiber
POF	plastic optical fiber/polymer optical fiber
PON	passive optical network
POTDR	polarisation optical time-domain reflectometer
PSA	Poincaré sphere analysis
PSP	principal state of polarisation
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
RML	restricted mode launch
RMS	root mean square
RNF	refracted nearfield method
ROADM	reconfigurable optical add/drop-multiplexer
RX	receiver
RZ	return to zero
SAN	storage area network
S-band	short band transmission band for small wavelengths (1460 nm to 1530 nm)
SBS	stimulated Brillouin scattering
SDH	synchronous digital hierarchy
SDM	space division multiplex
SERCOS	serial real-time communication system
SFF	small-form-factor
Si	silicone
SI	step index
SiO2	silicon oxide
SLA	semiconductor laser amplifier
SLED	super 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	synchronous optical network

Abbreviation	Explanation
SOP	state of polarisation
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
TDFA	thulium-doped fiber amplifier
TDM	time division multiplex
TINTY	traditional interferometry analysis
TODC	tunable optical dispersion compensator
TX	transmitter
U	ultra long-haul
UDWDM	ultra-dense wavelength division multiplex
UMD	uniform mode distribution
UV	ultraviolet
V	very long-haul
VAD	vapour phase axial deposition
VCSEL	vertical cavity surface emitting laser
VCSOA	vertical cavity semiconductor optical amplifier
VOA	variable optical attenuator
VSR	very short reach
WAN	wide area network
WDM	wavelength division multiplex
WFC	wavelength flattened coupler
WG	waveguide
WIC	wavelength independent coupler
WWDM	wideband wavelength division multiplex
XPM	cross-phase modulation
ZWP	zero water peak

Books

Reference literature

Dr. Dieter Eberlein

DWDM – Dichtes Wellenlängenmultiplex

Dr. M. Siebert GmbH
Berlin 2003
1st edition
231 pages
b/w
21.5 cm × 15.2 cm
Hardcover
ISBN-13: 978-3-00-010819-8
Price: €45
Purchase through Dr. M. Siebert GmbH
Köpenicker Straße 325/Haus 211,
12555 Berlin
Tel.: +49 (0)30-654740-36

Description

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 modern networks, planning and installation)
- Standardisation
- Appendix (abbreviations, symbols, units of measure, glossary)

Dr. Dieter Eberlein and four other authors

Lichtwellenleiter-Technik

expert verlag GmbH
Renningen 2007
7th edition
346 pages
b/w
ISBN-13: 978-3-8169-2696-2
Price: €54
Purchase through expert verlag GmbH
Postfach 2020, 71268 Renningen
Tel.: +49 (0)7159-9265-0

Description

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 7th edition additionally explores a range of new aspects, such as current standards, new fibers types, the reliability of fiber optic cables, particular requirements for transmitting Gigabit Ethernet or 10-gigabit Ethernet over multimode fibers and so forth.

Topics covered

- Principles of fiber optics
- Temporary joining techniques
- Permanent joining techniques
- Fiber optic measuring techniques, focusing particularly on backscattering measurements
- Optical transmission systems
- Development trends

Andreas Weinert

Plastic Optical Fibers

Publicis MCD Publishing
Erlangen and Munich
154 pages
Hardcover
ISBN: 3-89578-135-5

Description

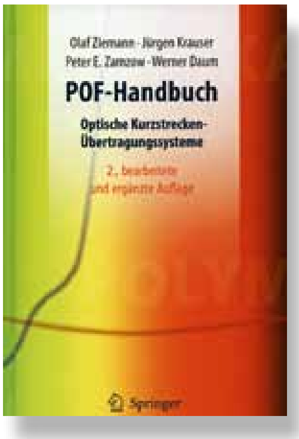
In recent years there has been a meteoric rise in the use of plastic fiber optic cables, e.g. for data transmission on short to medium-length transmission paths. The reason for this is that plastic fiber optic cables can be connected to the relevant transmission components at low cost and using simple 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 cable. 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.

Olaf Ziemann, Werner Daum, Jürgen Krauser, Peter E. Zamzow

POF Handbuch



Springer-Verlag Berlin Heidelberg
2nd edited and supplemented edition
2007
884 pages
Hardcover
ISBN: 978-3-540-49093-7

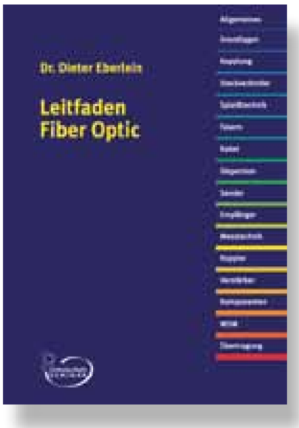
Description

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.

Dr. Dieter Eberlein

Leitfaden Fiber Optic



Dr. M. Siebert GmbH
Berlin 2005
1st edition
186 pages
two-colour
21.5 cm × 15.2 cm
Hardcover
ISBN-13: 978-3-00-015038-8
Price: €19.95
Purchase through Dr. M. Siebert GmbH
Köpenicker Straße 325/Haus 211,
12555 Berlin
Tel.: +49 (0)30-654740-36

Description

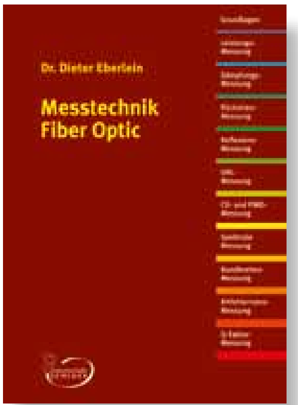
The guidebook provides an outline of key topics of fiber optics in the form of short descriptions, explanatory illustrations, summarising tables and references to current standards. It enables engineers, technicians and students alike to learn quickly about a topic, without having to explore the subject 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
- Optical components
- Wavelength division multiplexing
- Optical transmission systems

Dr. Dieter Eberlein

Messtechnik Fiber Optic



Dr. M. Siebert GmbH
Berlin 2006
1st edition
170 pages
four-colour
21.5 cm × 15.2 cm
Hardcover
ISBN-13: 978-3-00-018278-5
Price: €30
Purchase through Dr. M. Siebert GmbH
Köpenicker Straße 325/Haus 211,
12555 Berlin
Tel.: +49 (0)30-654740-36

Description

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 modern 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

Dr. Dieter Eberlein and four other authors

Messtechnik Fiber Optic
Part 1 Rückstreumessung

Dr. M. Siebert GmbH
Berlin 2007
1st edition
96 pages
four-colour
21.5 cm x 15.2 cm
Booklet, adhesive binding
ISBN-13: 978-3-00-022129-3
Price: €13.50
Purchase through Dr. M. Siebert GmbH
Köpenicker Straße 325/Haus 211,
12555 Berlin
Tel.: +49 (0)30-654740-36

Description

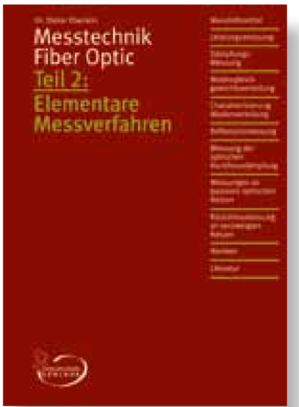
This booklet is the first in a series of four on fiber optic measuring techniques. The first booklet concentrates on the theoretical and practical aspects of backscattering measurements. Current developments and standards are also described and new products are presented.

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 documentation of the measurement results
- Passive and active monitoring of fiber sections
- Practical aspects
- Quality specifications
- Abbreviations, symbols, units of measure

Dr. Dieter Eberlein

Messtechnik Fiber Optic
Part 2 Elementare Messverfahren



Dr. M. Siebert GmbH
Berlin 2008
1st edition
96 pages
four-colour
21.5 cm x 15.2 cm
Booklet, adhesive binding
ISBN-13: 978-3-00-024216-8
Price: €13.50
Purchase through Dr. M. Siebert GmbH
Köpenicker Straße 325/Haus 211,
12555 Berlin
Tel.: +49 (0)30-654740-36

Description

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

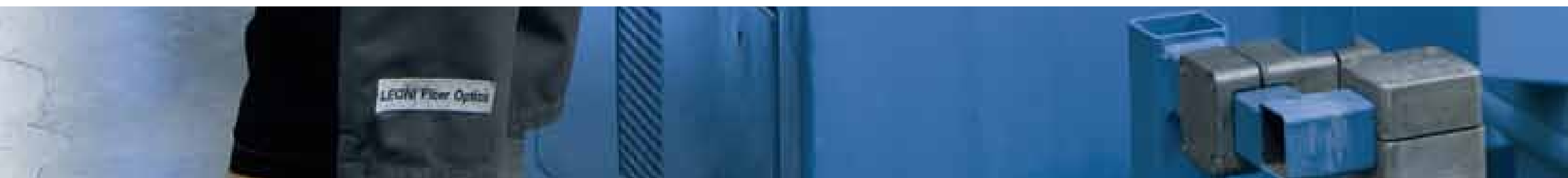
- Measuring aids
- Power measurements
- Attenuation measurements
- Reflection measurements
- ORL measurements
- Measurements on passive, optical networks

Find out more at
www.LWLtechnik.de

Service & Index

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 Germany.



Quality management

A consistently high standard of quality is essential for our products.

Our leading market position is consolidated not only through continuous improvements to our product quality and manufacturing standards but also through flexibility in responding quickly to customer and market demands.

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. Our quality management system is certified to ISO 9001 and this governs the entire production process from planning to completion.


CERTIFICATE
DQS GmbH
LEONI Fiber Optics GmbH
Quality Management System
DIN EN ISO 9001 : 2000


CERTIFICATE
DQS GmbH
LEONI Fiber Optics GmbH
Quality Management System
DIN EN ISO 9001 : 2000


APPROVAL
EC Directive 93/42/EEC Annex II, Article 3
Full Quality Assurance System
Medical Devices
TÜV


CERTIFICATE
DQS GmbH
LEONI Fiber Optics GmbH
ISO 9001 : 2008


Certificate
FiberTech GmbH
Special Optical Fiber Technologies
EN ISO 9001:2008


Certificate
FiberTech GmbH
Special Optical Fiber Technologies
EN ISO 13485:2003+AC:2007

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 activities.

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.


CERTIFICATE

DQS GmbH

LEONI Fiber Optics GmbH

Environmental Management System.

EN ISO 14001 : 2004

Quality assurance

We have the human resources to meet the demands of our quality management system in all divisions:

Business unit of **Fiber Optics**

Head of Quality Management
Quality Manager (QM)
Manager of Regulatory Affairs
Safety Officer for Medical Products
Environment Manager

for all production sites

Quality Management Officer (QMO) assistant safety officer for medical products	Quality Management Officer (QMO) assistant safety officer for medical products	Quality Management Officer (QMO) assistant safety officer for medical products	Quality Management Officer (QMO) assistant safety officer for medical products

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 manufacture 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 products

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. The objective of this standard is to verify that the efficiency of the quality management system is being maintained rather than just being continuously improved.

Packaging units

Drums

Fiber optic cables with larger cross-sections are usually delivered on wooden drums made by KTG Kabeltrommel GmbH & Co. KG, in Cologne. These are supplied on loan under the conditions of this company, which we can send you on request.

All cables with POF, PCF and special fibers are supplied on disposab-le 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

Special cables on request.

Standard wooden reels

Type	Flange dia.	Core dia.	Total width	Layer width	Spool weight	Load-bearing capacity
	mm	mm	mm	mm	approx. kg	max. kg
KT081	800	400	520	400	31	400
KT101	1000	500	710	560	71	900
KT121	1250	630	890	670	144	1700
KT141	1400	710	890	670	175	2000
KT161	1600	800	1100	850	280	3000
KT181	1800	1000	1100	840	380	4000
KT201	2000	1250	1350	1045	550	5000
KT221	2240	1400	1450	1140	710	6000
KT250	2500	1400	1450	1140	875	7500

On request, we also supply fiber optic cables on the following disposable drums:

Disposable drums (wooden)

Type	Flange dia.	Core dia.	Total width	Layer width	Hole	Spool weight
	mm	mm	mm	mm	mm	approx. kg
K3000	300	212	103	90	51	0.7
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
H7601	760	312	415	390	80	8.5
H7603	760	470	544	520	80	12.0
H1001	1000	500	590	560	80	15.0
G1001	1000	540	650	550	80	49.0
G1201	1000	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

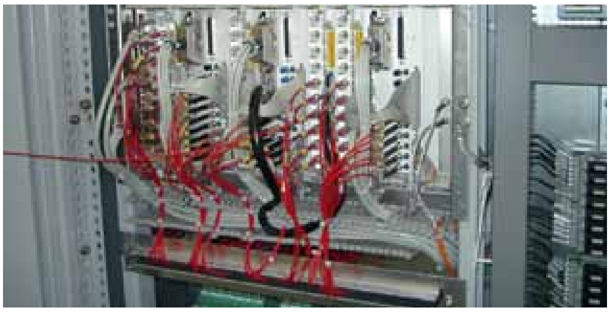
Installation service

Assistance on site

In addition to the well-known scope of the LEONI range, our experienced installation team provides the following services using state-of-the-art technology:

- Assembly of all types of connectors (ST, FC, SMA, HP, F05/F07, etc.)
- Installations inside and outside Germany (new installations and repairs)
- Cable laying and splicing
- Measurement analyses

If you have experienced cable and connector failures in your network, we are also happy to analyse them and design simple, cost-effective solutions on site.



Our global presence

Close proximity to the customer is a key component of our corporate philosophy. For that reason LEONI is always close at hand, wherever you are in the world. Take advantage of our extensive sales network.

Corporate head office

GERMANY

LEONI Fiber Optics GmbH
Mühldamm 6
96524 Neuhaus-Schierschnitz
Germany
Tel.: +49 (0)36764-81-100
Fax: +49 (0)36764-81-110
fiber-optics@leoni.com

Any country not listed falls under the responsibility of corporate head office.

Europe

BELGIUM
LUXEMBOURG
NETHERLANDS

Regional Office
Joeri Van Bogaert
LEONI WCS Benelux BV
Siliciumweg 31
3812 SV Amersfoort, Niederlande
Phone +31 (0)33-43 28 007
Telefax +31 (0)33-46 19 228
j.vanbogaert@leoni.com

Regional Representative
Guy Colman
Cynerpro NV
Laagstraat 65
9140 Temse, Belgium
Phone +1 480 993-2143
guy.colman@cynerpro.be

DENMARK
FINLAND
NORWAY
SWEDEN

Regional Office
Lilli Winnicki
LEONI Fiber Optics GmbH
Dyrlägegaards Alle 174
3600 Frederikssund, Denmark
Phone +45 40 15 04 00
lilli.winnicki@leoni.om

FRANCE

Regional Manager
Imke Küster
LEONI CIA Cable Systems S.A.S.
1, Avenue Louis Pasteur
Z. I. de Gellainville
28630 Gellainville
Phone +33 (0)977-05 77 40
imke.kuester@leoni.com

UNITED KINGDOM

Regional Manager
Frank Gumm
LEONI Fiber Optics GmbH
Simmerner Straße 7
55442 Stromberg, Germany
Phone +49 (0)6724-607-132
Fax +49 (0)6724-607-100
frank.gumm@leoni.com

ITALY

Regional Representative
Giordano Picchi
Unifibre s.r.l.
Via Salvemini, 17
20019 Settimo Milanese
Phone +39 (0)233-55501
Fax +39 (0)233-512203
gpicchi@unifibre.it

SLOVENIA

Regional Representative
Ales Strazar
Optisis d.o.o.
Avtomibilska ulica 17
1001 Ljubljana
Phone +386 (2)3338-754
Fax +386 (2)3338-757
Ales.Strazar@Optisis.si

SPAIN

Regional Manager
Lars Leininger, Ph. D.
LEONI Fiber Optics GmbH
Nalepastr. 170–171
12459 Berlin, Germany
Phone +49 (0)30 5300-5812
Fax +49 (0)30 5300-5858
lleininger@fibertech.de

North America

CANADA
Regional Representative
Rafal Pawluczek, Jeff Dupuis
FiberTech Optica Inc.
330 Gage Avenue, Suite 1
Kitchener, Ontario N2M 5C6
Phone +1 519-745-2763
Fax +1 519-342-0128
rpawluc@fto.ca
jeffdup@fto.ca

USA
Regional Manager
Armin Kaus, Ph. D.
FiberTech Inc. USA
5070 S. Gilbert Road, Suite 100
Chandler, AZ 85249
Phone +1 480 993-21-43
Fax +1 480 892-45-38
a.kaus@us-fibertech.com

Asia & Pacific

AUSTRALIA
Regional Representative
Ruth Roberts
Device Technologies Australia
10/59 Main North Road
Medindie SA 5081
Phone +61 (08)8111-4900
Fax +61 (08)8111-4901
rroberts@device.com.au

BANGLADESH
INDIA
NEPAL
SRI LANKA
Regional Manager
Pravin Narayan
LEONI Special Cables (India) Pvt. Ltd.
A-405, Galleria
Hiranadani Gardens Powai
Mumbai - 400076, India
Phone +91 (22) 4005-66-44
+91 (22) 4005-66-45
Fax +91 (22) 4005-66-46
pravin.narayan@lsc.leoni.com

BRUNEI
MALAYSIA
PAKISTAN
PHILIPPINES
SINGAPORE
Regional Office
Max Ong
LEONI Special Cables GmbH
28, Gul Avenue
Singapore 629668
Phone +65 6844-8722
Fax +65 6741-8722
max.ong@lsc.leoni.com

CHINA
Regional Manager
William Fang, Anthem Zao
LEONI Special Cables Co. Ltd.
Room 707 Aetna Mansion, No. 107
Zunyi Road, Changning Area
200051 Shanghai, China
Phone +86 21 237 5569
Fax +86 21 6237 5589
william.fang@leoni.com
anthem.zhao@leoni.com

INDONESIA
CAMBODIA
LAOS
MYANMAR
THAILAND
VIETNAM
Regional Office
Frank Wagner, Judono Soekendra
LEONI Special Cables GmbH
S. Widjojo Center, 10th floor
Jl. Jendral Sudirman No. 71
Jakarta 12190, Indonesia
Phone + 62 21-526 -5767
Fax + 62 21-526-4340
frank.wagner@lsc.leoni.com
soekendra.judono@lsc.leoni.com

JAPAN
Regional Representative
Jojiro Kimura
Opto Science, Inc. Tokyo Office
Naitocho Bldg., 1, Naitocho,
Shinjuku-ku
Tokyo 160-0014
Phone +81 3-3356-1064
Fax +81 3-3356-3466
kimura@optoscience.com

JAPAN
Regional Representative
Koichiro Sakamoto
Opto-Works Co., Ltd
8F-5 Shatore-Gotanda
4-10-9 Higashigotanda,
Shinagawa-Ku
Tokyo 141-0022
Phone +81 3-3445-4755
Fax +81 3-6479-8044
sakamoto@opto-works.co.jp

JAPAN
Regional Representative
Kotomi Shimada
CORNES DODWELL LTD.
Cornes House, 13-40 Nishi Honmachi
1-chome, Nishi-ku
Osaka 550-0005
Phone +81 6-6532-1012
Fax +81 6-6532-7749
shimadak@cornes-dodwell.co.jp

TAIWAN
Regional Representative
James Chen
JIMCOM Co. Ltd.
6F-1, No. 159, Sec.1
Hsin Tai Wu Rd. HsiChih City
Taipei Hsien 221
Phone +886 2-2690 2318
Fax +886 2-2690 2378
jimcom@ms19.hinet.net

TAIWAN
Regional Representative
Terry Huang
Smartech Medical Co. Ltd.
No 66–1, Chaufu Rd., Shituen Chiu
Taipei 40757
Phone +886 4225-48026
Fax +886 4225-48028
smart.ech@msa.hinet.net

Index

LEONI Fiber Optics GmbH

Mühldamm 6
96524 Neuhaus-Schierschnitz
Germany
Phone +49 (0)36764-81-100
Fax +49 (0)36764-81-110
E-mail fiber-optics@leoni.com
www.leoni-fiber-optics.com