Fibre Optic Excellence from KRONE

Configuration of a fibre optic transmission route

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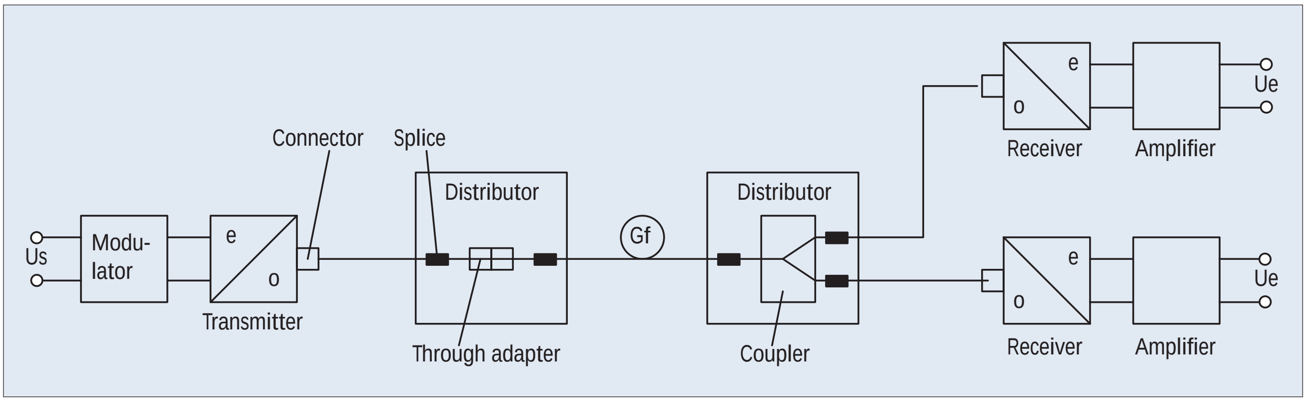
Transmission components may vary greatly, depending on the user's requirements for the configuration of his network. The pure fibre optic connection and distribution components between the active components, however, have to meet very similar requirements in all fields of applications.

A fibre optic route always comprises the same basic components:



Principle of an optical transmission route

Optical communications are based on light rather than electricity as the information carrier and on optical fibres instead of copper wires as the transmission medium. The light is generated and processed by the active components (transmitter and receiver) and transmitted through the optical fibre.

Connections of optical fibres and fibre optic cables pose special requirements for positioning precision and processing. Optical fibres are made of silica glass, so that it is not possible to solder individual fibre segments to each other or to connect them using insulation displacement techniques. Special processes have thus been developed for joining fibre segments together, either temporarily or permanently.

Fibre optic connectors are used for non-permanent connections of optical fibres. A large number of different connector systems exists world-wide, with differences in terms of operating principles and applications. Positioning, precision and manufacturing tolerances, however, have to fulfil extremely demanding requirements in each case.

Permanent connections are established by means of thermal or mechanical splices.

In the case of the thermal process, the ends of the fibres to be connected are fused together by means of a special welding device. In the case of mechanical splicing, the two fibre ends are precisely positioned in relation to each other and subsequently secured mechanically.

When laying fibre optic cables, it must be ensured that suitable splice support devices are available. These devices can be contained in junctions or in the racks where the optical fibre cables are stored or distributed. These racks or fibre optic distributors are available in many different versions, depending on the number of fibres to be managed and the place of use.

Other components of a fibre optic network are couplers and wavelength multiplexers. Both devices help optimise network structures by saving active components and/or fibre optic cables whilst at the same time ensuring higher transmission capacity.

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The advantages of optical fibres are reflected by the following properties

- Fibre optic networks have very low attenuation, so that long transmission distances are possible without signal conditioning.
- Optical fibres offer a large transmission bandwidth, so that large amounts of data can be transmitted at high rates.
- Glass, as a material, is immune to electromagnetic interference, so that fibre optic cables can be laid parallel to power cables without any mutual interference. Optical fibres can be used without any risk in areas with an explosion hazard.
- Glass does not conduct electricity, so that the transmitting and receiving equipment is galvanically isolated within a fibre optic network.
- Fibre optic networks feature a high degree of protection against eavesdropping.
- Their light weight, small dimensions and high transmission capacity help save installation space.
- The supply of glass (= silicon) as a material is unlimited.

Optical fibre

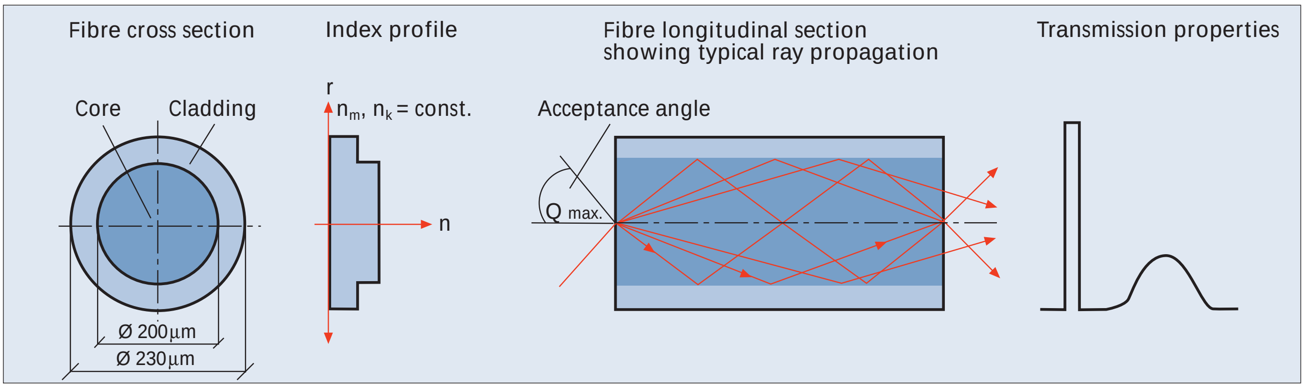
Optical fibres are dielectric light waveguides made of silica glass or plastic. They consist of a light-guiding core with the refractive index n_k which is covered by a glass cladding with a lower refractive index n_m. There are three different types of optical fibres:

Step index, multi-mode fibres

The core diameters of multi-mode (MM) optical fibres with a step profile range from 100 to 200µm. The refractive-index profile features a constant refractive index n_k in the core and a sharp decline at the interface with the cladding with the refractive index n_m.

Several hundred light waves (= modes) with different distribution patterns and considerable differences in propagation times are transmitted.

Use:	short-range applications of up to 1km
Typical values:	wavelengths: 850nm, data rates of up to 10Mbit/s.



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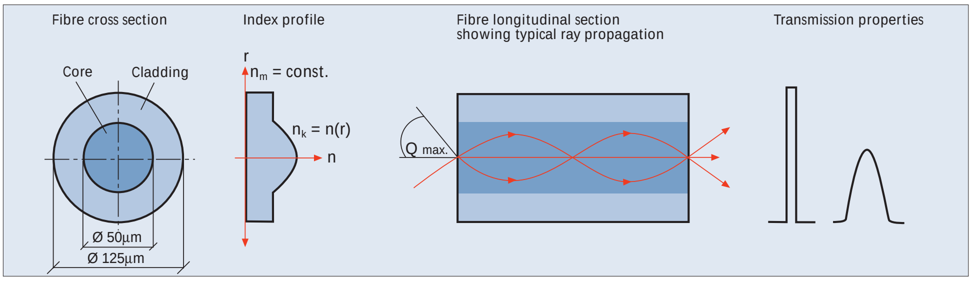
Graded index multi mode fibres

Graded index fibres have the core glasses so formed that the index of the glass becomes lower towards the outside of the fibre, this leads to slight time differences in the transmission speeds of the various modes. Low-cost LEDs can be used to launch the light. The core diameter totals 50 or 62.5µm in most cables.

The 50µm fibre features a larger product of bandwidth and length (B x L) and lower attenuation. The smaller diameter of this fibre, however, also means a reduced light power in comparison to the 62.5µm fibre, so that the attenuation margin is less favourable.

Applications: in-house cabling, ranges of up to 4km
Typical values: wavelengths: 850nm and 1310nm, data rates of up to 100Mbit/s.

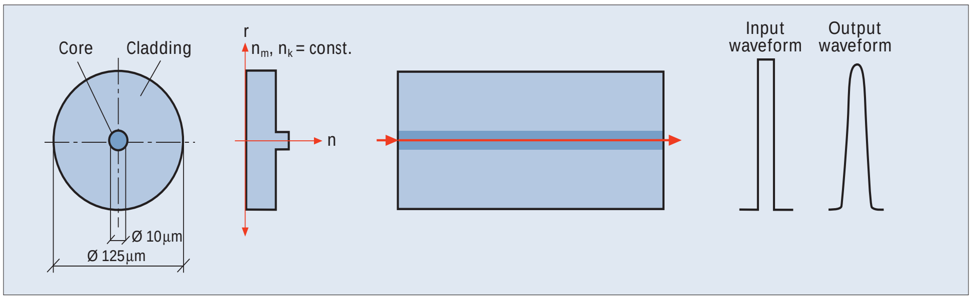


Single-mode (optical) fibres

Single-mode (SM) optical fibres have a core diameter of 10µm, permitting the propagation of just one light wave (= mode). This eliminates the problem of differences in propagation times of different modes. Launching of the light, however, requires high-quality optical laser diodes.

Single-mode optical fibres thus feature the highest transmission capacity of all types of fibres.

Applications: long-range transmission, ranges of up to 50km without repeaters
Typical values: wavelengths: 1310nm and 1550nm data rates of up to 2.4Gbit/s and more



The following table summarises the most important criteria for assessing the suitability of the different types:

Fibre type	Typical attenuation at [dB/km] 850nm	1310nm	1550nm	B x L at [Mhz x km] 850nm	1310nm	1550nm
Multi-mode optical fibre with a step profile (100/140µm)	5…12	–	–	20	–	–
Multi-mode optical fibre with a graded-index profile (50/125 µm)	3.5	1.0	–	160	400	
Multi-mode optical fibre with a graded-index profile (62.5/125µm)	3.0	0.6	–	400	1000	
Single-mode optical fibre (9/125µm)	2.5	0.4	0.2	–	100,000	100,000

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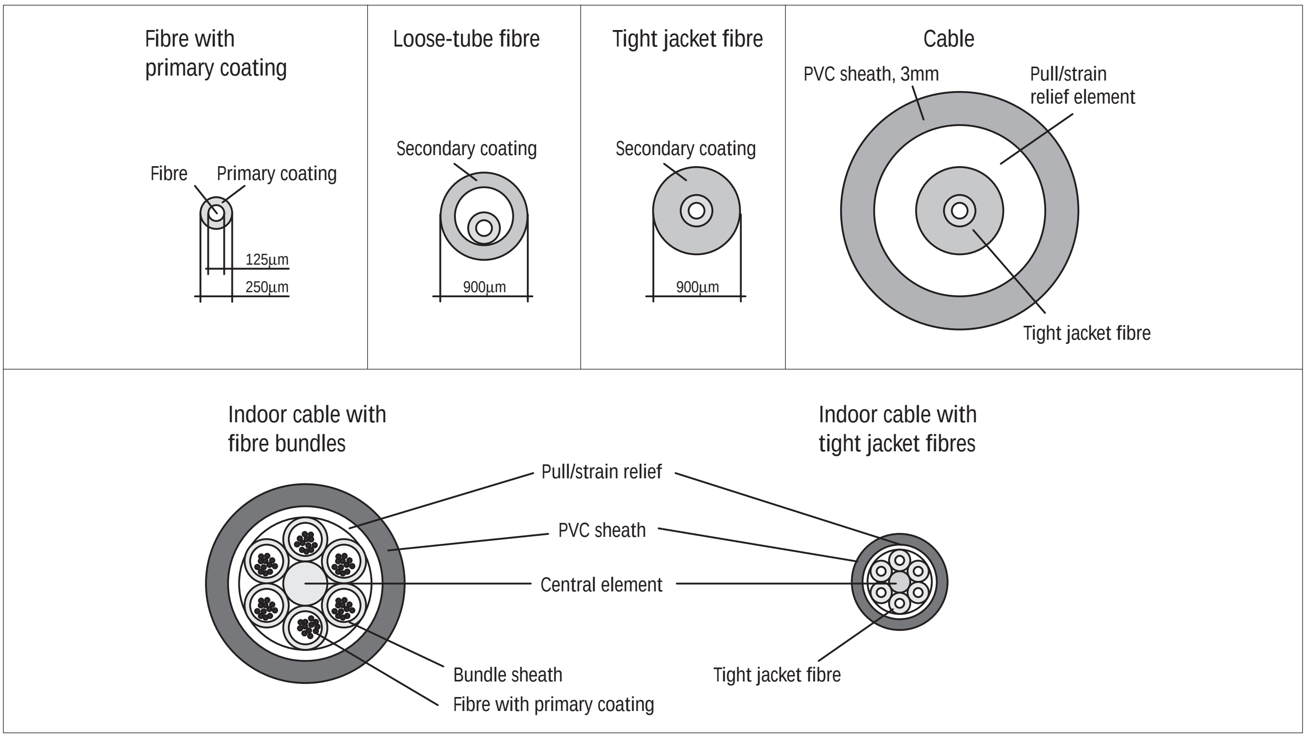
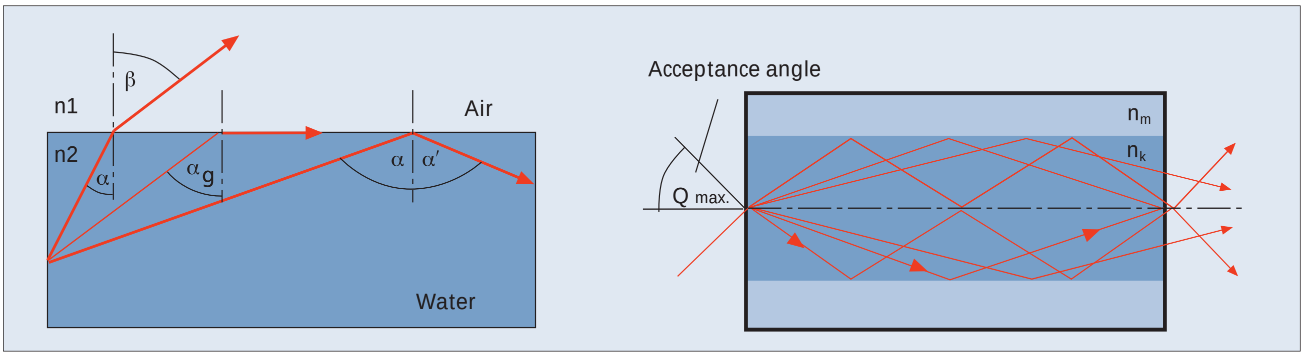
Layered plastic coatings protect the fibre against mechanical damage.



Fibre optic cables

Light guiding principles

The light is guided in accordance with the principle of total reflection as described by the law of refraction: when a certain angle of incidence is exceeded, light is reflected at the interface between a dense medium (such as water) and a thin medium (such as air). In the case of optical fibres, the core has a higher refractive index - i.e. it is optically denser than the surrounding cladding - so that this effect is achieved (e.g. n_k=1.48, n_m=1.47).



Total reflection and light guidance

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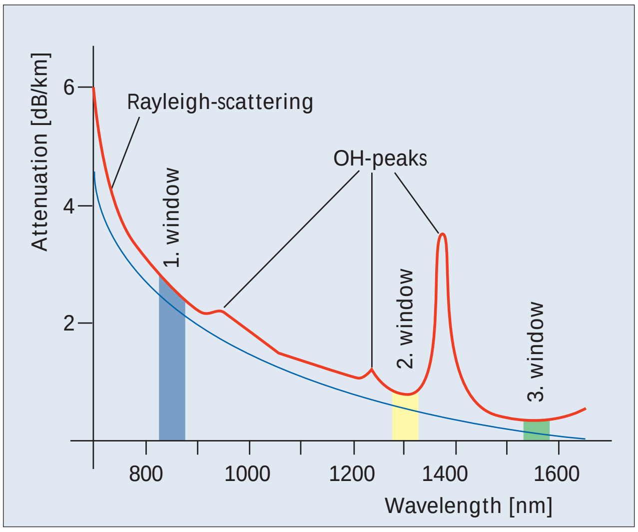
Attenuation

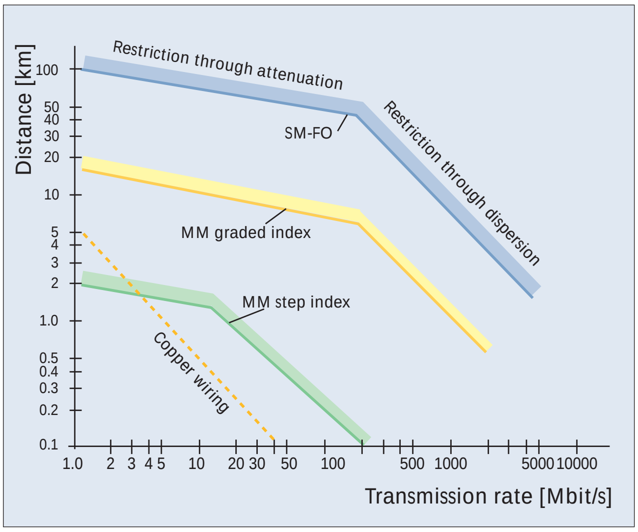
The term “attenuation” refers to the reduction in optical performance between the signal sent out and the signal received. Attenuation can result from impurities and scattering at inhomogenous areas in the glass (intrinsic losses), and can occur at a connection of two optical fibres due to misalignment, Fresnel losses, dust, eccentric cores, unsuitable connectors, etc. (extrinsic losses). The attenuation also depends on the wavelength used. The most favourable values are achieved with wavelengths in the so-called optical windows.



Attenuation characteristics of optical fibres at different wavelengths

Dispersion

The transmission properties of optical fibres are influenced by dispersion and attenuation. The dispersion is made up of material dispersion (= wavelength dependence of the refractive index of a given material) and mode dispersion (signal distortion due to superimposition of modes with different propagation times). Both phenomena widen the pulse of the input signal.



Possible transmission rates and ranges

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Transmission principle / transmitter and receiver

For an electrical signal to be transmitted through an optical fibre it must be converted to an optical signal. This is carried out by **transmitter modules** with a separate control and power supply. The most important criteria for transmission systems are the transmission power launched into the core of the optical fibre, as well as the bandwidth of the optical power. Digital versions have been developed for simple V.24 transmission with a few kbit/s, for Ethernet and token-ring applications with 4, 10 or 16Mbit/s up to FDDI backbones with several 100Mbit/s. Analogue systems are used for audio transmissions up to 30kHz or video applications from 10 to 150MHz.

Two types of light sources are used in optical communications, with different power levels, light-emitting principles, life spans and characteristics:

Light-emitting diodes (LEDs) have a non-linear characteristic, are relatively temperature-independent and do not necessarily require temperature and power control loops. They are slower and less powerful than laser diodes. Their light is incoherent and has a spectral width of 60nm.

Applications:	multi-mode fibres
Typical values:	wavelengths: 850nm, 1310nm, transmission power < 0.5mW, data rate up to 50Mbit/s range: several 100m to 10km

Laser diodes (LDs) are semiconductor diodes which emit a coherent beam with a spectral width of < 10nm. They require sophisticated temperature and power control equipment and are used in the upper Mbit range because of their high switching speed. Above a defined threshold current, they feature a largely linear characteristic and are hence also suitable for analogue transmission.

Applications:	predominantly single-mode fibres
Typical values:	wavelengths: 1310nm, 1550nm, transmission power up to 4mW range - depending on type and bit rate - up to several 10km; data rate from several MHz up to the GHz range, depending on the specific type of LD.

Optical **receiver modules** consist of several stages with properties which are optimised for the specific application. In the first step, a photo detector (PIN or avalanche photo diode) converts the optical signals back to electrical pulses. This is followed by a pre-stage which - together with the photo diode - is mainly responsible for the bandwidth that can be achieved, the input sensitivity and for the signal-to-noise ratio. The pre-stage is followed by a variable-output amplifier which equalises different levels of the optical signals received. The next step is signal regeneration in order to eliminate noise or restore signals which may be subject to a distorted pulse length.

Repeaters are used in order to regenerate the optical signals transmitted over longer distances. Regional and supra-regional long-distance networks require transmission at medium to high bit rates (34 or 140Mbit/s to 622Mbit/s) over relatively long distances. Fibre optical systems used for this purpose are usually made up of single-mode fibres.

Suitable optical transmitters for multi-mode fibres are LEDs or laser diodes. LDs are today clearly the economic choice due to their enhanced data transmission capabilities. This trend also continues in the field of optical fibres: at 1300nm (2nd optical window) single-mode fibres feature, for instance, a lesser pulse widening than multi-mode fibres and permit larger distances between repeaters. Besides the trend towards the single-mode system, new approaches now also use the 3rd optical window with 1550nm.