Amphenol SOCAPEX

Understanding Fiber Optics

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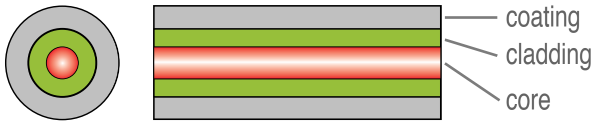
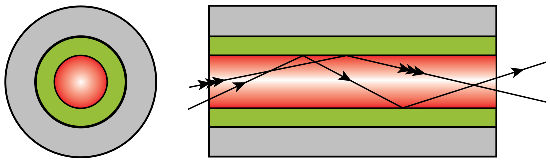
WHAT IS AN **OPTICAL FIBER ?**

Fiber structure and fiber types - An optical fiber is made of 3 concentric layers as described on the following sketch:



• **core:** This central section, made of silica, is the light transmitting region of the fiber.
• **cladding:** It is the first layer around the core. It is also made of silica, but not with the same composition as the core. This creates an optical waveguide which confines the light in the core by total reflection at the core-cladding interface.
• **coating:** It is the first non-optical layer around the cladding. The coating typically consists of one or more layers of a polymer that protect the silica structure against physical or environmental damage.

• Multimode fiber



This type of fiber is called "multimode" because light rays travel through the fiber following different paths called "modes".

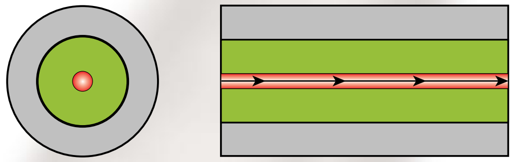
Multimode fiber

50 / 125 or 62,5 / 125

cladding diameter in microns (µm)

core diameter in microns (µm)

• Singlemode fiber



In that case, the fiber is called "singlemode" because only one mode is propagated. It travels "straight" through the fiber. The core diameter is typically 9 *µm*.

Singlemode fiber

9 / 125

cladding diameter in microns (µm)

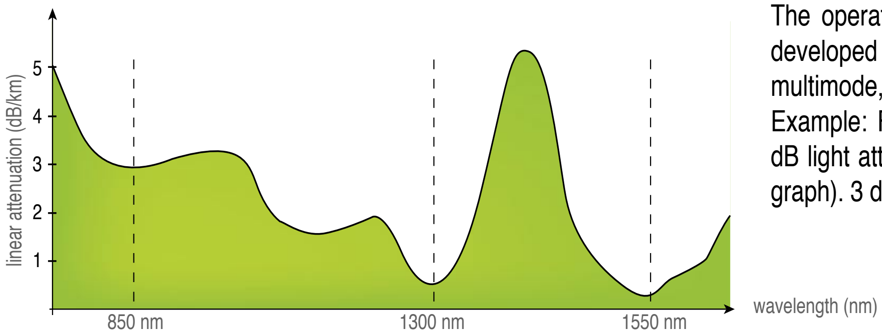
core diameter in microns (µm)

CHARACTERISTICS OF **OPTICAL FIBER**

Attenuation and wavelength

Light is gradually attenuated when it is propagated along the fiber. The attenuation value is expressed in dB/km (decibel per kilometer). It is a function of the wavelength (λ), i.e. of the color (frequency) of the light. That means that the operating wavelength to transmit a signal in an optical fiber is not any wavelength.It corresponds to a minimum of attenuation.

The following graph gives the linear attenuation as a function of the wavelength:

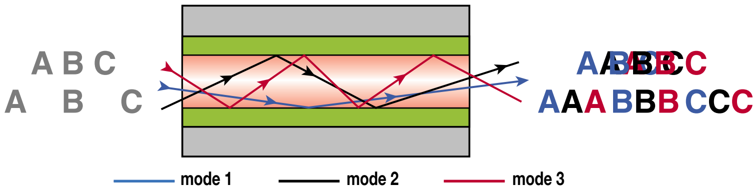


The operating wavelengths, which light sources have been developed for, are 850 nm (nanometers) and 1300 nm in multimode, and 1310 nm and 1550 nm in singlemode.
Example: For a 850 nm operating wavelength, there is a 3 dB light attenuation after 1 km propagation (according to the graph). 3 dB mean that 50% of the light has been lost.

Bandwidth

Bandwidth is a measure of the data-carrying capacity of an optical fiber. It is expressed as the product of frequency and distance. For example, a fiber with a bandwidth of 500 MHz.km (Mega-hertz kilometer) can transmit data at a rate of 500 MHz along one kilometer. Bandwidth in singlemode fibers is much higher than in multimode fibers:

• multimode case



Information (A, B or C) is propagated in fiber according to N modes (paths), which deform it, as if it were "duplicated" N times (for example on the diagram above, the mode 3 path is longer than the mode 2 path, which is itself longer than the mode 1 path). If information is too close one to the other, there is a risk of mixing, and it will not be recoverable at the exit of fiber. That is why it is necessary to space it sufficiently, i.e. to limit the flow.

• singlemode case

Information (A, B or C) is propagated in fiber according to only one mode, therefore is not deformed. It is thus possible to closer the information, i.e. to obtain a much more important flow.

WHY TO CHOOSE **FIBER OPTICS ?**

The main benefits of fiber optics are:

- **Lower loss:** Optical fiber has lower attenuation than copper conductors, allowing longer cable runs and fewer repeaters.

- **Increased bandwidth:** The high signal bandwidth of optical fiber provides a significantly greater information-carrying capacity. Typical bandwidths for multimode fibers are between 200 and 600 MHz.km, and > 10 GHz.km for singlemode fibers. Typical values for electrical conductors are 10 to 25 MHz.km.

- **Immunity to interference:** Optical fibers are immune to electromagnetic and radio frequency interference and also emit no radiation themselves.

- **No detection:** Standard fiber optic cables are dielectric, so they cannot be detected by any type of detector.

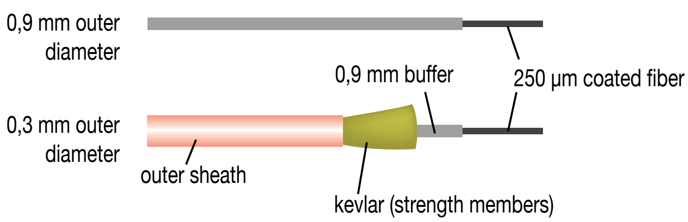
- **Electrical isolation:** Fiber optics enables to transmit information between two points at two different electrical potentials, and also next to high voltage equipments.

- **Decreased size and weight:** Compared to copper conductors of equivalent signal-carrying capacity, fiber optic cables are easier to install, require less duct space, and weight about 10 to 15 times less.

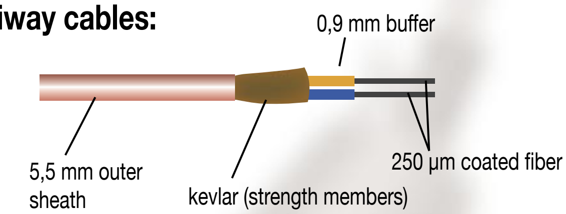
FIBER OPTIC CABLES

The coated fiber, i.e. the two active layers (core and cladding) and the protective coating, has an external diameter of 250 microns. It is very fragile. It is thus necessary to build cables to reinforce this fiber and to make it easier to handle. There is a great number of different cable constructions (see below some examples).

singleway cables:



multiway cables:



HOW TO LINK TWO OPTICAL FIBERS ?

- **There are two ways of linking two optical fibers:**

1 - Fusion splice

This operation consists in directly linking two fibers by welding with an electric arc, by aligning best possible both fiber cores. The specific device to make this fusion is called a fusion splicer.

Advantages:
- This linking method is fast and relatively simple to make.
- The light loss generated by the welding, due to an imperfect alignment of the cores, remains very weak.

Drawbacks:
- This type of link is relatively fragile (in spite of a protection of fusion by a heat-shrinkable tube).
- It is a permanent link.
- It is necessary to invest in a fusion splicer.

2 - Use of connectors

In this case, it is important to terminate a connector at each end of the fibers to be connected. The two fibers can then be connected by connecting the two connectors together.

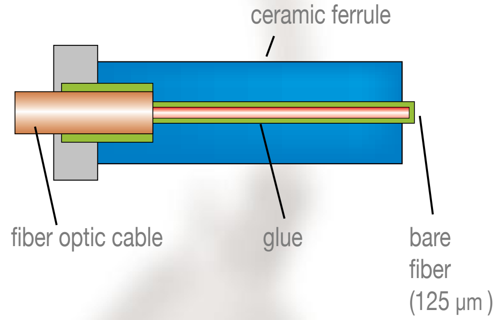
Advantages:
- This type of connection is robust.
- The type of connector can be chosen according to the application field of the system.
- Connection is removable. It is possible to connect and disconnect two fibers hundreds to thousands times without damaging the connectors.

Drawbacks:
- The implementation is longer than fusion, and requires an experiment as well as specific tools.
- The light loss due to connection is higher than in the splicing solution.

CONNECTORS TYPES

Fiber termination in the ferrule

Whatever the needed connector, the first step consists in inserting the fiber in a ferrule, to allow to simplify the fiber handling with less risk to damage it. This ferrule is generally made of ceramics and is manufactured with high precision machining process.

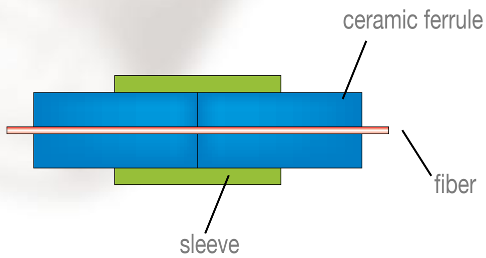


The different steps to terminate the fiber in the ferrule are:

• **fiber stripping** to keep only the active layers (core and cladding).
• **fiber epoxy bonding** in the ceramic ferrule. The fiber is introduced into the ceramic ferrule hole whose diameter is very precise, and adjusted to that of fiber.
• **fiber cleaving** at the ceramic ferrule surface.
• **polishing** of the end of the ceramic ferrule. Using lapping films of increasingly fine grains, the fiber surface is perfectly well polished, and all the awkward residual particles have been eliminated.

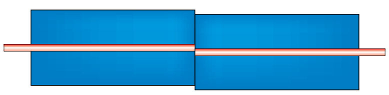
Butt joint technology

Principle:
The principle of the butt joint connectors consists in putting in physical contact the two ceramic ferrules. To realign perfectly fibers face to face, we use an alignment sleeve generally in ceramics.

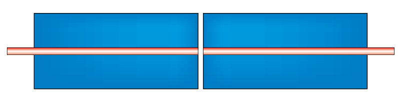


The light passes thus directly from one fiber to the other.

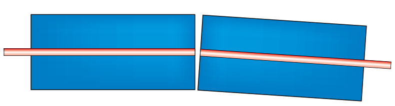
Defects:
The alignment of fibers is never perfect, some light is lost when going from one side to the other. This loss can be high according to the residual defects of alignment or polishing:



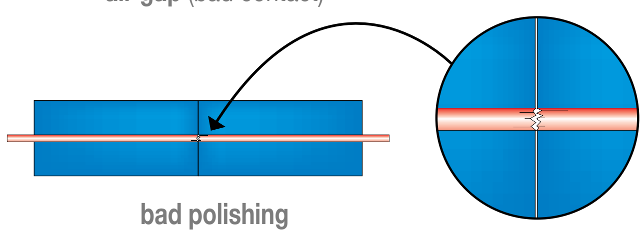
transverse shift



air gap (bad contact)



angular shift



bad polishing

Butt joint connectors characteristics:

- The loss of light generated by connection (called Insertion Loss) is low (approximately 0,3 dB typical).
- This type of connection is sensitive to pollution (dust, mud...). If a dirtiness stays between the two ceramic ferrules, a big part of the light can be lost.

Butt joint connectors examples:

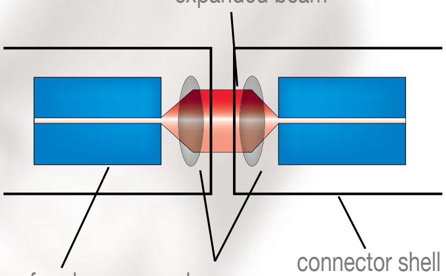
ST (singleway)

RNJOP (4 channels)

Lens technology (expanded beam technology)

Principle:

The principle of the expanded beam connectors consists in placing a lens at the exit of each fiber, in order to widen the beam by collimating it - i.e. by creating light beams parallel to the optical axis. In this configuration, there is no more physical contact between the two optical fibers.



Defects:

In this case it is the alignment of the two shells one to the other which will guarantee that the collimated beam going out from the first lens will be well refocused through the second lens. The precision of the mechanical interface parts of the connector is highly important. As for the butt joint connectors, transverse and angular shifts, and also bad polishing will generate losses.

Lens connectors characteristics:

- The light loss generated by connection (called Insertion Loss) is more important than in the previous case, due to the presence of the lenses and sometimes also of windows (approximately 1 to 1,5 typical dB).
- This type of connection is much less sensitive to pollution because the beam is much larger than the one that goes out directly from a fiber. A dust at the interface of two butt joint connectors will create a much higher loss than located at the interface of two lens connectors.

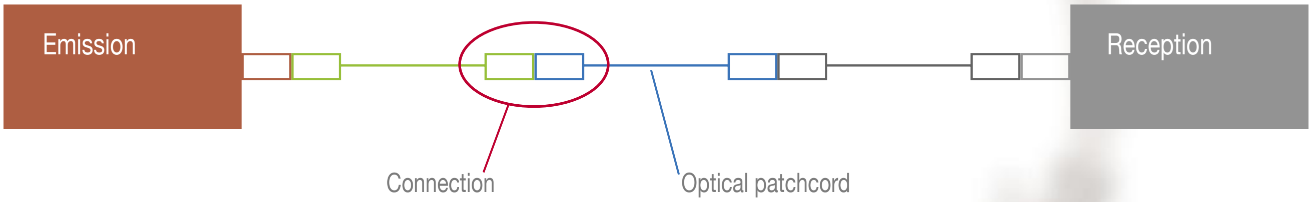
Lens connectors examples:

CTOS (2/4 channels)

CTOL (8 channels)

CHARACTERISTICS OF **FIBER OPTIC LINKS**

A fiber optic interconnection system can generally be described by the following sketch:



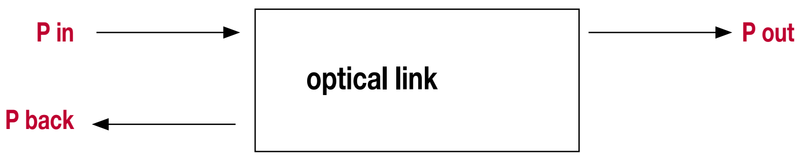
It is made of the following elements :

• emission system

It contains a light source. To obtain a well functioning system, it is important to know :
• the type of light source (LED or laser).
• the operating wavelength (1300 nm for example).
• the light source power.
• the interface connector type at the light source output.

• one or more optical patchcords

The pachcords are defined by:
• the fiber optic cable described by its length, the number of channels, the fiber type (singlemode, multimode 50/125 or 62,5/125).
• the connectors terminated at both ends of the cable.
• the whole patchcord is characterized by a loss named Insertion Loss, expressed in dB. This loss gives the quantity of lost light when introducing this patchcord in the transmission line. It includes the linear attenuation of the cable and the loss due to the connectors.
• for singlemode patchcords, another important parameter, called Return Loss, represents the quantity of light which is reflected by the line and which returns in the direction of the source. The laser sources used in singlemode applications can be very sensitive to this phenomenon.



The Insertion Loss of the link is: PI = 10 log (Pout / Pin)
The Return Loss of the link is: RL = 10 log (Pback / Pin)

• reception system

It contains a receiver which has a photosensitive surface, and which converts the light into electric signal. It is important to know:
• its sensitivity, i.e. the minimal quantity of detectable light.
• the interface connector type at the receiver input.

Amphenol is the fiber optic expert you need to solve your problem !

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