Optical Fiber 101

Optical Fiber

An optical fiber is a flexible filament of very clear glass and is capable of carrying information in the form of light. This filament of glass is a little thicker than a human hair. In its simplest terms, fiber optics is a medium for carrying information from one point to another in the form of light. Unlike the copper form of transmission, fiber optics is not electrical in nature.

Core and Cladding

The two basic elements of optical fiber are its core and cladding. The core, or the axial part of the optical fiber, is the light transmission area of the fiber. The cladding is the layer completely surrounding the core. The difference in refractive index between the core and cladding is less than 0.5%. The refractive index of the core is higher than that of the cladding, so that light in the core strikes the interface with the cladding at a bouncing angle and is trapped in the core by total internal reflection.

Multimode vs. Single-mode

A mode is a defined path in which light travels. A light signal can propagate through the core of the optical fiber on a single path (single-mode fiber) or on many paths (multimode fiber). The mode in which light travels depends on geometry, the index (refractive index) profile of the fiber, and the wavelength of the light. The number of modes allowed in a given fiber is determined by a relationship between the wavelength of the light passing through the fiber, the core diameter of the fiber, and the material of the fiber.

Single-mode fiber has the advantage of high information-carrying capacity, low attenuation and low fiber cost, but multimode has the advantage of low connection and electronics cost that may lead to lower system cost.

Mode-Field Diameter

Not all light travels through the core of the fiber, but is distributed through both the core and the cladding. The "mode field" is the distribution of light through the core and cladding of a particular fiber. Mode-Field Diameter (MFD) defines the size of the power distribution. When coupling light into or out of a fiber, MFD is important in understanding light loss.

Total Internal Reflection

Total internal reflection causes the light to be guided down the fiber. Total internal reflection is directly related to the fact that the refractive index of the cladding is less than the refractive index of the core.

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Numerical Aperture

Total internal reflection is what causes light to be guided along the length of an optical fiber. First, however, light must fall inside an acceptable angle so that it can enter into the fiber's core. Acceptance angle or numerical aperture (NA) measures the range of acceptance of light into a fiber. The angle over which a fiber accepts light depends on the refractive indices of the core and cladding glass. Refraction bends a ray of light entering a fiber so that it is at a smaller angle to the axis of the fiber than it was in air.

Rays entering a fiber at an angle greater than the NA will not be reflected internally, and will pass through, or be absorbed by, the cladding of the fiber. Either way, these rays are lost. Rays entering a fiber at an angle equal to or less than the acceptance angle will be reflected internally, and will propagate down the length of the fiber.

Attenuation

The reduction in signal strength is measured as attenuation. Attenuation measurements are made in decibels (dB). The decibel is a logarithmic unit that indicates the ratio of output power to input power. Each optical fiber has a characteristic attenuation that is normally measured in decibels per kilometer (dB/km). You will probably read a specification that looks like this:
9.50dB/Km @ 0800 nm.
This means:
9.50 decibels per kilometer at 800 nanometers of wavelength.

There are three things one need to remember about attenuation:
1. Attenuation is a loss per unit length.
2. Attenuation can be converted to percent transmission for a given length.
3. Attenuation is wavelength specific.

Optical fibers are distinctive in that they allow high-speed transmission with low attenuation.

Dispersion

Generally, light is sent down the fiber in the form of a pulse. As pulses travel down the fiber they spread out. This spreading is known as dispersion. Dispersion is undesirable because it can cause bit errors when the signal reaches the receiver. To avoid bit errors, it is necessary to condition the signal using dispersion compensation or to regenerate the signal using a repeater. The signal must be regenerated prior to the occurrence of any errors.

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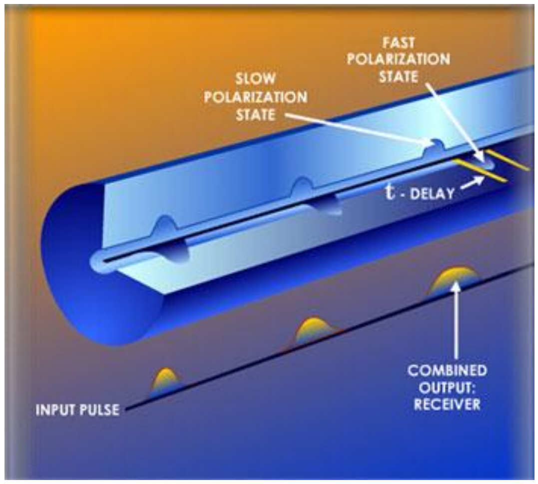
Polarization Mode Dispersion

Polarization Mode Dispersion is where the two orthogonal polarization states of the mode separate, resulting in pulse spreading.



Typical Construction

An optical fiber is constructed of a transparent core made of nearly pure silicon dioxide (SiO_2), through which the light travels. The core is surrounded by a cladding layer that reflects light, guiding the light along the core. A plastic coating covers the cladding to protect the glass surface. Cables also include fibers of Kevlar and/or steel wires for strength and an outer sheath of plastic or Teflon for protection.

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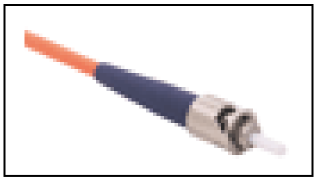
Various Fibers



Fiber SMA Connector

Fiber Optics Lab Kit

Fiber Wire Stripper

Fiber Optics AD Kit

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