So What Do I Need An Attenuator For?

An **optical attenuator** is a device used to reduce the power level of an optical signal, either in free space or in an optical fiber. They are commonly used in fiber optic communications. The basic types of optical attenuators are fixed, step-wise variable, and continuously variable. In some cases an optical light source can overload a detector to the point where it cannot distinguish between the presence or absence of light pulses. That is when an attenuator is quite handy.

Fiber optic attenuators are devices that reduce signal power in fiber optic links by inducing a fixed or variable loss. They are used to control the power level of optical signals at the outputs of light sources and electrical-to-optical (E/O) converters. They are also used to test the linearity and dynamic range of photo sensors and photo detectors. Fiber optic attenuators use several methods of attenuation. Examples include air gaps, microbends, acousto-optic modulators, and electro-optic modulators. Air gaps between optical fibers cause light to be reflected because of the change in refractive index. Microbends are sharp curvatures with local axial displacements of a few micrometers and spatial wavelengths of a few millimeters. Microbending can cause significant radiative loss and mode coupling. Acousto-optic modulators use sound waves to modify the amplitude, frequency, or phase of light passing through an acousto-optic material. Similarly, electro-optic modulators use an electric field to alter the characteristics of light passing through an electro-optic material.

FIBER SOLUTIONS, INC.

Fiber optic attenuators can use single-mode and/or multi-mode optical cable. Single-mode cable allows only one mode to propagate and features very small core diameters of approximately 8 µm. Single-mode cable permits signal transmissions at extremely high bandwidths and allows very long transmission distances. By contrast, multi-mode cable supports the propagation of multiple modes and features core diameters ranging from 50 to 100 µm. Multi-mode cable has a graded or stepped refractive index and allows the use of inexpensive light emitting diode (LED) light sources. With multi-mode cables, connector alignment and coupling is less critical than with single-mode fibers. Because of dispersion, however, multi-mode cable provides reduced transmission distances and transmission bandwidths.

Many types of connectors are used with fiber optic attenuators. Biconic connectors have precision-tapered ends for low insertion loss. D4 and FC connectors are durable, zirconia-ceramic ferrules with a keyed body for repeatability. FC connectors are used primarily with single-mode fibers, but are also used in telephone systems, instruments, and high-speed communication links. Designed for use in FDDI networks, FDDI connectors are

2.5 mm ferrules that include a fixed shroud. ESCON connectors have the same measurements, but use an adjustable shroud. LC connectors are high-precision, zirconia-ceramic ferrules that feature an RJ-45 push-pull housing and latching. MT-RJ connectors hold two fibers with a ferrule that is smaller than the one used in MTP connectors, devices that are threaded and well-suited for high-density applications. ST connectors are easy-to-assemble devices that feature a bayonet mounting system. They are used with both single-mode and multi-mode fibers in communications applications. SMA connectors include a low-cost, multi-mode coupling that is suitable for military applications. Loop back connectors are used to test transceiver systems.

Important specifications for fiber optic attenuators include wavelength range, attenuation range, resolution, polarization dependent loss (PDL), and return loss. Attenuation range measures the signal loss produced by fiber optic attenuators. For fixed attenuators, this is a single value. For variable attenuators, this is a range of values. Resolution measures attenuation sharpness. As a rule of thumb, higher resolutions indicate sharper distinctions between attenuation levels. PDL is the polarization dependent signal loss produced by fiber optic attenuators. Return loss is the ratio of reflected power to incident power. Expressed in decibels (dB), return loss also measures the amount of reflected power on a transmission line that is terminated or connected to a passive or active device. Some fiber optic attenuators are rack-mounted or include a pigtail. Others maintain the polarization of the incoming signal.

Attenuation

Attenuation is the loss of optical power as light travels down a fiber. It is measured in decibels (dB/km). Over a set distance, a fiber with a lower attenuation will allow more power to reach its receiver than a fiber with higher attenuation.

While low-loss optical systems are always desirable, it is possible to lose a large portion of the initial signal power without significant problems. A loss of 50% of initial power is equal to a 3.0 dB loss. Any time fibers are joined together there will be some loss. Losses for fusion splicing and for mechanical splicing are typically 0.2 dB or less.

Attenuation can be caused by several factors, but is generally placed in one of two categories: intrinsic or extrinsic.

Intrinsic Attenuation

Intrinsic attenuation occurs due to something inside or inherent to the fiber. It is caused by impurities in the glass during the manufacturing process. As precise as manufacturing is, there is no way to eliminate all impurities, though technological advances have caused attenuation to decrease dramatically since the first optical fiber in 1970.

When a light signal hits an impurity in the fiber, one of two things will occur: it will scatter or it will be absorbed.

Scattering
Rayleigh scattering accounts for the majority (about 96%) of attenuation in optical fiber. Light travels in the core and interacts with the atoms in the glass. The light waves elastically collide with the atoms, and light is scattered as a result.

Rayleigh scattering is the result of these elastic collisions between the light wave and the atoms in the fiber. If the scattered light maintains an angle that supports forward travel within the core, no attenuation occurs. If the light is scattered at an angle that does not support continued forward travel, the light is diverted out of the core and attenuation occurs.

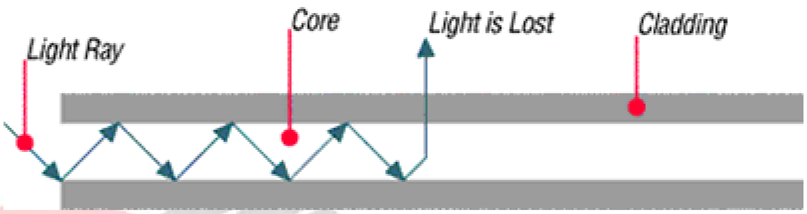

Figure 11

Some scattered light is reflected back toward the light source (input end). This is a property that is used in an Optical Time Domain Reflectometer (OTDR) to test fibers. This same principle applies to analyzing loss associated with localized events in the fiber, such as splices.

FIBER SOLUTIONS, INC.

Absorption
The second type of intrinsic attenuation in fiber is absorption. Absorption accounts for 3-5% of fiber attenuation. This phenomenon causes a light signal to be absorbed by natural impurities in the glass, and converted to vibrational energy or some other form of energy. (Figure 12)

Unlike scattering, absorption can be limited by controlling the amount of impurities during the manufacturing process.

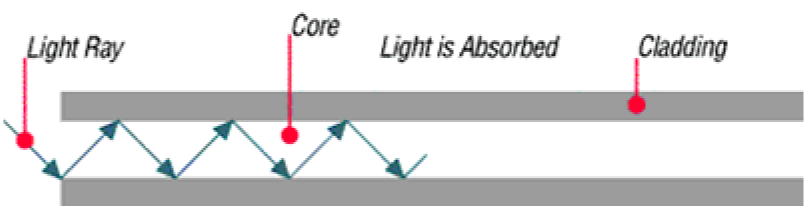

Figure 12

Extrinsic Attenuation

>

The second category of attenuation is extrinsic attenuation. Extrinsic attenuation can be caused by two external mechanisms: macrobending or microbending. Both cause a reduction of optical power.

Macrobending
If a bend is imposed on an optical fiber, strain is placed on the fiber along the region that is bent. The bending strain will affect the refractive index and the critical angle of the light ray in that specific area. As a result, light traveling in the core can refract out, and loss occurs. (Figure 13)

A macrobend is a large-scale bend that is visible; for example, a fiber wrapped around a person's finger. This loss is generally reversible once bends are corrected.

To prevent macrobends, all optical fiber (and optical fiber cable) has a minimum bend radius specification that should not be exceeded. This is a restriction on how much bend a fiber can withstand before experiencing problems in optical performance or mechanical reliability. The rule of thumb for minimum bend radius is 1 1/2" for bare, single-mode fiber; 10 times the cable's outside diameter (O.D.) for non-armored cable; and 15 times the cable's O.D. for armored cable.

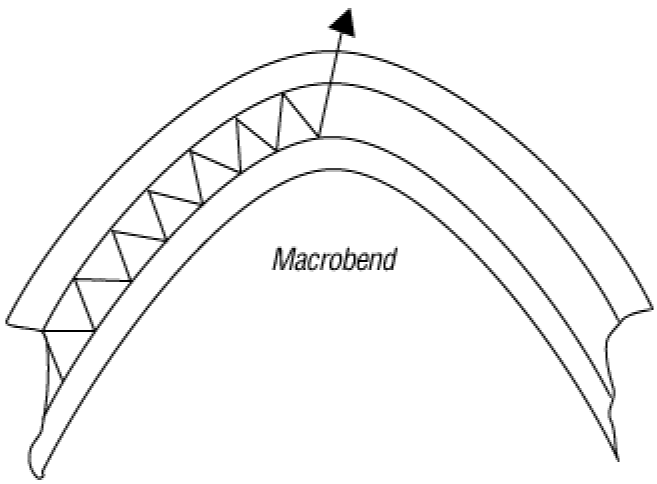

Figure 13

Microbending

The second extrinsic cause of attenuation is a microbend. This is a small-scale distortion, generally indicative of pressure on the fiber. (See Figure 14 below.) Microbending may be related to temperature, tensile stress, or crushing force. Like macrobending, microbending will cause a reduction of optical power in the glass.

Microbending is very localized, and the bend may not be clearly visible upon inspection. With bare fiber, microbending may be reversible; in the cabling process, it may not.

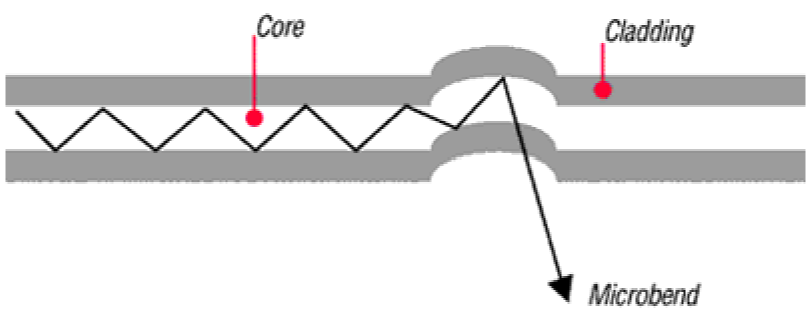

Figure 14

FIBER SOLUTIONS, INC.