What Is Optical Fiber?

Very thin strands of pure silica glass through which laser light travels

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If you were to shine a light through a glass rod, very little would reach the far end. This is because, no matter how clear the glass may appear, it is full of impurities brought about by its composition and the manufacturing process. All these impurities absorb the light, and only a small amount manages to fight its way through to the end. The key to optical fiber is that it is made from extremely pure glass — silica. Light is still lost on the way through the fiber, but far less than with regular glass.

The problem is how to guide the light through optical fiber that might be hundreds or even thousands of miles in length. The understanding of this comes from basic physics lessons. You may remember shining some light through glass blocks and seeing how it was bent, or "refracted" when it left the glass. If you sent the light into the glass at an angle greater than the "critical" angle, then it would be totally reflected within the block and not exit where you expected. It is all to do with refractive indices and a law in physical properties law called Snell's law. The refractive index of a material determines how quickly light can travel through it.

Optical fiber is manufactured by first "drawing" a very thin circular cross section of pure silica. Typically for multi-mode (modal discussion to follow) this "core" is either 50 or 62.5 microns in diameter. For single-mode optical fiber the "core" is typically 8-9 microns in diameter. Once you have an optical fiber core of pure silica, you add an extra layer of glass known as a "cladding layer," which has a lower refractive index than the core. This refractive index difference serves to guide the light in the core and allow as little as possible to leave through the sides (according to Snell's law as described above). On top of the cladding layer are typically some polymer coatings which just make it easier to handle the fiber. Typically these are acrylate for commercial optical fibers or polyimide for high temperature aerospace fibers.

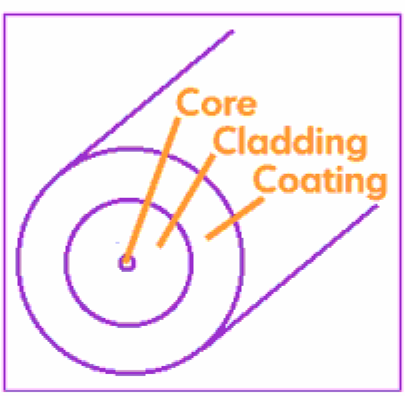

Figure 1: Optical Fiber Layers

The size of the optical fiber core determines how the light travels through it. Each optical signal can actually generate many different lightwaves, which can all travel through the fiber at the same time. This is allowed to happen in so-called 'multimode' fibers, but can cause problems with each wave arriving at the end of the fiber slightly out of sync. Most modern optical networks will use 'singlemode' fiber, which has a much smaller core than that of multimode. The core size is small enough to ensure that only one lightwave from each optical signal can travel in the fiber, so there are no problems at the receiving end.

Today most optical fiber is driven toward an industry standard , 125 micrometer outside glass diamters. To provide an idea of the typical construction, in a singlemode fiber the core is usually around 8-9 micrometers in diameter (0.000009 m) and the cladding is over 10 times thicker at a diameter of 125 micrometers (0.000125m or 0.125mm). Once the polymer coatings are added, the whole package may be around 0.25 millimeters in diameter.

Even the very pure glass in optical fiber "attenuates" light, that is, it causes some of the intensity of the light to be lost within the fiber. These losses can be due to several mechanisms, particularly light losing its energy to atoms in the fiber (absorption), light scattering because of slight changes in the core's refractive index (Rayleigh scattering), and light scattering because the core is not always a perfect cylinder (Mie scattering).

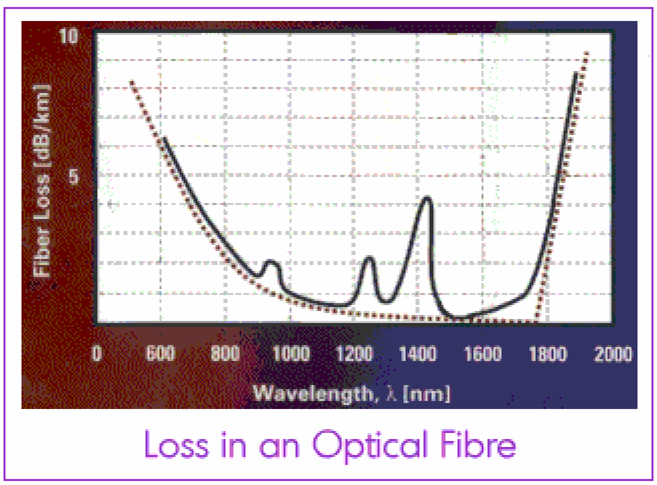

Figure 2: Optical Fiber Loss Characteristics

The fact that different wavelengths travel at different speeds in a fiber is called "chromatic dispersion." Optical signals cannot be totally pure wavelengths (physics again); they must contain a range, so they smudge as they travel down the fiber.

"Polarization mode dispersion" (PMD) is another effect whereby different parts of the light signal travel at different speeds down a fiber. It's caused by inhomogeneity in the fiber material (e.g., the fiber is slightly more dense along one side than the other) and is much more difficult to predict and correct for than chromatic dispersion.

The loss within optical fiber dictates the wavelengths a designer selects to transmit information. Modern optical networks transmit at wavelengths around 1550 nanometers (1nm is 0.000000001 meters), as this is the point of minimum loss in standard optical fibers (often called the 3rd transmission window). Older systems operated at around 1300nm, which is another point of minimum loss in optical fibers known as the 2nd transmission window. The region around 850nm was one of the first used in optical networks, and is referred to as the 1st transmission window.

More modern designs of fiber try to smooth out the attenuation curve through complex chemical engineering of the fiber material. The result is an increased range of wavelengths at which information can be transmitted at low loss through the fiber, and hence an increase in the total information capacity of optical fiber systems.