**In the name of GOD**

**Optical fiber**

Optical fiber can be used as a medium for telecommunication and computer networking because it is flexible and can be bundled as cables. It is especially advantageous for long-distance communications, because light propagates through the fiber with little attenuation compared to electrical cables. This allows long distances to be spanned with few repeaters. Additionally, the per channel light signals propagating in the fiber can be modulated at rates as high as 111 Gb/s. In today's WDM systems the net data rate (data rate without overhead bytes) per fiber is the per channel data rate reduced by the FEC overhead multiplied by the number of channels (usually up to 80 channels in commercially available systems as of 2008). (Some communication companies are revealing that net data rates as fast as 1Tb/s are currently being developed), and each fiber can carry many independent channels, each by a different wavelength of light ([wavelength-division multiplexing](http://en.wikipedia.org/wiki/Wavelength-division_multiplexing)).

Over short distances, such as networking within a building, fiber saves space in cable ducts because a single fiber can carry much more data than a single electrical cable. Fiber is also immune to electrical interference, which prevents cross-talk between signals in different cables and pickup of environmental noise. Also, [wiretapping](http://en.wikipedia.org/wiki/Wiretapping) is more difficult compared to electrical connections, and there are concentric dual core fibers that are said to be tap-proof. Because they are non-electrical, fiber cables can bridge very high electrical potential differences and can be used in environments where explosive fumes are present, without danger of ignition.

Although fibers can be made out of transparent [plastic](http://en.wikipedia.org/wiki/Plastic_optical_fiber), [glass](http://en.wikipedia.org/wiki/All-silica_fiber), or a [combination of the two](http://en.wikipedia.org/wiki/Plastic-clad_silica_fiber), the fibers used in long-distance telecommunications applications are always glass, because of the lower optical attenuation. Both multi-mode and single-mode fibers are used in communications, with multi-mode fiber used mostly for short distances (up to 500 m), and single-mode fiber used for longer distance links. Because of the tighter tolerances required to couple light into and between single-mode fibers (core diameter about 10 micrometers), single-mode transmitters, receivers, amplifiers and other components are generally more expensive than multi-mode components.

**Principle of operation**

An optical fiber is a cylindrical [dielectric](http://en.wikipedia.org/wiki/Dielectric) [waveguide](http://en.wikipedia.org/wiki/Waveguide_%28optics%29) that transmits light along its axis, by the process of [total internal reflection](http://en.wikipedia.org/wiki/Total_internal_reflection). The fiber consists of a core surrounded by a [cladding](http://en.wikipedia.org/wiki/Cladding) layer. To confine the optical signal in the core, the [refractive index](http://en.wikipedia.org/wiki/Refractive_index) of the core must be greater than that of the cladding. The boundary between the core and cladding may either be abrupt, in [step-index fiber](http://en.wikipedia.org/wiki/Step-index_profile), or gradual, in [graded-index fiber](http://en.wikipedia.org/wiki/Graded-index_fiber).

**Total internal reflection**

When light traveling in a dense medium hits a boundary at a steep angle, the light will be completely reflected. This effect is used in optical fibers to confine light in the core. Light travels along the fiber bouncing back and forth of the boundary. Because the light must strike the boundary with an angle less than the critical angle (minimum angle for total internal reflection), only light that enters the fiber within a certain range of angles can travel down the fiber without leaking out. This range of angles is called the [acceptance cone](http://en.wikipedia.org/wiki/Acceptance_cone) of the fiber. The size of this acceptance cone is a function of the refractive index difference between the fiber's core and cladding.

In simpler terms, there is a maximum angle from the fiber axis at which light may enter the fiber so that it will propagate, or travel, in the core of the fiber. The [sine](http://en.wikipedia.org/wiki/Sine) of this maximum angle is the [numerical aperture](http://en.wikipedia.org/wiki/Numerical_aperture) (NA) of the fiber. Fiber with a larger NA requires less precision to splice and work than that fiber with a smaller NA. Single-mode fiber has a small NA.

**Multimode fiber**

A laser that bouncing down an [acrylic](http://en.wikipedia.org/wiki/Acrylic_glass) rod, illustrating the total internal reflection of light in a multimode optical fiber. Fiber with large (greater than 10 [μm](http://en.wikipedia.org/wiki/Micrometre%22%20%5Co%20%22Micrometre)) core diameter may be analyzed by [geometric optics](http://en.wikipedia.org/wiki/Geometric_optics). Such fiber is called [multimode fiber](http://en.wikipedia.org/wiki/Multi-mode_fiber), from the electromagnetic analysis. In a step-index multimode fiber, [rays](http://en.wikipedia.org/wiki/Ray_%28optics%29) of light are guided along the fiber core by total internal reflection. Rays that meet the core-cladding boundary at a high angle greater than the [critical angle](http://en.wikipedia.org/wiki/Critical_angle) for this boundary are completely reflected. The critical angle is determined by the difference in index of refraction between the core and cladding materials. Rays that meet the boundary at a low angle are refracted from the [core](http://en.wikipedia.org/wiki/Core) into the cladding, and do not convey light and hence information along the fiber. The critical angle determines the [acceptance angle](http://en.wikipedia.org/wiki/Acceptance_angle) of the fiber, often reported as a [numerical aperture](http://en.wikipedia.org/wiki/Numerical_aperture). A high numerical aperture allows light to propagate down the fiber in rays both close to the axis and at various angles, allowing efficient coupling of light into the fiber. However, this high numerical aperture increases the amount of [dispersion](http://en.wikipedia.org/wiki/Dispersion_%28optics%29) as rays at different angles have different [path lengths](http://en.wikipedia.org/wiki/Optical_path_length) and therefore take different times to traverse the fiber. A low numerical aperture may therefore be desirable.

**Single-mode fiber**

Fiber with a core diameter less than about ten times the [wavelength](http://en.wikipedia.org/wiki/Wavelength) of the propagating light cannot be modeled using geometric optics. Instead, it must be analyzed as an [electromagnetic](http://en.wikipedia.org/wiki/Electromagnetic) structure, by solution of [Maxwell's equations](http://en.wikipedia.org/wiki/Maxwell%27s_equations) as reduced to the [electromagnetic wave equation](http://en.wikipedia.org/wiki/Electromagnetic_wave_equation). The electromagnetic analysis may also be required to understand behaviors such as [speckle](http://en.wikipedia.org/wiki/Speckle) that occur when [coherent](http://en.wikipedia.org/wiki/Coherence_%28physics%29) light propagates in multi-mode fiber. As an optical waveguide, the fiber supports one or more confined [transverse modes](http://en.wikipedia.org/wiki/Transverse_mode) by which light can propagate along the fiber. Fiber supporting only one mode is called [single-mode](http://en.wikipedia.org/wiki/Single-mode_optical_fiber) or mono-mode fiber. The behavior of larger-core multimode fiber can also be modeled using the wave equation, which shows that such fiber supports more than one mode of propagation (hence the name). The results of such modeling of multi-mode fiber approximately agree with the predictions of geometric optics, if the fiber core is large enough to support more than a few modes.

The waveguide analysis shows that the light energy in the fiber is not completely confined in the core. Instead, especially in single-mode fibers, a significant fraction of the energy in the bound mode travels in the cladding as an [evanescent wave](http://en.wikipedia.org/wiki/Evanescent_wave). The most common type of single-mode fiber has a core diameter of 8 to 10μm and is designed for use in the [near infrared](http://en.wikipedia.org/wiki/Near_infrared). The mode structure depends on the wavelength of the light used, so that this fiber actually supports a small number of additional modes at visible wavelengths. Multi-mode fiber, by comparison, is manufactured with core diameters as small as 50 micrometers and as large as hundreds of micrometers.

<http://en.wikipedia.org/wiki/Optical_fiber>

  



