# OPTICAL FIBER

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An optical fiber (or optical fibre) is a glass or plastic fiber designed to guide light along its length by confining as much light as possible in a propagating form. In fibers with large core diameter, the confinement is based on total internal reflection. In smaller diameter core fibers, (widely used for most communication links longer than 200 meters (m)) the confinement relies on establishing a waveguide. Fiber optics is the overlap of applied science and engineering concerned with such optical fibers. Optical fibers are widely used in fiber-optic communication, which permits transmission over longer distances and at higher data rates than other forms of wired and wireless communications. They are also used to form sensors, and in a variety of other applications.

The term optical fiber covers a range of different designs including graded-index optical fibers, step-index optical fibers, birefringent polarization-maintaining fibers, and more recently, photonic crystal fibers, with the design and the wavelength of the light propagating in the fiber dictating whether or not it will be multi-mode optical fiber or single-mode optical fiber. Because of the mechanical properties of the more common glass optical fibers, special methods of splicing fibers and of connecting them to other equipment are needed. Manufacture of optical fibers is based on partially melting a chemically doped preform and pulling the flowing material on a draw tower. Fibers are built into different kinds of cables depending on how they will be used.

Although fibers can be made out of transparent plastic, glass, or a combination of the two, 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, single-mode transmitters, receivers, amplifiers, and other components are generally more expensive than multi-mode components.

Optical fibers can be used as sensors to measure strain, temperature, pressure, and other parameters. The small size and the fact that no electrical power is needed at the remote location gives the fiber optic sensor advantages to conventional electrical sensor in certain applications.

Optical fibers are used as hydrophones for seismic or SONAR applications. Hydrophone systems with more than 100 sensors per fiber cable have been developed. Hydrophone sensor systems are used by the oil industry as well as a few countries' naval forces. Both bottom mounted hydrophone arrays and towed streamer systems are in use. The German company Sennheiser developed a microphone working with a laser and optical fibers[2].

Optical fiber sensors for temperature and pressure have been developed for downhole measurement in oil wells. The fiber optic sensor is well suited for this environment as it is functioning at temperatures too high for semiconductor sensors (Distributed Temperature Sensing).

Another use of the optical fiber as a sensor is the optical gyroscope which is in use in the Boeing 767, some car models (for navigation purposes), and Hydrogen microsensors.

Fibers are widely used in illumination applications. They are used as light guides in medical and other applications where bright light needs to be shone on a target without a clear line-of-sight path. In some buildings, optical fibers are used to route sunlight from the roof to other parts of the building (see non-imaging optics). Optical fiber illumination is also used for decorative applications, including signs, art, and artificial Christmas trees. Swarovski boutiques use optical fibers to illuminate their crystal showcases from many different angles while only employing one light source. Optical fiber is an intrinsic part of the light-transmitting concrete building product, LiTraCon[3].

Optical fiber is also used in imaging optics. A coherent bundle of fibers is used, sometimes along with lenses, for a long, thin imaging device called an endoscope, which is used to view objects through a small hole. Medical endoscopes are used for minimally invasive exploratory or surgical procedures (endoscopy). Industrial endoscopes (see fiberscope or borescope) are used for inspecting anything hard to reach, such as jet engine interiors.

An optical fiber doped with certain rare-earth elements such as erbium can be used as the gain medium of a laser or optical amplifier. Rare-earth doped optical fibers can be used to provide signal amplification by splicing a short section of doped fiber into a regular (undoped) optical fiber line. The doped fiber is optically pumped with a second laser wavelength that is coupled into the line in addition to the signal wave. Both wavelengths of light are transmitted through the doped fiber, which transfers energy from the second pump wavelength to the signal wave. The process that causes the amplification is stimulated emission.

Optical fibers doped with a wavelength shifter are used to collect scintillation light in physics experiments.

Optical fiber can be used to supply a low level of power (around one watt) to electronics situated in a difficult electrical environment. Examples of this are electronics in high-powered antenna elements and measurement devices used in high voltage transmission equipment.

An optical fiber is a cylindrical dielectric waveguide that transmits light along its axis, by the process of total internal reflection. The fiber consists of a core surrounded by a cladding layer. To confine the optical signal in the core, the 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, or gradual, in graded-index fiber.

Standard optical fibers are made by first constructing a large-diameter preform, with a carefully controlled refractive index profile, and then pulling the preform to form the long, thin optical fiber. The preform is commonly made by three chemical vapor deposition methods: Inside vapor deposition, outside vapor deposition, and vapor axial deposition.

With inside vapor deposition, a hollow glass tube approximately 40cm in length, known as a "preform," is placed horizontally and rotated slowly on a lathe, and gases such as silicon tetrachloride ($SiCl_4$) or germanium tetrachloride ($GeCl_4$) are injected with oxygen in the end of the tube. The gases are then heated by means of an external hydrogen burner, bringing the temperature of the gas up to 1900 Kelvin, where the tetrachlorides react with oxygen to produce silica or germania (germanium oxide) particles. When the reaction conditions are chosen to allow this reaction to occur in the gas phase throughout the tube volume, in contrast to earlier techniques where the reaction occurred only on the glass surface, this technique is called modified chemical vapor deposition.

The oxide particles then agglomerate to form large particle chains, which are subsequently deposited on the walls of the tube as soot. The deposition is due to the large difference in temperature between the gas core and the wall causing the gas to push the particles outwards (this is known as thermophoresis). The torch is then traversed up and down the length of the tube to deposit the material evenly. After the torch has reached the end of the tube, it is then brought back to the beginning of the tube and the deposited particles are then melted to form a solid layer. This process is repeated until a sufficient amount of material has been deposited. For each layer the composition can be changed by varying the gas composition, resulting in precise control of the finished fiber's optical properties.

In outside vapor deposition or vapor axial deposition, the glass is formed by flame hydrolysis, a reaction in which silicon tetrachloride and germanium tetrachloride are oxidized by reaction with water ($H_2O$) in an oxyhydrogen flame. In outside vapor deposition the glass is deposited onto a solid rod, which is removed before further processing. In vapor axial deposition, a short seed rod is used, and a porous preform, whose length is not limited by the size of the source rod, is built up on its end. The porous preform is consolidated into a transparent, solid preform by heating to about 1800 Kelvin[4].

The preform, however constructed, is then placed in a device known as a drawing tower, where the preform tip is heated and the optic fiber is pulled out as a string. By measuring the resultant fiber width, the tension on the fiber can be controlled to maintain the fiber thickness.

This manufacturing process is accomplished by numerous optical fiber companies like Corning, OFS, Sterlite Optical Technologies, Furukawa, Sumitomo, Fujikura, and Prysmian. In addition, various fiber optic component manufacturers, assembly houses, and custom fiber optic providers exist.

In practical fibers, the cladding is usually coated with a tough resin buffer layer, which may be further surrounded by a jacket layer, usually plastic. These layers add strength to the fiber but do not contribute to its optical wave guide properties. Rigid fiber assemblies sometimes put light-absorbing ("dark") glass between the fibers, to prevent light that leaks out of one fiber from entering another. This reduces cross-talk between the fibers, or reduces flare in fiber bundle imaging applications[5].

For indoor applications, the jacketed fiber is generally enclosed, with a bundle of flexible fibrous polymer strength members like Aramid (for example Twaron or Kevlar), in a lightweight plastic cover to form a simple cable. Each end of the cable may be "terminated" with a specialized optical fiber connector to allow it to be easily connected and disconnected from transmitting and receiving equipment.

For use in more strenuous environments, a much more robust cable construction is required. In loose-tube construction the fiber is laid helically into semi-rigid tubes, allowing the cable to stretch without stretching the fiber itself. This protects the fiber from tension during laying and due to temperature changes. Alternatively the fiber may be embedded in a heavy polymer jacket, commonly called "tight buffer" construction. These fiber units are commonly bundled with additional steel strength members, again with a helical twist to allow for stretching.

Another critical concern in cabling is to protect the fiber from contamination by water, because its component hydrogen (hydronium) and hydroxyl ions can diffuse into the fiber, reducing the fiber's strength and increasing the optical attenuation. Water is kept out of the cable by use of solid barriers such as copper tubes, water-repellent jelly, or more recently water absorbing powder, surrounding the fiber.

Finally, the cable may be armored to protect it from environmental hazards, such as construction work or gnawing animals. Undersea cables are more heavily armored in their near-shore portions to protect them from boat anchors, fishing gear, and even sharks, which may be attracted to the electrical power signals that are carried to power amplifiers or repeaters in the cable.

Modern fiber cables can contain up to a thousand fibers in a single cable, so the performance of optical networks easily accommodates even today's demands for bandwidth on a point-to-point basis. However, unused point-to-point potential bandwidth does not translate to operating profits, and it is estimated that no more than 1 percent of the optical fiber buried in recent years is actually lit.

Modern cables come in a wide variety of sheathings and armor, designed for applications such as direct burial in trenches, dual use as power lines,http://www.newworldencyclopedia.org/entry/Optical_fiber - cite_note-5 installation in conduit, lashing to aerial telephone poles, submarine installation, or insertion in paved streets. In recent years the cost of small fiber-count pole mounted cables has greatly decreased due to the high Japanese and South Korean demand for Fiber to the Home (FTTH) installations.

REFERENCES

1. Gowar, John. 1993. Optical Communication Systems. 2 ed. Hempstead, UK: Prentice-Hall.

2. Hecht, Jeff. 1999. City of Light, The Story of Fiber Optics. New York, NY: Oxford University Press.

3. Hecht, Jeff. 2002. Understanding Fiber Optics. 4th ed. Upper Saddle River, NJ: Prentice-Hall.

4. Mirabito, Michael M.A., and Barbara L. Morgenstern. 2004. The New Communications Technologies: Applications, Policy, and Impact. 5th ed. Woburn, MA: Focal Press.

5. Ramaswami, R., and K. N. Sivarajan.1998. Optical Networks: A Practical Perspective. San Francisco: Morgan Kaufmann Publishers.