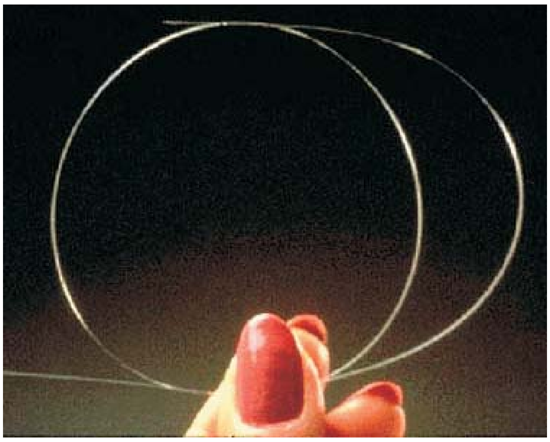
Basic Principles of Fiber Optics



Since its invention in the early 1970s, the use and demand of optical fiber has grown tremendously.
The uses of optical fiber today are quite numerous. The most common are telecommunications, medicine, military, automotive, and industrial. Telecommunications applications are widespread, ranging from global networks to local telephone exchanges to subscribers' homes to desktop computers. These involve the transmission of voice, data, or video over distances of less than a meter to hundreds of kilometers, using one of a few standard fiber designs in one of several cable designs.

Companies such as AT&T, MCI, and U.S. Sprint use optical fiber cable to carry plain old telephone service (POTS) across their nationwide networks. Local telephone service providers use fiber to carry this same service between central office switches at more local levels, and sometimes as far as the neighborhood or individual home.
Optical fiber is also used extensively for transmission of data signals. Private networks are owned by firms such as IBM, Rockwell, Honeywell, banks, universities, Wall Street firms, and more.
These firms have a need for secure, reliable systems to transfer computer and monetary information between buildings to the desktop terminal or computer, and around the world. The security inherent in optical fiber systems is a major benefit.
Cable television or community antenna television (CATV) companies also find fiber useful for video services.
The high information carrying capacity, or bandwidth, of fiber makes it the perfect choice for transmitting signals to subscribers. Finally, one of the fastest growing markets for fiber optics is intelligent transportation systems, smart highways with intelligent traffic lights, automated toll booths, and changeable message signs to give motorists information about delays and emergencies. These are only a few of the many applications possible with the use of optical fiber.
Other telecommunications benefits will be emphasized in more detail throughout this text. website focuses primarily on telecommunications uses of optical fiber. To understand these applications, it is important to define fiber optics.

WHAT IS FIBER OPTICS ?
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.
A basic fiber optic system consists of a transmitting device, which generates the light signal; an optical fiber cable, which carries the light; and a receiver, which accepts the light signal transmitted.
The fiber itself is passive and does not contain any active, generative properties.

THE BENEFITS
Optical fiber systems have many advantages over metallic-based communication systems.
These advantages include: Long Distance Signal Transmission
The low attenuation and superior signal integrity found in optical systems allow much longer intervals of signal transmission than metallic-based systems. While single-line, voice-grade copper systems longer than a couple of kilometers (1.2 miles) require in-line signal repeaters for satisfactory performance, it is not unusual for optical systems to go over 100 kilometers (km), or about 62 miles, with no active or passive processing. Emerging technologies promise even greater distances in the future.

The optical fiber cable in the foreground has the equivalent information-carrying capacity of the copper cable in the background.

Large Bandwidth, Light Weight, and Small Diameter

While today's applications require an ever-increasing amount of bandwidth, it is important to consider the space constraints of many end-users. It is commonplace to install new cabling within existing duct systems.
The relatively small diameter and light weight of optical cables makes such installations easy and practical, and saves valuable conduit space in these environments.

Long Lengths

Long, continuous lengths also provide advantages for installers and end-users. Small diameters make it practical to manufacture and install much longer lengths than for metallic cables: twelve-kilometer (12 km) continuous optical cable lengths are common. Corning Cable Systems manufactures continuous single-mode cable lengths up to 12 km, with a 96-inch reel size being the primary limiting factor. Multimode cable lengths can be 4 km or more, although most standards require a maximum length of 2 km or less. Multimode cable lengths are based on industry demand.
(Single-mode and multimode fibers will be covered in detail later in this text.)

Easy Installation and Upgrades

Long lengths make optical cable installation much easier and less expensive. Optical fiber cables can be installed with the same equipment that is used to install copper and coaxial cables, with some modifications due to the small size and limited pull tension and bend radius of optical cables.
Optical cables can typically be installed in duct systems in spans of 6000 meters or more depending on the duct's condition, layout of the duct system, and installation technique. The longer cables can be coiled at an intermediate point and pulled farther into the duct system as necessary.

System designers typically plan optical systems that will meet growth needs for a 15- to 20-year span.
Although sometimes difficult to predict, growth can be accommodated by installing spare fibers for future requirements. Installation of spare fibers today is more economical than installing additional cables later.

The dielectric nature of optical fiber can eliminate the dangers found in areas of high lightning-strike incidence.

.

Non-Conductivity
Another advantage of optical fibers is their dielectric nature. Since optical fiber has no metallic components, it can be installed in areas with electromagnetic interference (EMI), including radio frequency interference (RFI). Areas with high EMI include utility lines, power-carrying lines, and railroad tracks. All-dielectric cables are also ideal for areas of high lightning-strike incidence.

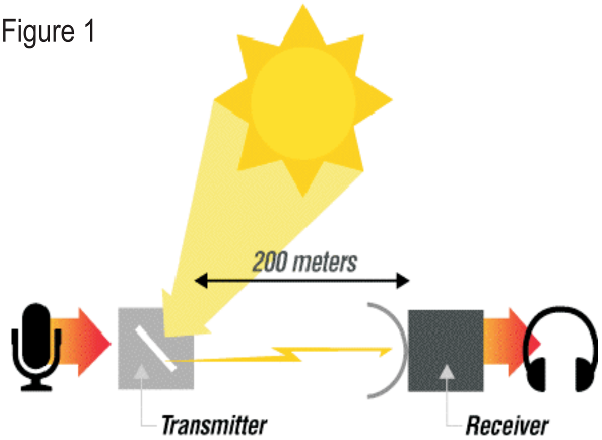
Security
Unlike metallic-based systems, the dielectric nature of optical fiber makes it impossible to remotely detect the signal being transmitted within the cable. The only way to do so is by actually accessing the optical fiber itself. Accessing the fiber requires intervention that is easily detectable by security surveillance.
These circumstances make fiber extremely attractive to governmental bodies, banks, and others with major security concerns.

Designed for Future Applications Needs
Fiber optics is affordable today, as electronics prices fall and optical cable pricing remains low. In many cases, fiber solutions are less costly than copper.

As bandwidth demands increase rapidly with technological advances, fiber will continue to play a vital role in the long-term success of telecommunications.

KEY POINTS IN FIBER OPTICS
Most people remember Paul Revere's "one if by land, and two if by sea" from early American history.
He used lanterns to communicate information. Although not sophisticated, this was an early example of optical communication.
In 1870, British physicist John Tyndal gave us another example. Tyndal set up a tank of water with a pipe that ran out one side. He allowed the water to flow from the pipe, and then shone a bright light from inside the tank into the water stream. As the water fell, an arc of light followed the water down. This demonstrated total internal reflection, a principle that will be discussed in more detail later. In 1880, Alexander Graham Bell invented the photophone. Bell considered this a greater discovery than his previous invention, the telephone. With the photophone, Bell would speak into a microphone, which would cause a mirror to vibrate.
The sun's light would strike the mirror, and the vibration of the mirror would transmit the light across an open distance of about 200 meters (656 feet). The receiver's mirror would receive the light and cause a selenium crystal to vibrate, and the noise would come out on the other end. (See Figure 1 below.) Although the photophone was successful in allowing conversation over open space, it had a few drawbacks: it did not work well at night, in the rain, or if someone walked between the signal and the receiver. Eventually, Bell gave up on this idea.

Figure 1



It wasn't until the late 1950s that the laser was invented.
This device was a finely-controlled beam of light that could transmit information over long distances. Unfortunately, the same drawbacks experienced by Alexander Graham Bell also plagued the laser. Although it could be used at night, it didn't work during rain, fog, or any time a building was erected between the sender and the receiver.
Dr. Robert Maurer, Peter Schultz, and Donald Keck of Corning Incorporated in Corning, New York, came up with the first low loss optical fiber, with less than 20 dB/km (decibels per kilometer) loss. (Today, single-mode, premium grade fiber is sold with specifications of 0.25 dB/km or better.)