

# Fiber Optics Basics

A little introduction to the technology of fiber Optics



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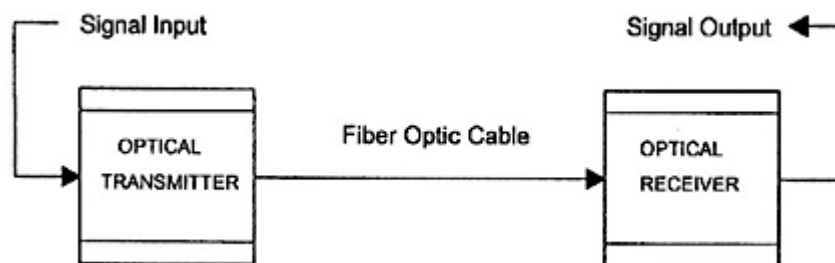
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## Introduction

Our current "age of technology" is the result of many brilliant inventions and discoveries, but it is our ability to transmit information, and the media we use to do it, that is perhaps most responsible for its evolution. Progressing from the copper wire of a century ago to today's fiber optic cable, our increasing ability to transmit more information, more quickly and over longer distances has expanded the boundaries of our technological development in all areas.

Today's low-loss glass fiber optic cable offers almost unlimited bandwidth and unique advantages over all previously developed transmission media. The basic point-to-point fiber optic transmission system consists of three basic elements: the optical transmitter, the fiber optic cable and the optical receiver.



- The Optical Transmitter:** converts an electrical analog or digital signal into a corresponding optical signal. Operates mostly at wavelengths of 850 or 1300nm.
- The Fiber Optic Cable:** consists of one or more glass fibers, which act as waveguides for the optical signal.
- The Optical Receiver:** converts the optical signal back into a replica of the original electrical signal.

## Advantages of Fiber Optic Systems

These three Elements, used in Fiber optic transmission systems, offer a wide range of benefits not offered by traditional copper wire or coaxial cable. These include:

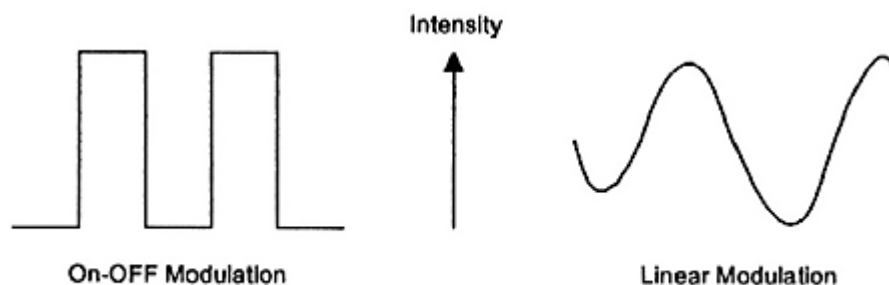
1. The ability to carry much more information and deliver it with greater fidelity than either copper wire or coaxial cable.

2. Fiber optic cable can support much higher data rates, and at greater distances, than coaxial cable, making it ideal for transmission of serial digital data.
3. The fiber is totally immune to virtually all kinds of interference, including lightning, and will not conduct electricity. It can therefore come in direct contact with high voltage electrical equipment and power lines. It will also not create ground loops of any kind.
4. As the basic fiber is made of glass, it will not corrode and is unaffected by most chemicals. It can be buried directly in most kinds of soil or exposed to most corrosive atmospheres in chemical plants without significant concern.
5. Since the only carrier in the fiber is light, there is no possibility of a spark from a broken fiber. Even in the most explosive of atmospheres, there is no fire hazard, and no danger of electrical shock to personnel repairing broken fibers.
6. Fiber optic cables are virtually unaffected by outdoor atmospheric conditions, allowing them to be lashed directly to telephone poles or existing electrical cables without concern for extraneous signal pickup.
7. A fiber optic cable, even one that contains many fibers, is usually much smaller and lighter in weight than a wire or coaxial cable with similar information carrying capacity. It is easier to handle and install, and uses less duct space.
8. Fiber optic cable is ideal for secure communications systems because it is very difficult to tap but very easy to monitor. In addition, there is absolutely no electrical radiation from a fiber.

The next Points will show how fiber optic cables are able to provide all these advantages and why fiber-optics are steadily replacing copper wire as an appropriate means of communication signal transmission.

## Optical Transmitters

The basic optical transmitter converts electrical input signals into modulated light for transmission over an optical fiber. Depending on the nature of this signal, the resulting modulated light may be turned on and off or may be linearly varied in intensity between two predetermined levels. The Figure shows a graphic representation of these two basic schemes.



The most common devices used as the light source in optical transmitters are the light emitting diode (LED) and the laser diode (LD). In a fiber optic system, these devices are mounted in a package that enables an optical fiber to be placed in very close proximity to the light emitting region in order to couple as much light as possible into the fiber. In some cases, the emitter is even fitted with a tiny spherical lens to collect and focus "every last drop" of light onto the fiber and in other cases, a fiber is "pigtailed" directly onto the actual surface of the emitter.

LEDs have relatively large emitting areas and as a result are not as good light sources as LDs. However, they are widely used for short to moderate transmission distances because they are much more economical, quite linear in terms of light output versus electrical current input and stable in terms of light output versus ambient operating temperature. LDs, on the other hand, have very small light emitting surfaces and can couple many times more power to the fiber than LEDs. LDs are also linear in terms of light output versus electrical current input, but unlike LEDs, they are not stable over wide operating temperature ranges and require more elaborate circuitry to achieve acceptable stability. In addition, their added cost makes them primarily useful for applications that require the transmission of signals over long distances.

LEDs and LDs operate in the infrared portion of the electromagnetic spectrum so that their light output is usually invisible to the human eye. Their operating wavelengths are chosen to be compatible with the lowest transmission loss wavelengths of glass fibers and highest sensitivity ranges of photodiodes. The most common wavelengths in use today are 850 nanometers, 1300 nanometers, and 1550 nanometers. Both LEDs and LDs are available in all three wavelengths.

## **The Optical Fiber**

The amount of light that will enter the fiber is a function of one of four factors: the intensity of the LED or LD, the area of the light emitting surface, the acceptance angle of the fiber, and the losses due to reflections and scattering.

Other than the losses exhibited when coupling LEDs or LDs into a fiber, there are losses that occur as the light travels through the actual fiber and because of that the core of an optical fiber is made of ultra-pure low-loss glass. Considering that light has to pass through thousands of kilometers or more of fiber core, the purity of the glass must be extremely high!

Light pulses move easily down the fiber-optic line because of a principle known as total internal reflection. This principle of total internal reflection states that when the angle of incidence exceeds a critical value, light cannot get out of the glass; instead, the light bounces back in. When this principle is applied to the construction of the fiber-optic strand, it is possible to transmit information down fiber lines in the form of light pulses.

## **SingleMode and MultiMode Fibers**

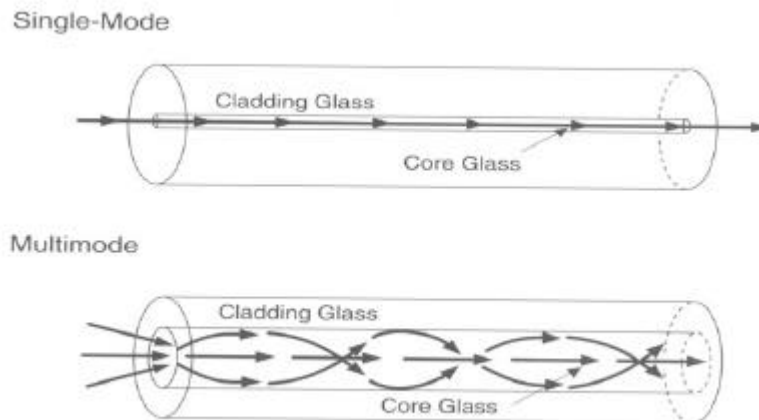
There are two types of optical fiber: singlemode and multimode.

MultiMode fiber has a much larger core than SingleMode fiber, allowing hundreds of rays of light to propagate through the fiber simultaneously.

Singlemode fiber, on the other hand, has a much smaller core that allows only one mode of light to propagate through the core.

While it might appear that MultiMode fibers have higher information carrying capacity, in fact the opposite is true. Singlemode fibers retain the integrity of each light pulse over longer distances, allowing more information to be transmitted.

This high bandwidth has made SingleMode fiber the ideal transmission medium for many applications. Multi-Mode fiber today is used primarily in premise applications, where transmission distances are less than two kilometers.



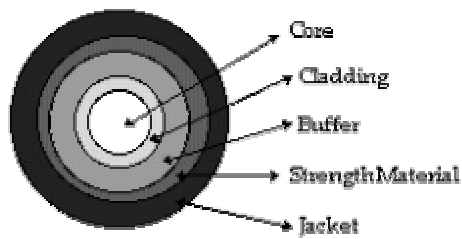
## The two basic cable designs are:

Loose-tube cable, used in the majority of outside-plant installations in North America, and tight-buffered cable, primarily used inside buildings.

### 1. Tight-Buffered Cable

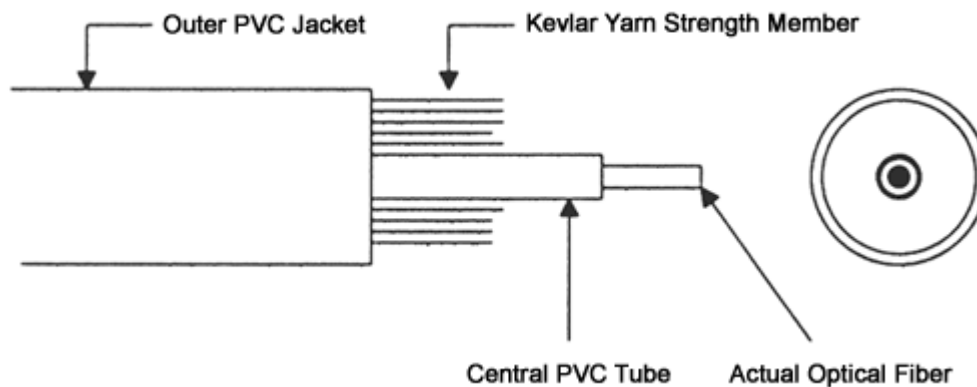
Single-fiber tight-buffered cables are used as pigtails, patch cords and jumpers to terminate loose-tube cables directly into opto-electronic transmitters, receivers and other active and passive components.

There are generally five elements that make up the construction of a fiber-optic strand, or cable: the optic core, optic cladding, a buffer material, a strength material and the outer jacket. The optic core is the light carrying element at the center of the optical fiber. It is commonly made from a combination of silica and germania. Surrounding the core is the optic cladding made of pure silica. It is this combination that makes the principle of total internal reflection possible. The difference in materials used in the making of the core and the cladding creates an extremely reflective surface at the point in which they interface. Light pulses entering the fiber core reflect off the core/cladding interface and thus remain within the core as they move down the line.



Cut away of a fiber-optic cable.

Surrounding the cladding is a buffer material used to help shield the core and cladding from damage. A strength material surrounds the buffer, preventing stretch problems when the fiber cable is being pulled. The outer jacket is added to protect against abrasion, solvents, and other contaminants.



## 2. Loose-Tube Cable

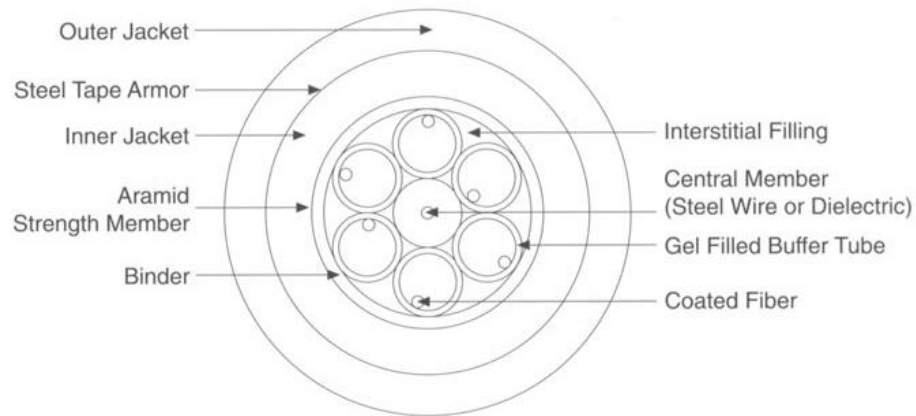
Typically holds up to 12 fibers per buffer tube with a maximum per cable fiber count of more than 200 fibers.

The modular buffer-tube design permits easy drop-off of groups of fibers at intermediate points, without interfering with other protected buffer tubes being routed to other locations.

In a loose-tube cable design, color-coded plastic buffer tubes house and protect optical fibers. A gel filling compound impedes water penetration. Excess fiber length (relative to buffer tube length) insulates fibers from stresses of installation and environmental loading. Buffer tubes are stranded around a dielectric or steel central member, which serves as an anti-buckling element.

The cable core, typically surrounded by aramid yarn, is the primary tensile strength member. The outer polyethylene jacket is extruded over the core. If armoring is required, a corrugated steel tape is formed around a single jacketed cable with an additional jacket extruded over the armor.

Loose-tube cables typically are used for outside-plant installation in aerial, duct and direct-buried applications.



*Loose-Tube Cable*

## Optical Receivers

The basic optical receiver converts the modulated light coming from the optical fiber back into a replica of the original signal applied to the transmitter.

The detector of this modulated light is usually a photodiode and is mounted in a connector similar to the one used for the LED or LD. Photodiodes usually have a large sensitive detecting area that can be several hundred microns in diameter.

As in the case of transmitters, optical receivers are available in both analog and digital versions. Both types usually employ an analog preamplifier stage, followed by either an analog or digital output stage (depending on the type of receiver).

The electronic information is now ready for input into electronic based communication devices, such as a computer, telephone, or TV.