Fiber optic transmission

BENEFITS OF OPTICAL FIBER COMMUNICATION SYSTEM :

Some of the innumerable benefits of optical fiber communication system are:

- Immense bandwidth to utilize
- Total electrical isolation in the transmission medium
- Very low transmission loss,
- Small size and light weight,
- High signal security,
- Immunity to interference and crosstalk,
- Very low power consumption and wide scope of system expansion etc.

These are the main advantages that have made optical fiber communication system such an indispensable part of modern life.

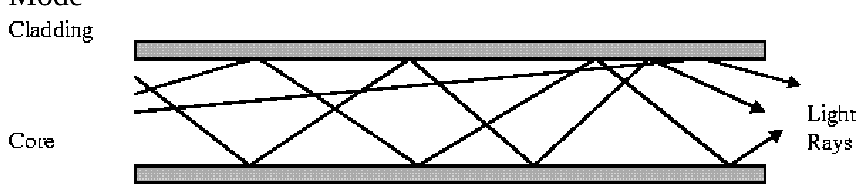
FIELD OF APPLICATION :

Due to its variety of advantages optical fiber communication system has a wide range of application in different fields namely :

- Public network field which includes trunk networks, junction networks, local access networks, submerged systems, synchronous systems etc.
- Field of military applications ,
- Civil, consumer and industrial applications,
- Field of computers which is the center of research right now.

There are three primary types of transmission modes using optical fiber. They are

- Step Index
- Graded Index
- Single Mode

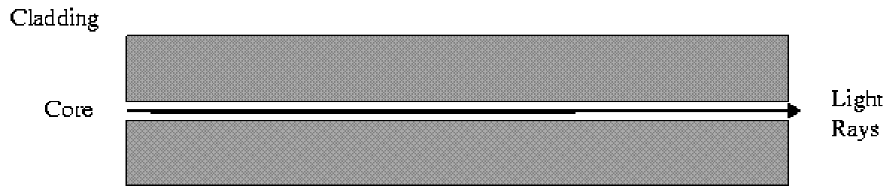


Step index

Step index has a large core, so the light rays tend to bounce around inside the core, reflecting off the cladding. This causes some rays to take a longer or shorter path through the core. Some take the direct path with hardly any reflections while others bounce back and forth taking a longer path. The result is that the light rays arrive at the receiver at different times. The signal becomes longer than the original signal. LED light sources are used. Typical Core: 62.5 microns.

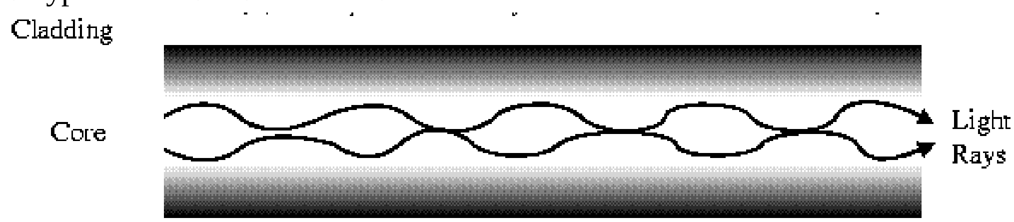
Single mode

Single mode has separate distinct refractive indexes for the cladding and core. The light ray passes through the core with relatively few reflections off the cladding. Single mode is used for a single source of light (one color) operation. It requires a laser and the core is very small: 9 microns.



Graded index

Step index has a gradual change in the core's refractive index. This causes the light rays to be gradually bent back into the core path. This is represented by a curved reflective path in the attached drawing. The result is a better receive signal than with step index. LED light sources are used. Typical Core: 62.5 microns.



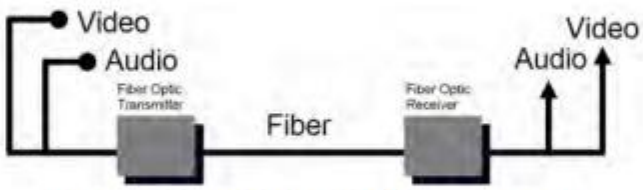
Fiber-Optic Medium

Fiber optics is a method of carrying information using optical fibers. An optical fiber is a thin strand of glass or plastic that serves as the transmission medium over which information is sent. It thus fills the same basic function as a copper cable carrying a telephone conversation, computer data, or video. Unlike the copper cable, however, the optical fiber carries light instead of electrons. In so doing, it offers many distinct advantages that make it the transmission medium of choice for applications ranging from telephone calls, television, and machine control. The basic fiber-optic system is a link connecting two electronic circuits. Figure 6.10-1 shows a simple fiber-optic link.

There are three basic parts to a fiber-optic system:

- Transmitter: The transmitter unit converts an electrical signal to an optical signal. The light source is typically a light-emitting diode, LED, or a laser diode. The light source performs the actual conversion from an electrical signal to an optical signal. The driving circuit for the light source changes the electrical signal into the driving current.
- Fiber-optic cable: The fiber-optic cable is the transmission medium for carrying the light. The cable includes the optical fibers in their protective jacket.
- Receiver: The receiver accepts the light or photons and converts them back into an electrical signal. In most cases, the resulting electrical signal is identical to the original signal fed into the transmitter. There are two basic sections of a receiver. First is the detector that converts the optical signal back into an electrical signal. The second section is the output circuit, which reshapes and rebuilds the original signal before passing it to the output.

Depending on the application, the transmitter and receiver circuitry can be very simple or quite complex. Other components that make up a fiber-optic transmission system, such as couplers, multiplexers, optical amplifiers, and optical switches, provide the means for building more complex links and communications networks. The transmitter, fiber, and receiver, however, are the basic elements in every fiber-optic system. Beyond the simple link, the fiber-optic medium is the fundamental building block for optical communications. Most electrical signals can be transported optically. Many optical components have been invented to permit signals to be processed optically without electrical conversion. Indeed, one goal of optical communications is to be able to operate entirely inthe optical domain from system end to end.



Basic building blocks of a fiber-optic system.

INFORMATION TRANSMISSION OVER FIBER OPTICS

A fiber-optic cable provides a pipeline that can carry large amounts of information. Copper wires or copper coaxial cable carry modulated electrical signals but only a limited amount of information, due to the inherent characteristics of copper cable. Free-space transmission, such as radio and TV signals, provides information transmission to many people, but this transmissions scheme cannot offer private channels. Also, the free-space spectrum is becoming a costly commodity with access governed by the FCC. Fiber-optic transmission offers high bandwidth and data rates, but it does not add to the crowded free space spectrum.

Information Modulation Schemes

The modulation scheme is the manner in which the information to be transported is encoded. Encoding information can improve the integrity of the transmission, allow more information to be sent per unit time, and in some cases, take advantage of some strength of the communication medium or overcome some weakness.Three basic techniques exist for transmitting information such as video signals over fiber optics:

- Amplitude modulation (AM) includes baseband AM, radio frequency (RF) carrier AM, and vestigial sideband AM.
- Frequency modulation (FM) includes sine wave FM, square wave FM, pulse FM, and FM-encoded vestigial sideband.
- Digital modulation of the optical light source with the ones and zeros of a digital data stream. A simplified explanation is that the light or laser source is off for a digital zero and on for a digital one. In actual practice, the light source never completely shuts off. The light source modulates darker and lighter for digital zero and one information.

ADVANTAGES OF FIBER-OPTIC TRANSMISSION

In addition to fiber optics technical advantages, the cost of materials for Fiber optics is becoming more attractive because the cost of copper wire has risen substantially in revent years.

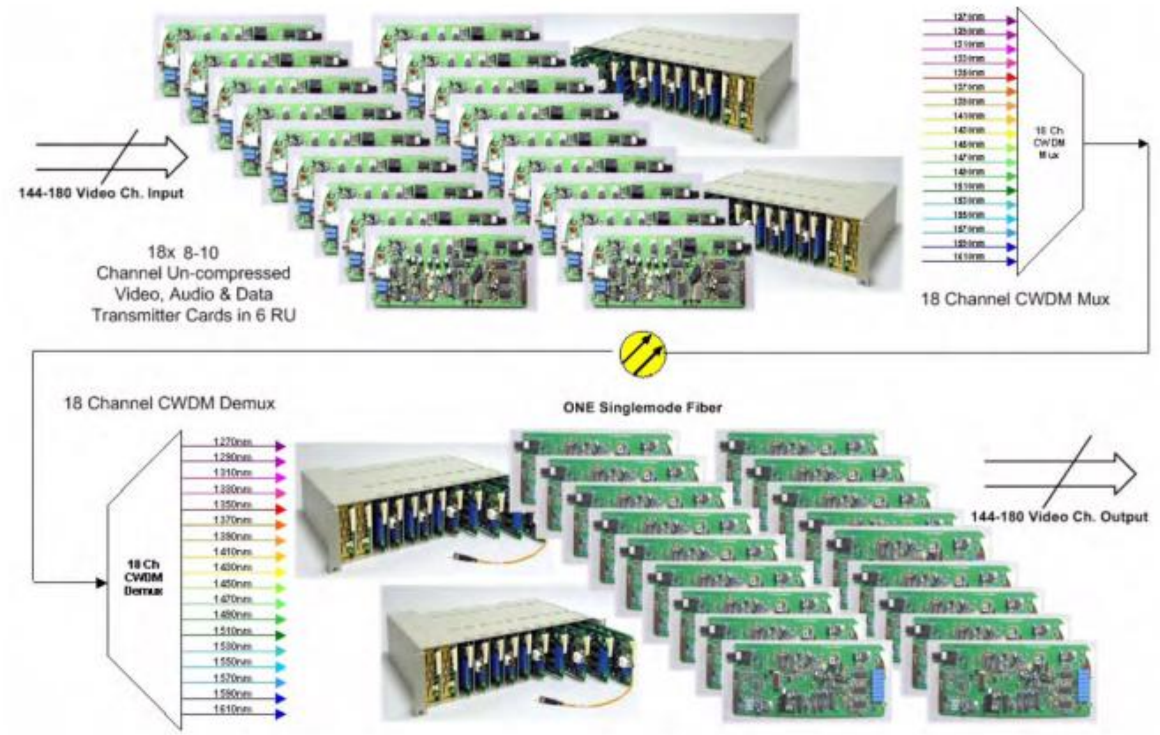
Longer Distances
A significant benefit of fiber-optic transmission is the capability to transport signals long distances. Basic systems are capable of sending signals up to 5 km over multimode fiber and up to 80 km over single mode without repeaters. Most modern fiber-optic systems transport information digitally. A digital fiber-optic system can be repeated or regenerated virtually indefinitely. An electro-optical repeater or an erbium doped fiber amplifier (EDFA) can be used to regenerate or amplify the optical signal.

Multiple Signals
As discussed in previous sections, fiber has a bandwidth of more than 70 GHz using typical off-the-shelf fiber-optic transport equipment. Theoretically, hundreds, even thousands, of video and audio signals can be transported over a single fiber. This is achieved by using a combination of time-division multiplexing (TDM) and optical multiplexing. Fiber-optic transport equipment is readily available to transport more than 8 video and 32 audio channels per wavelength. Offthe-shelf coarse wave-division multiplexing CWDM equipment easily provides up to 18 wavelengths. This combination of equipment provides up to 144 video and 576 audio channels, as shown in Figure below.

Size
Fiber-optic cable is very small in diameter and size when compared to copper. A single strand of fiberoptic cable is about 3 mm. A video coaxial cable is typically much larger. Fiber cable facilitates higher capacity in building conduits. There is often limited space in existing building conduits for infrastructure expansion. In mobile and field productions for sports and news events, fiber is often the cable of choice due to space limitations in a mobile and electronic newsgathering vehicle.

Weight
A fiber-optic cable is substantially lighter in weight than copper cable. A single core PVC-jacketed fiber weighs about 25 pounds per kilometer; RG-6 copper coaxial cable may be three to four times as much.

Noise Immunity
A signal traveling on a copper cable is susceptible to electromagnetic interference. In many applications it is unavoidable to have to route cabling near power substations; heating, ventilating, and air-conditioning (HVAC) equipment; and other industrial sources of interference. A signal traveling as photons in an optical fiber is immune to such interference. The photons traveling down a fiber cable are immune to the effects of electromagnetic interference. In military applications, fiber systems are immune to an electromagnetic pulse (EMP) generated by a nuclear explosion in the Earth’s atmosphere. Fiber-optic equipment is used in command and control bunkers to isolate facilities and systems from EMP interference. A fiber-optic signal does not radiate any interference or noise.

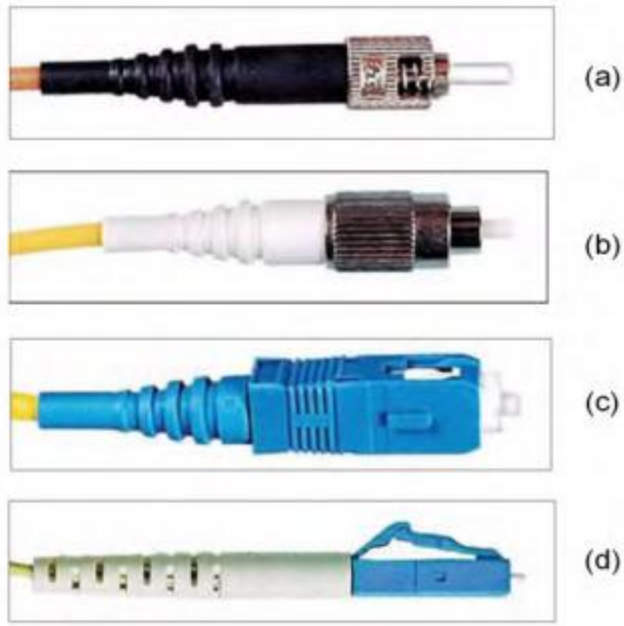


Ease of Installation

One of the myths regarding fiber is that it is difficult to install and maintain. This may have been true in the early days, but now it is as simple to terminate an optical fiber with a connector as it is to install a BNC connector on coax. Fiber-optic termination kits are now available that require no epoxy and special polishing. Simple cable stripping tools are used, similar to those used for copper coax, to prepare the fiber for termination. Epoxy-free connectors are available to terminate both multimode and single-mode fiber-optic cable. The connectors are already republished. No polishing equipment is needed.

Connector Types

Over the years as fiber-optic communications have grown and changed, there have been many different types of connectors. Today there are four common connector types that are used in most fiber-optic applications. The first is the ST connector. It is a bayonet-style connector similar to a coaxial BNC connector, and is available for single-mode and multimode applications. The next style is the FC connector. This connector has a threaded screw–type receptacle. It is similar to an RF-type connector, and is only used for single-mode applications. The telecommunications industry standardized on the SC connector (Figure 6.10-10(c)). It is a square snap-in–type connector and has gained popularity in the video and computer networking industries. Telecommunications and networking applications typically require two fibers: one for transmitted data and one for received data traffic. Since SC-type connectors were popular in these types of applications two SC connectors were required. As the size of fiber. equipment reduced and the density of fiber-optic input/outputs (I/Os) increased, a small alternative to the SC connector was required. This led to the LC connector as shown in Figure 6.10-10(d). An LC is approximately half the size of an SC connector. It is rectangular in shape and has a locking clip



Ease of Splicing

Another myth is the repair or maintenance of a broken or cut fiber. The cost of fusion splicing equipment has come down significantly. The fusion splicer is a small portable device that is easily carried in the field. A fusion splice is easy to perform. First, the fiber is stripped and prepared using simple tools. The fiber is then placed in the fusion-splicing machine. An LCD screen shows the device automatically aligning the fibers. With the press of a button a fusion arc is generated to splice the fibers together. The fusion splicer even tests the connection when complete. There is now an even simpler way to splice a fiber in the field—mechanical splicing. A mechanical splice consists of a small device that is used to splice a fiber. It is about 2 inches long by 1/2 inch wide. The process involves first stripping the fiber-optic cable and then inserting the ends into the splicing unit with mating gel. A key is used to close and clamp the unit shut. The mechanical splice gives fiber installers the ability to splice and repair with inexpensive equipment in areas where no electrical power is available.

Radiation and Security

Fiber-optic transport is a secure means of communications. Since a fiber-optic cable emits or radiates no RF energy, it is impossible to passively listen or to tap into a fiber-optic circuit. The only way to tap into a fiberoptic cable is to physically cut the cable. An eavesdropper would have to cut the fiber and install a splitter to tap into the fiber-optic link. The cut in the fiber and the inserted splitter can be detected by fiber-optic test equipment.

Environmental Conditions

Fiber-optic cable is immune to most environmental conditions. Fiber-optic cable is capable of tolerating temperature extremes. Unlike copper cable, fiber is immune to moisture. Fiber is available with jacketing that is resistant to nuclear radiation. Many fiber-optic systems are used for the inspection of nuclear reactors. Many military applications require fiber-optic equipment and cable to have resistance to radiation.

END-TO-END SYSTEM DESIGN

A common misconception is that it is difficult to design a fiber-optic system. There are simple calculations to be made using information from the fiberoptic product datasheet. When designing a fiber-optic system it is necessary to know the number and type of signals to be sent through the fiber as well as the transmission distance or required optical budget. We also need to know the transmission distance or required optical budget.

Transmitter Launch Power

The datasheet of any fiber-optic transport system wil provide the transmitter unit's output optical power. There may be different models with varying levels of output power. A more powerful transmitter can be chosen to reach a further transmission distance. A typical fiber-optic transmitter has an output optical power of –8 dBm or 0.158 mW.

Receiver Sensitivity

The receiver sensitivity is another parameter found on any fiber-optic equipment datasheet. The receiver sensitivity is the minimum optical signal or power required for the receiver unit to operate properly. Many systems have a minimum receiver sensitivity of –28 dBm or 0.00158 mW. The –28 dBm value represents an optical power that is 28 decibels below the 0 dBm or 1 mW reference point.

Optical Power Budget

The optical budget of a fiber-optic transport system takes into account the optical power of the transmitter, loss in the fiber for a given distance, receiver sensitive it, and signal-to-noise required. Optical power, like electrical power, is measured in watts or milliwatts. Fiber-optic systems are typically designed using decibels referenced to 1 milliwatt or 0 dBm. The following formula shows the conversion from watts to decibels:

$$\text{dBm} = 10 \times \log(\text{laser power in mW}).$$

The output power of an optical laser may be 1 milliwatt. The equivalent power in dBm would be 10 * log (1mW) = 0 dBm. For 0.5 mW laser, output power would be 10 * log(0.5 mW) = –3 dBm. The optical attenuation of a multimode fiber at the 850 nm wavelength is about 3 dB/km. The attenuation on single-mode fiber at 1310 and 1550 nm is 0.5 and 0.2 dB/km, respectively. Using these numbers we can calculate how much optical power is required to reach a certain transmission distance. For example, a 10 km run over single-mode fiber at 1310 nm would incur a loss of 5 dB (10 km × 0.5 dB/km). The optical budget that a fiber-optic system provides is the difference between the fiber-optic transmitter optical output power and the receiver sensitivity. For example, if the transmitter power is –8 dBm and the minimum receiver level is –28 dBm, then the maximum loss the system can withstand is 20 dBm. In many cases it may seem that a multimode or single-mode fiber run has optical power to reach 40–60 km. When transmissions exceed about 5 km in multimode systems and about 15 km in single-mode systems, other factors due to dispersion come into play and limit the transmission distance.

Bandwidth

The optical losses and usable bandwidth of a fiberoptic system have to be taken into account. As mentioned previously, multimode fibers have greater losses and less bandwidth compared to single mode. Single mode has lower losses and very high bandwidth than does multimode. Most manufacturers of multimode fiber-optic cable do not specify dispersion. They will provide a figure of merit known as the bandwidth-length product or just bandwidth with units of MHz-kilometer. For example, 500 MHz-km translates to a 500 MHz signal that can be transported 1 km. The product of the required bandwidth and transmission distance cannot exceed 500: $BW \times L \leq 500$ A lower bandwidth signal can be sent a longer distance. A 100 MHz signal can be sent L = BW – product/BW = 500 MHz-km/100 MHz = 5 km Single-mode fiber typically has a dispersion specification provided by the manufacturer. The dispersion is specified in picoseconds per kilometer per nanometer of light source spectral width or ps/km/nm. This loosely translates to the wider the spectral bandwidth of the laser light source, the more dispersion. The analysis of dispersion of a single-mode fiber is very complex. An approximate calculation can be made with the following formula:

$$\mathbf{BW = 0.187/(disp \times SW \times L),}$$

where: disp is the dispersion of the fiber at the operating wavelength with units seconds per nanometer per kilometer. SW is the spectral width (rms) of the light source in nanometers. L is the length of fiber cable in kilometers. For example, with a dispersion equal to 4 ps/nm/ km, spectral width of 3 nm, and a transmission length of 20 km, then: $BW = 0.187/(4 \times 10^{-12}$ s/nm/km) × (3 nm) × (20 km) BW = 779,166,667 Hz or about 800 MHz. If the spectral width of the laser light source is doubled to 6 nm the bandwidth will drop to about 390 MHz. This shows how significant the spectral width of the laser source is on the usable bandwidth of a fiber. If a laser light source with a narrow optical spectral width is used, or a fiber with a lower dispersion figure, the bandwidth and transmission distance will increase. In single-mode fiber communications, there are two basic types of laser light sources. The first type is the less expensive laser that uses Fabre-Perot laser diode (FP-LD) technology. The FP-LD is an inexpensive choice for digital fiber-optic communication. With a spectral width of typically 4 nm or more, it is primarily used for lower bandwidth or short-distance applications. The second is the distributed feedback laser diode (DFB-LD) technology. These light sources are more expensive and are widely used for longdistance fiber-optic communications. The typical spectral width for a DFB laser is about 1 nm. When a DBF laser is used in combination with a low dispersion fiber, the transmission bandwidth and distance can be significantly higher.
See Table below, which shows the typical fiber-optic cable losses, and Table 6.10-4, which shows the bandwidth for different types of fiber cable.

Fiber		**Bandwidth-Distance Product (MHz × km)**		
Size (μm)	**Type**	**850 nm**	**1300 nm**	**1550 nm**
9/125	SM	2000	20,000+	4000–20,000+
50/125	MM	200–800	400–1500	300–1500
62.5/125		100–400	200–1000	150–500