SYBEX Sample Chapter

Cabling: The Complete Guide to Network Wiring

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Chapter 10: Fiber Optic Media

Fiber optic media (or *fiber*, for short) are any network transmission media that use glass fiber to transmit network data in the form of light pulses. Data is encoded within these pulses of light using either a laser diode or light emitting diode (LED).

Within the last five years, fiber optic media has become an increasingly popular type of network transmission media. Let's begin this chapter with a brief look at how fiber optic transmissions work.

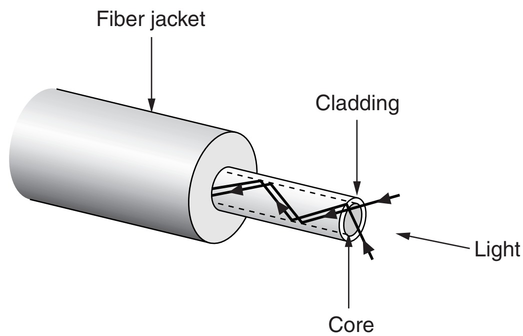
How Fiber Optic Transmissions Work

Fiber optic technology is more complex in its operation than standard copper media. The source of this complexity is the fact that fiber optic transmissions are light pulses instead of voltage transitions. Fiber optic transmissions encode the ones and zeros of a network transmission into ons and offs of some kind of light source. This light source is usually either a laser or some kind of light emitting diode (LED). The light from the light source is flashed on and off in the pattern of the data being encoded.

These light pulses travel from source to destination almost instantaneously within a glass (or sometimes plastic) conductor. This conductor (or *core*, as it is known) is surrounded by a coating known as the *cladding*. Cladding a glass fiber allows the light signal to bounce around inside the fiber (as shown in Figure 10.1) because the cladding has a lower refractive index than the core, and it acts like a mirror, reflecting the light signal back into the core. The cladding makes it possible for the signal to travel in angles other than a straight line from sender to recipient—it's kind of like shining a flashlight onto one mirror and reflecting the light onto another, then another, and so on. The light bounces around inside the fiber until the light signal gets to its intended destination.

FIGURE 10.1:

Reflection of a light signal within a fiber optic cable



When the light pulses reach the destination, a sensor picks up the presence or absence of the light signal and transforms those ons and offs back into electrical signals that represent 1s and 0s.

It is important to note that the more the light signal bounces, the more possibility there is for signal loss (also known as *attenuation*). Additionally, for every fiber optic connector between signal source and destination, there is a possibility for signal loss. Thus, the connectors must be installed perfectly at each connection.

Most kinds of LAN/WAN fiber transmission systems use two fibers: one fiber for transmitting and one for reception. This system is used because light only travels in one direction for fiber systems—the direction of transmission. It would be difficult (and expensive) to transform a fiber optic transmitter into a dual-mode transmitter/receiver (one that could receive and transmit within the same connector).

Advantages of Fiber Optic Cabling

The main reason fiber optic cabling is currently enjoying popularity as a network cabling medium is because of its advantages over other types of cabling systems. Some of these advantages include the following:

- Immunity to electromagnetic interference (EMI)
- Higher data rates

- Longer maximum distances
- Better security

Let's begin our discussion of the advantages of fiber optic cabling with a discussion of fiber's immunity to electromagnetic interference (EMI).

Immunity to Electromagnetic Interference (EMI)

All copper cable network media share one common problem: they are susceptible to electromagnetic interference (EMI). EMI is a type of interference to proper data transmission that occurs due to stray electromagnetism. All electrical cables generate a magnetic field around their central axis. If you pass a metal conductor through a magnetic field, an electrical current is generated in that conductor. Similarly, if you pass an electrical field through a conductor, a magnetic field is formed around the axis of the conductor.

You may be asking yourself, "Okay, but what does that have to do with fiber optics?" Well, when you place two copper cables next to each other, this principle will cause signals from one cable to be induced into the other in a phenomenon known as *crosstalk* (often abbreviated as *xtalk* or *xt*). The longer a particular copper cable run goes, the more chance there is for crosstalk.

WARNING Never place copper cables next to AC current-carrying wires or power supplies. These devices produce very large magnetic fields and thus will introduce large amounts of crosstalk into any copper cable placed next to them. For data cables, this will almost certainly cause data transmissions on that particular cable to fail completely.

Fiber optic cabling is immune to crosstalk because fiber uses light signals in a glass fiber to transmit data rather than electrical signals. Because of this, it cannot produce a magnetic field, and thus it is immune to EMI. Fiber optic cables can be run in areas considered to be "hostile" to regular copper cabling (e.g., elevator shafts, near transformers, in tight bundles with other electrical cables) because of their immunity to EMI.

Higher Possible Data Rates

Because light is immune to interference and travels almost instantaneously to its destination, much higher data rates are possible with fiber optic cabling technologies than they are with traditional copper systems. Data rates in the gigabit per second (Gbps) range and higher are possible.

Longer Maximum Distances

Typical copper data transmission media are subject to distance limitations of maximum segment lengths no longer than one kilometer. Because they don't suffer from the EMI problems of traditional copper cabling and because they don't use electrical signals that can degrade substantially over long distances, fiber optic cables can span distances greater than three kilometers.

Better Security

As you know, *eavesdropping* is the practice of listening in on other people's conversations without the knowledge of the participants. Copper cable transmission media are susceptible to eavesdropping through the use of "taps." A *tap* (short for wiretap) is any device that punctures through the outer jacket of a copper cable and touches the inner conductor. The tap intercepts signals sent on a LAN and sends them to another (unwanted) location. Electromagnetic (EM) taps are similar devices, but rather than puncturing the cable, they use the tendency of the cable to produce magnetic fields similar to the pattern of electrical signals to provide the signal for the tap. If you'll remember, simply placing a conductor next to a copper conductor with an electrical signal in it will produce a duplicate (albeit a lower-power version) of the same signal. The EM tap then simply amplifies that signal and sends it on to the unwanted person who initiated the tap.

Because fiber optic cabling uses light instead of electrical signals, it is immune to most types of eavesdropping. Traditional taps won't work because any intrusion on the cable will cause the light to be blocked and the connection simply won't function. EM taps won't work because there is no magnetic field generated. Because of its immunity to traditional eavesdropping tactics, fiber optic cabling is used in networks that must remain secure, such as government and research networks.

Disadvantages of Fiber Optic Cabling

With all of its advantages, many people are using fiber optic cabling on their networks. However, fiber optic cabling does have a couple of major disadvantages, including the following:

- Higher cost
- Difficult to install

Let's examine these drawbacks to fiber optic cabling, starting with its higher cost.

Higher Cost

The first disadvantage of fiber optic as a transmission medium is its higher cost per foot (thus a higher total cost). The prices for cables are typically given in cents per foot. Traditional unshielded twisted pair (UTP) copper cabling for a data network costs in the range of $0.03 to $0.05 per linear foot. At the time of the writing of this book, costs for fiber optic cable are between $0.20 and $1.50 per foot, depending on the number of fibers. Even though these prices are coming down, fiber is still used primarily only for backbone links. However, as more people begin to use fiber optic for cabling their networks, the price will go down, and fiber to the desktop will become affordable for more and more organizations.

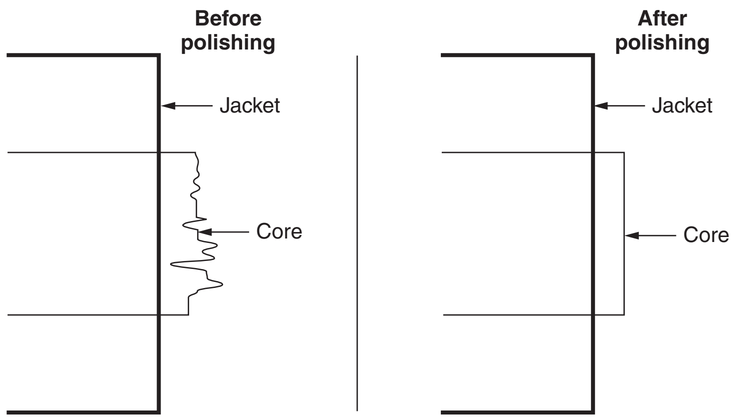
Difficult to Install

The other main disadvantage to fiber optic cabling is that it's more difficult to install. Copper cable ends simply need a mechanical connection to make an electrical connection, and those connections don't have to be perfect. Most often, the connectors for copper cables are crimped on (as discussed in Chapter 8, "Wall Plates").

Fiber optic cables are much trickier to make connections for. This is mainly because of the nature of the glass or plastic core of the fiber cable. When you cut or "cleave" (in fiber optic terms) the inner core, the end of the core consists of many very small shards of glass that diffuse the light signal. This will prevent the entire light signal from hitting the receiver correctly. The end of the core must be polished with a special polishing tool in order to make the end of the core perfectly flat so that the light will shine through correctly. Figure 10.2 illustrates the difference between a polished and a nonpolished fiber optic cable core end. This polishing step adds extra complexity to the installation of cable ends. The extra complexity translates to a longer, and thus more expensive, cabling plant installation.

FIGURE 10.2:

The difference between a freshly cut and a polished end



Types of Fiber Optic Cables

Now that you've learned about the basics of fiber optic cabling systems, including how they work and their advantages and disadvantages, it's time to learn the details of the individual cables. Some of the topics you'll learn about in this section include the following:

- Composition of a fiber optic cable
- Designations of fiber optic cables

Let's start with a discussion of the composition of a fiber optic cable.

Composition of a Fiber Optic Cable

A typical fiber optic cable (if there is such a thing) consists of several components, including the following:

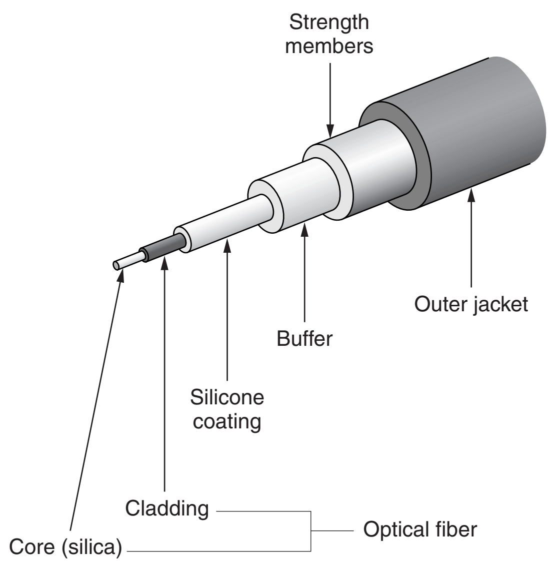
- Optical fiber

- Buffer
- Strength members
- Outer jacket

Each of these components has a specific function within the cable to help ensure the data gets transmitted reliably. Figure 10.3 shows a cutaway diagram of a typical fiber optic cable. Note the individual components and their relationship to each other.

FIGURE 10.3:

Cutaway diagram of a typical fiber optic cable



The most important part of the cable is the core, so let's discuss that first.

Optical Fiber

An *optical fiber* (also called an *optical waveguide*) is the central part of a fiber optic cable. It consists of three main parts: the core, its cladding, and often, a protective coating. These three parts are usually manufactured together because of their close relationship.

A fiber optic cable's *core*, which is usually anywhere from two to several hundred microns thick (a *micron* is a millionth of a meter, usually designated by the symbol µ), is the central part of the fiber optic cable that actually carries the light signal. To put that size in perspective, a human hair is around 75 microns.

The fiber core is usually made of some type of plastic or glass. As a matter of fact, there are several types of materials that make up the core of a typical optical fiber. Each material differs in its chemical makeup and cost as well as its index of refraction. The *index of refraction* is a number for a particular material that indicates how much light will bend when passing through that material. It also indicates how fast light will travel through a particular material. The cladding for the core has a lower index of refraction than the core itself. Therefore, light from the core that hits the "wall" between the core and cladding will be reflected back into the core.

A fiber optic cable's *cladding* is the coating around the central core that performs two functions. First, it is the first, albeit the smallest, layer of protection around the glass or plastic core. Second, as mentioned earlier, it provides a surrounding surface for the light inside the core to reflect off of. This is because the cladding has a lower index of refraction than the core. Cladding is usually fairly thin (around 25 microns), except in the case of single-mode glass core fibers.

The *protective coating* around the optical fiber at the center of a fiber optic cable protects the fiber core and cladding from damage. It does not participate in the transmission of light at all. It is simply a protective measure. It protects the cladding from abrasion damage and adds additional strength to the core.

Some of the types of optical cable, listed from highest quality to lowest, include the following:

- Single-mode glass
- Graded-index glass
- Step-index glass
- Plastic-clad silica (PCS)
- Plastic

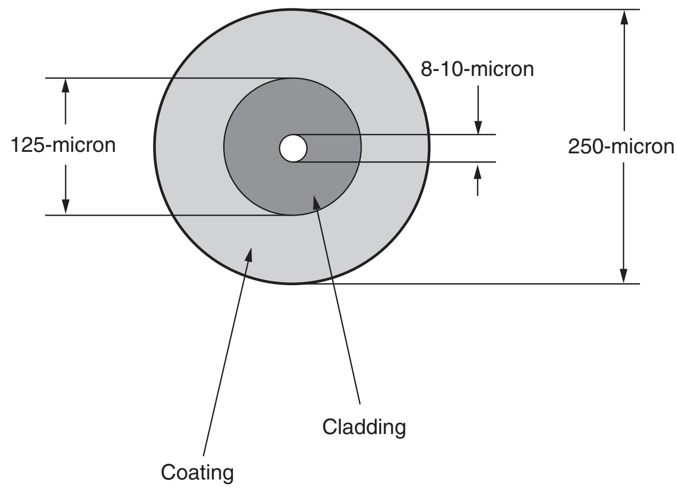
In this section, you'll learn about each of these types and how they differ from each other.

Single-Mode Glass A *single-mode glass fiber core* is a core, made of silica glass, where the core is very narrow (usually less than 10 microns). Conversely, to keep the cable size manageable, the cladding for a single-mode glass core is usually

10 times the size of the core (around 125 microns). It is called single mode because only one light path is possible. This single path reduces the light loss (attenuation) in the signal. Single-mode fibers are expensive, but because of the lack of attenuation (less than 2dB per kilometer),very high speeds are possible. In some cases, speeds of up to 50Gbps are possible. Figure 10.4 shows an example of a single-mode glass fiber core.

FIGURE 10.4:

An example of a single-mode glass fiber core

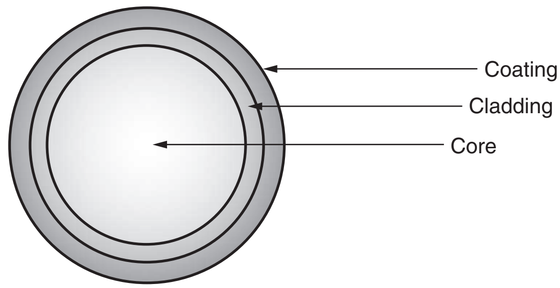


Graded-Index Glass A graded-index glass fiber core is a core fiber made of silica glass, where the index of refraction changes gradually from the center outward to the cladding. The center of the cable has the highest index of refraction; thus the signals travel slowest in the center of the cable. If the signals travel outside the center of the core, the lower index of refraction will bend them back towards the center, but they will travel faster. This allows light signals to travel in the exact center of a larger diameter cable. The larger the diameter of the core, the greater the cost, but the equipment (i.e., connection) costs will be lower.

Figure 10.5 shows an example of graded-index glass core. Notice that the core is bigger than the single-mode core and that there is a smooth transition from the center of the core out.

FIGURE 10.5:

A graded-index glass fiber core

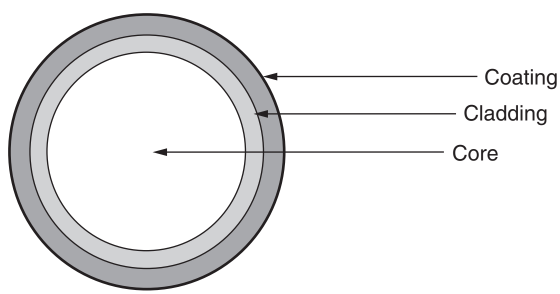


Step-Index Glass A *step-index glass core* is a glass fiber core similar to a single-mode glass but with a much larger core diameter (usually around 62.5 microns, although it can vary largely in size between 50 and 125 microns). It gets its name from the large step in the change of index of refraction from the glass core to the cladding. In fact, a step-index glass core has a uniform index of refraction. Because the signal bounces around inside the core, it is less controllable and thus suffers from larger attenuation values and, effectively, lower bandwidths. However, equipment for cables with this type of core is cheaper than other types of cable, so step-index glass cores are found in many cables.

Figure 10.6 shows an example of a step-index glass core optical fiber. Notice the larger diameter glass core.

FIGURE 10.6:

A step-index glass core optical fiber



Plastic-Clad Silica (PCS) A *plastic-clad silica (PCS) fiber core* is a fiber core made out of glass clad with a plastic coating around the central glass core, hence the name. PCS optical fibers are usually very large (200 microns or larger) and thus have limited bandwidth availability. However, the PCS core optical cables are relatively cheap when compared to their glass-clad counterparts.

Plastic Plastic optical fibers consist of a plastic core of anywhere from 50 microns up to any size surrounded by a plastic cladding of a different index of refraction. Generally speaking, these are the lowest quality optical fibers and are seldom of sufficient quality to transmit light over long distances. Plastic optical cables are used for very short distance data transmissions, but they are more often used for decoration.

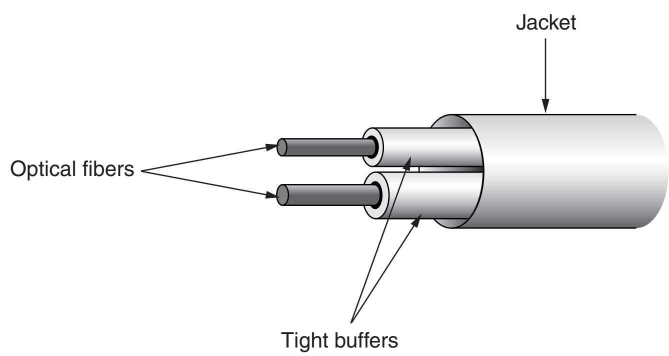
Buffer

In addition to the optical fiber, the *buffer* is the component of a fiber optic cable that provides the most protection of the optical fibers inside the cable. The buffer does just what its name implies: it acts as a buffer, or cushion, between the optical fiber and the outer jacket of the fiber optic cable.

Optical fiber buffers are categorized as either tight or loose. *Tight buffers* are optical fiber protection where there is a protective coating (usually a 900-micron thermoplastic covering) over each optical fiber in the cable. Tight buffers on the fibers within a fiber optic cable make the entire cable more durable, easier to handle, and easier to terminate (put connectors on). Figure 10.7 shows an example of tight buffering.

FIGURE 10.7:

A fiber optic cable using tight buffering

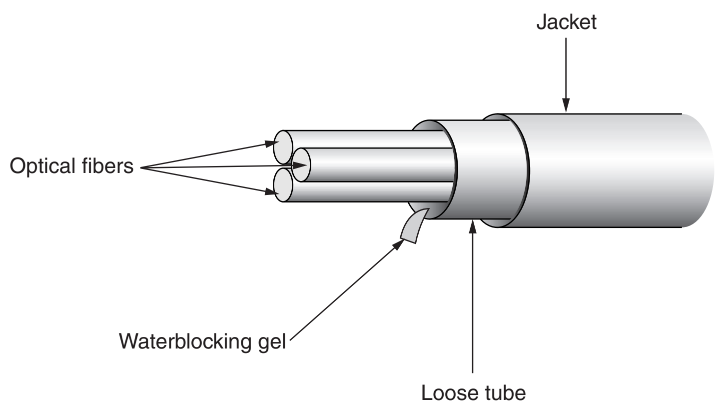


A *loose buffer*, on the other hand, is a type of buffer where all optical fibers in the cable are encased in one plastic tube (often called a *loose tube*). The tube is then filled with a protective substance to provide cushioning, strength, and protection from the elements. The protective substance is usually a water-blocking gel.

Figure 10.8 shows an example of a loose-buffered fiber optic cable. Notice that the cable shown uses water-blocking gel.

FIGURE 10.8:

A fiber optic cable using loose buffering with water-blocking gel



Strength Members

Some cables require additional support to prevent breakage of the delicate optical fibers within the cable. That's where the strength member part of some fiber optic cables comes in. The *strength member* of a fiber optic cable is the part of the fiber optic cable that provides additional tensile strength through the use of an additional strand or fibers of material.

The most common strength member is *aramid yarn*, a popular type of which is the product known as Kevlar™, the same material found in bulletproof vests. Larger fiber optic cables sometimes use a strand of either fiberglass or steel wire as strength members. Fiber optic cables can use strength members around the perimeter of a bundle of optical fibers within a single cable, or the strength member can be located in the center of the cable with the individual optical fibers clustered around it.

TIP

Kevlar is extremely durable, so cables that use this type of buffering require a special cutting tool to cut them, called Kevlar scissors. They cannot be cut with ordinary cutting tools.

Cable Jacket

The *cable jacket* of a fiber optic cable is the outer coating of the cable that protects all the inner optical fibers from damage. It is usually made of a durable rubberized or plastic material and comes in various colors.

There are two main categories of fiber optic cable jackets: PVC and plenum-rated. *Polyvinyl chloride (PVC)* is a plastic that is cheap to manufacture and is a durable coating for cables; thus, it is a very popular coating for many types of LAN cables, including fiber optic cables. Unfortunately, the main drawback to PVC-coated cables is that when they burn, the PVC coating turns to two toxic chemicals, hydrochloric acid and the toxic gas dioxin. Both substances are particularly nasty.

For this reason, the National Electrical Code (NEC) specifies that when installing cables in common air spaces (known as plenums), that the cable should have a *plenum-rated* jacket. Plenum-rated cable jackets will not turn into toxic gas when burned, so they are safe to use in plenum airways.

Exterior Protection of Fiber Optic Cables

If you ever need to install fiber optic cabling outdoors, you will need to keep some things in mind. First of all, the cable you install should be rated for an exterior installation. An exterior rating means that the cable was specifically designed for outdoor use. It will have features such as UV protection, superior crush and abrasion protection, protection against the extremes of temperature, and an extremely durable strength member. If you use standard indoor cable in an outdoor installation, the cables could get damaged and not function properly. Make sure to look for a cable rated for an outdoor installation when performing outdoor installations.

Designations of Fiber Optic Cables

In addition to the composition of the optical fibers, fiber optic cables have different designations of types and ratings of cables. When buying fiber optic cables, you will have to decide which fiber ratings you want for each type of cable you need. Some of these ratings include the following:

- Single-mode or multimode
- Useable wavelengths
- Core/cladding sizes
- Number of optical fibers
- LAN/WAN application

Let's begin this discussion of fiber optic cable ratings with the difference between single-mode and multimode optical fibers.

Single-Mode or Multimode

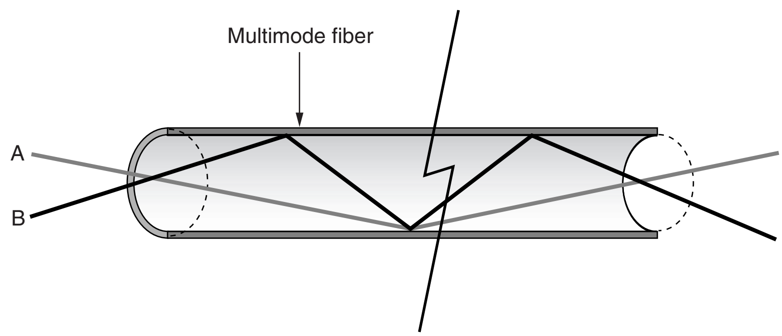
All fiber optic cables are designated as either single-mode or multimode. They differ mainly by the number of *modes*, or signals they can carry. *Single-mode* optical fibers (sometimes called *monomode* fibers), as the name suggests, can carry only one optical signal at a time. Generally speaking, these cables use the single-mode optical fibers and are very small, which keeps attenuation of the light signal to a minimum. Additionally, because of their simplicity, single-mode cables can transmit data over great distances and at very high rates. Many LAN backbones use single-mode fiber optic cables because of their high bandwidth and distance capabilities.

As you may have guessed, *multimode* fiber optic cables can transmit more than one signal at a time. This is because their optical fiber cores are larger in diameter. Many signals can travel over a multimode fiber cable, but there is a finite amount of bandwidth available. Each additional signal that is placed on a multimode fiber decreases the bandwidth available to each fiber. This is mainly because the signal is less concentrated within the optical fiber core.

Also, multimode cables suffer from a unique problem known as modal dispersion. *Modal dispersion* is a situation that causes transmission delays in multimode fibers. Here's how this situation occurs. The angle through which an optical fiber can accept incoming signals is known as the *acceptance angle* and is measured relative to the axis of the optical fiber (or the *acceptance cone* when measured around the axis). The different modes (signals) enter the multimode fiber at different angles. The different angles mean that the different signals will bounce differently inside the fiber and arrive at different times (as shown in Figure 10.9). The more severe the difference between the entrance angles, the greater the arrival delay between the modes. In Figure 10.9, mode A will exit the fiber first because it has fewer "bounces" inside the core than mode B. Mode A has fewer bounces because its entrance angle is less severe (i.e., it's of a *lower order*) than that of mode B. The difference between the time mode A and mode B exit is the modal dispersion. Modal dispersion gets larger as the difference between the entrance angles increases.

FIGURE 10.9:

Illustration of modal dispersion

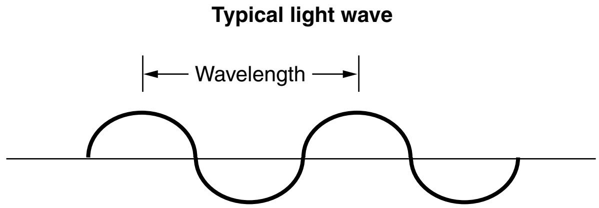


Useable Wavelengths

Another of the many types of fiber optic designations is the wavelength of light used to transmit data. The *wavelength* of a particular light source is the length between wave peaks in a typical light wave from that light source (as shown in Figure 10.10). This length is measured in *nanometers* (billionths of a meter). You can think of the wavelength of light as its color. Different wavelengths produce different colors. For example, when a laser produces a green light, it is producing light in the 500 nanometer (nm) range.

FIGURE 10.10:

A typical light wave



Fiber optic cables are optimized for use with a specific wavelength of light. Typically, optical fibers use wavelengths between 800 and 1500nm, depending on the light source. For a reference, visible light (the light that you can see) has wavelengths in the range between 400 and 700nm. Most fiber optic light sources operate in the infrared range (between 700 and 1100nm). Infrared light is light that you can't see and is a very effective fiber optic light source.

NOTE Most traditional light sources can only operate within the visible wavelength spectrum. Additionally, they can only operate over a range of wavelengths, not one specific wavelength. The only light source that can transmit light at a specific wavelength is a *laser* (light amplification by stimulated emission of radiation) device. Many fiber optic devices use lasers to provide light at a particular wavelength.

Core/Cladding Size

In addition to other methods of designating fiber optic cables, the individual fiber optic cables within a cable are most often rated with a ratio of core to cladding size. The *core/cladding size* (also known as the optical fiber size) is the size of both the core and the cladding of a single optical fiber within the cable. This size is shown as two numbers, expressed as a ratio. The first number is the diameter of the optical fiber core, given in microns (µ). The second number is the outer diameter of the cladding for that optical fiber, also given in microns. For example, a picture with a 10-micron core with a 50-micron cladding would be designated as 10/50.

There are three major core/cladding sizes in use today:

- 8/125

- 62.5/125
- 100/140

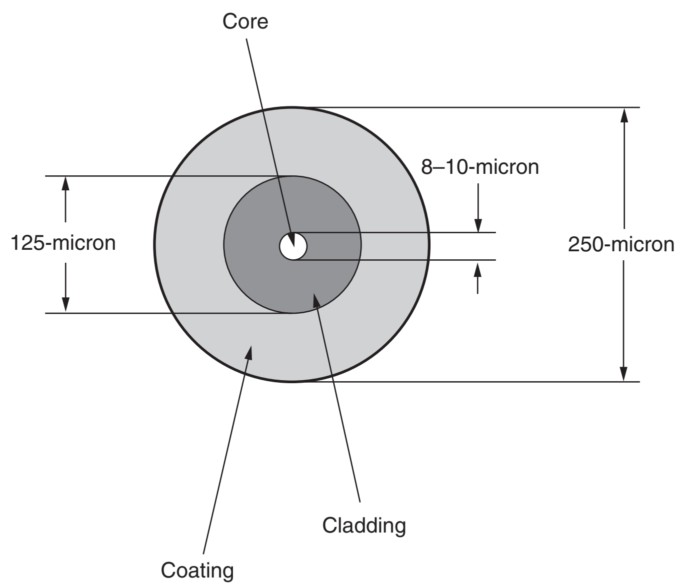
Let's take a brief look at each of these sizes and what each one looks like as well as its major use(s).

NOTE Sometimes, you will see a third number in this ratio (e.g., 8/125/250). The third number is the outside diameter of the protective coating around the individual optical fibers.

8/125 An 8/125 optical fiber is one where the core fiber has a diameter of 8 microns and the surrounding cladding is 125 microns in diameter (as shown in Figure 10.11). These fibers are almost always designated as single-mode fibers because the core size is only approximately 10 times larger than the wavelength of the light it's carrying, and thus there isn't much room in the fiber for the light to bounce around. Essentially, the light is traveling in a straight line through the fiber.

FIGURE 10.11:

An 8/125 optical fiber

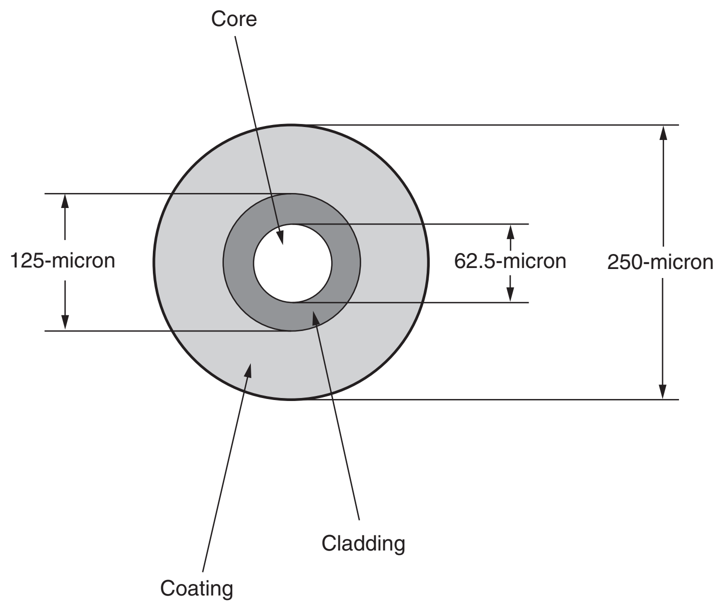


As discussed earlier, 8/125 optical fibers are used for high-speed applications like backbone fiber topologies such as FDDI, ATM, and Gigabit Ethernet.

62.5/125 Of all the fiber cable designations, the most common is 62.5/125. This is because optical fibers with this designation are large enough to be multimode fibers (i.e., support more than one signal within the fiber core). A standard multimode fiber optic cable (the most common kind of fiber optic cable), uses an optical fiber with a 62.5-micron core with 125-micron cladding (as shown in Figure 10.12).

FIGURE 10.12:

A sample 62.5/125 optical fiber



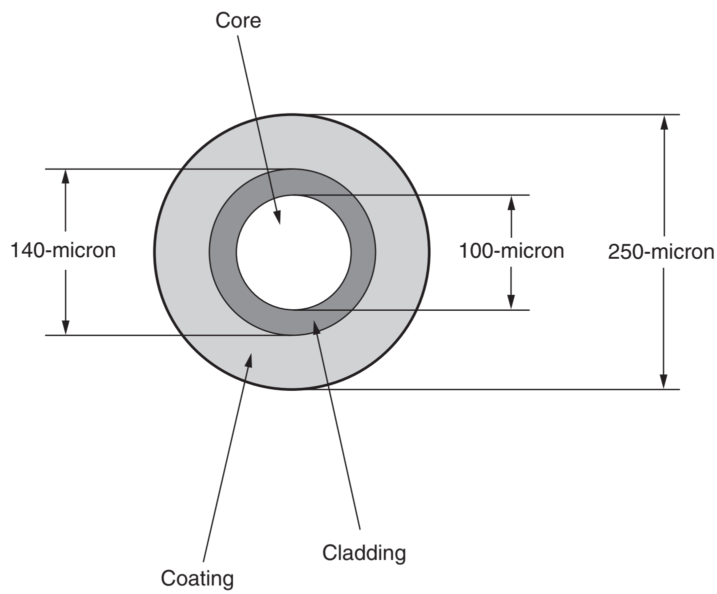
62.5/125 optical fibers are used mainly in LAN/WAN applications as a kind of "general use" fiber (if there really is such a thing).

100/140 An optical fiber with the 100/140 designation is not found in the mainstream. As you would expect, a 100/140 designation for an optical fiber means that that fiber has a 100-micron diameter core with a 140-micron diameter cladding (as shown in Figure 10.13).

This is a rather odd combination, as you can see. However, because of its rather odd sizing and, therefore, very specialized application, you might be able to guess the vendor who primarily uses this combination. Not sure? It's the designer of such proprietary technologies as Token Ring and Micro channel: International Business Machines, or IBM. IBM uses a 100/140 optical fiber in the cables for their fiber optic implementation of Token Ring.

FIGURE 10.13:

A 100/140 optical fiber



Number of Optical Fibers

Yet another difference between fiber optic cables is the number of individual optical fibers within them. The number of fibers in each cable differs depending on the intended use of the cable and can increase the cable's size, cost, and capacity.

Fiber optic cables can be divided into three categories based on the number of optical fibers:

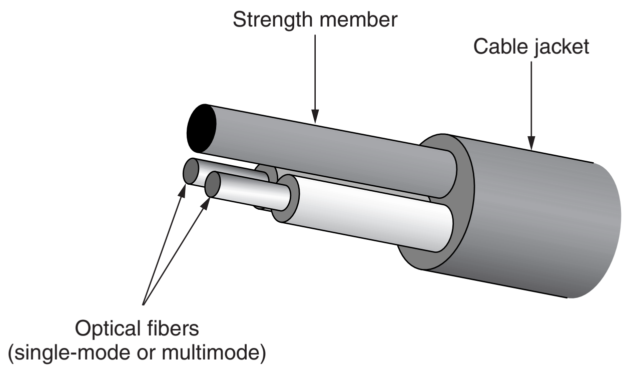
- Simplex cables
- Duplex cables
- Multifiber cables

A *simplex fiber optic cable* is a type of fiber optic cable that has only one optical fiber inside the cable jacket. An example of a simplex cable was shown earlier in this chapter in Figure 10.3. Since simplex cables only have one fiber inside them, there is usually a larger buffer and a thicker jacket to make the cable easier to handle.

Duplex cables, in contrast, have two optical fibers inside of a single jacket (as shown in Figure 10.14). The most popular use for duplex fiber optic cables is as a fiber optic LAN backbone cable. Duplex cables are perfect for this because all LAN connections need a transmission fiber and a reception fiber. Duplex cables have both inside a single cable, and running a single cable is of course easier than running two.

FIGURE 10.14:

A sample duplex fiber optic cable

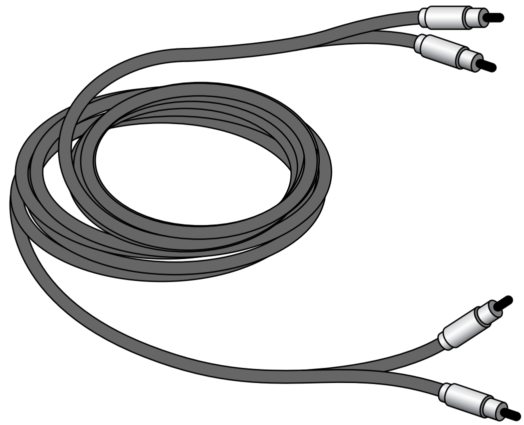


TIP

There is one type of fiber optic cable that is called a duplex cable but technically is not one. This cable is known as *zipcord*. Zipcord is really two simplex cables bonded together into a single flat optical fiber cable. It's called a duplex because there are two optical fibers, but it's not really duplex, because the fibers aren't covered by a common jacket. Zipcord is used primarily as a duplex patch cable. It is used instead of true duplex cable because it is cheap to make and to use. Figure 10.15 shows an example of a zipcord fiber optic cable.

FIGURE 10.15:

A sample zipcord cable



Finally, there are fiber optical cables that contain more than two optical fibers in one jacket. These cables are known as *multifiber* cables. There are multifiber cables with anywhere from three to several hundred optical fibers in them. More often than not, however, the number of fibers in a multifiber cable will be a multiple of two because, as discussed earlier, LAN applications need to have a send and a receive optical fiber for each connection.

LAN/WAN Application

Different fiber cable types are used for different applications within the LAN/WAN environment. Table 10.1 summarizes this section by showing the relationship between the fiber network type and the wavelength and fiber size for both single-mode and multimode fiber optic cables.

TABLE 10.1: Network Type Fiber Applications

Network Type	Single Mode Wavelength–Size	Multimode Wavelength–Size
Ethernet	1300nm – 8/125-micron	850nm – 62.5/125-micron
Fast Ethernet	1300nm – 8/125-micron	1300nm – 62.5/125-micron
Token Ring	Proprietary – 8/125-micron	Proprietary – 62.5/125-micron
ATM 155Mbps	1300nm – 8/125-micron	1300nm – 62.5/125-micron
FDDI	1300nm – 8/125-micron	1300nm – 62.5/125-micron

Fiber Installation Issues

Now that we've discussed details about the fiber optic cable itself, we must cover some of the issues involved with actually installing it into a LAN or WAN. These issues include, but are not limited to the following:

- Components of a typical fiber installation
- Fiber optic performance factors

Let's examine some of these fiber optic installation issues, starting with the components of a typical fiber optic installation.

NOTE The actual process of installing fiber optic cable will be covered in Part III, "Cabling Design and Installation."

Components of a Typical Installation

Just like copper-based cabling systems, fiber optic cabling systems have a few specialized components that are used only on fiber optic cabling systems. Some of these components include the following:

- Fiber optic cable
- Fiber optic enclosures
- Fiber optic connectors

Fiber Optic Cable

Although it seems like we've already discussed fiber optic cable to death, it has to be mentioned in this section because choosing the right fiber optic cable for your installation is critical. If you don't, your fiber installation is doomed from the start. A few things to remember:

Match the rating of the fiber you are installing to the equipment you are installing. It may seem a bit obvious, but if you are installing fiber for a hub and workstations with single-mode connections, it is not a good idea to use multimode fiber, and vice versa.

Use fiber optic cable appropriate for the locale. Don't use outdoor cable in an interior application. That would be overkill. Similarly, don't use interior cable outside. The interior cable doesn't have the protection features that the exterior cable has.

Unterminated fiber is dangerous. Fiber can be dangerous in two ways: You can get glass slivers in your hands from touching the end of a glass fiber. Also, laser light is dangerous to unprotected eyes. Many fiber optic transmitters use laser light that can damage the cornea of the eyeball when looked at. Bottom line: protect the end of an unterminated fiber cable.

Fiber Optic Enclosures

Because laser light is dangerous, the ends of every fiber optic cable must be encased in some kind of enclosure. The enclosure not only protects the fiber from damage, but also protects humans from exposure to dangerous laser light (as discussed earlier). There are two main types of fiber enclosures: wall plates and patch panels. You learned about wall plates in Chapter 8, so let's discuss patch panels here.

When most people think about a fiber enclosure, a fiber patch panel is what comes to mind. A *fiber patch panel* allows connections between different devices to be made and broken at the will of the network administrator. Basically, a bunch of fiber optic cables will terminate in a patch panel. Then, short fiber optic *patch cables* are used to make connections between the various cables. Figure 10.16 shows an example of a fiber optic patch panel. Note that there are dust caps on all the fiber optic ports. This is to prevent dust from getting into the connector and preventing a proper connection.

In addition to the standard fiber patch panels, a fiber optic installation may have one or more fiber distribution panels. A *fiber distribution panel* is just like a patch panel, in that many cables interconnect in this box. However, in a distribution panel (see Figure 10.17), the connections are more permanent. Distribution panels usually have a lock and key to prevent end users from getting in the panel and making unauthorized changes. Generally speaking, a patch panel is found wherever fiber optic equipment (i.e., hubs, switches, and routers) is found. Distribution panels are found wherever multifiber cables are split out into individual cables.

FIGURE 10.16:

An example of a fiber optic patch panel

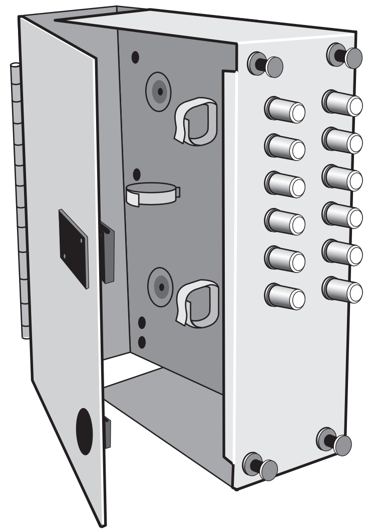
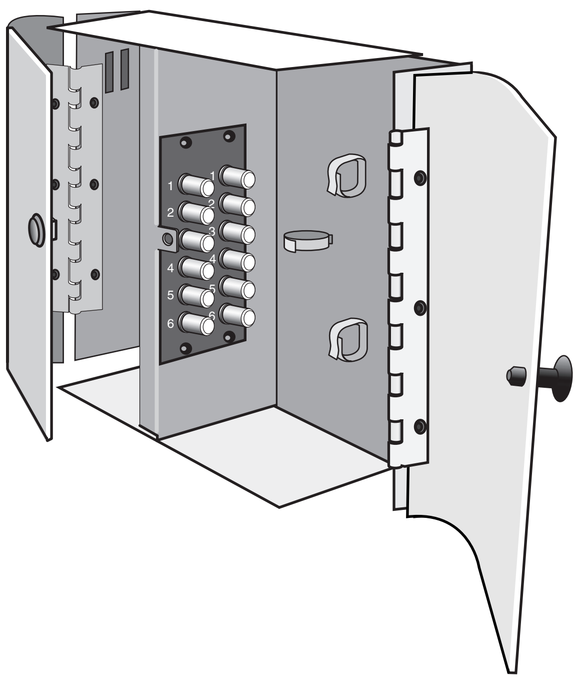


FIGURE 10.17:

A sample fiber optic distribution panel



Fiber Optic Connectors

Fiber optic connectors are unique in that they must make both an optical and a mechanical connection. Connectors for copper cables, like the RJ-45 connector used on UTP, make an electrical connection between the two cables involved. However, the pins inside the connector only need to be touching to make a sufficient electrical connection. Fiber optic connectors, on the other hand, must have the fiber internally aligned almost perfectly in order to make a connection. The fiber optic connectors use various methods to accomplish this.

Some of the types of optical connectors currently in use include the following:

- Subscriber connector (SC)
- 568SC (Duplex SC)
- Straight-tip (ST)
- Duplex ST
- Biconic
- FDDI (MIC)
- FC
- Enterprise system connection (ESCON)
- SMA

In this subsection, we will briefly examine each connector type, starting with the SC connector. Note that each connector differs primarily in the way the connection is made, the maximum number of connections (called *mating cycles*), and the size of the connector.

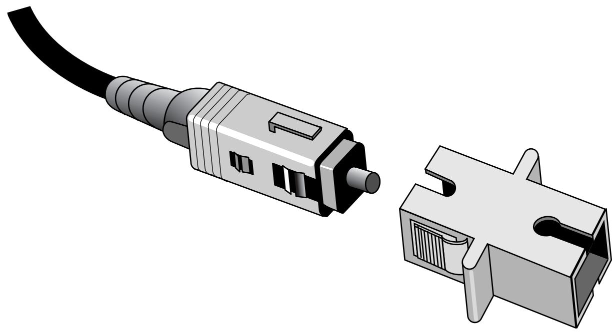
NOTE Fiber optic connector installation (called connectorizing) is covered in more detail in Chapter 13, "Cable Connector Installation."

Subscriber Connector (SC)

The *subscriber connector (SC)* (also sometimes known as a *square connector*) is a type of fiber optic connector, as shown in Figure 10.18. As you can see, SC connectors are latched connectors. This makes it impossible for the connector to be pulled out without releasing the connector's latch, usually by pressing some kind of button or release.

FIGURE 10.18:

A sample SC connector

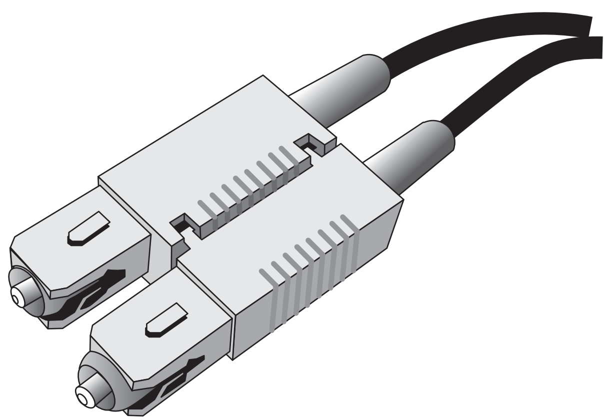


SC connectors work with either single- or multimode optical fibers and will last for around 1000 matings. They are currently seeing increased use but they still aren't as popular as ST connectors for LAN connections are.

568SC (Duplex SC) *568SC connectors* (also known as *duplex SC* connectors) are basically a pair of SC connectors in a single plastic enclosure. Figure 10.19 shows a 568SC connector. Compare the connector shown in Figure 10.19 with the one in Figure 10.18 and notice the similarities.

FIGURE 10.19:

A sample 568SC connector

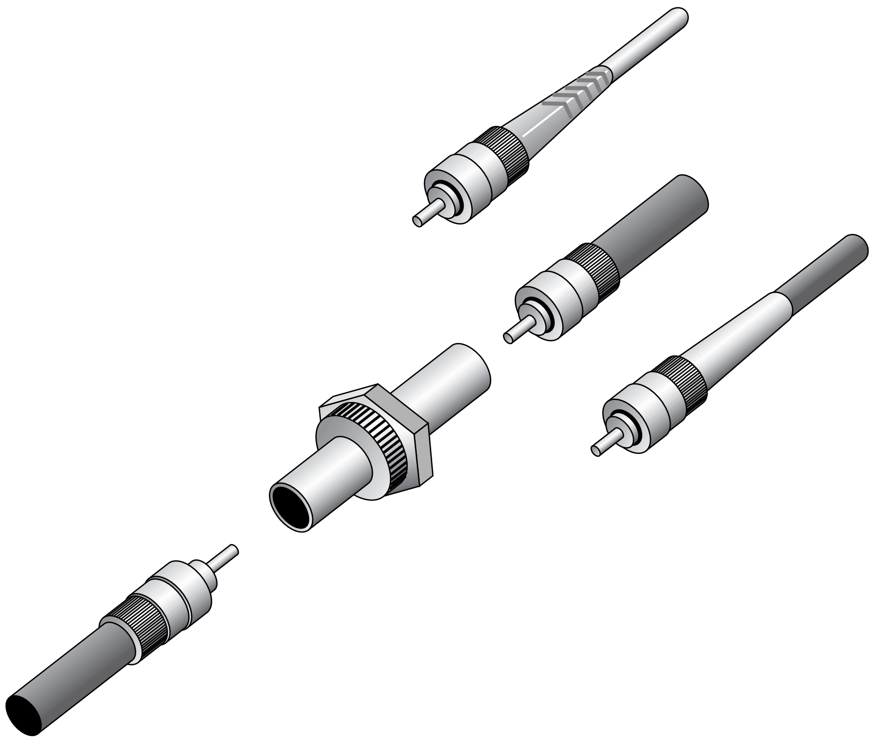


Because the SC and Duplex SC connectors are basically the same, they share the same characteristics, including maximum matings and support for single- and multimode optical fibers.

Straight Tip (ST) The straight tip (ST) fiber optic connector, developed by AT&T, is probably the most widely used fiber optic connector. It uses a BNC attachment mechanism, similar to the thinnet Ethernet connection mechanism, which makes connections and disconnections fairly easy. The ease of use of the ST is one of the attributes that makes this connector so popular. Figure 10.20 shows some examples of ST connectors. Notice the BNC attachment mechanism.

FIGURE 10.20:

Some examples of ST connectors



Because it is so widely available, adapters to other fiber connector types are available for this connector type. Additionally, this connector type has a maximum mating cycle of around 1000 matings.

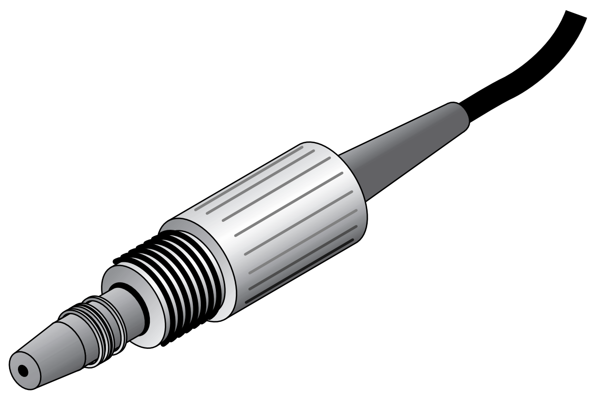
NOTE Some ST connectors use a plastic end; these will only survive around 250 mating cycles.

Duplex ST Like the duplex SC connector, the *duplex ST* connector is simply a pairing up of the single connector version of its namesake (in this case, the ST connector). It shares the same details of its singular version.

Biconic The biconic connector was developed by AT&T; it has fallen out of favor with fiber installers. It uses a screw-together connection system, as you can see in Figure 10.21. Biconic connectors are available for both single- and multimode optical fibers.

FIGURE 10.21:

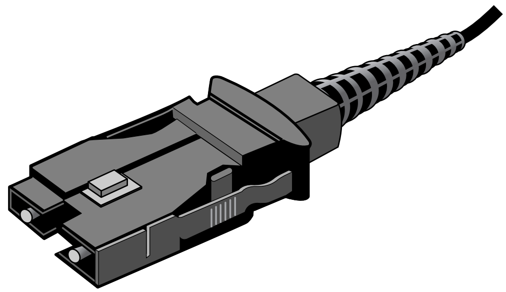
A biconic fiber optic connector



FDDI (MIC) Since the fiber-distributed data interface (FDDI) has become popular as a LAN type, the *media interface connector* (MIC) for FDDI is a popular connector choice for terminating fiber and is the main choice for use with FDDI. Figure 10.22 shows an example of an FDDI (MIC) connector. Notice that it is keyed (the red tab on top of the connector). This prevents the connector from being installed incorrectly.

FIGURE 10.22:

An FDDI (MIC) connector

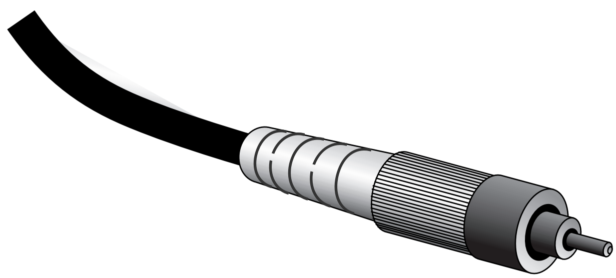


NOTE FDDI connectors work ONLY with multimode fiber.

FC The FC connector was one of the first of the smaller connectors used. The FC fiber optic connector has a keyed all-metal connector with a screw-on fastening system. Along with its derivative, the D4 connector, it is quickly becoming one of the more popular small-size connectors. Figure 10.23 shows an example of an FC connector. Note the all-metal construction that makes it a durable connector despite its small size.

FIGURE 10.23:

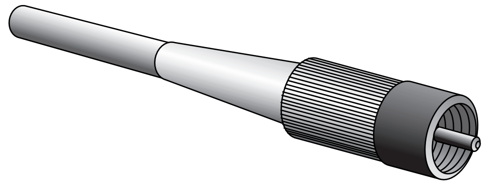
An FC fiber optic connector



The D4 connector is a variant of the FC connector that is often confused with the FC connector. The D4 connector is basically the same as the FC, but there is a "hood" over the end of the connector to prevent damage to the fiber (as shown in Figure 10.24). Compare the D4 connector in Figure 10.24 to the FC connector in Figure 10.23.

FIGURE 10.24:

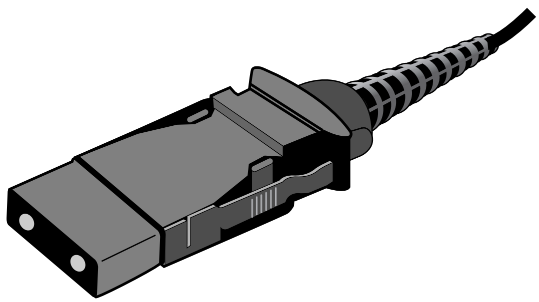
A D4 fiber optic connector



Enterprise System Connection (ESCON) The Enterprise System Connection (ESCON) connector is much like the FDDI (MIC) fiber optic connector, except that the ESCON connector has a retractable cover and lower max mating cycle (only 500 matings). Figure 10.25 shows an example of an ESCON connector. Note the similarities between the ESCON connector shown here and the FDDI (MIC) connector shown earlier in Figure 10.22.

FIGURE 10.25:

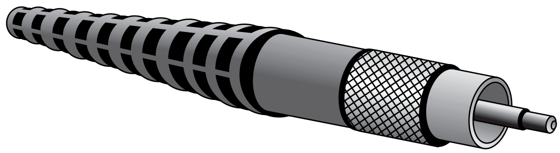
An ESCON connector



SMA The SMA connector, developed by AMP Corporation, was designed to be a low-cost multimode fiber connector. As you can see in Figure 10.26, it's a fairly simple connector. Because it is simple and made of plastic, it is only rated for a maximum of 200 mating cycles. However, it is rated for military use. That, along with its low cost, makes it a very popular connector type.

FIGURE 10.26:

An SMA fiber optic connector



NOTE SMA connectors are currently available for both single- and multimode optical fibers.

Fiber Optic Performance Factors

During the course of a normal fiber installation, there are a few factors that you must be aware of. If not acknowledged, these factors can cause a serious degradation in performance.

Some of the factors that can negatively affect performance include the following:

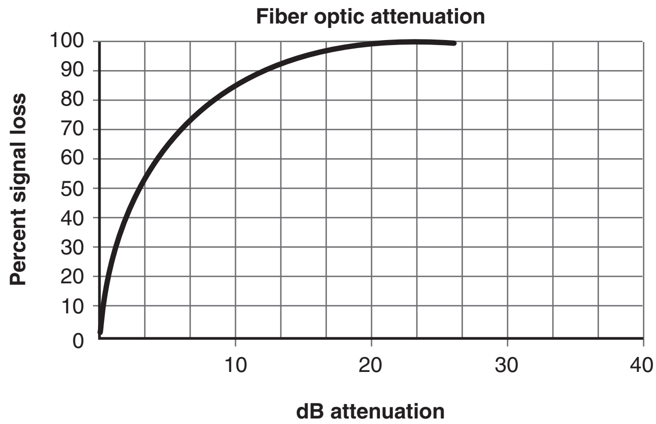
- Attenuation
- Acceptance angle
- Numerical aperture (NA)
- Light source type

Attenuation

The biggest factor in any fiber optic cabling installation is attenuation. *Attenuation* is the loss or decrease in power of a data-carrying signal (in this case, the light signal). It is measured in decibels (dB or dB/km for a particular cable run). In real world terms, a 3dB attenuation loss in a fiber connection is equal to about a 50 percent loss of signal. Figure 10.27 graphs attenuation in decibels versus percent signal loss. Notice that the relationship is exponential.

FIGURE 10.27:

Relationship of attenuation to percent signal loss of a fiber optic transmission



The more attenuation that exists in a fiber optic cable from transmitter to receiver, the shorter the maximum distance between them. Attenuation negatively affects transmission speeds and distances of all cabling systems, but fiber optic transmissions are particularly sensitive to attenuation.

There are many different problems that can cause attenuation of a light signal in an optical fiber. Some of those problems include the following:

- Excessive gap between fibers in a connections
- Improperly installed connectors
- Impurities in the fiber itself
- Excessive bending of the cable
- Excessive stretching of the cable

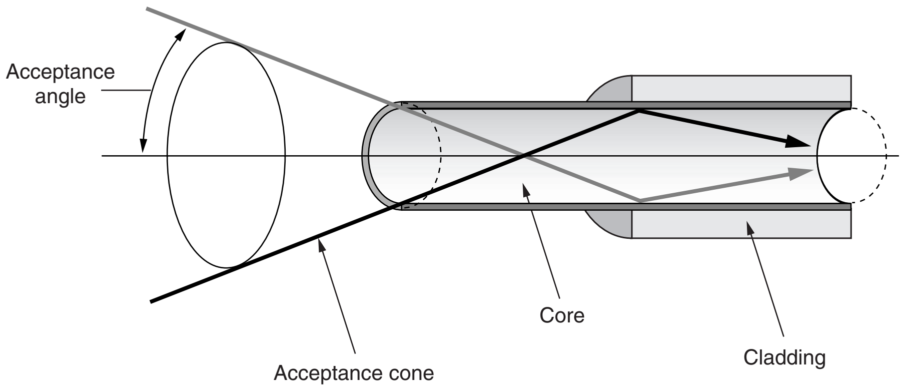
These problems will be covered in Chapter 14, "Cabling System Testing and Troubleshooting." For now, just realize that these problems cause attenuation, an undesirable effect.

Acceptance Angle

Another factor that affects the performance of a fiber optic cabling system is the acceptance angle of the optical fiber core. The acceptance angle (as shown in Figure 10.28) is the angle over which a particular (multimode) fiber can accept light as an input to that fiber.

FIGURE 10.28:

Illustration of multifiber acceptance angles



The greater the acceptance angle difference between two or more signals in a multimode fiber, the greater the effect of modal dispersion (discussed earlier in this chapter; see the section "Single-Mode or Multimode"). The modal dispersion effect also has a negative effect on the total performance of a particular cable segment.

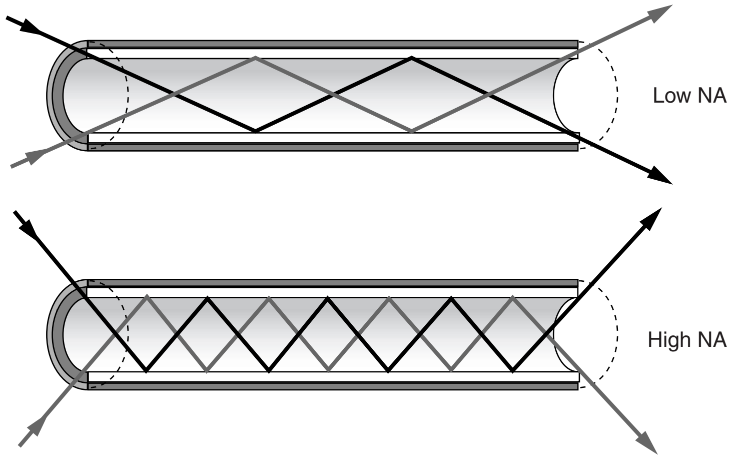
Numerical Aperture (NA)

One of the most misunderstood performance factors of fiber optic cable is the numerical aperture (NA). Most people ignore this value when choosing their fiber optic cable. However, it is a very important performance factor, especially when splicing two optical cables. The *numerical aperture (NA)* is a number that reflects the ability of a particular optical fiber to accept light. The number is the result of a mathematical equation involving the acceptance angle.

The value of the NA is a decimal value between the numbers of 0 and 1. A value for NA of 0 indicates that the fiber gathers no light. A value of 1 for NA indicates that the fiber will accept all light it's exposed to. The lower the NA, the less light that gets accepted into the fiber, and thus the less distance the signal can travel. However, a lower NA also means there is more possible bandwidth available. Conversely, a higher NA means that the signal can travel farther, but there is lower bandwidth for that signal. Figure 10.29 illustrates the difference between high and low NA values.

FIGURE 10.29:

The difference between high and low NA values



Chromatic Dispersion

The last fiber optic performance factor is a factor known as chromatic dispersion, which limits the bandwidth of certain single-mode optical fibers. *Chromatic dispersion* is when the various wavelengths of light spread out as they travel through an optical fiber. This happens because different wavelengths of light travel different speeds through the same media. As they bounce around through the fiber, the different wavelengths will reflect off the sides of the fibers at different angles (as shown in Figure 10.30). The different wavelengths of light will spread farther and farther apart until the different wavelengths arrive at the destination at completely different times.

FIGURE 10.30:

Single-mode optical fiber chromatic dispersion