

Understanding Fiber Optics & Local Area Networks

Just the Technical Facts

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Scalable. Robust. Cost-effective. Ready for what's now and what's next. If this is what you require from your local area network, then doesn't it make sense to demand it from the technologies supporting it? That's why optical fiber is the ideal technology for local area networks.

The Benefits of Fiber Optics

In its simplest terms, fiber optics is the technology of using “waveguides” to transport information from one point to another in the form of light. Unlike the copper form of transmission, fiber optics are 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. (This basic information transmission sequence will be discussed in more detail later.) Optical fiber systems have many advantages over metallic-based communication systems. These advantages include:

Large bandwidth, light weight and small diameter

The amount of information carried in two strands of optical fiber would require a copper cable four inches in diameter. While today's applications require an ever-increasing amount of bandwidth, it is important to consider the space constraints of many end users. The relatively small diameter and light weight of optical cables make such installations in existing duct systems easy and practical, and saves valuable conduit space in these environments.

Easy installation and upgrades

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. 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.

Designed for future applications needs

Fiber optics is affordable today, as the price of electronics 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.

Long-distance signal transmission

The low signal loss and superior signal integrity found in optical systems allow much longer intervals of signal transmission without active or passive processing than metallic-based systems.

Security

Unlike metallic-based systems, the dielectric (nonconducting) 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 for security applications.

Nonconductivity

Optical fibers, because they are dielectric, 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.

Common Myths about Optical Fiber

MYTH: Optical fiber is fragile.

FACT: Fiber may be made of glass, but don't let that fool you. Inch for inch, it's stronger than steel. Optical fiber also is more environmentally robust than copper, and does not corrode, rust, or decay when exposed to the environment.

MYTH: Optical fiber is so complex to install, it requires a specialist.

FACT: Not at all. Unlike copper products, whose designs have become increasingly complex over the years to keep up with bandwidth demand, fiber technologies are trending toward ever-easier designs while staying ahead of bandwidth demand.

MYTH: Optical fiber is cost prohibitive.

FACT: Actually, optical fiber is usually the less costly investment for your network because of its nearly limitless bandwidth capacity and ease of upgrade.

MYTH: Testing and troubleshooting is difficult.

FACT: Optical testing is no more difficult than coaxial copper cable testing and is often simpler, as fewer parameters are needed to ensure the operability of optical fiber. For example, while copper technologies are affected by electromagnetic interference and "cross talk," and therefore must be tested for this, fiber suffers no such issue.

Optical Fiber Deconstructed

Optical fiber for telecommunications consists of three components:

- Core
- Cladding
- Coating

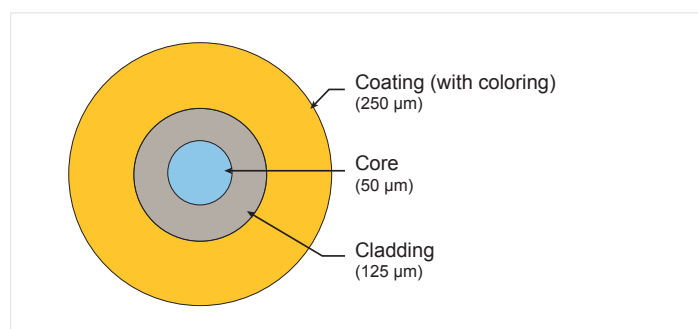


Figure 1 - Cross Section of Typical Fiber

The core is the central region of an optical fiber through which light is transmitted. In general, telecommunications uses sizes from 8.3 micrometers (μm) to 62.5 μm . The standard telecommunications core sizes in use today are 8.3 μm

(single-mode), 50 μm (multimode), and 62.5 μm (multimode). (Single-mode and multimode will be discussed shortly.) The diameter of the cladding surrounding each of these cores is 125 μm . Core sizes of 85 μm and 100 μm have been used in early applications, but are not typically used today.

To put these sizes into perspective, compare them to a human hair, which is approximately 70 μm or 0.003 inch. The core and cladding are manufactured together as a single piece of silica glass with slightly different compositions and cannot be separated from one another. Contrary to myth, this glass does not have a hole in the core, but is completely solid throughout.

The third section of an optical fiber is the outer protective coating which has a diameter of 250 μm . This coating is typically an ultraviolet (UV) light-cured acrylate applied during the manufacturing process to provide physical and environmental protection for the fiber. During the installation process, this coating is stripped away from the cladding to allow proper termination to an optical transmission system.

Types of fiber

Once light enters an optical fiber, it travels in a stable state called a mode. There can be from one to hundreds of modes depending on the type of fiber. Each mode carries a portion of the light from the input signal. Generally speaking, the number of modes in a fiber is a function of the relationship between core diameter, numerical aperture, and wavelength, which will be discussed later.

Every optical fiber falls into one of two categories:

- Single-mode
- Multimode

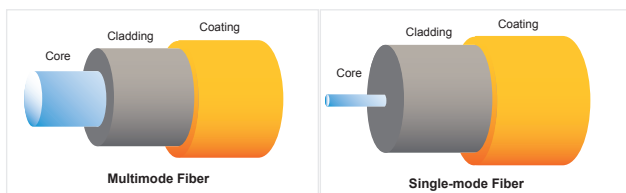


Figure 2 - Fiber Categories

It is impossible to distinguish between single-mode and multimode fiber with the naked eye. There is no difference in outward appearances. Only the core size is different. Both fiber types act as a transmission medium for light, but they operate in different ways, have different characteristics, and serve different applications. Single-mode fiber allows for only one pathway, or mode, of light to travel within the fiber.

The core size is 8.3 μm . Single-mode fibers are used in applications where low-signal-loss and high-data-rates are required, such as on long spans where repeater/amplifier spacing needs to be maximized.

Multimode fiber allows more than one mode of light. Common multimode core sizes are 50 μm and 62.5 μm . Of the two, 50 μm fiber, particularly 50 μm fiber optimized for laser transmission, offers the highest bandwidth. Multimode fiber is better suited for shorter distance applications where a higher concentration of costly electronics are located. Multimode fiber is more economical because it can be used with low-cost transmitters for high bandwidth. Of the two, 50 μm fiber offers the highest bandwidth as compared to 62.5 μm fibers. 62.5 μm fiber is primarily found in legacy systems where existing and matching fiber is present. Multiple grades of 50 μm exist (OM2, OM3, and OM4) where maximum bandwidth and distance vary. OM4 fibers are the highest grade of 50 μm fiber and are primarily found in data centers.

Inside an Optical Fiber

Index of refraction (IOR)

The index of refraction (IOR) is a way of measuring the speed of light in a material. The IOR is calculated by dividing the speed of light in a vacuum (the fastest possible speed of light) by the speed of light in some other medium. The larger the IOR, the more slowly that light travels in that medium.

Total internal reflection

When a light ray traveling in one material hits a different material and reflects back into the original material without any loss of light, total internal reflection occurs. Since the core and cladding are constructed from different compositions of glass, theoretically, light entering the core is confined to the boundaries of the core because it reflects back whenever it hits the cladding. For total internal reflection to occur, the index of refraction of the core must be higher than that of the cladding.

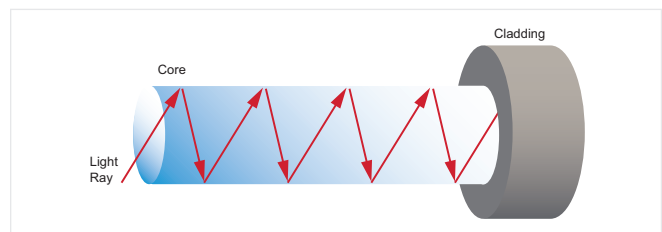


Figure 3 - Total Internal Reflection

Numerical aperture and the “acceptance cone”

Electrical signals are converted to light signals before they enter an optical fiber. To ensure that the signals reflect and travel correctly through the core, the light must enter the core through an imaginary acceptance cone. The size of this acceptance cone is a function of the refractive index difference between the core and the cladding.

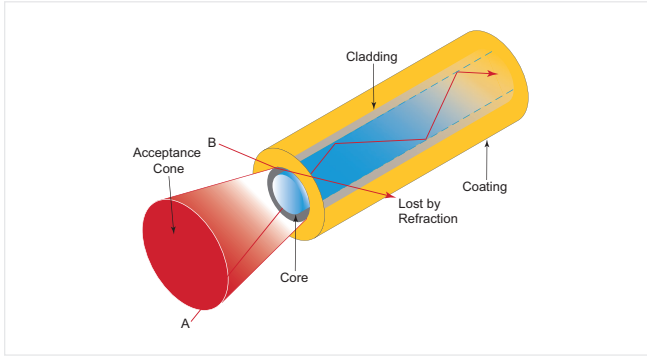


Figure 4 - Acceptance Cone

Light ray A: entered acceptance cone; transmitted through the core by total internal reflection (TIR)

Light ray B: did not enter acceptance cone; signal lost

In simpler terms, there is a maximum angle from the fiber axis at which light may enter the fiber so that it will propagate, or travel, in the core of the fiber. The sine of this maximum angle is the numerical aperture (NA) of the fiber. Fiber with a larger NA requires less precision to splice and work with than fiber with a smaller NA. Single-mode fiber has a smaller NA than multimode fiber.

Optical Fiber Parameters

As with any type of transmission system, certain parameters affect the system’s operation.

Wavelength

Light that can be seen by the unaided human eye is said to be in the visible spectrum. In the visible spectrum, wavelength can be described as the color of light.

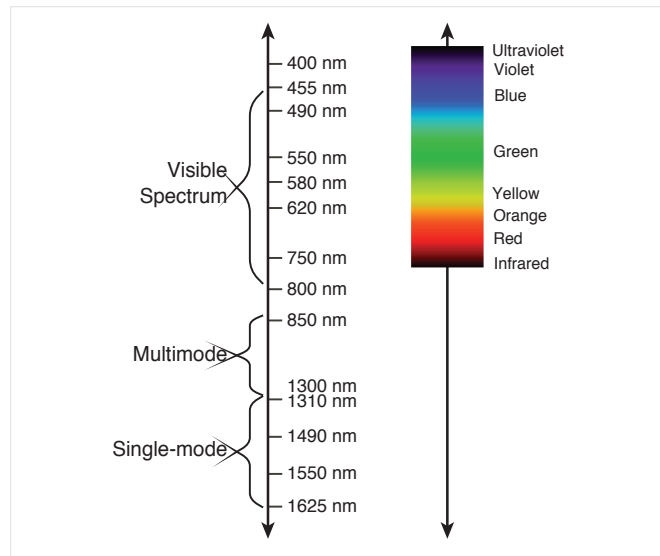


Figure 5 - Visible Spectrum of Light

To put this into perspective, take a look at Figure 5. Notice that the colors of the rainbow – red, orange, yellow, green, blue, (indigo, not shown), and violet – fall within the visible spectrum. Optical fiber transmission uses longer wavelengths which are invisible to the unaided eye. (Longer wavelengths have higher readings; for example, red light has a longer wavelength than blue light.) Typical optical transmission wavelengths are 850 nanometers (nm), 1300 nm, and 1550 nm.

Safety note: Never look into the end of a fiber that may have a laser coupled to it. Laser light is invisible and can damage the eyes. Viewing it directly does not cause pain. The iris of the eye will not close involuntarily as when viewing a bright light; consequently, serious damage to the retina of the eye is possible. Should accidental exposure to laser light be suspected, an eye examination should be arranged immediately.

Both lasers and light-emitting diodes (LEDs) are used to transmit light through optical fiber. (More information on lasers and LEDs is available later in the text.) Lasers typically transmit at 850, 1310, and 1550 nm, making them ideal for laser-optimized multimode fibers (850 nm) and single-mode fiber (1310 and 1550 nm). LEDs are used at 850 or 1300 nm, making them useful for standard multimode fiber.

Window

There are operational ranges of wavelengths at which the fiber best operates. Each range is known as an operating window. Each window is centered on the typical operational wavelength.

Window Operating Wavelength	
800-900 nm	850 nm
1250-1350 nm	1310 nm
1500-1600 nm	1550 nm

Frequency

The frequency of a system is the speed of modulation of the digital or analog output of the light source; in other words, the number of pulses per second emitted from the light source (see Figure 6). Frequency is measured in units of hertz (Hz), where 1 hertz is equal to 1 pulse or cycle per second.

A more practical measurement for optical communications is megahertz (MHz) or millions of pulses per second.

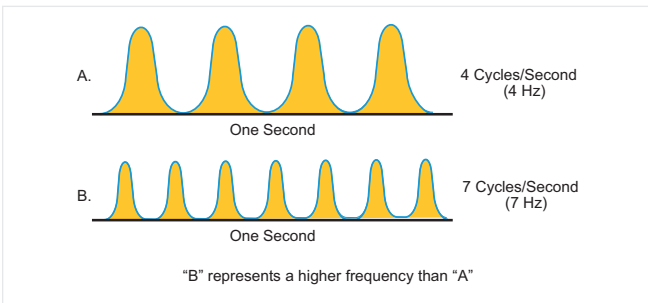


Figure 6 - Frequency Measurement

Intrinsic attenuation

Attenuation is the loss of optical power as light travels down a fiber. It is measured in decibels (dB). Over a set distance, a fiber with a lower attenuation will allow more power to reach its receiver than a fiber with higher attenuation.

Attenuation can be caused by several factors, but is generally placed in one of two categories: intrinsic or extrinsic.

Intrinsic attenuation occurs due to something inside or inherent to the fiber. It is caused by impurities in the glass during the manufacturing process. As precise as manufacturing is, there is no way to eliminate all impurities, though technological advances have caused attenuation to decrease dramatically since 1970. When a light signal hits an impurity in the fiber, one of two things will occur: it will scatter or it will be absorbed.

Scattering

Rayleigh scattering accounts for the majority (about 96 percent) of attenuation in optical fiber. Light travels in the core and interacts with the atoms in the glass. The light waves elastically collide with the atoms, and light is scattered as a result.

Some scattered light is reflected back toward the light source (input end). This is a property that is used in an optical

time domain reflectometer (OTDR) to test fibers. This same principle applies to analyzing loss associated with localized events in the fiber, such as splices.

Absorption

The second type of intrinsic attenuation in fiber is absorption. Absorption accounts for three to five percent of fiber attenuation. This phenomenon causes a light signal to be absorbed by natural impurities in the glass. Unlike scattering, absorption can be limited by controlling the amount of impurities during the manufacturing process.

Extrinsic attenuation

The second category of attenuation is extrinsic attenuation. Extrinsic attenuation can be caused by two external mechanisms: macrobending or microbending. Both cause a reduction of optical power.

Macrobending

If a bend is imposed on an optical fiber, strain is placed on the fiber along the region that is bent. The bending strain will affect the refractive index and the critical angle of the light ray in that specific area. As a result, light traveling in the core can refract out, and loss occurs.

A macrobend is a large-scale bend that is visible; for example, a fiber wrapped around a person's finger. This loss is generally reversible once bends are corrected.

To prevent macrobends, all optical fiber (and optical fiber cable) has a minimum bend radius specification that should not be exceeded. This is a restriction on how much bend a fiber can withstand before experiencing problems in optical performance or mechanical reliability.

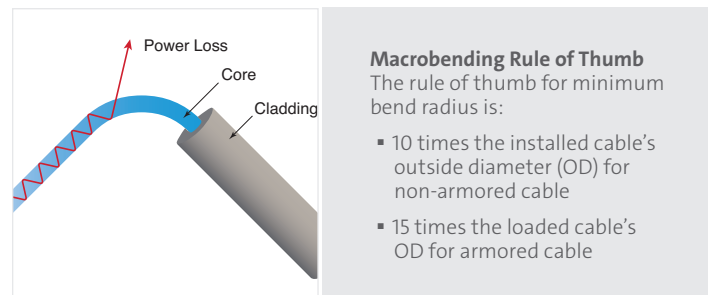


Figure 7 - Macrobending

Microbending

The second extrinsic cause of attenuation is a microbend. This is a small-scale distortion, generally indicative of pressure on the fiber. Microbending may be related to temperature, tensile stress, or crushing force. Like macrobending, microbending will cause a reduction of optical power in the glass.

Microbending is very localized, and the bend may not be clearly visible upon inspection. With bare fiber, microbending may be reversible; in the cabling process, it may not. Microbending attenuation affects all optical wavelengths.

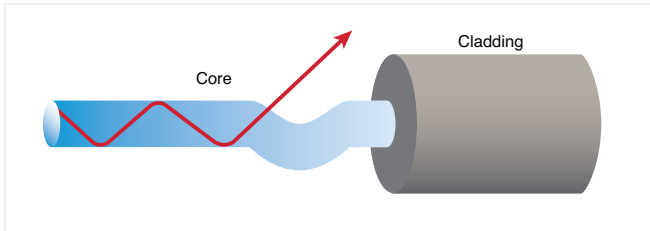


Figure 8 - Microbending

Dispersion

Dispersion is the “spreading” of a light pulse as it travels down a fiber. As the pulses spread, or broaden, they tend to overlap and are no longer distinguishable by the receiver as 0s and 1s. Light pulses launched close together (high-data-rates) that spread too much (high dispersion) result in errors and loss of information

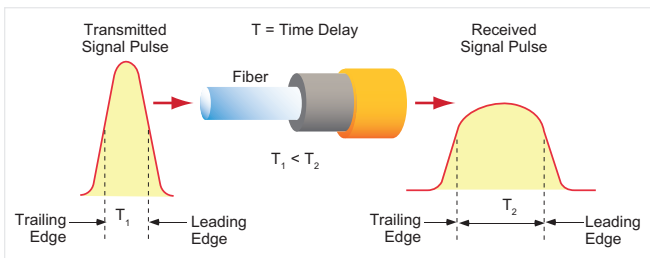


Figure 9 - Dispersion

Pulse width is measured at full width-half maximum; in other words, the full width of the pulse, at half the maximum pulse height. Dispersion limits how fast, or how much, information can be sent over an optical fiber.

Chromatic dispersion occurs as a result of the range of wavelengths in the light source. Light from lasers and LEDs consists of a range of wavelengths. Each of these wavelengths travels at a slightly different speed. Over distance, the varying wavelength speeds cause the light pulse to spread in time. This is of most importance in single-mode applications.

The index of refraction of a material is dependent on the wavelength, so each frequency component actually travels at a slightly different speed. As the distance increases, the

pulse becomes broader as a result. This type of dispersion is a blend of material and waveguide dispersion described below.

Material dispersion is caused by molecular and light energy interactions. It occurs in all mediums except a perfect vacuum. The amount of material dispersion varies with the composition of the glass and is a function of the wavelength of the light sources. The speed of light in a medium is a function of wavelength. No transmitter produces a pure light source of only one wavelength. Sources produce a range of wavelengths around a center wavelength. Light at these wavelengths travels at slightly different speeds, resulting in the pulse spreading that increases with distance.

Modal dispersion affects multimode fibers only and is a result of the modes of light traveling down the fiber arriving at the receiver at different times, causing a spreading effect. Graded index profiles, only used in multimode fibers, are used to mitigate the effects of modal dispersion.

Bandwidth

In simplest terms, bandwidth is the amount of information a fiber can carry so that every pulse is distinguished by the receiver at the end.

As discussed in the previous section, dispersion causes light pulses to spread. The spreading of these light pulses causes them to merge together. At a certain distance and frequency, the pulses become unreadable by the receiver. The multiple pathways of a multimode fiber cause this overlap to be much greater than for single-mode fiber. These different paths have different lengths, which cause each mode of light to arrive at a different time.

System bandwidth is measured in megahertz (MHz) at one km. In general, when a system’s bandwidth is 20 MHz•km, it means that 20 million pulses of light per second will travel down 1 km (1000 m) of fiber, and each pulse will be distinguishable by the receiver.

The Basics of Fiber Optic Transmission

As depicted in Figure 10, information (voice, data, or video) is encoded into electrical signals. At the light source, these electrical signals are converted into light signals. It is important to note that fiber has the capability to carry either analog or digital signals. Many people believe that fiber can transmit only digital signals due to the on/off binary characteristic of the light source. The intensity of the light and the frequency at which the intensity changes can be used for AM and FM analog transmission.

Once the signals are converted to light, they travel down the fiber until they reach a detector, which changes the light signals back into electrical signals. (This is called OEO, or optical-to-electrical-to-optical conversion.) The area from light source to detector constitutes the passive transmission subsystem; i.e. that part of the system manufactured and sold by Corning. Finally, the electrical signals are decoded into information in the form of voice, data, or video.

Inside each of the electronics (switches, routers, etc.) resides a receiver/photodetector to accept the incoming information and a transmitter to send the information back out on the network. Typical switches in a local area network use an OEO conversion. The data comes into the switch as an optical signal, is converted into an electrical signal and switched/routed as needed. The signal is then converted back to an optical signal and sent out the port. OEO is not protocol transparent like a true optical switch, but does allow for the 3Rs (re-amplification, reshape and re-time) of digital signals.

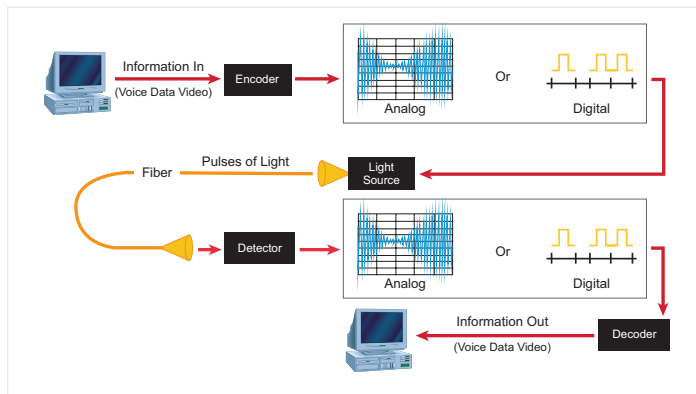


Figure 10 - Information Transmission Sequence

Lasers and LEDs

Historically, light-emitting diode (LED) devices have been used with multimode fiber, and are inexpensive compared to single-mode fiber lasers. The light from the LED is not very intense, but is sufficient to couple enough power to achieve the distances needed at lower data rates. LED transmitters have been deployed for use at 850 nm and 1300 nm, up to speeds of 622 Mb/sec. However, because LEDs cannot modulate faster than 622 Mb/sec, a new technology was developed for Gigabit speeds and above.

Vertical-cavity surface-emitting lasers (VCSELs) are low-cost lasers that operate at 850 nm on multimode fiber to support Gigabit speeds. As a result of their higher speed capabilities, VCSELs are the optical sources utilized in transmitters for up to 100 Gigabit Ethernet multimode systems. The light emitted is more powerful and more

concentrated than the light from LEDs and provides much higher system performance. VCSELs are also significantly less expensive than typical single-mode fiber lasers and use far less power, requiring far less cooling.

Fabry-Perot lasers can operate in the 850, 1310, and 1550 nm windows and are typically used for single-mode applications.

They offer a higher power output than VCSELs but are also more expensive (though less expensive than distributed feedback lasers, which are also used in single-mode systems).

Fiber Optic Cabling Basics

In general, fiber optic cable can be categorized by its deployment environment.

Fiber coloring

All fibers are colored for identification purposes. There is a standard U.S. coloring scheme. This identification scheme is based on TIA/EIA-598, "Fiber Optic Color Coding." This standard allows for fiber units to be identified by means of printed legend. This method can be used for identification of fiber ribbons and fiber subunits. As you can see by the legend provided, each fiber position contains a corresponding printed numerical position number and/or color for use in identification.

Standard U.S. Fiber Coloring Scheme		
Position Number	Base Color and Tracer	Abbreviation
1	Blue	BL
2	Orange	OR
3	Green	GR
4	Brown	BR
5	Slate	SL
6	White	WH
7	Red	RD
8	Black	BK
9	Yellow	YL
10	Violet	VI
11	Rose	RS
12	Aqua	AQ
13-24	Colors 1 through 12 repeated with a black tracer	Example: BL/BK, OR/BK, etc.

Figure 11 - Standard U.S. Fiber Color Scheme

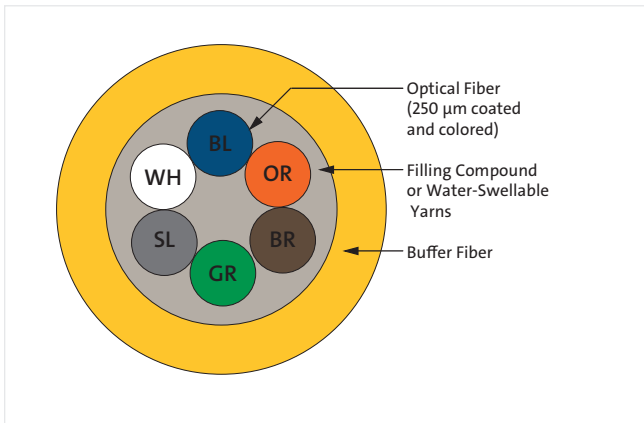


Figure 12 - Standard U.S. Fiber Color Scheme

Cable jacket coloring

Cable jacketing serves many purposes in the overall elements to a cable construction. Specific materials are used in the jacket composition to meet the standards requirements such as those needed in flame-retardant or UV-protected installation environments. As shown in Figure 13, the color of the cable also signifies the standardized fiber type of the overall cable construction. Typically in indoor multimode cables, orange is used in OM1 and OM2 62.5 μm fiber types while aqua is used for OM3 and OM4 50 μm fiber types. Indoor single-mode cables are yellow. Outdoor cables are black but may contain a single colored stripe to signify the fiber type inside.

Standard U.S. Cable Jacket Coloring Scheme		
Cable Type	Color	
Outside Plant/UV-Resistant	Black	
OM1 (62.5 μm)	Orange	
OM2 (50 μm)	Orange	
OM3 and OM4 (Laser-Optimized 50 μm)	Aqua	
OS2 (SM)	Yellow	

Figure 13 - Standard U.S. Cable Jacket Color Scheme

Cable armor

Cable armor provides additional structural protection against the environmental rigors and hazards found in outdoor or harsh environment applications. Armored fiber optic cable is often exposed to the most rugged of installation environments. It provides superior crush and impact performance, as well as increased rodent resistance. In addition, armored cable construction is often a cost-effective alternative to installing rigid metal conduit or innerduct and separately pulling cable.

Its sole purpose is to protect its fiber optic core throughout the cable's life. In extreme instances, multiple layers of metal armoring can increase the resistance of a cable installation, but is typically not necessary.

The three main commonly used armor constructions are steel tape, interlocking, and all-dielectric.

Outdoor

Outside plant (OSP) cables must withstand a variety of environmental and mechanical extremes. The cable must offer excellent attenuation performance over a wide range of temperatures, resist water ingress, sustain years of ultraviolet radiation from direct sunlight, and tolerate a wide range of mechanical forces.

Indoor

Inside plant cables generally experience a more controlled, stable environment. Therefore, performance requirements are based on other factors. The cables must meet the requirements of the U.S. National Electrical Code® (NEC®) and local building codes based upon their installed location. These cables should also be easy to terminate.

Indoor and outdoor

Corning led the development of flame-retardant indoor/outdoor cables. These cables use specialty materials to meet the flame-retardant requirements of the U.S. National Electrical Code indoor environment. They also provide reliable waterblocking and robust construction critical for OSP use.

Cable ratings

Article 770 of the U.S. NEC requires indoor fiber cables to meet different requirements based on where they are placed in the environment requirement: Listed most to least stringent, they are plenum, riser, and general purpose areas.

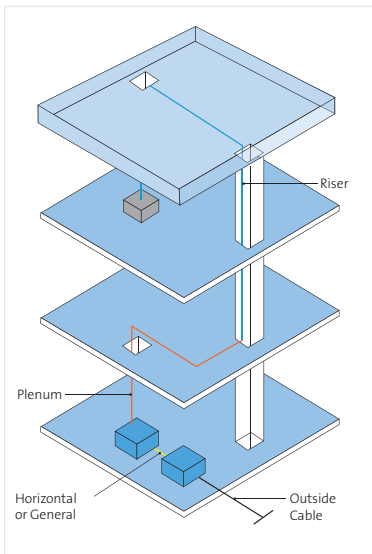


Figure 14 - Flame Rating Installation Environments for Indoor Cable

Plenum area: A compartment or chamber that forms part of the air distribution system and to which one or more air ducts are connected. Any space with a primary function of air handling is also considered a plenum space. These cables must be listed optical fiber nonconductive-plenum (OFNP) or optical fiber conductive-plenum (OFCP) in accordance with the NEC®.

- Riser: An opening or shaft through which cable may pass vertically from floor to floor in a building. These cables must be listed optical cable nonconductive-riser (OFNR) or optical fiber conductive-riser (OFCR) in accordance with the NEC.
- General purpose: All other indoor areas that are not plenum or risers. These cables must be listed optical fiber nonconductive (OFN) or optical fiber conductive (OFC) in accordance with the NEC.

Typical Cable Types

Loose tube cables

Loose tube cables like Corning's ALTOS® cables are designed primarily for OSP environments and campus backbone applications. One to 12 fibers are placed in individual, waterblocked buffer tubes to isolate them from external forces and are typically stranded around a fiberglass central strength member to provide additional strength and resistance. A loose tube cable typically will hold up to 432 fibers in total within these tubes. With more than 35 years of successful operation in the field, the loose tube cable design has been used more extensively than any other in the industry. It provides stable and highly reliable optical

transmission characteristics over a wide temperature range. Corning offers stranded loose tube cables for outdoor as well as indoor, indoor/outdoor, and LSZH™ riser applications.

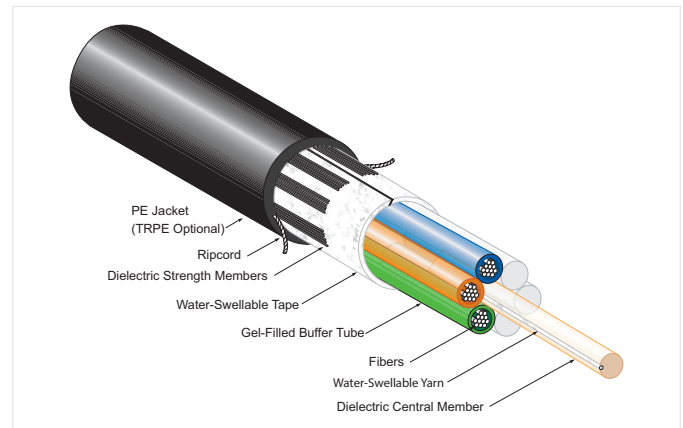


Figure 15 - Loose Tube Cable

Tight-buffered cables

Tight-buffered cables are designed for use in building and data center backbones, horizontal applications and patch cords, and equipment cables. This proven design is the most widely deployed cable type for indoor applications. Tight-buffered cables contain 250 μm optical fibers that are directly coated with a thermoplastic buffer to a diameter of 900 μm. Tight-buffered cables are desirable for intrabuilding applications because of their ability to meet building fire code requirements as well as their increased physical flexibility, smaller bend radius, and easier handling characteristics. These cables, however, are more sensitive to temperature extremes and mechanical disturbances than loose tube or ribbon cables and, with the exception of Corning's FREEDM® fan-out and FREEDM One cables, do not have waterblocking materials.

Corning FREEDM fan-out cables utilize flame-retardant, 900 μm TBII® buffered fiber subunits surrounded by water-resistant, dielectric strength members, and protected by a flexible, flame-retardant outer jacket. These OFNR and FT-4 rated cables eliminate the need for a transition splice entering the building and have 2.9 mm subunits to enable easy field termination. These environmentally robust, small diameter cables are ideal for routing inside/outside buildings into riser spaces to security, surveillance or monitoring cameras, and within telecommunications rooms and workstations.

FREEDM One cable offers select attributes of both indoor and OSP cables. Selecting a FREEDM One cable is often more cost-effective than making a splice transition from OSP to indoor cabling. FREEDM One cable is available with riser and plenum ratings.

Corning MIC® cables, available in 2-144 fibers, are constructed by stranding the desired number of color-coded, tight-buffered optical fibers around a dielectric central member, applying a layer of strength member yarns and extruding a flame-retardant jacket over the cable core. Corning's unique TBII® buffered fiber buffering method allows for easy, one-pass stripping, and a slick jacket on 2-24 fiber tight-buffered cables for easier pulling during cable installation.

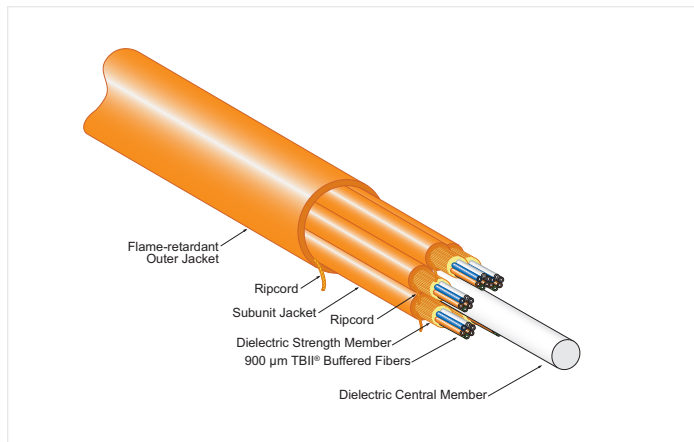


Figure 16 - Tight-Buffered Cable

Ribbon cables

Ribbon cables like Corning LANscape® Solutions ribbon riser and plenum cables are designed primarily for indoor use, though outside and inside/outside versions are also available. The cable ribbonizing process takes 12 individual fibers, positions them into a horizontal array, and extrudes an acrylate coating onto and around them. These 12-fiber ribbons can then be stacked via a cable buffering process inside a central tube. Dielectric strength members are typically stranded around the tube for additional durability.

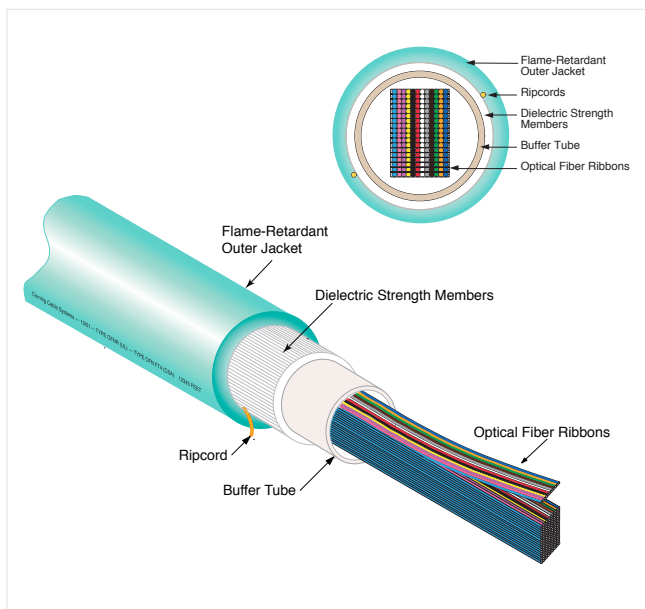


Figure 17 - Ribbon Riser Cable

Fiber Optic Connectivity Hardware

One of the most important steps in the installation of fiber optic systems is the termination of the individual fibers. There are several widely used termination methods. Field installing the connector is commonly done using either an epoxy-and-polish connector or the labor-saving no-epoxy/no-polish connector. Fusion splicing of pigtails is a common practice in single-mode applications. Finally, a fast-growing approach to termination is to purchase factory-terminated assemblies in the form of complete preterminated solutions.

Field-installable connectors

No-epoxy/no-polish (NENP) connectors have become a widely deployed connector-termination technology. As its name suggests, this connector type eliminates the most laborious tasks associated with traditional connectors: the epoxy and polish of the fibers. These connectors utilize mechanical splicing, an optical junction where two or more fibers are aligned, and held in place by a self-contained assembly. In an NENP connector, the fiber to be terminated is inserted into the connector body and mechanically spliced to an existing pre-polished, factory-installed fiber stub.

Corning's UniCam® connectors, which are NENP connectors, consistently exhibit excellent end-face geometry characteristics, as the polishing and epoxy insertion and adhesion are precisely measured and controlled in the factory. Unlike a traditional epoxy and polish connector, a UniCam connector's insertion loss and reflectance values are much more consistent and reliable.

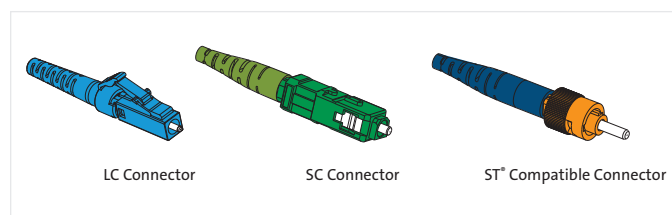


Figure 18 - The Most Commonly Used Connector Types

Reflectance, in particular, is not controlled or typically measured during field termination. The elimination of these processes in the field dramatically increases yield, performance consistency, and drastically increases ease of installation. In fact, they require only a fiber optic stripper, a cleave tool, the workstation installation tool, and an alcohol pad. As a result, assembly space can be kept to a minimum, setup is quick, and assembly is relatively fast and easy with

no consumables. When taking into account the material, labor, and consumables costs of termination, the UniCam® connector is the most cost effective. However, epoxy-and-polish connectors are also widely deployed as field-installable connectors. There are several types of connectors within this broad category, the primary difference being the type of epoxy utilized to adhere the fiber within the ferrule of the connector (i.e., heat cure, UV cure, and anaerobic).



UniCam® Connectors | Photo LAN3278

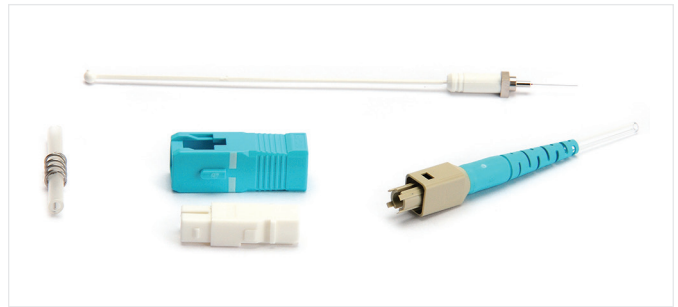
The process for terminating an epoxy-and-polish connector includes preparing the connector and consumables, injecting epoxy into the ferrule of the connector, feeding the fiber through the ferrule micro-hole, allowing the epoxy to cure, scribing the fiber stub protruding from the ferrule, and then following a series of polishing steps. Polishing in the field is most typically performed using a hand-polishing procedure.



UniCam Installation Tool Kit | Photo LAN3333

Splice-on connectors

Another option for field installation would be a splice-on connector. Corning's FuseLite® splice-on connector offers field flexibility with reflectance sensitive connectivity.



Splice-On Connector | Photo LAN2822

Splicing pigtails

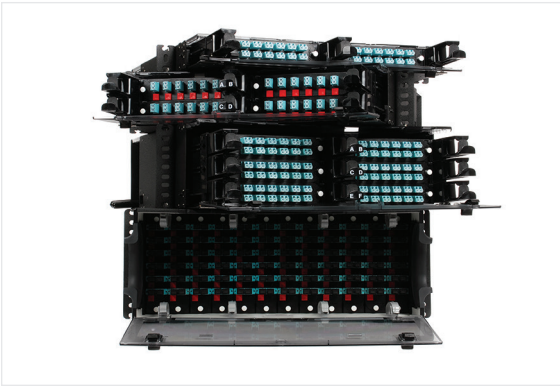
A common approach to providing high-quality end-face terminations is to splice a pigtail. A fiber optic pigtail is a factory-finished connector with a predetermined length of fiber attached. This length of fiber can be spliced, typically via fusion splice; however, it can be mechanically spliced to another segment of cable to complete the cable run. The factory- or machine-finished connector enables the installer to provide a connector type that may be difficult to achieve using a field-installable connector, such as an APC connector. Pigtail splicing requires a splice tray and housing to ensure these connections are well protected from physical or mechanical factors.



CCH Pigtailed Cassette | Photo LAN2692

Fusion splicing

Fusion splicing consists of aligning and then fusing together two stripped, cleaned, and cleaved fibers with an electric arc. The fiber ends can be positioned and aligned using various methods, and can be manual or automatic. This is typically accomplished with the aid of a viewing scope, video camera, or a specialized type of optical power meter. High voltage applied to the electrodes contained in the splicer generates an arc across the fiber ends as the fibers are moved together, fusing the fibers.



Rack-Mountable Closet Connector Housings (CCH) | Photo LAN2510

Optical hardware

Optical hardware is another key component in the complete optical cable infrastructure, as it provides optical connection management, protection of optical connections, labeling of optical circuits, consolidation points for multiple cable runs, and security of optical connections.

Optical hardware selection is typically based on environment, volume of connections, and type of connections. There are many hardware options to choose from when designing a security network. Typical options include splice closures, pedestals, cabinets and housings; hardware that is rack- and wall-mountable, outdoor weatherproof, industrial-grade, aerial, below-ground, direct-buried, high-fiber-count, low-fiber-count, and secure/lockable products, just to name a few.

One of the primary factors affecting the hardware selection is the mounting method. Rack-mountable hardware provides interconnect or cross-connect capabilities. The units can be rack-mounted in 19-in racks and are measured by rack units (1.75 in). The hardware provides pre-installed routing guides to ensure proper jumper management and routing. LANscape® solutions rack-mountable hardware includes all of the accessories needed to complete typical installations, saving time, and money.

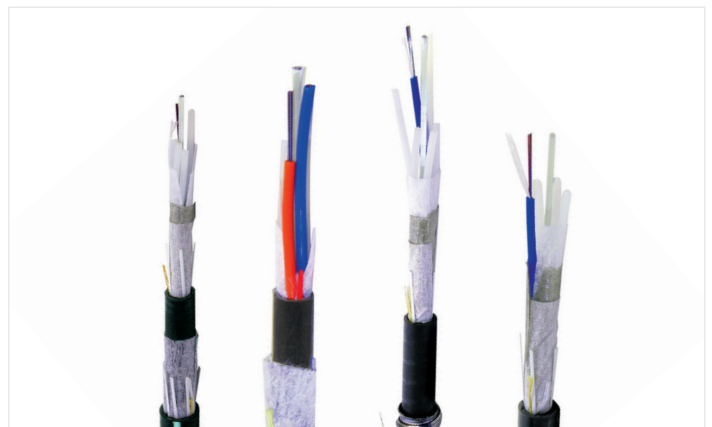


Wall-Mountable Connector Housing (WCH) | Photo LAN6915

Hardware can also be mounted on any vertical surface. Hardware of this design is called wall-mountable hardware. Wall-mountable hardware can accommodate splicing, termination, or a combination of splicing and termination. It is ideally suited for small-scale installations or if rack space is limited or unavailable. Wall-mountable hardware is engineered to offer minimal projection from the wall.

Harsh Applications

Harsh applications can include oil and gas, mining, manufacturing, transportation, and energy utilities infrastructures. Keeping the network up and running in harsh environments requires more than just properly protecting the cabling from the elements. Corning's harsh products are designed and engineered to protect against damage, breakage, exposure to extreme temperatures, shock, pressure, and other adverse conditions that could hinder performance.



Tray-Rated LSZH™ Industrial Fiber Optic Cables | Photo LAN1462

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