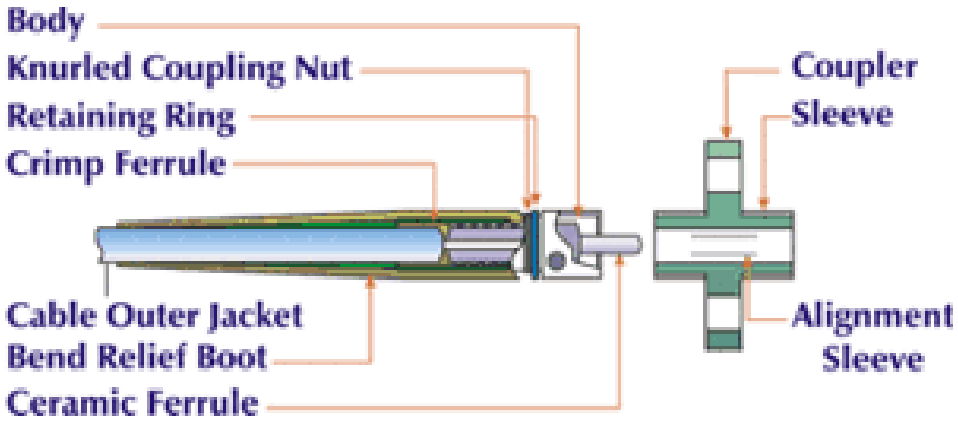
Fiber Optic Connectors

Fiber optic connectors have traditionally been the biggest concern in using fiber optic systems. While connectors were once unwieldy and difficult to use, connector manufacturers have standardized and simplified connectors greatly. This increasing user-friendliness has contributed to the increase in the use of fiber optic systems; it has also taken the emphasis off the proper care and handling of optical connectors. This article covers connector basics including the parts of a fiber optic connector, installing fiber optic connectors, and the cleaning and handling of installed connectors. For information on connector loss, see Connector Loss Test Measurement.

Figure 1 - Parts of a Fiber Optic Connector



Fiber-to-fiber interconnection can consist of a splice, a permanent connection, or a connector, which differs from the splice in its ability to be disconnected and reconnected. Fiber optic connector types are as various as the applications for which they were developed. Different connector types have different characteristics, different advantages and disadvantages, and different performance parameters. But all connectors have the same four basic components.

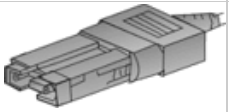
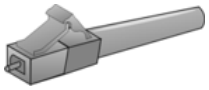
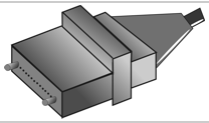
The Ferrule: The fiber is mounted in a long, thin cylinder, the ferrule, which acts as a fiber alignment mechanism. The ferrule is bored through the center at a diameter that is slightly larger than the diameter of the fiber cladding. The end of the fiber is located at the end of the ferrule. Ferrules are typically made of metal or ceramic, but they may also be constructed of plastic.

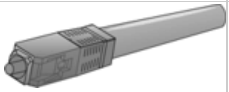
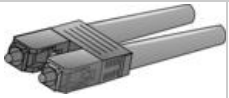
The Connector Body:	Also called the connector housing, the connector body holds the ferrule. It is usually constructed of metal or plastic and includes

	one or more assembled pieces which hold the fiber in place. The details of these connector body assemblies vary among connectors, but bonding and/or crimping is commonly used to attach strength members and cable jackets to the connector body. The ferrule extends past the connector body to slip into the coupling device.
The Cable:	The cable is attached to the connector body. It acts as the point of entry for the fiber. Typically, a strain-relief boot is added over the junction between the cable and the connector body, providing extra strength to the junction.
The Coupling Device:	Most fiber optic connectors do not use the male-female configuration common to electronic connectors. Instead, a coupling device such as an alignment sleeve is used to mate the connectors. Similar devices may be installed in fiber optic transmitters and receivers to allow these devices to be mated via a connector. These devices are also known as feed-through bulkhead adapters.

Table 1 illustrates some types of optical connectors and lists some specifications. Each connector type has strong points. For example, ST connectors are a good choice for easy field installations; the FC connector has a floating ferrule that provides good mechanical isolation; the SC connector offers excellent packing density, and its push-pull design resists fiber end face contact damage during unmating and remating cycles.

Table 1- Types Of Optical Connectors

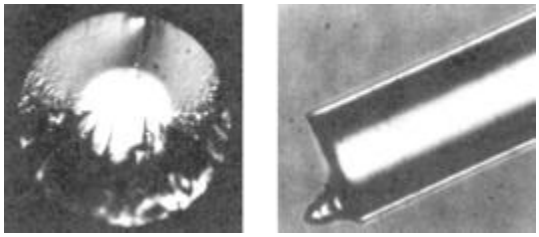
Connector	Insertion Loss	Repeatability	Fiber Type	Applications
 FC	0.50-1.00 dB	0.20 dB	SM, MM	Datacom, Telecommunications
 FDDI	0.20-0.70 dB	0.20 dB	SM, MM	Fiber Optic Network
 LC	0.15 db (SM) 0.10 dB (MM)	0.2 dB	SM, MM	High Density Interconnection
	0.30-1.00 dB	0.25 dB	SM, MM	High Density Interconnection

MT Array				
 SC	0.20-0.45 dB	0.10 dB	SM, MM	Datacom
 SC Duplex	0.20-0.45 dB	0.10 dB	SM, MM	Datacom
 ST	Typ. 0.40 dB (SM) Typ. 0.50 dB (MM)	Typ. 0.40 dB (SM) Typ. 0.20 dB (MM)	SM, MM	Inter-/Intra-Building, Security, Navy

Installing Fiber Optic Connectors

The method for attaching fiber optic connectors to optical fibers varies among connector types. While not intended to be a definitive guide, the following steps are given as a reference for the basics of optical fiber interconnection. 1. Cut the cable one inch longer than the required finished length. 2. Carefully strip the outer jacket of the fiber with "no nick" fiber strippers. Cut the exposed strength members, and remove the fiber coating. The fiber coating may be removed two ways: by soaking the fiber for two minutes in paint thinner and wiping the fiber clean with a soft, lint-free cloth, or by carefully stripping the fiber with a fiber stripper. Be sure to use strippers made specifically for use with fiber rather than metal wire strippers as damage can occur, weakening the fiber. 3. Thoroughly clean the bared fiber with isopropyl alcohol poured onto a soft, lint-free cloth such as Kimwipes®. NEVER clean the fiber with a dry tissue. Note: Use only industrial grade 99% pure isopropyl alcohol. Commercially available isopropyl alcohol is for medicinal use and is diluted with water and a light mineral oil. Industrial grade isopropyl alcohol should be used exclusively. 4. The connector may be connected by applying epoxy or by crimping. If using epoxy, fill the connector with enough epoxy to allow a small bead of epoxy to form at the tip of the connector. Insert the clean, stripped fiber into the connector. Cure the epoxy according to the instructions provided by the epoxy manufacturer. 5. Anchor the cable strength members to the connector body. This prevents direct stress on the fiber. Slide the back end of the connector into place (where applicable). 6. Prepare the fiber face to achieve a good optical finish by cleaving and polishing the fiber end. Before the connection is made, the end of each fiber must have a smooth finish that is free of defects such as hackles, lips, and fractures. These defects, as well as other impurities and dirt change the geometrical propagation patterns of light and cause scattering.

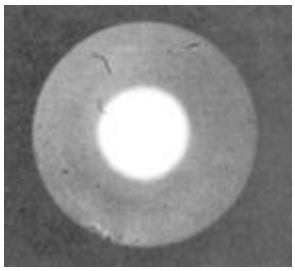
Figure 2 - Fiber End Face Defects: Hackle (left), Lip (right)



Cleaving

Cleaving involves cutting the fiber end flush with the end of the ferrule. Cleaving, also called the scribe-and-break method of fiber end face preparation, takes some skill to achieve optimum results. Properly done, the cleave produces a perpendicular, mirror-like finish. Incorrect cleaving will result in lips and hackles as seen in Figure 2. While cleaving may be done by hand, a cleaver tool, available from such manufacturers as Fujikura, allows for a more consistent finish and reduces the overall skill required. The steps listed below outline one procedure for producing good, consistent cleaves such as the one shown in Figure 3. 1. Place the blade of the cleaver tool at the tip of the ferrule. 2. Gently score the fiber across the cladding region in one direction. If the scoring is not done lightly, the fiber may break, making it necessary to reterminate the fiber. 3. Pull the excess, cleaved fiber up and away from the ferrule. 4. Carefully dress the nub of the fiber with a piece of 12-micron alumina-oxide paper. 5. Do the final polishing. (See Figure 4.)

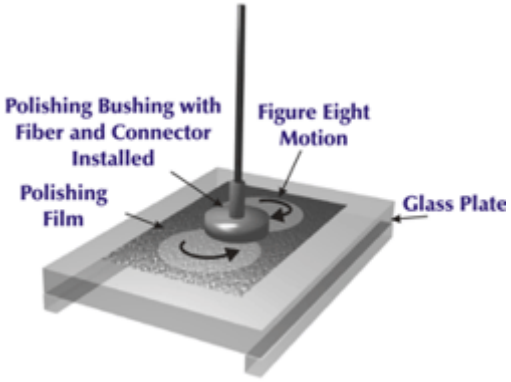
Figure 4 - A Well-cleaved Multimode Fiber



Polishing

After a clean cleave has been achieved, the fiber end face is attached to a polishing brush, and the fiber is ground and polished. The proper finish is achieved by rubbing the connectorized fiber end against polishing paper in a figure-eight pattern approximately sixty times.

Figure 4 - Polishing Technique



To increase the ease and repeatability of connector installation, some companies offer connector kits. Some kits are specific to the type of connector to be installed while others supply the user with general tools and information for connecting different types of connectors. Some connectors require the use of an alignment sleeve, also called an interconnection sleeve. This sleeve serves to increase repeatability from connection to connection.

Care and Handling of Fiber Optic Connectors

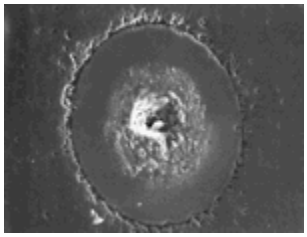
A number of events can damage fiber optic connectors. Unprotected connector ends can experience damage by impact, airborne dust particles, or excess humidity or moisture. The increased optical output power of modern lasers also have the potential to damage a connector, an often overlooked factor in discussions about handling and caring for optical fibers and connectors. Most designers tend to think of the power levels in optical fibers as relatively insignificant. However, a few milliwatts at 850 nm will do permanent damage to a retina. Today, optical amplifiers can generate optical powers of 1 Watt of more into a single-mode fiber. This becomes quite significant when one considers that the optical power is confined in the optical core only a few microns in diameter. Power densities in a single-mode fiber carrying an optical power of 1 Watt (+30 dBm) can reach 3 megawatts/cm2 or 30 gigawatts/m2! To put it in everyday terms, sunlight at the surface of the Earth has a power density of about 1,000 Watts/m2. Most organic materials will combust when exposed to radiant energies of 100 kilowatts/m2. Clearly, power densities of 30 gigawatts/m2 deserve attention.

Effects on Fiber Optic Connectors

One should never clean an optical connector attached to a fiber that is carrying light. Optical power levels as low as +15 dBm, or 32 milliwatts, may cause an explosive ignition of the cleaning material when it contacts the end of the optical connector, destroying the connector. Typical cleaning materials, such as tissues saturated with alcohol, will combust almost instantaneously when exposed to optical power levels of +15 dBm or higher. The micro-explosions at the tip of the connector can leave pits in the

end of the connector and crack the connector's surface, destroying its ability to carry light with low loss. Figure 5 shows an optical connector that has been heavily damaged by high optical power levels. Usually the damage is limited to less severe pitting.

Figure 5 - Connector Damaged by High Optical Power (Photo courtesy of Dr. D.D. Davis.)



Cleaning

Another important thing to remember in handling fiber optic connectors is that the fiber end face and ferrule must be absolutely clean before it is inserted into a transmitter or receiver. Dust, lint, oil (from touching the fiber end face), or other foreign particles obscure the end face, compromising the integrity of the optical signal being sent over the fiber. From the optical signal's point-of-view, dirty connections are like dirty windows. Less light gets through a dirty window than a clean one. It is hard to conceive of the size of a fiber optic connector core. Single-mode fibers have cores that are only 8-9 µm in diameter. As a point of reference, a typical human hair is 50-75 µm in diameter, approximately 6-9 times larger! Dust particles can be 20 µm or larger in diameter. Dust particles smaller than 1 µm can be suspended almost indefinitely in the air. A 1 µm dust particle landing on the core of a single-mode fiber can cause up to 1 dB of loss. Larger dust particles (9 µm or larger) can completely obscure the core of a single-mode fiber. Fiber optic connectors need to be cleaned every time they are mated and unmated; it is essential that fiber optics users develop the necessary discipline to always clean the connectors before they are mated. It is also important to cover a fiber optic connector when it is not in use. Unprotected connector ends are most often damaged by impact, such as hitting the floor. Most connector manufacturers provide some sort of protection boot. The best protectors cover the entire connector end, but they are generally simple closed-end plastic tubes that fit snugly over the ferrule only. These boots will protect the connector's polished ferrule end from impact damage that might crack or chip the polished surface. Many of the tight fitting plastic tubes contain jelly-like contamination (most likely mold release) that adheres to the sides of the ferrule. A blast of cleaning air or a quick dunk in alcohol will not remove this residue. This jelly-like residue can combine with common dirt to form a sticky mess that causes the connector ferrule to stick in the mating adapter. Often, the stuck ferrule will break off as one attempts to remove it. The moral of the story is always thoroughly clean the connector before mating, even if it was cleaned previously before the protection boot was installed.

Cleaning Technique

Required Equipment: • Kimwipes® or any lens-grade, lint-free tissue. The type sold for eyeglasses work quite well. • Denatured alcohol. Note: Use only industrial grade 99% pure isopropyl alcohol. Commercially available isopropyl alcohol is for medicinal use and is diluted with water and a light mineral oil. Industrial grade isopropyl alcohol should be used exclusively. • 30X microscope. • Canned dry air. 1. Fold the tissue twice so it is four layers thick. 2. Saturate the tissue with alcohol. 3. First clean the sides of the connector ferrule. Place the connector ferrule in the tissue, and apply pressure to the sides of the ferrule. Rotate the ferrule several times to remove all contamination from the ferrule sides. 4. Now move to a clean part of the tissue. Be sure it is still saturated with alcohol and that it is still four layers thick. Put the tissue against the end of the connector ferrule. Put your fingernail against the tissue so that it is directly over the ferrule. Now scrape the end of the connector until it squeaks. It will sound like a crystal glass that has been rubbed when it is wet. 5. Use the microscope to verify the quality of the cleaning. If it isn't completely clean, repeat the steps with a clean tissue. Repeat until you have a cleaning technique that yields good, reproducible results. 6. Mate the connector immediately! Don't let the connector lie around and collect dust before mating. 7. Air can be used to remove lint or loose dust from the port of a transmitter or receiver to be mated with the connector. Never insert any liquid into the ports.

Handling

1. Never touch the fiber end face of the connector. 2. Connectors not in use should be covered over the ferrule by a plastic dust cap. It is important to note that inside of the ferrule dust caps contain a sticky residue that is a by-product of making the dust cap. This residue will remain on the ferrule end after the cap is removed. 3. The use of index-matching gel, a gelatinous substance that has a refractive index close to that of the optical fiber, is a point of contention between connector manufacturers. Glycerin, available in any drug store, is a low-cost, effective index-matching gel. Using glycerin will reduce connector loss and backreflection, often dramatically. See article ""Backreflection — The Bane of Good Performance" for more information. However, the index-matching gel may collect dust or abrasives that can damage the fiber end faces. It may also leak out over time, causing backreflections to increase.
2. **Standards For Fiber Optic Connectors**

Industrial Standards	
TSB-62	Informative Test Methods for Fiber Optic Fibers, Cable, Opto-Electronic Sources and Detectors, Sensors, Connecting and Terminating Devices, and Other Fiber Optic Components
EIA-440-A	Fiber Optic Connector Terminology
EIA-455-A	Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating

	Devices, and Other Components
EIA-455-1A	Cable Flexing for Fiber Optic Interconnecting Devices
EIA/TIA-455-6B	Cable Retention Test Procedure for Fiber Optic Cable Interconnecting Devices
EIA-455-9	Fiber Optic Test Procedure for Bundle Connector
EIA/TIA-455-13	Visual and Mechanical Inspection of Fibers, Cables, Connectors and/or Other Fiber Optic Devices
EIA-455-17A	Maintenance Aging of Fiber Optic Connectors and Terminated Cable Assemblies
EIA-455-21A	Mating Durability for Fiber Optic Interconnecting Devices
EIA-455-26A	Crush Resistance of Fiber Optic Interconnecting Devices
EIA-455-34A	Interconnection Device Insertion loss Test
EIA-455-36A	Twist Test for Fiber Optic Connecting Devices
TIA/EIA-455-158	Measurement of Breakaway Frictional Force in Fiber Optic Connector Alignment Sleeves
EIA-455-172	Flame Resistance of Fire wall Connector
EIA/TIA-455-187	Engagement and Separation for Fiber Optic Connector Sets
EIA/TIA-4750000-B	Generic Specification for Fiber Optic Connectors
EIA/TIA-475C000	Sectional Specification for Type FSMA Connectors
TIA/EIA-475EA	Blank Detail Specification for Connector Set for Optical Fiber and Cables, Type BFOC/2.5, Environmental Category I
TIA/EIA-475EB	Blank Detail Specification for Connector Set for Optical Fiber and Cables, Type BFOC/2.5, Environmental Category II
TIA/EIA-475EC00	Blank Detail Specification for Connector Set for Optical Fiber and Cables, Type BFOC/2.5, Environmental Category III
TIA/EIA-604	Fiber Optic Connector Intermateability Standards
Bellcore Standards	
GR-326	Generic Requirements for Single-Mode Optical Fiber Connectors
GR-1081	Generic Requirements for Field Mountable Optical Fiber

	Connectors
GR-1435	Generic Requirements for Multi-fiber Optical Connectors
SR-ARH-002744	Single-mode Fiber Connectors Technology
SR-4226	Fiber Optic Connector Certification
TR-73536	Technical Requirements for Optical Connectors

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