Fiber Optic Connectors

Normally, we terminate fiber optic cable with connectors that can mate two fibers to create a temporary joint or permanent joint between the two fibers. These connectors must be of the right style, installed in a manner that makes them have little light loss and protected against dirt or damage in use.
No area of fiber optics has been given greater attention than termination. Manufacturers have come up with over 80 styles of connectors and about a dozen ways to install them. Fortunately for us, only a few types are used most applications.
Different connectors are used for single-mode and multimode connectors, so make sure you know what the fiber will be before you specify connectors!

Connectors
Since fiber optic technology was introduced in the late 70s, numerous connector styles have been developed. Each new design was meant to offer better performance (less light loss and back reflection), easier and/or termination and lower cost. Of course, the market-place determines which connectors are ultimately successful.

Connector Loss Mechanisms
Connector loss is caused by a number of factors. Loss is minimized when the two fiber cores are identical and perfectly aligned, the connectors are properly finished and no dirt is present. Only the light that is coupled into the receiving fiber's core will propagate, so all the rest of the light becomes the connector loss.

End gaps cause two problems, insertion loss and return loss. The emerging cone of light from the connector will spill over the core of the receiving fiber and be lost. In addition, the air gap between the fibers causes a reflection when the light encounters the change n refractive index from the glass fiber to the air in the gap. This reflection (called fresnel reflection) amounts to about 5% in typical flat polished connectors, and means that no connector with an air gap can have less than 0.3 dB loss. This reflection is also referred to as back reflection or optical return loss, which can be a problem in laser based systems. Connectors use a number of polishing techniques to insure physical contact of the fiber ends to minimize back reflection

The end finish of the fiber must be properly polished to minimize loss. A rough surface will scatter light and dirt can scatter and absorb light. Since the optical fiber is so small, typical airborne dirt can be a major source of loss. Whenever connectors are not terminated, they should be covered to protect the end of the ferrule from dirt. One should never touch the end of the ferrule, since the oils on one's skin causes the fiber to attract dirt. Before connection and testing, it is advisable to clean connectors with lint-free wipes moistened with isopropyl alcohol.

Two sources of loss are directional; numerical aperture (NA) and core diameter. Differences in these two will create connections that have different losses depending on the direction of light propagation. Light from a fiber with a larger NA will be more sensitive to angularity and end gap, so transmission from a fiber of larger NA to one of smaller NA will be higher loss than the reverse. Likewise, light from a larger fiber will have high loss coupled to a fiber of smaller diameter, while one can couple a small diameter fiber to a large diameter fiber with minimal loss, since it is much less sensitive to end gap or lateral offset.
These fiber mismatches occur for two reasons. The occasional need to interconnect two dissimilar fibers and production variances in fibers of the same nominal dimensions. With two multimode fibers in usage today and two others which have been used occasionally in the past and several types of single-mode fiber in use, it is possible to sometimes have to connect dissimilar fibers or use systems designed for one fiber on another. Some system manufacturers provide guidelines on using various fibers, some don't. If you connect a smaller fiber to a larger one, the coupling losses will be minimal, often only the fresnel loss (about 0.3 dB). But connecting larger fibers to smaller ones results in substantial losses, not only due to the smaller cores size, but also the smaller NA of most small core fibers.

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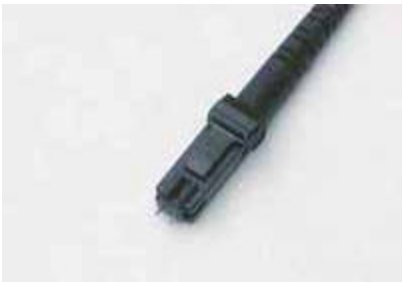
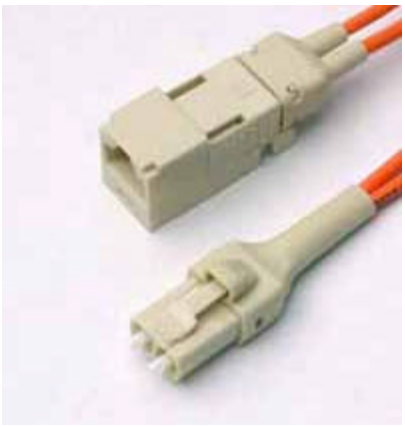
Check out the "spotters guide" below and you will see the most common fiber optic connectors. (All the photos are to the same scale, so you can get an idea of the relative size of these connectors.)

ST (an AT&T Trademark) is the most popular connector for multimode networks. It has a bayonet mount and a long cylindrical ferrule to hold the fiber. Most ferrules are ceramic, but some are metal or plastic. And because they are spring-loaded, you have to make sure they are seated properly. If you have high loss, reconnect them to see if it makes a difference.	
FC/PC has been one of the most popular single-mode connectors for many years. It screws on firmly, but make sure you have the key aligned in the slot properly before tightening. It's being replaced by SCs and LCs.	
SC is a snap-in connector that is widely used in single-mode systems for it's excellent performance. It's a snap-in connector that latches with a simple push-pull motion. It is also available in a duplex configuration.	
Besides the SC Duplex, you may occasionally see the FDDI and ESCON* duplex connectors which mate to their specific networks. They are generally used to connect to the equipment from a wall outlet, but the rest of the network will have ST or SC connectors. *ESCON is an IBM trademark **Below are some of the new Small Form Factor (SFF) connectors:**	
LC is a new connector that uses a 1.25 mm ferrule, half the size of the ST. Otherwise, it's a standard ceramic ferrule connector, easily terminated with any adhesive. Good performance, highly favored for single-mode.	

MT-RJ is a duplex connector with both fibers in a single polymer ferrule. It uses pins for alignment and has male and female versions. Multimode only, field terminated only by prepolished/splice method.	
Opti-Jack is a neat, rugged duplex connector cleverly designed aournd two ST-type ferrules in a package the size of a RJ-45. It has male and female (plug and jack) versions.	
Volition is a slick, inexpensive duplex connector that uses no ferrule at all. It aligns fibers in a V-groove like a splice. Plug and jack versions, but field terminate jacks only.	
E2000/LX-5 is like a LC but with a shutter over the end of the fiber.	

MU looks a miniature SC with a 1.25 mm ferrule. It's more popular in Japan.	
MT is a 12 fiber connector for ribbon cable. It's main use is for pre-Terminated cable assemblies.	

The ST/SC/FC/FDDI/ESON connectors have the same ferrule size - 2.5 mm or about 0.1 inch - so they can be mixed and matched to each other using hybrid mating adapters. This makes it convenient to test, since you can have a set of multimode reference test cables with ST connectors and adapt to all these connectors. Likewise, the LC, MU and E2000/LX-5 use the same ferrule but cross-mating adapters are not easy to find.

Connector Types

The ST is still the most popular multimode connector because it is cheap and easy to install. The SC connector was specified as a standard by the old EIA/TIA 568A specification, but its higher cost and difficulty of installation (until recently) has limited its popularity. However, newer SCs are much better in both cost and installation ease, so it has been growing in use. The duplex FDDI, ESCON and SC connectors are used for patchcords to equipment and can be mated to ST or SC connectors at wall outlets. Single-mode networks use FC or SC connectors in about the same proportion as ST and SC in multimode installations. There are some D4s out there too.
EIA/TIA 568 B allows any fiber optic connector as long as it has a FOCIS (Fiber Optic Connector Intermateability Standard) document behind it. This opened the way to the use of several new connectors, which we call the "Small Form Factor" (SFF) connectors, including AT&T LC, the MT-RJ, the Panduit "Opti-Jack," 3M's Volition, the E2000/LX-5 and MU. The LC has been particularly successful in the US.

Connector Ferrule Shapes & Polishes

Fiber optic connectors can have several different ferrule shapes or finishes, usually referred to as polishes. early connectors, because they did not have keyed ferrules and could rotate in mating adapters, always had an air gap between the connectors to prevent them rotating and grinding scratches into the ends of the fibers.
Beginning with the ST and FC which had keyed ferrules, the connectors were designed to contact tightly, what we now call physical contact (PC) connectors. Reducing the air gap reduced the loss and back reflection (very important to laser-based single-mode systems), since light has a loss of about 5% (~0.25 dB) at each air gap and light is reflected back up the fiber. While air gap connectors usually had losses of

0.5 dB or more and return loss of 20 dB, PC connectors had typical losses of 0.3 dB and a return loss of 30 to 40 dB.
Soon thereafter, it was determined that making the connector ferrules convex would produce an even better connection. The convex ferrule guaranteed the fiber cores were in contact. Losses were under 0.3dB and return loss 40 dB or better. The final solution for single-mode systems extremely sensitive to reflections, like CATV or high bitrate telco links, was to angle the end of the ferrule 8 degrees to create what we call an APC or angled PC connector. Then any reflected light is at an angle that is absorbed in the cladding of the fiber.

Hints for doing field terminations

Here are a few things to remember when you are terminating connectors in the field. Following these guidelines will save you time, money and frustration.

Choose the connector carefully and clear it with the customer if it is anything other than an epoxy/polish type. Some customers have strong opinions on the types or brands of connectors used in their job. Find out first, not later!
NEVER take a new connector in the field until you have installed enough of them in the office that you can put them on in your sleep. The field is no place to experiment or learn! It'll cost you big time!

Have the right tools for the job. Make sure you have the proper tools and they are in good shape before you head out for the job. This includes all the termination tools, cable tools and test equipment. Do you know your test cables are good? Without that, you will test good terminations as bad every time. More and more installers are owning their own tools like auto mechanics, saying that is the only way to make sure the tools are properly cared for.

Dust and dirt are your enemies. It's very hard to terminate in a dusty place. Try to work in the cleanest possible location. Use lint-free wipes (not cotton swaps or rags made from old T-shirts!) to clean every connector before connecting or testing it. Don't work under heating vents, as they are blowing dirt down on you continuously.

Don't over-polish. Contrary to common sense, too much polishing is just as bad as too little. The ceramic ferrule in most of today's connector is much harder than the glass fiber. Polish too much and you create a concave fiber surface, increasing the loss. A few swipes is all it takes.

Remember single-mode fiber requires different connectors and polishing techniques. Most Single-Mode fiber is terminated by splicing on a pre-terminated pigtail, but you can put Single-Mode connectors on in the field if you know what you are doing. Expect much higher loss, approaching 1 dB and high back reflections, so don't try it for anything but data networks, not telco or CATV.

Change polishing film regularly. Polishing builds up residue and dirt on the film that can cause problems after too many connectors and cause poor end finish. Check the manufacturers' specs.

Put covers on connectors and patch panels when not in use. Keep them covered to keep them clean.
Inspect and test, then document. It is very hard to troubleshoot cables when you don't know how long they are, where they go or how they tested originally! So keep good records, smart users require it and expect to pay extra for good records.