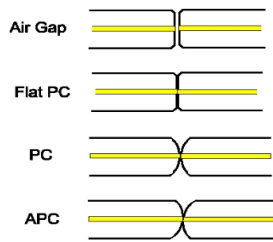


Connector Ferrule Shapes & Polishes



Fiber optic connectors can have several different ferrule shapes or finishes, usually referred to as end finish or polish types. Early connectors, which 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. The ends of the ferrules were polished on hard, flat surfaces.

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. These connectors were still polished flat on the end. Reducing the air gap reduced the loss and reflectance (very important to laser-based singlemode 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 a reflectance of -20 dB, PC connectors had typical losses of 0.3 dB and a reflectance of -30 to -40 dB. PC connectors required polishing on a flat surface with a soft rubber pad to allow the end to be polished convex.

Soon thereafter, it was determined that polishing the connector ferrules to a convex end face would produce an even better connection. The convex ferrule guaranteed the fiber cores were in contact. Losses were under 0.3dB and reflectance -40 dB or better.

The ultimate solution for singlemode 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, resulting in reflectance of >-60 dB.

Connector Color Codes:

Since the earliest days of fiber optics, orange, black or gray was multimode and yellow singlemode. However, the advent of metallic connectors like the FC and ST made color coding difficult, so colored boots were often used.

The TIA 568 color code for connector bodies and/or boots is Beige for multimode fiber except aqua for laser-optimized fiber, Blue for singlemode fiber, and Green for APC (angled) connectors.

Termination Procedures

Whatever you do, always follow the manufacturer's termination instructions closely.

Multimode connectors are usually installed in the field on the cables after pulling, while singlemode connectors are usually installed by splicing a factory-made "pigtail" onto the fiber. The tolerances on singlemode terminations are much tighter than multimode and the polishing processes are more critical, so singlemode termination is better done in a factory environment using polishing machines (left, below). You can install singlemode connectors in the field for low speed data networks, but you may not be able to get losses lower than 1 dB and reflectance may be a problem! Multimode connectors are easier to install and polish (below, right) so are often done in the field by trained technicians.



Connectors can be installed directly on most cable types, including jacketed tight buffer types like simplex, zipcord and breakout cables, where the where the aramid fiber strength members in the cable are crimped or glued to the connector body to create a strong connector. Connectors can be attached to the 900 micron buffered fibers in distribution cables, but the termination is not as rugged as those made to jacketed cables, so they should be placed in patch panels or boxes for protection. The 250 micron buffered fibers in loose tube cables cannot be easily terminated unless they have a reinforcement called a breakout kit or furcation kit installed, where each fiber is covered by a larger plastic tube. Generally loose tube and ribbon cables are terminated by splicing on a terminated pigtail.

Cables can be pulled with connectors already on them if, and a big if, you can deal with two issues: First, the length must be precise. Too short and you have to pull another longer one (its not cost effective to splice), too long and you waste money and have to store the extra cable length. Secondly, the connectors must be protected. Some cable and connector manufacturers offer protective sleeves to cover the connectors, but you must still be much more careful in pulling cables. You might consider terminating one end and pulling the unterminated end to not risk the connectors. There is a growing movement to install preterminated systems with the MTP 12 multifiber connector. It's tiny not much bigger than a ST or SC, but has up to 12

fibers. Manufacturers sell multifiber cables with MIPs on them that connect to preterminated patch panels with SIs or SCs. (See "Do You Have To Terminate In The Field" below.)

Multimode Terminations: Several different types of terminations are available for multimode fibers. Each version has its advantages and disadvantages, so learning more about how each works helps decide which one to use.

Singlemode Terminations: Singlemode fiber requires different connectors and polishing techniques that are best done in a factory environment. Consequently most SM fiber is field terminated by splicing on a factory-terminated pigtail. Singlemode termination requires special connectors with much tighter tolerances on the ferrule, especially the hole for the fiber. Polishing requires special diamond polishing film on a soft rubber pad and a polishing slurry to get low reflectance. But you can put SM connectors on in the field if you know what you are doing. Expect higher loss and high reflectance.

Termination Processes

Adhesive/Polish Terminations: Most connectors use epoxies or other adhesives to hold the fiber in the connector ferrule and polish the end of the fiber to a smooth finish. Follow termination procedures carefully, as they have been developed to produce the lowest loss and most reliable terminations. Use only the specified adhesives, as the fiber to ferrule bond is critical for low loss and long term reliability! We've seen people use hardware store epoxies, Crazy Glue, you name it! And they regretted doing it. Only adhesives approved by manufacturers or other distributors of connectors should be used. If the adhesive fails, not unusual when connector ferrules were made of metal, the fiber will "piston" - sticking out or pulling back into the ferrule - causing high loss and potential damage to a mated connector.

The polishing process involves three steps which only takes a minute: "air polishing" to grind down the protruding fiber, polishing on a soft pad with the fiber held perpendicular to the polishing surface with a polishing puck and a quick final fine polish.



Epoxy/Polish: Most connectors, including virtually all factory made terminations, are the simple "epoxy/polish" type where the fiber is glued into the connector with epoxy and the end polished with special polishing film. These provide the most reliable connection, lowest losses (less than 0.5 dB) and lowest costs, especially if you are doing a lot of connectors. The small bead of hardened epoxy that surrounds the fiber on the end of the ferrule even makes the cleaving and polishing processes much easier - practically foolproof. The epoxy can be allowed to set overnight or cured in an inexpensive oven. A "heat gun" should never be used to try to cure the epoxy faster as the uneven heat may not cure all the epoxy or may overheat some of it which will prevent it ever curing. Don't use "Hot Melt" ovens either, as they use a much higher temperature and will ruin the epoxy.

"Hot Melt" Adhesive/Polish: This is a 3M trade name for a connector that already has the epoxy (actually a heat set glue) inside the connector. You insert the connector in a special oven. In a few minutes, the glue is melted, so you remove the connector, insert the stripped fiber, let it cool and it is ready to polish. Fast and easy, low loss, but not as cheap as the epoxy type, it has become the favorite of lots of contractors who install relatively small quantities of connectors. Remember you need a special Hot Melt oven, as it needs a much higher temperature than is used for curing epoxy.

Anaerobic Adhesive/Polish: These connectors use a quick setting "anaerobic" adhesive to replace the epoxy or Hot Melt adhesive that cures faster than other types of adhesives. They work well if your technique is good, but some do not have the wide temperature range of epoxies. A lot of installers are using Loctite 648, with or without the accelerator solution, that is neat and easy to use.

[More on adhesive/polish connectors.](#)

Crimp/Polish: Rather than glue the fiber in the connector, these connectors use a crimp on the fiber to hold it in. Early types offered "iffy" performance, but today they are pretty good, if you practice a lot. Expect to trade higher losses for the faster termination speed. And they are more costly than epoxy polish types. A good choice if you only install small quantities and your customer will accept them.

Prepolished/Splice Connectors (also called "cleave & crimp")





Some manufacturers offer connectors that have a short stub fiber already epoxied into the ferrule and polished and a mechanical splice in the back of the connector, so you just cleave a fiber and insert it like a splice, a process which can be done very quickly. Several connectors use a fusion splice instead of a mechanical splice to attach the connector, a better process but requiring more expensive equipment - a fusion splicer, sometimes a dedicated splicer for that connector. This method has both good and bad points. The manufacturing process is complex so these connectors are costly, as much as ten times as much as an adhesive/polish type, since they require careful manufacturing. Some of that extra cost can be recovered in lower labor costs for installation. You must have a good cleave on the fiber you are terminating to make them low loss, as the fiber cleave is a major factor in the loss of a mechanical splice. Using a high quality cleaver like those used for fusion splicing, available from some manufacturers as part of their termination kits, is recommended. Even if you do everything correctly, loss will be somewhat higher, because you have a connection loss plus a splice loss in every connector. The best way to terminate them is to verify the loss of the splice with a visual fault locator and "tweak" them. (Photo: Corning, Unicam)

[More on prepolished/splice connectors.](#)

Read more about termination processes and view the actual processes involved in termination with "Virtual Hands-On" tutorials. See the [Table of Contents](#) for listings of termination types under Components.

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, never, 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 or splice 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.

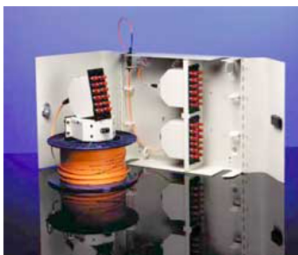
Don't overpolish. Contrary to common sense, too much polishing is just as bad as too little. The ceramic ferrule in most of today's connector is much harder than the glass fiber. Polish too much will cause undercutting of the fiber and you create a concave fiber surface not convex as it should be, increasing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

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.

Prefabricated Cabling Systems: Do You Have To Terminate In The Field?



Not necessarily. Many manufacturers offer prefabricated fiber optic cabling systems for both premises and outside plant systems. In fact, the largest application for prefabricated systems is fiber to the home (FTTH) where it saves a tremendous amount of time in installation and cost. Using prefab systems requires knowing precisely where the cable will be run so cable lengths can be specified. Using CAD systems and design drawings, a complete fiber optic cabling system is designed to the customer's specifications and built in a factory using standard components. Early prefabricated systems (some are still available) simply terminated cables with standard connectors like STs or SCs and put them inside a plastic pulling boot with a pulling loop attached

to the fiber strength members. The cable would be placed with the boot in place then removed to connect into patch panels.

Today, it's more common to use backbone cables terminated in small multifiber MTP connectors that are pulled from room to room and connected to rack-mounted modules that have MTP connectors on the back and single fiber connectors on the front (see photo of Fiberware system.) Like everything else, there are tradeoffs. The factory-assembled connectors usually have lower loss than field terminations but the MTP connectors, even factory assembled, are not low loss, so the total loss may be more than field terminated systems. Costs also involve tradeoffs, as factory systems are more expensive for the components but installation time is much less.

In new facilities, considering prefabricated systems is always a good idea, but all factors should be considered before making a decision.

[More on prefab cable systems.](#)

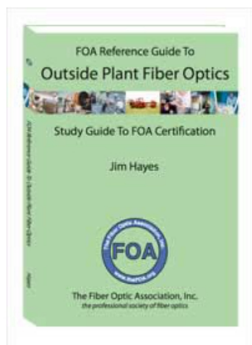
[More on connectors and termination, including hands-on tutorials.](#)

Test Your Comprehension

References

[The FOA Reference Guide to Outside Plant Fiber Optics](#)

[The FOA Online Reference Guide to Fiber Optics](#)



You can buy the printed version of the [The FOA Reference Guide to Outside Plant Fiber Optics](#) from the [FOA eStore](#) or [Amazon](#).

Table of Contents: The FOA Reference Guide To Fiber Optics

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The Fiber Optic Association, Inc.
the non-profit professional society of fiber optics

Reference Guide To Fiber Optics

Topic: OSP Fiber Optic Network Design

[Table of Contents: The FOA Reference Guide To Fiber Optics](#)

Outside Plant Fiber Optic Network Design

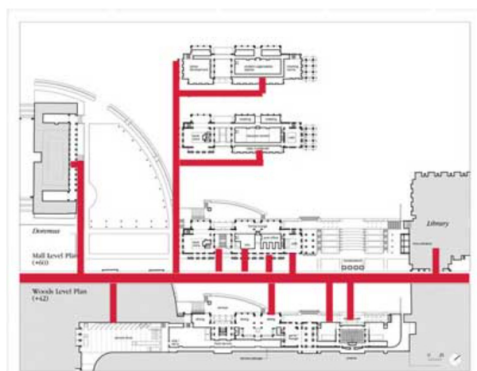
Jump To:

[The Communications System](#)
[Cabling Design](#)
[Choosing Transmission Equipment](#)
[Planning The Route](#)
[Choosing Components](#)
[Cable Plant Link Loss Budget Analysis](#)
[Project Documentation](#)
[Planning for the Installation](#)
[Planning for Restoration](#)
[Managing A Fiber Optic Project](#)

Fiber optic network design refers to the specialized processes leading to a successful installation and operation of a fiber optic network. It includes determining the type of communication system(s) which will be carried over the network, the geographic layout (premises, campus, outside plant (OSP, etc.), the transmission equipment required and the fiber network over which it will operate. Designing a fiber optic network usually also requires interfacing to other networks which may be connected over copper cabling and wireless.

Next to consider are requirements for permits, easements, permissions and inspections. Once we get to that stage, we can consider actual component selection, placement, installation practices, testing, troubleshooting and network equipment installation and startup. Finally, we have to consider documentation, maintenance and planning for restoration in event of a future outage.

The design of the network must precede not only the installation itself, but it must be completed to estimate the cost of the project and, for the contractor, bid on the job. Design not only affects the technical aspects of the installation, but the business aspects also.



Campus network design