FOA Reference Guide For Fiber Optics

Virtual Hands-On
Epoxy/Polish Termination

1

This FOA virtual hands-on (VHO) tutorial on fiber optics covers fiber optic cable termination using an epoxy/polish connector process. It is copyrighted by the FOA and may not be distributed without FOA permission.

This VHO covers similar material to the videos on YouTube.

Safety Rules

- Read and follow rules in lab manual
- Wear safety glasses
- Be careful with chemicals
- No eating or drinking
- Dispose of fiber scraps carefully

2

The lab manual has several pages of rules for safety in fiber optic labs. Each student should be familiar with them and follow them carefully. Instructors must follow them too!

Connector Termination - Adhesive/Polish

- Tools
  - Cable Jacket stripper
  - Aramid Yarn Scissors
  - Fiber Stripper
  - Crimp Tool
  - Scribe
  - Polishing Puck
  - Polishing Plate with Rubber Pad
  - Connector Adhesive Curing Oven

3

The first step in terminating optical fiber is to gather all the tools you will need and arrange them for easy use. It helps to be working in an area that has good light and is not dusty.For photo purposes, we use a light colored background, but a black background on the workspace makes it easier to see the fiber during termination and easier to find fiber shards.

If you are using a curing oven to cure the epoxy in less than 10 minutes, you will need power, either AC or the optional battery, also. If you plan to let the epoxy cure overnight, you will need a place to keep the cable away from handling.

Connector Termination - Adhesive/Polish

- Accessories
  - Fiber disposal bin
  - Lint-free wipes
  - Isopropyl alcohol
  - Instructions

For safety, have a bin to dispose of all fiber scraps. We like to use disposable deli containers used for soup or salad. Put all the scraps in it and tape it shut for proper disposal.

For cleaning, use lint-free wipes and lab-grade isopropyl alcohol.

And have exact instructions for the connector you are terminating, including a cable stripping guide.

Connector Termination - Adhesive/Polish

- Consumables
  - Two part epoxy (BiPax)
  - Syringe with needle
  - Polishing film (multimode
    - 12, 3, 0.3 micron
  - Cable to terminate

Next, get all your consumables ready. In our training courses, we start with a 2 meter (or 6 foot) ST to ST cable with 62.5 multimode fiber. This allows us to test it first to make certain both connectors are good, then cut it in half and terminate the cut ends. This allows us to test the connectors as soon as we make them.

If you use a unterminated cable, we recommend a 3 mm jacketed simplex or zipcord cable so you learn how to terminate cable with strength members properly. *And before you start stripping raw cable, tie a knot in the end to keep the fiber and kevlar strength members from pulling out when you try to strip the fiber.*

After doing several connectors on 3 mm jacketed cable, do some on 900 micron buffered fiber and even use a breakout kit on loose tube cable for termination.

Our first exercise will be multimode termination, but we will cover singlemode later also.

Connector Termination - Adhesive/Polish

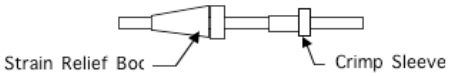
- ST Connectors
- From left:
  - Strain relief boot
  - Crimp sleeve
  - Connector
  - Dust cap for ferrule

Note: Some connectors may have slightly different construction. Some do not have a crimp sleeve, but rely on crimping the body of the connector onto the cable jacket and epoxying the aramid fibers to the connector. Connectors for 900 micron buffered fiber, such as found in distribution cables, may not need a crimp, as there are no strength members to crimp to, so they are epoxied to the fiber and a strain relief is attached.

Make sure you have the termination instructions for the exact connector you are using before you start!

Connector Termination - Adhesive/Polish

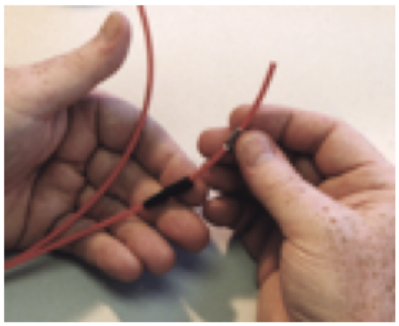
- Stripping the cable (3mm jacket):
- Before you start, slide the strain relief boot on the cable first, then the crimp sleeve. Some crimp sleeves have two steps - make sure they are on the cable the right way!



Note: Some connectors from different manufacturers or made for different cables may have slightly different construction. Make sure you have the termination instructions for the exact connector you are using before you start!

Connector Termination - Adhesive/Polish

- Before you start, slide the strain relief boot on the cable first, then the crimp sleeve.
- Some crimp sleeves have two steps - make sure they are on the cable the right way!



Be sure to put the crimp sleeve and strain relief boot onto the cable before you strip the jacket! After you strip the jacket off jacketed simplex cable, it's very hard to get the boot and sleeve onto the cable!

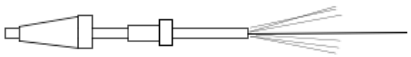
The crimp sleeve tightly holds the aramid strength members of the cable to the body of the connector to provide a strong assembly.

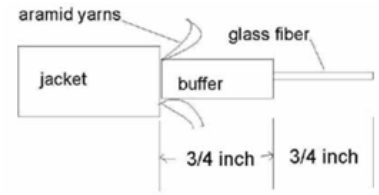
The strain relief boot keeps the cable from bending in too small a radius and breaking the fiber.

If you are terminating 900 micron buffered fiber, you will not need a crimp sleeve, but will need a boot, although it will be different than for jacketed cable. It will have a smaller back to fit the 900 micron fiber and a thinner taper to provide a gentler strain relief.

Connector Termination - Adhesive/Polish

- Stripping the fiber - process:
- Strip jacket
- Cut strength members
- Cut fiber to length
- Strip buffer





For typical 3mm jacketed cable, you will need to perform three separate operations to prepare the cable for termination. The jacket strip tool will expose the buffered fiber and strength members, next you must cut the strenth members to the correct length and then carefully remove the buffer with the fiber stripper in a series of small strips as explained below.

If the cable you are using is unterminated at both ends, then the cable jacket is unstable - the fiber will slide right out. Before you begin to strip the cable, tie a firm knot in the other end so the fiber will not pull out.. This will keep the jacket, aramid yarns, and buffer all in the same relative position .

Allow at least 3 inches (75mm) from the cut end of the fiber for termination.

If the fiber has been cut for some time, the fiber may be brittle at the end, so cutting off 6 inches (150 mm) may make working with the fiber easier.

The instructions for the connector you are using should include a drawing of the required dimensions of the prepared end of the cable ready for termination like the one shown above. If the instructions only gives dimensions, making an exact-size drawing for visual reference will be very helpful.

Connector Termination - Adhesive/Polish

- Stripping the jacket
  - Locate the place to strip
  - Nick the jacket with the stripper
  - Twist the jacket and pull off gently
  - Be careful not to break fiber!

Use the jacket strip tool (don't confuse it with the fiber buffer stripper) to cut through the protective jacket.

Set the jacket cutting tool on the desired mark (#4 for 3 mm fiber as shown below), bite down on the fiber at the desired location, and hold the tool closed.

Do NOT try to strip the jacket off as you might with copper wire!

Release the tool and grab the jacket with your fingers. Twist it and pull. It will slide off easily. Be careful not to break the fiber. If you do, cut off the cable and start the process over.

Connector Termination - Adhesive/Polish

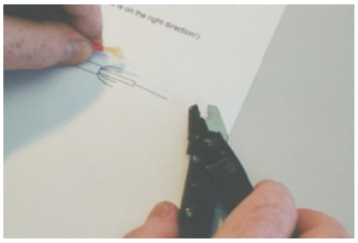
- Cutting the strength members
  - Shake loose
  - Twist together
  - Loop over blades of scissors
  - Cut to proper length (usually 1 cm or 3/8”)

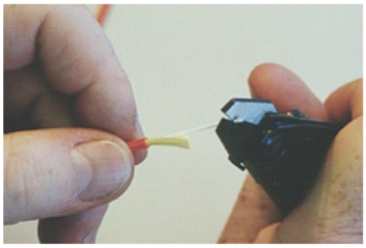
Shake the Aramid yarns loose (blowing on them often helps loosen them), gather them together in a twist, make a loop, and cut the yarns with the special scissors designed to cut this material so that 1/4 - 3/8 inch of yarn is left, as required by the connector you are using.

The strength members (aramid fibers, often called Kevlar, the DuPont trade name) will be crimped to the connector to give additional strength to the connection.

Connector Termination - Adhesive/Polish

- Stripping buffer from fiber
  - Check measurements
  - Hold Miller stripper at 45º angle
  - Take small “bites”





Stripping the primary buffer coating from the glass:

It helps to have a drawing of the stripping dimensions in the exact size you must strip to to compare directly to the fiber itself. This is much easier than measuring!

It is very important that care be taken here so that the glass fiber does not break. Attempt to strip no more than 1/8 in of buffer at a time until you get a "feel" for the fiber, then you may be able to strip longer lengths without breaking the fiber!

There are a number of different types of stripping tools, but the "Miller Stripper" shown here is one of the most popular, since it is very reliable. Another type is the "No-Nik" which works well if kept clean. The “Micro-Strip” is a one-step tool popular with fusion splicers.

Hold the Miller Stripper at a 45 degree angle to the fiber so that it does not bend the fiber when you clamp down on the fiber. Squeeze the stripper firmly on the fiber to cut the buffer fully. Pull slowly and steadily, keeping the fiber straight as you strip the buffer off. It will NOT slide off easily like the jacket. Continue to take 1/8 to 1/4 inch bites of buffer (3-6 mm). You must leave enough exposed buffer for the connector body to adhere to, so there must be at least 5/8 to 1 inch of fiber exposed (15-25 mm) or whatever length is required by the connector you are terminating.

Connector Termination - Adhesive/Polish

- Preparing the epoxy
  - Open package
  - Remove BiPax divider
  - Mix thoroughly
  - Assemble needle to syringe

Preparing The Epoxy

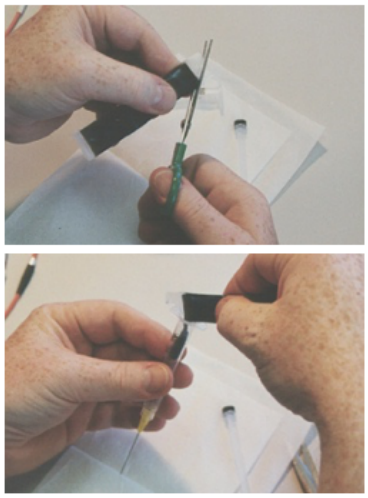
Open the epoxy package and remove the syringe and the two part epoxy mix. Assemble the syringe.

Remove the divider that separates the epoxy and hardener in the plastic bag. Lay the bag flat and mix the two ingredients by sliding a flat object back and forth over the surface of the bag . The plastic divider works fine for this. A popsicle stick is another good choice. You can also mix the epoxy by kneading with your fingers.

Make sure the epoxy is thoroughly mixed. You will have to turn the bag over and mix it on both sides. It will take a couple of minutes to mix the epoxy properly. Once it is mixed, it will be useable for just over a half hour. Hold the bag up and the mixture will settle to one end.

Connector Termination - Adhesive/Polish

- Preparing the epoxy
  - Cut corner off BiPax with cheap scissors - not the ones used to cut strength members!
  - Remove plunger from syringe
  - Pour epoxy slowly into syringe



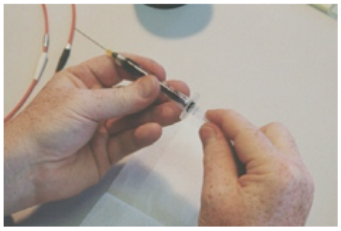
The epoxy is very sticky and hard to remove from anything it gets on. Be aware of this as you prepare to cut the bag open.

Using an inexpensive pair of scissors (NOT the good Kevlar scissors!), snip off one corner of the bag to make an opening about 1/16 inch (1mm) across.*Do not use the same scissors that you used to cut the aramid yarns - you don't want to get any epoxy on those - they will be ruined!*

Remove the plunger from the syringe, and pour the epoxy into the syringe. Have Kim wipes handy.

Connector Termination - Adhesive/Polish

- Preparing the epoxy
  - Replace plunger in syringe
  - Hold needle-up to let epoxy run down
  - Use plunger to remove air from syringe
  - Put aside for next step



Put the plunger back into the syringe, just enough to hold it in place - *don't push it in yet*.

Hold syringe vertically with the needle up. Let the epoxy run to the bottom. Slowly move the plunger up, forcing out the air.

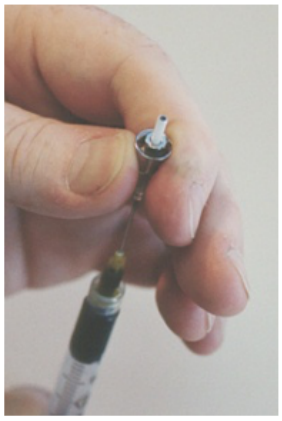
Wipe the epoxy that squirts out of the needle with a wipe.

Set the syringe aside, and put the cover on the needle if it has one or lay the needle on a clean wipe.

You now have about a half hour to do terminations.

Connector Termination - Adhesive/Polish

- Inject epoxy into connector
  - Squeeze through the hole in the ferrule
  - Leave a small bead on ferrule end



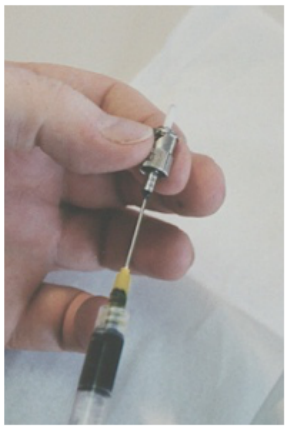
Remove the dust cover from the ferrule of a connector and set it aside - we'll put it back on after we're through.Lightly press on the plunger of the syringe to remove the air bubble.

Insert the needle into the connector body as far as it will go. Lightly squeeze on the plunger until a bead of epoxy appears at the tip of the ferrule.

Having the right bead of epoxy on the end of the connector ferrule is the most important issue for getting a good finish on the end of the fiber. The bead of epoxy supports the fiber during the polishing process and makes it just about impossible to make a bad connector! The proper bead will be 1/3 to 1/2 the diameter of the ferrule of the connector.

Connector Termination - Adhesive/Polish

- Inject epoxy into connector
  - Back needle out halfway
  - Fill connector body with epoxy
  - Remove needle
  - Set connector aside
  - Pull back plunger to prevent drips



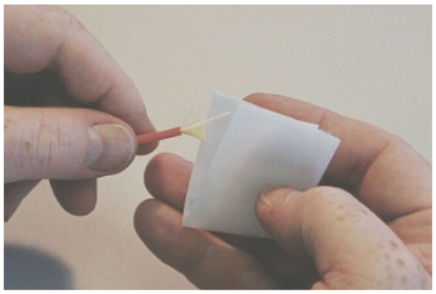
Back the needle halfway out of the connector. Continue to gently squeeze more epoxy into the body of the connector. Stop when epoxy comes out the back of the connector body.

Remove the syringe from the connector. Lay the connector down for a moment while you deal with the syringe and clean the fiber with a wipe.

Pull back on the plunger of the syringe so that epoxy does not continue to seep out. Wipe the tip of the needle with a clean wipe and set it aside with the wipe wrapped around the needle to prevent getting epoxy on anything.

Connector Termination - Adhesive/Polish

- Clean fiber
  - Wipe with lint-free wipe and isopropyl alcohol
  - Careful - do not break fiber!

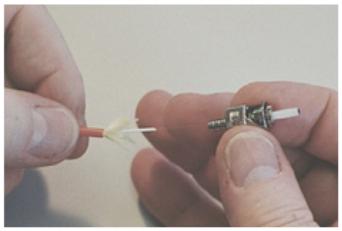


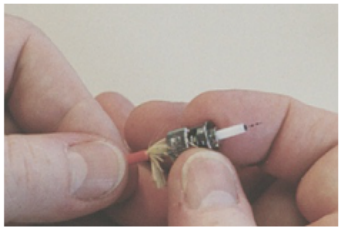
Place an Alco pad or lint-free wipe lightly wet with alcohol between your thumb and forefinger, and wipe the fiber between them.

Careful- do not break the fiber!

Connector Termination - Adhesive/Polish

- Place connector on fiber
  - Rotate connector as it slides on the fiber
  - Slide all the way onto the cable
  - Epoxy will saturate cable and strength members





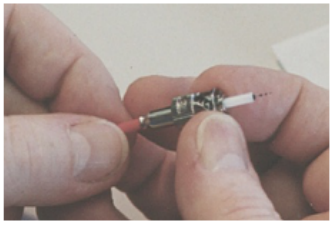
Slide the connector onto the fiber. As you feed the fiber into the connector, rotate the connector back and forth so the fiber will find its way through the ferrule. This rotation will also spread the epoxy all around the fiber and float the fiber to the center of the hole in the ferrule.

Slide the connector all the way back to the jacket. Some epoxy will leak out the back onto the yarn and jacket. This will help secure the connection.

A short length of fiber will protrude from the ferrule end.

Connector Termination - Adhesive/Polish

- Crimp the connector to the cable
  - Slide the crimp sleeve onto the connector, capturing the strength members
  - Crimp with the proper size crimp die
  - Second crimp if required

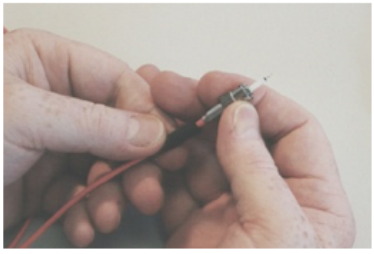


While you hold the connector against the jacket, slide the crimping sleeve onto the connector body. On some connectors, you will have to make two crimps on the sleeve.

Adjust the crimp tool to the proper size hex to crimp the wider part of the sleeve. Sqeeze the tool to maximum compression to complete the crimp. Adjust the tool to the smaller hex to crimp the narrow part of the sleeve over the jacket.

Connector Termination - Adhesive/Polish

- Slide connector boot over crimp sleeve
- Careful! If you break the fiber at this stage you must start over!



Slide the strain relief boot over the crimp sleeve. Be careful not to break the glass fiber protruding from the ferrule. This will be removed in the polishing step after the epoxy cures.

If you break the fiber at this point, cut the connector off and start over. The fiber always breaks below the end of the ferrule and cannot be polished properly.

Connector Termination - Adhesive/Polish

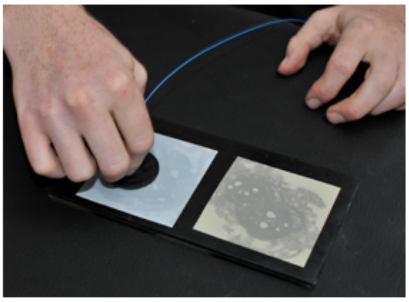
- Epoxy curing
  - Room temperature cure epoxy: allow to cure overnight
  - Heat-cure epoxy: cure in oven for 5-10 minutes

If you use room-temperature curing epoxy the connector must sit for 18 hours (overnight) to allow the epoxy to cure. A faster alternative is to use a heat-curing epoxy and a curing oven, which requires only 5-10 minutes.

While this connector is curing, you have time to make several more terminations. In the field, you can make up to a dozen connectors an hour once you gain experience by having several connectors curing while you attach more connectors.

Connector Termination - Adhesive/Polish

- While the connector is curing prepare the polishing setup
  - Flat plate with polishing pad
  - Polishing films: 12µ for air polish, 3 and 0.3µ for final polish



While the connector is curing, get your polishing setup ready on the tabletop. For PC connectors, which are most connectors sold today, the surface should be soft, for example a rubber pad, to allow the convex surface of the PC connector ferrule to be polished correctly.

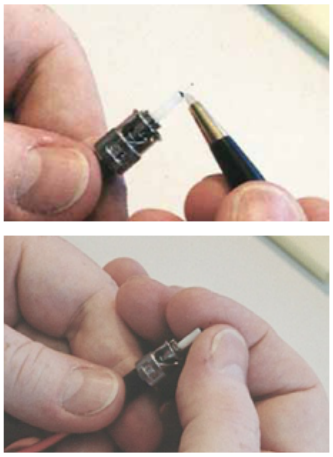
You need a flat plate with polishing pad. The polishing pad should be ~3mm (1/8") thick rubber with a ~80durometer rating. This allows the rounded end of the connector ferrule to guide the fiber into a physical contact (PC) finish. Photos show just a glass plate and not the black rubber polishing pad for easier photography.

You need 3 polishing films: 12μ for air polish, 3 and 0.3μ for final polish on the pad. Polishing films are color-coded for identification.

We also recommend polishing on a black surface since it will make it easier to find fiber scraps, but you can see from the photo above that photos this way are not as visible, so we'll use white backgrounds.

Connector Termination - Adhesive/Polish

- Cleave the fiber end
  - Scribe just past the epoxy bead
  - Grasp with fingers and pull off
  - Dispose of fiber scrap carefully!



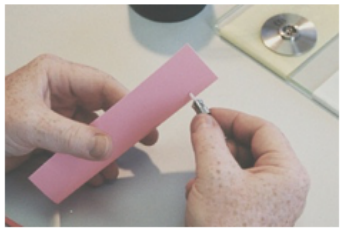
Once the epoxy has cured, you are ready to scribe and remove the excess glass and epoxy from the tip.

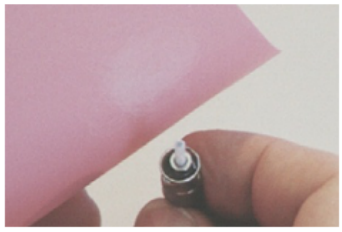
The next step is to "cleave" the stub of glass protruding from the ferrule. Take the connector in one hand and the scribe in the other. Holding the scribe very lightly, delicately give the glass 3 scratches at the point where it protrudes from the epoxy bead on the ferrule.

Lay the scribe aside and grasp the glass. Carefully pull up and away from the scribe. The glass should break cleanly at the scribe point, but there will be a little bit left at the tip *and it may be sharp!* ***Discard the glass fiber fragment in the fiber disposal bin!***

Connector Termination - Adhesive/Polish

- "Air Polish"
- Use 12 micron film, hand-held
- Lightly polish until most of epoxy bead is gone





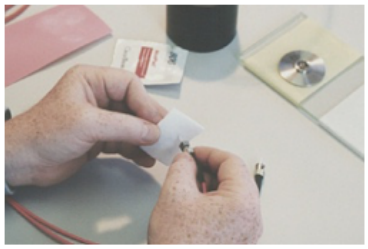
"AIr Polish" the fiber stub first with 12 micron film, holding it as shown.

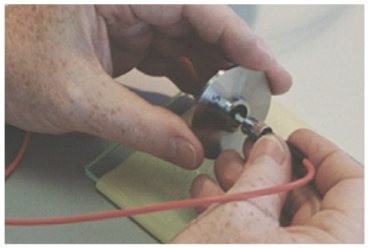
Polish the tip lightly for 10 to 20 seconds. Notice the change in sound (quieter) as the burr gets filed down and the epoxy bead is removed. Remember to brush the tip lightly and do not overpolish as it will create scratches that cannot be removed in finer polishes.

Visually inspect the tip. There should be some epoxy left, indicated by a faint color, and the glass itself will be not be smooth.

Connector Termination - Adhesive/Polish

- Preparing to polish
  - Clean ferrule tip with wipe
  - Hold puck and insert connector



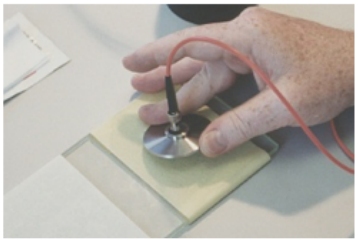


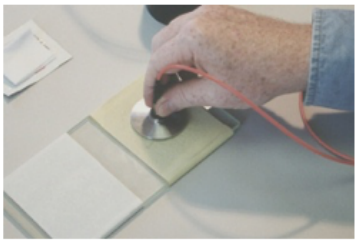
Clean the tip with an alcohol wipe to remove any loose grit or epoxy.

Now prepare to use the polishing puck with the polishing plate. Always hold the puck up in your hand and then insert the connector. Never insert the connector into the puck while it is lying on the glass because you may chip the glass at the ferrule tip.

Connector Termination - Adhesive/Polish

- Polishing the connector
  - Gently place puck on 3 micron film
  - Polish in “figure 8s”
  - Maybe 4-8 cycles
  - Quit when it feels “slick”
  - Only takes a few seconds!





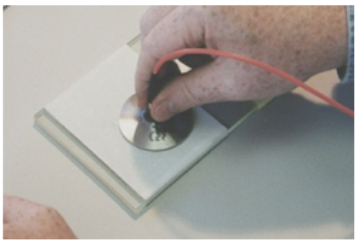
Remember the tip is a exposed glass end which can be easily damaged before it is polished properly. Gently place the puck with the connector in it on the yellow film which is on the polishing glass.

Very lightly make 4 or 5 figure eights as you polish the tip. You'll actually feel a smoothing of the surface as the epoxy wears off and the ceramic surface of the ferrule meets the surface of the abrasive. Do not overpolish the tip. Remember, the glass is softer than the polishing abrasives. Overpolishing can cause the glass to be undercut, and this will cause excess light loss at the connection.

Stop as soon as the connector feels "slick"! The polishing film and the ferrule are made of similar materials. As soon as all the epoxy and protruding fiber is removed, the ferrule will be rubbing against the film and it will feel like the puck is floating on air.

Connector Termination - Adhesive/Polish

- Final Polish
- Clean ferrule
- Inspect to see all epoxy is polished off
- Final polish on 0.3 micron film

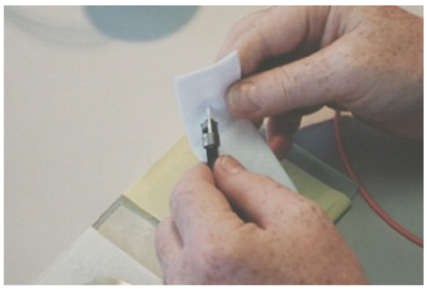


Clean the tip with an alcohol pad and inspect it to see that all the epoxy is gone. If not, give it 1 or 2 more figure eights on the yellow 3 micron film to remove it. Remember -do not overpolish!

Very gently lay the puck on the 0.3 micron film. With almost no pressure, make about six figure eight strokes.

Connector Termination - Adhesive/Polish

- Polishing is finished!
  - Gently remove ferrule from puck
  - Clean with alcohol wipe
  - Ready for visual inspection



Remove the connector ferrule from the puck and clean the ferrule with an alcohol wipe.

Now it is ready for visual inspection.

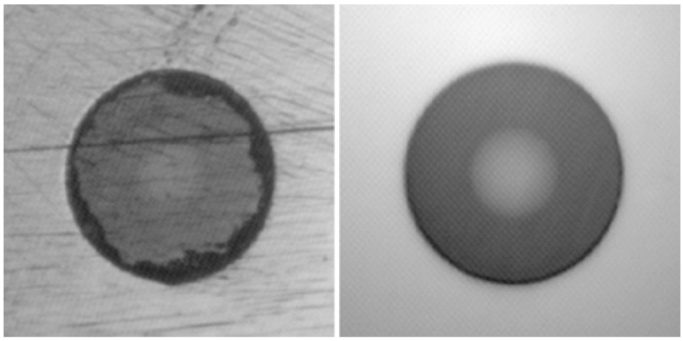
Connector Termination - Visual Inspection

- Microscope inspection
  - Can be 30-400X
  - 100-200X recommended
  - Direct view, with or without core illumination
  - Angle view – illuminated from the side

At this point, inspect the polished end of the ferrule with the microscope to see that the epoxy is completely removed and that the tip is smooth and free of scratches.

Microscopes for fiber optic connector inspection range from 30 to 400 power. We think that anything under 100X is too low for proper inspection and anything over 200X makes inspection too critical. It is very important to have the ability to shine light through the fiber during inspection, to check for cracks in the connector caused by the termination process.

Connector Termination - Visual Inspection

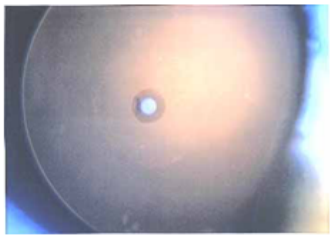


Bad (L) and Good (R)

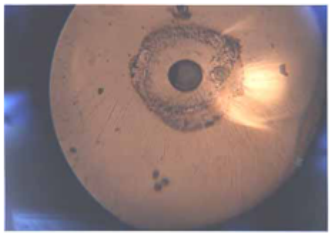
The core should be nice and smooth, an even gray color, with no big scratches. If you see large scratches, go back to the 0.3 micron film and use the polishing puck to very lightly give 1 or 2 more figure eights to remove them. The film of epoxy can be removed by polishing on the same film on the rubber polishing pad, which polishes the entire convex PC ferrule.

Connector Termination - Visual Inspection

Direct view -
Core illuminated



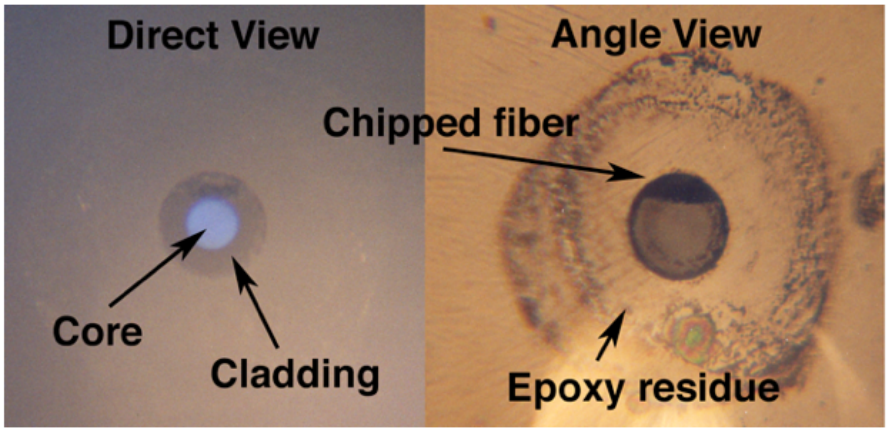
Angle View



A direct view at 100 times magnification should look like this: The bright dot in the center is the core of the fiber and the darker annular ring is the cladding. On this connector, notice the dark area to the left of the core, in the cladding. This appears to be a small crack in the fiber that only affects the cladding, not the core, so it is not a problem. If the crack had been in the core, we would not have seen a round dot for the illuminated core.

You should also look at the tip under the microscope illuminated at an angle if this is possible with the microscope you are using. The angular view will highlight any surface irregularities better than the head on view. It may look like this: Now you can see some small amount of epoxy still on the end of the ferrule, which shows up as the dark, uneven ring around the fiber (the ring is caused by the convex end of the PC ferrule.) You can also see the dark area to the left of the fiber, which is the small crack we saw on the direct view, but is more obvious here. The core should be nice and smooth, an even gray color, with no big scratches. If you see large scratches, go back to the 0.3 micron film and use the polishing puck to very lightly give 1 or 2 more figure eights to remove them. The film of epoxy can be removed by polishing on the same film on the rubber polishing pad, which polishes the entire convex PC ferrule.

Connector Termination - Visual Inspection

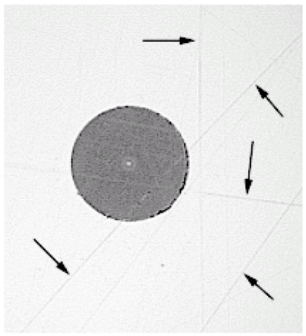


A closer look at this connector shows all is not well. A chip on the side of the fiber is hard to see in the direct view, but is visible in the angle view. Since it does not quite reach the fiber core, it may not affect loss, but it is so large that it is probably cause for rejection.

The direct view looks fine, but the angle view shows some minor residue from the epoxy bead on the end of the ferrule. This would probably be OK for a multimode connector but not for singlemode.

Connector Termination - Visual Inspection

- Scratches
  - Singlemode fiber
  - Scratches miss core



Here is a connector with scratches on the ferrule and fiber at high magnification. This is SM fiber, as you can see from the small core of the fiber. The scratches are mostly on the ferrule and none cross the core of the fiber, so it should be OK. Just test it for insertion loss before accepting it.

Connector Termination - Visual Inspection

Typical 3 micron finish

Typical 1 micron finish

Typical 0.3 micron finish

Cracked and chipped finish

Plucked finish

Cracked and plucked finish.

More polishing results and faults found by visual inspection.

FOA Guide - Virtual Hands-On

By

The Fiber Optic Association, Inc.
1-760-451-3655 Fax 1-781-207-2421
Email: info@foa.org http://www.foa.org