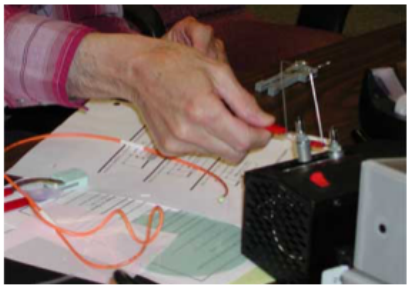
FOA Reference Guide For Fiber Optics



Virtual Hands-On
3M Hot Melt Termination

This FOA virtual hands-on (VHO) tutorial on fiber optics covers fiber optic cable termination using the 3M HotMelt 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
- Dispose of fiber scraps carefully
- Careful with chemicals
- No eating or drinking

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!

FOTM Chapter 11

Safety Rules

- The 3M Hot Melt Oven gets extremely hot! The connector holders and the oven itself are a burn hazard. Be very careful!

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!

Caution: The Hot Melt oven operates at twice the temperature of the epoxy curing oven - 245 - 270 degrees C. or 473 - 518 degrees F. ° C. It can cause burns if the metal parts are touched while hot. Be extremely careful with the oven!

NOTE: Paper catches fire at 451 degrees F, so don't rest anything on the oven.

Connector Termination - Hot Melt /Polish

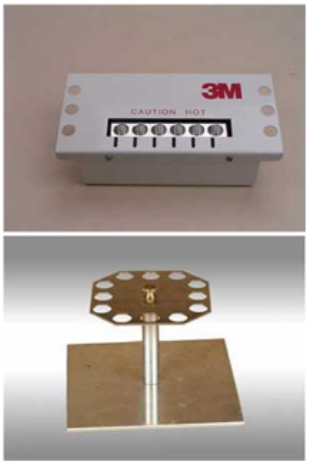
- Tools
  - Cable Jacket stripper
  - Aramid Yarn Scissors
  - Fiber Stripper
  - Crimp Tool
  - Scribe
  - Polishing Puck
  - Polishing Plate with Rubber Pad
  - 3M Hot Melt Oven

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.

With the Hot Melt connectors, you need the same tools you need for epoxy/polish or anaerobic/polish connectors, plus a special high temperature oven to melt the adhesive before the fiber is inserted. You can get a complete kit from 3M or use the same tools for other methods and add in the proper oven.

Connector Termination - Hot Melt /Polish

- Hot Melt oven
  - Higher temperature than epoxy curing ovens
  - Includes holders for connectors
  - Heat connectors before inserting fiber
- Cooling stand used after fiber insertion/crimping



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With the Hot Melt connectors, you need the same tools you need for epoxy/polish or anaerobic/polish connectors, plus a special high temperature oven to melt the adhesive before the fiber is inserted and a rack for allowing the connectors to cool down. You can get a complete kit from 3M or use the same tools for other methods and add in the proper oven.

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Connector Termination - Hot Melt /Polish

- Accessories
  - Fiber disposal bin
  - Lint-free wipes
  - Isopropyl alcohol
  - Instructions
- Consumables
  - 3M Hot Melt Connectors
  - Polishing film (multimode)
    - 12, 2 micron
  - Cable to terminate

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.

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 - Hot Melt /Polish

- Connectors (SC)
- From left:
  - Strain relief boot
  - Crimp sleeve
  - Connector shell
  - Connector body
  - Not shown: dust cap for ferrule, sleeve for 900 micron fiber

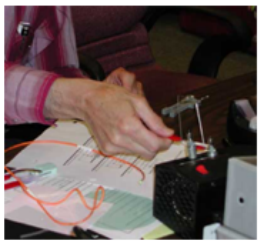
While all "ST" and "SC" style connectors are compatible - that is they can be mated with low loss - they may look different. Differences include the material used in the ferrule and the design of the locking nut.All use a 2.5 mm ferrule to hold and align the fiber. Ferrules can be made of ceramic materials (zirconia or alumina), stainless steel or plastics (usually liquid crystal polymers, which are very hard and stable over temperatures.) Ceramics are by far the most popular, for their high performance and low cost. It is vitally important that the ferrule have the proper size hole for the fiber. Most fibers are about 125 microns OD, so the hole in the ferrule is slightly larger.

Each Hot Melt SC connector comes in five parts, strain relief boot - 900 micron fiber sleeve - connector body -connectorshell - dust cap(not shown.) The main body of the connector is glued to the fiber and the aramid strength members of the cable to provide a strong assembly. The strain relief boot keeps the cable from bending in too small a radius and breaking the fiber. The dust cap protects the end of the ferrule (and the fiber after termination) and should be left on the connector unless it is connected!

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

Connector Termination - Hot Melt /Polish

- When ready to terminate the connector
- Insert connector in oven holder
- Insert holder into oven
- Leave for at least 1 minute <u>but no longer than 10 minutes</u>



Hot Melt connectors use a “hot melt” adhesive preloaded into the connector. The termination process involves heating up the connector until the adhesive becomes a liquid, then inserting the stripped and cleaned fiber. It is then set aside to allow the adhesive to cool and set before cleaving and polishing.

The adhesive needs at least 1 minute in the oven to liquefy but after more than 10 minutes in the oven, it may not set when cooled, so the range of time in the oven is limited.

To start terminations, turn the oven on and let warm up for at least 5 minutes.

Insert a connector in the oven.

Strip and clean the fiber.

Remove the connector from the oven and insert the fiber.

Let the connector cool to set the adhesive.

Cleave and polish as normal.

Hint: Make sure you have the 3M termination instructions for the exact connector you are using before you start! Different styles of connectors have slightly different termination processes.

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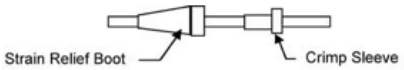
Connector Termination - Hot Melt /Polish

- 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!
- Some Hot Melt connectors, such as the ST, have no crimp sleeve but rely on the adhesive to hold the cable and strength members.

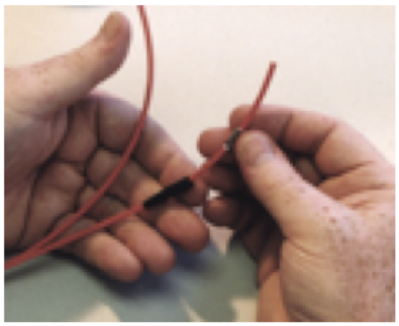


Note:Not all Hot Melt connectors have the same construction. Some connectors may have slightly different construction. Some do not have a crimp sleeve, but rely on crimping the body of the connector onto the cable jacket and adhesive holding the aramid fibers to the connector. Connectors for 900 micron 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 glued to the fiber and a strain relief is attached.

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

Connector Termination - Hot Melt/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.

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

Connector Termination - Hot Melt /Polish

- Stripping the fiber - process:
- Strip jacket
- Cut strength members
- Cut fiber to length
- Strip buffer
- Follow stripping guide in Hot Melt instructions

You will need to perform two separate operations to prepare the cable for termination. The jacket strip tool will expose the buffered fiber and strength members, then you must 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 - it will slide.

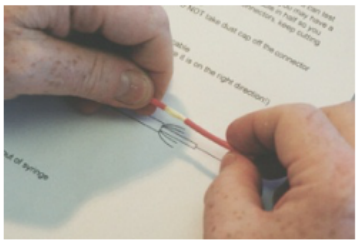
Before you begin to strip it, tie a firm knot in the other end. This will keep the jacket, aramid yarns, and buffer all in the same relative position.Allow at least 3 inches (75mm) from the cut end of the fiber for termination.

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. If it only gives dimensions, making an exact-size drawing will be very helpful.

Connector Termination - Hot Melt /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 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!

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 - Hot Melt /Polish

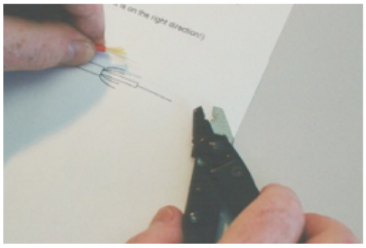
- Cutting the strength members
  - Shake loose
  - Twist together
  - Loop over blades of scissors
  - Cut to proper length (usually 1 cm or 3/8")

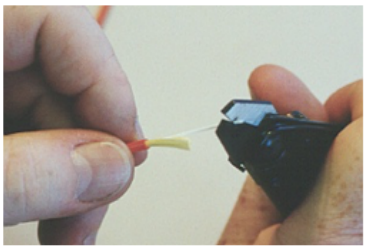
Shake the Aramid yarns loose (blowing on them often helps loosen them), gather them together in a twist, make a loop, and cut the yarns with the special scissors designed to cut this material so that 1/4 - 3/8 inch of yarn is left, as required by the connector you are using.

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

Connector Termination - Hot Melt /Polish

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





Stripping the buffer 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!

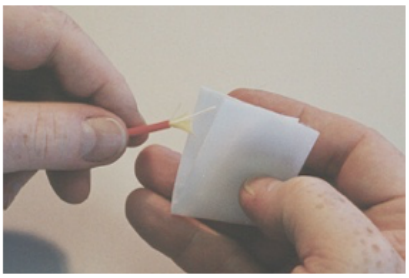
It is very important that care be taken here so that the glass fiber does not break. Attempt to strip no more than 1/8 in of buffer at a time until you get a "feel" for the fiber, then you may be able to strip longer lengths without breaking the fiber!

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 - Hot Melt /Polish

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



Place an alcohol pad between your thumb and forefinger, and wipe the fiber between them.

Careful- do not break the fiber!

Connector Termination - Hot Melt /Polish

- Remove holder from oven - it is extremely hot, so be careful!
- Insert fiber into connector fully

FOA Reference For Fiber Optics

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The adhesive needs at least 1 minute in the oven to liquefy but after more than 10 minutes in the oven, it may not set when cooled, so the range of time in the oven is limited.

Remove the connector from the oven when ready and insert the fiber.

Let the connector cool to set the adhesive.

Cleave and polish as normal.

Trick: Leave about 1/8 inch (3mm) more bare fiber than the specified amount. After inserting the fiber fully into the connector, pull it back about that same amount and let it set. If you break the fiber during cleaving or have problems polishing, reheat the connector and push the extra fiber forward. Let it cool and you can have a second chance!

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Connector Termination - Hot Melt /Polish

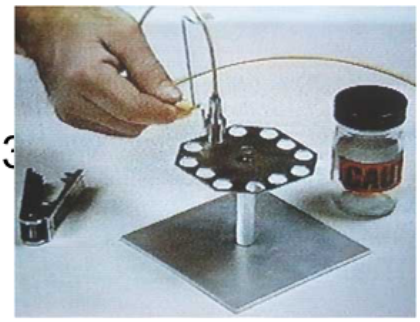
- Crimp the connector to the cable
  - Slide the crimp sleeve onto the connector, capturing the strength members or the strain relief tube for 900 micron buffered fiber.
  - Crimp with the proper size crimp die
  - Second crimp if required

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. Squeeze 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 - Hot Melt /Polish

- Put connector into cooling rack
- Allow to cool for 2-3 minutes to allow adhesive to set

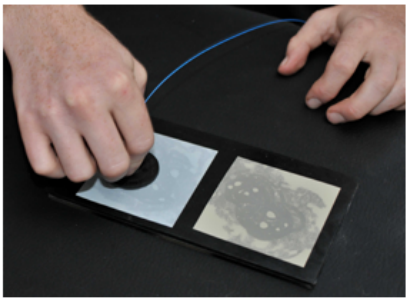


Place the connector assembly in the cooling rack and allow to cool 2-3 minutes to set the adhesive and become cool enough to handle for polishing.

IT'S HOT!!!

Connector Termination - Adhesive/Polish

- While the connector is cooling 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.

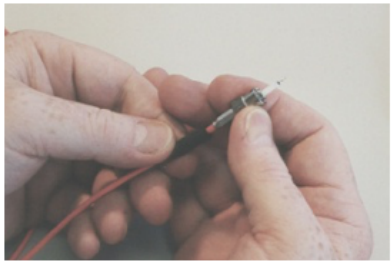
You need a flat plate with polishing pad. The polishing pad should be ~3mm (1/8") thick rubber with a ~80durometer rating. This allows the rounded end of the connector ferrule to guide the fiber into a physical contact (PC) finish. Photos show just a glass plate and not the black rubber polishing pad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

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

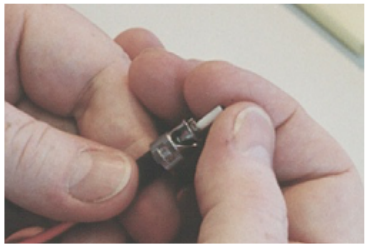


Slide the strain relief boot over the crimp sleeve. Be careful not to break the glass fiber protruding from the ferrule. This will be removed in the polishing step after the epoxy cures.

If you break the fiber at this point, cut the connector off and start over, unless you left extra fiber in the back of the connector. The fiber always breaks below the end of the ferrule and cannot be polished properly. But if you pulled the fiber back ~3mm (1/8") you may reheat the adhesive and push the fiber forward, let it cool and set and try again.

Connector Termination - Hot Melt /Polish

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

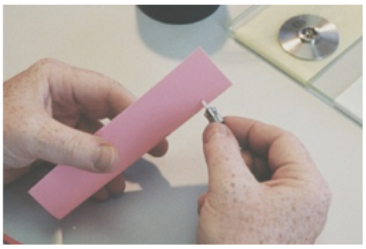


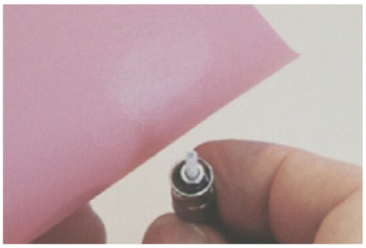
Once the adhesive has cooled, you are ready to scribe and remove the excess glass from the tip.

Carefully scribe the fiber just above the surface of the ferrule. Be very gentle or you can break the fiber. 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 - Hot Melt /Polish

- "Air Polish"
- Use 12 micron film, hand-held
- Lightly polish until most of the protruding fiber is gone





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

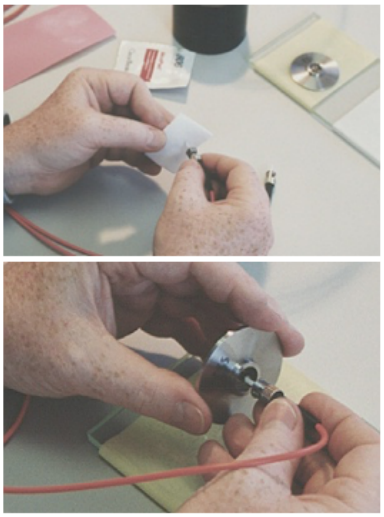
Start with virtually NO PRESSURE since the fiber is not supported like with the bead of epoxy on the epoxy/polish method- it's just sticking out of the ferrule. Slightly more pressure can be applied as you progress. Polish about 40-50 quick strokes.

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 - Hot Melt /Polish

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

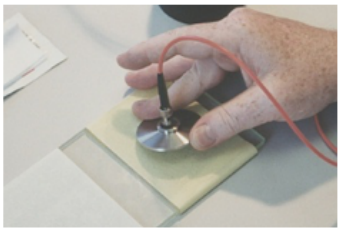


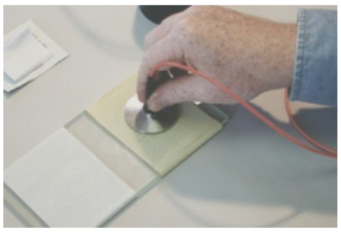
Clean the tip with an alcohol wipe to remove any loose grit or epoxy.

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 - Hot Melt /Polish

- Polishing the connector
  - Gently place puck on 2 micron film
  - Polish in “figure 8s”
  - Maybe 4-8 cycles
  - Quit when it feels “slick”
  - Only takes a few seconds!





Apply a sheet of 2 micron lapping film to the polishing glass as shown. 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.

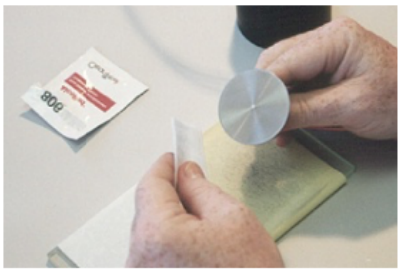
Gently place the puck with the connector in it on the yellow film which is on the polishing glass. Remember the tip is a ragged glass end which can be easily damaged.

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 - Hot Melt /Polish

- Final Polish
- Clean ferrule
- Inspect to see all adhesive is polished off the end of the ferrule

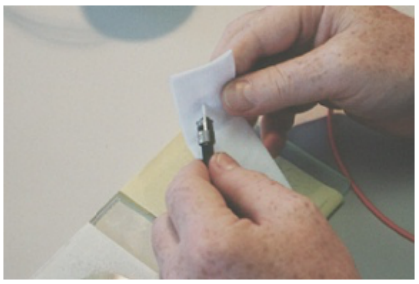


Clean the tip with an Alco pad and inspect it to see that all the epoxy is gone. If not, give it 1 or 2 more figure eights on the yellow 3 micron film to remove it. Remember - do not overpolish!

Clean the connector and it is ready for inspection.

Connector Termination - Hot Melt /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 a alcohol wipe. Now it is ready for visual inspection.

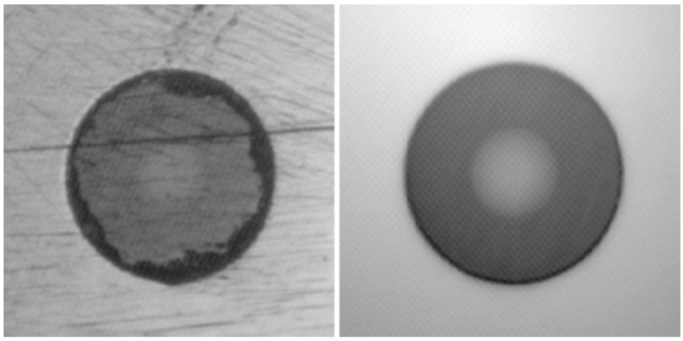
Connector Termination - Visual Inspection

- 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

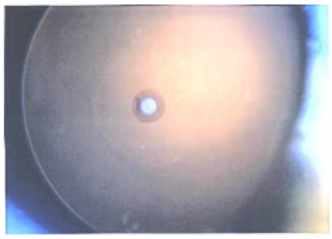


Bad (L) and Good (R)

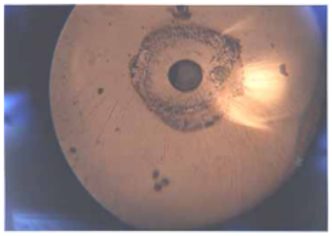
The core should be nice and smooth, an even gray color, with no big scratches. If you see large scratches, go back to the 0.3 micron film and use the polishing puck to very lightly give 1 or 2 more figure eights to remove them. The film of epoxy can be removed by polishing on the same film on the rubber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

Connector Termination - Visual Inspection

Direct view -
Core illuminated



Angle View



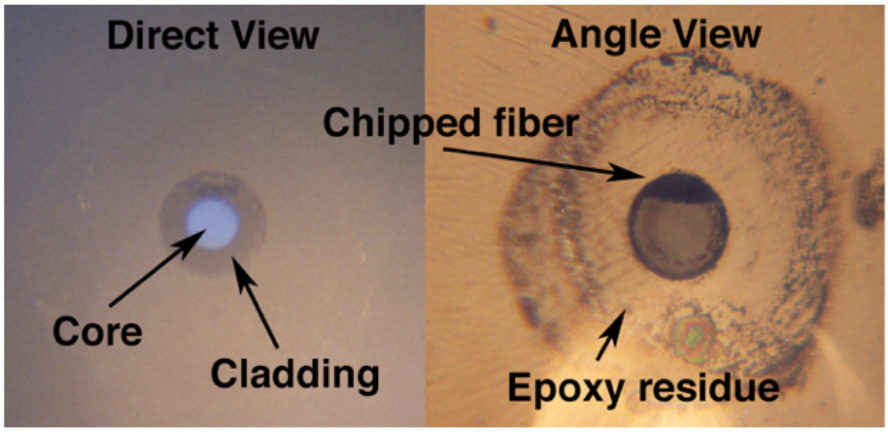
A direct view at 100 times magnification should look like this: The bright dot in the center is the core of the fiber and the darker annular ring is the cladding. On this connector, notice the dark area to the left of the core, in the cladding. This appears to be a small crack in the fiber that only 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 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.

FOTM, Chapter 6,7,9,17, DVVC, Chapter 12,13, 14

Also see the “Virtual Hands-On” section of Lennie Lightwave’s Guide

Connector Termination - Visual Inspection

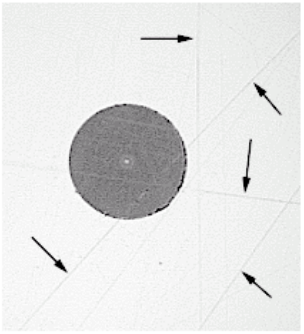


A closer look at this connector shows all is not well. A chip on the side of the fiber is hard to see in the direct view, but is visible in the angle view. Since it does not quite reach the fiber core, it may not affect loss, but it is so large that it is probably cause for rejection.

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

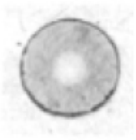


Here is a connector with scratches on the ferrule and fiber at high magnification. This is SM fiber, as you can see from the small core of the fiber. The scratches are mostly on the ferrule and none cross the core of the fiber, so it should be OK.

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

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