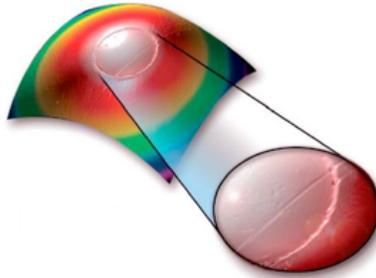


FOA Reference For Fiber Optics



Singlemode Termination Virtual Hands-On



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Safety Rules

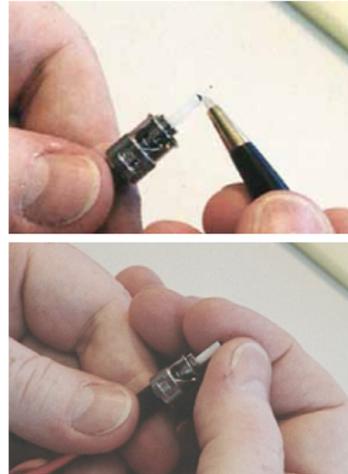
- Read and follow rules in lab manual
- Wear safety glasses
- Dispose of fiber scraps carefully
- Careful with chemicals
- No eating or drinking



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!

Connector Termination - Singlemode

- Similar to multimode, except polishing procedure
- Requires more care to get low loss and low back reflection
- Attach connector with epoxy or anaerobic adhesive



Singlemode Polishing

Singlemode termination can use any of the normal adhesive processes (epoxy, anaerobic, HotMelt), but polishing is different to get a better finish on the ferrule end to reduce back reflection.

In some singlemode applications there is little concern over reflectance or return loss. In these situations, using multimode polishing techniques on the single mode connector may be acceptable. But short SM links as found in premises and campus cabling backbones can be very sensitive to back reflection. There is little attenuation in the short links of cable, causing reflectance to cause light to be reflected multiple times between connections, building up optical “background noise” that can adversely affect transmission in high speed (gigabit or above) networks.

When reflectance is a concern, the polishing technique must be changed from that used with multimode connectors. Because the diameter (or mode field diameter-note 2) of singlemode fiber is only approximately $9\mu\text{m}$ compared to $62.5\mu\text{m}$ diameter of multimode fiber, minute scratches and alignment become more critical in single mode connectors. And the end of the ferrule must be properly convex to get physical contact for low back reflection.

A rubber pad is used to present a soft surface to the connector. This helps give the ferrule a convex-shape and provide a physical contact (PC) connection when mated with another connector. An 80-durometer rubber pad 1/8 inch (3mm) thick is the proper polishing pad.

After air polishing to remove the fiber stub, the connector is “wet” polished on diamond grit lapping films. Diamond lapping film will cut the ferrule as well

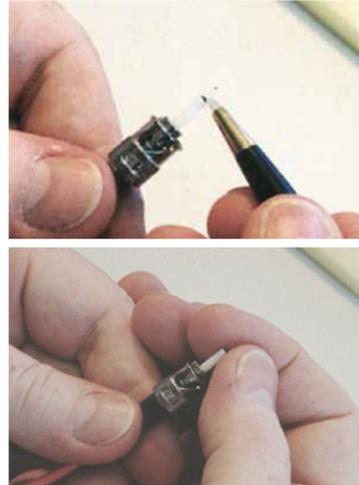
as the fiber, creating a better end surface for the ferrule. Alcohol or a polishing “slurry” acts as a coolant, lubricant and helps keep the lapping film clean.

Note 1: Diamond grit is used in place of aluminum oxide lapping film. When using the aluminum oxide paper the fiber is polished away at a faster rate than the ferrule. This can actually leave the fiber recessed in the ferrule. The diamond grit will polish away ferrule material to leave a clean, convex, physical-contact connector.

Note 2: Singlemode fiber core diameter is usually expressed in “mode field diameter” not the geometric diameter of the glass core. Some light travels in singlemode fiber slightly outside the core, so the effective diameter of the core is larger than the geometric dimension.

Connector Termination - Singlemode

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



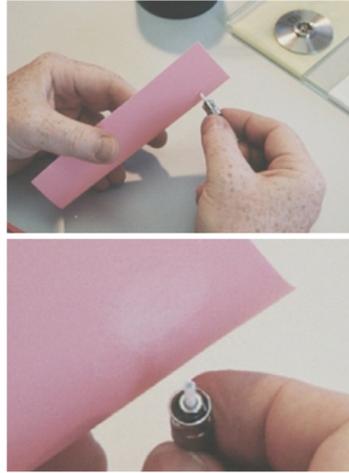
Singlemode connectors are almost always adhesive connectors, and epoxy, anaerobic or HotMelt adhesive can be used. Factory made connectors are almost all done with heat-cured epoxy. Once the adhesive has cured, you are ready to scribe and remove the excess glass and epoxy from the tip.

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 - Singlemode

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



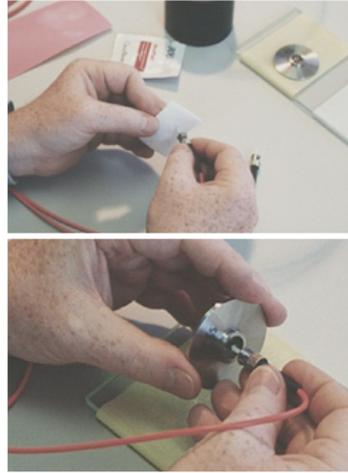
"Air Polish" the fiber stub first with 12 micron film, holding it as shown.

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 - Singlemode

- Preparing to polish
 - Clean ferrule tip with wipe
 - Hold puck and insert connector
 - Prefer nylon or plastic puck, although stainless works also



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.

Note:

Polishing: After deburring, the connector should be placed preferably in a plastic or Nylon polishing puck although a stainless steel puck will work also. (The diamond grit will grind stainless away and the shavings will “gum up” the polishing film, requiring more frequent replacement of the polishing film.) Some manufacturers even recommend that a Nylon puck be dedicated to each grade of polishing paper. This will avoid transferring contaminants when moving to a finer grit.

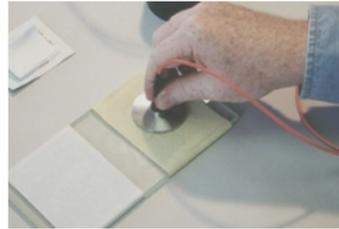
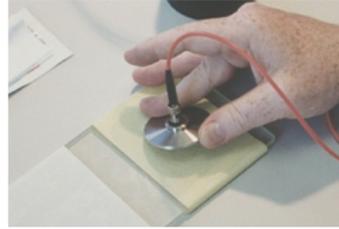
The polishing films should be 5 micron for first or “rough” polishing, and a 1 micron final polish. This should give better than 30 dB return loss. If if very high return loss (>40 dB) is critical, then a final polish with 0.3 micron film can be used.

Alcohol or a polishing “slurry” acts as a coolant, lubricant and helps keep the lapping film clean. Special polishing slurries available from connector suppliers, will provide a better polish and lower back reflection.

The connector is polished in a “figure O” pattern. The “figure O” will give a more thorough polish and help give the connector a convex shape.

Connector Termination - Singlemode

- Polishing the connector
 - Gently place puck on 5 micron diamond film
 - Polish in “Os”
 - Maybe 4-8 cycles
 - Quit when it feels “slick”
 - Only takes a few seconds!



Apply sheets of 5 and 1 micron **diamond** lapping film to the polishing plate and pad. The surface should be soft, for example a rubber pad of 80 durometer rubber about 3 mm (1/8 inch) thick, to allow the convex surface of the PC connector ferrule to be polished correctly.

Apply a few drops of polishing slurry or alcohol to the polishing film.

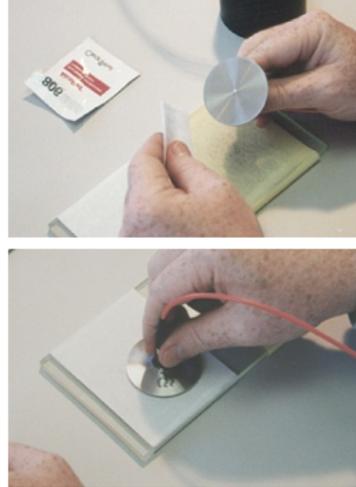
Gently place the puck with the connector in it on the 5 micron film which is on the polishing pad. Remember the tip is a ragged glass end which can be easily damaged.

The connector is polished in a “figure O” pattern. The “figure O” will give a more thorough polish and help give the connector a convex shape.

Very lightly make 4 or 5 circles. 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.

Connector Termination - Singlemode

- Second Polish
 - Clean ferrule
 - Inspect to see all epoxy is polished off
 - Second polish on 1 micron film



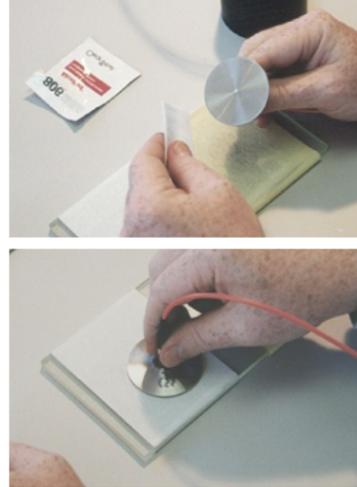
Clean the tip with an Alco pad and inspect it to see that all the epoxy is gone. If not, give it 1 or 2 more strokes on the 5 micron film to remove it. Remember -do not over polish!

Apply a few drops of polishing slurry or alcohol to the 1 micron polishing film.

Very gently lay the puck on the 1 micron film. With almost no pressure, make about ten strokes.

Connector Termination - Singlemode

- Final Polish (if necessary)
- Clean ferrule
- Final polish on 0.3 micron film

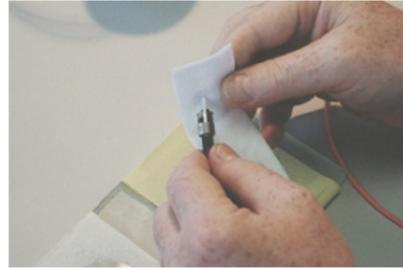


If if very low reflectance or high return loss (>40 dB) is critical, then a final polish with 0.3 micron film can be used, also using polishing slurry.

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

Connector Termination - Singlemode

- 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.

Hints: To achieve the scratch free polish needed for a low return loss and low insertion loss singlemode connector:

1. Place soft rubber pad on the glass polishing plate.
2. Change the polishing film to a diamond grit and wash the film with alcohol.
3. Wash the polishing puck used to hold the connector with alcohol.
4. Gently place the connector in the puck and carefully lay it on the polishing film.

Use a few drops of polishing slurry or alcohol as a lubricant and sweep the fixture across the film in a “figure O” motion. Place only moderate pressure on the connector as you polish. Polish on the 5 micron film until all the epoxy is removed.

Polish on the 1 micron film for about ten “O’s”. When changing to a finer grit polishing film; remove the connector from the puck, wash it with alcohol and insert it into the other cleaned puck reserved for the finer grit if you are using two pucks.

After every 5 -10 connectors wash the polishing films and wash out the polishing puck with a small brush and alcohol.

A final polish on finer film (0.5 or finer) can be done if best backreflection performance is necessary.

Connector Termination - Visual Inspection

- Microscope inspection
 - Can be 30-400X
 - 100-400X recommended
 - Direct view, with or without core illumination
 - Angle view

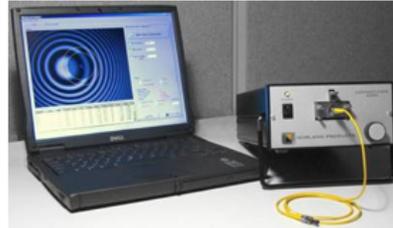


At this point, inspect the polished end of the ferrule with the microscope to see that the epoxy is completely removed and that the tip is smooth and free of scratches.

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 quite critical, although many prefer to use as high a magnification as possible with singlemode. 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.

Singlemode Inspection By Interferometer

- Interferometer can measure end surface of ferrule to micron resolution
- Determines shape of domed PC-finished ferrule
- Lab instrument - not field!



Interferometry used a Michelson-Morley interferometer which uses optical interference to profile the fiber optic connector endface. Singlemode connectors should generally be tested with an interferometer since reflectance is a major performance specification.

Interferometry testing is used in fiber optics to measure the three key physical endface parameters of a PC polished connector.

These parameters include:

Radius of Curvature

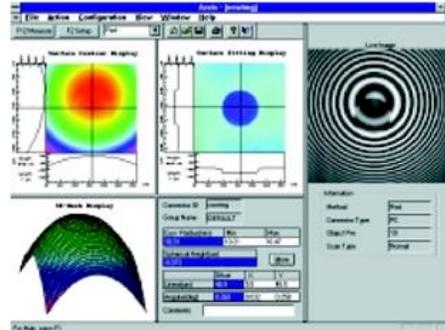
Eccentricity of Polish (Apex Offset)

Fiber Undercut or Protrusion (Fiber Height)

Photos courtesy of Norland Products, manufacturer of the interferometer.

Singlemode Inspection By Interferometer

- Measures three parameters of domed PC connectors:
 - Radius of curvature
 - Eccentricity of dome
 - Fiber undercut or protrusion



Interferometry testing is used in fiber optics to measure the three key physical endface parameters of a PC polished connector.

These parameters include:

Radius of Curvature

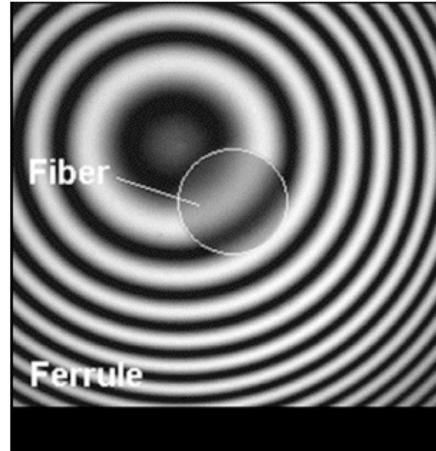
Eccentricity of Polish (Apex Offset)

Fiber Undercut or Protrusion (Fiber Height)

Photos courtesy of Norland Products, manufacturer of the interferometer.

Singlemode Inspection By Interferometer

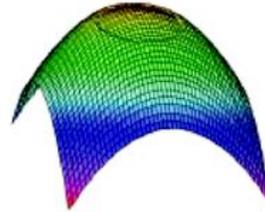
- Concentric “fringes” are interferometric
- Show center of domed polish
- Show consistency of dome



Interferometry produces a display that shows concentric circles light and dark circles called “fringes” caused by light interference. Fringes should be even and concentric. In addition, for normal PC or super PC finish connectors, they should center over the fiber. APC connectors will show a center for the fringes offset from the center of the fiber as shown here.

Singlemode Inspection By Interferometer

- Computer analysis of fringes can create an exaggerated 3D view of the fiber end
- Here you can see the domed polish and the end of the fiber



3D MESH DISPLAY
helps the user
visualize the surface
under inspection.

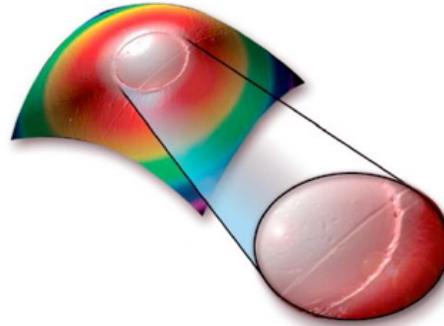


Computer analysis of fringes can create an exaggerated 3D view of the fiber end like this.

Here you can see the domed polish and the end of the fiber which is slightly inset from the ferrule end, which means it has been slightly overpolished. Because the computer exaggerates the end for better visualization, the actual surface is much less domed and fiber offset is very small.

Singlemode Inspection By Interferometer

- The exaggerated 3D view of the fiber end can easily show scratches and other surface defects.



Computer analysis of fringes can create an exaggerated 3D view of the fiber end like this.

The exaggerated 3D view of the fiber end can easily show scratches and other surface defects like you see here. You can also see the fiber is not fully polished to the ferrule surface.

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