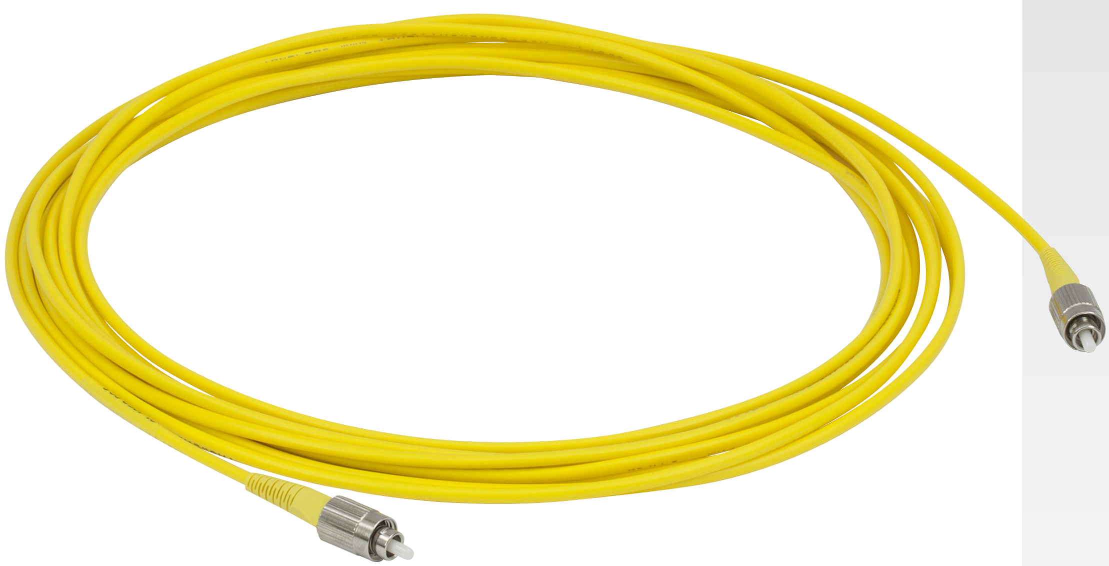
FN96A

Guide to Connectorization and Polishing Optical Fibers

- Cable Assembly
- Manual Fiber Polishing
- Manual Fiber Cleaving



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Chapter 1 Introduction and Safety

This Fiber Connectorization and Polishing Guide is intended for users with little or no experience with optical fibers. Part 2 describes the assembly of the fiber optical cable including installing the connectors. Part 3 details the steps involved in polishing the cable and connector end faces. Part 4 details the steps for cleaving manually cleaving the end of a fiber.

All statements regarding safety of operation and technical data in this instruction manual will only apply when the guide, tools, and procedures are followed correctly.

WARNING

Be aware of fiber fragments – also known as sharps – when working with optical fibers. Safety goggles must be worn at all times. Be cautious not to touch your eyes when working with optical fibers. Small fragments may cause serious eye damage.

WARNING

These fiber fragments can be small and can penetrate or irritate the skin. Fiber fragments should be picked up with tape and discarded immediately to avoid unnecessary contact.

WARNING

The solvents and epoxy used during the assembly and polishing procedures should be handled in accordance with manufacturers' recommendations. Rubber gloves and eye protection should be worn.

Note: This guide shows the assembly, polishing, and cleaving of only a small variety of fibers. There are many different compatibility issues when connectorizing optical fibers. For example, some hard clad fibers, such as Thorlabs' TECS clad fibers, have a TECS coating that is damaged by TRA-CON's F112 epoxy and require the use of F123 or 353ND epoxy. This guide discusses many of these fiber compatibility issues but may not be all inclusive. For any compatibility questions not addressed in this guide, please contact our tech support department.

Note: This document is intended as a general guideline to help individuals build and polish a fiber optic cable. Thorlabs does not claim that these procedures have been recommended by any fiber or connector manufacturer. Some steps in the procedures will vary with regards to the fiber and connectors being used. It is expected that individuals will modify these procedures as they develop their own technique.

Chapter 2 Fiber Optic Cable Assembly

Fiber connectorization begins with selecting an optical fiber and connector compatible with your system. This section covers a wide variety of single mode (SM) and multimode (MM) fibers and connectors. Visit www.thorlabs.com for a wide variety of optical fiber components. Once the fiber and connector are chosen, several standard and fiber/connector-specific tools are required for assembly. In this section, A complete parts list and fiber assembly procedure are provided.

2.1. Assembly Parts List

Required Parts and Tools:

- Optical Fiber to be Connectorized
- Optical Fiber Stripper (see Appendix A)
- Fiber Optic Connector
- Fiber Connector Crimp Tool (Item # CT042)
- Furcation Tubing (Ø3.0 mm - FT030, Ø3.8 mm - FT038, Ø900 µm - FT900SM)
- Fiber and Tubing Strip Tools (Item # FTS3, FTS4, or AFS900)
- Small Wire Snips/Kevlar Sheers (Item # T865)
- Standard 10x Eye Loupe (Item # JEL10)

Many of the required tools are included in the Thorlabs FiberOptic Termination Kit found at www.thorlabs.com.

- Fiber Optic Epoxy (see Appendix C)
- Epoxy Syringe (Item # MS403-10)
- Fiber Optic Scribe (Item # S90R)
- Kimwipes (Item # KW32) or Lint-Free Wipes (Item # LFW90)
- Calipers (Item # DIGC6)
- Wire Cleaner (Item # WC100)
- Rubber/Latex Gloves (Item # MC8-x)
- Reagent-Grade Isopropyl Alcohol*
- Glass Beaker*
- Safety Goggles/Glasses*

*Not available from Thorlabs

Figure 1 Thorlabs Fiber Optic Assembly Parts

2.2. Fiber Optic Cable Assembly Procedure

An optical fiber that has been connectorized using an FC/PC connector is shown in Figure 2 for reference.

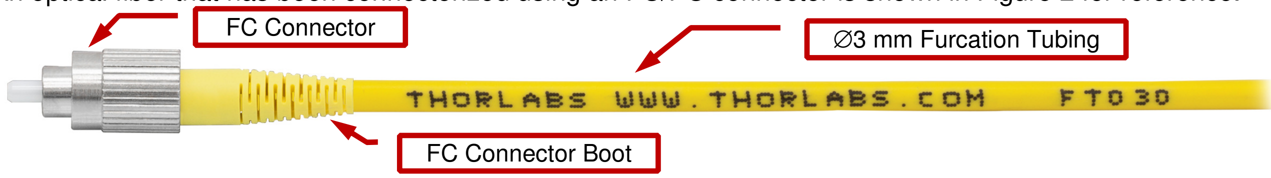


Figure 2 FC-Connectorized Fiber

The connectorization procedure in Chapter 2 is demonstrated using Single Mode (SM) fiber, Ø3 mm furcation tubing, and FC/PC connectors with ceramic ferrules. For details concerning the differences in the process for other fiber and connector types, please see Chapter 3.

Step 1: Clean Fiber Optic Connectors

Place the fiber optic connectors (see www.thorlabs.com for a complete list) in a beaker or large container and fill with enough reagent-grade isopropyl alcohol to completely cover the connectors. Let the connectors soak for a few minutes. After soaking, remove the connectors and place on a clean, dry surface. Shake any excess solvent off of the connectors, and place them aside to let the remaining solvent evaporate.

After the connectors have completely dried, inspect the ferrule to verify the capillary, which holds the optical fiber, is clear and free of debris. A light source may be used to facilitate inspection of the ferrule. Light should be clearly visible at the front of the ferrule when the light source is placed at the backside of the connector. Any debris should be removed either by resoaking the fiber or using clean, compressed air to gently flush out the ferrule. This holds true for both single and multimode connectors. Debris in the ferrule may interfere with the insertion of the optic fiber into the connector.

Step 2: Add Strain Relief Boots and Crimp Sleeves

Slip a strain relief boot and crimp sleeve included with the fiber optic connector onto the end of the furcation tubing as shown in Figure 3. The boot and sleeve may be secured using some tape.

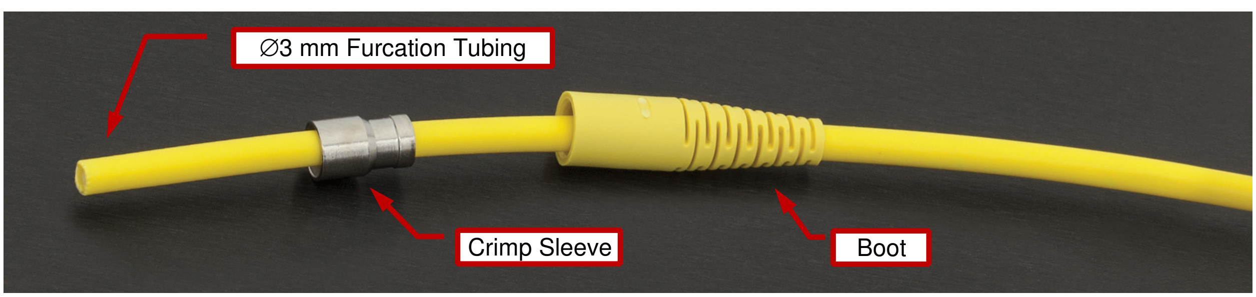


Figure 3 Furcation Tubing (Item # FT030-Y), connector crimp sleeve, and boot. (Crimp sleeve and boot come with connector Item # 30126C3)

Note: Furcation tubing should be selected based on the diameter of the fiber being connectorized and the application. Visit www.thorlabs.com for a wide selection of furcation tube sizes and colors. The most common furcation tubing sizes are Ø900 µm, Ø2 mm, Ø3 mm, and Ø3.8 mm.

Step 3: Cut Furcation Tubing

The furcation tubing forms the outer jacket of the completed cable, which protects the optical fiber. Figure 3 shows furcation tubing that is comprised of a PVC outer jacket, Kevlar protective threading, an inner tube, and a nylon pull string.

The furcation tubing should be cut so that it is approximately 26 mm longer than the desired length, allowing 13 mm per end to be stripped prior to insertion into each connector. Kevlar Scissors (Item # T865) can be used to easily cut through the protective Kevlar threads.

Step 4: Prepare Furcation Tubing

Strip one end of the furcation tubing using a stripping tool (Item # FTS3), exposing approximately 13 mm of Kevlar threads and inner tubing as shown in Figure 4a. Take care not to damage the inner tube or remove too much of the Kevlar threads.

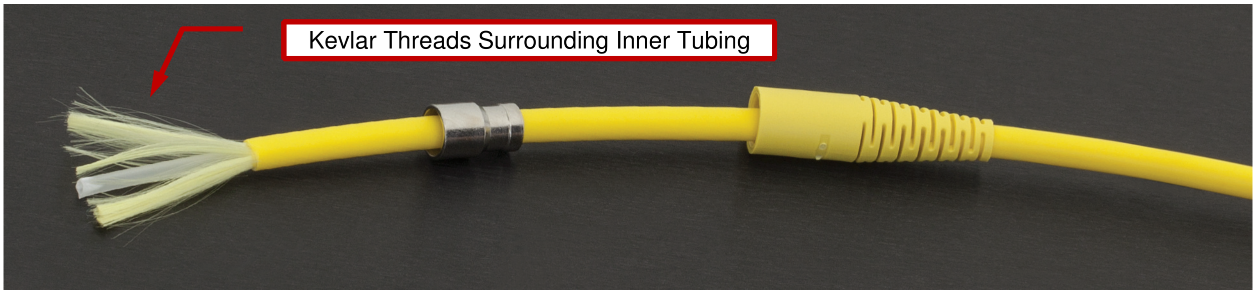


Figure 4a The furcation tubing after stripping 13 mm of the outer tube.

At this point, the Kevlar threads and inner tube should extend approximately 13 mm from the end of the furcation tubing. Trim the inner tube back so that it is the same length as the outer tubing, as shown in Figure 4b. Repeat this step for the opposite end of the furcation tubing.

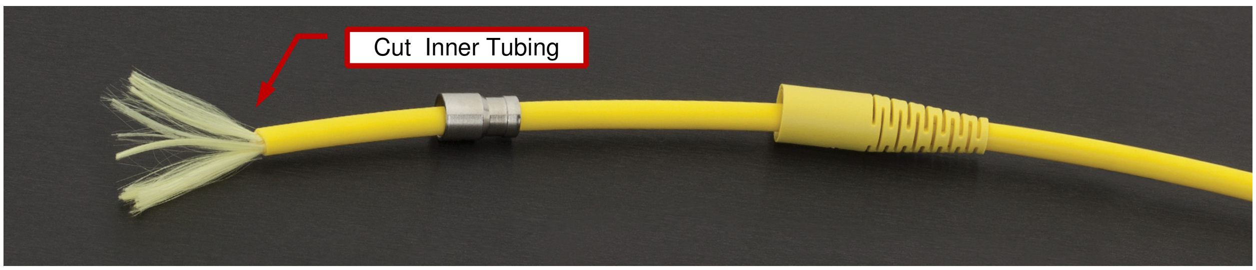


Figure 4b The inner tube is trimmed close to the length of the outer furcation tube.

Note: The exact length of the Kevlar threading that should be exposed depends on the connector type being used. Please refer to the length dimensions in Chapter 3 for other connector styles.

Step 5: Inserting the Optical Fiber into the Furcation Tubing

The standard Ø2 mm, Ø3 mm, and Ø3.8 mm furcation tubing (Item # FT020, FT030 series or FT038, respectively) have nylon pull strings, which aid in inserting small-diameter (usually SM) optical fibers into the inner tubing. Rigid or larger fibers, or shorter lengths, generally do not require the pull string for insertion into the inner tube.

If the pull string will be utilized, the optical fiber should be trimmed so that it is at least 13 **cm** longer than the furcation tube length. Prepare the pull string and fiber by cleaning both ends with isopropyl alcohol. Using a quick cure adhesive or epoxy such as super glue, secure the fiber and pull string together and allow enough time to dry or cure. Make sure the adhesive is completely dry and the bond between the fiber and pull-string is strong before trying to pull the fiber through the inner tubing. Talcum powder should be used after adhesive has dried to allow the bond to smoothly travel down the length of the tubing as it is pulled.

With the furcation tubing pulled straight, gently pull the pull string and fiber through the inner tube. As the fiber is drawn into the inner tube, make sure the fiber does not get caught or knot up inside the tubing. Be careful not to pull too quickly or too hard as the fiber or fiber/pull string bond may break. In addition, take care not to pull too much fiber through the inner tube leaving no fiber at the other end.

Optical fibers with larger diameters are usually rigid enough to push through the inner tube and do not require the pull string. If the pull string will not be used, it may be removed. The fiber should be trimmed so that it is 80 mm longer than the furcation tubing. It may then be inserted into the furcation tubing so that 40 mm of fiber protrudes from each end.

Step 6: Trim and Strip Fiber to Length

The optical fiber needs to be trimmed and stripped so that approximately 10 mm of stripped fiber protrudes from both fiber optic connectors. The total length of the optical fiber must also be controlled to allow proper assembly at both ends of the cable. Using Figure 5 as a guide, trim and strip the fiber so that specified amount of stripped fiber protrudes out of each end of the furcation tubing.

A sample optical fiber is shown in Figure 5. Please note the length of the exposed fiber, cladded fiber, Kevlar threading, and inner tube is dependent on the type of connector used. See Section 3.1 for the specific requirements for each connector type.

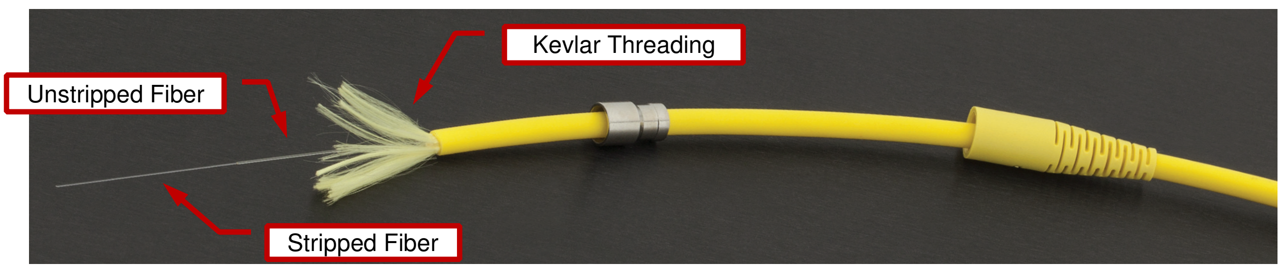


Figure 5 A properly trimmed and stripped optical fiber (SM Fiber, Item # SMF-28e) and furcation tubing (Ø3 mm, Item # FT030-Y) for an FC-style connector (Item # 30126C3).

Choose a fiber stripping tool (see Appendix A) whose cladding and coating ranges are compatible with the fiber being connectorized. For best results, remove the fiber optic jacket in a series of 3 mm to 7 mm pieces. See Appendix A for a full description of the fiber stripping tools offered by Thorlabs. Also, see the Note in Appendix A for specialty fibers.

Hint: Acetone may be used on silica/silica fibers to soften the acrylate jacket prior to stripping. Only the length of fiber to be stripped should be placed in acetone for a few minutes. If stripping is difficult, repeat the soaking process.

WARNING

Acetone should only be used on glass fibers. Many of the special coatings on multimode fibers can be damaged by acetone.

Step 7: Clean Optical Fiber

Some of the fiber cladding and/or buffer will remain on the fiber after the fiber is stripped. Remove this material by gently wiping the fiber with a Kimwipe moistened with reagent-grade isopropyl alcohol. Any debris left on the optical fiber will prevent proper insertion of the fiber into the ferrule.

Step 8: Test-Fit the Optical Fiber and Connector

At this point, the optical fiber and connector should be tested (without any epoxy) to ensure that the fiber fits into the connector and the length of exposed fiber is sufficient for connectorization.

After the solvent has evaporated from the fiber, slip the stripped fiber into the back end of the connector, as shown in Figure 6a. Slowly rotate the connector as the fiber is gently pushed through the ferrule. See Appendix B, troubleshooting, if the fiber does not easily pass through the connector. About 10 mm of stripped fiber should protrude from the tip of the ferrule.

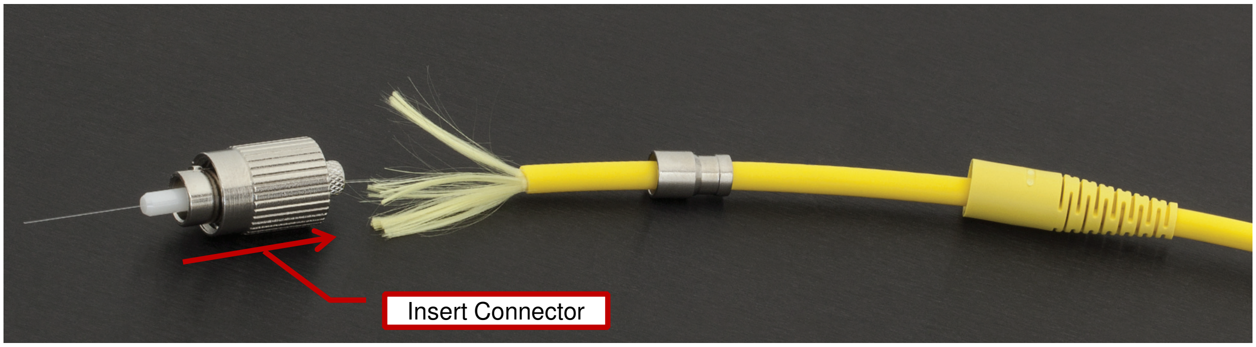


Figure 6a Inserting the fiber into the connector. Shown here is a SM Fiber (Item # SMF-28) and FC/PC connector with a ceramic ferrule (Item # 30126C3).

Slip the furcation tubing up against the back end of the first connector. Cut the Kevlar threads as shown in Figure 6b. Press the connector fully against the furcation tubing, and slide the crimp sleeve over the connector as shown in Figure 6c. Repeat this step for the other end of the cable.

Figure 6b The Kevlar threads being cut.

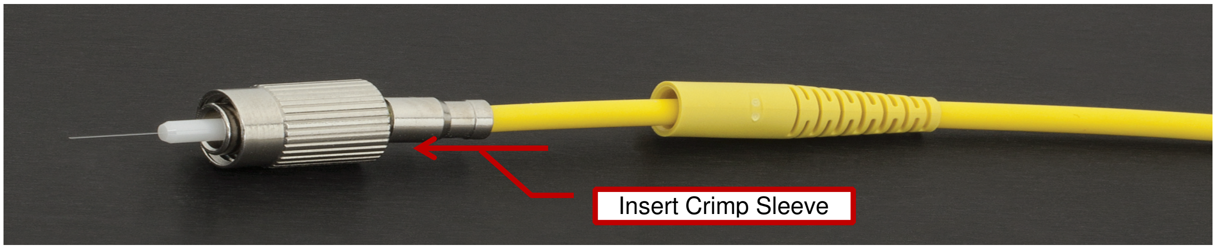


Figure 6c The fully inserted fiber and furcation tube.

If the fiber does not protrude 10 mm from both ends, after both connectors are seated against the furcation tubing, remove the connector from one end and adjust the length of the stripped section of the fiber and/or adjust the length of the furcation tubing.

Remove the connectors and set all the pieces aside.

Step 9: Prepare the Epoxy

For general purpose use on silica fibers, the F112, 2-gram epoxy BI-PAX is recommended. If you are using a TECS-coated fiber or any other fibers that are not made exclusively of glass, we recommend the F123 Epoxy. Call Thorlabs for details. The F112 Epoxy has a working life of about 30 minutes and 24-hour, room temperature cure. The F112 epoxy does not require a curing oven, but cure time can be accellerated if one is used.

Remove the separator bar on the epoxy BI-PAX, and mix the two parts by rubbing the package on the edge of your work table for one minute as shown in Figure 7. Take special care not to burst the epoxy package while mixing.

Figure 7 Mixing the epoxy (Item # F112).

After thoroughly mixing the epoxy, cut off the corner of the BI-PAX in preparation for loading the syringe (Item # MS403-10). With the syringe tip firmly threaded onto the syringe body, add the mixed epoxy to the syringe. Once the epoxy has been loaded, insert the syringe plunger and invert the syringe.

Leave the plunger positioned in the vertical position until the epoxy settles on the rubber piston; then slowly press the plunger into the syringe body expelling the trapped air through the needle. Continue pressing the plunger into the syringe until only epoxy is expelled. Wipe off any excess epoxy from the tip.

The epoxy in the syringe will now have a useful working time of about 30 minutes for large-core multimode fiber and about 15 minutes for single mode fiber, since single mode fiber is generally not as rigid as multimode fiber.

Step 10: Add Epoxy to the Connector

Insert the syringe into the back of the connector until it bottoms out within the ferrule. (Please see 3.2 for details on epoxy use with specific connector types.) While pressing the syringe plunger, maintain pressure between the syringe tip and the connector body. This pressure will ensure the epoxy injected into the connector flows mainly into the ferrule hole, rather than filling the rear area of the connector (see Figure 8). Continue injecting epoxy through the connector ferrule until a small bead appears on the outside face of the connector ferrule.

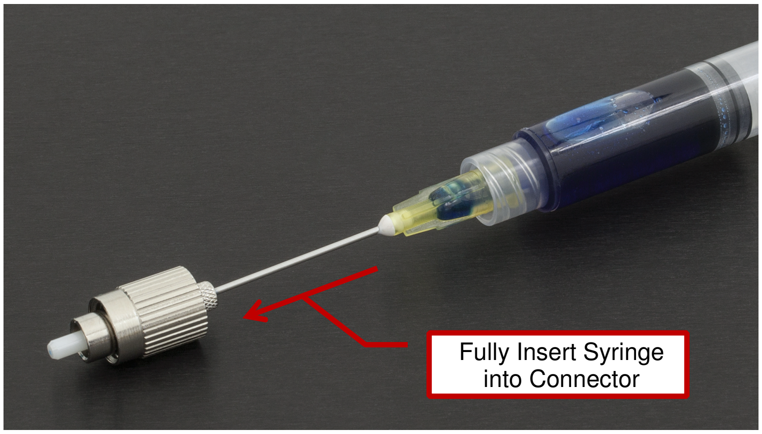


Figure 8 Injecting epoxy into the FC connector (Item # 30126C3).

Step 11: Insert Fiber into Epoxied Connector

Slide the fiber out of the furcation tube about 50 mm. Push the connector onto the fiber while slowly rotating the connector. This helps to both funnel the fiber into the connector and evenly distribute the epoxy between the fiber and the connector ferrule. Check for fiber breakage by sliding the connector back and forth, ensuring that the protruding fiber moves in and out of the connector.

Step 12: Fully Seat Connector

With the back end of the connector seated against the furcation tube, slide the crimp sleeve over the back end of the connector and the Kevlar threads as shown in Figure 9.

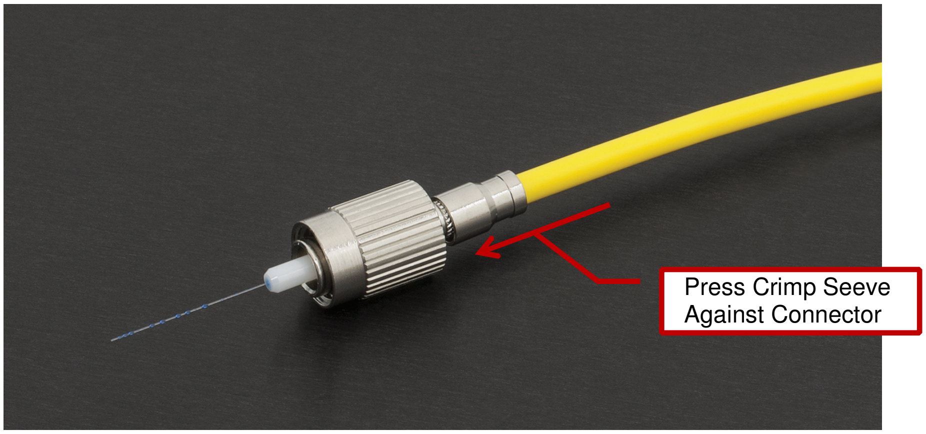


Figure 9 Seating the crimp sleeve into the FC connector (Item # 30126C3).

Step 13: Secure Crimp Sleeve

With the connector seated against the PVC jacket and Kevlar, use the 0.178" hex section of the crimp tool die (Item # CT042) to crimp the front portion of the sleeve as shown in Figure 10. Us the 0.151" hex to crimp the rear portion of the sleeve.

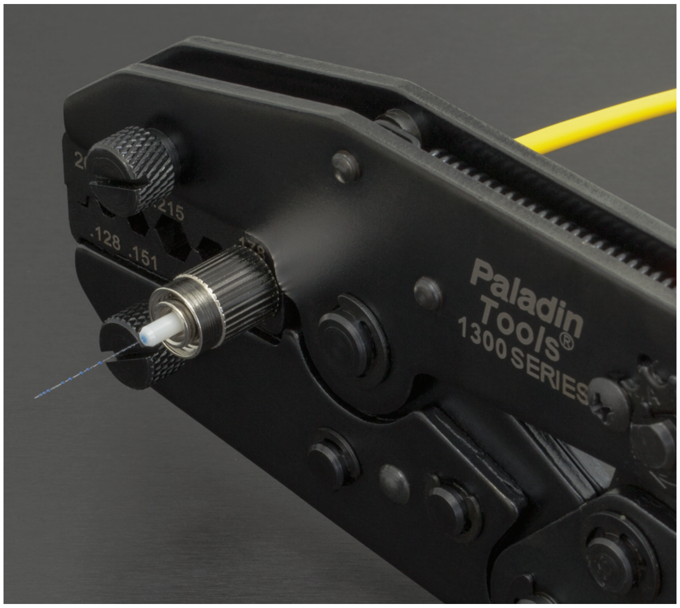


Figure 10 Fixing the crimp sleeve with Thorlabs' Crimp Tool (Item # CT042).

Step 14: Examine Epoxy Bead

The end of the connector must have a sufficient bead of epoxy to support the end of the fiber during polishing. Visually compare the connector end to Figure 11. If there does not appear to be sufficient epoxy dab on a small amount.

Figure 11 Proper sized epoxy bead on a SM fiber (Item # SMF-28e) and FC/PC connector (Item # 30126C3).

A short section of scrap fiber is ideal for applying epoxy since it is rigid enough and large enough to pick up a small bead of epoxy; at the same time, it is flexible enough to minimize the danger of breaking the fiber that protrudes through the connector.

Step 15: Secure the Strain Relief Boot

Add a small amount of epoxy where the crimp sleeve meets the furcation tubing, as shown in Figure 12. Slide the boot up onto the connector, leaving a small gap between the connector shell and the relief boot.

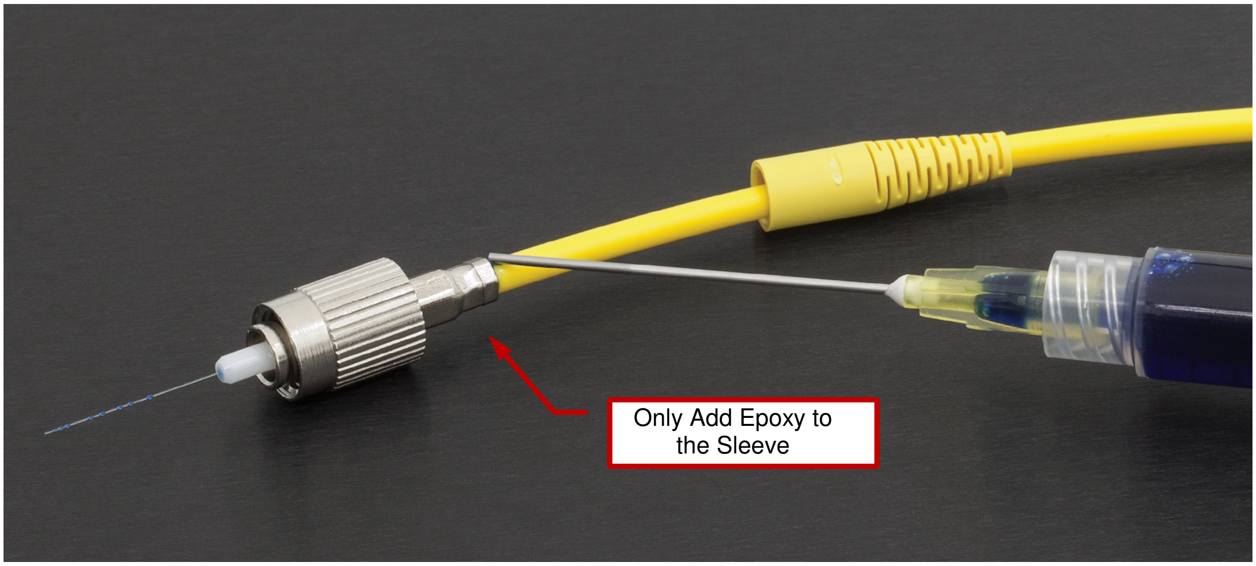


Figure 12 Add epoxy to the crimp sleeve and boot.

Note: Be careful not to apply too much epoxy in the sleeve/relief boot area, as excess epoxy on the boot can cause the boot to inadvertently adhere to the locking nut. The locking nut must move freely for the cable to operate properly.

Step 16: Check the Fit of the Second Connector

Test the connector on the second end of the fiber. The stripped section should protrude about 10 mm from the tip of the connector. If the fiber is too long, it may break during installation of the final connector. Trim the fiber to size, and strip enough of the fiber so 10 mm of stripped fiber protrudes from the ferrule. When stripping second end of fiber, extra care must be taken to ensure it does not recess in the first connectorized end.

Step 17: Connectorize the Second Connector

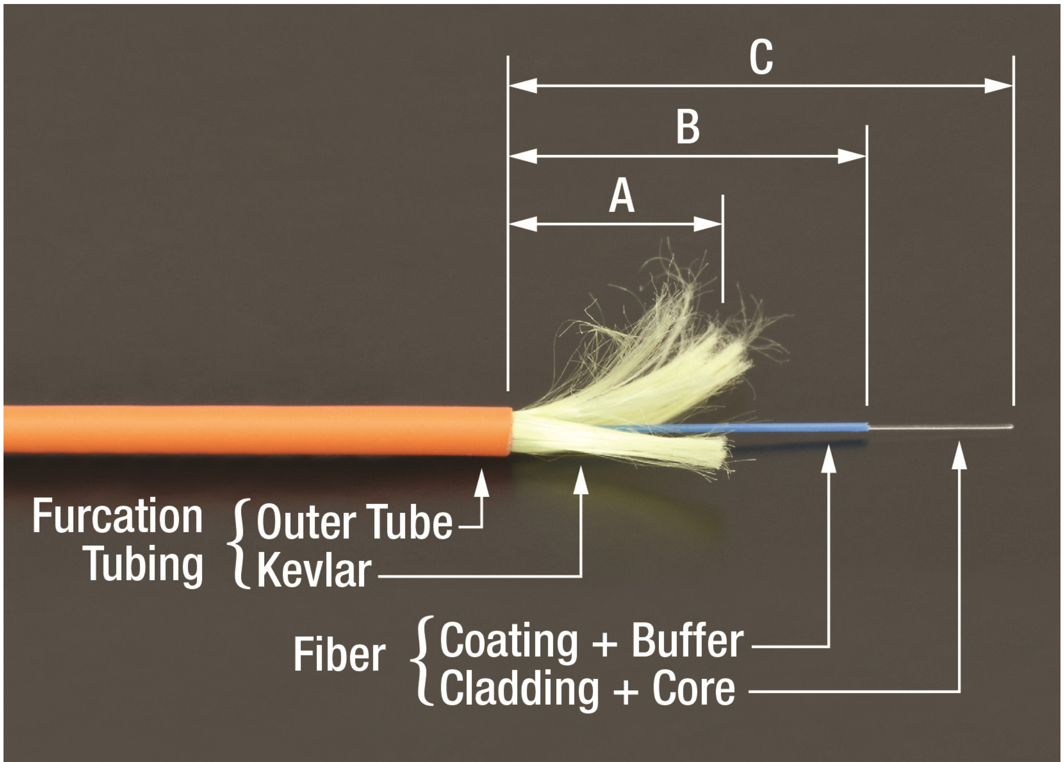
Repeat Steps 10 – 15 for the second connector. While connectorizing the first end, 50 mm of play is noted within the instructions. Since the first end is already secured, this play will not be present for connectorizing the second end. Please take steps to ensure the first end is not altered while the second end is being connectorized.

Step 18: Epoxy Curing

If the F112 epoxy was used, allow the cable assembly to cure overnight. The curing process can be accelerated by heating the connectorized ends of the cable. Refer to Appendix C for a list of commonly used epoxies, their pot lives, and respective curing times.

Chapter 3 Variations on Cable Assembly

3.1. Component Lengths for Popular Connector Types



Connector Type	A	B	C
SMA	7 mm	22 mm	32 mm
MM SS FC	5 mm	21 mm	31 mm
MM Ceramic FC	5 mm	15 mm	35 mm
SM Ceramic FC	5 mm	13 mm	33 mm
MM SS ST	7 mm	25 mm	35 mm
SM Ceramic SC	7 mm	17 mm	37 mm

Figure 13 Furcation tubing dimensions for popular fiber connectors.

Please note that the values in Figure 14 are approximate and assume crimp style connectors are used to attach the connectors to the furcation tubing. The actual fiber length may vary depending on the individual connector manufacturer.

3.2. Epoxy

3.2.1. Epoxy Types

Thorlabs offers three types of epoxies that are appropriate for use in different situations. The F112 epoxy, used in Chapter 2, is 24-hour room temperature cure epoxy. The F112 should not be used with TECS clad fiber (Thorlabs' part numbers FG* and FT*). The F123 and 353 ND epoxies require a heat cure at 100 °C and can be used with any of our current fiber offerings.

3.2.2. Epoxy Ammounts and Connector Type

The amount of epoxy required varies depending on the connector type. The table below indicates the correct epoxying procedure for the most common connector types.

Connector Type	Epoxying Instructions
SM Connector with Ceramic FC Ferrule	**Very small amount of epoxy required:** Locate the flange inside the back of the connector and carefully insert the syringe as far as it can go. Hold the tip of the syringe firm against the back of the ferrule and slowly apply pressure to the plunger until a small bead forms at the tip of the connector ferrule. Relieve pressure and remove the syringe.
Multimode Connector with Ceramic FC Ferrule	**Small amount of epoxy required:** Locate the flange inside the back of the connector and carefully insert the syringe as far as it can go. Apply pressure to the plunger until a bead forms at the endface of the ferrule. Slowly retract the syringe ~2 mm to allow a small amount of extra epoxy into the ferrule flange, relieve the pressure on the syringe then remove. If filled completely, the inserted fiber can displace some of the epoxy causing overflow. Overflow can result in excess epoxy leaking out of the flange, into the connector, and gluing the spring tight in place.
MM Connector with Stainless Steel FC Ferrule	**Moderate amount of epoxy required:** Locate the flange inside the back of the connector and carefully insert the syringe as far as it can go, taking note of the distance. Apply pressure to the plunger until a bead forms at the endface of the ferrule, then slowly retract the syringe until the ferrule and flange begin to fill with epoxy. Stop ~5 mm from the back of the flange and remove the syringe. If filled completely, the inserted fiber can displace some of the epoxy causing overflow. Overflow can result in excess epoxy leaking out of the flange, into the connector, and gluing the spring tight in place.
All SMA Connectors	**Large amount of epoxy required:** Insert syringe into the back of the connector as far as it can go. Apply pressure to the plunger and slowly retract the syringe until the connector body begins to fill with epoxy. Stop ~5 mm from the back of the connector so as not to overfill. If filled completely, the inserted fiber can displace some of the epoxy causing overflow. Overflow can result in excess epoxy gluing the SMA locking nut in place.

3.3. Furcation Tubing

The diameter and composition of the furcation tubing used effects the connectorization procedure detailed in Chapter 2. The table below highlights the differences in that procedure.

Furcation Tubing	Diameter / Composition	Connectorization Alterations
FT900SM	∅900 µm / Hytrel	In all cases of using ∅900 µm tubing, fiber buffer should be stripped close to flush with the end of the furcation tubing. While connectorizing, imagine the tubing as an extension of your buffer and insert it into the connector until it bottoms out against the back of the ferrule. It is important to remember that since there is no crimp sleeve used with FT900SM, the tubing and connector will not be secured together until the epoxy cures completely. Handle with care.
FT020	∅2 mm / PVC	∅2 mm tubing should be treated the same way as the FT030 3 mm tubing, but remember to use compatible crimp sleeves (190066CP-2) and boots (190066CP-1). The smaller diameter crimp back requires the 0.128 setting on your crimp tool.
FT030	∅3 mm / PVC	This furcation tubing is the one used in Chapter 2.
FT038	∅3.8 mm / PVC	∅3.8 mm tubing requires specific connector components, generally only available with SMA connectors. The front and the back of the crimp sleeve require the 0.178 setting on your crimp tool.
FT05SS	∅5.0 mm / Stainless Steel	Stainless steel ∅5 mm tubing uses our custom sleeves to secure the connector to the tubing rather than the boot used with the other tubing types. Three (3) different sized sleeves are available to accommodate our various connectors. These sleeves are secured with epoxy only, not using any kind of crimp. After the connector ferrule is filled with the proper amount of epoxy, epoxy should be placed around the stem of the connector and inserted into the smaller diameter of the sleeve. Begin inserting the fiber in to the connector ferrule then add epoxy to the end of the FT05SS tubing before sliding the sleeve over it. Slowly finish pushing the connector/sleeve onto the fiber/tubing until both are bottomed out against each other. Similar to the FT900SM, since no crimping takes place in this process, the bond is not complete until the epoxy cures so handle with care.
FT061PS	∅5.0 mm / Stainless Steel w/ black plastic sheath	This stainless steel tubing is identical to the ∅5.0mm FT05SS except that it is covered in a plastic coating for added protection. This tubing has its own (3) different sizesd sleeves to accommodate various Thorlabs connectors. Termination process is identical to that of ∅5.0mm version.

3.4. Fiber Type

Due to the difference in core sizes between SM and MM fiber, the connectorization procedure may vary.

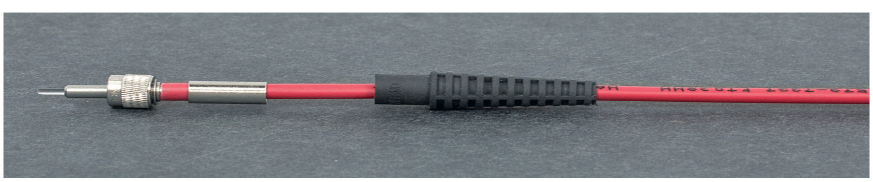


Figure 14 A Ø1000 µm hard clad fiber (Item # FT1000EMT) with a MM SMA connector (Item # 11040A).

Many large-core-diameter fibers will not fit inside the furcation tubing's inner tube. When connectorizing large-core-diameter fibers, remove the inner tube and Kevlar threads and slide the optical fiber into the outer jacket of the furcation tubing. Figure 14 shows a large-core optical fiber (Item # FT1000EMT) with SMA connector (Item # 11040A). The black rubber boot was trimmed so that it fits around the furcation tubing.

Chapter 4 Manual Fiber Polishing

After a fiber has been connectorized, the exposed fiber at the connector must be cleaved and polished to provide a low light loss connection. Improper polishing may lead to significant losses in the connection or a break in the fiber itself. In this section, a complete parts list and manual fiber polishing procedure are provided.

4.1. Fiber Polishing Parts List

Required Parts and Tools: (Shown in Figure 15)

- Glass Polishing Plate (Item # CTG913)
- Rubber Polishing Pad (Item # NRS913)
- Polishing Films: 30 µm, 6 µm, 3 µm, and 1 µm, and Final Polish (Item # LF30D, LF6D, LF3D, LF1D, and LFCF, respectively)
- Polishing Pucks for Appropriate Connectors (Item # D50-xx)
- Ruby Fiber Scribe (Item #S90R)
- Eye Loupe (Item # JEL10)
- Fiber Inspection Scope (Item # FS200)
- Compressed Air (Item # CA3)
- Kimwipes (Item # KW32) or Lint-Free Wipes (Item # LFW90)
- Mechanical Fiber Cleaver (Item # XL411) (Optional)
- Distilled Water and Reagent-Grade Isopropanol

Figure 15 Manual optical fiber polisihing parts available from Thorlabs.

4.2. Manual Fiber Polishing Procedure

The polishing process described here is for connectors with ceramic ferrules. Please see Chapter 5 for information on polishing connectors with stainless steel ferrules.

Step 1: Scoring the Fiber

Hold the connector as shown in Figure 16. Using a fiber scribe (Item # S90R), very lightly score the fiber just above the epoxy bead. Make sure the cutting edge of the scribe is held perpendicular to the protruding fiber. Ideally, the scribe should make contact with the fiber about one fiber diameter above the epoxy.

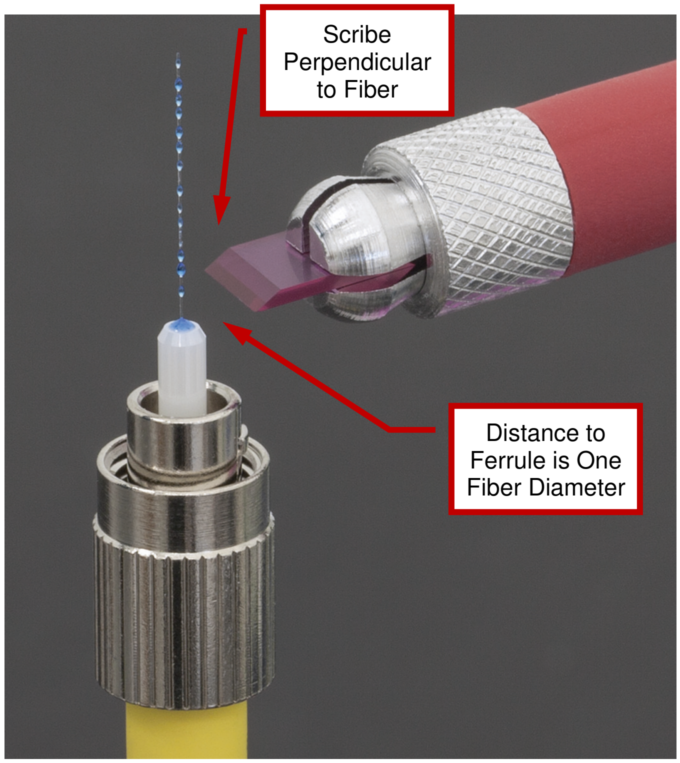


Figure 16 Scoring the optical fiber.

Note: The fiber should not break during scoring. Fiber breaking during scoring may lead to a fiber with a jagged edge and a fiber that cannot be polished correctly. The scribe only needs to gently touch the fiber to produce a score mark that will facilitate a clean fiber cleave.

Step 2: Cleaving the Scored Fiber

From the scored side of the fiber, gently squeeze the fiber tip and then pull along the mechanical axis of the fiber, directly away from the connector. The fiber should cleave easily at the score.

If the fiber does not cleave easily, rotate the fiber 180 degrees and rescore it. Cleave the fiber at the new score mark. Multimode fibers will require slightly more force to cleave because they have a larger core diameter.

Step 3: Inspection of the Cleaved Fiber

With a 5X or 10X magnifier or eye loupe (Item # JEL10), look at the cleaved end of the fiber. An ideal cleave leaves the fiber protruding no more than one fiber diameter above the epoxy bead.

If the fiber is cleaved below the epoxy bead, the fiber may not polish correctly. Continue with the polishing procedure as there may be enough fiber above the ferrule tip to polish properly. You will not be able to determine whether there is enough fiber until after you are done polishing away the epoxy bead.

If the fiber is protruding more than a fiber diameter above the epoxy bead, special care must be taken to prevent the fiber end from shattering during the initial polishing stages. Prevent any contact with the exposed fiber until the polishing steps are complete.

Step 4: Hand Polishing the Protruding Fiber

If the fiber is protruding from the surface of the epoxy bead, it must be gently hand polished before it can go through the normal polishing procedure.

To hand polish the protruding fiber, take a sheet of 30 µm polishing film (Item # LF30D) and cut a small section as shown in Figure 17. Fold the sheet over, and pinch the sheet while gently applying pressure to the fiber connector. Rub the fiber in a back and forth motion until it is flush with the epoxy bead. Repeat this step for all connectors.

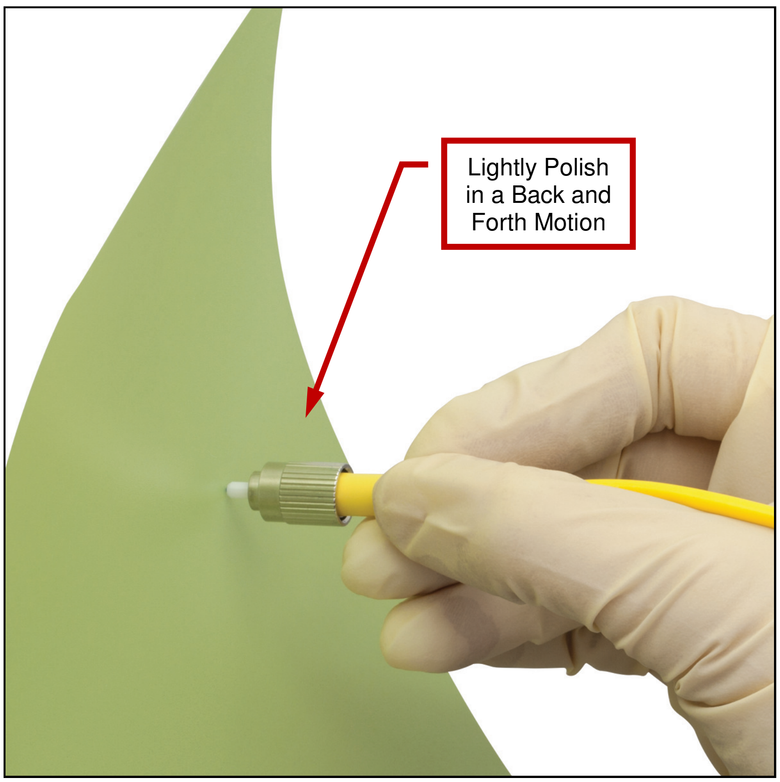


Figure 17 Manually polish the fiber using the 30 µm polishing film (Item # LF30D).

Step 5: Prepare Polishing Plate

Clean the surface of the glass polishing plate (Item # CTG913) with a lint-free towel moistened with isopropyl alcohol. If using PC-style connectors (with pre-radius), then clean and add the rubber polishing pad (Item # NRS913) to the top of the glass plate. The rubber polishing pad is added to maintain the radius of the connector end. For SMA-type connectors, no rubber pad is needed as the connectors have a flat end face.

Blow off the surface of the plate and pad using compressed air (Item # CA3). Any debris left on the plate or pad may prevent a flat, clean polish.

Step 6: Clean and Assemble the Polishing Disc and Connector

Clean the bottom surface of the polishing disc (Item # D50-xx) with a lint-free towel moistened with isopropyl alcohol. Use clean, compressed air to dry the disc and connector. Insert the connector into the polishing disc as shown in Figure 18. Pull the connector back until the fiber tip is recessed in the polishing disc. This ensures that the fiber end does not fracture upon initial contact with the polishing film.

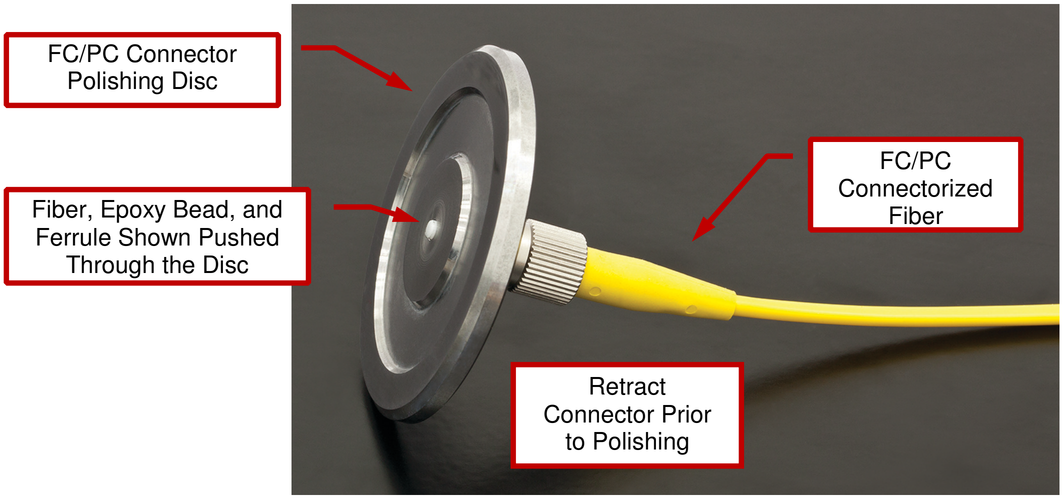


Figure 18 Insert the FC/PC connector into a polishing disc (Item # D50-FC).

Step 7: 30 µm Polish

IMPORTANT NOTE:

This is the most sensitive step in the polishing procedure! If the exposed fiber tip breaks below the epoxy bead, or if the fiber shatters, it is likely that the end will be excessively damaged and cannot be salvaged. If this occurs, it will be difficult to determine the extent of the damage until after the polishing procedure is complete. Therefore, complete the polishing procedure on the damaged fiber followed by a careful inspection of the fiber to determine whether the fiber can be used.

Place a sheet of the 30 µm polishing film (Item # LF30D) on the glass plate or glass plate + rubber polishing pad. With the fiber/connector recessed in the polishing disc, gently place the polishing disc on the film. Slowly advance the fiber/connector towards the film, allowing the fiber end to gently contact the film.

Without applying downward pressure, begin polishing the fiber in a figure eight pattern. If the fiber is making contact with the polishing film, a light figure eight will appear on the film. If no pattern appears, gently slide the connector into the polishing disc until light contact is made between the film and the fiber. A proper polishing pattern is shown in Figure 19.

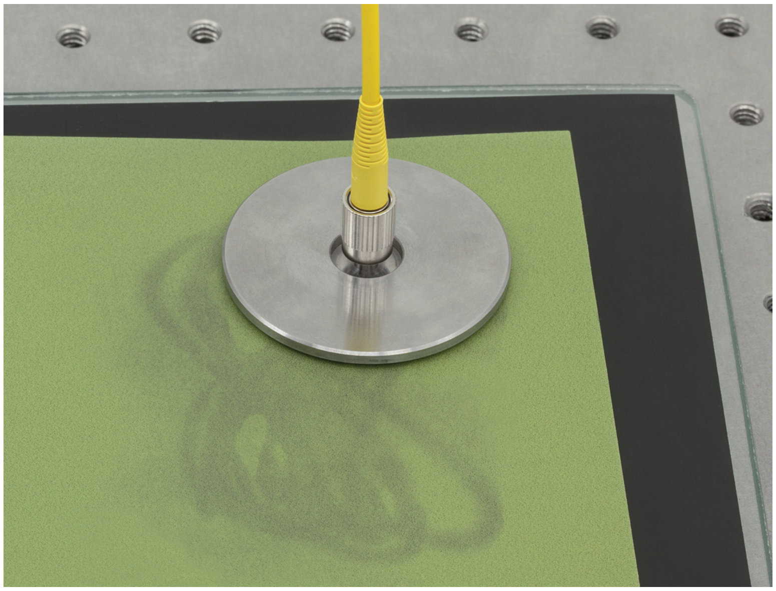


Figure 19 Polishing an FC/PC connector with a 30 µm polishing film on the Polishing Pad (Item # NRS913) and Polishing Plate (Item # CTG913).

As the fiber and epoxy bead are polished, pressure can be gradually increased between the connector and the polishing film. When the polished area of the epoxy is about 80% of the bead area, the downward pressure may be substantially increased.

While learning the polishing process, frequently inspect the fiber tip with the 10X Eye Loupe to determine if your connector is properly polished. Figure 20 shows an unpolished, partly 30 µm polished, and completely 30 µm polished connector. If any epoxy remains on the connector, clean the film and repeat this step. Use compressed air to clean the film and the polishing disc/connector each time you inspect the fiber.

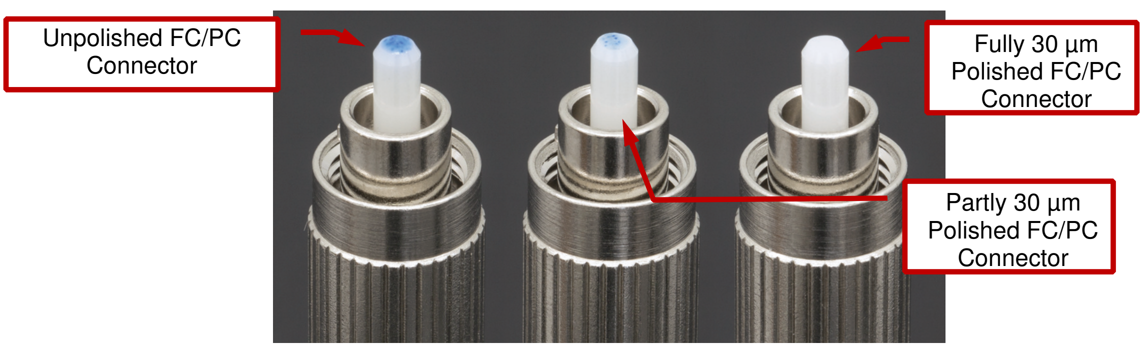


Figure 20 Three FC/PC connectors, from left to right, showing an unpolished, partly polished, and completely polished fiber using the 30 µm polishing film.

Continue polishing until the epoxy bead is removed from the ferrule tip as shown in the right-most connector in Figure 20. This state is reached when the outer edges of the epoxy begin to break up. When proper pressure is applied, a properly polished fiber should be achieved after approximately 10 figure eight polishing laps; the number of polishing laps will vary depending on the epoxy bead thickness and pressure applied.

The 30 µm polishing film can be reused for approximately 8 – 10 connectors. The film, polishing plate, and disc should be cleaned with a lint-free cloth moistened with isopropyl alcohol after each connector is polished. After polishing all of the prepared connectors, clean and remove the 30 µm polishing film from the plate.

Usage Tip: To increase longevity of the polishing film, store the different grits between paper towels to avoid cross contamination. Eg. 30 µm stacked on top of a 1 µm or final sheet could result in damage to the finer grit rendering it unusable.

Special Note: It is recommended that Diamond Polishing/Lapping Sheets (Thorlabs Item #LF1D, LF3D, LF6D, and LF30D for 1 µm, 3 µm, 6 µm, and 30 µm polishing sheets, respectively) be used over the standard aluminum oxide sheets when polishing ceramic or zirconia ferrules. Compared to aluminum oxide sheets, the diamond polishing sheets do not cause undercutting when polishing these connectors. Undercutting occurs when the fiber material is removed quicker than the ferrule material causing the fiber to recess within the ferrule. When the connector is mated to another connector, an air gap is created between the optic fibers instead of achieving a good glass-to-glass interface.

Step 8: 6 µm Polish

Clean the polishing plate and polishing disc with isopropyl alcohol and a lint-free cloth. Dry with clean compressed air. For PC connectors, the rubber polishing pad must be used on the plate. Wipe the rubber pad and shiny side of the 6 µm polishing film (Part # LF6D) with a lint-free cloth moistened with isopropyl alcohol. Place the 6 µm polishing film on the polishing plate (or rubber pad) with the shiny surface face down. Clean the connector ferrule before inserting it into the polishing disc.

Gently place the polishing disc on the polishing film. Applying light, downward pressure on the connector, begin polishing the fiber in a figure eight pattern as shown in Figure 21. Approximately 10 figure eights should be made while traversing the film. Inspect the end face with the fiber scope (FS200).

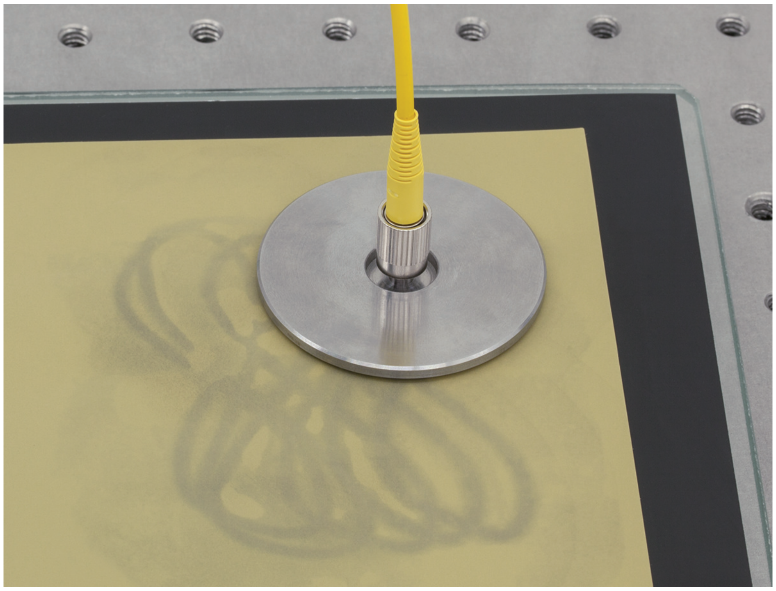


Figure 21 The 6 µm Polish

The 6 µm polishing film can be reused for approximately eight connectors. Carefully clean the film, polishing disc, and polishing plate after each connector. After polishing all of the prepared connectors, clean and remove the polishing film from the polishing plate.

Step 9: 3 µm Polish

Clean the polishing plate and polishing disc with isopropyl alcohol and a lint-free cloth. Dry with clean compressed air. For PC connectors, the rubber polishing pad must be used on the plate. Wipe the rubber pad and shiny side of the 3 µm polishing film (Part # LF3D) with a lint-free cloth moistened with isopropyl alcohol. Place the 3 µm polishing film on the polishing plate (or rubber pad) with the shiny surface face down. Clean the connector ferrule before inserting it into the polishing disc.

Place three to four drops of distilled water on one side of the 3 µm polishing film. Gently place the polishing disc on the water-soaked polishing film. Applying light downward pressure on the connector, begin polishing the fiber in a traversing figure eight pattern, moving towards the dry end of the film, as shown in Figure 22. Approximately 15 figure eights should be made while traversing the film. This number should be sufficient to finish polishing one connector.

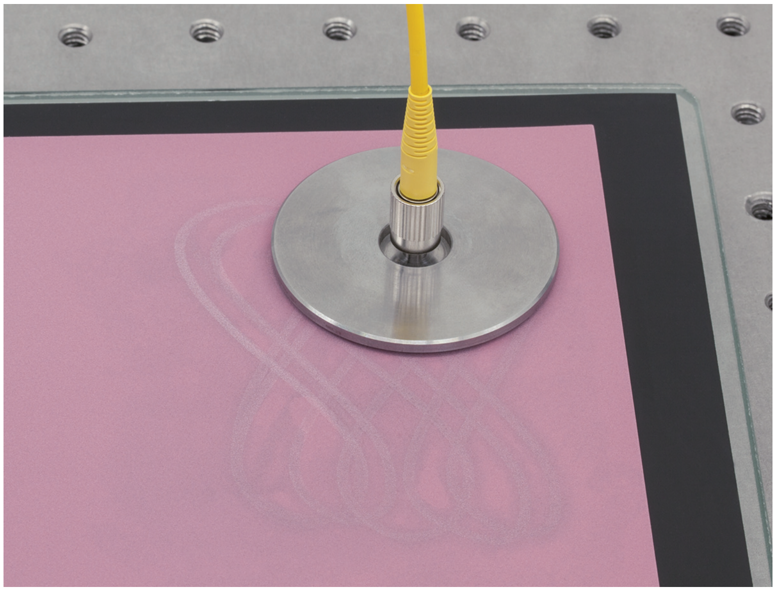


Figure 22 The 3 µm Polish

Inspect the connector with a 200X fiber microscope (Item # FS200). Clean the 3 µm film with a lint-free wipe and isopropyl alcohol. The 3 µm film can be reused for about two to four connectors as long as no deep scratches appear in the film. It is not recommended to use the 3 µm film more than four times.

Step 10: 1 µm Polish

Clean the polishing plate and polishing disc with isopropyl alcohol and a lint-free cloth. Dry with clean compressed air. For PC connectors, the rubber polishing pad must be used on the plate. Wipe the rubber pad and shiny side of the 1 µm polishing film (Part # LF1D) with a lint-free cloth moistened with isopropyl alcohol. Place the 1 µm polishing film on the polishing plate (or rubber pad) with the shiny surface face down. Clean the connector ferrule before inserting it into the polishing disc.

Place three to four drops of distilled water on one side of the 1 µm polishing film. Gently place the polishing disc on the water-soaked polishing film. Applying light downward pressure on the connector, begin polishing the fiber in a traversing figure eight pattern, moving towards the dry end of the film, as shown in Figure 22. Approximately 15 figure eights should be made while traversing the film. This number should be sufficient to finish polishing one connector.

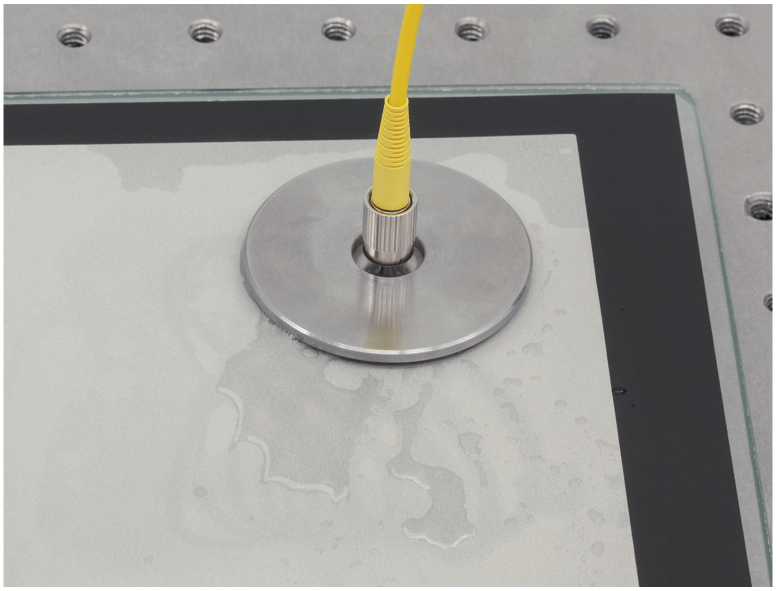


Figure 23 The 1 µm Polish

Inspect the connector with a 200X fiber microscope (Item # FS200). If any deep scratches or digs remain on the endface, clean the film and repeat this step.

Clean the 1 µm film with a lint-free wipe and isopropyl alcohol. The 1 µm film can be reused for about two to four connectors as long as no deep scratches appear in the film. It is not recommended to use the 1 µm film more than four times.

Step 11: Final Polish

An optional final polishing step can be performed using final polishing film (Item # LFCF). The LFCF film is clear so be sure the shiny side is facing down for the correct polish. Place three to four drops of distilled water on the film. Place the polishing disc and connector on the water and make two or three figure eight patterns, always polishing on a fresh, clean piece of the film as shown in Figure 24. This step should result in a finer polish than that achieved from the 1 µm polish and result in lower light losses.

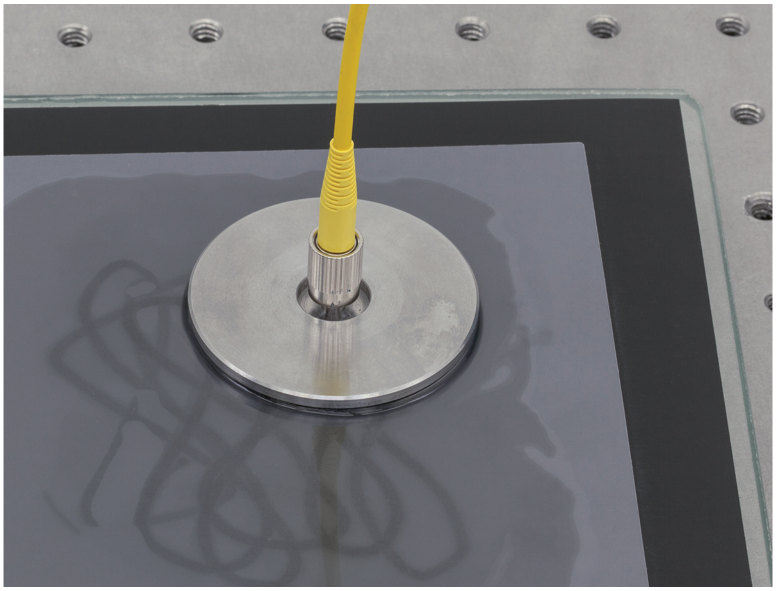


Figure 24 The Final Polish

Note: The final polishing step may cause additional scratches to form on the fiber end if the polishing is performed incorrectly. If this happens, repeat the 3µm and 1µm polishing steps to remove these surface scratches.

Step 12: Final Inspection

After polishing, remove the connector from the polishing disc and clean the connector ferrule with isopropyl alcohol. Using a 200X inspection microscope (Item # FS200), ensure the following:

- The connector end surface is free of epoxy
- The fiber is flush with the end of the connector ferrule
- There are no heavy scratches through the core of the fiber. Light, random scratches in the fiber cladding are acceptable. However, the majority of the area of the fiber should be free of all visible scratches or defects. Magnified views of a well polished and a poorly polished fiber are shown in Figure 24.
- The core of a multimode fiber can have a few light random scratches. However, the core and region around the core of a single mode fiber should have no visible scratches.
- There can be light random scratches across the connector end provided:
  - There are no chips of the fiber that extend into the core of the fiber.
  - There are no more than two chips in the edges of the fiber, such that the length plus the width of these chips does not exceed 20% of the circumference of the fiber.

If the connector fails to pass any of the final inspection checklist items pertaining to scratches, repeat steps 9 through 10. If any chips are noticed, the polishing steps may be repeated; however depending on the depth of the chip, the fiber may or may not be salvageable.

The images below are Single Mode fiber endfaces shown through a 400X scope. The cladding is the dark grey ring and the white background is the ferrule. The small light grey circle in the center is the core. Figure 25a shows a successfully polished fiber. Figures 25b, c, and d depict common errors and describe how to fix them.

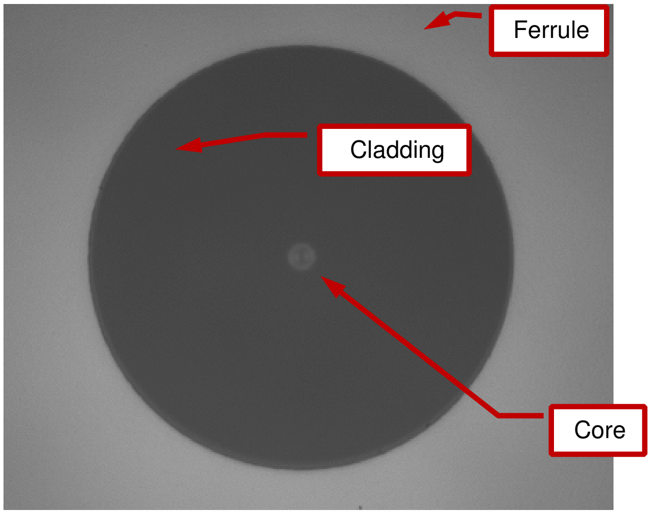


Figure 25a Clean Polished Endface: This is how a successful final polish should appear.

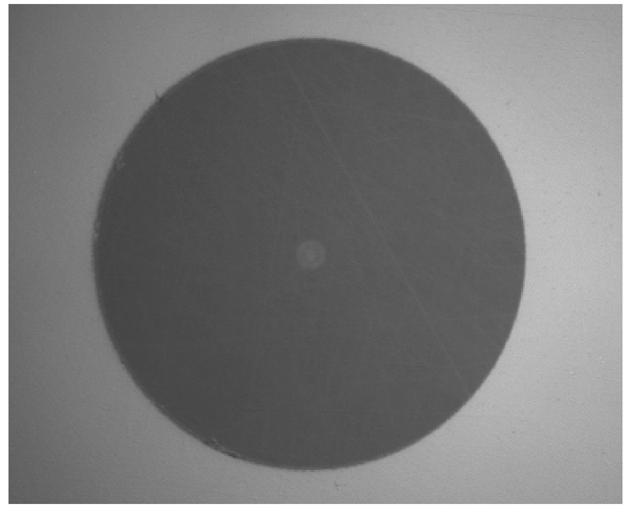


Figure 25b Light Scratches: Clean the polishing sheet and puck. Repeat the final polish step until a polished end face is achieved. Additionally, this is how the endface should appear after 1 µm polishing.

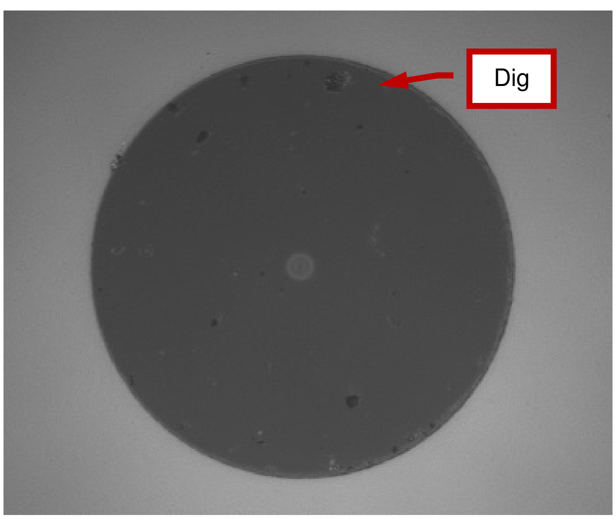


Figure 25c Small Digs: This is the result of moving to the final polish step too soon. Clean polishing sheet and puck, return to the 1 µm polishing step until you achieve a polish similar to that in Figure 25b before you move to final polishing.

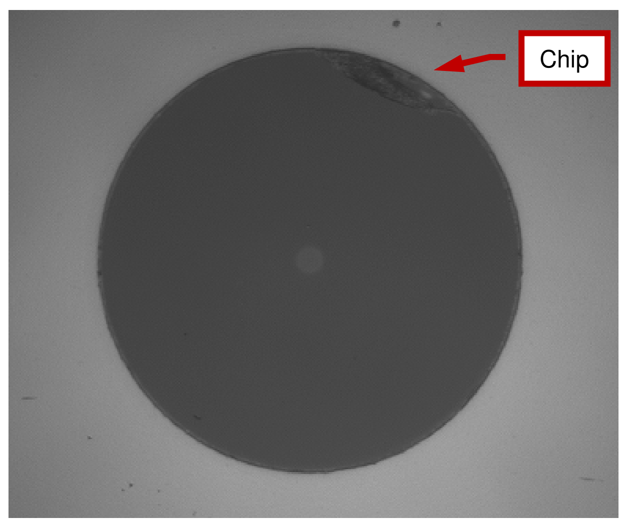


Figure 25d Cracks / Chips: This is a result of a poor rough polishing by hand where a linear crack occurs below the surface of the fiber. If a chip or crack is observed, return to the the 30 µm step and repeat the entire process. Check the fiber often until it is polished down below the crack. If the crack is still present, the end must be reconnectorized.

Chapter 5 Variations on Polishing

The polishing procedure detailed in Chapter 4 shows how to polish a Single Mode FC/PC connector with a ceramic ferrule. The table below highlights the differences in the polishing procedure with other connector types.

Connector Type	Polishing Procedure Alterations
SM Connector with Ceramic FC/PC Ferrule	The process currently outlined in Chapter 4 shows the proper procedure for hand polishing FC/PC ceramic ferrules. This is also compatible for all other connectors which use ∅2.5 mm ceramic ferrules (ST, SC/PC, FC/APC, bare ferrules) as long as the proper puck is used.
MM Connector with Stainless Steel FC/PC Ferrule	The process is the same for stainless steel except for the final step. Our LFCF final polish sheets are ***not*** compatible with steel ferrules. We recommend our aluminum oxide sheets for this step task (LFG03P). This is true for all ∅2.5 mm steel ferrules.
All SMA Connectors	For SMA connectors, only the CTG913 glass plate is used. Set aside the rubber sheet to achieve a flat polish. A height gauge (10125HG) is recommended for maintaining the proper ferrule height. We recommend the aluminum oxide sheets for these connectors (LFG5P, 3P, 1P). Please remember the LFG03P (aluminum oxide final polish sheet) is required for ***ALL*** stainless steel ferrules.

Chapter 6 Manual Fiber Cleaving

Bare fiber may be cleanly and easily cleaved using manual (shown in Section 4.2) or automatic (Mechanical Fiber Cleaver Item # XL411) methods. In this section, a list of tools to cleave bare fiber and the manual fiber cleaving procedure are provided. The mechanical cleaver is useful for cleaving large quantities of bare fiber.

6.1. Fiber Cleaving Parts List

Required Parts and Tools: (shown in Figure 26)

- Ruby Fiber Scribe (Item # S90R)
- Mechanical Fiber Cleaver (Item # XL411)
- Fiber Stripping Tool (see Appendix A)
- Eye Loupe (Item # JEL10)
- Water Dispenser
- Compressed Air (CA3)
- Kimwipes (Item # KW32) or Link-Free Wipes (Item # LFW90)
- Masking or Cellophane Tape
- Reagent-Grade Isopropyl Alcohol*
- Glass Beaker*
- Safety Goggles/Glasses*

*Not Available from Thorlabs

Figure 26 Tools for the manual cleaving of an optical fiber.

6.2. Manual Fiber Cleaving Procedure

Step 1: Strip and Clean the Fiber

Using the proper fiber stripping tool (see Appendix A), remove approximately 50 mm of the jacket and buffer from ond end of the fiber to be cleaved. For best results, remove the cladding in sections of 3 mm – 7 mm lengths. Clean the stripped fiber using a lint-free wipe moistened with isopropyl alcohol.

Hint: Acetone may be used on silica/silica fibers to soften the acrylate jacket prior to stripping. Place only the length of fiber to be stripped in acetone for a few minutes. If stripping is difficult, repeat the soaking process.

Note: Acetone should only be used on glass fibers. Many of the special coatings on multimode fibers are damaged by acetone.

Step 2: Secure Fiber to Bench

Carefully tape the stripped edge of the fiber to the edge of a bench or work station, allowing approximately 6 mm between the edge of the table and tape, as well as the table and jacket/buffer. See Figure 27 for the correct orientation.

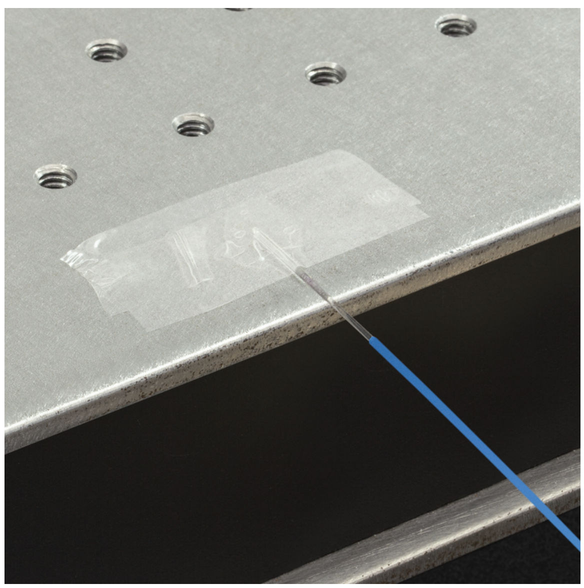


Figure 27 Securing a ∅1000 µm optical fiber (Item # FT1000EMT) to the work bench.

Hint: Secure the free end of the fiber to a support to prevent it from breaking on the edge of the bench. The weight of even a short section of fiber may cause the fiber to break.

Step 3: Scribe and Cleave the Fiber

While pulling the fiber taut, bring the cleaving tool to the fiber and gently scribe the fiber, perpendicular to the fiber as shown in Figure 28. (This is the critical step in obtaining a good cleave.)

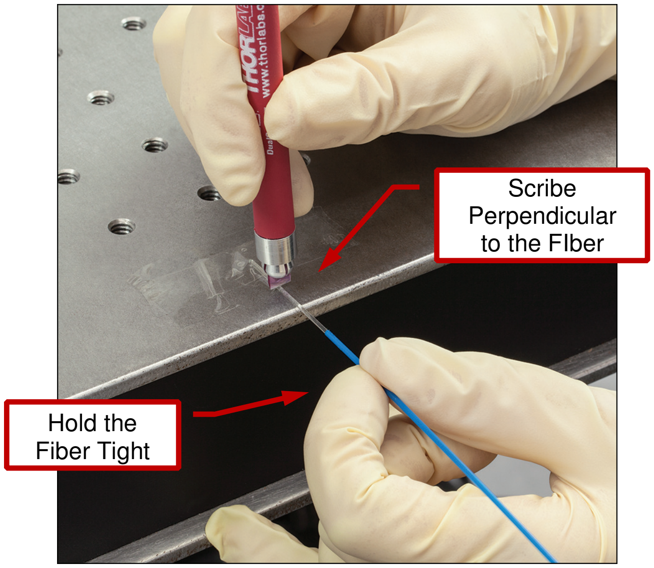


Figure 28 Scoring the ∅1000 µm optical fiber (Item # FT1000EMT) with a ruby scribe (Item # S90R).

If the scribe is made too hard, the fiber will break instead of cleaving. If the scribe is too light, the fiber will not cleave. Whether the fiber was scribed correctly will not be known until after the fiber is cleaved.

To cleave the fiber, place a drop of water on the cleave site. Then, while pressing on the taped end of the fiber, pull the fiber straight back until the fiber cleaves as shown in Figure 29.

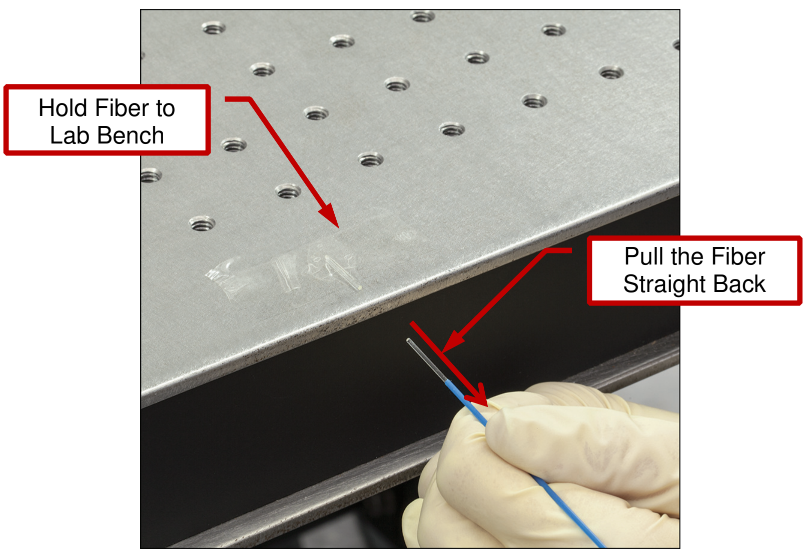


Figure 29 Cleaving the Optical Fiber

Step 4: Inspect the Cleaved End

The end of the fiber may be inspected with an eye loupe or microscope. A good cleave will be flat across the fiber and perpendicular to the optic axis. There should be no ‘tag’ (i.e., protrusion) from the edge of the fiber. The region where the initial scribe was made may be visible. It should be less than 5% of the core diameter. If the cleave is not acceptable, repeat steps 1 through 4. Be patient as this process takes a little practice. Please be aware that it will be more difficult to achieve a high-quality cleave in large-core-diameter fibers compared to thinner fibers.

Appendix A. Fiber Stripping Tool Selection Guide

Thorlabs provides a wide assortment of fiber for many different industries and applications. Therefore we offer fiber stripping tools, shown in Figure A1, for fibers with core diameters from 80 µm to 1.5 mm.

Figure A1 Fiber stripping tool with the blade removal tool, guide lock, replacement blades, replacement guide, and cleaning brush.

The fiber stripping tool features replacement blades and fiber guides. The location of the replacement blades, fiber guide, and fiber guide lock are shown in Figure A2. To replace the blades, locate the white blade removal tool, shown in Figure A1. Insert the removal tool into the fiber stripper and press down. The blades should pop out of the tool. Insert the removal tool into the fiber stripper near the fiber guide and depress to remove the fiber guide lock. Remove all components.

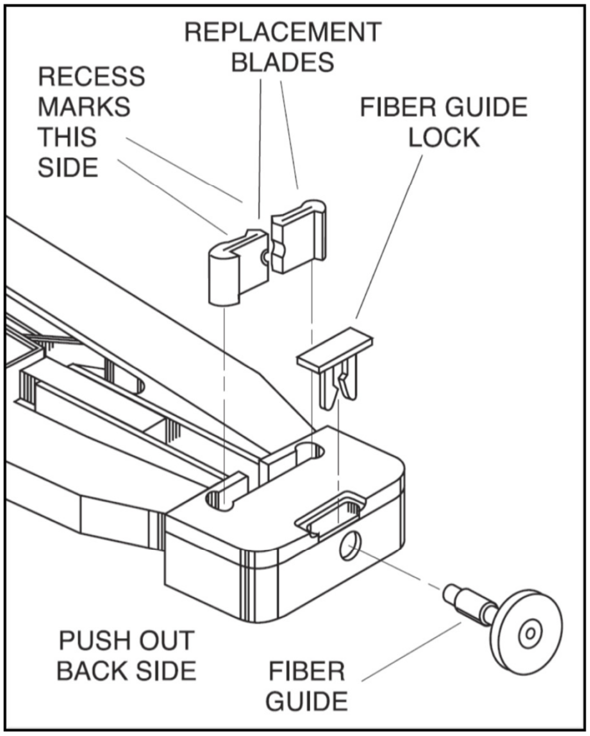


Figure A2 Fiber stripping tool.

To determine the proper stripping tool for your optical fiber:

1. Note the CLADDING and the COATING diameters along with their respective high side tolerances.

2. In Table A1, Look for those diameters in the second column of the table.

3. With your fiber size identified in the table below, verify whether the high side tolerances fall within the CLADDING RANGE and the COATING RANGE. If the maximum fiber dimensions fall outside the range shown, choose the next largest tool.

Table A1. Compatible cladding and coating diameters for different optical fiber stripping tools.

Item #	Typical Fiber Cladding/Coating Diameters (µm)	Cladding Diameter Range (µm)	Coating* Diameter Range (µm)
T04S10	80 / 170	65 – 80	150 – 250
T06S13	125 / 250	125 – 135	250 – 343
T06S16	125 / 400	125 – 135	250 – 343
T08S13	125 / 250	125 – 175	250 – 343
T08S40	125 / 900	125 – 175	889 – 1016
T10S13	200 / 300	180 – 230	250 – 343
T12S16	250 / 400	235 – 280	343 – 407
T12S18	250 / 430	235 – 280	407 – 457
T12S21	250 / 500	235 – 280	457 – 533
T12S25	250 / 580	235 – 280	533 – 635
T14S21	285 / 500	285 – 330	457 – 533
T16S31	360 / 650	335 – 380	635 – 787
T18S31	400 / 730	385 – 430	635 – 787
T23S31	500 / 730	505 – 550	635 – 787
T23S46	500 / 1000	505 – 550	1016 – 1168
T28S46	630 / 1040	605 – 680	1016 – 1168
M37S46	860 / 1080	835 – 900	1016 – 1168
M37S63	860 / 1400	835 – 900	1397 – 1600
M44S63	1035 / 1400	905 – 1050	1397 – 1600
M44S67	1035 / 1600	905 – 1050	1600 – 1702
M54S76	1250 / 1850	1055 – 1350	1778 – 1930
M63S86	1550 / 2000	1390 – 1600	2057 – 2184

*Coating refers to the jacket/coating and buffer (where applicable) that is being removed.

For a complete, up-to-date version of this table, please see our website: **www.thorlabs.com**.

Note: A standard fiber is usually comprised of a silica or glass core, wrapped in a cladding layer and an acrylate outer jacket buffer. This buffer material must be removed/stripped in order to properly connectorize the fiber. Some specialty and multimode fibers may contain a second cladding material (usually a hard polymer) between the cladding layer and buffer. In most cases,

The fiber optic stripper features replaceable blades, guides, and guide lock as shown in Figure A1 and A2. Contact tech support for more information.

Appendix B. Troubleshooting

If the fiber does not fit through the connector check the following:

- The connector ferrule diameter is sufficient to accept the maximum fiber cladding diameter.
- Ensure that enough of the fiber jacket (and buffer where applicable) has been removed to allow the fiber to pass through the connector. If in doubt, strip off some extra jacket.
- Visually inspect the ferrule to ensure the capillary is clear by holding the connector up to a light. With the connector 30 cm to 45 cm from your eye, light should be clearly visible through the connector body. This holds true for both single mode and multimode connectors.
- Try another connector. The tolerance on the ferrule hole size allows some variation from connector to connector.

If none of these suggestions solve the problem, contact Thorlabs technical support for assistance.

Appendix C: Epoxy Schedule

Item #	Pot Life	Cure Time 25 ℃	Typical Cure Schedule	Operating Temperature	Cured Color
F112*	40 Minutes	18 Hours	1 Hour @ 65 ℃	-60 to 110 °C	Blue
F120*	5 Minutes	18 Hours	1 Hour @ 25 ℃	-60 to 115 °C	Straw
F123	4 Hours	No Cure	5 Minutes @ 100 ℃	-60 to 175 °C	Reddish-Amber
353NDPK	4 Hours	N/A	1 Minute @ 150 ℃	-50 to 200 °C	Dark Red
			2 - 5 Minutes @ 120 ℃		
			5 - 10 Minutes @ 100 ℃		
			15 - 30 Minutes @ 80 ℃		

*Not recommended for hard polymer clad fiber.

Please contact Thorlabs' Tech Support with any question on compatible fiber epoxies.

Chapter 7 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

- This offer is valid for Thorlabs electrical and electronic equipment:
- Sold after August 13, 2005
- Marked correspondingly with the crossed out "wheelie bin" logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated

Wheelie Bin Logo

As the WEEE directive applies to self-contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:

- Pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

7.1. Waste Treatment is Your Own Responsibility

If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

7.2. Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

Chapter 8 Thorlabs Worldwide Contacts

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