The Fiber Optic Association Inc.
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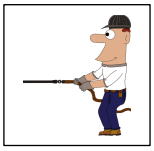


Fiber U Basic Skills Workbook

Fiber Optic Cable Termination

What You Will Learn:
How to prepare cables for termination
How to terminate fibers with basic adhesive/polish connectors and/or other types
How to inspect polished connectors
How to test connectors for insertion loss

Exercises:
Cable Preparation
Fiber Preparation
Adhesive (Epoxy, anaerobic, HotMelt) Preparation
Connector Attachment
Cleaving
Polishing Multimode Connectors
Testing the Patchcord
Terminating Buffered Fiber

Visual Aids
The following visual aids show the processes described in these exercises.

FOA YouTube Videos
(https://foa.org/tech/ref/contents.html#YT)

- Fiber Optic Stripping Tools
- Visual Inspection of Connectors With A Microscope
- Fiber Optic Termination, Part 1, Setup & Tools
- Fiber Optic Termination, Part 2, Jacketed Cable Prep
- Fiber Optic Termination, Part 3, Adhesive Prep
- Fiber Optic Termination, Part 4, Stripping Fiber
- Fiber Optic Termination, Part 5, Connector Attachment
- Fiber Optic Termination, Part 6, Polishing
- Fiber Optic Connector Polishing Technique
- Fiber Optic Termination, Part 7, Inspection
- Fiber Optic Termination, Part 8, Distribution Cable Termination
- FOA Online Reference Guide To Fiber Optics:
- Prepolished/Splice Connector Termination (Corning Unicam)
- Prepolished/Splice Connector Termination (Panduit OptiCam)

Virtual Hands-On (VHO) Instructions
(https://foa.org/tech/ref/contents.html#Components)

Each type of fiber optic termination has a VHO – a virtual hands-on instruction that provides step-by-step instructions in more detail for that method. Download the appropriate VHO for your exercises.

- Epoxy/Polish
- Anaerobic
- Hot Melt
- Prepolished/splice connectors
- Singlemode fiber termination

Safety:
All students and instructors must wear safety glasses in this lab.
Follow all safety rules for working with fiber.
Safely dispose of all fiber scraps and cables after use.

Adhesive/Polish Connectors

Tools And Materials Needed

Termination Toolkit

Lab Table Setup

Fiber Optic Stripper
Crimp Tool
Polishing puck
Aramid Yarn Scissors
Scribe
Cable Jacket Stripper
Cable: 3 mm jacketed fiber optic cable, 1-2 m (3-6 ft)
6 ST or SC connectors (connector, crimp sleeve, and strain relief boot),

Adhesive, Epoxy, 2 epoxy syringes, Curing Oven or Anaerobic (Loctite 648)
Curing over for epoxy or HotMelt connectors
Wipes
Polishing Film films (12, 3 and 0.3 micron)
Polishing Plate (Glass or plastic) and Rubber Pad
Microscope with ST, SC or universal stage
3 mm jacketed fiber optic cable, 1-2 m (3-6 ft)

Before starting this session, review the process at the Virtual Hands-on Termination Session on the FOA Online Guide, view the YouTube videos on Termination or read the sections in the Termination PPT

Fiber Optic Connector Termination Overview

It was not long ago that the proper methods used to terminate fiber optic connectors were tedious and the labor involved was a big concern. However, in the last decade, manufacturers have developed new types of cable, connectors and termination methods that make fiber termination quick and easy.

Some of the old methods are still in use today. Every patchcord, millions per year, are built in factories using standard heat-cured epoxy/polish termination processes, except usually with automated polishing machines doing the polishing.

Progressive installers have been fast to accept many of these new products and procedures. It has been the development of these newer products and techniques that has led to the accelerated use of fiber in the marketplace.

In this section, we will examine the most common methods of fiber optic connector termination used in the field, epoxy/polish. (The next most common types are anaerobic adhesive, HotMelt, SOCs (splice-on connectors), prepolished/splice. Please note that the points examined here are generic in nature and will vary somewhat from manufacturer to manufacturer.)

In this lab, we will terminate fiber optic cables using ST or SC style connectors of adhesive/polish type, typically the “epoxy and polish” type. This is the most basic type of termination and most widely used, due to its low cost. Other types include “anaerobic/polish”, “HotMelt” or “anaerobic” adhesives will be described also. All types use adhesive to hold the fiber and are polished to get a good optical finish for mating to another connector.

Once you know how to terminate with this type, you can easily follow the instructions for any other type. Prepolished/splice connectors (PPS) are becoming more popular in the field but are expensive to teach because they require special tools and expensive connectors. Fusion splice-on connectors (SOCs) are becoming even more popular because the special fusion splicers are not much more expensive than the PPS tooling and the connectors are comparable to HotMelt connectors. Use the Termination PPT section on them to review the process with students.

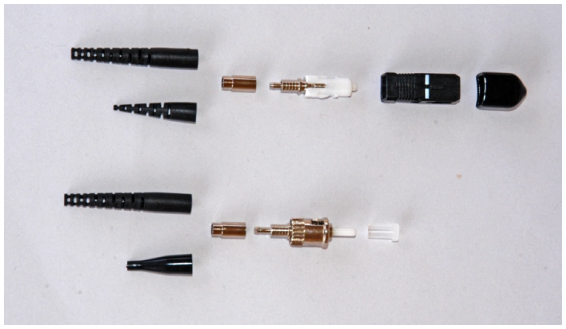
We cannot stress enough the importance of following the manufacturers specific instructions for each type of connector.

We will start each section with a review of the necessary tools. Each connector type will have a set of tools specific to that connector, but the Toolbox contains tools that will work with most epoxy/polish connectors of ST, SC and FC styles. You will practice termination with a 3 mm jacketed cable, but working with most multifiber cables will be similar, although the strength members may have different uses.

In each type of connector there are three procedures to follow:

1. Prep the cable to be terminated and assemble the connector on to the cable.
2. Scribe and polish the assembled connector.
3. Inspect the final product.

Connector Parts



SC connector (top) and ST connector (bottom) with strain relief boots, crimp sleeve, connector and protective cap. Shown are large boots for 3mm jacket cable and small boots for 900 micron tight buffer fiber.

Some connectors are three parts (connector, crimp sleeve and strain relief as above), while others are two part (connector and strain relief). The actual connectors you use should have specific instructions on how to terminate them, so follow them exactly. The following instructions refer to a standard 3-part ST connector.

The polishing part is basically the same for each application and each cable type. The termination procedure is also the same with regard to cable type regardless of the connector type.

Work in a clean workplace - dirt and dust are the worst enemies of good terminations!

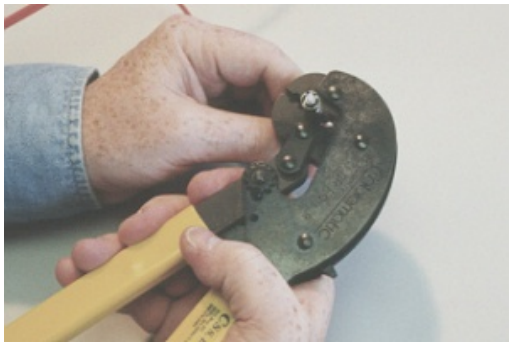
A black work mat will make it easier to see fibers during the termination process and when cleaning up.

Cut off about 4-6 feet of a 3mm jacketed cable or remove a length of buffered fiber from a distribution cable in the Fiber Optic Cables section.

Preparation: All tools should be laid out on the lab table in an orderly fashion. Check at this time to make sure that you are not missing anything.

Clockwise from left: 3 mm jacketed cable, connector curing oven, epoxy, polishing plate, wipes, trash bin, crimper, Kevlar scissors, jacket stripper, fiber stripper, instructions and stripping guide.

Fiber Optic Crimp Tool



The crimp tool provides the proper compression force on the crimp sleeve required to insure retention of the connector on the cable. The ratcheting action assuring a proper crimp each time.

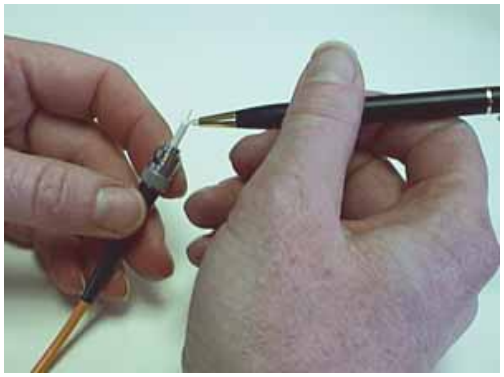
If the ring and connector are not secured on the cable after crimping, check for undersize outside diameter of the cable. Never Re-Crimp in a smaller hex die opening. This may damage the tool.

Correct Crimp

Wrong Crimp
(Over-sized Ring or
too small crimp die)

If the finished crimp looks like the one pictured above right, an over sized crimp ring was used. Completing the crimp may damage the tool. Check with the connector manufacturer for the proper crimp ring size.

Scribe



The scribe is a sharp, hard crystal that is used to scratch or scribe the fiber for cleaving. It is used in termination to remove the excess fiber from the connector ferrule before polishing.

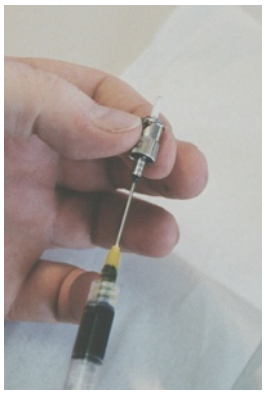
Polishing Plate, Pad and Puck

One needs a flat hard plate as a polishing surface for the connector. Most connectors are PC or physical contact types, so the end of the ferrule is convex. They should be polished on a 1/8 inch (3mm) rubber pad placed on top of the plate or multiple layers of old polishing film. A polishing puck or fixture is used to hold the connector perpendicular to the plate during the polishing process.

Applying Adhesives

Epoxy is normally supplied in a “bipax” of epoxy and hardener. When ready to use, mix by removing the center divider and working the two liquids inside the bipax with your fingers or on a hard surface. When fully mixed, cut one corner to create a small (3 mm, 1/8”) opening. Attach a square tip needle to the syringe and remove the plunger from the syringe. Carefully squeeze the adhesive into the syringe. Just start the plunger into the syringe, then hold needle up long enough to let the epoxy run down to the

bottom, then squeeze the air out of the syringe. You now have about 30 minutes of working time to use the epoxy, long enough to share among all students in a class, so the instructor can be responsible for the adhesive.



The epoxy is applied by injecting a small amount into the connector until a bead appears on the end of the connector, then the needle is pulled back slightly and more epoxy injected into the body of the connector.

Anaerobic adhesives do not require mixing. The recommended adhesive, Loctite 648, comes in a dropper bottle that can be simply wiped along a fiber that has been stripped and cleaned, and then the fiber is inserted in the connector.

HotMelt connectors already have adhesive – a hot melt adhesive – in the connector. The connectors are placed in an oven to melt the adhesive to allow inserting the fiber, then allowed to cool to set the adhesive.

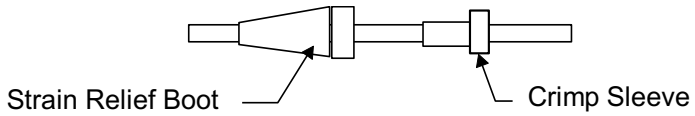
Cable Preparation: 3mm Jacketed Cable

1. Open the connector package in front of you and take out the parts. If the area is very dusty do not let the connector fall into the dust as this may clog the fiber hole. Also the connector should have a dust cap on the ferrule. Do not take it off until you are ready to install the connector.

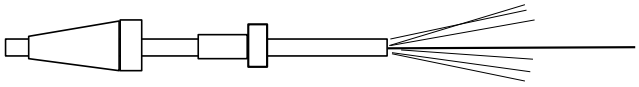
2. On each cable end place a strain relief boot with the small side first.

3. Next place the crimp sleeve on the cable. It will be used to clamp on the Kevlar strength member of the cable and hold the strain relief boot to the connector after assembly.

Your assembly should look as below.



4. Use the jacket strip tool to strip back the jacket of the cable exposing the needed length of buffered fiber, about 2 inches. This also exposes the Kevlar strength member of the cable. Use the #4 flat on the Miller stripper for 3mm jacket cable.



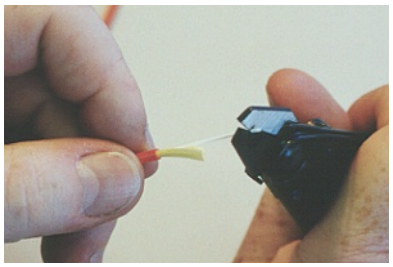
5. Using the scissors made to cut Kevlar provided in the Toolbox, cut back the Kevlar strength members,(leaving about 3/8 inch).

NOTE: Connector manufacturers will specify the exact dimensions needed for stripping cable for their connectors. Ensure you have the proper information before trying to terminate that connector.

Fiber Preparation

Wear Safety Glasses for this exercise!!

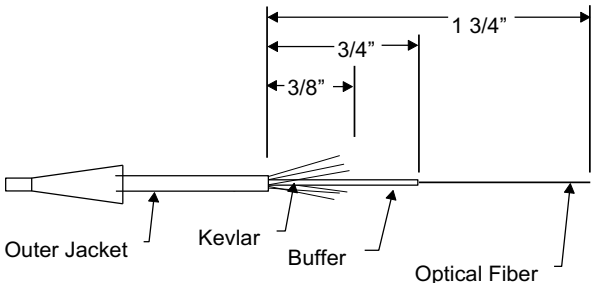
This part will take a bit of practice but as in all things just go step by step. We will proceed to connectorize one fiber at a time



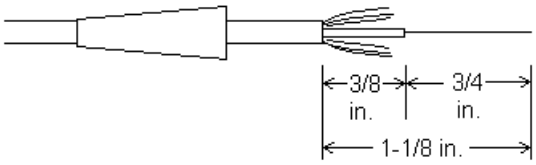
Take your buffer strip tool and strip off from .75" to 1.0 inch of buffer material from the fiber. Be careful that there is no debris in the tool jaws as it will cause the fiber to break. Some buffer materials adhere to the glass fiber tighter than others. It is advised that you

take off short strips of about 1/8” to 1/4” at a time. Do not clamp squarely down on the fiber. This will bend and kink the fiber. Hold the tool at a steady angle to the fiber and pull buffer slowly and steadily down the fiber. (You may want to practice this step 5-6 times before mixing the epoxy)

Stripping Guide for 3 piece connectors with separate crimp ring (typical):



Stripping Guide for 2 piece connectors with integral crimp ring (typical)::

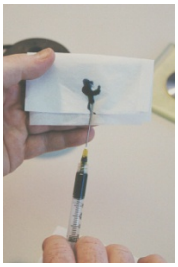


There may be some debris left on the fiber after stripping. Take a clean lint-free wipe dabbed with a little alcohol and wipe the fiber clean.

Note: Do not use rubbing alcohol as it is mostly water and may prevent adhesive setting or affect its cured strength and reliability. Use 99% lab grade isopropyl alcohol ONLY.

Epoxy Preparation





Take the package of epoxy and remove the two-part mix from the package. You will notice that there are two parts with a divider. Remove the divider. Mix the two halves together. If you do not have a tool designed specifically for mixing, such as a roller, the divider may be used. It is extremely important that you completely mix both halves together or the adhesive will not cure 100%.
Having mixed the epoxy completely take the empty syringe with needle attached and pull out the plunger. Be careful not to let the plunger roll in any dust.
Clip off one corner of the mixed epoxy pack and pour the mixture into the syringe. When the syringe is full place the plunger back in the syringe.
NOTE! Only place the plunger back in the syringe a very little bit as it will be full of air. Hold the syringe upside down and let the epoxy run down to the back of the syringe. When the epoxy runs down all the way you can push the plunger all the way forward removing the air.

NOTE! your epoxy has a working time of 20 to 30 minutes.

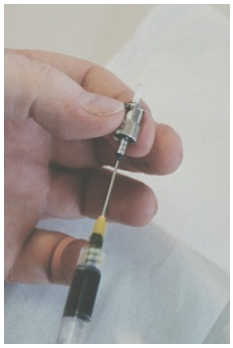
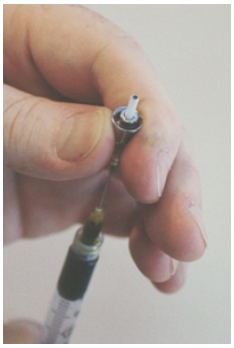
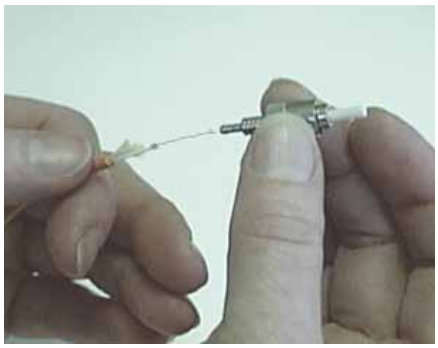
Other adhesives:

Anaerobic adhesives are quick-setting one- or two-part adhesives that do not require a heat cure. Anaerobic adhesives do not require mixing. The recommended adhesive, Loctite 648, comes in a dropper bottle that can be simply wiped along a fiber that has been stripped and cleaned, and then the fiber is inserted in the connector.

3M HotMelt: 3M offers a heat setting adhesive that you heat the connector up to soften the adhesive, insert the stripped fiber and let it cool before polishing. Information and videos are available from 3M. Note that HotMelt connectors use a much hotter oven than heat-cured epoxy. An epoxy oven will not soften the adhesive in HotMelt Connectors and a HotMelt oven will overheat and ruin epoxy!

Attaching the Connector

Wear Safety Glasses for this exercise!!

1. Remove the dust cap on the connector ferrule.

2. From the back of the connector body inject the connector with the epoxy. Make sure that the needle of the syringe is inside the connector body as far as it will go. Use light pressure on the plunger as you inject the epoxy until you see a small bead of the adhesive emerge from the ferrule tip. This bead will help hold the fiber during the cleaving process and ensure the proper cleave.
Remove the syringe from the connector half way and continue to fill the connector until epoxy appears from the end of the connector. Remove the syringe from the connector and pull back on the plunger to prevent any adhesive from coming out of the needle.

3. Insert the stripped fiber through the back of the body of the connector towards the ferrule. Use a twisting motion on the connector to aid the glass fiber in finding the hole in the ferrule. Push the fiber in as far as it will go.

4. Move the crimp sleeve up over the back of the connector body, capturing the Kevlar, and crimp it to the body using the recommended crimp tool.

5 Place the strain relief boot over the back body of the connector.

6. Place the special protective sleeve provided over the ferrule of the connector, making sure not to break off the fiber and set it aside for overnight curing. This is to protect the fiber from breaking while you handle it before polishing and while curing.

After you have successfully attached a connector to one end of the cable, do the same for the other end. If you have taken longer than 20 minutes, the epoxy will have hardened too much for use. You should wait until you polish your connector and then terminate the other end in another session to make a patchcord which you can test.

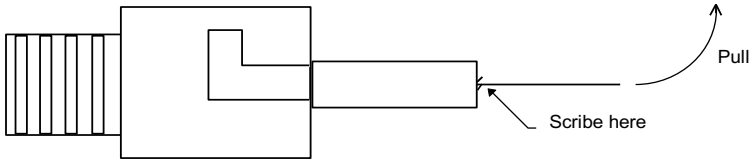
Leave the cable assembly in a safe place to cure overnight or cure for the recommended curing time in an oven!

Cleaving
After oven or overnight curing:

Wear Safety Glasses for this exercise!!

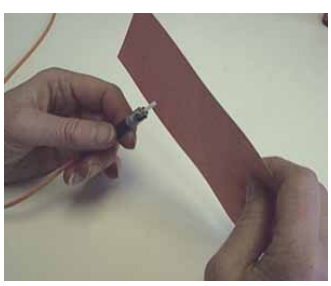
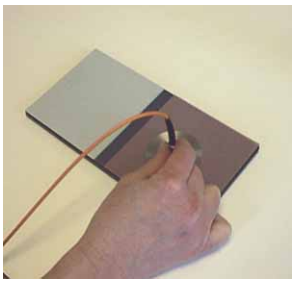
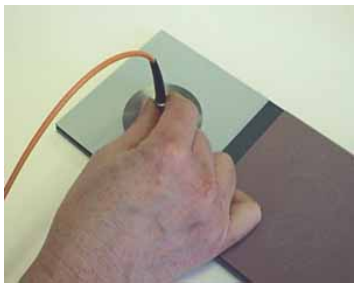
1. Take your scribe tool and scribe the glass using light pressure so as not to break off the glass fiber from each connector. 2 or 3 scratches is enough.

2. Remove the glass by pulling both up and away as in figure 9.



3. You are now ready to polish the connector ferrule.

Polishing for Multimode Connectors

Polishing fiber optic connectors in the field is to some extent an art form. So it takes a “few tricks of the trade” so to speak to make it a clean and easy process. The operative word here is clean. This is the most important factor.

Lay your tools in front of you in an orderly fashion. You should have the glass plate, lapping films, polishing tool, and lint-free wipes.

1. Lay the 3 micron and 0.3 micron on the glass plate. Note that some films are adhesive backed. Make a double layer of these to create a softer surface.

2. For air-polishing, use the 15 micron film and one of the connectors to be polished. Hold the connector upright and the film with the grit facing down. With very light pressure, polish the face of the connector so as only to take down the glass burr that remains from the scribe step.

3. Observe the adhesive bead. Polish this down until it is a thin layer but not completely gone.

Note: If you are doing an crimp connector with a stainless ferrule, polish the fiber down to the metal tip.

4. Place your connector in the polishing puck. Lay it down gently on the 3 micron lapping film, one side first. Do not slam it down hard as you could shatter the fiber. Using a figure 8 motion polish the connector until the adhesive bead is gone. If you are polishing a ceramic connector you will notice that the connector gets slippery on the plate. Stop polishing instantly. Now go to the 0.3 micron film With the same motion, go only one or two figure 8's. Your connector is done.

Note: With a ceramic connector, you should use almost no pressure at all on the connector as you polish. With a metal ferrulel connector you will want a moderate amount of pressure of about two to three pounds.

5. Remove the connector from the polishing puck and wipe off the sides of the ferrule and the face of the ferrule to remove any dust and debris.

Testing the Termination

After you have terminated both ends of a cable, you can test it to see how good your connectors are. Follow the procedure you learned in the Testing hands-on session and fill in the worksheet.

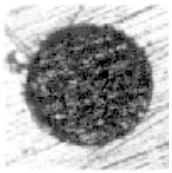
Continuity Test

Using the Visible fiber tracer, test your cable to make sure it is continuous. Note your observations on the worksheet.

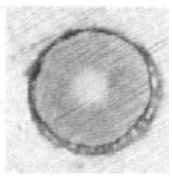
Microscope Viewing

Using the microscope, observe the end face of the connector ferrule in the three ways you learned in the Test session. Record your observations on the worksheet.

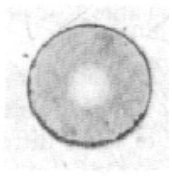
Back light the fiber to observe the core it too should be scratchless.



Typical 3 micron finish



Typical 1 micron finish



Typical 0.3 micron finish

Cracked and chipped finish

Plucked finish

Cracked and plucked finish.

Photos courtesy of Beuhler.

C. Loss Testing

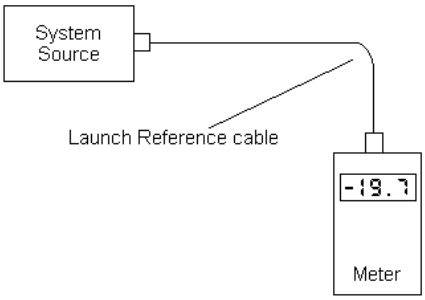
Single-ended Loss Test

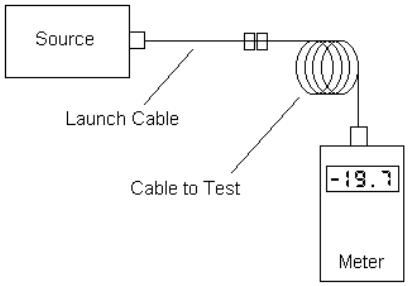
Using the methods for single-ended testing (described below and in the Test session,) test each of your connectors for loss using the single ended test method. Record the data on the worksheet.

A single-ended test uses a matching “launch” cable on the source to mate with the cable under test. This tests only the connector of the cable being tested which is connected to the launch cable, (plus any loss in the cable itself which is too small to measure in our short cables we use in this exercise) which will allow the student to test the connector they just made in the lab.

1. Set test reference value

Using a connector cleaner, clean the ends of all the connector ferrules and replace the dust caps.
Attach one of the ST-ST cables to the source’s 850 nm LED. This will be the launch cable
Turn the source and meter on
Use the power meter to measure the power out of the launch cable.
Use the meter function to set the power level to “0 dB.” This is your “0 dB” reference power for loss measurements.
Disconnect the launch cable from the power meter.





2. Measure single ended loss

Attach a ST-ST mating adapter to the end of the launch cable.
Attach one end (A) of the cable to be tested to the launch cable.
Attach the other end (B) of the cable under test to the power meter.
Measure the output of the second cable and record it on the worksheet _____dBm (2)
Calculate the loss: ___dBm (2) - _____dBm (1) = ____loss in dB, end A
Reverse the cable and test the connector on the other end of the cable.

Terminating Buffered Fiber

Terminate a piece of plain 900 micron buffered fiber from a distribution cable (perhaps from a cable that you prepared in the Fiber Optic Cables section.) This requires a different strain relief boot than 3 mm jacketed cable and will not be crimped.

Follow The Same Cable Preparation steps, ignoring the directions to strip the cable jacket.

Other Connector Termination Types

There are dozens of different termination methods in use including prepolished/splice connectors with an internal mechanical splice and fusion splice-on connectors (SOC) that are also prepolished but have a cleaved fiber stub that is fusion spliced onto a cable using a fusion splicer with special alignment hardware. We will describe these connectors briefly but if they are used in class, students should be given the manufacturer's specific directions for the connector types and review the manufacturer's videos for instructions.

Prepolished/Splice Connectors (PPS)

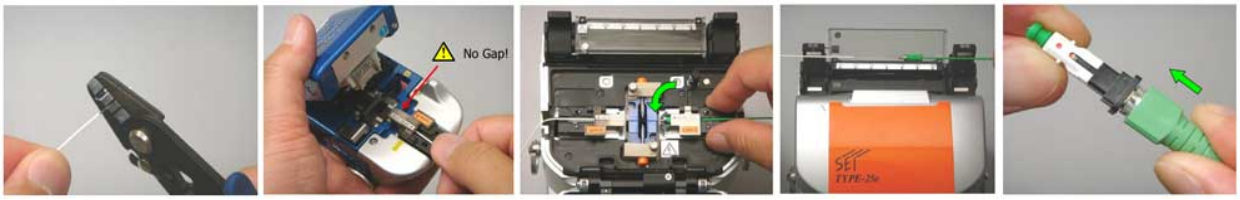
Prepolished/splice connectors are terminated in a factory with a cleaved fiber inside a mechanical splice in the back of the connector ferrule. The termination is simply a matter of cleaving the fiber to be terminated, preferably in a precision cleaver such as supplied with a fusion splicer or with some high-quality termination kits, inserting it into the mechanical splice and locking or crimping the fiber in place. PPS connectors can be monitored with a visual fault locator (VFL) during termination, When the light from the

VFL leaking out of the splice is minimized, the fiber is properly inserted in the mechanical splice.

Corning UniCam termination process (Corning)

Splice-On Connectors (SOC)

The SOC is a prepolished connector made in a factory with a short length of cleaved fiber that is fusion spliced onto the fiber being terminated. The SOC process is straightforward, much like fusion splicing. Strip the fiber, cleave it with a fusion splice cleaver, place the connector in the fixture in the splicer, fuse the fibers, shrink a protector over the splice and place the boot on the connector.



Sumitomo SOC termination process (Sumitomo)

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Fiber Optic Cable Termination Worksheet

Name: _____

What are the most common methods of fiber optic connector termination used in the field? 1._____ 2. _____ 3. _____ 4. _____

What are the worst enemies of terminations?
_____

How do you know when you have injected epoxy into the connector properly?
_____

What do we call the polishing motion we use on the lapping films?
_____

Testing The Termination

Once you have terminated your cable, test it and record the data on this worksheet. Make extra copies for each patchcord if you need them.

Cable No._____

Continuity Test
1. Were you able to see light through your cable? _____
_____
2. Was there any difference in intensity when direction was reversed?
_____

Microscope Inspection
Inspect each connector you install and record your observations in the table below.

Connector No.	1	2
Polish G=good, F=fair, B=bad		
Scratches Y=yes, N=no		
Cracks Y=yes, N=no		

Chipping Y=yes, N=no

Loss Test, Single-ended
single ended.
Reference power level _____ dBm (1)

	meter reading dBm (2)	loss in dB
Cable tested one way		
Cable reversed		

Connector Installation Scorecard

Here is a “scorecard” for adhesive/polish connector termination. Print this page and duplicate it for each style of connector termination you use in your exercises. Check off when you have correctly completed each step. If you have a mentor or instructor, have them provide feedback.

Connector Installation Scorecard. (Print this & duplicate for each exercise)

Below is a “scorecard” for connector installation. Check off “√” when you have correctly completed each step; repeat the step if it is a “X” until it is done correctly. If you have a mentor or instructor, have them provide feedback.

Process Step	Completed		Comments or Mentor/Instructor Feedback
	√	X	
Conducts parts inventory			
Strips fiber to appropriate length			
Checks for fiber integrity after stripping			

Cleans fiber			
Prepares/Applies Adhesive			
Inserts fiber into connector			
Ensures curing completed			
Scribes excess fiber			
Discards glass shards			
Air polishes protruding glass			
Polishes according to steps			
Cleans and inspects polishing quality			
Installs connector dust cap Test splice with OLTS if available			