FOA Reference For Fiber Optics

Insertion Loss Testing
Virtual Hands-On

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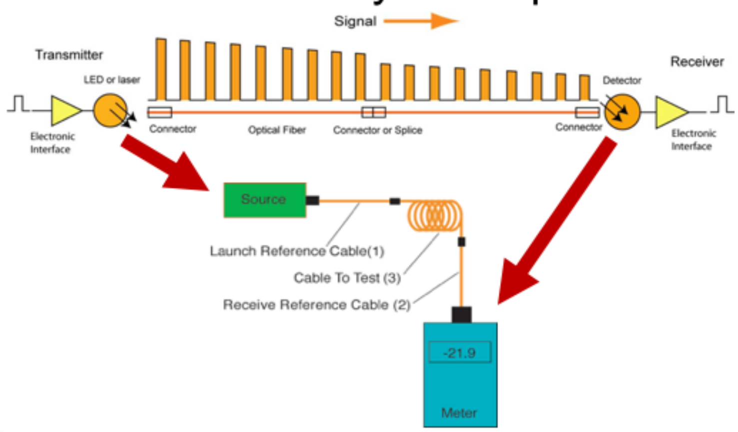
Insertion Loss Testing

- Simulates actual system operation



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Insertion loss testing simulates the way the cable will be used by the systems operating over it. A source, similar to the system source is used for inserting light into the cable under test. A meter is used to measure the source output and the loss when the cable under test is added.Known-good reference cables are used to mate with the cable under test to insert light into the cable and allow testing loss of the connectors on the cable. A double-ended test like this measures the loss of the fiber and connectors on both ends, plus anything in the middle.

Insertion Loss Testing

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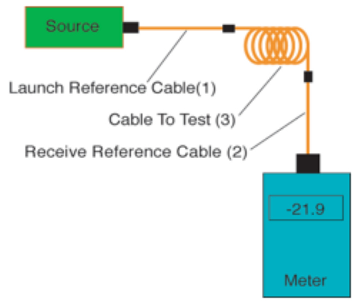


The test equipment for insertion loss testing includes a test source (L) and a meter (R), sometimes available as separate instruments and sometimes integrated into one instrument, called an OLTS (optical loss test set.) The source, similar to the system source, is used for inserting light into the cable under test. The meter is a specialized light meter used to measure the source output and the loss when a cable under test is added. A double-ended test shown measures the loss of the fiber and connectors on both ends, plus anything in the middle.

Insertion Loss Test Equipment
Test Sources

- Source should match transmitter type and wavelength
  - 850/1300 LEDs
  - 1310/1550 nm laser
  - 850 VCSEL
  - Connects to “launch” reference cable to connect to cable under test

Loss is a function of both wavelength (lower loss at higher wavelength) and source type (or more accurately, the mode fill typical or the source type, since LEDs launch light with a wider bean angle (higher mode fill) than a laser.)

The source should match the system source in type (LED or laser) and wavelength (850 or 1300 nm for LEDs and 850, 1310 or 1550 nm for lasers) to accurately reproduce system loss. Multimode systems using VCSELs at 850 nm may require testing with those sources.

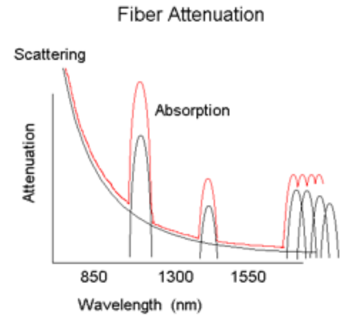
Most sources have only a power switch (On/Off) but some may have an adjustable power output, allowing setting the power level to a particular value (e.g. -20 dBm) when setting a reference to allow checking the reference level with any power meter, not just the one used to set the “0 dB” reference for loss.

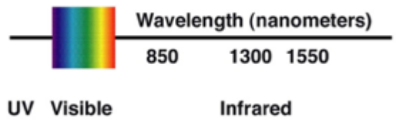
The source requires a launch reference cable to mate the the cable under test. The launch cable is used as a the calibration point for source power (the “ 0 dB reference”) and reference connector to mate to the cable under test.

The mode power distribution of the launched power from the source into a multimode launch cable can affect loss measurements. If the light fills higher order modes, the losses will be higher. A measure of launch mode distribution is “coupled power ratio” (CPR) or the ratio of power coupled from the launch cable into a matching cable compared to power coupled into a singlemode cable (5 micron core for 850 nm, 9 microns for 1300 nm.) A full description of CPR is in the appendix of OFSTP-14.

Test Source Wavelength

- Fiber loss is function of wavelength
- Scattering function of wavelength to 4th power
- Absorption is in bands
- Sources should match system source wavelengths





Remember that fiber loss is a function of the wavelength of light. Loss in fiber is a function of two major sources, absorption and scattering, both of which are wavelength dependent.

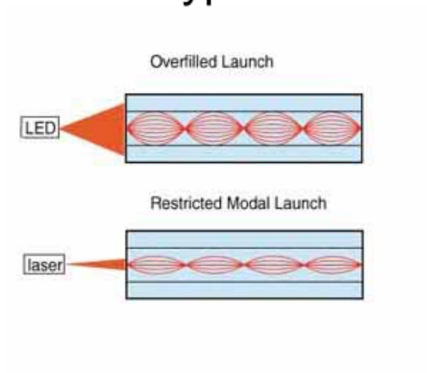
Absorption occurs at specific wavelengths where materials used in the fiber manufacture or miniscule amounts of water (parts-per-billion) in the fiber absorb light strongly.

Scattering is light bouncing off photons and is a function of the 4th power of the wavelength. Double the wavelength of the light and the scattering losses are reduced by 2 to the 4th power or 16 times.

Fiber sources, therefore are chosen to fit in areas where the loss of the fiber is lower, in the infrared between absorption peaks, at 850 and 1300 nm for multimode fiber and 1310 and 1550 nm for singlemode fiber. On very long singlemode links, the variation of the test source wavelength can be a major factor in measurement uncertainty so try to get sources near the actual 1310 and 1550 nm nominal wavelengths.

Source Modal Conditioning
Attenuation Vs Source Type

- Multimode fiber loss is function of mode power distribution
- Core has higher loss in the outer sections (higher order modes)
- LEDs fill core with light, have higher loss
- Lasers underfill core, have lower loss



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What is "Modal Distribution" In Multimode Fibers?

In multimode fibers, some light rays travel straight down the axis of the fiber while all the others wiggle or bounce back and forth inside the core. In step index fiber, the off axis rays, called "higher order modes" bounce back and forth from core/cladding boundaries as they are transmitted down the fiber. Since these high order modes travel a longer distance than the axial ray, they are responsible for the dispersion that limits the fiber's bandwidth.

In graded index fiber, the reduction of the index of refraction of the core as one approaches the cladding causes the higher order modes to follow a curved path that is longer than the axial ray (the "zero order mode"), but by virtue of the lower index of refraction away from the axis, light speeds up as it approaches the cladding and it takes approximately the same time to travel through the fiber. Thus the "dispersion" or variations in transit time for various modes, is minimized and bandwidth of the fiber is maximized.

However, the fact that the higher order modes travel farther in the glass core means that they have a greater likelihood of being scattered or absorbed, the two primary causes of attenuation in optical fibers. Therefore, the higher order modes will have greater attenuation than lower order modes. A long length of fiber that was fully filled (all modes had the same power level launched into them) at a distance from the source will have a lower amount of power in the higher order modes than will a short length of the same fiber due to the higher loss in the higher order modes.

This difference in "modal distribution" between long and short fibers can be described as a "transient loss", and can make big differences in the measurements one makes with the fiber. It not only changes the modal distribution, it changes the effective core diameter and numerical aperture also.

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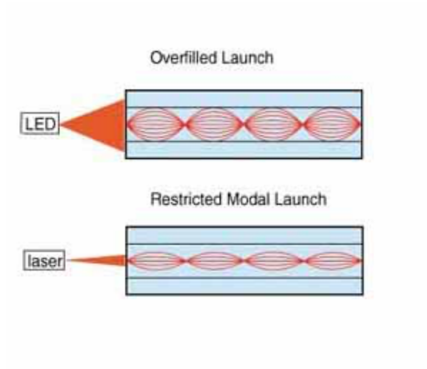

What is "Modal Distribution" In Multimode Fibers?

A similar effect occurs when sources of different beam patterns are used. LEDs launch light with a broad pattern, often filling all the modes in the fiber, while lasers have a very narrow beam, launching ilight mostly into the center of the core. Thus a LED source will have higher loss in multimode fiber than a laser, an important consideration with gigabit networks using VCSELs (vertical cavity surface-emitting lasers) for sources.

In addition to the attenuation of the fiber, modal distribution affects connector and splice loss in multimode networks. If the higher order modes are absent, the effective NA and core diameter are lower, so when a connector is tested, it is similar to having a smaller fiber launching into a larger one, and the connector loss is lower. Thus the whole cable plant loss is dependent on the way the source launches light.

Controlling Modal Distribution

- Mode <u>Strippers</u> remove cladding modes
- Mode <u>Scramblers</u> equalize modes
- Mode <u>Filters</u> remove higher order modes
  - Most common mode filter is a mandrel wrap (shown right)

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Mode Conditioners There are three basic "gadgets" to condition the modal distribution in multimode fibers): mode strippers which remove unwanted cladding mode light, mode scramblers which mix modes to equalize power in all the modes, and mode filters which remove the higher order modes to simulate EMD or steady state conditions.

Cladding Mode Strippers: Cladding mode strippers are used to remove any light being propagated in the cladding to insure that measurements include only the effects of the core. For many years, fibers have been "self-stripping"; the buffer is chosen to have an index of refraction that will promote the leakage of light from the cladding to the buffer. Thus mode strippers are unnecessary, but are still mentioned in the literature and sometimes confused with mode filters.

Mode Scramblers: Mode scrambling is an attempt to equalize the power in all modes, simulating a fully filled launch or some reduced power launch. This should not be confused with a mode filter which simulates the modal distribution of a fiber in equilibrium modal distribution (EMD). Both may be used together sometimes however, to properly simulate test conditions. Mode scramblers are easily made by fusion (or mechanical) splicing a short piece of step index fiber in between two pieces of graded index fiber being tested.

Mode Filters: Mode filters are used to selectively remove higher order modes to attempt to create standard modal conditions, assuming that one starts with fully filled modes. Higher order modes are easily removed by stressing the fiber in a controlled manner, since the higher order modes are more susceptible to bending losses. The most popular mode filter is the "mandrel wrap", where the fiber is snugly wrapped around a mandrel several times. The size of the mandrel and the number of turns will determine the effect on the higher order modes. Other mode filters can be made where the fiber is subjected to a series of gentle S bends, either in a form or by wrapping around pins in a plate or by actually using a long length of fiber attached to an overfilling source.

Controlling Modal Distribution

- Mode Strippers remove cladding modes
- Mode Scramblers equalize modes
- Mode Filters remove higher order modes
  - Most common mode filter is a mandrel wrap (shown right)

All standards for testing mention modal conditioning. It's simple with singlemode fiber, you just need to ensure the fiber is transmitting only a single mode of light, easily done with a ~30mm (1.2") loop in the launch fiber.

Multimode is more complicated because of the large number of modes and the way they are transmitted and attenuated. There have been several methods specified for modal conditioning and measurement in standards, using optics, the mandrel wrap and some more complex ones associated with the current specification called "encircled flux." For decades, TIA-568 and other FOTPs called for using a mandrel wrap with a LED source for testing multimode fiber. That method works well to provide launch conditions approximating encircled flux requirements.The main effect the mandrel wrap has is to reduce measured loss - often significantly in systems with lots of connections. .

Insertion Loss Test Equipment
Fiber Optic Power Meters

- Specialized light meter
- Adapts to FO connectors
- Calibrated at proper wavelengths
  - 850/1300/1550 nm
- Measurement ranges
  - dBm/dB

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The power meter is a specialized light meter with adapters to allow connection to the fiber optic connectors on the cables and calibration at the wavelengths used in fiber optic systems.

The power meter needs to be calibrated to NIST (standards US national standards labs) and be able to measure at appropriate wavelengths (850, 1310 or 1550 nm.)

Most meters have measurement ranges for “dBm” for measuring absolute power and “dB” or relative power for measuring loss. If it has a dB scale, it will be able to set a “0 dB reference” for simplifying loss measurements. Some meters may have a linear range - usually milliwatts - used for measuring absolute power.

Meters should offer adapters to most popular fiber optic connectors (ST, SC, LC, etc.) to make it easier to measure power and loss in cable plants with various types of connectors.

The meter has a light detector, usually a germanium semiconductor with thin glass window, chosen to allow use at all the wavelengths of interest. The detector may also be made of silicon for plastic fiber systems operating at 650 nm or InGaAs (Indium-gallium-arsenide) which is more expensive that germanium but has the ability to measure lower power levels.

It is mandatory that the detector be large enough to capture all the light from the fiber, which in most meters means at least 2 mm diameter, to allow proper calibration with any fiber type.

Some meters read db to a tenth (0.1 dB) while others read to one-hundreth (0.01 dB). A meter that reads to a tenth is perfectly adequate for most field testing, where the measurement uncertaintly is fairly high (up to 0.5 dB) while a meter that reads to 0.01 dB is preferable for testing patchcords, where losses may only be a few tenths.

Fiber Optic Power Meters Measure dB

- Loss is measured in “dB” (decibels)
- Log scale: dB=10 log (power ratio)
  - 10 dB= 10X
  - 0 dB = 1X
  - 3 dB = 2X
  - -10dB = 0.1X
- dB is relative to any preset reference power
- dBm is dB referenced to 1 mw (milliwatt)
  - 0 dBm = 1 mw

dB is a measure of optical power on a log scale, simplifying measurements over a wide dynamic range. Fiber optics uses power levels from +20 to -40 dBm, a range of 1,000,000 to 1! But that translates to 60 dB, an easier number to deal with.

Absolute power is measured in dBm or dB referenced to 1 mw. Positive dBm means the power is greater than 1 mw, while negative numbers mean the power level is less than 1 mw.

The ratios shown give you an idea of how dB relates to linear power in watts.

A nice thing about dB is that loss is easily measured by subtracting the reference level for “0” dB from the measured value of the loss. That is, if you measure -20 dBm from the end of the reference cable, then -22 dBm when testing cables, the cable loss is 2 dB.

Fiber Optic Power Meters Measure dB

- Loss is measured in "dB"
- Example
  - "0 dB" reference measured = -20 dBm
  - Cable test power measured = -22 dBm
  - Loss = (-22 dBm) - (-20 dBm) = -2 dB
- Loss is generally referred to as a positive number, so we say the loss here is 2 dB
- Meters with "0 dB" reference set function will read loss as negative number (-2 dB)
- Note the measured power is absolute power in dBm and loss is relative power or dB

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Convention: Note that mathematically (-22 dBm) - (-20 dBm) = (-2 dB) so loss is measured as a negative number and meters with a 0 dB set level will show loss as a negative (-) number on the display. But loss is generally referred to as a positive (+) number; people always say the loss is 2 dB. And of course the absolute values are in dBm and the loss is in dB. Thus OLTSs (optical loss test sets) and OTDRs (optical time domain reflectomerters) generally show loss as a positive number.

Insertion Loss Test Equipment Reference Cables

- Reference cables attach to cable under test to:
- Launch light from test source into cable under test
- Mate with connectors to test loss
- May need one or two reference cables

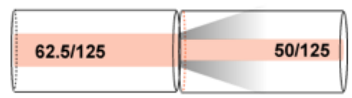
The reference cables are critical to making good measurements. They mate with the cable under test to launch light from test source into the cable under test and mate with the connectors on each end to allow testing the loss of those connectors.

They must mate with the cable under test, so connectors must match or mating adapters be available, and the fiber must be the same type (MM or SM) and core diameter. Mixing 50/125 and 62.5/125 fiber will lead to low loss when testing with the smaller fiber as a launch and the larger as receive cables - or the cable under test but more than 2 dB higher loss when launching from a larger 62.5 micron fiber into a 50! With singlemode, the difference can be 20 dB!

It is very important to understand that the quality of reference cables is going to determine the loss of the cable plant being tested!

Match Reference Cables To Test

- Reference cables must be of the same size fiber as the cable plant being tested to prevent excess loss!
- 62.5/125 micron into 50/125 micron fiber = ~2-4 dB excess loss
- MM into SM = ~20 dB excess loss



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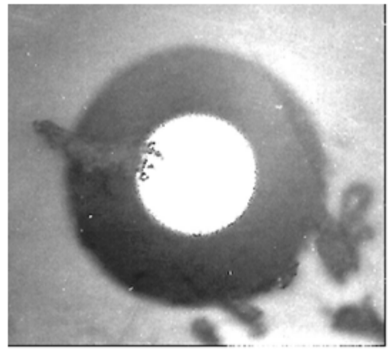
We know of contractors who install a cable plant and test it with the wrong reference cables then call wanting to know why every test fails by about 2 dB!

Inspect Reference Cables

- The quality of the reference cables is very important as it will affect the loss measured!
  - Setting reference levels
  - Testing loss mated to cable under test
- Clean regularly
- Test with FOTP-171 against known good cables



Dirty connectors cause errors!

It is very important to understand that the quality and cleanliness of reference cables is going to determine the loss of the cable plant being tested!

The connectors must be low loss and they must be kept free of scratches and contamination by grease or dirt. Bad connectors on a reference cable will insure that all cables tested with them will test bad!

Regularly clean the connectors on your reference cables and test them with other reference cables to make sure they are OK. Inspect with a microscope for scratches or dirt.

Here's a summary of what we have learned and tell people we train.

1. Always keep dust caps on connectors, bulkhead splices, patch panels or anything else that is going to have a connection made with it.

2. Use specific cleaning supplies or lint free pads and isopropyl alcohol to clean the connectors. Some solvents MIGHT attack epoxy, so only alcohol should be used. Cotton swabs and cloth leave threads behind. Some optical cleaners leave residues. Residues usually attract dirt and make it stick. We supplied Alco Pads for over 10 years with every Test Kit with no problems.

3. All "canned air" now has a liquid propellant. Years ago, you could buy a can of plain dry nitrogen to blow things out with, but it's long gone. Today's aerosol cleaners use non-CFC propellant and will leave a residue unless you hold them perfectly level when spraying and spray for 3-5 seconds before using to insure that any liquid propellant is expelled from the nozzle. These cans can be used to blow dust out of bulkheads with a connector in the other side or an active device mount (xmit/rcvr). NEVER use compressed air from a hose (they emit a fine spray of oil from the compressor!) or blow on them (you breath is full of moisture , not to mention all those yukky germs!)

More>>>>>

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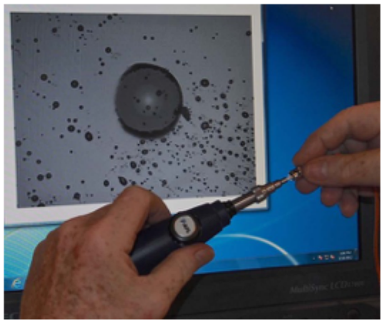

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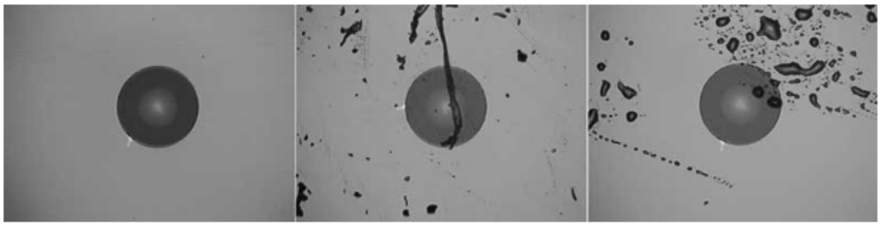
4. A better way to clean these bulkheads is to remove both connectors and clean with Alco Pads, then use a swab made of the same material with alcohol on it to clean out the bulkhead.

5. Detectors on FO power meters should also be cleaned with the AlcoPads occasionally to remove dirt. Take the connector adapter off and wipe the surface, then air dry.

6. Ferrules on the connectors/cables used for testing will get dirty by scraping off the material of the alignment sleeve in the splice bushing. Some of these sleeves are molded glass-filled thermoplastic and sold for multimode applications. These will give you a dirty connector ferrule in 10 insertions! You can see the front edge of the connector ferrule getting black! The alignment sleeve will build up an internal ledge and create a gap between the mating ferrules - viola a 1-2 dB attenuator! Use the metal or ceramic alignment sleeve bulkheads only if you are expecting repeated insertions. Cleaning the above reguires agressive scrubbing on the ferrules with the AlcoPad and tossing the bulkhead away.

7. Repolish connectors when scratched with singlemode film (fine diamond film), reterminate them or replace them.

Inspecting Connectors For Cleanliness

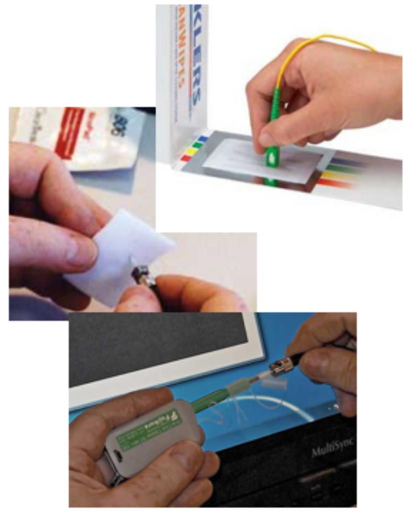


Clean Carpet dirt Oil off finger

Here are examples of a clean connector that was wiped through a carpet and picked up dirt, then after cleaning was touched by a finger. Simple processes like these get connectors dirty. Try this during your labs – even try wiping the connector on your shirt or pants and then inspecting it.

Connector Inspection And Cleaning

- Inspect – clean if needed
- Many methods used to clean – fiber specific cleaners are recommended
- Wet with alcohol and dry
- Dry “click and clean”
- Inspect again to determine effectiveness of cleaning

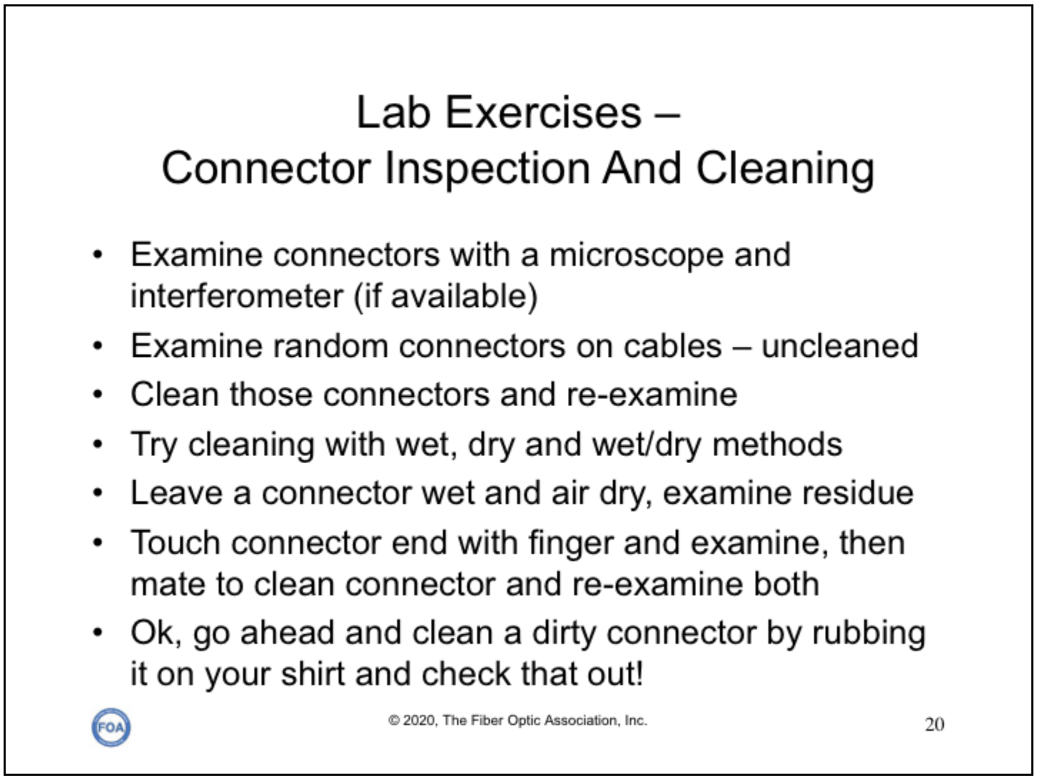


Dirt is the #1 enemy of fiber optic connectors because it can cause loss and reflectance, even damage connectors. Inspect every connector before you make a connection with it. Check the connector and the receptacle it will be plugged into as either or both may be dirty.

Right Way To Clean Connectors

Wet a small spot on the cleaning wipe then swipe the connector from the wet spot to the dry side of the wipe

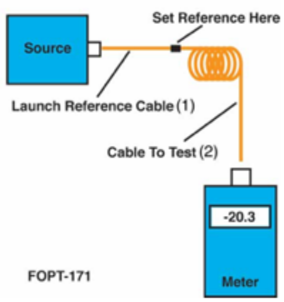
A wet to dry cleaning is usually the most effective. Wet a small spot on the cleaning wipe then swipe the connector from the wet spot to the dry side of the wipe to finish cleaning and drying the ferrule end.

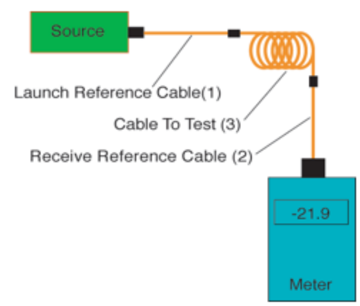


Here are suggestions for lab exercises on cleaning and inspection. More lab exercises are in the Instructor Guide.

Insertion Loss Testing Procedures

- FOTP-171 vs OFSTP-14/OFSTP-7





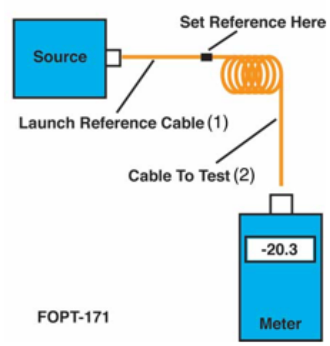
Two types of insertion loss testing

So far we have talked about testing installed and terminated cable plants, where we want to test the connectors on each end and everything in between. So we use a meter and source with two reference cables - one on each end. This test is defined by a standard OFSTP-14 (OFSTP = optical fiber standard test procedure) for multimode and OFSTP-7 for singlemode.

Another test, FOTP-171, uses only a launch reference cable and the cable under test. This method allows testing a single cable from each end to find out if either connector is bad.

FOTP-171 (Single-ended)

- Uses one launch reference cable (1) only
- Measures loss of connector mated to the launch cable plus any loss in the fiber itself
- Allows testing each connector separately to diagnose connector faults
- Use for troubleshooting cable plant connector problems.



FOTP-171 or single-ended testing

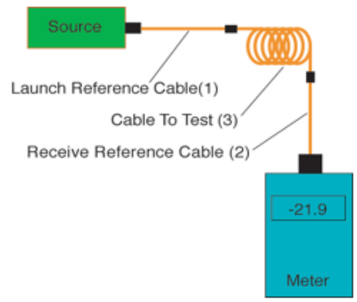
A FOTP-171 test uses only a single launch reference cable to test the cable. This method allows testing a single cable from either end to find out if one connector is bad. It's main use is testing patchcords to insure both connectors are good, but it can also be used to troubleshoot installed cables where one connector is suspected of being bad.

The 0 dB loss reference is made by connecting the power meter to the output of the launch cable and measuring the power output. The cable under test is connected to the launch cable and the meter. The loss measured is only the loss of the mated connectors and any loss of the fiber in the cable, usually very small when testing patchcords this way.

The fact that the connector on the launch cable and the cable under test are mated directly to the meter, with it's large detector, means that the connection loss to the meter is calibrated out of the loss test, allowing testing of only the connector mated to the launch cable.

OFSTP-14 (MM) & OFSTP-7(SM) (Double Ended)

- OFSTP-14/OFSTP-7 are “double ended” tests for testing installed cable plants
- Measures loss of connectors on both ends plus anything in between
- Requires two reference cables
- How do you set reference?



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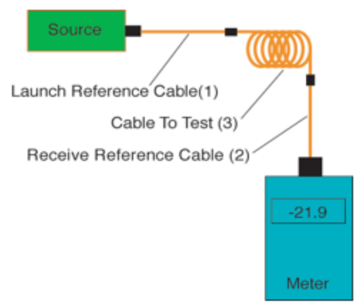
OFSTP-14 and OFSTP-7, double ended testing - that is they test cables including connectors on both ends and everything in the middle - fiber, intermediate connections and splices.

OFSTP-14/OFSTP-7 are used for testing installed and terminated cable plants, where we want to test the connectors on each end and everything in between. So we use a meter and source with two reference cables - one on each end.

The big issue with this test method is how one sets the 0 dB reference.

OFSTP-14/7 “0 dB” Reference

- How do you set reference?
- Method B: with one reference cable (the launch cable)
- Method A: with two cables (launch and receive cables)
- Method C: with three cables (launch, receive and a “golden” reference cables)



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OFSTP-14/OFSTP-7 offers three options on how one sets the 0 dB reference.

Method B: with one reference cable (the launch cable)

This method sets the “0 dB reference” with the power meter measuring the output of the launch cable directly, so that no connector loss is included when setting the reference. Then when testing a cable with both launch and receive cables, the loss includes the loss of both connectors on the cable under test and the loss of all the components in between.

Method A: with two cables (launch and receive cables)

This method sets the “0 dB reference” with the launch cable mated to the receive cable, so that one mated connector loss is included when setting the reference. Then when testing a cable with both launch and receive cables, the loss includes the loss of connectors on the cable under test and the loss of all the components in between, less the loss of the mated connectors included in the reference.

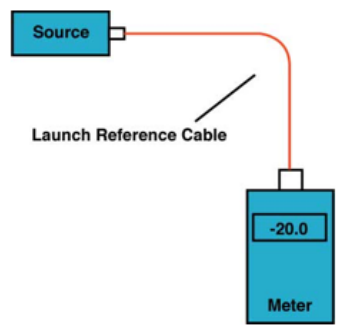
Method C: with three cables (launch, receive and a “golden” reference cables)

This method sets the “0 dB reference” with the launch cable and the receive cable, plus a “golden” reference cable mated to them, so that two mated connector losses and any fiber loss in the third cable are included when setting the reference. Then when testing a cable with both launch and receive cables, the loss includes the loss of connectors on the cable under test and the loss of all the components in between, less the loss of the mated connectors included in the reference.

What is the reason for three different methods?

OFSTP-14/7 “0 dB” Reference Method B

- Method B (1 cable, shown): test equipment compatible with cable plant connectors
- Single reference cable attached to source
- Measure output with meter for “0 dB” reference
- No connectors included in reference



OFSTP-14/OFSTP-7 offers three options on how one sets the 0 dB reference.

What is the reason for three different methods?

Method B: with one reference cable (the launch cable).

The reference is set using a single cable only connected between the meter and source, so no connector mating losses are included in setting the reference. Simply connect the meter and source with the reference cable and measure your “0dB” reference power. Set the meter to “0” if it has a zero loss set feature.

Once you set the reference value, do not remove the launch cable from the source as it may not couple exactly the same power, ruining the set reference.

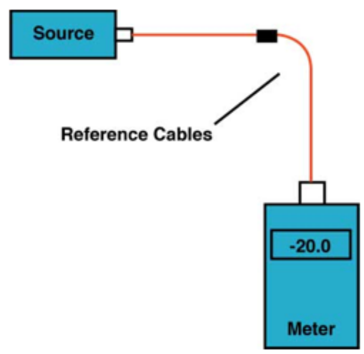
This method works when you have test equipment with adapters on the meter that match the connectors on the cables being tested and all connectors are the same. It can also be used if the meter has replaceable adapters for connectors that do not affect calibration, so you can set a reference with one connector and test with another by changing the adapter, eg using ST connectors to test FC, SC or other 2.5 mm ferrule connectors.

Method A: with two cables (launch and receive cables) - See next slide.

Method C: with three cables (launch, receive and a “golden” reference cables) - See third slide.

OFSTP-14/7 "0 dB" Reference Method A

- Method A (2 cable , shown): test equipment not compatible, male connectors mate with adapter
- Reference with two cables
- Measure output with meter for "0 dB" reference
- Includes one connector loss



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OFSTP-14/OFSTP-7 offers three options on how one sets the 0 dB reference.

Method A: with two cables (launch and receive cables)

This method works if you need to test cables with connectors that can be mated to each other but do not mate with the test equipment, e.g. testing LC connector cables with test equipment with fixed ST connector interfaces.

Set your reference by connecting a hybrid cable (one with a connector that mates to the instrument on one end and the cable plant to be tested on the other, e.g. ST to LC) to the meter and another to the source. Mate them in the middle with an adapter and measure the power for your "0dB" reference.

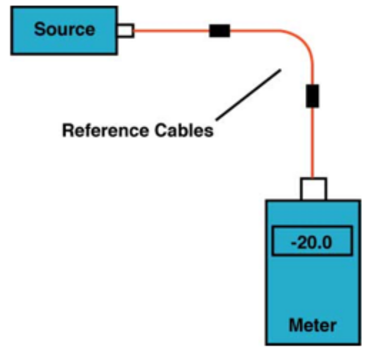
Once you set the reference value, do not remove the launch cable from the source as it may not couple exactly the same power, ruining the set reference. Meters usually have large detectors so disconnecting the meter cable is probably not a problem, but it is still recommended to not remove it either.

Note the reference includes one mated pair of connectors, so the loss you measure will be that much less than using Method B. ALWAYS report the method used whenever providing test results so the user can properly evaluate the measurements.

Method C: with three cables (launch, receive and a "golden" reference cables) - See next slide.

OFSTP-14/7 "0 dB" Reference Method C

- Method C (3 cable , shown): test equipment not compatible, e.g. male/female connectors
- Reference with three cables
- Third is "golden standard"
- Measure output with meter for "0 dB" reference
- Includes two connector losses



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OFSTP-14/OFSTP-7 offers three options on how one sets the 0 dB reference.

Method C: with three cables (launch, receive and a "golden" reference cables) - See next slide.

This method works if you need to test cables with connectors that can be mated to each other but do not mate with the test equipment, e.g. testing MT-RJ connector cables with test equipment which has fixed ST connector interfaces.

Set your reference by connecting hybrid cables (one with a connector that mates to the instrument on one end and the cable plant to be tested on the other, eg ST to MT-RJ without pins) to the meter and another to the source. Using a compatible cable, eg MT-RJ with pins on either end, mate them in the middle with an adapter and measure the power for your "0dB" reference.

Once you set the reference value, do not remove the launch cable from the source as it may not couple exactly the same power, ruining the set reference. Meters usually have large detectors so disconnecting the meter cable is probably not a problem, but it is still recommended to not remove it either.

Note the reference includes two mated pairs of connectors, so the loss you measure will be that much less than using Method B. ALWAYS report the method used whenever providing test results so the user can properly evaluate the measurements.

Loss Difference With 3 Reference Methods

- Test results with 520 meter multimode cable plant in 4 sections (10/250/250/10 meter links)
- Tested with 850 nm LED
- OTDR not a standard test method, shown for reference

Test	Results (loss , standard deviation)
Method B: 1 Cable Reference	2.96 dB , 0.02 dB
Method A: 2 Cable Reference	2.66 dB, 0.20 dB
Method C: 3 Cable Reference	2.48 dB, 0.24 dB
OTDR	1.91 dB / 2.05 dB (2 directions)

When you measure the loss of a cable plant using these three different methods, you will obviously get different losses, since Method B includes no mated connector losses, while Methods A and C include one and two mated connector losses respectively.

Here are carefully controlled results in a lab of the same cable plant tested with the same reference cables but using all three reference methods. As you see, the loss is highest with method B and lowest with Method C, but notice the standard deviation, a measure of the reproducibility of the measurement, is much higher - worse - as you include the connectors.

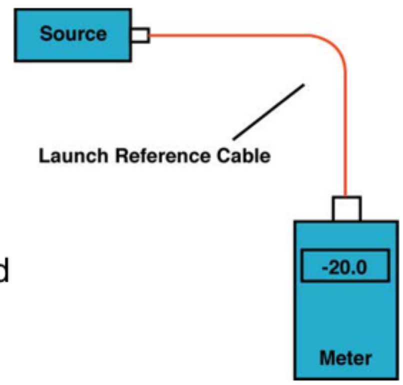
Thus the most repeatable measurement is Method B, also the highest loss. Method A yields a measurement of about 0.3 dB less loss (obviously the connectors on our reference cables were good - 0.3 dB mated loss) and Method C about 0.5 dB less.

Again, all three methods are acceptable, as long as the method is included in the documentation.

We will look at the OTDR discrepancy later in the OTDR section.

What If Connectors Are Not Mateable?

- Some connectors do not mate with other connectors, just attach to transmitters and receivers
- Use a "cable substitution test"
- Attach <u>known good cable</u> (reference) between meter and source, measure = "0 dB ref"
- Remove and attach cable to test, measure difference



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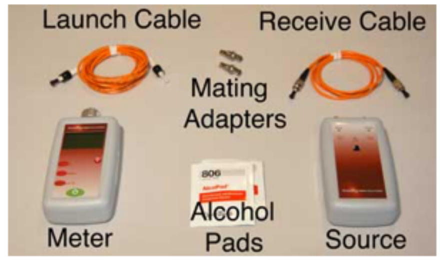
Some connectors, for example POF connectors, do not mate with other connectors, only with transmitters or receivers. These connectors must be tested with a source and power meter in a "cable substitution" test.

The cable substitution test still requires a reference cable, where you set the reference based on the transmission of the reference cable. Then you substitute the cable you want to test and measure the transmission again. The measurement result will be the dB difference between the coupling of the two cables from the source and the losses of the cables themselves.Thus the measurement result can be + or -, it's just relative. You must set criteria for pass fail based on the difference,not an absolute value like insertion loss.

Step-By Step #1
Gather Equipment Needed

- Power meter
- Source
- Reference cables - at least 2
- Connector mating adapters
- Connector cleaners



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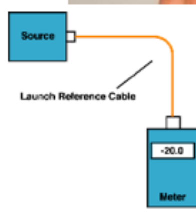
First gather all equipment needed for the test. Make sure you know how it all works and that it is in good working condition and charged up.

To get good measurements, you must clean all connectors carefully. Dirt, whether during setting references or measuring loss, will cause uncertainty. After cleaning, inspect with a microscope like you use when checking polish during termination.

Eye Safety: Most fiber optic systems have very low power levels - much too low to harm your eyes. However, some CATV and telco WDM systems do have power levels that can be harmful.If you are working on a installation, there should be no network equipment connected that could be dangerous, but someone could be using an OTDR on the cables.Always use a power meter to check for power in the fiber before inspection with a microscope anytime!Remember looking into a fiber is silly - systems use infrared light which you can't see anyway!

Step-By Step #3
Set “0 dB” Reference (Method B)

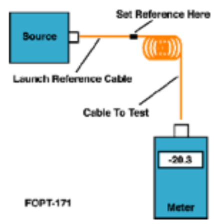
- Attach launch reference cable to source
- Connect to meter
- Read power
- Zero meter or note reference level



Once you set the “0 dB” reference, do not disconnect the launch reference cable from the source connector. Disconnecting and reconnecting may lead to slightly different power levels coupled from the source and will ruin your “0 dB” reference.

Step-By Step #4
Single-Ended Test (FOTP-171)

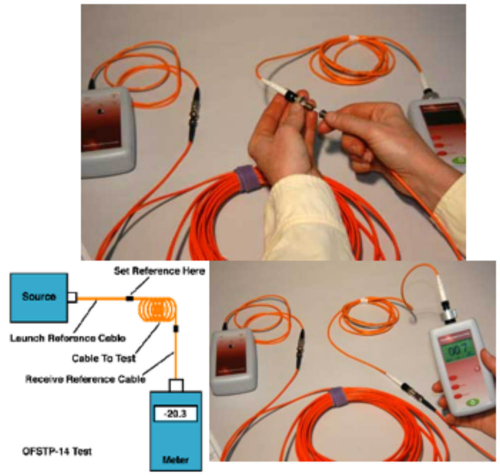
- Attach the cable to be tested to the launch cable using a mating adapter
- Attach other end of cable to meter
- Read loss
- Reverse to test other connector



Attach the cable to be tested to the launch cable using a mating adapter
Attach other end of cable to meter
Read loss
Reverse to test other connector

Step-By Step #5
Double-Ended Test (OFSTP-14/7, Method B)

- Attach the cable to be tested to the launch cable
- Attach other end of cable to receive cable
- Attach receive cable to meter
- Read loss



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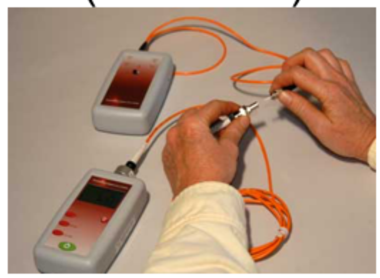
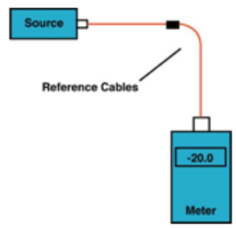
Attach the cable to be tested to the launch cable
Attach other end of cable to receive cable
Attach receive cable to meter
Read loss

Step-By Step #3-A
Set “0 dB” Reference (Method A)

- Attach launch cable to source
- Attach receive cable to launch cable
- Connect receive cable to meter
- Read power
- Zero meter or note reference level

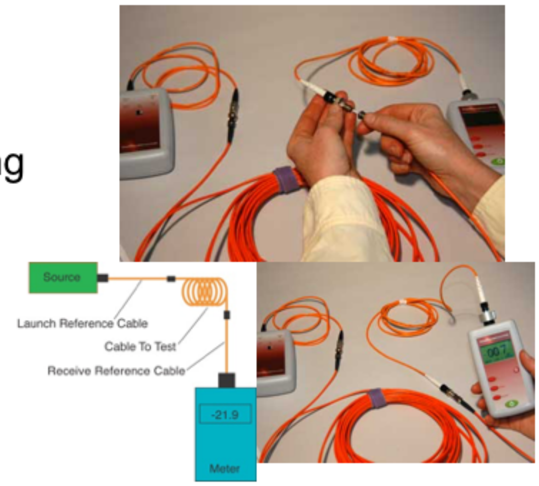




Once you set the “0 dB” reference, do not disconnect the launch reference cable from the source connector. Disconnecting and reconnecting may lead to slightly different power levels coupled from the source and will ruin your “0 dB” reference.

Step-By Step #5-A
Double-Ended Test (Method A)

- Attach the cable to be tested between the launch and receive cables using additional mating adapter
- Read loss

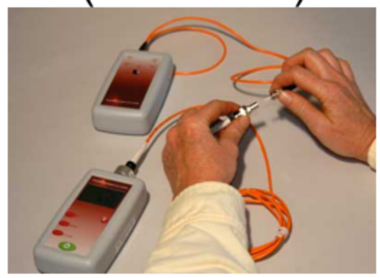


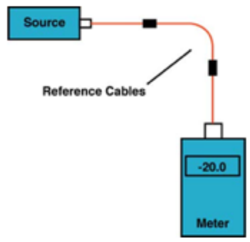
Attach the cable to be tested between the launch and receive cables using additional mating adapter

Read loss

Step-By Step #3-A
Set "0 dB" Reference (Method C)

- Attach launch cable to source
- Attach 3rd reference cable to launch cable
- Attach receive cable to 3rd reference cable
- Connect receive cable to meter
- Read power
- Zero meter or note reference level

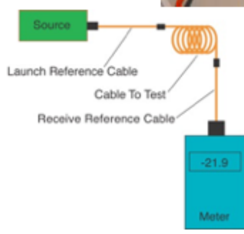




Once you set the "0 dB" reference, do not disconnect the launch reference cable from the source connector. Disconnecting and reconnecting may lead to slightly different power levels coupled from the source and will ruin your "0 dB" reference.

Step-By Step #5-A
Double-Ended Test (Method C)

- Remove 3rd reference cable
- Attach the cable to be tested between the launch and receive cables
- Read loss



Remove 3rd reference cable
Attach the cable to be tested between the launch and receive cables
Read loss

Lab Exercises – Insertion Loss Testing

- Test cables single-ended and double-ended and compare results
- Reverse cables and compare results
- Test MM cables with and without mandrel wrap mode conditioner and compare results.

Here are some exercises to try when you run tests on your own.

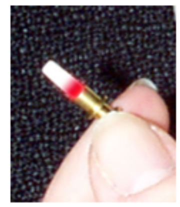
Lab Exercises – Insertion Loss Testing

- Test cables with wrong size reference cables, e.g. 50/125 fiber with 62.5/125 micron reference cables and vice versa
- Even try mixing SM and MM
- Test with clean and dirty connectors and compare results.

Here are some exercises to try when you run tests on your own.

Troubleshooting High Loss

- Check reference cables
- Check “0 dB” reference
- Retest each section of the cable plant
- Test cables single-ended and reverse to find bad connectors
- Check connectors with microscope
- Check prepolished/spice connectors with VFL (right)
- If loss at long wavelength is too high, look for stress or tight bends



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The first step in troubleshooting is to check your reference cables. Are they clean and test with low loss in a single-ended test? Do they match the size of the fiber you are testing? We’ve gotten calls from people saying everything they test has 20 dB of loss but the connectors look great in a microscope! Well, that’s what you get testing SM fiber with MM reference cables. A consistent 2-4 dB means you may be testing 50 micron fiber with 62.5 patchcords.

If that’s not the problem, recheck you instruments to make sure the reference for “0 dB” has not changed.

If the instruments and reference cables are OK, retest the questionable cable plant segment by segment, so you are only testing one fiber with connectors on each end. If all the fibers in a cable test bad, start looking for stress on the cable causing loss. It may also show up as loss at 1300 nm being equal to 850 nm in MM cable, although it should be much less (fiber loss is about 1 dB/km at 1300 nm and 3 dB/km at 850 nm). In SM cable, loss at 1550 nm is highly sensitive to stress loss so the difference to 1310 nm is reduced.

For any single fiber link, test single ended from both directions. A bad connector will have high loss mated to the reference connector but less effect when mated to the detector on the meter, so one way should have higher loss – and the bad connector is then the one mated to the launch reference cable.

FOA Guide For Fiber Optics Virtual Hands-On

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