Fiber U Basic Skills Workbook

Fiber Optic Testing

Students Will Learn
Basics of fiber optic test procedures
Variables in testing methods
Accuracy of testing

Exercises:
Continuity
Visual Inspection And Fault Location
Measuring Optical Power With A Power Meter
       Power or Loss? ("Absolute" vs. "Relative")
       Optical Power Range
       Wavelength Calibration   Differences
Insertion Loss Testing
       The Power/Loss Budget
       Single Ended Loss Test
       Double Ended Loss Test
       Effects of mode power distribution
       Effects of three different 0 dB reference methods
OTDR Testing

Visual Aids
The following visual aids show the processes described in these exercises. They may be shown to the students before the lab or just used as a reference by the instructor.
FOA Instructional YouTube Videos: Testing (https://foa.org/tech/ref/contents.html#YT)

- FOA Lecture 12: Fiber Optic Testing Overview
- FOA Lecture 13: Testing Fiber Visually
- FOA Lecture 14: Testing Optical Power
- FOA Lecture 15: Five Ways To Test Fiber Optic Cable Plants
- FOA Lecture 16: Insertion Loss Testing
- FOA Lecture 17: OTDR Testing
- FOA Lecture 18: OTDR Setup
- FOA Lecture 19: OTDR Measurement Uncertainty
- FOA Lecture 20: Other Fiber Optic Tests - Reflectance, Dispersion, Spectral Attenuation

- Insertion Loss Testing

Virtual Hands-On (VHO)
- Insertion loss testing
- Using an OTDR,

Download the appropriate VHOs for the exercises you are doing.

Textbook

The FOA has a comprehensive textbook on fiber optic testing covering all the topics in this lesson in great detail. It is highly recommended that you get a copy for use in learning about fiber optic testing and keep available as a reference when questions arise. (https://foa.org/FOArgTest.html)

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.

Equipment Required

Cleaning kit or alcohol pads or lint-free wipes and 99% isopropyl alcohol for cleaning connectors

Visual Fault Locator (VFL) or Fiber Tracer (MM only)
Connector Inspection microscope

For Insertion Loss Testing
Light source and power meter (OLTS)
Appropriate connector adapters (ST or SC) for the power meter
2 reference test cables (launch and receive)
Testing Consumables:
Cables to test (terminated cables of various lengths which can be interconnected to create longer cables for testing)
2 ST-ST or SC-SC mating adapters
Simulated cable plant (see below)

For OTDR Testing
FOA OTDR Simulator running on a Windows PC (download from https://foa.org/tech/ref/testing/OTDR/OTDRsimulator.html)
Or OTDR with Launch and receive test cables
Simulated cable plant (see below)

OTDR Simulator

FOA has an OTDR Simulator that runs on a Windows PC and allows the user to view and measure OTDR traces. This link has information on downloading and using the FOA OTDR Simulator: https://foa.org/tech/ref/testing/OTDR/OTDRsimulator.html

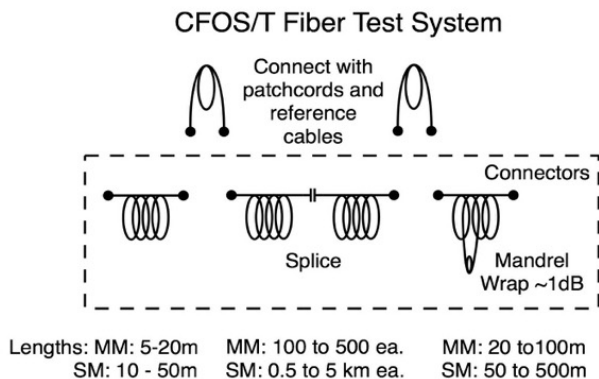## Fiber Optic Testing Lab Overview

In the hands-on testing, each student should have exercises in all five test methods: microscope inspection of a connector, visual tracing and fault location, optical power measurement, insertion loss testing and OTDR testing. Labs should have available a simulated cable plant, either a complete packaged one or a variety of cables both long and short, some of which are good and some bad for use in student exercises. One way to have lots of cables to test is to save student termination exercises for the student to test in this lab and for other students to test also.

If time permits and equipment is available, an OTDR lab is recommended. OTDRs are used for testing and troubleshooting many fiber optic networks, but these instruments are often considered too specialized to include in a basic course on fiber optics. However, we highly recommend including an OTDR lab.

The FOA Curriculum includes an OTDR simulator that runs on Windows and can be projected for class use. Instructors have told us this simulator is better for teaching than a real OTDR. Students may be given a copy of the OTDR simulator to install on their computers to analyze traces for homework or use in the future for practice and reference.

Simulated Cable Plant For Testing Labs

The labs for this course should use a simulated cable plant similar to this diagram. For the course, both singlemode and multimode simulated cable plants will be needed.

CFOS/T Fiber Test System

Lengths: MM: 5-20m	MM: 100 to 500 ea.	MM: 20 to100m
SM: 10 - 50m	SM: 0.5 to 5 km ea.	SM: 50 to 500m

Schools should build their own simulated cable plants or purchase one from FOA approved vendors. Contact FOA for sources.

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Visual Inspection With A Microscope

Check the fiber with a power meter before inspecting connectors! Microscopes can focus light from the fiber into the eye which can be harmful.

What Students Learn:
How to operate a fiber optic microscope
How to identify various faults of connectors
How to clean and inspect connectors properly

Using the microscope and one of the test cables, inspect the connector polished end three ways and note the differences.

Direct inspection, where the connector is aimed straight toward the microscope lens. How well does the fiber fit in the hole in the connector ferrule? Is it centered? Sketch what you see on the worksheet.

Direct inspection with light in the core of the fiber, by attaching the other end of the cable to the Visible fiber tracer. Note the light transmitted through the core now allows you to determine where the core and cladding on the fiber are. Sketch your observations on the worksheet.

Angular or oblique inspection. Following the microscope instructions, set the connector stage at an angle or use oblique lighting. Note the fine finish on the fiber end. Can you find the core this way? What do you see best?

Direct Inspection

Angular/Oblique Inspection

Remove the connector from the microscope and touch it to your fingertip. Inspect it again. Touch the connector to a dirty surface and inspect it again.

Lab Exercises: Cleaning Connectors
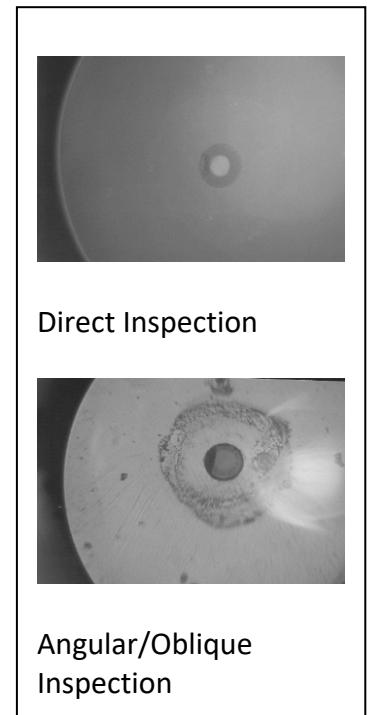
Connectors can be cleaned with wet, dry and wet/dry methods – wet dry is usually the best. Review the methods described in the Textbook or Online Guide.

1. Find one or more dirty connectors. If you do not find one, create one – wipe it on your finger, gently drag it on a carpet, even try wiping on your clothes. Be creative!

2. Clean the connector with a tissue wetted with alcohol. Inspect it with a microscope and report what you see? Is the connector clean? Repeat with a lint-free wipe and alcohol. Which cleans better?

3. Clean the dirty connector with a special dry fiber optic connector cleaner. How well does that work?

4. Clean the dirty connector with a wet/dry method. First use a lint-free wipe wet with alcohol, then dry with another lint-free wipe. You can often do this by only wetting a section of the wipe then moving the connector across the wet section to the dry section in one stroke. How does this clean the connector?

Which method of cleaning works best?

Visual Continuity Testing And Fault Location

What Students Learn:
What is the difference between a visual tracer and visual fault locator
How to operate both tools

In the field, you can use the visible fiber tracer to test all your cables for continuity and find any with broken fibers or connectors. It also allows tracing fibers to ensure transmitters are properly connected to receivers.
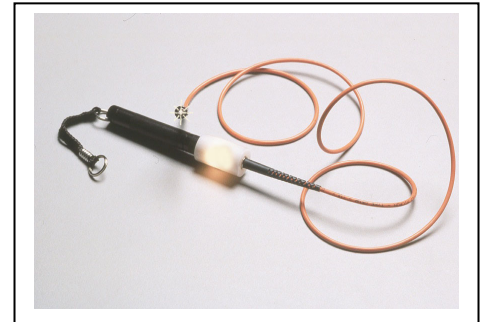

Attach one of the two terminated cable assemblies supplied to the visible fiber tracer "flashlight". Look at the other end of the cable and notice the light transmitted through the core of the fiber.
Repeat the test with other cables supplied.
Record your observations on the worksheet.

Notice how you can use the Visible fiber tracer to trace the path of the fiber throughout networks, as its range can be up to two miles (3 km) or more.
Visible laser sources with higher power called visual fault locators or VFLs can be used to trace singlemode fiber for longer distances and find breaks or stress loss in shorter fibers.
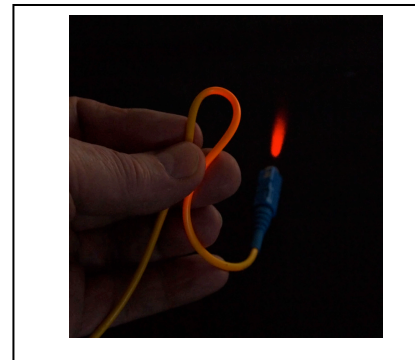
Using a SM fiber cable with a yellow jacket, attach the cable to a VFL.
Using your fingers, put a bend in the cable and see the light shining through the jacket. Don't bend too tightly; although fiber optic cable is strong, it will break under abuse.

Optical Power Testing

What Students Learn:
What is the difference between absolute and relative optical power?
What is the difference between "dB" and "dBm"?

Why are power meters calibrated at certain wavelengths?

Power or Loss? ("Absolute" vs. "Relative" power)

Practically every measurement in fiber optics refers to optical power. The power output of a transmitter or the input to receiver are "absolute" optical power measurements, that is, you measure the actual value of the power and express it in dBm. Relative to 1mW. Loss is a "relative" power measurement, the difference between the power into a component like a cable or a connector and the power that is transmitted through it. This difference is what we call optical loss, expressed in dB, and defines the performance of a cable, connector, splice, etc.

Optical Power Ranges

Relative Optical Power Measurements

Because optical power measurements cover such a wide range, up to 1,000,000:1, the power is expressed in a compressed logarithmic scale, called decibels or dB. For every 10 dB change in optical power, there is a 10 times change in power. If the dB value is "+", the power has increased and if the dB is "-", the power has decreased. However, to confuse the issue, "loss" is read from the meter as a "-dB" but generally expressed as a positive term!

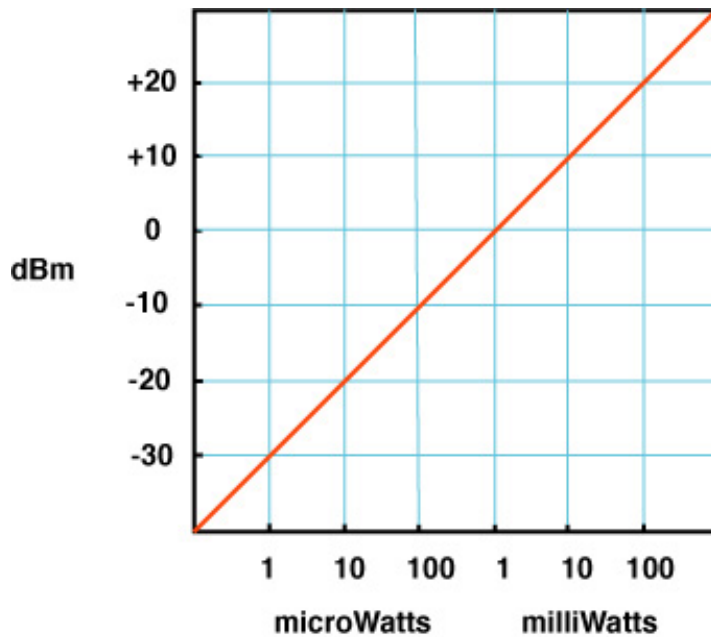See the table below for some ratios of power to dB measurements.

	dB loss	% change in power		dB change	Multiplier
	0	0		10	10
	0.1	2.3		20	100
	0.2	4.5		30	1,000
	0.5	10.9		40	10,000
	1.0	20.6		50	100,000
	2.0	36.9		60	1,000,000
	3.0	50.1			
	5.0	68.4			
	10.0	90			

Absolute Power Measurements

The optical power meter usually measures power in "dBm", or "dB" referenced to one milliwatt of power. dBm is absolute power, a measure of power referred to a standard value of 1 milliwatt (one one-thousandth of a watt.)

See also the graph below.

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	dBm	watts		dBm	watts
	+10	10 mW (milliwatts)		-10	100 µW
	+3	2 mW		-20	10 µW
	0	1 mW		-30	1 µW
	-3	500 µW (microwatts)		-40	100 nW (nanowatts)
	-6	250 µW		-50	10 nW

Wavelength Calibration

Power meters, generally, are calibrated at 850, 1300, and 1550nm to compensate for the wavelength variation of the sensitivity of the detector used. There are applications were 665nm and 790nm wavelengths are used, for example 665nm is often used with plastic optical fiber. Multimode networks use the 850nm and 1300nm wavelengths and singlemode networks use 1300nm and 1550nm wavelengths.

When testing, it is important to make sure that the wavelength selected on the meter matches that of the source.

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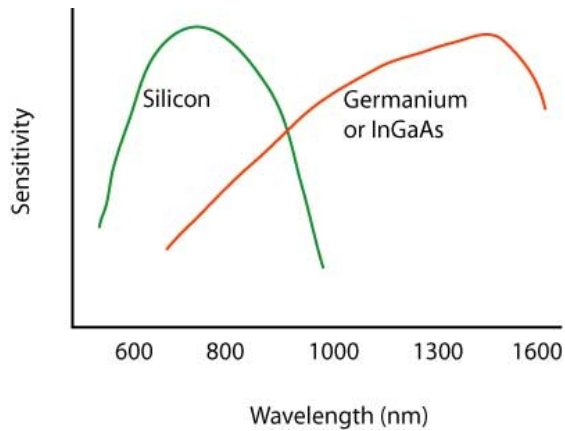
Measuring Optical Power with a Power Meter

What Students Learn:
What is the difference between absolute and relative optical power
What is the difference between "dB" and "dBm"
How to operate a fiber optic power meter

Measuring Power – Absolute Power
        You need a power meter, source and reference cable or any patchcord. Connect a cable and connect it between the source's 850 nm LED output and the meter. Turn on the source with the switch toward the 850 nm LED. Turn on the meter and set the meter calibration switch to 850 nm and the range to "dBm." Read the meter and note it on the worksheet below.
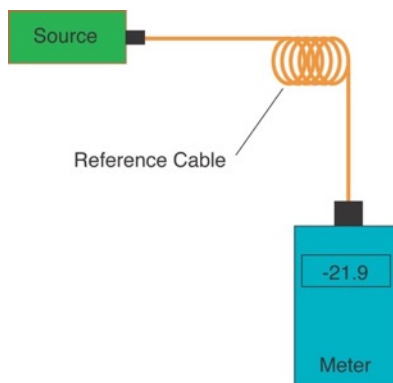
Meter reading @850 nm: _____ dBm

        If the source output power is adjustable, decrease the power output of the source. You may also use an attenuator or induce attenuation in the cable by wrapping it around a 13 mm (1/2") mandrel. Note as the power decreases, the number on the meter display becomes a

"larger" negative number, e.g. it will go from -10 dBm down to -12, -15, -20, -30, etc. Increasing the power (turning the pot counterclockwise) will cause the numbers on the meter display to get "less negative". This is a consequence of the logarithmic display of power.

If you can get power levels over 1 mW (possible with many laser sources), you will find the numbers will go to "0" at exactly 1 mW, then become positive (+) and become larger as the power is increased. This is caused by the fact that the scale of dBm is all relative to 1 mW and the reading is "+" for power levels greater than 1 mW and "-" for levels below 1 mW.

When you measure loss, expect the meter to read a "larger" negative number. The difference between the reference power and the test power will be the loss, but the value for loss will generally be expressed as a positive number, like 3 dB loss.

Meter reading @850 nm with lower power level: _____ dBm

Relative Power

Repeat the exercise using the meter's "dB" scale. Set up with the source and use the meter's "0 dB" function to make the meter read "0.0 dB." Reduce the source power (on the source or by attenuation in the cable) and note the reading on the meter. Is the reading "+" or "-" when the power decreases?

Meter reading @850 nm with lower power level: _____0_____ dB
Meter reading @850 nm with lower power level: _____ dB

Wavelength Calibration

Using the same setup as above, with the meter set on the "dBm" scale, measure the optical power from the cable attached to the source at the wavelength of the source, e.g. 850 nm. Change the meter to a calibration of 1300 nm and 1550 nm (as available) and record the difference. What does this tell you about the detector sensitivity?

Meter reading @   850 nm _____ dBm
1300 nm _____ dBm
1550 nm _____ dBm

Loss Testing

The Power Budget And The Loss Budget

The term "power budget" refers to the difference between the power output of the transmitter and the minimum required power input to the receiver. The loss budget is the calculated estimate of the loss of the cable plant. The loss budget is compared to the power budget to ensure that the link will operate properly. That means the loss of the cable plant is less than the power budget. The cable plant loss budget is also compared to insertion loss test

results to ensure the cable plant has been installed within the expected loss parameters of each component.

In this lab, we will calculate power budgets and loss budgets and compare them.

The Power Budget

Fiber Optic networks are designed to operate within certain power levels. If the loss is too high the signal power at the receiver will be too low for proper operation. If the signal power is too strong at the receiver the receiver will saturate. This is why you test with a power meter, to ensure the received power is within the correct range.

Consider the specifications of a typical fiber optic link:

	850nm LED	850nm VCSEL	1310 Laser
	MM, slow	MM, fast	SM, fast
Transmitter Min Output Power (dBm)	-20	-6	0
Receiver Min Input Power (dBm)	-30	-12	-20
Power Budget (dB)	10	6	20

Note that very fast MM links using VCSELs usually have power penalties caused by dispersion and/or limited link lengths to allow for dispersion. For example a 10G link in OM3 or OM4 fiber using a 850nm VCSEL may have only a 2dB margin and a 300m maximum length. The same is true for very long SM links. Refer to the actual transmission link specifications or link standards to determine if there are dispersion penalties to consider.

Use link standards or transceiver specs to illustrate the power budget to the students. Give them data sheets and let them calculate it for themselves. Use the FOA Guide page on network standards for reference. (http://www.thefoa.org/tech/Linkspec.htm)

The Loss Budget

Will a given link with a known power budget operate over the cable plant's estimated loss? What loss value should you expect when testing insertion loss? The answer to these questions is determined by calculating a loss budget.

The loss you measure when testing a link should be close to what you predict when you do a loss budget. The loss is the sum of the loss in the fibers over the length installed, plus the loss of all connectors and splices in the installed cable plant.

Lab Exercises

Using the guidelines for component loss and the worksheets below, calculate the loss budget for the following two cable plants using typical component specifications:

1) Multimode campus LAN backbone, 300m (0.3 km) long, four connector pairs (plus the end connectors) and no splices. Calculate loss at 850 nm. Calculate with both typical and Max (TIA) loss values.

2) Multimode LAN link at 10G, 100m (0.1km) long, one intermediate connection (plus the end connectors) and no splices. Calculate loss at 850 nm.

3) Singlemode network, 27 km long, 6 fusion splices, connectors only on each end. Calculate loss at 1550nm.

4) Singlemode metro network link, 5km long, 2 intermediate connections, 3 fusion splices. Calculate loss at 1310nm.

Below are some tables of component loss that can be used to calculate the loss budget.

Fiber Type	MM	MM	SM	SM
Wavelength (nm)	850	1300	1310	1550
Fiber Atten. (dB/km) Typical	3	1	0.4	0.3
Fiber Atten. (dB/km) MAX TIA (Premises)	3.5	1.5	1.0	1.0

	Typical	TIA Maximum (Premises only)
Connector Loss (dB)	0.3dB	0.75dB

Splice Type	Mechanical	Fusion
Typical Splice Loss (dB) Typical	0.3	0.1
Typical Splice Loss (dB) MAX TIA (Premises)	0.3	0.3

Cable Plant Loss Budget Exercises

Cable Plant Exercise #	1	2	3	4
Fiber length (km)				
Fiber type				
Fiber attenuation (dB/km)				

Total Fiber Loss (dB)				
Total number of connectors or connections				
Connection loss (dB)				
Total Connector Loss (dB)				
Total number of splices				
Splice loss(dB)				
Total Splice Loss (dB)				
Other (dB)				
Total Link Loss (dB)				

Hint: don't forget the connectors on each end!
That said, including the connectors on each end assumes you are using a "1-cable" reference method. We'll discuss this again in the labs for insertion loss testing.

If exercise 4 were a link in a PON FTTH network with a 32 port splitter, how would the loss budget be calculated?

There are many more case studies in the FOA Design curriculum that have loss budget calculations. You can download them from the Design curriculum and use here or create your own.

Insertion Loss Testing

Lab Exercises – Single Ended Loss Test Of Patchcords

Use the single ended test method to test your launch and receive jumpers that you will use to test cables later.
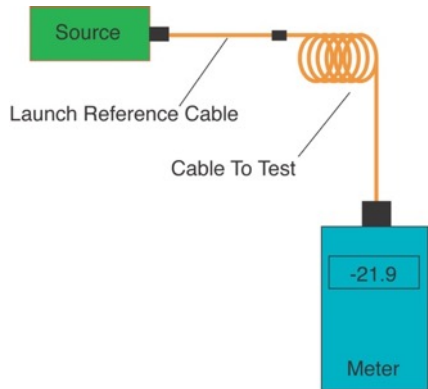
Diagram for single-ended insertion loss test

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.)

Set test "0 dB" reference value

Using the connector cleaners, clean the ends of all the connector ferrules and replace the dust caps.
Attach one of the reference cables to the source's output. This should be an 850 nm LED for multimode cables and a 1310nm Laser for singlemode cables. This will be the launch cable
Turn the source and meter on. Set the meter to the dBm scale.
Use the power meter to measure the power out of the launch cable.
Do not use the "0dB" reference setting button to set the test reference at this time - record the source output level instead to calculate the loss.
Disconnect the launch cable from the power meter.
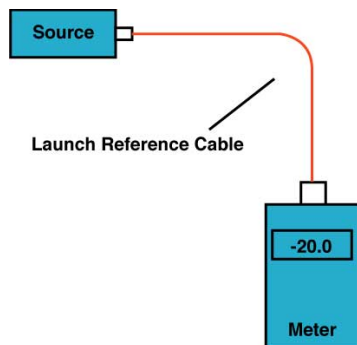
Setting reference for single-ended test

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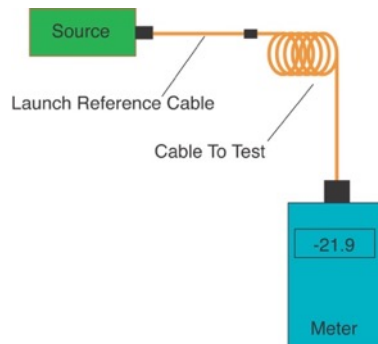**Measure single ended loss**

Attach a connector 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 second cable to the power meter.
Measure the output of the second cable and record it on the worksheet _____dBm (2)
Calculate the loss: ____dBm (measured) - _____dBm (reference) = ____loss in dB, end A

Measure opposite direction

Reverse the cable being tested and test the other direction
Measure the output of the second cable _____dBm (measured)
Calculate the loss: ____dBm (measured) - _____dBm (reference) = ____dB loss, end B
Is there a difference in the two measurements? How much ____dB? Why?

When you measure loss, expect the meter to read a "larger" negative number. The difference between the reference power and the test power will be the loss, but the value for loss will generally be expressed as a positive number, like 3 dB loss.

Double Ended Loss Test Of Simulated Cable Plant

Installed fiber optic cable plants are generally tested in a double-ended test which tests both end connectors and all the fiber optic cables and other components in the cable plant.
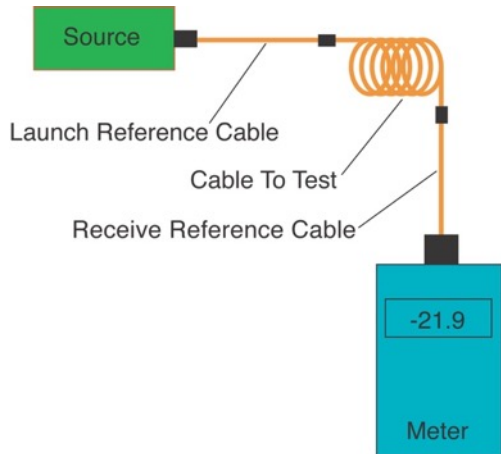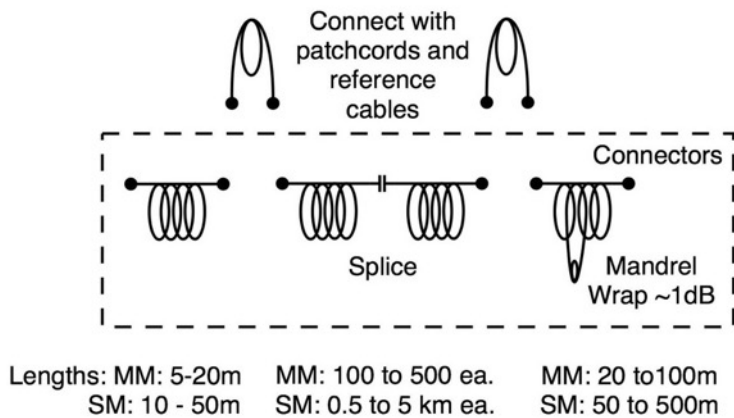
Diagram for double-ended insertion loss test

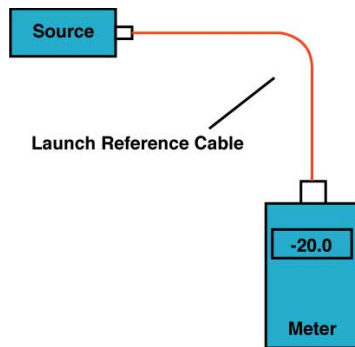**Simulated Cable Plant For Use In Labs**

The labs for this course should use a simulated cable plant similar to this diagram. For the course, both singlemode and multimode simulated cable plants will be needed.

Schools should build their own simulated cable plants or purchase one from FOA approved vendors. Contact FOA for more information.

Setting 0dB Reference

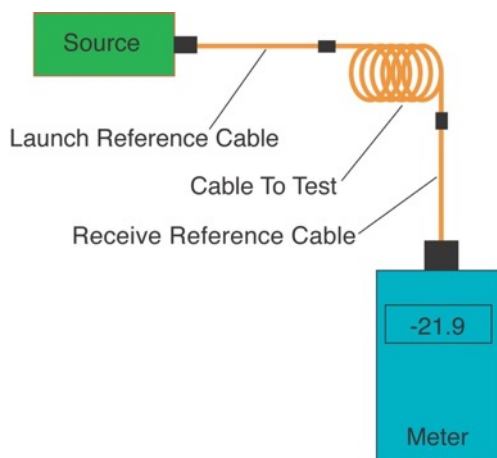Setting reference for double-ended test using 1-cable reference

Diagram for double-ended insertion loss test

Lab Exercises - Measure double ended cable loss

Attach a mating adapter to the end of the launch cable.

Attach one end (A) of the cable to be tested to the launch reference cable.

Attach a mating adapter to the other end (B) of the simulated cable plant being tested.

Attach a second cable to the end of the cable being tested to become the receive reference cable.

Attach the other end of the receive cable to the power meter.

Measure the output of the second cable and record it on the worksheet _____dBm (measured)

Calculate the loss: ____dBm (measured) - _____dBm (reference) = _____loss in dB, end A and B.

This is the loss in "Direction A"

Lab Exercises - Reverse Test:

Reverse the cable being tested and test the other direction
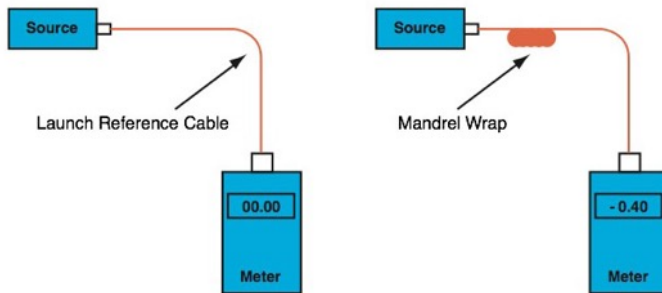
Measure the output of the meter _____dBm (measured)

Calculate the loss: ____dBm (measured) - _____dBm (reference) = _____dB loss, reversed.

This is the loss in "Direction B"

Is there a difference in the two measurements? How much _____dB? Why?

Optional: Lab Exercises - Multimode Fiber Mode Control:
Repeat the tests above with multimode fiber using a mandrel wrap mode conditioner and verify the mandrel wrap with a HOML (higher order mode loss) test.

1. Connect the meter to the launch reference cable and measure the output and record the result _____.

2. Attach a mandrel wrap (5 turns around a mandrel) to the launch cable per the table below.

TIA-568 Specified Mandrel Size (Wrap launch reference cable five turns over the specified size mandrel)			
Fiber Type	3mm Jacketed Cable	2.0 or 2.4mm Jacketed Cable	1.6mm Jacketed Cable	900 micron Buffered Fiber
50/125	22 mm	23 mm	24 mm	25 mm
62.5/125	17 mm	18 mm	19 mm	20 mm

3. To check the effect of the mandrel, measure and record the output of the launch cable again _____.

If the measured power is reduced by 0.2 to 0.6 dB, the source is essentially EF compliant and ready to use, without the mandrel. Remove the mandrel and make your measurements.

If the HOML is >0.6dB, leave the mandrel on the reference launch cable and make measurements.

If the HOML is <0.2dB, the source mode fill is too low and should not be used.

Retest The Simulated Cable Plant With Mode Control
Follow the instructions above for double-ended testing of the simulated cable plant (Direction A) and record the result _____.
Compare to the test without mode control. Describe what you find_____.
Repeat the test with the mode control in Direction B and record the result.
Compare to the test without mode control. Describe what you find_____.

What did you learn about mode control of multimode sources? _____

Optional: Lab Exercises - Measurements With 1, 2, and 3 Cable References For "0dB"

International standards offer three methods of setting a "0dB" reference using 1, 2 or 3 reference cables.
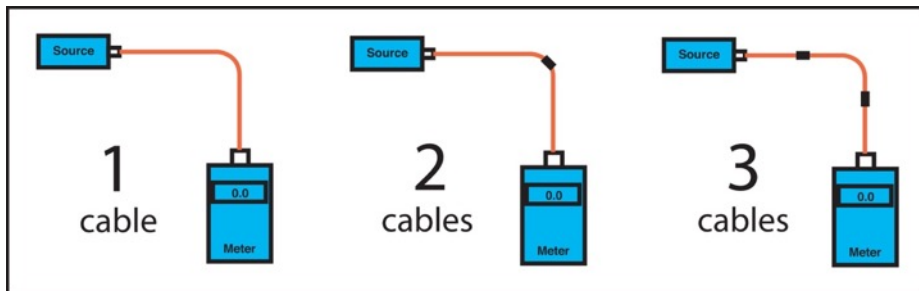
In the tests of the simulated cable plant above, you used the one cable reference. Try it again with the 2- or 3-cable reference methods and record your results.

Test results from above, 1-cable reference, Direction A_____ Direction B _____
Test results with 2-cable reference, Direction A_____ Direction B _____
Test results with 3-cable reference, Direction A_____ Direction B _____

What did you learn from the results with different reference methods? _____

OTDR Testing

What Students Learn:
The appropriate applications of an OTDR
The correct way to set up the OTDR
How to analyze traces on the OTDR
OTDR problems and limitations

OTDRs test optical fibers and fiber optic cable systems using an indirect method that depends on the backscatter of light in the fiber. While all international standards require OLTS (light source and power meter) testing of installed cable plants, OTDRs are routinely used to check splices and find sources of stress loss that can affect long term reliability. OTDRs are also used for fault location and troubleshooting.

While OTDRs are primarily used for outside plant cabling, manufacturers have been promoting their use in premises and campus networks. The technical calls taken by the FOA indicates that the use of OTDRs in these types of short cable plants has been a major source of confusion, particularly for installers who are new to OTDRs and have been told to connect it to the network and hit the "autotest" button.

Thus, the goal of the classroom training and this lab is to show the students the proper applications in which to use of the instrument as well as how to use it properly. This may be done in two ways, using the OTDR Simulator available from the FOA or an OTDR and simulated cable plant. We will offer both ways.

Using The OTDR Simulator

The FOA Testing textbook and OTDR PPTs have details on how the OTDR works. The instructions for the OTDR simulator are in the manual and on a PPT presentation in the zip file package you download. The simulator can be loaded on a PC using the installation instructions. There are three file folders containing about 80 traces that should be loaded on the PC also. One contains multiple traces of the same cable plant taken with different OTDR setups, one contains field traces and one has FTTX traces through a PON-type coupler (with only 2 ports to simplify understanding how couplers are seen on OTDRs.)

Lab Exercises - Using The FOA OTDR Simulator

The FOA OTDR simulator runs on PCs with Windows 7 or XP or Windows 10 in the compatibility mode. It can also run on a MAC using one of the Windows emulators like Parallels Desktop. The OTDR simulator has dozens of files of OTDR traces in a standard format (.sor) that can also be viewed using other OTDR analysis programs supplied by OTDR manufacturers.

OTDR Setup

The OTDR Simulator has a file folder of "Parameter Demo Traces" that show traces of one cable plant taken with many variables that are settable in the OTDR according to the needs of the tests. The OTDR Simulator allows comparing traces to make it easy to see the effects of changing setup parameters.

This part of the lab can be done with the whole class, projecting the OTDR Simulator display on a screen for teaching and discussion.

The files in Parameter Demo Traces have filenames that describe what is being changed:

Number or averages: avg-x.sor

Index of refraction: n-xxxxx.sor
Pulse width: pw-xns.sor
Range: r-xkm.sor
Wavelength: w-xxx.sor

Within each group, open the first file and look at the trace. Then open the next file in the window and compare to the first file. For each settable parameter, what is the best choice for viewing the cable plant being shown in the trace?
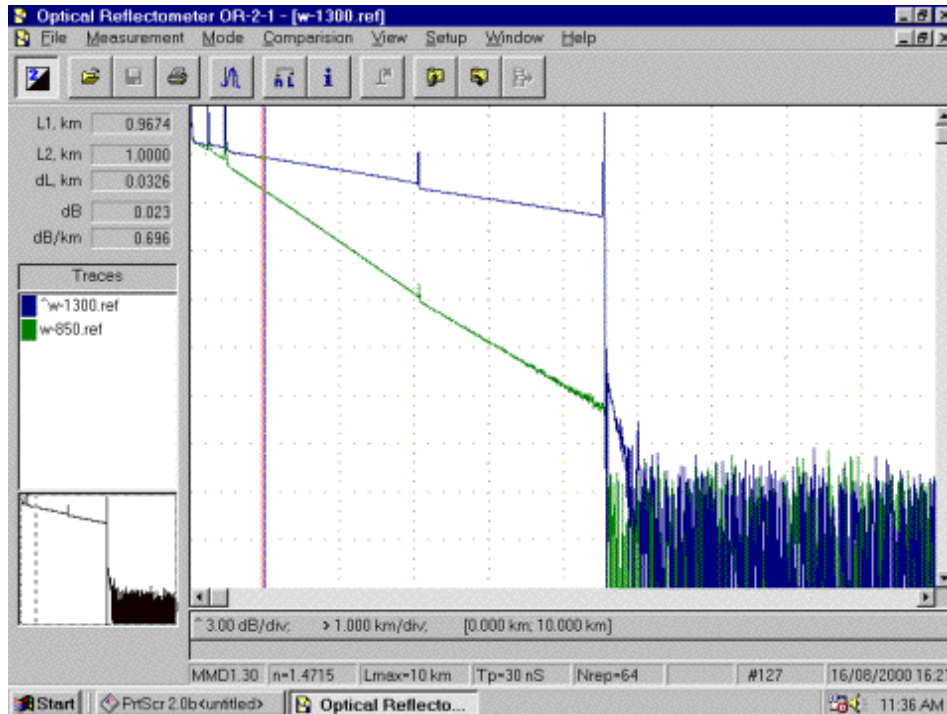
OTDR Simulator showing comparison of MM traces at 850 and 1310nm

OTDR Trace Analysis
The file folders Span Traces, Traces and FTTX traces have many files for analysis by students. We recommend doing some as a class then assigning them to students as homework if they have PCs that can run the software.

Analyze the traces by:
Finding the length of the launch cable
Finding the length of the entire cable plant being tested
Finding all events – splices and connectors – and trying to identify which is which
Looking for ghosts and gainers

Setting up the OTDR

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The secret to getting good traces in the OTDR is to set the test parameters properly. In the "Parameters" folder, there are 26 traces taken of one cable plant – about 5.2 km of multimode fiber in 4 segments - with each trace using a different setup parameter. Thus, one can open traces from the folder that can be shown as comparisons on the display to allow the student to see the effects of the setup.

Range

There are 6 range files. Range changes the scale on the display and the timing of the test pulses. Note that on the longer ranges, the 5.2 km cable plant has poor resolution and on the shortest one, the display is distorted since the OTDR does not have time to get the test pulse back before the next pulse is sent.

Averaging

The OTDR sends out multiple test pulses and averages the result. Take a look at the traces at 1 and 1024 averages and note the difference in signal to noise in the trace. Try several others to see what is a good value for this cable plant.

Index of Refraction (n)

The Index of Refraction (n) is a measure of the speed of light in the fiber, so it is used to calibrate the distance to events. Compare the three traces taken at different values of n and see how the traces change.

Pulse Width

Wider pulse widths give the test pulse more energy so the OTDR can see a longer distance. But the tradeoff is resolution, not just in distance but in dB, as the comparison between these traces show.

Wavelength

OTDRs typically test at two wavelengths, 850 and 1300 nm for multimode, 1310 and 1550 for singlemode and sometimes 1620 nm for finding high stress loss areas in singlemode cable plants. Open the 850 and 1300 nm traces and compare them.

Analyzing Fiber Traces

There are more than 50 traces to analyze, including 4 through couplers for seeing what happens in a PON system. Some of these are analyzed in the notes to the OTDR simulator but all are available for classroom or student analysis. See if you can find the one with the "perfect" gainer.

Autotest

After thoroughly analyzing the trace including distance and loss at all events, make the same test using the OTDR autotest function. How do the manual and auto values compare?

Bidirectional Testing

After getting a good trace and analyzing it, disconnect the cable at the end of the reference cable and test in the opposite direction. If possible, compare the loss results of a connector or splice taken in two directions. Do you get the same loss value?

Effects of the Launch Reference Cable

After getting a good trace and analyzing it, remove the launch cable and try again, connecting the cable directly to the OTDR. What information is now missing? Add a cable to the end of the cable under test (called a tail or receive cable) as required in many international standards. What new information does this give you?

Experiments With Your Own OTDR

Exercise 1
What is an OTDR, how does it work and what can it test?
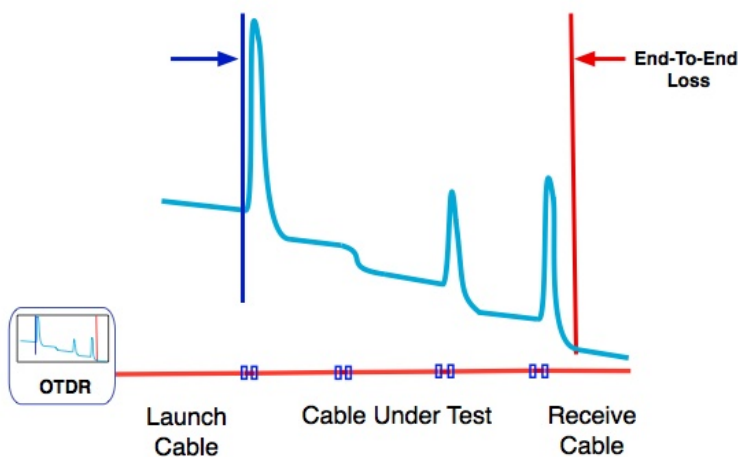
1. If you have an OTDR and some long-ish fiber optic cables, here are some experiments to perform. Use connectors and splices to connect the cables.
2. Create a simulated cable plant with some fiber optic cables long enough to be seen by the OTDR, typically 10-100 meters or more. (It's called "Cable Under Test" in the drawing above.)
3. Connect your OTDR with launch and receive cables to the simulated cable plant.
4. Using the automatic test mode of the OTDR take a trace.
5. Measure the length of your simulated cable plant, the location of all connections and splices and the end-to-end loss as shown in the article. The OTDR should also give you losses and reflectance for all connections and splices. Save the data on the OTDR memory or write it down.
6. Using the manual controls for setup of the OTDR parameters, select the proper wavelength, the shortest range that allows you to test your simulated cable plant, the shortest test pulse and minimal averaging.

7. Measure the length of your simulated cable plant and the location of all connections and splices.
8. Using manual controls for 2-point losses, set the OTDR markers for each splice or connection and manually measure the loss. Compare this to the data from the autotest done above. Are they different?

Exercise 2
Using the OTDR "least squares" measurement features to make more accurate measurements. Using the same setup as in Exercise 1, measure several connection or splice losses with both 2-point and LSA methods.

How close do they agree?

Exercise 3
Understanding OTDR "gainers," one of the more confusing measurement quirks of all fiber optics. Using the same setup as in Exercise 1, measure several connection or splice losses with LSA methods. Then reverse the "cable under test" so you can test the same connections or splices in the opposite direction. (Be sure to keep track of which is which so you compare the same connections or splices.)

How close do they agree?

Exercise 4
A "ghost story" – how OTDRs can confuse you if you are not watching carefully. Set up your OTDR and launch cable only. Attach a fairly short cable to the launch cable and take a trace.

Do you see more than one reflection from the connection and the end of the short cable?

How do you know those are ghosts.

Want to test what you have learned? Go here to take a quiz:
https://fiberu.org/FOtest/quiz/LP5%20quiz.htm

Fiber Optic Testing Worksheet

Name: _____

Continuity

1. What does the visual tracer test? _____

2. How far will it reach? _____

3. What problem will it solve when connecting up all the different fibers and equipment in a network?

Microscope Inspection

Which way do you want to look at the fiber to see:

Fiber centering in the ferrule hole_____

Polishing finish _____

Cracks _____

Microscope Inspection:

Sketch what you see

Measuring Optical Power:

1. Which optical power measurement is absolute and which is relative?
Transmitter power
Connection loss
Cable loss
Receiver power

2. Which is the higher power?

        0dBm   or   -30dBm ?

        0dBm   or   +10dBm ?

        3. Convert to 0dBm to Watts.

3. 0dBm = _____

Power/Loss Budget Worksheet

Cable Plant Passive Component Loss Budget Worksheet

Using these guidelines, calculate the loss budget for the following cable plant.

Design: Singlemode network, 17 km long, 6 fusion splices. Calculate loss for both 1300 and 1550nm.

Step 1. Fiber loss at the operating wavelength

Cable Length (km)				
Fiber Type	Multimode		Singlemode	
Wavelength (nm)	850	1300	1300	1550
Fiber Atten. (dB/km)	3	1	0.5	0.4
Total Fiber Loss				

Step 2. Connector Loss

Typical Connector Loss	0.5 dB
Total # of Connectors	
Total Connector Loss	

Step 3. Splice Loss

	Mech.	Fusion
Typical Splice Loss	0.5 dB	0.2 dB
Total # splices		
Total Splice Loss		

Step 4. Total Cable Plant Attenuation

	1300nm	1550nm
Total Fiber Loss (dB)		
Total Connector Loss (dB)		
Total Splice Loss (dB)		
Other (dB)		
Total Link Loss (dB)		

(Hint: don't forget the connectors on each end!)

Cable Plant Passive Component Loss Budget Worksheet

Using these guidelines, calculate the loss budget for the following cable plant.

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Design: Multimode campus LAN backbone, 1.7 km long, four connector pairs (plus the end connectors) and no splices. Calculate loss at both 850 and 1300 nm.

Step 1. Fiber loss at the operating wavelength

Cable Length (km)				
Fiber Type	Multimode		Singlemode	
Wavelength (nm)	850	1300	1300	1550
Fiber Atten. (dB/km)	3	1	0.5	0.4
Total Fiber Loss				

Step 2. Connector Loss

Typical Connector Loss	0.5 dB
Total # of Connectors	
Total Connector Loss	

Step 3. Splice Loss

	Mech.	Fusion
Typical Splice Loss	0.5 dB	0.2 dB
Total # splices		
Total Splice Loss		

Step 4. Total Cable Plant Attenuation

	850nm	1300nm
Total Fiber Loss (dB)		
Total Connector Loss (dB)		
Total Splice Loss (dB)		
Other (dB)		
Total Link Loss (dB)		

(Hint: don't forget the connectors on each end!)

Loss Testing

Single-Ended Loss Testing

Test 1. One direction

Reference power level _____ dBm (1)

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

Test 2. Reverse Direction

Reference power level _____ dBm (1)

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

Test 3. Mandrel wrap

Reference power level _____ dBm (1)

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

Why is this called a "single-ended" test? _____.
_____
2. Were the results the same when the cable was reversed? Why? _____

_____
3. Were the results the same when the mandrel wrap on the launch cable was used? Why?

_____
_____

Double-Ended Loss Testing

Test 1. One direction

Reference power level _____ dBm (1)

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

Test 2. Reverse Direction

Reference power level _____ dBm (1)

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

Test 3. Effects of reference methods
Loss with Method A (2 cable reference) _____ dB
Loss with Method B (1 cable reference) _____ dB
Loss with Method C (3 cable reference) _____ dB

Test 3. Mandrel wrap

Reference power level _____ dBm (1)

	meter reading dBm (2)	loss in dB
Cable tested with plain launch cable		
Cable tested with mandrel wrap on launch cable		

1. Why is this called a "double-ended" test? _____
_____

2. Were the results the same when the cable was reversed? Why? _____
_____

3. What is the difference in the loss measured with the three different reference methods?
_____
_____

Test 2. Reverse Direction

Reference power level _____ dBm (1)

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

Test 3. Effects of reference methods
Loss with Method A (2 cable reference) _____ dB
Loss with Method B (1 cable reference) _____ dB
Loss with Method C (3 cable reference) _____ dB

Test 3. MM Mandrel wrap

Reference power level _____ dBm (1)

	meter reading dBm (2)	loss in dB
Cable tested with plain launch cable		
Cable tested with mandrel wrap on launch cable		

1. Why is this called a "double-ended" test? It measures the connector loss on both ends, testing the entire cable end-to-end.
2. Were the results the same when the cable was reversed? There may be directional differences in connectors due to mode power distribution
3. What is the difference in the loss measured with the three different reference methods? Each reference method has a different number of connections included in the reference set which are subtracted from the measured loss.

OTDR Testing

Range
How does one properly set the range on an OTDR?

Averaging
How does one properly set the averaging on an OTDR?

Index of Refraction (n)
What is the effect of changing the index of refraction?

Pulse Width
What are the trade-offs in setting pulse width and how do you decide which is best?

Autotest
How do the manual and auto values compare? Which is best?

Bidirectional Testing
Do you get the same loss value testing with an OTDR in two directions on the same fiber?

Effects of the Launch/Receive Reference Cables
Why does one use a launch or receive reference cable when testing with an OTDR?