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Optical Fiber Cabling for Data Communication –
Test and Troubleshooting Quick-Reference Guide



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1. Introduction

As fiber links support higher speed network bandwidths with increasingly stringent requirements, it is becoming all the more important to ensure that your backbone links meet tightening loss standards. The need for higher data transmission capacity continues to grow as network applications grow and expand. These higher transmission speeds demand cabling that delivers higher bandwidth support. This testing guide outlines cabling performance requirements, field testing, certification and troubleshooting techniques and instruments to ensure that the installed optical fiber cabling supports the high data rate applications such as 1 and 10 Gigabit per second (Gbps) Ethernet, Fibre Channel and the anticipated 40 and 100 Gbps Ethernet applications.

A local area network (LAN) or an enterprise (“premises”) network connects users up to a distance of 5 km. It encompasses the intra-building connectivity as well as inter-building cabling or the campus cabling. Optical fiber cabling is primarily used for longer distance, higher bandwidth connectivity while twisted pair copper cabling typically provides the connection to the end-user or to the edge devices. This copper cabling can support network connectivity to a distance of 100 meters (328 feet). Optical fiber cabling is the preferred medium for distances beyond 100 meter such as riser cables in the building.

This booklet reviews best practices for test and troubleshooting methods as well as the test tools to ensure that installed optical fiber cabling provides the transmission capability to reliably support LAN or enterprise network applications. “Certification,” or the process of testing the transmission performance of an installed cabling system to a specified standard, ensures a quality installation. It also provides official documentation and proof that the requirements set by various standards committees are fully satisfied.

Optical fiber is a reliable and cost effective transmission medium, but due to the need for precise alignment of very small fibers, problems ranging from end-face contamination to excess modal dispersion can cause failures to occur. Regardless, narrowing down the source(s) of failure is often a time-consuming and resource-intensive task.

For this reason, Fluke Networks has created an enterprise-focused fiber troubleshooting guide to assist in ensuring: 1) proper assessment of cable installation quality, and 2) efficient troubleshooting to reduce the time spent identifying the root cause of a problem before taking corrective action to fix it. Note that this guide does not address issues that are especially germane to the long-haul telecommunications application of the fiber optic technology.

2. Fiber Verification Testing

Fiber verification testing (including end-face inspection and cleaning) should be practiced continually as standard operating procedure. Throughout the cable installation process and prior to certification, loss of cabling segments should be measured to ensure the quality of the installation workmanship. This type of a test is normally accomplished with an Light Source and Power Meter (LSPM) test set. Fiber verification test tools are typically less expensive tools; they can also effectively be used to troubleshoot troublesome links. A quick inspection of the end-to-end link loss may provide the indication whether or not the optical fiber cable is suspect or whether other network functions are the cause of the detected malfunction.

An LSPM determines the total light loss along a fiber link by using a known light source at one end of the fiber and a power meter at the other. But before the test can be done, as described earlier, a reference power level from the source is measured and recorded to set a baseline for the power loss calculation. After this reference is established, the meter and source are plugged into the opposite sides of the fiber link to be tested. The source emits a continuous wave at the selected wavelength. On the distant end, the power meter measures the level of optical power it is receiving and compares it to the reference power level to calculate the total amount of light loss (**Figure 1**). If this total loss is within the specified parameters for the link-under-test, the test passes.

A loss budget should be well established and used as a benchmark during cabling installation. If this type of verification testing is performed during installation, it can be expected that yield will increase and certification testing will go smoother.

LSPM test sets have historically been more difficult to use, requiring manual calculations and subjective interpretation by an experienced technician. However, newer instruments have eliminated time-consuming loss calculations by automating the process of comparing power measurements versus set references.

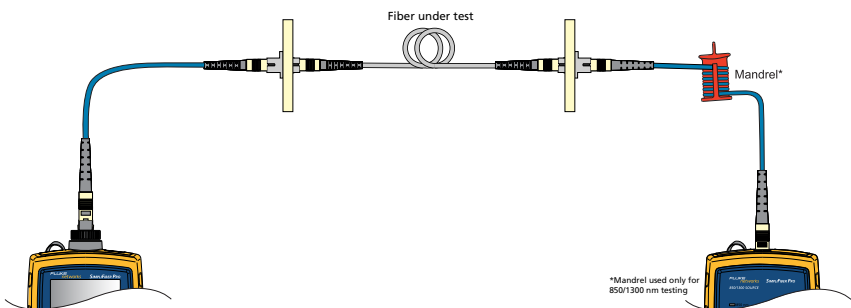


Figure 1 – Conducting an LSPM test

While convenient, basic verification of end-to-end loss using an LSPM set does not specify where the trouble areas are, making failures difficult to locate. Even in instances where the loss is within a specified threshold, the LSPM set does not provide any warning or indication of where a defect or problem may be located. In other words, although an entire link may pass, it is possible that individual splices or connections within it may fail industry specifications, creating a potential problem in the future during adds, moves, or changes where multiple dirty connectors can potentially be grouped together to result in a failure. An Optical Time Domain Reflectometer (OTDR) is the proper test tool to pinpoint locations (connections) displaying a high loss or reflectance.

3. How to Certify Optical Fiber Cabling with OLTS and LSPM

Industry standards require testing with an LSPM or Optical Loss Test Set (OLTS) to certify that the loss of each link meets performance standards. This is referred to as 'basic' or Tier 1 Certification.

It is a double-ended test which produces an absolute loss measurement which is then compared with installation cabling standards and/or channel application standards. Fluke Networks' DTX CableAnalyzer and OptiFiber OTDR can be equipped with optional multimode or singlemode fiber test modules that automate most of the test and make 'basic' or Tier 1 certification very easy.

Note that an OTDR also provides loss results for the total link but this measurement is based on the reflected light energy. The standards demand that the basic certification be executed with an OLTS or LSPM. These link loss results provided by using a light source on one end and a light meter at the opposite end are more accurate if properly executed.

The following steps should be followed to perform a basic loss length certification test.

- Establish Pass/Fail test limits
- Choose a test method and set a reference
- Run the test and save results
- Export to LinkWare to manage and archive the test results; LinkWare is Fluke Networks' popular and widely-used free data management software that lets you create printed or electronic reports.

1. Establish Pass/Fail limits in accordance to what your certification goals are. In this example, we will establish limits for the total allowable loss based on an application standard using the Fluke Networks DTX Series tester equipped with the DTX-MFM2 fiber loss test modules (for multimode). If you need to certify singlemode fiber use the DTX-SFM2 modules.

- a. Once the tester is turned on, turn the rotary switch to 'Setup' and select 'Instrument Settings' to input the operator name, job name etc.

b. Select 'Fiber Loss' from the Setup screen as shown in **Figure 2a**. Under this setup screen, you will choose from a menu of standards to select the correct limits. Select the 'Test limit' option as shown in **Figure 2b**. Note that the selected fiber type limits the test limit choices. Popular fiber types are also included in the instrument menu.

As **Figure 2b** shows, the same setup screen allows you to select the 'Remote End Setup'. When using the DTX Smart Remote equipped with the fiber test module, select 'Smart Remote' as we have done in this example. In this mode, the tester automatically measures the length of the link-under-test.

Lastly, this screen provides the option to tell the tester whether you need to test the link-under-test in both directions. If this is the case, remember never to disconnect the test reference cord (TRC) from the test modules; always swap the TRC at the connection with the link-under-test.

2. Choose a reference method and set a reference. As described earlier, setting a reference is a critical aspect of a loss test to obtain accurate test results. The power meter and light source are connected together and the power level is measured by the light meter to establish the 'reference' for loss calculations.

The steps for setting a reference are as follows:

- Step A. Turn the rotary switch to 'Special Functions' and choose 'Set Reference' (**Figure 2c**)
- Step B. Now press 'Enter' and connect the TRCs between main and remote as shown on the screen and press test to make the reference measurement.

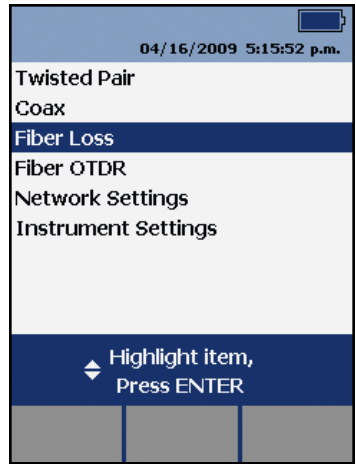


Figure 2a

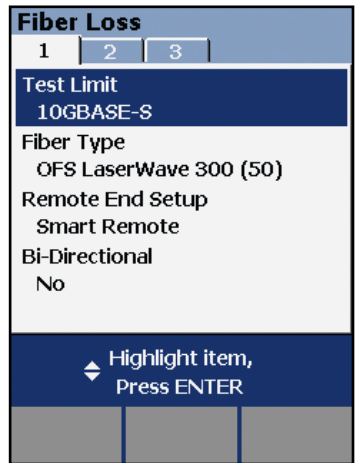


Figure 2b

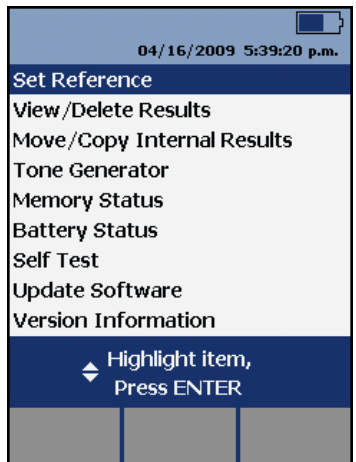


Figure 2c

With the DTX Series in Smart Remote setup, we are going to test the two fibers that make up the transmission link in one test. Each fiber test module is equipped with a light source and light meter. In the setup, we will use two duplex TRCs. One fiber will connect the Output (light source) at the main unit to the Input (light meter) at the remote unit. The second connects the Output at the remote unit to the input at the main unit.

Special Note: The DTX TRCs use the following convention in order to quickly make connections and verify the polarity of the link-under-test: The light enters the cord at the red boot and leaves the TRC at the black boot. So, one end of a TRC

has a red boot and at the other end of that same cord is a black boot. The light travels from red to black. The DTX screen display shows the boot color (**Figure 2d**).

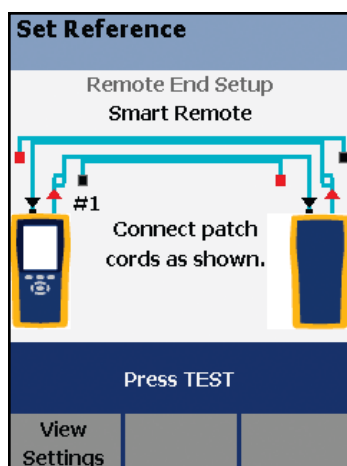


Figure 2d

Figure 2e shows a schematic representation of this reference setup. This figure uses a different color for the two duplex cords. These colors do not relate to the real cords but were chosen to add clarity to the figure. The yellow cord connects the Output (light source) of the main unit's fiber module to the Input (light meter) of the remote unit. One of the yellow cords is not connected in the reference setting. One of the darker colored cords makes the connection in the opposite direction. **Figure 2e** also shows the location of the mandrel near the end with the red boot that is to be connected to the light source. The duplex cords have one longer leg with the red boot. After this leg has been wrapped around the mandrel, the lengths of both cords in the duplex arrangement are equal.

The DTX fiber modules' Output ports are always SC connectors. The removable adapters for the Input ports are chosen to match the end connectors of the link-under-test. The example in **Figure 2e** depicts the example in which the link-under-test is equipped with LC connectors.

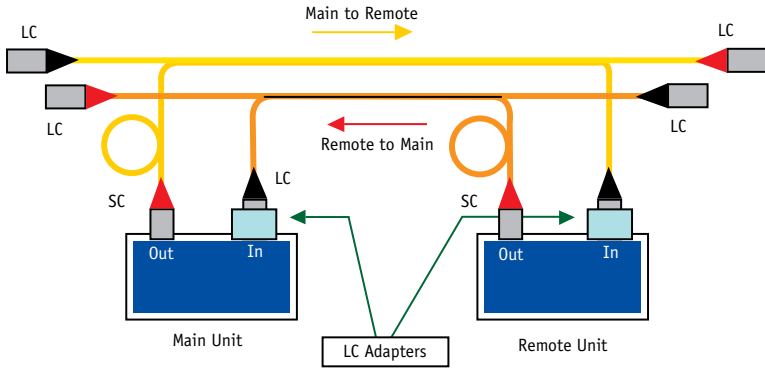


Figure 2e – Schematic representation of setting the reference with duplex TRCs for a link-under-test ending with LC connectors. The ring near the red boot indicates the location of the mandrel (for multimode fiber).

Step C. After the tester measures the reference power level, it displays these values as shown in **Figure 2f**. If your reference values are acceptable, press the F2 softkey to store these values and to proceed with link certification.

Acceptable Reference Values*

Model	62.5 μ m Multimode	50 μ m Multimode	9 μ m Singlemode
MFM, MFM2	-20 dBm	-24.5 dBm	N/A
SFM, SFM2, GFM, GFM2	-8 dBm	-8 dBm	-20 8m

*nominal level

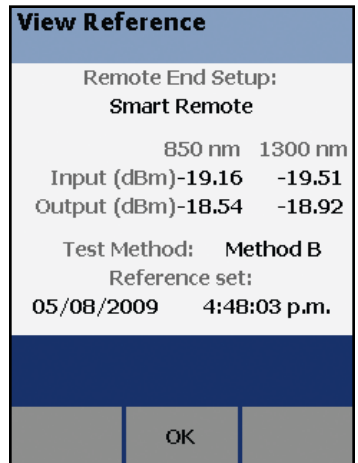


Figure 2f

Step D. Now disconnect your TRCs **at the Input ports only** and create the connection that is shown on the screen (**Figure 2g**). Disconnect the black boots from the input ports and connect the unused ends with the black boots in the duplex cord set to the adapter on the input port of the unit to which the duplex mate has been connected. Now you have separated the main and remote units so that you can connect a unit at each end of the optical fiber link to be tested.

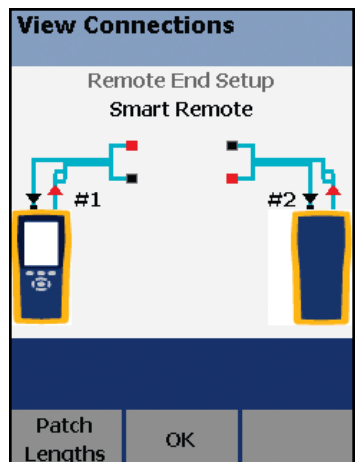


Figure 2g

Guidelines for setting a reference

- Use high-quality TRCs
- Clean TRC ends before you set the reference
- Let the tester warm up to a steady-state internal temperature (about 10 min. with ambient temp and storage temp difference of <math><20^{\circ}\text{F}</math>)
- Use preferred one-jumper reference method
- Plug the SC adapter with red boot plugs into the transmitter (OUT connection)
- Do not unplug red boot (on source) after setting the reference
- After the reference is set do NOT disconnect TRC from light source
- For a multimode optical link, use the proper mandrel
- Reference must be re-set after each time the units are powered down
- Ensure to maintain precise launch conditions of the reference

3. Run an autotest

Select “Autotest”. The test standard you selected for an Autotest determines the test parameters to be measured and the Pass/Fail criteria for each test

Polarity. When you run a successful Autotest using the DTX Fiber Modules, you will be able to ensure polarity.

- Connect the black boot of the TRC to the fiber in the link-under-test that is transmitting the light; this end of the link needs to be connected to the transmitter of the network device. (Light leaves the TRC at the black boot; the red boot end of that cord is connected to the Output on the tester)
- Connect the red boot of the TRC to the fiber in the link-under-test that is receiving the light from the other end of the link.
- When the connections to the link-under-test are established, the instrument will chirp a “happy tone” to let you know that connectivity has been established and that the polarity of the link is good.

Length. The tester measures the length as well as the link loss. When you select an application standard during the setup, it includes the maximum length for the application depending on the bandwidth rating of fiber used in the link-under-test.

Make sure that you are using the appropriate fiber test adapter with a connector that matches the fiber patch cord or the patch panel.

Connect TRCs to the link or channel to be tested: repeat the process displayed in **Figure 2g**.

Bidirectional testing. If you want to test each fiber in both directions, do not forget to select that option in the setup screen (see **Figure 2b**). When the tester prompts you to make the connection to test in the second direction, remember to switch the TRC at the link end. DO NOT remove the TRCs from the tester connections.

Test Results. Be sure to save results before moving onto the next fiber or testing in the other direction. **Figure 3** shows the detailed measurements of a fiber; note that each fiber is tested at both of the wavelengths demanded by the installation standard.

Applications standards, on the other hand, only specify performance for the wavelength of the applications. For example, the 10GBASE-S standard specifies the link requirements at 850 nm. The name “input” fiber or “output” fiber in the test result screen of the tester refers to the port in the main unit to which the fiber is connected. The result shown in **Figure 3** pertains to the fiber that is connected to the input port at the main tester unit. The screen title “Loss (R→M)”, which means Loss from the Remote unit to the Main unit, also indicates the fiber for which the result is displayed.

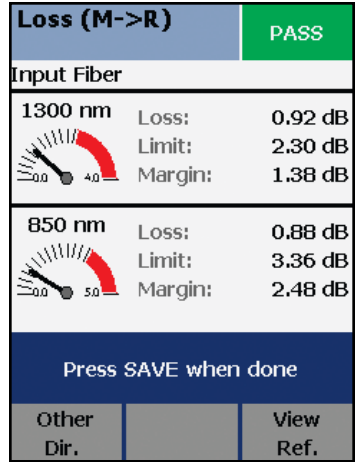


Figure 3 – Loss test results for the fiber connected to the input port on the main tester unit. The result includes the loss for both multimode wavelengths (installation test standard)

Once you have tested all the links and saved each record, results can be downloaded to a PC and managed with LinkWare Results Management software. LinkWare allows you to manage and inspect any stored test result on your PC screen.

You can also print a Summary Test Report for the job as well as a professional report for each link tested. LinkWare lets you create or emailed reports in PDF form.

4. How to Certify Optical Fiber Cabling with an OTDR

TIA 568C.0 TSB 140 and ISO 14763-3 recommend OTDR testing as a complementary test to ensure that the quality of fiber installations meets component specifications. The standards do not designate Pass/Fail limits for this test. It is recommended that generic cabling requirements for components and design criteria for the specific job be considered. An OTDR can be used as a single ended tester, bidirectionally if desired and optionally with a receive fiber for certification testing.

What you need to know about OTDRs. OTDRs were once laboratory equipment that were difficult to operate and impractical for field use. They were big, heavy and complicated for inexperienced technicians to set up for a test and operate accurately. Once a test was performed, it was difficult to understand test results. This led to a stigma of fear and confusion. However, today many new OTDRs are small, light, and easy to use. An ordinary technician can now troubleshoot like an expert – but a basic understanding of how an OTDR works is still helpful.

- **Basic operation.** An OTDR infers loss, reflectance, and location of events. It sends pulses of light into a fiber and uses a sensitive photo detector to see the reflections and plot them graphically over time. In order to accurately test, the optical characteristics of the fiber must be determined and set prior to running the test.
- **OTDR trace.** The OTDR plots the reflectance and loss over time in a graphical “trace” of the fiber. Experienced technicians can “read a trace” and explain it. For example, in **Figure 4**, an experienced eye can spot that one side of a cross connect is exhibiting excessive loss.

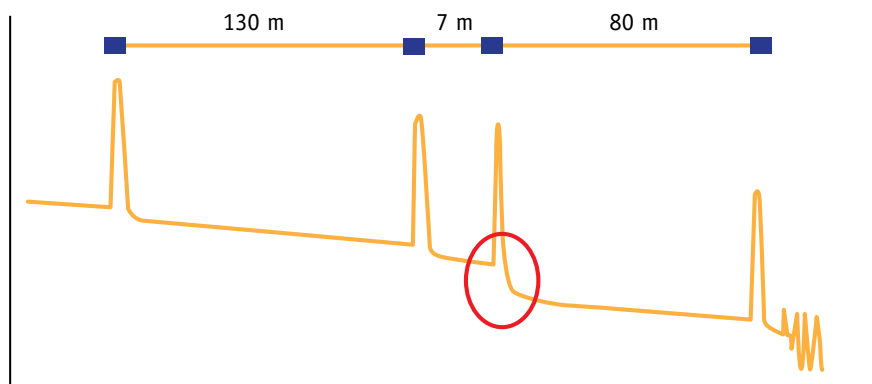


Figure 4 – Sample OTDR trace with high loss connector at 137m

- **Event analysis software.** The latest OTDRs run sophisticated software that automates trace analysis and set up of test parameters. Fluke Networks' OTDRs can automatically choose setup parameters, not only telling you where events (instances of reflectance and loss) are on the trace, but also telling you what the events are and qualifying each of them.
- **Dead zone.** This is the shortest fiber length an OTDR can detect. It can also be described as the distance following a reflective event after which another reflection can be detected. All OTDRs have dead zones and should be used with an appropriate launch fiber so that you can measure the first connection on the link.
- **Dynamic range.** Determines the length of fiber that can be tested. The higher the dynamic range, the longer the fiber-under-test can be. However, as the dynamic range increases, the wider the OTDR pulse becomes and as a result, the deadzone increases.
- **Ghosts.** Not as scary as they might seem, ghosting is caused by an echo due to highly reflective events in the link under test. Fluke Networks' OTDRs identify ghosts on the trace and tell you where the source of the ghost is so that you can eliminate it.
- **Gainers.** Another misunderstood phenomenon on an OTDR trace is called a gainer. Simply put, a gainer is an apparent negative loss at an event where there is a change in the optical performance. This is usually due to a mismatch between the index of refraction of two spliced fibers or connection of a 50µm multimode fiber into a 62.5µm fiber. This type of event will often exhibit excessive loss in the other direction.

OTDR certification set-up

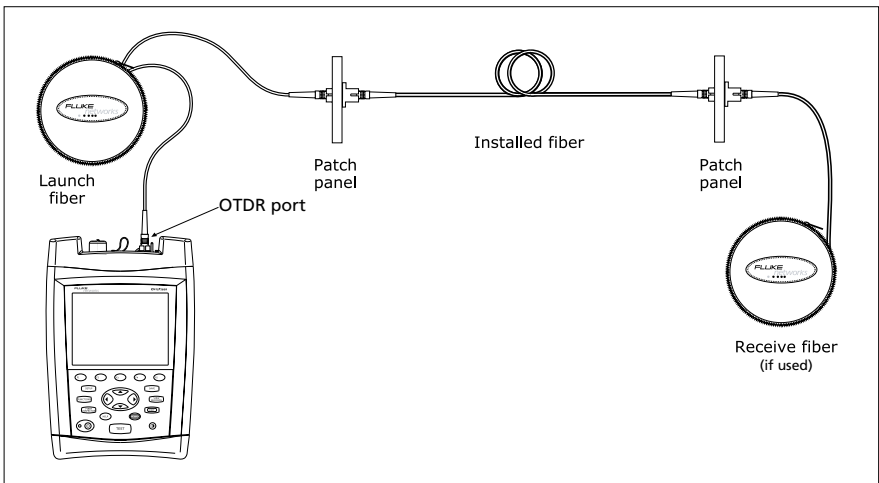


Figure 5 – Connecting the OTDR to installed fiber

OTDR certification set-up

Setting up for OTDR Certification Testing

Setup: Turn the rotary switch to ‘Setup’ and choose ‘Settings’ from menus in five setup screens.

1. First, select which port you want to test from (multimode or singlemode), what test limit you want to use, the fiber type, and desired wavelength.
 - It is possible to create multiple sets of OTDR test limits and select one for a particular job. Each OTDR test passes (**Figure 6**) or fails (**Figure 7**) based on a comparison against the selected set of test limits.
2. On the second setup screen, you may then set launch fiber compensation, designate which end you are testing from, and notate what you want to call each end of the fiber.

Using launch fiber compensation (LFC)

Launch fiber compensation is used to simplify testing and remove the launch and receive fibers’ losses and lengths from measurements.

- It shows you where your launch (and/or receive) fiber is on the trace, and eliminates it from the certification test results. If you are a contractor, your customers want to know where an event is in their fiber plant, not where it is on your test setup. When you enable ‘LFC’, a connector that is 50m from the patch panel will show up at 50m, not 150m on the trace. Just turn the rotary switch to ‘Setup’, go to the 2nd tab, and enable ‘Launch Fiber Compensation’. Then turn it again to ‘Special Functions’, and choose ‘Set Launch Fiber Compensation’. Choose ‘Launch’ only if you are just using a launch fiber, or ‘Other Options’ if you are also using a receive fiber.
3. Third, designate the fiber characteristics or allow default to the selected fiber in the first step or choose ‘User Defined’ and select ‘Numerical Aperture’ and ‘Back-scatter coefficient’ for the fiber-under-test.

OTDR Results		PASS
HBL LIMIT		
Multimode 50 Dual 850/1300 nm End 1: DATA CENTER		
✓ Length		55.5 m
✓ Overall Loss		0.19 dB
✓ Largest Event		-0.04 dB
View Trace View Events View Limits		

Figure 6 – “Pass” Screen on the DTX Compact OTDR

OTDR Results		FAIL
HL		
Multimode 50 Dual 850/1300 nm End 1: DATA CENTER		
✓ Length		312.0 m
✓ Overall Loss		1.98 dB
✗ Largest Event		0.78 dB
View Trace View Events View Limits		

Figure 7 – “Fail” Screen on the DTX Compact OTDR

4. Now choose from the menu to set 'Distance Range', 'Averaging Time'.
5. Finally, choose from the menu to set 'Pulse Widths' and 'Loss Threshold'.

With the DTX Compact OTDR, many settings such as 'Distance Range', 'Averaging Time', 'Pulse Widths', and 'Loss Threshold' can be automatically set. Just turn the rotary switch to 'Autotest', and when you push the test button, the OTDR will choose the most appropriate setting for the fiber that you are testing.

Running an autotest. Now that you are all set up for testing, turn the dial to 'Autotest', plug in your launch fiber and press 'Test'. If it passes, press 'Save', name the test, and test the next fiber. If you want to see a trace just press the f1 softkey. The event table and limits are also accessible via softkeys on the main screen.

Summary of extended certification

- OTDR traces characterize the individual components of a fiber link: connectors, splices and other loss events. Extended certification compares the data to specifications for these events to determine if they are acceptable
- Critical because it identifies faults that may be invisible to basic certification
- Evidence that every component in a fiber optic cabling system was properly installed

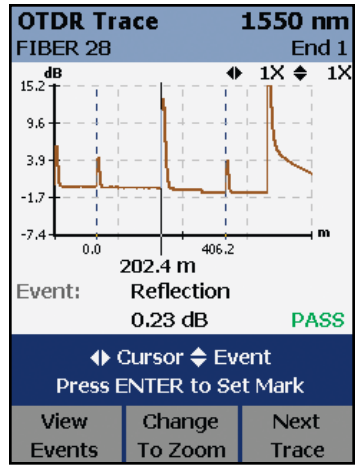


Figure 8 – Trace Screenshot on the DTX Compact OTDR

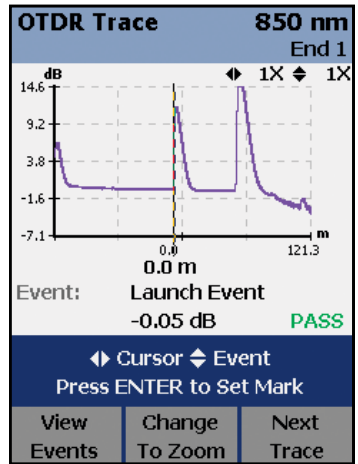


Figure 9 – "Pass" Trace Screenshot on the DTX Compact OTDR

As with the first tier of testing, results can be downloaded to a PC and managed with LinkWare Results Management Software. It is easy to merge OTDR test results with the other records if the same naming sequence is used. The FiberInspector option for OptiFiber also allows end-face images to be merged into the same test results record to prove cleanliness and to generate professional reports that combine all the test data into one document. These can be easily created and printed out or emailed in PDF form.

Cable certification test strategy

There are several possible ways to perform a complete certification test of fiber optic cabling. The standards are clear about defining required and optional tests, test limits and test equipment that may be used. But they do not suggest how the testing should be performed for optimum efficiency in the field. Based on decades of working with contractors, installers, technicians, Fluke Networks has developed proven, best-practice procedures to perform a complete fiber certification in the most efficient way.

- Make sure that design criteria and test limits are established before installation
- Confirm proper fiber strand polarity, end-face conditions, and verify loss with simple verification tools during installation
- Perform extended tests using the tier 2 certification tests (OTDR analysis) as the first certification step. Doing so:
 - Ensures connector performance meets generic cabling standards or system designer’s requirements
 - Qualifies workmanship for cabling installation
 - Identifies problems for immediate troubleshooting with OTDR
- Secondly, perform basic tier 1 test for the channel against the application standard. This certifies channel length and loss and calculates margin based on the standard

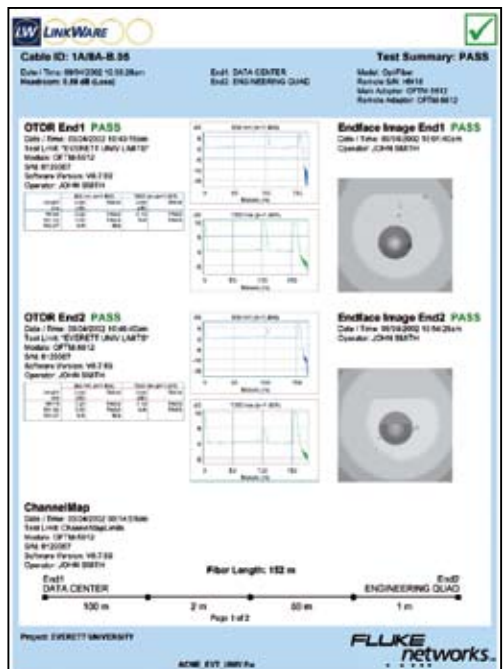


Figure 10 – Sample LinkWare Results Management Software printout

- If bidirectional testing is not required, measure channel loss at the wavelength of the application

5. Common Faults

Insufficient power or signal disturbances resulting from common faults cause failures in optical transmission.

Fiber optic connections involve the transmission of light from one fiber core into another. Fiber cores are smaller than the diameter of a human hair. To minimize loss of signal power, this requires good mating of two fiber end-faces.

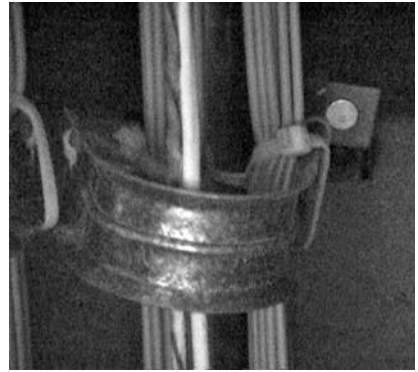


Figure 11 – Example of a common cause of a fiber failure

- **Contaminated fiber connections.** The leading cause of fiber failures results from poor connector hygiene. Dust, fingerprints, and other oily contamination cause excessive loss and permanent damage to connector end-faces
- **Too many connections in a channel.** Simple, but it is important to consider the total allowable loss (per intended application standard) and typical loss for connector type during the design process. Even if the connectors are properly terminated, if there are too many in a channel, the loss may exceed specifications
- **Misalignment.** The best way to achieve good fiber alignment is to fuse the two fibers together with a precision splicing machine. But for several practical reasons, connection of fibers is often done mechanically with fiber optic connectors. There are many commercially available connector types that all have their advantages and disadvantages. Typical loss specifications are a good proxy for how good they are able to align fibers. Any such specifications used for data communications should be compliant with Fiber Optic Connector Interchangeability Standard (FOCIS) standards
 - **Poor quality connectors or faulty termination.** Good quality connectors have very tight tolerances in order to maintain precise alignment
 - **End-face geometry.** Performance of fiber optic connectors is largely a function of the geometry of the end-face. This geometry can be measured in a laboratory with precision interferometry equipment. In the field, the following parameters are inferred in loss and reflectance measurements
- **Roughness.** Scratches, pits and chips produce excess loss and reflectance
- **Radius of curvature.** The convex surface of the connector should nicely mate up with another connector
- **Apex offset.** The core of the fiber should be centered near the highest point of the connector
- **Fiber height.** A protruding (underpolished) fiber does not mate well and an undercut (overpolished) connector will perform poorly due to the presence of an air gap
 - **Unseated connectors.** A connector may be plugged into an adapter bulkhead but may not be seated and connected with its mate. Worn or damaged latching mechanisms on connectors or adapters are sometimes the culprit
 - **Poor cable management.** Strain on a connector may cause misalignment due to becoming partially retracted, broken, or unplugged

- **Polarity.** Perhaps the simplest fiber cabling fault is a reversal of transmit and receive fibers. This is usually easy to detect and repair. But sometimes connectors are duplexed together and must be broken apart to be reversed. Standards designate polarity with a labeling convention that is seldom taken advantage of, resulting in confusion
 - Polarity should be designated with A and B labels or colored boots
 - A is for transmit and B is for receive; OR, red is for transmit and black is for receive

Poor cable management, system design, or damaged cable also causes faults in fiber cabling systems. Fiber has a very high tensile strength, but is susceptible to crushing and breaking if abused.

- **Bends.** Macro and microbending caused by tight cable ties or bend radius violations result in excessive and unexpected loss
- **Breaks.** Light will no longer propagate past a location where the glass is crushed or cracked in an optical fiber
- **Intersymbol interference (ISI).** Disturbed Signal is a fault that is usually the result of poor system design. A system that is not certified with the application standard in mind is susceptible to ISI
 - Modal dispersion from violation of distance limitations on multimode fibers
 - Reflections from too many highly reflective connectors causing increased bit errors due to excessive return loss

Troubleshooting basics

- Keep it clean. Dirty connections are the worst cause of failing connections and testing challenges. Clean fibers each time they are connected. You can verify that fibers are clean by using an instrument such as a FiberInspector microscope to examine fiber end faces.
 - Dust blocks light transmission
 - Finger oil reduces light transmission
 - Dirt on fiber connectors spreads to other connections
 - Contaminated end-faces make testing difficult
 - Remember to inspect equipment ports, as these equipment ports (routers, switches, NICs) get dirty too
- Use the correct test setup. Test standard per specifications will ensure that you get the most accurate, consistent, understandable and repeatable results
- Use recommended fiber mandrels to improve loss measurement accuracy and repeatability.
- High quality TRCs and launch fibers should always be used; use of random, questionable quality test cords should always be avoided.
 - All TRCs for loss testing should be delivered with good test result data
 - Test cords should make polarity easy for you – Fluke Networks’ cords feature red boots on the end at which light enters and black boots on the end at which light exits
 - Cords should be kept clean and replaced when they show signs of wear
- Choose test limits that are appropriate to both generic cabling standards and application standards

6. End-Face Inspection and Cleaning Inspection

Proper inspection helps in detecting two of the most common (yet easiest to prevent) causes of failure: damaged and dirty fiber end-faces.

Damage occurs in the form of chips, scratches, cracks, and pits to the core or cladding and can result from mating contaminated end-faces. Tiny foreign debris left on the core can also damage end-faces during the mating process as they are connected together.

As alluded to earlier, sources of contamination are everywhere, whether it be from a touch of a finger or the brush of a clothing fabric, much less the omnipresent dust or static-charged particles in the air. Ports are also subject to the same contamination but are often overlooked. Mating a clean connector to a dirty port not only contaminates the previously clean connector but can also cause fiber damage or failure. Even the protective coverings or “dust caps” on straight-from-the-package connectors and assemblies can cause contamination due to the nature of the production process and materials.

The typical assumption is that a quick visual check of the end-faces is sufficient to verify cleanliness. As mentioned previously, the cores of these fibers are extremely small – ranging from roughly 9 to 62.5 μm . Put into perspective, with a diameter of 90 μm , the average human hair is anywhere from 1.5 to 9 times larger! With such a tiny core size, it is impossible for any end-face defects to be spotted without the aid of a microscope.

There are two types of fiber inspection microscopes:

- **Optical (Figure 12)** – tube-shaped and compact, these enable you to inspect the end-faces directly. Popular because they are inexpensive; however, they are not able to view end-faces inside equipment or through bulkheads.
- **Video (Figure 13)** – small optical probe is connected to a handheld display. The probe size makes them excellent for examining ports that are in hard-to-reach places; large displays enable easy identification of end-face defects. They are also safer as they show an image and not the actual end-face being observed, reducing the risk of exposing one’s eye to harmful lasers.

Within the context of inspecting fiber optics – showing the user what the naked eye cannot see, the primary desired attribute is detection capability – basically the smallest-sized object that it can detect.



Figure 12 –
Optical microscope

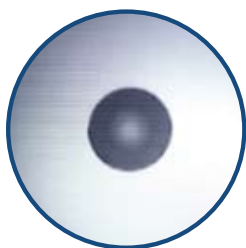


Figure 13 –
Video microscope

Cleaning

Properly cleaned end-faces can actually “add” up to 1.39 dB onto your loss allowance. **(Figure 14)**. In other words, if you have a fiber plant with an overall loss of 5.0 dB against a specified budget of 4.5 dB, cleaning any dirty end-faces may help to drop the link loss down to just above 3.6 dB, providing a “Pass” and plenty of head-room. Consequently, it is important to choose your cleaning tools and methods wisely while avoiding commonly-practiced bad habits. Perhaps the most typical mistake is using canned air to blast fiber connectors or ports. While helpful for displacing large dust particles, it is ineffective on oils, residues, or tiny static-charged particles that are equally detrimental in causing failures.

Clean fiber end-face



Contaminated fiber end-face

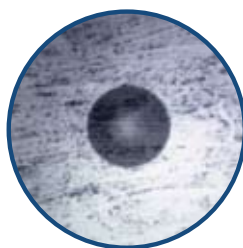


Figure 14 – Comparison between a clean and dirty fiber end-face

The same problem occurs when using shirt sleeves or “clean” cloths to wipe connectors; in fact, the trace amounts of lint and dust-attracting static from using such materials will likely add to the contamination rather than reduce it. Even isopropyl alcohol (IPA), which has historically been viewed as an acceptable solvent, is proving to be inferior to specially formulated solutions. IPA’s inability to dissolve non-ionic compounds such as pulling lube and buffer gel, and its residue-leaving evaporation process make engineered solvents the superior choice. When using these solvents, the proper cleaning order is “wet to dry” using clean, lint-free wipes **(Figure 15)**.



Figure 15 – “Wet to dry” cleaning methodology. Apply a small spot of solvent to the starting edge of a wipe. Holding the end-face connector perpendicularly, swipe the end-face from the wet spot to the dry zone.

The types of cleaning resources vary in complexity and price, ranging from simple wipes to devices that incorporate ultrasound with water. Which tool you use will be dependent upon need and budget – but for the majority of the cabling jobs and projects, the pairing of lint-free wipes and swabs with engineered solvents now found in fiber inspection, certification, and cleaning kits will be sufficient.

7. Conclusion

Cabling installation is a multi-step process. It is a prudent practice to certify the cabling system after installation to ensure that all installed links meet their expected level of performance. Certification will likely identify some failing or marginally passing results. In order to deliver a high quality cabling system, the defects that cause the failures and marginal passes must be uncovered and corrected.

Fluke Networks' full suite of fiber certification instruments (Appendix 2) have an unparalleled history of providing unique and powerful diagnostics assistance to installation technicians. By knowing the nature of typical faults and how the tester's diagnostics report them, you can significantly reduce the time to correct an anomaly, an installation error, or a defective component. Personnel responsible for the network's operation can also benefit from the diagnostic capabilities of a certification test tool; with the tester's assistance, they can limit the duration of network downtime and restore service quickly.

We highly recommend that you thoroughly familiarize yourself with the capabilities of your test tool – it is truly a modest investment that pays for itself many times over. In addition to your precision instrument, Fluke Networks also provides a wide variety of expert and timely support options. Whether you are an installer, network owner, or contractor, the following resources are available:

- **White papers and Knowledge Base articles** – insightful studies and helpful advice on relevant structured cabling topics
- **Unsurpassed technical assistance** from the highly trained Fluke Networks Technical Assistance Center (TAC)
- **Certified Test Technician Training (CCTT) classes** available around the world
- **Gold Support program** – comprehensive maintenance and support including priority repair with loaner, annual calibration and priority TAC support with after hours and weekend coverage

8. Glossary

Certification testing – the process of testing the transmission performance of an installed cabling system to a specified standard; requires an OLTS for “Tier 1” certification and an OTDR for “Tier 2” certification

Channel – end to end transmission medium between a transmitter and receiver

dB – function of a ratio of two power levels, typically used to express the relation of the output power to the input power such as the gain in an amplifier or the loss in a transmission line

dBm – power level expressed as the logarithm of the ratio relative to one milliwatt

FiberInspector – Fluke Networks’ popular line of handheld fiber end-face and bulkhead port inspection instruments, ranging from tube to video microscopes

Gbps – gigabits per second

Launch cord fiber – length of fiber placed between the link-under-test and the OTDR to improve the OTDR’s ability to grade the near-end connector and any abnormalities in the first connection

LED – Light Emitting Diode, a relatively low-intensity light source

Link – the physical cabling for a transmission

Mbps – megabits per second

OLTS – Optical Loss Test Set, a baseline “Tier 1” certification instrument that measures the loss of a link over its length

LSPM – Light Source Power Meter, basic fiber verification instrument composed of a power meter and a source to measure loss over a link

TRC – Test Reference Cord, a high-quality fiber cord between 1 to 3 meters long with high performance connectors, ideally with end-faces with special scratch resistant hardened surfaces that enable numerous insertions without degradation in loss performance

VCSEL – Vertical Cavity Surface Emitting Laser, commonly used in multimode light sources

Verification testing – the process of testing the transmission performance of an installed cabling system to ensure that it meets a minimum threshold

VFL – Visual Fault Locator, optical source that transmits a low-powered laser to identify breaks in fiber links

Appendix – Fluke Networks Fiber Test and Troubleshooting Instruments

	Verification			Troubleshooting			Certification		
	Check connectivity	Check polarity	Verify loss over entire link to ensure loss budget not exceeded	Check for fiber end-face contamination or damage	Clean contamination	Find faults	Basic (Tier 1)	Extended (Tier 2)	
Specialized Fiber Cleaning Supplies			✓		✓				
VisiFault VFL						✓			
FindFiber Remote ID	✓	✓							
SimpliFiber Pro Optical Loss Test Kit	✓	✓	✓						
FiberInspector Video Microscope				✓					
DTX Series with Fiber Module							✓		
DTX Compact OTDR								✓	
OptiFiber OTDR				✓		✓		✓	

Download the extended version of this guide, which includes additional optical-fiber theory, test, and certification information at www.flukenetworks.com/FiberHandbook

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