White Paper

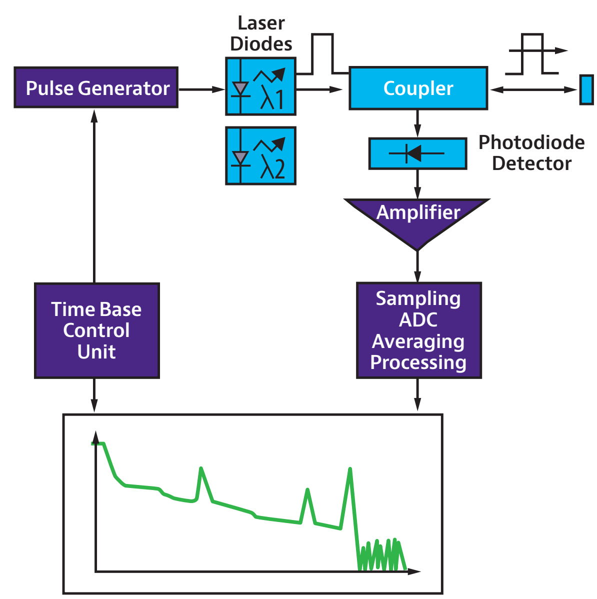
Choosing the Right Optical Time Domain Reflectometer (OTDR)

VIAVI Solutions

This white paper provides key information about OTDRs and guidance to newcomers in the telecommunication fiber optic market for selecting an OTDR appropriate to their testing needs.

What Is an OTDR?

An OTDR is a fiber optic tester for the characterization of optical networks that support telecommunications. The purpose of an OTDR is to detect, locate, and measure elements at any location on a fiber optic link. An OTDR needs access to only one end of the link and acts like a one-dimensional radar system. By providing pictorial trace signatures of the fibers under test, it's possible to get a graphical representation of the entire fiber optic link.



OTDR block diagram

What an OTDR Measures

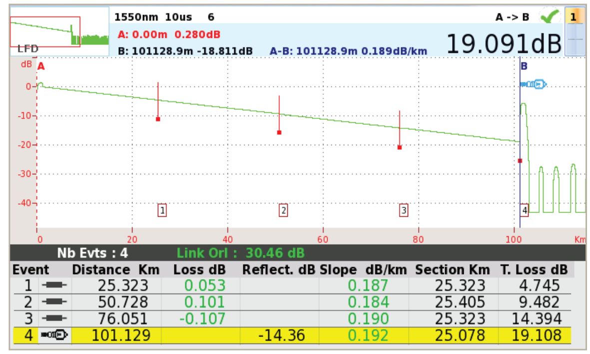
Injecting pulses of light into one end of a fiber and analyzing the backscattered and reflected signals, an OTDR measures:

Optical Distance

- To elements: splices, connectors, splitters, multiplexers …
- To faults
- To end of fiber

Loss, Optical Return Loss (ORL)/Reflectance

- Loss of splices and connectors
- ORL of link or section
- Reflectance of connectors
- Total fiber attenuation



Event		Distance Km	Loss dB	Reflect. dB	Slope dB/km	Section Km	T. Loss dB
1		25.323	0.053		0.187	25.323	4.745
2		50.728	0.101		0.184	25.405	9.482
3		76.051	-0.107		0.190	25.323	14.394
4		101.129		-14.36	0.192	25.078	19.108

Graphical representation of the fiber optic link, also called an OTDR trace

Why Do I Need an OTDR?

Fiber testing is essential to provide confidence that the network is optimized to deliver reliable and robust services without fault.

Outside Plants

Telecom, video, and data wireless service providers and network operators want to insure that their investments into fiber networks are protected. In outside fiber optic plant, every cable shall be tested with an OTDR to ensure the installation was properly made. Installers will be asked to use loss test sets (source and power meters) as well as OTDRs, to provide accurate cable documentation to certify their work. Later, OTDRs can be used for troubleshooting problems such as break locations due to dig-ups.

Premises, LAN/WAN, Data Centers, Enterprise

Many contractors and network owners question whether they should perform OTDR testing for premises cabling. They also want to know if OTDR testing could replace the traditional loss testing with a power meter and a light source. Premises fiber networks have tight loss budgets and less room for error. Installers should test the overall loss budget with a light source and power meter (Tier 1 certification required by TIA-568C standards). OTDR testing (Tier 2 certification) is a best practice that can pinpoint the causes for excess loss and verify that splices and connections are within appropriate tolerances. It is also the only way to know the exact location of a fault or a break. Testing a fiber link with an OTDR also helps document the system for future verification.

Understanding Key OTDR Specifications

Wavelengths

In general, fiber should be tested using the same wavelength that is used for transmission.

- 850 nm and/or 1300 nm wavelengths for multimode fiber links
- 1310 nm and/or 1550 nm and/or 1625 nm wavelengths for single-mode fiber links
- Filtered 1625 nm or 1650 nm for in-service troubleshooting of single-mode fiber links
- CWDM wavelengths (from 1271 nm to 1611 nm with a channel spacing of 20 nm) for commissioning and troubleshooting single-mode fiber links carrying CWDM transmission
- 1490 nm wavelength for FTTH systems (optional — test can be performed at 1490 nm, but a common recommendation is to test at 1550 nm to minimize additional investments)

Testing at a single wavelength will only allow fault location. Testing at dual wavelengths is recommended during the installation phase and troubleshooting as it detects fiber bends.

Dynamic Range

The dynamic range is an important characteristic since it determines how far the OTDR can measure. The dynamic range specified by OTDR vendors is achieved at the longest pulsewidth and is expressed in decibels (dB). The distance range or display range sometimes specified is usually misleading as this represents the maximum distance the OTDR can display, not what it can measure.

Wavelength	1310 nm	1550 nm	1310 nm	1550 nm	1310 nm	1550 nm	1310 nm	1550 nm
Dynamic range	35 dB	35 dB	40 dB	40 dB	45 dB	45 dB	50 dB	50 dB
Typical maximum OTDR measurement range	80 km	125 km	95 km	150 km	110 km	180 km	125 km	220 km

Actual OTDR measurement range depends upon the actual fiber and event loss in the network.

Dead Zones

Dead zones are important characteristics since they determine the OTDR's ability to detect and measure two closely spaced events on fiber links. Dead zones are specified by OTDR vendors at the shortest pulsewidth and are expressed in meters (m).

- The event dead zone (EDZ) is the minimum distance where two consecutive reflective events (such as two pairs of connectors) can be distinguished by the OTDR
- The attenuation dead zone (ADZ) is the minimum distance after a reflective event (for instance, a pair of connectors) that a non-reflective event (for instance, a splice) can be measured

Pulsewidths

The relationship between dynamic range and a dead zone is directly proportional. To test long fibers, more dynamic range is needed so a wide pulse of light is required. As dynamic range increases, the pulsewidth increases and the dead zone increases (close events won't be detected by the OTDR). For short distances, short pulsewidths should be used to reduce the dead zones. The pulsewidth is specified in nanoseconds (ns) or microseconds (μs).

Knowing Your Application

There are a wide number of OTDR models available, addressing different test and measurement needs. A solid understanding of key OTDR specifications as well as the application will help buyers make the right choice for their specific needs. These are the questions to answer before looking for an OTDR:

- What kind of networks will you be testing? LAN, FTTH/PON, metro, long haul?
- What fiber type will you be testing? Multimode or single-mode?
- What is the maximum distance you might have to test? 700 m, 25 km, 150 km?
- What kind of measurements will you perform? Construction (acceptance testing), troubleshooting, in-service?

Recommended OTDRs Depending on the Application

Premises, LAN/WAN, Data Centers, Enterprise

Type of Fiber	Multimode	Single-mode	Single-mode and Multimode
Wavelengths	850/1300 nm	1310/1550 nm	850/1300/ 1310/1550 nm
Key specifications	Shortest possible dead zones to locate and characterize events that are closely spaced		

FTTA, DAS, and Cloud RAN

Type of Fiber	Multimode	Single-mode	Single-mode and Multimode
Wavelengths	850/1300 nm	1310/1550 nm	850/1300/ 1310/1550 nm
Key specifications	Shortest possible dead zones to locate and characterize events that are closely spaced		

Point-to-Point Access/Backhaul

Type of Fiber	Single-mode
Wavelengths	1310/1550 nm
Key specifications	Dynamic range ≤35 dB at 1550 nm
	Shortest possible dead zones to locate and characterize events that are closely spaced

Point-to-Multipoint Access/FTTH/PON

Type of Test	Installation — Before and After Splitter(s)	Installation with one or cascaded Splitter(s)	In-Service Trouble-shooting
Wavelengths	1310/1550 nm	1310/1550 nm	Filtered 1625 nm or 1650 nm
Key specifications	Dynamic range ≤35 dB at 1550 nm	Dynamic range ≥35 dB at 1550 nm to test through 1/32 splitter type	Dynamic range not relevant
		Dynamic range ≥40 dB at 1550 nm to test fibers with 1/64 splitter type	
	Shortest possible dead zones to locate and characterize events that are closely spaced	Shortest possible PON/splitter dead zones + automatic multi-pulses acquisition	Shortest possible dead zones to locate and characterize events that are closely spaced + automatic multi-pulses acquisition

CWDM & DWDM

Type of Test	Installation, Wavelength Provisioning, or Troubleshooting
CWDM Wavelengths	From 1271 nm to 1611 nm with a channel spacing of 20 nm
DWDM Wavelengths	C-band tuning – C62 to C12 (1527.99nm –1567.95nm)
Key specifications	Dynamic range ≥35 dB to test through mux, optical add/drop multiplexer (OADM), and demux
	Shortest possible dead zones to locate and characterize events that are closely spaced
	Integrated continuous-wave light source capability to verify end-to-end continuity

Metro/Long/Ultra Long Haul

Type of Network	Metropolitan/ Long Haul	Very Long Haul	Ultra Long Haul
Wavelengths	1310/1550/ 1625 nm	1310/1550/ 1625 nm	1550nm/ 1625 nm
Key specifications	Dynamic range ≥40 dB at 1550 nm	Dynamic range ≥45 dB at 1550 nm	Dynamic range ≥50 dB
	Shortest possible dead zones to locate and characterize events that are closely spaced		

Multiple Applications

Type of Network	Premises/Access	Metro to Very Long Haul
Wavelengths	850/1300/1310/1550 nm (1625 nm optional)	1310/1550/1625 nm (adding an external filter on the 1625 nm wavelength makes OTDR suitable for FTTH/PON network troubleshooting)
Key specifications	Dynamic range: Not relevant for multimode; ≤35 dB at 1550 nm for single-mode	Highest dynamic range
	Shortest possible dead zones	
	Modular platform that evolves according to testing needs and provides the most flexibility	

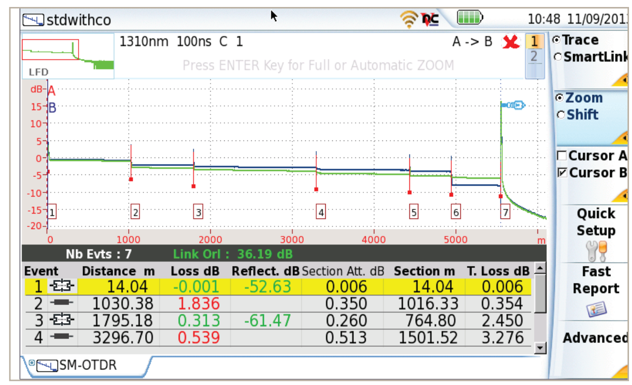
Other Important OTDR Specifications when testing FTTH/PON networks

To be able to measure each segment of a PON network and detect all "events" along the fiber link from the ONT (customer) to the OLT (central office), a traditional OTDR requires multiple manual tests (acquisitions) using different parameters for each.

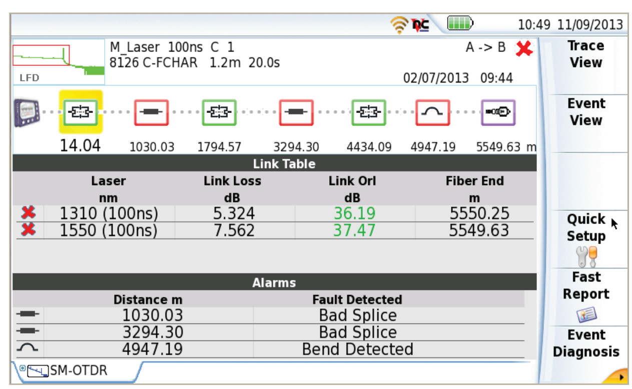
Latest PON OTDRs adjust the testing parameters and automatically perform multiple acquisitions at multiple pulsewidths to achieve the optimum test results and detect all "events" (bends, splices, connectors) before and after the PON splitter(s). It's highly recommended to check if the OTDR can be equipped with such function before choosing it to test fibers with one or cascaded PON optical splitters.

OTDR Test Results

Operating an OTDR is not especially difficult, but it does require familiarity with fiber testing best practices in order to measure correctly. OTDR traces can only be analyzed and correctly interpreted by trained and experienced technicians. It's difficult for a less-qualified technician to operate an OTDR and make sense out of the results. An intelligent software application, integrated into the instrument, can help technicians use an OTDR more effectively, without the need to understand or interpret OTDR traces. It schematically shows the fiber link tested and automatically recognizes and interprets each OTDR event and represents it as a simple icon for easy understanding. However, it is mandatory to be able to correlate the results to the original OTDR trace if needed.



OTDR trace view



Icon-based OTDR results view

Factors to take into account when choosing an OTDR include:

- **Size and Weight** — important if you have to climb up a cell tower or work inside a building
- **Display Size** — 5" should be the minimum requirement for a display size; OTDRs with smaller displays cost less but make OTDR trace analysis more difficult
- **Battery Life** — an OTDR should be usable for a day in the field; 8 hours should be the minimum
- **Trace or Results Storage** — 128 MB should be the minimum internal memory with options for external storage such as external USB memory sticks
- **Bluetooth and/or WiFi Wireless Technology** — wireless connectivity enables easily exporting test results to PCs/laptops/tablets
- **Modularity/Upgradability** — a modular/upgradable platform will more easily match the evolution of your test needs; this may be more costly at the time of purchase but is less expensive in the long term
- **Post-Processing Software Availability** — although it is possible to edit and document your fibers from the test instrument, it is much easier and more convenient to analyze and document test results using post-processing software

OTDR Best Practices

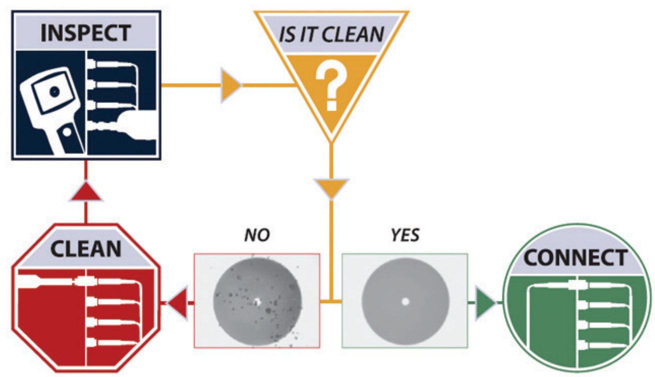
Several best practices ensure reliable OTDR testing.

Use of Launch/Receive Cables

Launch and receive cables, consisting of spools of fiber with specific distances, should be connected to both ends of the fiber link under test in order to qualify the front end and the far end connectors using an OTDR. The length of the launch and receive cables depends on the link being tested, but it's generally between 300 m and 500 m for multimode testing and between 1000 m and 2000 m for single-mode testing. For very long haul, 4000 m of cable may be used. The fiber length highly depends on the OTDR attenuation dead zone, which is function of the pulsewidth. The larger the pulsewidth, the longer the launch cable and receive cables. However, if a multi-pulse function is available on the OTDR, the length of the launch and receive cable can be reduced to 20 m. Launch/receive cables must be of the same type as the fiber under test.

Proactive Connector Inspection

A single dirty fiber connection can affect overall signal performance. Proactively inspecting each fiber connection with a fiber microscope probe will significantly reduce network downtime and troubleshooting. Always follow this simple "Inspect Before You Connect™" process to ensure fiber end faces are clean prior to mating connectors. A dirty OTDR port or a dirty launch/receive cable connector will impact the OTDR measurement. It needs to be inspected and cleaned before the launch cable is connected.



Inspect Before You Connect process diagram

Summary

An optimized fiber optic network's infrastructure delivers reliable and robust services to customers. Positive customer experience drives loyalty, enabling a fast return on investment and sustained profitability. An OTDR is a key field tester for maintaining and troubleshooting fiber optic infrastructures. Before selecting an OTDR, consider the applications that the instrument will be used for and check the OTDR's specifications to ensure that they are suited to your applications. To learn more, visit VIAVI OTDR Testing page.

References

1. VIAVI Solutions white paper: *Achieving IEC Standard Compliance for Fiber Optic Connector Quality through Automation of the Systematic Proactive End Face Inspection Process*
2. VIAVI booklet: *VIAVI Reference Guide to Fiber Optic Testing, Volume 1*
3. VIAVI poster: *Understanding Optical Time Domain Reflectometry*

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