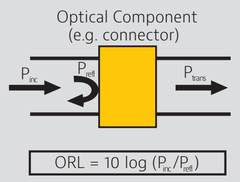
Understanding Fiber Characterization

VIAVI Solutions

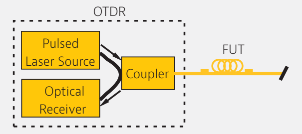
Optical Return Loss

ORL is the ratio (expressed in dB) between incident power and reflective power in a fiber optic network. The reflected power is due to Fresnel reflections or changes in the index of refraction.
The higher the ORL value, the lower the reflected power, therefore, 40 dB is better than 30 dB.

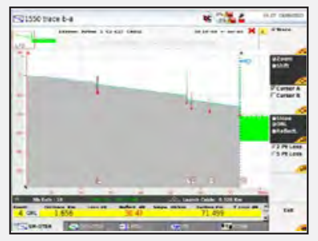


- IEC 61300-3-6 – Fiber optic interconnecting devices and passive components – Basic test and measurement – Part 3-6: Examinations and measurements – Return loss

OTDR Method

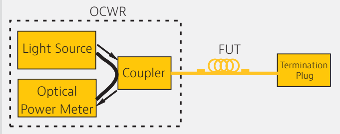


The OTDR launches light pulses into the device under test and collects backscatter information as well as Fresnel reflections.



Accuracy:	±2 dB
Typ. Appl.:	Spatial characterization of reflective events & estimation of sectional and total link ORL
Strength:	Reflective event localization
Weaknesses:	Accuracy Longer acquisition time

OCWR Method



The OCWR launches a stable, continuous wave signal into the optical fiber and measures the strength of the time-integrated return signal.

Accuracy:	± 0.5 dB
Typ. Appl.:	Total link ORL
Strengths:	Accurate Fast and real time information Possibility to measure short link
Weaknesses:	No reflective event localization

Measuring ORL

Measuring backreflection is essential when installing and maintaining networks, especially in DWDM or analog CATV transmission systems.
High levels of ORL will decrease system performance.

Typical Values

(defined by Telcordia GR-1312-CORE)

Requirement: 27 dB
Objective: 40 dB

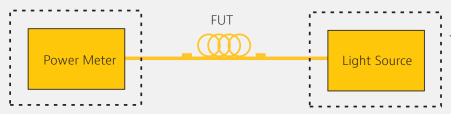
Insertion Loss/Bidirectional Insertion Loss

Insertion Loss (IL) represents the decrease of power (expressed in dB) when optical light path travels down a fiber link through passive components, such as connectors and splices.

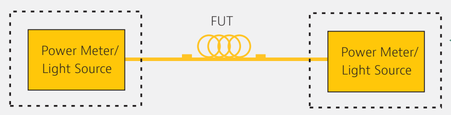
- IEC 60512-25-2 – Connectors for electronic equipment – Tests and measurements – Part 25-2: Test 25b- Attenuation (insertion loss)
- IEC 61300-3-34 – Fiber optic interconnecting devices and passive components – Basic test and measurement
- ITU-T G650.1 – Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable

Measuring IL

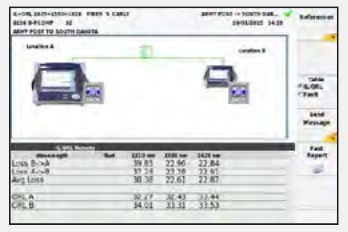
Measuring insertion loss is extremely important because each transmitter/receiver combination has a limited power range. Exceeding these limitations can result in transmission failure or excessive noise.



Insertion loss is typically tested using a power meter and a 2- or 3-wavelength light source.



Automatic bidirectional insertion loss is tested using a loss test set that combines a light source and power meter.



Typical Values

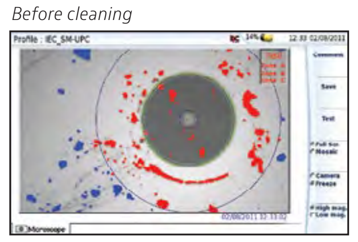
Mechanical splice: 0.5 dB
Fusion splice: 0.1 dB
PC connector: 0.3 dB
APC connector: ~0.5 dB

Optical Connection Inspection

Use a connector inspection scope to guarantee that optical connectors are operational and free of contamination.
Particles, such as dust, are the primary source of problems in optical networks causing backreflection, signal loss, and equipment damage.

Mating contaminated connectors embeds debris into the glass causing permanent damage.

Before cleaning



After cleaning

Cleaning connectors is important.

A dirty connector will dramatically increase power loss! Inspect connectors before and after cleaning using a video inspection scope.

Fiber connectors should always be visually inspected *before mating!*

Fiber Characterization Test Requirements

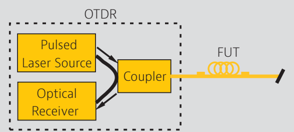
This table is greatly simplified and each user must review and modify it in accordance with their specific Network Element equipment and application.

	Non-coherent detection		Coherent detection					
DWDM transmission speed	10 Gb/s	40 Gb/s	40 Gb/s	100 Gb/s	4 x 25 Gb/s	200 Gb/s	Equipment required	Recommended Test procedure
Modulation format	**NRZ-OOK**	**NRZ-DPSK**	**NRZ-QPSK**	**PM RZ-QPSK**	**NRZ / DB**	**16-QAM**		
Insertion Loss	1310/1550nm	1310/1550nm	1310/1550nm	1310/1550nm	1310/1550nm	1310/1550nm	Power Meter & Light source or Loss Test Set	Uni-directional or Bi-directional (in case of bi-dir transmission of request for automation)
Return Loss	1310/1550nm	1310/1550nm	1310/1550nm	1310/1550nm	1310/1550nm	1310/1550nm	ORL meter, Loss Test Set or OTDR	Uni-directional or Bi-directional (in case of bi-dir transmission of request for automation)
Link certification (inc. Splices and connector losses, span attenuations)	1310/1550nm	1310/1550nm	1310/1550nm	1310/1550nm	1310/1550nm	1310/1550nm	OTDR	bi-directional
PMD	Required	Required	Recommended	Recommended	Recommended	Recommended	Broadband Source PMD analyzer	Uni-directional
CD	Required	Required	Recommended	Recommended	Recommended	Recommended	Broadband Source CD analyzer	Uni-directional
Attenuation Profile	DWDM C-Band	DWDM C-Band	DWDM C-Band	DWDM C-Band	DWDM C-Band	DWDM C-Band	Broadband Source Spectrum analyzer	Uni-directional

Optical Time Domain Reflectometry

The OTDR retrieves the fiber signature and distance and loss/reflectance information for each event present along the link.

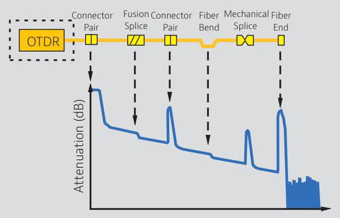
- IEC 61786 – Calibration of optical time-domain reflectometers (OTDRs)
- GR-196 – Generic Requirements for OTDR Type Equipment
- ITU-T G650.1 – Definitions and test methods for linear, deterministic attributes of single-mode fiber and cable



The OTDR injects a short, intense laser pulse into the optical fiber and measures the backscatter and reflection of light as a function of time. It then analyzes the information to determine the location of fiber optic breaks or splice losses.

Measuring Loss and Reflectance

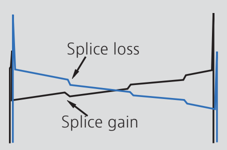
Testing components, such as splices and connectors, during installation or commissioning is important because their losses and reflectances greatly impact link quality. An OTDR can detect, localize, and measure events along a fiber link.



Typical Values

Mechanical splice: 0.5 dB
Fusion splice: 0.1 dB
UPC connector: Loss: 0.3 dB, Reflectance: −55 dB
APC connector: Loss: 0.5 dB, Reflectance: −65 dB

True Splice Loss: Bidirectional OTDR Measurement

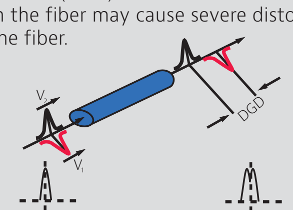


Mismatches in fiber backscatter coefficients can cause a splice to appear as a gain or a loss, depending upon the test direction. Use of bidirectional analysis can minimize mismatches by measuring the splice loss in both directions and averaging the result to obtain the true splice loss.

Polarization Mode Dispersion

PMD refers to the temporal spreading of the transmission signal pulses due to birefringence resulting from the differential time delay between principal states of polarization (PSPs) of the fiber. Two PSPs propagating at different speeds through the fiber may cause severe distortion in the optical receiver at the end of the fiber.

- IEC 60793-1-48 – Optical fibers - Part 1-48: Measurement methods and test procedures – polarization mode dispersion
- ITU-T G650.2 – Definitions and test methods for statistical and nonlinear attributes of single-mode fiber and cable



PMD Transmission limits according to bit rate and modulation formats

Bit rate	10 Gb/s	40 Gb/s	40 Gb/s	40 Gb/s [1]	100 Gb/s [1]	4 x 25 Gb/s	200 Gb/s [1]
Modulation format	**NRZ-OOK**	**NRZ-DPSK**	**RZ-DPSK**	**DP-QPSK NRZ-QPSK**	**DP-QPSK** **PM-QPSK**	**NRZ / DUOB**	**16-QAM**
Max. PMD [ps]	10 … 15	3 … 4	6 … 8	>30	>25	4 … 6	>20

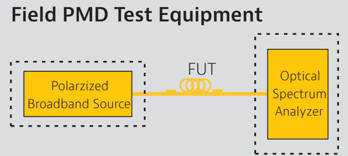
[1] Data assumes that Coherent detection is used with multiple polarization (DP, 16-QAM) modulation formats.

PMD may vary with time and with optical frequency, therefore, signals transmitted over different wavelength channels of a fiber usually experience varying amounts of distortion.

Measuring PMD

Measuring PMD during the manufacturing process, fiber installation, or system upgrades ensures that the fiber link is suitable for high-speed transmissions of 10 Gbps or higher and within network equipment or system constraints.

Field PMD Test Equipment



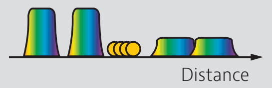
Send a polarized light over the FUT to enable analysis of the transmitted spectrum through a polarizer. The analysis of the fixed-analyzer response is shifted to the time domain by taking the Fourier transform. Calculate mean DGD from the Gaussian distribution.

Typical Values

For a new fiber - Max PMD: 0.2 ps/√km ITU-T G.652D

Chromatic Dispersion

Chromatic dispersion (CD) results from different wavelengths (colors or spectral components of light) traveling at different speeds, due to the variation of index of refraction, including a pulse width variation.



- IEC 60793-1-42 – Optical fibers – Part 1-42: Measurement methods and test procedures – Chromatic dispersion
- ITU-T G650.1 – Definitions and test methods for linear, deterministic attributes of single-mode fiber and cable

CD Transmission limits according to bit rate and modulation formats

Bit rate	10 Gb/s	40 Gb/s	40 Gb/s	40 Gb/s [1]	100 Gb/s [1]	4 x 25 Gb/s	200 Gb/s [1]
Modulation format	NRZ-OOK	NRZ-DPSK	RZ-DPSK	DP-QPSK NRZ-QPSK	DP-QPSK PM-QPSK	NRZ / DUOB	16-QAM
Max. CD [ps/nm]	1600	80	160	>50,000	>30,000	250 … 500	20,000

[1] Data assumes that Coherent detection is used with multiple polarization (DP, 16-QAM) modulation formats.

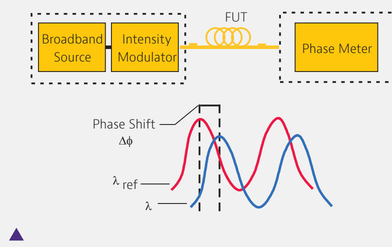
Measuring CD

Measuring CD during the manufacturing process, fiber installation, or system upgrades ensures that the fiber link is suitable for high-speed transmissions of 10 Gbps or higher and within network equipment or system constraints.

Typical Values

ITU-T G.652: ~17 ps/(nm.km) at 1550 nm
ITU-T G.653: 0 ps/(nm.km) at 1550 nm
ITU-T G.655: ~4 ps/(nm.km) at 1550 nm

Phase Shift Method

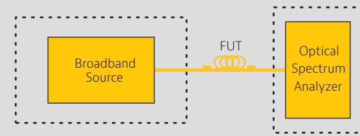


The modulated light is sent over the FUT. The phase of the test signal is compared to the phase of the reference signal used to modulate the input signal. The phase measurement is performed over the entire wavelength range of the broadband source.

Attenuation Profile

Attenuation profile is the loss of signal power per wavelength, normalized to 1 km, and is caused by material absorption, impurities, waveguide geometry, and scattering.

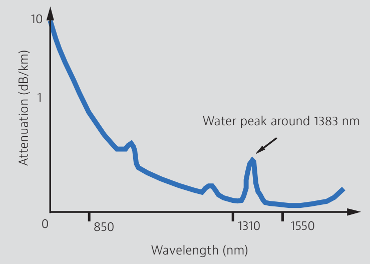
- IEC 60793-1-40 – Measurement methods and test procedures

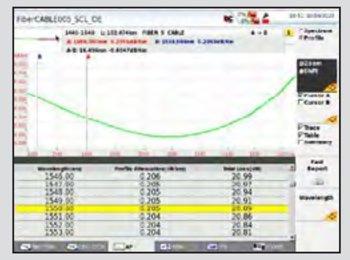


Test spectral attenuation using a broadband source and optical spectrum analyzer. The spectrum analyzer compares the broadband source reference signal to the resulting signal at the end of the fiber under test.

Measuring Attenuation

In DWDM systems, obtaining the attenuation profile of the wavelength range used for transmission is important because it impacts channel equalization as well as the amplifier specifications for equipment placed in the network. Check CWDM systems, covering the entire wavelength range of 1261 to 1611 nm, for fiber suitability, especially within the "water peak" region around 1383 nm.





Typical Values

1260 nm – 1360 nm: 0.35 dB/km
1530 nm – 1565 nm: 0.22 dB/km
1565 nm – 1625 nm: 0.25 dB/km

Fiber Test Products

P5000i Digital Analysis Microscope
Optical Video Inspection Probe

T-BERD®/MTS-2000
Compact Optical Test Platform

SmartClass™
OBS-500/550 Optical
Broadband Light Sources

T-BERD/MTS-8000E
Scalable Optical Test Platform

T-BERD/MTS-6000A
Compact Optical Test Platform

T-BERD/MTS-4000 V2
Multiple Services Test Platform