

# Optical Network Testing: What the Terms Mean

Don't know what index of refraction, or single-mode fiber means?  
Can't figure out contract terms or test reports?  
Skim the glossary below. It's all here, from A to Z.

By Steven S. Ross ■ *Broadband Properties*

It is a measure – a test, if you will – of fiber's popularity that we now frequently receive calls from new network builders asking about certification testing and maintenance of fiber networks. The calls have spurred us to bring the topic down to earth.

On the one hand, testing fiber is straightforward. Fiber that is installed properly may last for 20 years or more with little or no maintenance. On the other hand, fiber networks, like copper, are often modified in the field as new customers are added or as bandwidth is increased with new electronics.

Central offices, in particular, often evolve into a tangled mess.

The good news is that only a few test devices are needed:

- Microscopes for visual inspection of connections for dirt and other contaminants.
- Light sources and signal level meters (often in the same instrument) for checking basic connectivity.
- Devices to trace a specific cable by sensing the light pulses inside without damaging the fiber.
- Instruments like the OTDR that can track specific defects by type and location, and even sense cable that is likely to fail early by sending out carefully timed light pulses, timing the echoes that return, and determining what caused them – different kinds of backscatter or reflections.

The OTDR – it stands for Optical Time Domain Reflectometer – is the only really expensive one. It can cost \$20,000

or more (they can be rented). Only a few years ago, they were rack-mounted. Today, they are available in handheld versions as well. Some are modular – they can be outfitted for specific network technologies and configurations.

Many vendors of fiber and network electronics sell test equipment – almost always made by major vendors such as JDSU and EXFO, and relabeled – so sometimes it is possible to negotiate a good deal while you are buying the things you need to build a network in the first place.

Property owners and builders (and service providers) that are large enough to keep technicians on staff can send them for retraining in fiber technology. Good test courses (see [www.theFOA.org](http://www.theFOA.org)) take a few days and are often available at local community colleges.

In this glossary section, we define the basic terms that show up in contract documents, test reports and instrument spec sheets. We also offer some approximate pricing information. Just as consumer HDTV sets and digital cameras can vary in price by a factor of 10 depending on features, so can fiber test equipment. There is quite a bit of used equipment on the market. In accompanying articles, we describe some of the basic test procedures for indoor and outside network plant.

Testing is always made easier if you fully document the network you are building. The documentation should include exact distances of each node and piece of electronics in your system, and even the index of refraction and type of glass fiber being used.

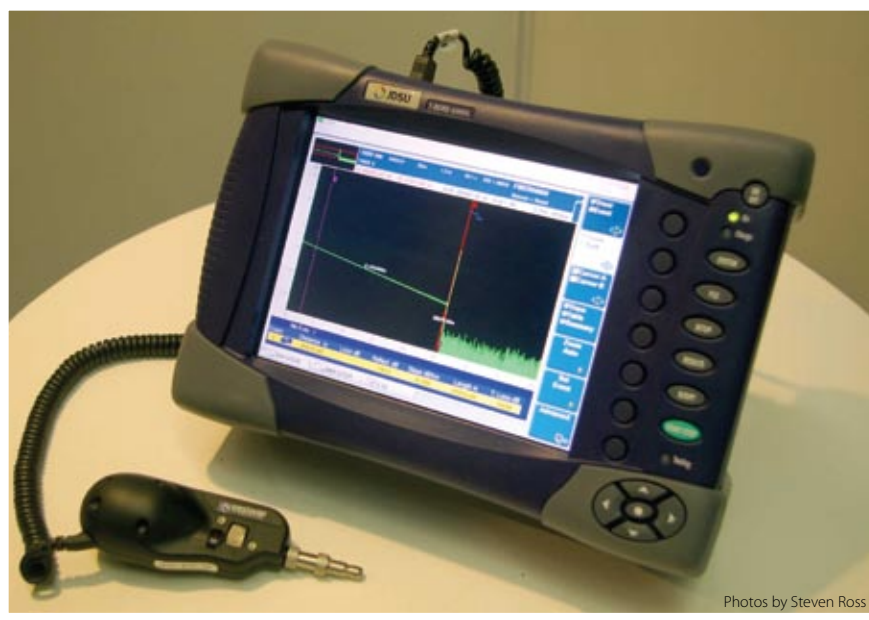
**Accuracy:** How close your indicated results are to the real situation. An OTDR, for instance, can measure the distance to many defects. But its accuracy is limited by its internal clock or “time base” (which calculates the interval between the time a pulse is sent and its echo is received), the shaping of the pulse's width, and

the technician's knowledge of the fiber's index of refraction at the wavelength being used. See also OTDR, index of refraction, and precision.

**Attenuation:** Degradation of the signal due to absorption or scattering of light in the fiber or at a junction (coupling loss). Different wavelengths of light have different levels

of absorption and scattering. There are differences among fibers as well; some absorb signals particularly strongly at 1244 and 1383 nm, for instance, due to water in the glass. See also zero water peak, microbend and macrobend.

**Attenuator:** A device that reduces the strength of a signal. In tests, it can



Photos by Steven Ross

**The non-modular “lite” version of JDSU’s T-BERD 6000 series OTDR. The screen measures more than 8 inches diagonally. Many tests can be done at the touch of a single button. As with many OTDRs, data can be transferred into a laptop for analysis via USB, or over Ethernet.**

simulate signal loss in a long fiber link. A mandrel is one simple attenuator; see mandrel.

**Auto-configuration:** Some instruments select the light levels to use, wavelengths to test at, and so forth. This automatic configuration can be overridden by an experienced technician. See also injection or insertion level.

**Bend-insensitive fiber:** Fiber that is resistant to light loss or strain when bent. Care must be taken when connecting such fiber to standard varieties. See mode field mismatch, macrobend, microbend.

**Certification test:** Initial test of a network, usually before actual use. Often required by contract before the network owner accepts the build.

**Chromatic dispersion:** Different wavelengths of light travel at slightly different speeds in glass, so the signal “spreads out” or disperses as it travels down the fiber.

**Clip-on devices:** These detect light from a non-signal source inside a fiber (such as from a visual fault de-

tector) by bending the fiber so that some light “leaks.” Similar to a fiber identifier, but usually can only detect a stronger beam of light than would be typical of a signal. See fiber identifier.

**Coupling loss:** See attenuation, injection or insertion loss.

**Dead zone:** The photodetector of an ODTR must be very sensitive to detect backscatter (at perhaps 0.001 percent of the original signal strength). If the detector is hit by a brighter back-reflection (reflectance) it is overwhelmed and takes a short time to recover. The distance the light signal travels during that “recovery period” is the dead zone.

**Dispersion:** Widening of signal pulses in the fiber as light travels down it. Once the dispersion causes the signal peaks to widen and flatten too much, the signal cannot be reliably detected. There are three main types. See model dispersion, chromatic dispersion and polarization mode dispersion.

**Display resolution:** The number of decimal points or other significant digits in the display. See precision.

**Distance resolution:** See accuracy.

**Dynamic range:** A measure of the signal-to-noise ratio in an OTDR, in dB. The higher the range, the better. Vendors cite different measurement methods for dynamic range, and they are not directly comparable. The International Electrotechnical Commission (IEC) has a standard definition, but you may also see the dynamic range calculated as RMS, SNR-1, “Telcordia,” and so forth. To compare different devices, ask for the dynamic range to be defined using the same definition.

**Effective area or effective diameter:** Same as MFD; see mode field diameter.

**Fault locator:** See visual fault locator.

**Fiber identifier:** A simple instrument that detects a signal inside a single-mode fiber. It works by bending the fiber slightly so that some light “leaks”; the fiber’s outer cover does not have to be cut. See also clip-on devices. Typical units sell for \$700 to \$1,100.

**Fiber inspection microscope:** Just what it sounds like – a microscope designed to easily inspect fiber to make sure it is clean, before splicing



**Handheld optical power meter.**



**EXFO fiber identifier (live fiber detector).** Fiber is bent when clamped into the device, which then “reads” the light traveling inside.

or joining with a mechanical connector. They cost as little as \$80, but the most rugged units are \$150-200. There are “video” versions selling for \$500 to \$1,300 (with small screens; versions that plug into a laptop cost less) that can be used to inspect fiber in hard-to-reach spots such as the back of a patch panel.

**Fresnel reflection:** Reflection or back-reflection from a splice, connector or contaminant in the fiber.

**Gainer:** See splice gain.

**Gel:** A clear jelly used to fill the tiny gap between an instrument’s port and the fiber, to reduce signal loss.

**Ghost:** A reading of an extra-strong reflection from something in the fiber link (usually, Fresnel or due to a mode field diameter mismatch, where multimode fiber joins single-mode). See Fresnel reflection, mode field diameter, single-mode fiber, multimode fiber.

**Index of refraction:** The ratio of the speed of light in a vacuum to the speed of light in the fiber. Typically

around 1.5 for fiber optic strands. That means the speed of light in the glass is about a third slower than in a vacuum. Some test measurements involve timing a light pulse’s travel to and from a defect site, splice or piece of equipment in the network. To determine the location of a defect, the index of refraction must be known exactly.

**Injection or insertion level:** The brightness of the light pulse sent by the test instrument into the fiber being tested.

**Injection or insertion loss:** The amount of the signal’s light that does not make it into the fiber for transmission. Some light is reflected at the interface between the test device and the fiber. This can be mitigated using a gel or a mandrel wrap. Also, single-mode fiber can accept light only in a narrow angle from the axis of the fiber.

**Kink:** A bend caused by a kink in the fiber as it is laid. See microbend and macrobend.

**Laser diode:** Used as a light source in some instruments. More expensive than LEDs. Fabry Perot lasers are the most common laser type in instruments. They are more powerful and less expensive than distributed feedback lasers, but DFB lasers can be tuned to specific wavelengths more precisely.

**Light-emitting diode (LED):** Used as a light source in some instruments, especially for multimode fiber. LEDs are less expensive than lasers, but also less powerful.

**Linearity:** See accuracy.

**Live fiber detector:** See fiber identifier.

**Loss resolution:** See precision.

**Loss Test Set (LTS):** An inexpensive instrument that combines a power meter and a light source. Using an LTS at both ends of a network allows you to test the fiber link in both directions at once. Bidirectional LTS units (almost all of them are) can connect the power meter and the light source to the same port. Most do the tests totally automatically. Good units are available for well under \$1,000; the most automated devices can cost \$1,500 or more.

**Macrobend:** A bend in the fiber with a radius larger than 2 mm, often at a stapling point or kink.

**Mandrel:** A dowel around which fiber can be wrapped to reduce the signal insertion level. See injection or insertion level.

**Microbend:** A bend in the fiber due to stapling or other fiber-laying constraints, thermal stresses, or manufacturing defects. See attenuation.

**Modal dispersion:** See mode.

**Mode:** A path that light follows in a fiber. Multimode fiber is thicker than single-mode, so the light beam that carries the signal may follow multiple paths, depending on the angle



**EXFO’s modular AXS-200 Sharp-TESTER can be used for both copper and fiber testing tasks.**



**PON power meters such as this one from EXFO are inexpensive and easy to use.**

at which it enters the fiber's end. The more off-center the angle, the more the light bounces off the inner surface of the fiber, and the longer the path. Single-mode fiber has a sharply restricted entry angle, hence the signal retains its sharpness better (that is, it has lower modal dispersion). Multimode fiber is more expensive than single-mode, but is less expensive to deploy. The smaller diameter of single-mode fiber makes it more difficult to splice, and to test. It is also more

expensive than multimode to "light." Multimode, because of modal dispersion, cannot carry a signal as far.

**Mode field diameter (MFD):** The width of the fiber that transmits most of the signal. In single-mode fiber, this tends to be a bit wider than the fiber itself, because some of the signal travels in the cladding, the glass that surrounds the inner fiber. Wider MFDs lead to greater signal loss in fiber bends, but wide-MFD fibers are easier to connect to other fiber.

**Mode field mismatch:** A splice between fibers with different mode field diameters, usually when single-mode fiber is spliced to multimode, or when certain bend-insensitive fibers are spliced to standard fibers.

**Multimode fiber:** See mode.

**Optical Continuous Wave Reflectometer (OCWR):** This device uses a light source to inject a signal into the network, and then measures back-reflection to calculate the optical return loss. The OCWR can test much shorter pieces of fiber (such as drop cables) than an OTDR can.

**Optical Link Loss:** The end-to-end signal loss, in dB. Every system has a link loss "budget," an allowable amount of attenuation.

**Optical Loss Budget:** See Optical Link Loss.

**Optical power meter:** See power meter.

**Optical Return Loss (ORL):** Light reflected back ("returned") to the source when it scatters and reflects from couplings. ORL can interfere with RF video signals in particular. It is important to note that because of the way ORL is expressed, the *higher* the ORL value (in dB), the better the system.

**Optical Time Domain Reflectometer (OTDR):** Sends carefully timed light pulses down a fiber path. The OTDR is more expensive and slightly less accurate, but easier to use than an OCWR when testing for signal loss. But because the light pulses can be timed, and the time related to a distance (as the speed of light in the fiber is known), the distance to a fault can be quickly calculated by the device. Depending on the use, it can guide a technician to within a few inches to 150 feet of a fault. There are basic handheld OTDR models on the market for as little as \$2,000, but prices, including modules for super-flexible modular OTDRs, can be more than 10 times that. Many companies rent the more sophisticated units when they need them, for \$500 to \$1,000 a month or more.

**Polarization mode dispersion (PMD):** When glass is stressed by bending, stretching, or a manufac-



**Modular OTDR from EXFO is handheld but heavy (about 6 pounds). This device has two module bays, for handling a wide variety of tasks.**



**Senko FiberView camera for inspecting the ends of fiber, attached to a 2.5-inch portable monitor. Up to 23,000 images can be stored on an SD card in the device.**

turing defect, the molecular structure is changed in a way that can polarize light. Different polarizations travel at different speeds in the fiber, causing the signal to spread slightly (see dispersion). This can limit bandwidth in very high bandwidth (10 Gbps or greater) or in very long network links. Testing for it requires transmitting a signal and reading it with interferometry or some other technique such as Jones-Matrix analysis.

**Port:** The point in the central office at which the laser-light signal enters the fiber. One port's signal can be shared among many customers, if it is "split" using splitters.

**Power meter:** A test device that can be connected directly to a signal transmitter's laser-light output to measure the signal strength being transmitted, or it can be connected to the fiber network in place of the optical receiver to determine the strength of the received signal. Power meters have different types of detectors; silicon detectors are only suitable for multimode fiber; InGas and germanium detectors may be found in power meters for testing single-mode and multimode fibers. Look for units that have temperature compensation and that can be calibrated at multiple wavelengths.

These devices sell for about \$200 to \$600 depending on features.

**Precision:** How internally consistent your test results are. Note that various limitations in the test device might allow "precise" results that differ slightly from reality (see accuracy), just as a tight but off-center grouping of bullets on a target is said to be precise but inaccurate. For example, an instrument's display might only al-

low differences greater than 0.01dB to be shown. Some instruments automatically make tens or thousands of measurements in just a few seconds. In the test equipment business, the degree of precision is sometimes called "resolution."

**Reflectance:** A type of optical return loss caused specifically by back-reflection – light reflected back to its source from couplings. It is expressed differently from ORL, however – in dB but as a negative value. The more negative that value is, the worse it is.

**Remote test unit:** Test equipment (often, an OTDR) installed permanently in the network to monitor it. The remote testing units are usually controlled from the Network Operating Center.

**Resolution:** See precision.

**Sampling accuracy:** See accuracy.

**Sampling resolution:** See precision.

**Scattering:** Light signals scatter slightly, even in pure glass. There are several types of scattering. Raman scattering can actually transfer power from a signal at one wavelength to a signal at a longer wavelength. Brillouin scattering degrades the signal by scattering away some of its light energy.

**Single-mode fiber:** See mode.

**Signal level:** See insertion or injection level.

**Splice gain:** Sometimes a test measurement shows a signal gain at a splice or connector. This is a physical impossibility; the instrument is misreading a signal reflection. Technicians often call the splice point a "gainer."

**Talk set:** A device that allows field technicians to talk to each other in the field, over the fiber they are testing. Useful when copper wire is not available and cellular communications isn't possible. Talk sets are often rented (in pairs) when specific need arises, for about \$500 a month.

**Time base error:** See accuracy.

**Video inspection scope:** See fiber inspection microscope.

**Visual fault locator:** A bright laser light, almost always red, with a coupler to the fiber. The light will exit the fiber at a break or bend, allowing technicians to find the fault visually. These devices, which typically can shine light through a fault up to about three miles away, typically cost less than \$300. They are also used to identify one fiber in a multi-fiber cable, for splicing or for tracing a circuit. They can be used with an OTDR to find failures in the OTDR dead zone. See dead zone.

**Zero water peak:** Fiber with no included water, and hence no attenuation caused by it. Some fiber, especially older fiber, was manufactured with a bit of water inside the glass. Or, the glass may have absorbed water from the outside, in rare instances. The OH (oxygen-hydrogen) bonds in water absorb some wavelengths of light, causing a "peak" in the absorption pattern. The standard wavelengths used over fiber now are not absorbed, at least not greatly. But as we add wavelengths to increase bandwidth and network security, this may become an issue and should be tested for. **BBP**

### About the Author

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