White Paper

Testing Today's High-Speed Multimode Fiber Infrastructure

Which light source should you use or specify?

Private networks in premises and campus environments are moving towards high-speed applications such as Gigabit Ethernet in order to handle the ever-increasing bandwidth requirements for faster data transmission. To achieve faster data transmission rates, 1 or 10 Gigabit Ethernet network devices like routers and switches must use high-speed laser light sources rather than the slower light emitting diode (LED) sources. With both lasers and LEDs used for data transmission, what type of source should you use when certifying optical fiber links?

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High-speed network devices using singlemode fiber interfaces utilize Fabry-Perot (FP) laser light sources. The FP lasers used in LANs usually emit at either the 1310 nm or 1550 nm wavelength. Use a similar laser source to measure the loss of singlemode fiber. Since the light source used to measure the link loss matches the characteristics of the light source utilized in the network device, the measured loss will very closely approximate the loss of the transmitted network signal.

It is a bit more complicated with multimode fiber. Network devices designed for multimode fiber can utilize either LED or laser light sources. The majority of network devices that implement 10/100 Mb Ethernet technologies utilize LED sources. Higher speed network devices utilize laser light sources to support 1 or 10 Gigabit Ethernet technology. The type of laser most often used with multimode fiber is the VCSEL (Vertical Cavity Surface Emitting Laser). A VCSEL laser light source emits at the 850 nm wavelength; it is capable of a high data rate; and offers a cost advantage since it is considerably less expensive than a FP laser.

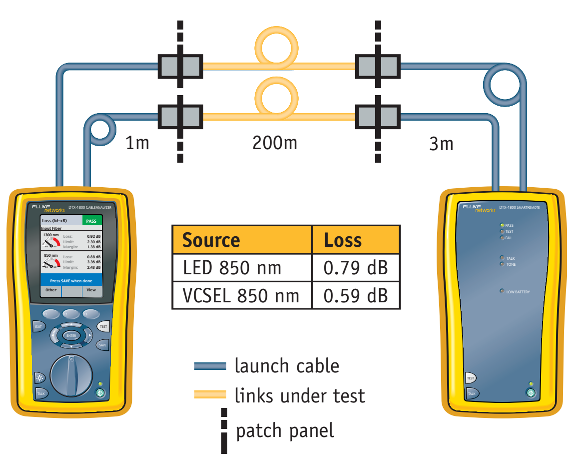
An 850 nm LED and an 850 nm VCSEL emit light differently. In technical terms, the launch conditions between these two light sources are different. An LED emits light relatively uniformly over the entire face of the multimode fiber core. In contrast, a VCSEL source emits light in a narrow beam, which shines bright in the center of the fiber core and quickly dims as it moves away from the center; it does not illuminate the core near the cladding interface. This difference in launch conditions results in different loss measurements. The loss measured with a LED is typically greater than the loss measured with a VCSEL.

To demonstrate this difference, we tested a 200 m link of 62.5 µm multimode fiber with both LED and VCSEL sources. See figure 1. The difference in link loss measured with an LED versus a VCSEL was 0.20 dB at 850 nm. This typical result can mean the difference between a pass and a fail decision when the loss budget is tight.

Certification of fiber optic links – generic or default versus specific light source specification

The TIA and ISO standards prescribe that the certification of fiber optic links should include a loss measurement of each fiber at the two common wavelengths and a verification of the polarity of the two fibers in the link. (Horizontal cabling – maximum length of 100 m – only needs to be tested at one wavelength.)

The TIA-568-B.1 standard refers to TIA standard 526-14, Optical Power Loss Measurements Of Installed Multimode Fiber Cable Plant – OFSTP-14. Annex A in the latter standard defines the Coupled Power Ratio (CPR) for Fiber Optic [Light] Sources. The standard defines a measurement method to determine the CPR of a light source and rates light sources from Category 1 "Overfilled" to Category 5



Source	Loss
LED 850 nm	0.79 dB
VCSEL 850 nm	0.59 dB

Figure 1: Example of a backbone multimode fiber link

"Very Underfilled." We can generally state that an LED light source represents a Category 1 light source while a FP laser typically would be a Category 5 light source. Section 3 in the TIA-526-14 standard discusses the light sources. Specifically, paragraph 3.1.3 states:

> *"The modal launch conditions from the light source shall be characterized as one of Categories 1 through 5 following the procedure in Annex A. If not otherwise specified in a referencing document, light sources from Category 1 shall be used, and noted in the test report per Section 7.1.3. Category 1 sources result in the highest measured cable plant loss and the most conservative test value."*

The industry standards for structured cabling emphasize the generic nature of structured cabling. They do not make any assumptions for the deployment of the installed links. As the quote above states, the signal loss in multimode fibers is greater (worse) for light sources and launch conditions exhibited by LED light sources (CPR Category 1). Therefore, unless specific light source requirements or link deployment instruction are mentioned in the statement of work, the structured cabling standards recommend the LED as the preferred light source to certify and measure multimode cabling links to cover the "worst case" situation.

			Light Sources	
Test Application	**Network Data Rate**	**Fiber Type**	**Network Device**	**Test Equipment**
New cabling installation				
Install, test and certify	10/100 Mbps	MM	LED	LED
	1/10 Gbps	Laser Optimized Fiber (MM)	VCSEL	VCSEL – specific to application* LED – generic
Existing cabling plant				
Certify for network upgrade	1/10 Gbps	MM	VCSEL	VCSEL*

* Note: The link loss measured will more closely emulate the loss of the transmitted network signals.

Table 1 – Selection of light sources for certification of multimode fiber links

However, the network owner of a specific installation most often knows which application the cabling must support. If a cabling system is installed to support Gigabit Ethernet, network engineers can request that the loss performance of the cabling be evaluated with the light sources that will be used when the network devices (switches, routers, servers, etc.) are turned on. In this scenario, the engineers may opt for loss tests of the multimode links using a VCSEL laser light source. Since the source used to measure loss matches the source utilized in the network device, the measured loss will more closely emulate the loss of the transmitted network signals.

When testing an existing multimode cabling installation to certify that the installed links offer the proper performance to upgrade the network to Gigabit Ethernet, more appropriate test results will be obtained using VCSEL and laser light sources.

In summary, the standards recommend that the more generic solution be chosen under the default conditions, but other sources may be specified by the network owner (or the consultant) if that information is relevant and known for the deployment of the cabling system. The most generic solution is the light source with a CPR of Category 1 (LED light source).

The key point in this discussion is that when you want to have the installation tested with a light source other than the default LED specification, you can and should specify this requirement in the statement of work. (See Table 1.)

Fundamentals of fiber optic light transmission

Lasers vs. LEDs

Lasers launch light in a very high-powered, concentrated or narrow beam, while LEDs emit light at a lower power level in a wider beam that is more diffuse. Lasers are also capable of a much faster pulse rate than LEDs, which is one of the main reasons they are required for high-speed networks. With singlemode links, conventional Fabry-Perot lasers are being used, while the new VCSEL (Vertical Cavity Surface Emitting Laser) lasers are being installed for short-wavelength Gigabit Ethernet over multimode fiber.

Multimode vs. singlemode fiber

The primary physical difference between multimode and singlemode fiber is the core size of the fiber. The core is the central glass conductor that transmits the light signal. Multimode fiber is available in two core sizes, 50.0 µm and 62.5 µm, while singlemode is available with a nominal core size of 9 µm. Multimode fiber allows the transmission of light over multiple paths (or modes) within the fiber core, while singlemode, as its name implies, allows light to travel only over a single path. See figure 2. The decision to deploy multimode versus singlemode fiber is typically not based on cost of the fiber itself, but on the cost of the optoelectronics (cost of the network devices) and on the requirements of link bandwidth and the length of the transmission link. Singlemode fiber combined with laser light sources delivers a greater bandwidth over a longer transmission distance than multimode fiber can.

Multimode vs. laser-optimized multimode fiber

Laser-optimized multimode fibers were developed to complement the 850 nm VCSEL light source to support Gigabit Ethernet networks over reasonable distances for LAN applications (campus or building backbone). Compared to conventional multimode fibers, laser-optimized fibers have the same core sizes and attenuation characteristics. Laser-optimized fibers possess different refractive index profiles as compared to conventional multimode fibers. The combination of the laser-like light source and the transmission characteristics of the fiber core deliver a higher bandwidth and can support longer distances than "legacy" multimode fiber optic links.

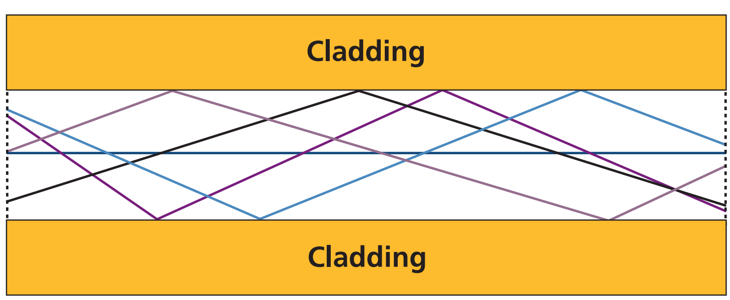


Figure 2a - Multimode fiber

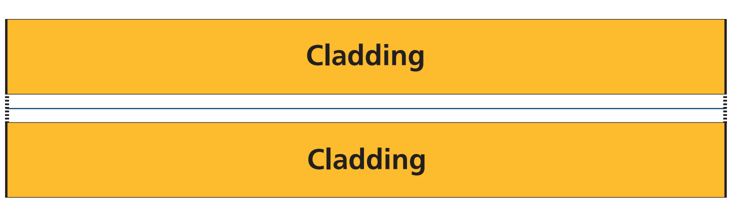


Figure 2b - Singlemode fiber

Higher order modes vs. lower order modes

The many possible paths along which the light can travel in a multimode fiber present different loss characteristics. The paths or modes that are confined to the center of the fiber core are called "lower order modes," while those that travel near the core/cladding interface are called "higher order modes". This distinction becomes important when measuring the loss of multimode fibers. Higher order modes are more susceptible to loss due to bending of the fiber. When bent tightly, the higher order modes are completely lost while many of the lower order modes continue to propagate down the fiber. Higher order modes are also the first modes lost due to core misalignment at connection points. To improve the repeatability and consistency of multimode loss measurements when using a LED source, the standards recommend wrapping the test launch cable connected to the light source around a cylinder called a "mandrel." These tight wraps or bends in the launch cable strip out the higher order modes before the test signal reaches the link-under-test. The measured loss of the fiber under test will be lower if a mandrel wrap is applied to the LED source jumper. For example, when testing the link illustrated in Table 2 we observed 0.15 dB difference in measured loss with the mandrel wrap compared to the loss test without the mandrel wrap.

Launch condition	Loss
LED 850 nm source, no wrap applied to test jumper	0.94 dB
LED 850 nm source, 5 wraps around 17 mm mandrel	0.79 dB

Table 2 - Difference in loss results with the use of the mandrel

Because the laser launches the light in a tight beam, the laser launch conditions create fewer high order modes in multimode fiber. Recall that an LED shines the light in a much wider cone onto the launch face of the fiber and thereby creates many high order modes. The light launched by a VCSEL resembles the conditions of the laser, a narrow, focused beam. This limits the dispersion of the light in the fiber core and enhances the bandwidth of the multimode fiber. Furthermore, mandrels are not used with lasers or VCSELs since few, if any, higher order modes are generated.

Application requirements

Application specifications always refer to the end-to-end link, which in the TIA or ISO context is defined as the "Channel." If the cabling is installed or tested by link segment, care must be taken that the total channel limits are adhered to for proper operation of the application. Table 3 below lists the maximum recommended length as well as the maximum link loss for a number of applications. It is obvious that the high-performance Gigabit requirements are the most demanding. The length is limited based on the bandwidth rating of the fiber; and the allowable channel loss is significantly lower than with older network technologies.

The loss limits specified in the Gigabit Ethernet standards approach the loss limits specified in the TIA or ISO standards, whereas older network applications show a significant amount of margin or headroom above the tighter TIA and ISO specifications. The latter specifications are based on the performance that can be expected from a properly installed cabling system without regard for the application. As long as the application does not demand better performance than the TIA or ISO specifications, the network application will not be impeded by the cabling infrastructure.

Application	Light Source	λ(nm)	Maximum Channel Length (m)		Maximum Channel Attenuation (dB)	
			62.5 μm	50 μm	62.5 μm	50 μm
10BASE-FL	LED	850	2000		12.5	7.8
100BASE-FX	LED	1300	2000		11	6.3
ATM 155	LED	1300	2000		10	5.3
ATM 155	Laser	850	1000		7.2	7.2
ATM 622	LED	1300	500		6.0	6.0
ATM 622	Laser	850	300		4.0	4.0
1000BASE-SX	Laser	850	220 - 275(1)	500 - 550(1)	2.38	3.56
1000BASE-LX	Laser	1300	550		2.35	2.35

1- Note: The channel length limit depends upon the bandwidth rating of the fiber; the lower number applies to the lower bandwidth fiber types (160 MHz·Km)

Table 3 - Application requirements based on fiber optic medium and light source

The observation that Gigabit Ethernet poses the tightest specifications that closely approach the TIA or ISO installation test standards may serve as an argument to test all new multimode fiber with the VCSEL and laser light sources. For example, the user requests that laser-optimized fiber be installed in anticipation of future 1 or 10 Gigabit Ethernet deployments. Initially 100 Mb/s equipment will be installed. When you certify the links with the VCSEL and laser light sources, you know you are not obtaining the worst-case loss figures for those links. The initial deployment of 100 Mb equipment may not at all suffer since those types of equipment operate with a significant loss margin above the TIA specification. It may be more important to obtain the assurance at installation time that the links at some future time will properly support the Gigabit Ethernet technology and that they fall within the link length and the link loss limits.

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