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Migration to 50/125 µm in the Local Area Network

By Doug Coleman

Introduction

Enterprise local area networks (LAN) should be designed to support legacy applications as well as emerging high-data-rate applications. Information technology (IT) managers typically include optical fiber as the primary media type in their structure wiring systems to support such requirements. Until recently, 62.5/125 µm multimode fiber has been the dominant fiber type deployed in the LAN. However, the emergence of high-data-rate systems such as 1 and 10 Gigabit Ethernet (GbE) now warrants a migration to 50/125 µm multimode fiber in the LAN.

History – Legacy Systems

Optical fiber was first deployed in the LAN to support campus backbone applications such as 10 Mb/s Ethernet. The primary fiber type was 62.5/125 um fiber. The fiber supported a 2000 m distance capability based on a 160 MHz•km bandwidth (BW) at the 850 nm wavelength. The large core size and numerical aperture of 62.5/125 µm fiber facilitated a high coupled power ratio (CPR) when used with light emitting diode (LED) sources. In addition, the fiber offered bend sensitivity that made it craft-friendly to the installer and end-user.

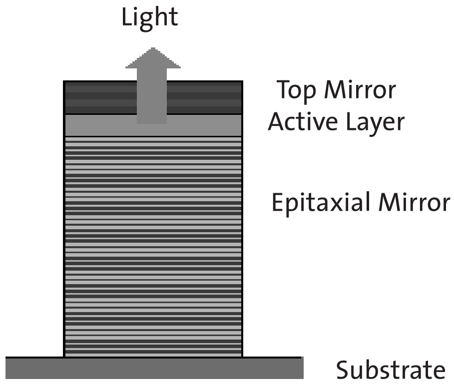
100 Mb/s Ethernet continued to support usage of 62.5/125 µm fiber. The operating wavelength was changed to 1300 nm due to the 500 MHz•km bandwidth requirement to support 2000 m campus backbone length applications. An LED source was also used for the 1300 nm wavelength.

With the success of 62.5/125 µm fiber in the campus backbone, end-users began to specify optical cable in riser backbone and horizontal applications. The performance benefits of optical fiber in the campus backbone could now be obtained in intrabuilding cable deployments.

High Data Rate Systems – Gigabit Ethernet

In 1998, the Institute of Electrical and Electronics Engineers (IEEE) 802.3z task force group released guidance for Gigabit Ethernet. Guidance provided support for 850 nm and 1300 nm serial operation on both 62.5/125 µm and 50/125 µm multimode fibers. At this time, 62.5/125 µm operation at 850 nm provided required LAN distance capability to maintain continued dominance. 850 nm operation was driven by the economics associated with the use of vertical cavity surface emitting lasers (VCSEL) instead of costly 1300 nm lasers such as Fabry Perot (FP) and distributed feedback lasers (DFB).

Gigabit Ethernet required lasers rather than LED because the latter cannot modulate (turn on and off) fast enough to support gigabit speeds. Figure 1 provides VCSEL characteristics.



Vertical Cavity Surface Emitting Laser: Figure 1

- 850 nm wavelength
- High transmission speed (10 GbE, 10 GFC)
- Small laser cavity
- Typical output power (0 to -4 dBm)
- Emits light vertically
- Narrow line width (< 0.5 nm)
- Low power consumption

A VCSEL or FP laser concentrates its light pulses into much smaller area than an LED. Due to the complexity of the manufacturing process for multimode fiber, perturbations in the fiber's index profile may exist that can lead to large differences in system bandwidth between various light sources. For instance, a given fiber could have a very high bandwidth with an LED, but also a very low bandwidth with a laser.

The reason for this involves the amount of modal dispersion that may be present where each source launches its power. Multimode fibers are all prone to index errors near the fiber's centerline, including what is commonly referred to as centerline "dips."

When a VCSEL or FP laser is launched into the center of a multimode fiber, excessive different modal transient times are susceptible due to a centerline "dip" in the refractive index profile of the fiber. When a laser is launched into this dip, multiple signals can be created that walk away from each other so that the receiver may not be able to accurately regenerate the signal. See Figure 2.

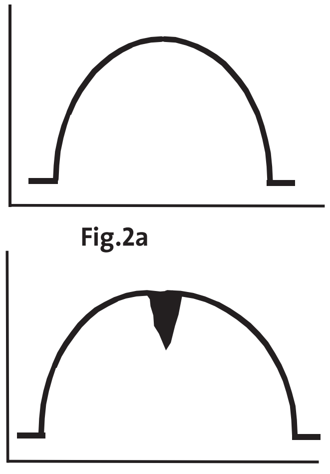


Fig.2a

Fig.2b

Figure 2

Fig.2a
Ideal: graded index profile varies smoothly across the core of the fiber
Fig.2b
Problem: some fibers have a dip or peak in the index profile, right in the center of the core

One way to minimize this type of modal dispersion effect is to precisely control the laser launch position into the core of the multimode fiber. The launch is shaped and positioned so that the light is offset from the center of the fiber core, minimizing the effects of the centerline "dip." The TIA FO 2.2 working group defined optimal launch conditions to minimize the DMD effect. For 1000BaseSX, (850 nm – GbE) the laser launch is conditioned at the transmitter level to yield an encircled power distribution flux of ≤ 25% at 4.5 µm radius and ≥ 75% at 15 µm radius. Encircle flux is the percent power within a given radius launch by a transmitter into a multimode fiber. For 1000BaseLX systems (1300 nm – GbE), the laser launch is not conditioned at the transmitter level because of the need to operate with multimode and single-mode fibers. Therefore, when using 1000BaseLX on multimode, a special launch-conditioning patch cord, also called an offset or mode-conditioning patch cord, must be used at both ends of the link.

The mode-conditioning patch cord launches the light from the laser source away from the centerline of the multimode fiber core. It contains a single-mode fiber (for attaching to the transmitter) that is off-center to the multimode fiber to yield the desired 17 to 24 µm offset launch. This is in contrast to an unconditioned laser launch, which, in worst case, might concentrate all of its light in the center of the fiber, thereby exciting only two or more modes closest to a potential centerline dip.

Restricted Mode Launch / Laser Bandwidth

A restricted mode launch (RML) measurement procedure was developed (FOTP-204) to accurately predict the GbE bandwidth of multimode fiber using a VCSEL at the 850 nm wavelength. It provided a measurable, repeatable method for gauging fiber performance under laser launch conditions. RML bandwidth is measured in accordance with standard bandwidth procedures where the OFL launch condition is filtered with a mode-restricting patch cord. The mode-restricting patch cord consists of special RML fiber that has a graded-index profile with a 23.5 µm core and a .208 numerical aperture. Filtering the OFL simulates a VCEL launch condition for the bandwidth measurement. See Figure 3.

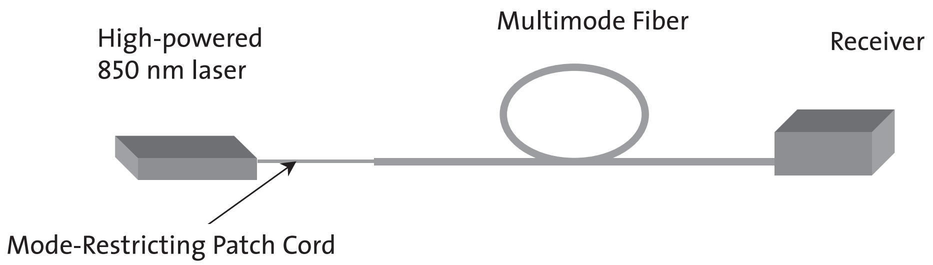


Figure 3

In OFL bandwidth measurements, optical power is distributed in 100% of the fiber core. Laser launch into fiber is much narrower, distributing power in the narrow center region of the fiber. As a result, small perturbations in the index profile significantly impact the functional bandwidth in laser-based systems, but often go unnoticed in OFL bandwidth because of the wide power distribution. RML bandwidth uses a restricted launch into fiber and thus more accurately characterizes laser system performance. See Figure 4.

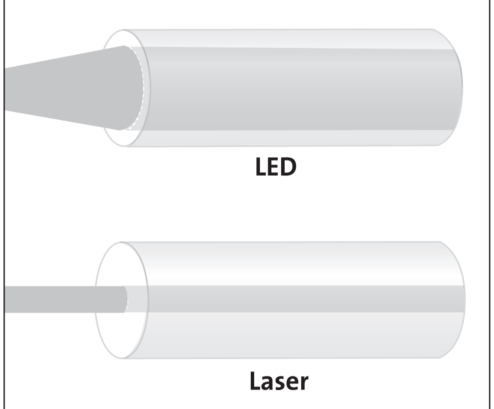


Figure 4

Over-Filled Launch (LED)
- Hundreds of modes
- Power distributed in 100% of core
- Maximum data rate of 622 Mb/s
- Traditional BW measurements

Restricted Mode Launch (Laser)
- Few modes, higher power
- Power distributed in the narrow center region of the fiber core, ~3% of fiber modes
- Simulates a VCSEL launch
- Provides a more accurate indicator of functional performance in laser-based systems

The cabled RML BW and GbE distance capabilities for Corning Cable Systems LANscape® Solutions cabled multimode fibers are provided in Table 5.

High Data Rate Systems – 10 Gigabit Ethernet

The Institute of Electrical and Electronic Engineers (IEEE) approved the 802.3ae 10 GbE certification in June 2002. Multimode fiber and single-mode fiber are specified for building and campus backbone applications, respectively. Guidance is offered for only one serial multimode fiber physical media dependent (PMD) solution, 10GBaseSX. The 850 nm serial PMD includes distances from 2 m to 300 m. The 850 nm wavelength is used for multimode fiber in response to the economic feasibility criteria of the IEEE 802.3ae task force. Simply, VCSELs render the 850 nm serial solution more economical when compared to a 1300 nm solution that would use long wavelength lasers.

The high data rate in conjunction with the desired application distances support 50/125 µm as the default choice fiber type. The small core size of 50/125 µm fiber yields an inherent higher BW capability than 62.5/125 µm fiber. The 300 m maximum distance requires use of 50/125 µm fiber with a 2000 MHz•km effective modal bandwidth (EMB). Standard 50/125 µm has a 500 MHz•km OFL BW at 850 nm with limited distance capability. Table 2 illustrates the different multimode fiber distance capabilities as specified in the 10 GbE standard.

Table 2

Fiber Type	Modal Bandwidth @ 850 nm (min) (MHz•km)	Operating Range (meters)
62.5 µm Multimode	160	2 to 26
	200	2 to 33
50 µm Multimode	400	2 to 66
	500	2 to 82
	2000	2 to 300

Similar to GbE, the 850 nm VCSEL encircled power distribution flux criteria had to be defined to address DMD effects such that a 300 m distance could be obtained. Once again, the TIA FO 2.2 working group provided optimal launch conditions. For 10GBaseSX, the encircled power distribution flux is ≤ 30% at 4.5 µm radius and ≥ 86% at 19 µm radius. See Figure 5.

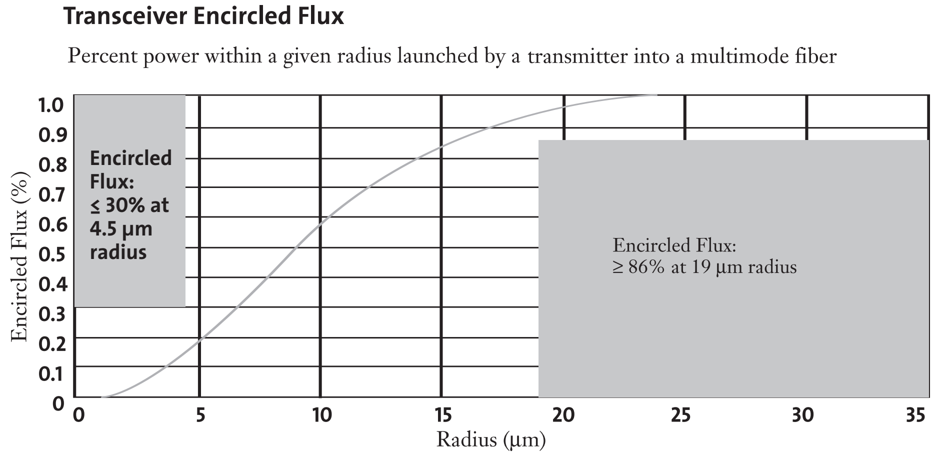


Figure 5

Differential Modal Delay (DMD)

In addition to specifying the encircle flux of the transceiver, TIA FO 4.2.1 used a DMD measurement procedure to ensure the required EMB of 2000 MHz•km. DMD is a fiber manufacturing measurement described in FOTP-220, where a single-mode pulse (≈ 5 µm spot size) is scanned across the 50/125 µm laser-optimized multimode fiber core in at most 2 µm increments. The method translates DMD data into an EMB prediction commonly referred to as the DMD mask approach, where the leading and trailing edges of each pulse are recorded and normalized in power relative to each other. This normalization approach reduces the raw DMD data to focus exclusively on time delay, where the overall fiber delay can be calculated by subtracting the slowest trailing edge from the fastest leading edge in units of ps/m.

According to standards, a fiber meeting any of the mask sets described in Table 3 and meeting all of the sliding masks given in Table 4 will meet a nominal 2000 MHz•km EMB. Note that the DMD mask method provides only a pass or fail estimation around 2000 MHz•km.

Table 3

Template Number	Inner Mask DMD (ps/m) for R_{INNER} = 5 µm to R_{OUTER} = 18 µm	Outer Mask DMD (ps/m) for R_{INNER} = 0 µm to R_{OUTER} = 23 µm
1	≤ 0.23	≤ 0.70
2	≤ 0.24	≤ 0.60
3	≤ 0.25	≤ 0.50
4	≤ 0.26	≤ 0.40
5	≤ 0.27	≤ 0.35
6	≤ 0.33	≤ 0.33

Table 4

Interval Number	R_{INNER} (μm)	R_{OUTER} (μm)
1	7	13
2	9	15
3	11	17
4	13	19

“Modal” vs. Nodal

The newer method for predicting EMB from DMD is called calculated effective modal bandwidth (EMBc). EMBc takes advantage of additional DMD data that is neglected by the DMD mask approach. As mentioned, the DMD measurement characterizes a single fiber’s modal performance in high detail, including both modal time delay and coupling as a function of radial position. With EMBc, this fiber’s performance is then characterized by a set of representative sources which are chosen to span across a range of over 10,000 standards-compliant VCSELs.

Conceptually, this is done by first weighting the individual DMD launches to represent any desired VCSEL. Those weightings are then combined with the richer DMD bench output (the raw DMD data) to build an output pulse for that fiber/laser combination. The output pulse may then be used to calculate EMB in units of MHz•km. Combining the source and fiber DMD measurements yields a synergistic method that accurately calculates the effective modal bandwidth of a 10 GbE system. EMB is calculated for the entire range of standards-compliant VCSELs.

In summary, the main purpose of the EMBc calculation is to ensure that the effective modal bandwidth (EMB) of a fiber will meet the 10 Gb/s requirement of 2000 MHz•km with any conforming laser. Further, the method provides a bandwidth value in units of MHz•km, which can in turn be used to design systems supporting 10 Gb/s performance beyond 300 meters.

The Advantages of EMBc

EMBc combines the properties of both the source and fiber (and more importantly their interactions) and has many advantages compared to other bandwidth measurements adopted to date for guaranteeing a system’s performance.

1 - Sound physics base and experimental verification

The EMBc process predicts source-fiber performance by integrating the fundamental properties of light sources with the multimode fiber’s modal structure which has been measured using a standardized DMD measurement.

2 - Ensures worst case compliance

The minimum EMBc used to specify the fiber performance ensures that the multimode fiber will work for all types of qualified sources, including, for example, the extreme hot centered and hot outside lasers. It is therefore a conservative and robust system performance metric.

3 - Standards compliance and multi-vendor support

EMBc is a method widely supported by many fiber, component and system vendors. Broad consensus was obtained during its adoption into the TIA and 10 GbE standards. This method is in the process of being adopted by the IEC as an international standard.

4 - Measurement of scalability

Since the EMBc method predicts fiber performance in scalable units (MHz•km), it can therefore be scaled to predict other bit rates and/.or link lengths. Conversely, the DMD mask approach provides a pass or fail estimation around a nominal 2000 MHz•km, so it does not easily lend itself to predicting other EMB values.

The 1 and 10 GbE distance capabilities for Corning Cable Systems multimode fiber are provided in Table 5.

Table 5

LANscape® Solutions Cabled Fiber	OFL BW MHz•km	EMB MHz•km	Serial GbE Distance (m)	Serial 10 GbE Distance (m)
Multimode	**850/1300 nm**	**850/1300 nm**	**850/1300 nm**	**850/1300 nm**
Standard 62.5/125 µm	200/500	220/-[1]	300/550	33/-
Standard 50/125 µm	500/500	510/-[1]	600/600	82/-
Laser-Optimized 50/125 µm - 300	1500/500	2000/-[2]	1000/600	300/-
Laser-Optimized 50/125 µm - 500	-/-	*4700 -[3]	1000/600	*550/-[4]

[1] As predicted by RML, BW, per TIA/EIA 455-204 and IEC 60793-1-41, for intermediate performance laser-based systems (up to 1 Gb/s)

[2] As predicted by minEMBc, per TIA/EIA and IEC 60793-1-49, for high performance laser-based systems (up to 10 Gb/s)

[3] As predicted by minEMBc, per TIA/EIA 455-220 and IEC 60793-1-49, for high performance laser-based systems (up to 10 Gb/s)

[4] The 550 m distance is equivalent to a 4700 EMB system with standards-compliant transceiver and fiber characteristics 3.0 dB/km cable attenuation and 1.0 dB total connector loss.

Why 50 µm?

Corning Cable Systems encourages 50/125 µm for new builds - campus and building backbones, horizontal and data centers. The high bandwidth at 850 nm accommodates longer distance capability and more budget margin when compared to 62.5/125 µm multimode fiber for high data rate applications such as 1 GbE and 10 GbE. Cable, connectors, hardware and transceivers/sources are readily available to support usage of 50 µm fiber. The technical and commercial community has recognized the benefits of 50/125 µm fiber. The fiber has been adopted into TIA-568-B.3 for structured cabling and connectivity standards such as Ethernet and Fibre Channel. Connectivity standards now exist to provide data rate migration from10 Mb/s, 100 Mb/s, 1 Gb/s to the emerging 10 Gb/s at the 850 nm wavelength. The 850 nm wavelength continues to offer the most economical solution for premise applications based on electronic costs. The bandwidth scalability of 50/125 µm provides the ultimate media solution for IT managers to ensure their structure wiring systems support legacy as well as future application needs.

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