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Applications Engineering Note

Selection of Multimode Fiber for Premises Applications

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Introduction

High data rate applications like Gigabit Ethernet (GbE) and 10 Gigabit Ethernet (10 GbE) are changing the way multimode fiber is being selected for premises networks. The two prevalent multimode fiber types in premises networks are 50/125 µm and 62.5/125 µm, where 50 µm and 62.5 µm indicate core diameter, and 125 µm is the common cladding diameter. Historically, 62.5/125 µm multimode fiber has been the multimode fiber of choice for premises networks operating at 850 nm or 1300 nm with Light Emitting Diode (LED) transmitters. The LED transmitters are significantly less expensive than the laser transmitters required for single-mode fiber and give multimode fiber a distinct cost advantage in Local Area Networks (LANs) where distances are short and fiber counts are high. Of the two prevalent multimode fiber types, the 62.5/125 µm fiber has been preferred in the past because its larger core provided better power coupling efficiency with the LED transmitters of the day. Now, however, higher data rate applications use laser transmitters which couple efficiently to both multimode fiber cores. The primary consideration now between the two fibers is the superior bandwidth of 50/125 µm fiber which allows longer channels and higher data rates than the larger core 62.5/125 µm multimode fiber. The purpose of this paper is to explain the differences between the currently available multimode fiber types and to help premises customers select the best fiber types for their applications.

System Electronics

Because much of what differentiates one multimode fiber from another is the information carrying capacity or “bandwidth” it will provide in a system, it is important to understand this measure of performance. Bandwidth depends on the type and speed of transmitters as well as the fiber being used; therefore transmitter types are addressed first.

The most common type of transmitter historically used with multimode fiber is the LED. These devices are inexpensive compared to single-mode lasers (i.e. Fabry-Perot, Distributed-feedback) and though the light from a LED is not very intense, the large-core multimode fibers have been able to couple sufficient power to achieve the distances needed with the lower speed applications of the past. LED transmitters have been deployed for use at 850 nm and 1300 nm, up to speeds of 622 Mb/sec. However, because LEDs cannot modulate faster than 622 Mb/sec, a new technology was developed for Gigabit speeds and above.

Vertical Cavity Surface Emitting Lasers (VCSELs) are low-cost lasers that operate at 850 nm on multimode fiber to support gigabit speeds. As a result of their higher speed capabilities, VCSELs are the optical sources utilized in transmitters for Gigabit and 10 Gigabit Ethernet multimode systems. The light emitted is more powerful and more concentrated than the light from LEDs and provides much higher system performance. The tests used to determine system bandwidth had to change when the system transmitters changed from LEDs to VCSELs and again when the VCSEL speeds changed from 1 Gb/sec to 10 Gb/sec.

Bandwidth

In order to accurately characterize system bandwidth for multimode systems using both transmitter types and for speeds up to 10 Gb/sec, three distinct methods have been developed. These bandwidth testing methods predict the Effective Modal Bandwidth (EMB) of systems using multimode fiber with specific transmitter types and application speeds.

The first method for characterizing system EMB is intended to determine the information carrying capacity of systems using multimode with LED transmitters. This method of predicting EMB is called “Over-Filled Launch” or the OFL method. The name of this method comes from the fact that in the intended systems, LED transmitters fully flood the fiber core. Therefore, bandwidth testing for fiber intended for use with LED sources must mimic this overfilled launch. Though a powerful laser (not a LED) is used in the OFL method to ensure adequate power to test long fiber lengths, the light is “scrambled” and spread out so that it simulates the launch conditions present with a LED. This OFL method of predicting EMB for LED-based systems is measured in accordance with the industry standard Fiber Optic Test Procedure (FOTP) 204 and is an accurate predictor of EMB for sub-gigabit, LED-based systems. However, this OFL method of predicting EMB does not accurately characterize system performance when the fiber is used at Gigabit speeds with VCSELs.

The second method for characterizing EMB is intended to determine the information carrying capacity of systems using multimode fiber with VCSEL transmitters for Gigabit Ethernet communications. This method of determining EMB is called “Restricted Mode Launch” (RML). Because VCSELs emit a much narrower and intense beam of light than LEDs, the launch conditions in this RML method simulate a VCESL rather than a LED. Specifically, the scrambled light from the test transmitter is “restricted” using a 23.5 mm core fiber to produce a narrow beam of light similar to what is produced by a VCSEL – hence the name “Restricted Mode Launch”. This RML method of predicting EMB for VCSEL-based Gigabit Ethernet systems is performed in accordance with the industry standard Fiber Optic Test Procedure (FOTP) 204 with the RML fiber. It is an accurate predictor of EMB for those systems. However, this RML method of determining EMB does not accurately characterize system performance when the fiber is used in LED-based systems or VCSEL-based systems operating at 10 Gb/sec. Therefore, a third method of bandwidth measurement was developed for 10 Gigabit Ethernet.

The third method for characterizing EMB is intended to determine the information carrying capacity of systems using 850 nm laser optimized 50/125 μm multimode fiber used at 10 Gb/sec with VCSEL transmitters. This test method scans radially across the fiber core measuring pulse delay differentials and is called “Differential Mode Delay” (DMD). The DMD method of predicting EMB is conducted in accordance with FOTP-220 and is an accurate predictor of EMB for systems using 850 nm laser optimized 50/125 μm fiber in 10 Gb/sec VCSEL-based systems. However, the DMD method of determining EMB is not used to characterize system performance for either the LED-based systems or VCSEL-based systems operating at 1 Gb/sec.

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In summary of bandwidth, there are three different ways to predict the Effective Modal Bandwidth (EMB) of multimode fiber systems, depending on the type and speed of the transmitters being used.

1. The OFL method is used for multimode fiber going into sub-gigabit LED-based systems.
2. The RML method is used for multimode fiber going into VCSEL-based systems operating at 1 Gb/sec (Gigabit Ethernet).
3. The DMD method is used for multimode fiber going into VCSEL-based systems operating at 10 Gb/sec (10 Gigabit Ethernet).

Therefore, multimode fiber should be selected based on its ability to provide adequate Effective Modal Bandwidth in systems with specific transmitter types and speeds.

System Requirements and Fiber Capabilities

Generally speaking, the choice of fiber type is driven by five main considerations.

1. Current applications and data rates
2. Future applications and data rates
3. Channel lengths
4. Compatibility with installed fiber types
5. Standards Compliance

System designers balance these and other circumstantial considerations to develop low-cost solutions with efficient, low-cost migration paths to higher data rates.

Selection of the proper fiber type begins with an understanding of the desired data rate and application. The various application standards (i.e. FDDI, Ethernet, Fibre Channel) have very specific requirements on the types of fiber that are permissible and the bandwidth performance requirements of each. Furthermore, the application standards establish the maximum channel lengths and channel power loss values that are acceptable. A benefit of the application standards is that if the proper fiber type and performance is chosen, and properly installed to the specified maximum channel lengths and maximum channel power loss, the system is expected to operate successfully over its useful lifetime. Table 1 displays the minimum Effective Modal Bandwidth provided by Corning Cable Systems' multimode fibers used with the appropriate transmitters. It also shows the maximum allowable channel length for three prevalent high-speed applications. Note that at the time of this publishing, the 10 GbE standard was still in the final stages of approval.

Premises network designers give consideration to anticipated upgrades to ensure that fiber types chosen for immediate use will also support future data rate increases. For example, InfiniCor® 300 62.5/125 µm fiber would easily accommodate a 250 meter GbE (1000BASE-SX) channel for immediate needs. However, it would not support migration to serial 10 GbE (10GBASE-S) on the existing fiber for that same 250 meters – re-cabling would be required. Alternatively, the higher bandwidth InfiniCor® SX+ 50/125 µm multimode fiber would accommodate the immediate Gigabit Ethernet requirements and allow a smooth migration to 10 GbE on the same fiber type for that 250 meter channel – no re-cabling would be needed.

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Table 1: Minimum EMB and Maximum Channel Lengths

	Minimum Effective Modal Bandwidth			Maximum Channel Length		
Fiber Type	EMB via OFL (MHz*km)	EMB via RML (MHz*km)	EMB via DMD (MHz*km)	1000BASE-SX Distance (m)	10GBASE-S Distance (m)	10GBASE-LX4 Distance (m)
Wavelength	850 / 1300 nm	850 / 1300 nm	850 / 1300 nm	850 / 1300 nm	850 / 1300 nm	850 / 1300 nm
FDDI 62.5/125 um	160 / 500	Not Specified	Not Specified	220 / -	26 / -	- / 300
InfiniCor® 300 62.5/125 um	200 / 500	220 / -	Not Specified	300 / -	33 / -	- / 300
InfiniCor® CL 1000 62.5/125 um	200 / 500	385 / -	Not Specified	500 / -	33 / -	- / 300
InfiniCor® 600 50/125 um	500 / 500	Not Specified	510 / -	600 / -	82 / -	- / 300
InfiniCor® SXi 50/125 um	700 / 500	Not Specified	850 / -	750 / -	150 / -	- / 300
InfiniCor® SX+ 50/125 um	1500 / 500	Not Specified	2000 / -	1000 / -	300 / -	- / 300
InfiniCor® eSX+ 50/125 um	1500 / 500	Not Specified	4,700 / -	1100 / -	550 / -	- / 300

Obviously, channel length goes hand-in-hand with immediate and future application speeds as the primary determinants of fiber type. In general, multimode fiber at 850 nm is the lowest cost LAN solution. Therefore, designers try to select fiber types for their premises networks that take full advantage of this cost efficiency. Designers should choose a multimode fiber type that supports immediate and expected application speeds over each relevant channel length. For simplicity, designers can standardize on one multimode fiber type that meets application speed requirements across all planned channel lengths. Some intermediate length channels may be short enough to operate on multimode fiber at 850 for immediate application speeds, but would require single-mode to upgrade to 10 Gigabit/sec speeds. These channels should be cabled with hybrid cables containing both multimode and single-mode fiber. Channel lengths that are too long to utilize multimode for even immediate application speeds should be cabled with single-mode fiber. Following these simple guidelines is a good first step at designing a structured cabling system that scales gracefully with user needs, without requiring recabling.

Another consideration in choosing the correct fibers for a premises network is the type of fiber already installed, called the “legacy” fiber. Considering that most legacy systems contain 62.5 µm fiber, what should be the approach if required to extend these systems? There should be no performance problem if different fiber types are isolated on different sides of appropriate electronics (hubs, switches, routers, etc). However, can 50/125 µm and 62.5/125 µm multimode fibers be used in the same channel? In theory, for an overfilled launch condition, the loss should be minimal when going from a smaller core (50/125 µm) to a larger core (62.5/125 µm) but considerably higher when light is passing in the opposite direction. A calculated value for the loss can be determined determined using the formula:

$$\Delta\text{Loss} = 20 \log (D_1/D_2) + 20 \log (NA_1/NA_2)$$

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Where:
- D_1 and D_2 are the two fiber diameters
- NA_1 and NA_2 are the two numerical apertures

When a LED overfilled launch condition is used to transmit light from a 62.5/125 µm fiber to a 50/125 µm fiber, the calculated power loss is 4.7 dB. Corning Cable Systems conducted splicing studies in order to validate the calculated values. The two fiber types were spliced together and then measurements were taken using a standard power source and meter. The measurements were taken with light transmitted in both directions. The power source used was a LED transmitter, which provided an overfilled launch condition. Measurements were also taken with a mandrel wrap placed between the source and the fiber under test. As per TIA/EIA-455-50B "Light Launch Conditions for Long-Length Graded-Index Optical Fiber Spectral Attenuation Measurements", the mandrel had a diameter of 17.8 mm (0.7 in). The mandrel was used to attenuate higher order modes traveling in the cladding, which could make the measured loss appear higher than normal, as discussed in Applications Engineering Note 68, "Mandrel Wrapping with Multimode Fiber." Despite the mandrel wrapping, the loss using a LED was significant. Additionally, a VCSEL source was used with the same test scenario to examine the effect. By using a VCSEL source a lower loss would be expected because of the narrower launch condition. Although there was notable loss when transmitting from the 62.5 µm to the 50 µm fiber, the loss was much lower with a VCSEL than with a LED. Table 2 summarizes the results of the splicing study and the effects depending on source type.

Table 2: Fusion Splice Loss Values Measured by Power-Through Testing

Test Type	50 to 62.5 µm with LED (dB)	62.5 to 50 µm with LED (dB)	62.5 to 50 µm with mandrel wrapping (dB)	62.5 to 50 µm with VCSEL (dB)
Average	0.01	4.58	3.93	0.45
St. Dev.	0.01	0.11	0.08	0.12

Standards Compliance

A final, but highly recommended consideration when selecting fiber types for premises networks is standards compliance. Both 50/125 µm and 62.5/125 µm multimode fibers are now recognized by all of the major international and North American standards documents for fiber, cabling, and applications. Therefore, premises network designers should be careful to specify only fibers that comply with published industry standards. This helps ensure the long-term performance and scalability of their optical fiber systems. Relevant standards used by most manufacturers, consultants, installers, and customers are listed below.

Fiber Standards:
- TIA/EIA 492AAAA Detailed Specification for 62.5 µm Multimode Fiber
- TIA/EIA 492AAAB Detailed Specification for 50 µm Multimode Fiber
- TIA/EIA492AAAC Detail Specification for 850-nm Laser-Optimized, 50-µm Core Diameter/125-µm Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers
- IEC 793-2 Optical Fibers Part 2: Product Specifications

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Cabling Standards:

- TIA/EIA 568-B.1 Commercial Building Telecommunications Cabling Standard
- TIA/EIA 568-B.3 Optical Fiber Cabling Components Standard
- ICEA S-83-596 Standard for Fiber Optic Premises Distribution Cable
- ICEA S-104-696 Standard For Indoor-Outdoor Optical Fiber Cable
- ICEA S-87-640 Standard for Fiber Optic Outside Plant Communications Cable
- IEC 11801 Generic Cabling for Customer Premises

Applications Standards:

- IEEE 802.3 Ethernet
- NCITS T-11 Fibre Channel
- ANSI X3T9.5 FDDI

Summary

Selection of multimode fiber requires balancing user preferences for speed and scalability with practical limitations like cost and an understandable aversion for re-cabling. The best rule of thumb is to select standards-compliant fibers for use in a standards-compliant structured cabling design to accommodate both near-term and anticipated speed requirements. Because of low-cost transmitter technology, multimode fiber at 850 nm is generally a less expensive solution than multimode at 1300 nm or single-mode at 1310 nm. It follows then, that the most economical upgrade paths are those that exploit the multimode 850 nm solutions wherever practical. Hybrid cables containing both multimode and single-mode fibers offer a good method of meeting immediate and anticipated speed requirements over the same cable plant where channels are too long to support future migration to 10 Gigabits/sec on multimode fiber. Lighting up the multimode fiber at 850 nm is relatively inexpensive and when, in years to come, 10 Gigabits/sec becomes a requirement, lighting up the single-mode with new electronics won't require re-cabling. Because of the higher-cost single-mode electronics, a purely single-mode cable solution in the LAN is generally reserved for long channel lengths that cannot be supported over multimode at all. Although Corning Cable Systems does not recommend mixing multimode fiber types (50/125 µm and 62.5/125 µm) in a single channel, it can sometimes be accommodated with a loss penalty based on the direction of transmission and transmitter type. In summary, the key point in fiber selection is to choose the multimode fiber with deliberate planning for both the immediate and the anticipated system requirements.

References

1) *TIA/EIA-568-B.1, Commercial Building Telecommunications Cabling Standard*
2) *TIA/EIA-568-B.3, Optical Fiber Cabling Components Standard*
3) *ANSI/TIA/EIA-455-204-2000 (FOTP-204), Measurement of Bandwidth on Multimode Fiber*
4) *TIA/EIA-455-220-2001 (FOTP-220), Differential Mode Delay Measurement of Multimode Fiber in the Time Domain*
5) *ANSI/TIA/EIA-455-54B-1998 (FOTP-54), Mode Scrambler Requirements for Overfilled Launching Conditions to Multimode Fibers*
6) *Corning Cable Systems Applications Engineering Note 67, 2002, Restricted Mode Launch (RML) Bandwidth*
7) *Corning Cable Systems Application Engineering Note 68, 2001, Mandrel Wrapping with Multimode Fiber*
8) *IEEE Standard 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD)*

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