Fundamental Fiber Choices for the Enterprise

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If you're selecting the transmission medium for an enterprise network of any size, chances are you're looking at optical fiber. For use in LANs, data centers and similar applications, fiber offers a number of important advantages compared to copper. First, it has much greater bandwidth to help you meet the demands of busy data communications networks – today and well into the future. In fact, for distances greater than 100 meters at 10 Gb/s, or 7 meters at 40 and 100 Gb/s, optical fiber is the only medium recognized by IEEE for these applications.

Not only can fiber can transmit higher data rates over longer distances, optical links consume significantly less power than copper links, an important criterion in today's "green" environment. And fiber is immune to EMI/RFI signals that can plague copper networks.

But opting for optics is only the first step – you're now faced with an increasingly complex set of decisions in your quest for the best network for your needs. Single-mode fiber, or multimode? OM2, OM3 or OM4? Standard or bend-insensitive? This article will take you through these fundamental decisions on your way to an optimized network.

Balancing Performance, Cost

Your first choice will be between the two main categories of fiber – single-mode and multimode. They are so named because of the way light is carried in the fiber. Because of their small core size (< 10 µm), single-mode fibers transmit light along a single path, or "mode." Multimode fibers have larger cores (50 µm or greater) that guide many modes simultaneously.

Single-mode fiber has advantages in terms of bandwidth and reach for longer distances (> 1 kilometer at 1 Gb/s). It is generally designed for systems of moderate to long distance (e.g., broadband / FTTx, metro, access, and long-haul networks). However, its tiny core requires precision alignment to inject light from the transceiver into the core, significantly driving up transceiver costs. Single-mode connections require more care, skill and precision to terminate, whether in the field or at the factory, adding cost to a single-mode system. Single-mode transceivers also consume more power than their multimode counterparts, an important consideration in operational costs.

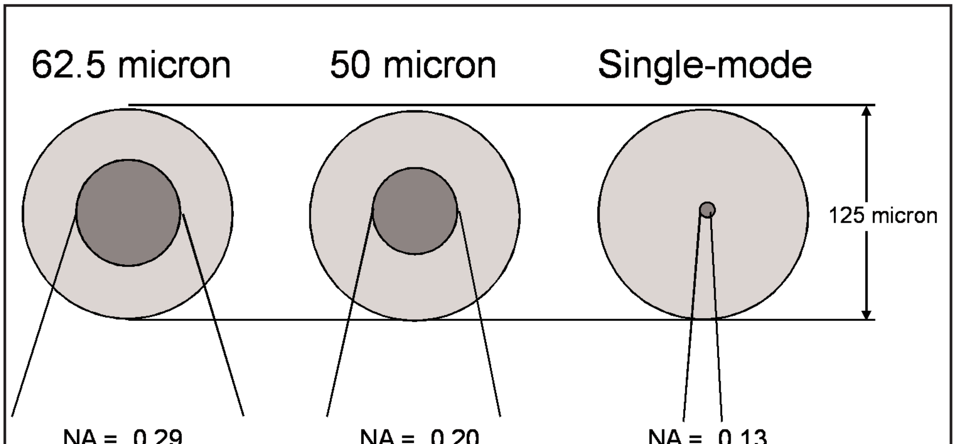

Fig 1: Optical fiber core diameters - larger cores reduce source and system costs

Multimode fiber, on the other hand, easily supports most distances required for premises and enterprise networks. In fact, it can support transmission up to 550 meters at 10 Gb/s for long backbone and short campus runs, and up to 150 meters at 40 and 100 Gb/s for longer data center runs. Furthermore, the optoelectronics used with multimode fiber is generally less expensive than that required for a single-mode system. And multimode fiber is easier to install and terminate in the field - an important consideration in enterprise environments with frequent moves, adds, and changes.

50 or 62.5 µm Fibers

Assuming you've opted for multimode fiber, your next decision will again be between two main product categories.

The two types of multimode fiber for enterprise networks are identified by their core diameter – 50 µm and 62.5 µm. While both have had their time in the sun as the preferred choice based on the standards of the day, changing market conditions have driven the re-establishment of 50 µm fiber as a better solution for applications operating at 850 nm – the preferred operating wavelength of today's laser-based enterprise networks.

As data rates hit 1 Gb/s and 10 Gb/s, it became apparent that 62.5 µm fiber had reached its performance limit, owing to its lower bandwidth at 850 nm. By comparison, 50 µm fiber could offer as much as ten times the bandwidth of the 62.5 µm option, enabling robust support of 1 Gb/s and 10 Gb/s applications. And because 1 Gb/s and 10 Gb/s transmission use small-spot lasers, issues about power coupling into 50 µm fiber disappeared.

The IEEE 1 Gigabit Ethernet standard, published in 1998, uses low-cost 850 nm Vertical Cavity Surface Emitting Lasers (VCSELs) that can reach 1000 meters over 50 µm fiber, compared to 220 - 275 meters on standard 62.5 µm fiber. The 10 Gb/s Ethernet standard, published in 2002, takes advantage of higher bandwidth 50 µm fiber that can support 550 meters using 850 nm VCSELs, compared to 26 - 33 meters on conventional 62.5 µm fiber.

In addition, 50 µm fiber uses the same connectors, installation techniques, and optoelectronics as 62.5 µm fiber. All of this, coupled with the fact that greatly improved cabling materials and processes have made 50 µm fiber cable-friendly, is driving the migration to 50 µm as the multimode fiber of choice in LANs, SANs, data center interconnects and, now, short distance access applications.

OM2, OM3 or OM4?

There are several types of 50 µm multimode fiber from which to choose. They are identified in the ISO/IEC 11801 international cabling standard as "OM" fibers, which stands for "optical multimode." OM fibers available today fall into these categories:

- OM1, for fiber with 200/500 MHz-km overfilled launch (OFL) bandwidth at 850/1300 nm (typically 62.5 µm fiber)
- OM2, for fiber with 500/500 MHz-km OFL bandwidth at 850/1300 nm (typically 50 µm fiber)
- OM3, for laser-optimized 50 µm fiber having 2000 MHz-km effective modal bandwidth

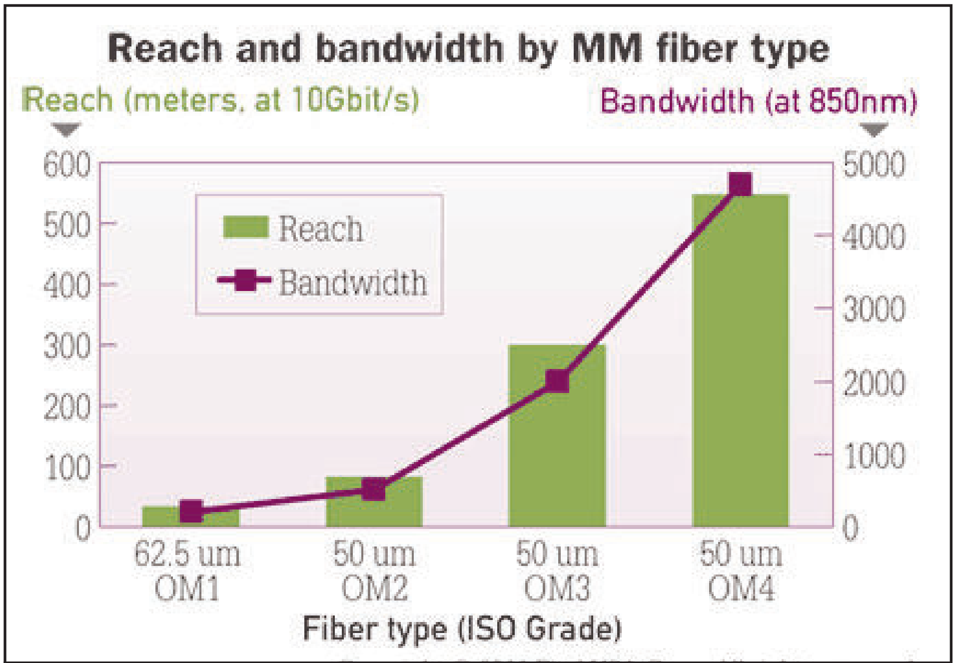

Fig. 2: Multimode fiber continues to evolve to provide greater reach and bandwidth performance.

(laser bandwidth), designed for 10 Gb/s transmission

- OM4, for laser-optimized 50 µm fiber having 4700 MHz-km effective modal bandwidth, designed for 10, 40 and 100 Gb/s transmission.

OM4 fiber is especially well suited for shorter reach data center and high performance computing applications, where optical loss budgets are getting tighter and tighter as speeds reach 10 Gb/s and beyond to 40 Gb/s and 100 Gb/s. The high bandwidth provided by OM4 fiber when deployed at less than its rated distance offers extra “headroom” for channel insertion loss.

OM4 is also backward compatible with applications calling for OFL bandwidth of at least 500 MHz-km at 1300 nm (e.g., FDDI, IEEE 100BASE-FX, 1000BASE-LX, 10GBASE-LX4, and 10GBASE-LRM). OM4 fiber is the “recommended” fiber in the latest draft of TIA-942-A, the first revision of the Telecommunications Infrastructure Standard for Data Centers.

(OM3 fiber is recognized in the draft as an accepted media type, but OM1 and OM2 fibers are not.)

Measuring Bandwidth

Let’s assume that, based on the information above, you’ve selected a 50 µm OM3 multimode fiber for your network. As mentioned, this fiber should provide an EMB of 2000 MHz-km. How will you know if it delivers the promised bandwidth? Multimode fiber bandwidth is certified by manufacturers according to one of two industry-accepted methods – the DMD Mask Method and the Calculated Effective Modal Bandwidth (EMBc) method. Both rely on a measurement called Differential Mode Delay (DMD), which measures and compares the arrival time of all the modes of light in a fiber.

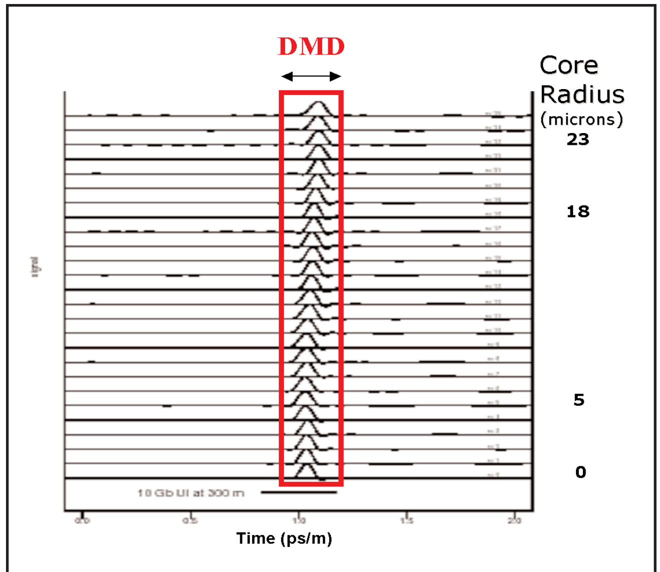

Fig. 3: DMD scan showing the difference in pulse arrival times at each position (“step”) in the core.

DMD is currently the only reliable method for verifying bandwidth required for 10 Gb/s performance or more, because it is the only method that checks all modes across the fiber core independently. TIA/EIA and ISO/IEC have both published standards for DMD measurement and DMD specifications for laser-optimized multimode fiber.

The DMD Mask method directly compares DMD test results against a set of specifications (called *templates* or *masks*) to see if the fiber has the necessary performance. This is a straightforward graphical approach to ensure the data pulses do not spread excessively beyond the required 10 Gb/s bit period. If the OM3 fiber in our example passes these DMD specs, it should provide at least 2000 MHz-km EMB no matter which standards-compliant VCSEL is used.

By comparison, the EMBc method takes the DMD results and matches them against a set of theoretical "weighting functions.” These weighting functions, of which there are 10, are intended to represent the launch distributions of all compliant VCSELs.

The DMD results are combined mathematically with each of the 10 weighting functions. This produces 10 different EMBc values, the minimum of which is called minEMBc. The minEMBc value is then multiplied by a factor of 1.13 to obtain the fiber’s EMB value. If this EMB value is > 2000 MHz-km, the fiber is deemed compliant and should support 300 meters at 10 Gb/s.

Because of all the complex calculations required by the EMBc method, and the fact that the weighting functions only represent a sampling of the launch characteristics of the many VCSELs that could actually be used in a real system, the

EMBc method does not provide the degree of scrutiny over fiber quality and performance that the DMD Mask technique does.

Furthermore, the EMBc method virtually ignores the center 0 – 5 µm (radial) region of a fiber's core because the weighting functions put little emphasis in this region. This can be misleading, because excess power can be introduced into a fiber's center region from hot-center-launch VCSELs, or from VCSELs that have been coupled off-center to the fiber.

For this reason, we recommend that you specify a fiber that has good control of DMD all the way to the center of the fiber.

Bend-Insensitive MM Fibers

Bend-insensitive multimode fibers (BI-MMF), first introduced in 2009, were developed to mitigate link failures when optical cables undergo small-diameter bends or kinks, particularly in jumper applications in data centers. There are several concerns about the use of these fibers in enterprise networks.

There are many technical issues with BI-MMF that need to be resolved by the standards bodies. For example, fiber manufacturers have altered the multimode core, or "waveguide," of these fibers to improve their macrobend performance. Making changes to the waveguide impacts many other fiber properties which then must be optimized.

All BI-MMF use a different profile design compared to the graded-index profile used in standard multimode fiber for more than 30 years. This causes BI-MMF to behave differently in systems. All BI-MMF guide more modes, which can reduce system bandwidth if not properly controlled. BI-MMF can also increase connection loss when mated to standard MMF.

The additional modes traveling in BI-MMF are of particular concern; the major reason that the industry moved from 62.5 µm fiber to a 50 µm core was to reduce the number of guided modes, allowing higher bandwidth.

Because high bandwidth is the primary concern in today's high speed systems, proper characterization of system performance is critical to ensure that BI-MMF can support today's and tomorrow's demanding requirements. Finally, it must be emphasized that the use of BI-MMF is no substitute for proper cable installation techniques.

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