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OM4 - The Next Generation of Multimode Fiber

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As the demand for bandwidth in enterprise applications such as data centers continues to boom, new transmission media must be developed continually to meet end user requirements. The latest in optical transmission media for the enterprise is called OM4 fiber.

OM4 fiber is a 50 micron (µm) laser-optimized multimode fiber with extended bandwidth. It is designed to enhance the system cost benefits enabled by 850 nm Vertical Cavity Surface Emitting Lasers (VCSELs) for existing 1 and 10 Gb/s applications as well as future 40 and 100 Gb/s systems.

Supporting Ethernet, Fibre Channel, and OIF applications, OM4 fiber allows extended reach upwards of 550 meters at 10 Gb/s for ultra long building backbones and medium length campus backbones. It offers an Effective Modal Bandwidth (EMB) of 4700 MHz-km, more than double the IEEE requirement for 10 Gb/s 300 meter support.

To help you use this advanced fiber to its greatest advantage, this paper describes the technology behind OM4 fiber, highlights the key differences with other fiber types, and explains how its high bandwidth is ensured through stringent measurement methods.

Multimode Fiber Basics

Compared to single-mode fibers, multimode fibers have larger cores that, as their name implies, guide multiple "modes" or rays of light simultaneously. Modes that travel at the outside edge of the core have a longer distance to go than modes that travel near the center.

The core's graded index profile is designed to slow down modes that have a shorter distance to travel so that all modes arrive at the end of the fiber as close in time as possible. This minimizes modal dispersion, also known as differential mode delay (DMD), and maximizes bandwidth, which is the amount of information that can travel through the fiber per unit of time.

In addition to their large core, multimode fibers have a large Numerical Aperture (NA), the maximum angle at which a fiber can accept the light that will be transmitted through it. This allows them to work with relatively low-cost optical components and light sources such as light-emitting diodes (LEDs) and VCSELs.

Multimode Fiber Options

Multimode products are identified by the OM ("optical multimode") designation as outlined in the ISO/IEC 11801 international cabling standard (see table 1).

Fiber designation	EMB (in MHz·km) @ 850 nm	OFL (in MHz·km) @ 850 nm	OFL (in MHz·km) @ 1300 nm
OM1 (62.5)	N/A	200	500
OM2 (50)	N/A	500	500
OM3 (laser-optimized 50)	2,000	1,500	500
OM4 (laser-optimized 50)	4,700	3,500	500

Table 1: ISO/IEC 11801 OM designations

OM4 fiber is the latest development in this series. It is especially well suited for shorter reach data center and high performance computing applications, where optical loss budgets are tight at 10 Gb/s (and are expected to get even tighter at 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 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).

The latest offerings in multimode fiber are 50 µm bend insensitive multimode fibers (BIMMF). These fibers have been promoted as offering all the advantages of high bandwidth laser-optimized multimode fiber, with the added advantage of lower bend sensitivity.

However, recent work has pointed to some areas of concern with these fibers. Studies have identified issues with the characterization of bend insensitive fibers, and questioned whether current requirements are adequate to guarantee system performance. Additional studies have shown that mating (connector) loss of BIMMFs with standard fibers is higher than with standard fibers connected to each other. This additional loss adds to the total link loss.

It has been proposed that standards organizations perform a thorough review of BIMMFs, and incorporate them into industry standards. Until this work is done, some caution is advised before widespread adoption takes place.

What Makes OM4 Different?

Like OM3 multimode fiber, OM4 fiber is considered to be "laser-optimized," or optimized for use with VCSEL light sources. OM3 and OM4 fibers are designed and manufactured in such a way as to get the most performance out of VCSELs compared to LEDs. That is why laser-optimized fibers are specified using Laser Bandwidth, or EMB.

OM2 fiber, although compatible with VCSELs, is not considered to be laser-optimized. OM2 fiber is intended for use with LED sources at speeds of 10 or 100 Mb/s, or for shorter reach 1 Gb/s networks. You can use OM2 fiber with VCSELs, but its performance is limited to 550 meters at 1 Gb/s and only 82 meters at 10 Gb/s, compared to OM4 fiber's reach of over 1000 meters at 1 Gb/s and 550 meters at 10 Gb/s.

As discussed, the speed at which each mode travels down a multimode fiber's core depends on its refractive index, which is governed by the amount of chemical dopant Germanium at that location in the core. Because modes traveling down the center of the core have shorter distance to travel than those traveling along the edge, the refractive index profile in a multimode fiber must be "graded" in a parabolic manner across the core. This slows down the modes that have a shorter distance to travel, equalizing the arrival time of all the modes.

The better the modes are equalized, the higher the bandwidth of the fiber. Mode equalization depends on how well the graded index profile is constructed during fiber manufacturing. The more precise the refractive index profile is in terms of shape, curvature and smoothness (free of dips, spikes or defects), the better the modes will be equalized (see Figure 2).

OM4 fiber, with its higher bandwidth, has an extremely precise refractive index profile, virtually free of perturbations or defects.

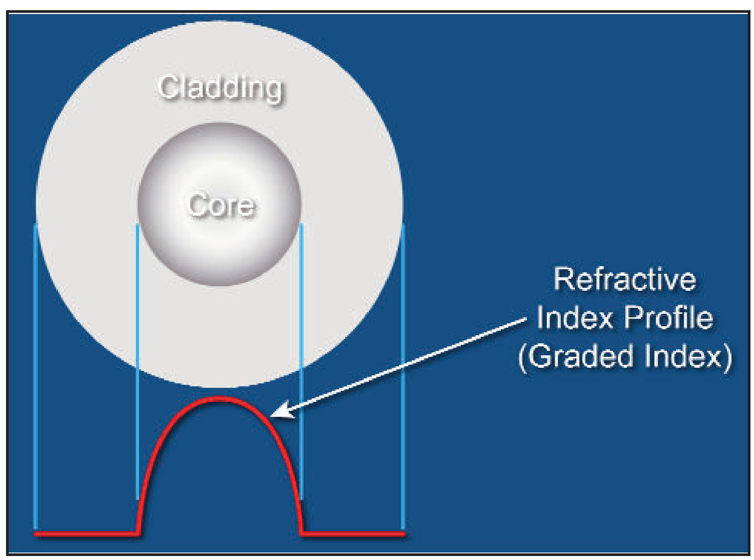

Figure 2: A refractive index profile optimized for shape, curvature and smoothness maximizes bandwidth.

In order to make such a precise fiber, one needs to use a pre-form manufacturing process that has exceptional control over the amount of Germanium that is incorporated at particular sub-micron positions within the fiber's core. An example of a process that lends itself to this level of control is OFS' proprietary MCVD process, in which each layer of the core is deposited and sintered individually, providing the utmost in refractive index precision and uniformity.

OM4 Fiber Standards

Two standards define the use of OM4 fiber in high-speed networks: TIA document TIA-492AAAD, which contains the OM4 fiber performance specifications; and the IEC 60793-2-10 international standard, which provides equivalent OM4 specifications under fiber type A1a.3. ISO/IEC 11801 will add OM4 fiber as an industry-recognized fiber type, and IEEE 802.3ba for 40G and 100G Ethernet will include OM4 fiber as an option that provides a reach of 150 meters (50 percent greater than OM3).

There was discussion and debate within the standards groups about a minimum OFL bandwidth requirement at 850 nm. Although current applications primarily use 850 nm VCSEL lasers with fibers that are specified to a minimum EMB, there was good reason to also establish a minimum 850 nm OFL bandwidth specification. It has been shown that fibers with higher OFL bandwidth will perform better with

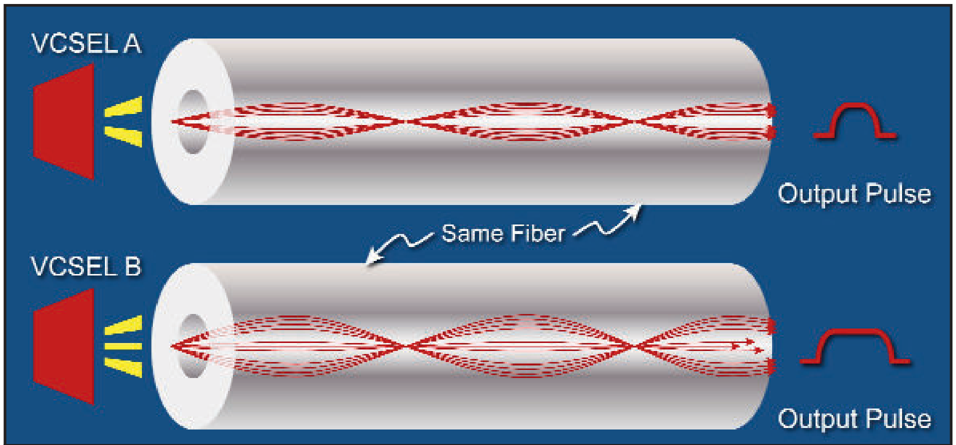

Figure 3: DMD testing measures how different VCSELs fill different modes in each fiber.

VCSELs that launch more power into outer modes. That is why the existing OM3 fiber standards require a minimum 1500 MHz-km OFL bandwidth at 850 nm.

For OM4 fiber, OFS and others in the standards group strongly recommended at least 3500 MHz-km OFL bandwidth in order to ensure the utmost performance and reliability; ultimately, that is the specification that was agreed upon.

Measuring Laser Bandwidth

Bandwidth performance of OM4 fiber is ensured using the same criteria as OM3, but to much tighter specifications. Due to a challenge posed when the now-familiar VCSEL was first introduced, new measurement methods had to be developed to verify laser bandwidth of OM3 and OM4 fibers.

Unlike an LED, laser VCSELs produce an energy output that is not uniform; it can change sharply across the face of the output. What's more, each laser fills a different set of light paths in each fiber, and does so with differing amounts of power in each path. Overfilled bandwidth measurements, used to measure LED bandwidth, could not emulate the operation of a VCSEL.

The standards allow two ways to measure and verify laser bandwidth: the DMD Mask Method, and the EMBc Method. Both methods require DMD testing -- the difference lies in how the DMD data is used and interpreted.

In DMD testing, small, high-powered laser pulses are transmitted through the fiber in tiny steps across the entire core of the fiber. Only a few modes are excited at each step, and their arrival times are recorded. The DMD of the fiber is the difference between the earliest and the latest arrival times of all modes at all steps.

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

The DMD Mask Method is a simple process that 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 ensuring the data pulses do not spread excessively beyond the required 10 Gb/s bit period. If the fiber passes these DMD specs, then you are assured of at least 2000 MHz-km EMB no matter which VCSEL you use (as long as the VCSEL is compliant).

The EMBc Method is an indirect and more complex process. It takes the DMD results and matches them against a set of theoretical "weighting functions" that 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 lowest 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 with OM3 requirements and therefore should support 300 meters at 10 Gb/s.

Due to 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 same scrutiny on fiber quality and performance as the DMD Mask technique. What's more, 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.

Conclusion

OM4 fiber provides next-generation multimode fiber performance for today and tomorrow's high speed applications. With its significantly higher bandwidth, network designers and operators can be assured that multimode fiber will continue to provide the most cost effective solutions for short reach applications in data centers and LANs.

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