WHITE PAPER

WIDEBAND MULTIMODE FIBER MEETS THE NEED FOR HIGHER SPEEDS

Is there any limit to user demand for bandwidth in the enterprise? Industry leaders are forecasting an increase in demand at a compound annual growth rate (CAGR) of nearly 25 percent over the next five years. In order to support this increased level of traffic, standards organizations are constantly working to support higher speeds for the transmission of data. In the past, transceiver vendors traditionally have increased the speed of their devices in order to achieve higher speeds. Later, transmission schemes using parallel fibers were adopted. At some point, however, simply increasing the number of fibers for each new speed becomes unreasonable, in part because the cable management of parallel fiber solutions, combined with the increasing number of links in a data center, is much more difficult.

Now, focus has moved to the optical fiber carrying the signal. A new multimode fiber under development will extend the ability of conventional OM4 fiber to support multiple wavelengths using short wavelength division multiplexing (SWDM). Referred to in the industry as "wideband" multimode fiber (WBMMF), this SWDM-enhanced fiber is expected to maintain the cost advantages of multimode fiber for short distance applications, up to 300 meters (m) or more. One such fiber is LaserWave® *FLEX* WideBand Multimode Fiber from OFS, expected to be commercially available by the end of 2015.

This white paper explores the drivers behind the development of this new fiber type, its technical capabilities and the standards work currently underway to support this advance in optical fiber performance.

Bandwidth Demand Continues to Boom

Demand for internet bandwidth is exploding (Figure 1). The number of traditional Internet access devices (PCs, tablets and mobile phones) continues to increase, as Gartner estimates that 2.5 billion units will be shipped in 2015. Meanwhile, the Internet of Things (IoT) has become the latest catchphrase for the networking industry. The IoT includes connections from industrial applications (automated manufacturing, process control and agriculture), smart buildings (lighting, HVAC control and security systems), consumer applications (automotive, point-of-sale and healthcare) and other emerging markets. Gartner estimates that connection to the Internet by non-traditional objects will grow to 26 billion devices by 2020 (Gartner, 2013).

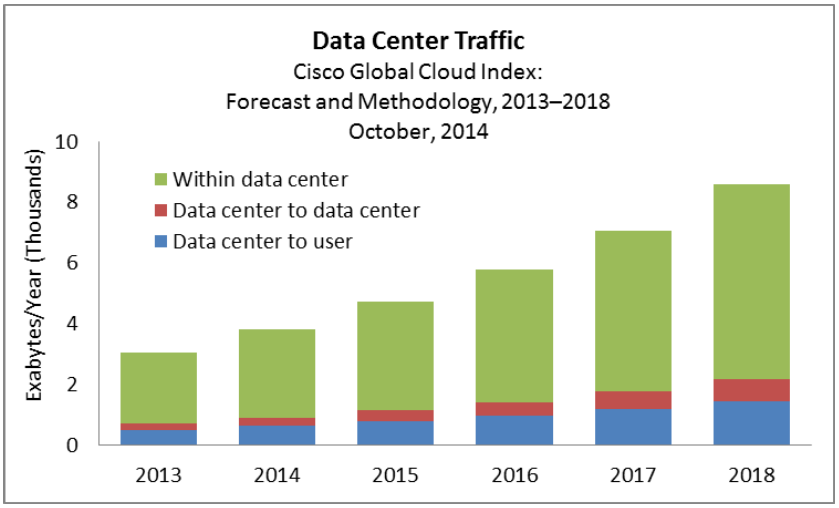


Figure 1: Demand for Internet bandwidth (Data Center Traffic)

All these connected devices drive the increased demand for Internet bandwidth. Cisco forecasts global IP traffic will grow at a CAGR of 23 percent (Cisco, 2015), from 720 Exabytes (EB) in 2014 to over 2000 EB in 2019. Nearly a million minutes of video will travel over the network *every second* by 2019. Data center traffic (Cisco, 2014), is estimated to grow at about the same rate. In order to support this increased level of traffic, networking standards are constantly working to support higher speeds.

As Speeds Increase, Standards Evolve

Two of the predominant networking standards groups, IEEE 802.3 Ethernet and INCITS T11 Fibre Channel, are currently developing new standards to support this increased demand. IEEE is working a 400 gigabit per second (Gb/s) standard, and also developing a 25 Gb/s standard to support the next generation of server link access.

Hyperscale data center operators are stressing the need for higher speed links and the rapid development of 400 Gb/s transmission speeds. The first Ethernet 400 Gb/s standard, under development in IEEE802.3bs, will have four different implementations, segmented by reach (Table 1).

Physical Medium Dependent (PMD)	Media	# Fibers	Reach (m)	Lanes/Lane rate	Encoding
400GBASE-SR16	Parallel multimode	32 Fibers	100	16 lanes x 25 Gb/s	NRZ
400GBASE-DR4	Parallel single-mode	8 Fibers	500	4 lanes x 100 Gb/s	PAM4
400GBASE-FR8	8λ CWDM single-mode	2 Fibers	2,000	8 lanes x 50 Gb/s	PAM4
400GBASE-LR8	8λ CWDM single-mode	2 Fibers	10,000	8 lanes x 50 Gb/s	PAM4

Table 1: Specifications of the first 400 Gb/s Ethernet standard.

As bit rates increase, the fiber optic industry continues to develop and standardize the most economical solutions that deliver the necessary bandwidth over the required distances. Traditionally the choice for long distance links (> 2 kilometers [km]), single-mode fiber will soon support solutions for intermediate distances (500 meters [m] – 2 km) in a more cost-effective manner. For shorter reach (< 500 m) links, multimode fiber will continue to have a cost advantage over single-mode systems, due to the cost of the optics involved. While the standard defines a multimode solution with a 100 m reach, transceiver suppliers are expected to continue their model of developing premium products that can support longer distance links.

As mentioned, IEEE is developing a 25 Gb/s standard in IEEE 802.3by to accommodate higher speed server links. The initial version of this standard will focus on short-reach, single-lane applications with copper twin axial cables up to 3 and 5 m, and a 100 m reach using duplex multimode fiber that is consistent with the 100 Gb/s (4 x 25 Gb/s) IEEE P802.3bm standard.

INCITS T11 is in the latter stages of adopting a standard for 128 Gb/s Fibre Channel and is beginning work on 64 Gb/s and 256 Gb/s standards. Fibre Channel is typically used in shorter links to connect data storage. Unlike Ethernet, there is less interest in longer reach, service provider-type applications. As seen in Table 2, maximum link distance is 2 kilometers (km) using single-mode fiber. INCITS plans for single-lane 64 Gb/s and 4-lane parallel 256 Gb/s speeds.

Description	**Speed**	**Variant**	**Media**	**# Fibers**	**Reach (m)**	**Lanes/Lane Rate**
FC-PI-6P	112 Gb/s	128GFC-SW4	Parallel multimode	8	100 (OM4) 70 (OM3)	4 lanes x 28 Gb/s
FC-PI-6P	112 Gb/s	128GFC-SWDM4	4λ SWDM single-mode	2	2,000	4 lanes x 28Gb/s
FC-PI-6P	112 Gb/s	128GFC-PSM4	Parallel single-mode	8	500	4 lanes x 28 Gb/s
FC-PI-7	56 Gb/s					
FC-PI-7	224 Gb/s					

Table 2: Fibre Channel standards for high-speed transmission.

In their roadmaps to even higher speeds, Ethernet extends to 10 Terabit (Tb/s) transmission (http://www.ethernetalliance.org/roadmap), while Fibre Channel (http://fibrechannel.org/fibre-channel-roadmaps.html) has identified speeds up to 1 Tb/s.

Adding Fibers, Adding Complexity

To achieve higher speeds up to 10/25 Gb/s, transceiver manufacturers simply increased laser and detector speeds when higher bit rates were needed. Beyond those speeds, however, a plateau was reached, and when first-generation 40 and 100 Gb/s standards were written, transceiver vendors (instead of using higher speed optics) used parallel 10 Gb/s lanes – four 10 Gb/s lanes (or multimode fibers) for 40 Gb/s and ten 10 Gb/s lanes for 100 Gb/s. Later, transceiver suppliers were able to increase the speed per lane to 25 Gb/s, and a new 100 Gb/s Ethernet standard was developed using four parallel multimode fibers, each carrying 25 Gb/s. This capability allowed end users to migrate their 40 Gb/s links to 100 Gb/s speeds simply by changing the transceivers on each end, without having to add cabling infrastructure.

Continually increasing network speeds adds pressure on multimode providers to develop novel solutions that allow higher capacity on individual fibers. Even more challenging, it becomes increasingly complex to manage cabling infrastructure as fiber counts continue to grow, not just from the increased number of links required in a large data center but also because the links themselves require more fibers. Table 3 shows how fiber counts increase as network speeds increase, and how that effect can be reduced by increasing individual fiber capacity from one wavelength (λ) to four λs.

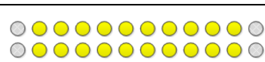
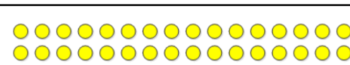
	10G/Fiber	25G/Fiber	25G/λ - 4λ /Fiber
10G		N/A	N/A
25G	N/A		N/A
40G		N/A	N/A
100G			
400G	N/A		

Table 3: Fiber counts grow as speeds increase.

Next-Generation Fibers Meet the Challenge

WBMMFs will extend the ability of conventional OM4 fiber to support multiple wavelengths. Instead of adding more fibers to increase data capacity, SWDM-enhanced multimode fiber adds more paths for the light to travel in a single fiber. WBMMFs will maintain the cost advantages of multimode fiber for short-distance applications, potentially up to 300 m or more. Instead of supporting transmission at a single wavelength, wideband SWDM fiber such as OFS' LaserWave® *FLEX* WideBand Multimode Fiber is designed to support traffic over a range of wavelengths from 850 nanometers (nm) to 950 nm. This capability will allow multiple lanes of traffic over the same strand of fiber (Figure 2).

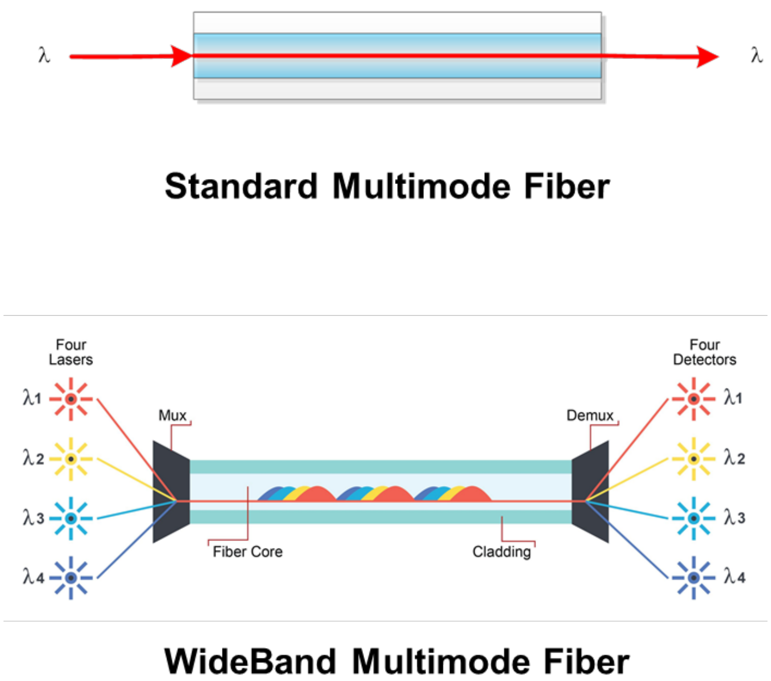


Figure 2: Signal transmission over standard multimode fiber (top) and wideband multimode fiber (bottom).

This technology has been used in single-mode fiber systems, but has only recently been proposed for standardization in short-reach multimode links. One of the first implementations of multimode SWDM technology was Cisco's 40 Gb/s BiDi transceiver. It uses two wavelengths

(850 nm and 900 nm) transmitting at 20 Gb/s each, to allow 40 Gb/s over a duplex link of multimode fibers. While BiDi technology is proprietary and not standardized, it has proven to be a popular solution in the data center market. Other SWDM solutions have also been announced. At OFC 2015, Finisar provided details of a 40 Gb/s solution that used four wavelengths, and could support links up to 300 m on standard OM3 multimode fiber, and 400 m on OM4 fiber. The company also announced that they would have a 100 Gb/s solution that used four 25 Gb/s lanes, providing data center operators with a duplex fiber 100 Gb/s link.

While all these products can work using a standard OM3 or OM4 multimode fiber, one that is optimized for operation at multiple wavelengths beyond just 850 nm could support longer link lengths. In the future, high-speed transceivers will take even greater advantage of the expanded wavelength capabilities of these fibers, supporting applications that will be extremely limited on current OM3/OM4 fibers.

SWDM-optimized fiber will maintain backward compatibility with OM4 fiber applications and link distances, but will also offer OM4 performance at more than one wavelength, instead of simply increasing bandwidth at 850 nm. Higher bandwidth across the entire 850 - 950 nm range enables transceiver suppliers to develop new devices that take advantage of lower chromatic dispersion at the higher wavelengths. Longer term, it may enable a shift to operate at higher wavelengths, where the chromatic dispersion penalty is less compared to 850 nm.

Backward compatibility to support current OM4 applications is critical. Many end users want the ability to support future generations of technology, but often deploy lower speed equipment in their initial installation. LightCounting studies show that, despite all the attention given to the deployment of 40 and 100 Gb/s solutions, the vast majority of Ethernet transceivers sold are 1 Gb/s and 10 Gb/s units. In fact, 10 Gb/s transceivers only surpassed 1 Gb/s shipments in 2014, even though the 10 Gb/s standard was first defined in 2002. Even customers who deploy the latest technology often need to support legacy applications operating at lower data rates.

Fiber Standards Are Keeping Pace

Work is underway in the Telecommunications Industry Association (TIA) to develop a standard for WBMMF. A Joint Task Group (JTG) in TIA's TR-42 committee, Telecommunications Cabling Subsystems, was formed in October 2014 with the goal of writing a standard for a 50 micron (µm) core multimode fiber with bandwidth to support SWDM applications. This fiber will support multiple wavelengths including and beyond 850 nm. The goal is to be able to support 100 Gb/s transmission per fiber to at least 100 m. The fiber will support transmission of at least 28 Gb/s per wavelength. The work is expected to be completed sometime in 2016.

Determining the fiber requirements to support these objectives is an important part of this standard. The JTG has established that the 100 GBASE-SR4 and 32G Fibre Channel spreadsheet link models will be used as baseline models. Because 50 µm multimode fiber has lower chromatic dispersion at longer wavelengths, the modal bandwidth requirement is decreased.

Using the two spreadsheet models, Table 4 shows the estimated Effective Modal Bandwidth (EMB) values required across the wavelength range, assuming that WBMMF is identical to OM4 fiber except for the bandwidth profile. The effect of lower chromatic dispersion at the longer wavelengths is evident as the EMB requirement drops as 950 nm is reached. The 4700 MHz-km requirement at 850 nm is required in order to maintain backward compatibility with OM4 specifications.

Wavelength (nm)	**EMB (MHz*km)**
850	4700*
875	3300
900	2900
925	2700
950	2550

Table 4: EMB values for wideband multimode fiber (*maintains backward compatibility with OM4 fiber).

There is work underway to better characterize chromatic dispersion in multimode fiber. Within the International Electrotechnical Commission (IEC), a round robin test has begun to confirm measurement uniformity across the industry. Once that work is complete, chromatic dispersion values may be revised in the IEEE and Fibre Channel spreadsheets. This change may lower some of the required bandwidth values, as chromatic dispersion is expected to be better than existing values in the spreadsheets.

It is important to note the range and scope of the participants in the JTG. Participation and input is not limited to TIA members. System vendors, transceiver suppliers, structured cabling suppliers and fiber manufacturers from across the data networking ecosystem contribute to the group. The JTG has received contributions from both IEEE (Ethernet) and INCITS (Fibre Channel) members, as well as IEC, the international cabling standards group. This broad representation is needed to develop the most cost-effective short-reach solution for data centers and enterprise networks. While each group has some competing interests, the industry understands the importance of developing the best solution for these customers. Once the TIA fiber standard is in place, IEC is expected to adopt the WBMMF standard as well, and the fiber can be incorporated into future application standards.

Future Developments

The first generation of SWDM links is expected to support up to 100 Gb/s over a pair of fibers, using wavelengths between 850 and 950 nm. Future-generation links may increase this speed in a number of ways. More complex encoding schemes, already being used in single-mode fiber solutions, could result in double the link capacity, or more. Higher speed VCSELs and detectors could also provide an increase in speed. Of course, technical issues will need to be overcome with all of these options.

Other possibilities include fibers that have even wider operating windows. This capability could increase the number of wavelengths used, or allow transceiver suppliers to move away from the chromatic dispersion-challenged 850 nm wavelength.

Conclusion

Bandwidth demand continues to grow unabated. Increasing amounts of traffic are traveling not just over the public network, but within data centers and enterprise networks. The use of virtualization in servers has driven intra-data center traffic to new levels, while the rapid deployment of cloud computing applications is creating demand for higher-speed enterprise networks. Application standards such as Fibre Channel and Ethernet are working to support these increased needs with higher speed protocols.

The fiber and cabling industry is supporting the need for higher network speeds with the development of WBMMFs, novel, next-generation SWDM fibers that will provide the most cost-effective short-reach solutions for data center and enterprise networks.

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