

Wideband Multimode Fiber – What is it and why does it makes sense?

November, 2015

Executive summary

Multimode fiber (MMF) cabling is the workhorse media of local area network (LAN) backbones and data centers because it offers the lowest cost means of transporting high data rates for distances aligned with the needs of these environments. MMF has evolved from being optimized for multi-megabit per second transmission using light emitting diode (LED) light sources to being specialized to support multi-gigabit transmission using 850 nm vertical cavity surface emitting laser (VCSEL) sources. Channel capacity has been multiplied through the use of parallel transmission over multiple strands of fiber. These advances have increased multimode supported data rates by an astounding factor of 40,000 – from 10 Mb/s in the late 1980s to 100 Gb/s in 2010, with 400 Gb/s in development in 2015. Today, these extraordinary rates are created from collections of 25 Gb/s lanes carried on either four or sixteen strands of fiber in each direction.

While parallel transmission is simple and effective, continuation of this trend drives higher cost into the cabling system. Wideband multimode fiber (WBMMF) enhances another means of multiplying data rates via wavelengths to increase the capacity of each fiber by at least a factor of four. This enables at least a four-fold increase in data rate for a given number of fibers (e.g. enabling 1600 Gb/s), or at least a four-fold reduction in the number of fibers for a given data rate (e.g. enabling 100 Gb/s per fiber). Optimized to support wavelengths in the 850 nm to 950 nm range, WBMMF ensures not only more efficient support for future applications to useful distances, but also complete compatibility with legacy applications, making it an ideal universal medium that supports not only the applications of the present, but also those of the future.

A brief history of MMF

MMF was the first fiber deployed in telecom networks in the early 1980s. With a light-carrying core diameter about six times larger than singlemode fiber, it offered a practical solution to the alignment challenges that faced designers of connectors, sources and detectors for efficiently getting light into and out of the cabling.

In the late 1980s, when alignments could achieve micron (one millionth of a meter, μm) accuracy and laser diodes became available, singlemode fiber started to become widely deployed in public networks. But due to the cost advantage of easier alignment and the ability to use low-cost LED sources, MMF found a home in enterprise networks supporting a variety of applications such as private telephone switches (PBXs), data multiplexers and LANs.

During the 1990s as Ethernet and Fibre Channel applications grew in prevalence for LANs and storage area networks (SANs), MMF became the main media for backbone and other deployments requiring reaches exceeding those of copper twisted pair cabling. As data rates surpassed 100 Mb/s, LED sources gave way to a new low-cost source – the 850 nm VCSEL – which could be modulated much faster. This in turn started a conversion of the MMF core diameter from 62.5 μm (i.e. OM1 cabling) to 50 μm (OM2 cabling) for two reasons:

1. The larger 62.5 μm core was no longer a useful advantage with the more concentrated output of VCSELs which could efficiently couple to the smaller 50 μm core as shown in Figure 1.

2. The 50 μm design offered inherently higher bandwidth to better support transmission at hundreds of megabits per second.

As the gigabit era dawned in the late 1990s, limitations with the bandwidth measurement techniques of that time became apparent. Originally designed to provide a bandwidth assessment that was useful for predicting performance of the fiber when used with LEDs, the measurement made with overfilling launch conditions no longer provided reliable indication for the concentrated under-filling launches of VCSELs. This led to significant advancement in bandwidth characterization via a newly standardized differential mode delay (DMD) measurement that employed many different laser launches to extract a minimum laser bandwidth. Fiber passing the new measurement became known as laser-optimized multimode fiber (LOMMF).

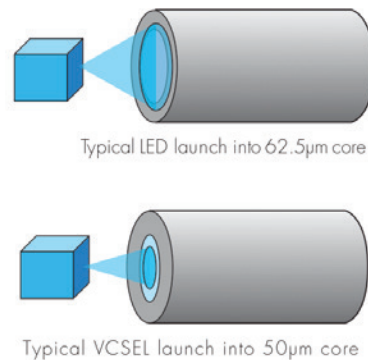


Figure 1 - Overfilling LED and under-filling VCSEL launches

The first standard LOMMF offered reliable bandwidth of at least 2000 $\text{MHz}\cdot\text{km}$ at 850 nm, four times higher than the overfilled bandwidth of OM2. Dubbed OM3 and shown in Figure 2, it ushered in the age of 10 Gb/s transmission in the early 2000s. By the late 2000s OM4 arrived, offering at least 4700 $\text{MHz}\cdot\text{km}$ in anticipation of 25 Gb/s per lane applications that are now being developed or delivered to the market as 25G Ethernet (25GBASE-SR), 100G Ethernet (100GBASE-SR4), and 400G Ethernet (400GBASE-SR16). For SANs, Fibre Channel applications track these advancements with 8GFC, 16GFC, 32GFC, and 128GFC (4 \times 32GFC). Today, OM3 and OM4 are the primary fiber media for Ethernet and Fibre Channel applications.

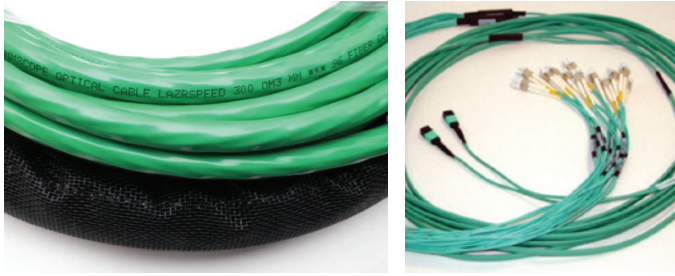


Figure 2 - LazrSPEED laser-optimized MMF

The role of fiber connectors

The first widely deployed fiber connector for multimode applications was the ST, featuring a 2.5 mm-diameter cylindrical ferrule with a bayonet-style attachment mechanism in a single-fiber form factor. The SC connector, with its push-pull mechanism and ability to be clipped together to form two-fiber “duplex” connectors, displaced the ST during the 1990s. A variety of small-form-factor duplex connectors followed that doubled connection density. Of these, the duplex LC connector emerged during the early 2000s as the predominant form. Featuring a 1.25 mm-diameter ferrule and a familiar tab-style latching mechanism, the LC remains the predominant connector today. All of these connector types can be seen in Figure 3.

While the evolution of duplex connectors was underway, array connectors were also emerging. First deployed in public networks to facilitate the joining of ribbon fiber structures having eight to twelve fibers per ribbon, the MPO shown in Figure 4 found great utility during the past decade as a means to rapidly deploy cabling into data centers. The compact form of the MPO, featuring a rectangular ferrule, allows a dozen or more fibers to be terminated in a plug occupying just the space of a duplex LC. The MPO’s high density enables installation of pre-terminated high-strand-count cables that eliminate the time consuming process of installing connectors on site. Typically plugged into the back of a fan-out cassette that presents LCs at its front, the MPO is now increasingly deployed directly at the front of patch panels in support of parallel applications like 40GBASE-SR4.

In preparation for the deployment of 400GBASE-SR16, a new array connector known as the MPO-16 is being standardized. As the name implies, the MPO-16 increases the number of fibers per row from twelve to sixteen. Not only is it the perfect match for “-SR16”, it also offers a simpler, more efficient match-up for cabling that supports applications having four lanes in each direction, such as 40GE, 100GE and 128GFC. Look for this connector to play a major role in the evolution of pre-term cabling in the coming decade.

Introducing WBMMF

OM3 and OM4 provide very high laser-optimized modal bandwidth at 850 nm, the predominant wavelength of multimode applications. But to provide equivalent performance over a range of wavelengths needed to support low-cost wavelength division multiplexing (WDM) requires a new fiber specification because the modal bandwidth of OM3 and OM4 can diminish quickly when operated at different

wavelengths, making them less than ideal for supporting WDM lane rates above 10 Gb/s per wavelength. Recognizing that the chromatic bandwidth of fiber improves as wavelength increases above 850 nm, and that proprietary applications like Cisco’s 40G-SR-BD (40 Gb/s using bi-directional transmission per fiber) employ 850nm and 900nm VCSELs, leads to a fiber specification starting at 850 nm and moving towards longer wavelengths.

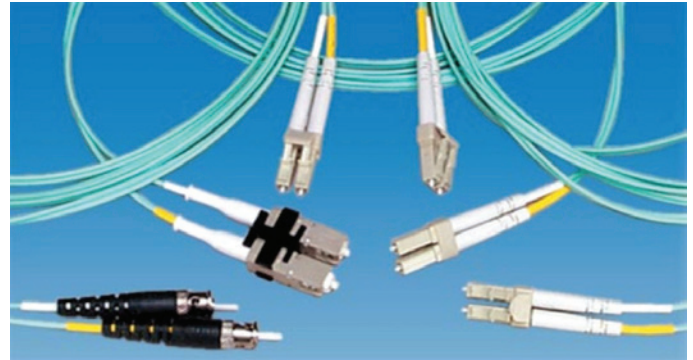


Figure 3- ST, duplex SC and duplex LC connectors

Low-cost WDM requires a nominal separation between wavelengths of about 30 nm.

The need to well support at least four wavelengths, as depicted in Figure 5, leads to a necessary wavelength range, including guard bands, of at least 100 nm spanning across 850 nm to 950 nm.

In October 2014 CommScope partnered with several fiber, transceiver and systems companies to initiate a project in the Telecommunications



Figure 4 - MPO connectors and adapter

Industry Association (TIA) to create a new standard for fiber having the effective total bandwidth of OM4 across this target wavelength range, conceptually illustrated in Figure 6.

The motivation for initiating the new standards project is to improve the utility of multimode fiber to better support future applications while also fulfilling the needs of present applications, with a set of goals and benefits summarized in Figure 7. This motivation was shared by TIA’s TR-42.11 and TR-42.12 subcommittees which approved the start of the new project without dissent.



Figure 5 - WDM concept showing four wavelengths

In March 2015 at the Optical Fiber Communications conference (OFC 2015), Finisar and CommScope demonstrated this WDM technology using live transmission of four wavelengths within the target band of the WBMMF standards proposal (i.e. 850 nm, 880 nm, 910 nm and 940 nm) each operating at greater than 25 Gb/s, to achieve a total throughput exceeding 100 Gb/s. This demonstration of short-wavelength division multiplexing (SWDM) operated error free over 100 m of LazrSPEED® 550 OM4 MMF and over 225 m of LazrSPEED 550 WideBand MMF without the assistance of forward error correction (FEC). FEC is a technology commonly used within Ethernet and Fibre Channel standards to make communications more tolerant to transmission errors. While these demonstrations cannot be assumed to represent the distances future standards may support, they do give insight as to the relative capability between OM4 and WideBand fibers. Photos of the demonstration can be seen in Figure 9 where three spools of LazrSPEED 550 WideBand MMF of various lengths (i.e. 50 m, 75 m and 100 m) have been concatenated together to form a 225 m channel. The transceiver consisted of four SFP modules, each operating at its own wavelength which were combined together in an external optical multiplexer into the fiber. On the output of the fiber an external optical demultiplexer separated the wavelengths to their respective receivers.

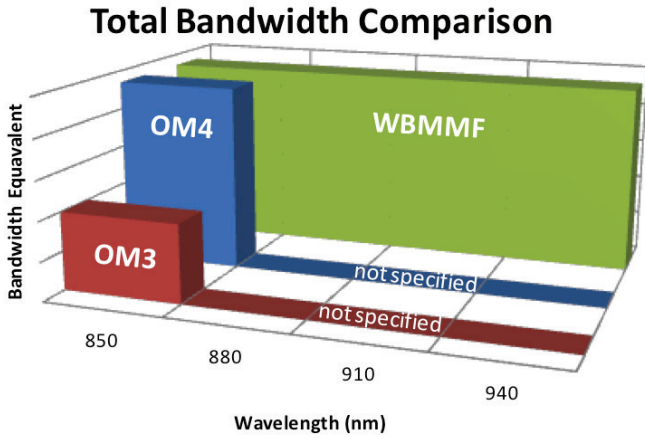


Figure 6 - Conceptual bandwidth comparison

Goals and benefits:

- Retain legacy application support of OM4
- Increase capacity to > 100 Gb/s per fiber
- Reduce fiber count by 4x
- Enable Ethernet: 100G-SR, 400G-SR4, 1600G-SR16
- Enable Fibre Channel: 128G-SWDM4
- Increase MMF's utility
- Extend MMF's value to customers

Figure 7 - WBMMF goals and benefits

Data Rate	10G Parallel		25G Parallel		10G, 25G Parallel w/ WDM	
	TX	RX	TX	RX	TX	RX
40G	[Parallel Fiber Icon]		N/A		[WDM Icon]	
100G	[Parallel Fiber Icon]		[Parallel Fiber Icon]		[WDM Icon]	
400G	N/A		[Parallel Fiber Icon]		[WDM + Parallel Icon]	

Legend

- [Parallel Fiber Icon] parallel fiber transmission
- [WDM Icon] WDM transmission
- [WDM + Parallel Icon] WDM + parallel transmission

Figure 8 - Technology roadmap for parallel and WDM

Because the specification retains the performance of OM4 at 850nm, this wideband MMF will continue to support and comply with the requirements of existing applications while also enhancing and enabling support for low-cost VCSEL-based WDM applications in the future. By providing high bandwidth at longer wavelengths, this fiber also provides a means to support signals from faster VCSELS, opening the door to 50 Gb/s lane rates and beyond. Clearly, this fiber can not only reduce the number of fibers used for parallel applications as shown in Figure 8, but when combined with the well established parallel transmission technologies, can enable higher data rates such as 800 and 1600 Gb/s Ethernet.

In September 2015 at the Building Industry Consulting Service International (BICSI) conference in Las Vegas, USA, CommScope demonstrated Finisar's 40G-SWDM4™ transceiver operating error free over 500 m of LazrSPEED 550 WideBand MMF. The left side of Figure 10 shows the QSFP transceiver mounted on a test fixture next to the spool of LazrSPEED 550 WideBand fiber. The right side is a photo of the screen displaying the transmission performance of each wavelength. These four channels produced zero errors during the demonstration, shown here at the one hour and twenty two minute mark.

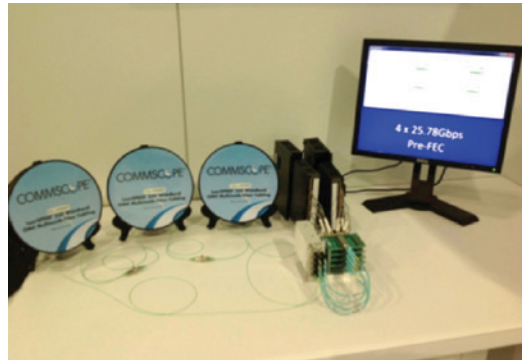


Figure 9 - 4 x 25 Gb/s WDM over 225 m of LazrSPEED 550 WideBand MMF at OFC 2015



Figure 10 - 40G-SWDM4 over 500 m of LazrSPEED 550 WideBand MMF at BICSI

Later in September 2015, at the European Conference on Optical Communications (ECOC 2015) in Valencia, Spain, CommScope demonstrated Finisar’s fully integrated 100G-SWDM4 QSFP transceiver over 300 m of LazrSPEED 550 WideBand multimode fiber, 75 m longer than the demonstration at OFC 2015. As before, the demonstration ran error free without the assistance of FEC. The lower photo of Figure 11 displays the transmission of more than 114 trillion bits through each of the four SWDM channels with zero errors.

In October this same demonstration was repeated at the Gulf Information Technology Exhibition (GITEX 2015) in Dubai, UAE.

In September 2015 the SWDM Alliance, a group of companies interested in fostering the adoption of cost-effective wavelength division multiplexing over multimode fiber, launched a website to promote public awareness and the industry ecosystem. Membership currently consists of ten companies that include transceiver, switch, server, fiber and cabling manufacturers. Visit www.swdm.org to find out more.

Standardization of WBMMF has progressed rapidly within the Telecommunications Industry Association (TIA) TR-42 committee. At their October 2015 meeting TR-42.12 advanced draft TIA-492AAAE to second ballot with publication anticipated in 2016. In concert with the maturation of the standard, multiple fiber manufacturers have released WBMMF products that meet or are superior to the draft specifications. And CommScope released the LazrSPEED 550 WideBand cabling solution that includes trunk cables, patch cords, and fan-out modules for the InstaPATCH platform. In summary all of

the pieces are coming together to form a complete solution that will advance multimode fiber communications to the next level.

A technological progression that takes MMF capability from 10Mb/s to potentially 1600Gb/s – a 160,000-fold increase – while never swaying from the low-cost paradigm that has been its hallmark for decades is a remarkable feat.

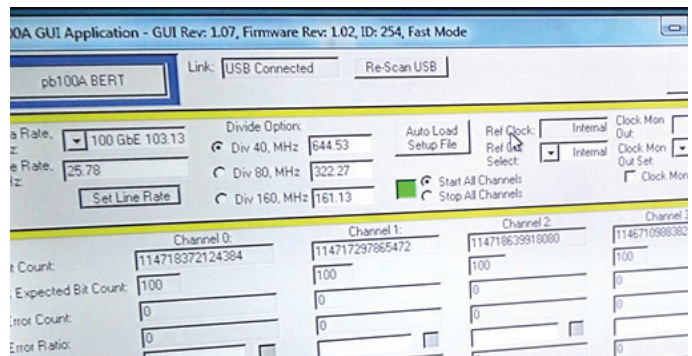


Figure 11 - 100G-SWDM4 over 300 m of LazrSPEED 550 WideBand MMF at ECOC 2015

From application speeds to fiber capability, CommScope is playing a key role in this amazing technological advancement, looking beyond present limitations to envision and drive the development of more capable multimode solutions. Complementing our existing industry-leading LazrSPEED 300 OM3 fiber and LazrSPEED 550 OM4 fiber, we now introduce LazrSPEED 550 WideBand fiber with the capacity to take your network well into the future.

Everyone communicates. It's the essence of the human experience. *How* we communicate is evolving. Technology is reshaping the way we live, learn and thrive. The epicenter of this transformation is the network—our passion. Our experts are rethinking the purpose, role and usage of networks to help our customers increase bandwidth, expand capacity, enhance efficiency, speed deployment and simplify migration. From remote cell sites to massive sports arenas, from busy airports to state-of-the-art data centers—we provide the essential expertise and vital infrastructure your business needs to succeed. The world's most advanced networks rely on CommScope connectivity.



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