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Applications Engineering Note

Multimode Optical Fiber Selection & Specification

AEN 75, Revision: 11

This Applications Engineering Note (AE Note) discusses the criteria for properly selecting the optimal multimode fiber (MMF) for enterprise applications. This AE Note classifies multimode fiber according to the following broad categories.

- 62.5-μm Core Diameter/125-μm Cladding Diameter (OM1)
- 50-μm Core Diameter/125-μm Cladding Diameter (OM2)
- Laser-Optimized 50-μm Core Diameter/125-μm Cladding Diameter (OM3/OM4)

All multimode fibers utilizing the above nomenclature should be graded-index MMF and compliant with industry prevailing standards and terminology for optical fiber. Prevailing standard organizations for defining and specifying optical fiber include the following:

- Telecommunications Industry Association (TIA)
- International Organization for Standardization (ISO)
- International Electrotechnical Commission (IEC)
- International Telecommunication Union (ITU)
- Institute of Electrical and Electronics Engineers (IEEE)
- InterNational Committee for Information Technology Standards (INCITS)

MMF Deployment Overview

Laser-Optimized 50-μm MultiMode Fiber (LOMMF) is the recommended fiber type in today's Local Area Network (LAN) and Data Center (DC) environments in conjunction with 850 nm vertical-cavity surface-emitting lasers (VCSELs). For prevailing 10 Gigabit transmission speeds, OM3 is generally suitable for distances up to 300 m, and OM4 is suitable for distances up to 550 m. The vast majority of commercial buildings and data centers fall within these ranges, and because of LOMMF's lower installation and operation costs, make it the optimal choice even when considering single-mode fiber.

Even with the standardization of 40 Gigabit and 100 Gigabit Ethernet (GbE) by IEEE 802.3ba in June of 2010, OM3 and OM4 are well positioned to support these burgeoning data rates over distances of 100 m and 150 m, respectively. OM4 should support the majority of data center links that utilize 40 and 100 GbE in high-speed/high-performance computing applications driven by server virtualization, cloud computing, streaming video, and ever-increasing IP traffic and convergence. 10 GbE in network core devices will slowly be supplanted by 40 and 100 GbE as more 10 GbE edge devices go into service. 40 and 100 GbE standards will not support previous generation OM1 and OM2 MMF types.

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MMF Industry Classification

MMF is classified today according to the following industry standard specifications:

62.5-µm MMF Specific Standards:

- TIA/EIA-492AAAA-A: "Detail Specification for 62.5-µm Core Diameter/125-µm Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers"
- IEC/CEI 60793-2-10: "Product specifications – Sectional specification for category A1b multimode fibres"

50-µm MMF Specific Standards:

- TIA/EIA-492AAAB: "Detail Specification for 50-µm Core Diameter/125-µm Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers"
- IEC/CEI 60793-2-10: "Product specifications – Sectional specification for category A1a.1 multimode fibres"
- ITU-T Recommendation G.651.1: "Characteristics of a 50/125 µm multimode graded index optical fibre cable for the optical access network"

Laser-Optimized 50-µm MMF Specific Standards:

- TIA/EIA-492AAAC: "Detail Specification for 850-nm Laser-Optimized 50-µm Core Diameter/125-µm Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers"
- TIA/EIA-492AAAD: "Detail Specification for 850-nm Laser-Optimized 50-µm Core Diameter/125-µm Cladding Diameter Class Ia Graded-Index Multimode Optical Fibers Suitable for Manufacturing OM4 Cabled Optical Fiber"
- IEC/CEI 60793-2-10: "Product specifications – Sectional specification for category A1a.2 multimode fibres"

Structured Cabling Standards:

- ANSI/TIA-568: "Commercial Building Telecommunications Cabling Standard"
- ANSI/TIA-942: "Telecommunications Infrastructure Standard for Data Centers"
- ISO/IEC 11801: "Information technology – Generic cabling for customer premises"

There exists considerable overlap and redundancy between the various standards and specifications for each class of MMF. In addition, product specifications can be confused with overall architecture, or structured (network) cabling standards. It is not necessary to understand every specification detail in MMF selection, but more importantly, it is critical to understand the specifications that differentiate today's system performance. The important points to consider are specifications' overall relationship to one another, the terminology they establish, and their bearing on overall system performance. Table 1 puts the different standards into overall context and lists their correspondence with one another.

Table 1: Industry Standard Designations for MMF

	Detail Product Specification			Network Cabling Standard	
Core Diameter	**TIA-492**	**IEC-60793-2-10**	**ITU-T**	**TIA-568**	**OM Fiber Type (TIA)**
62.5 µm	492AAAA-A	Type A1b	---	TIA 492AAAA	OM1
50 µm	492AAAB-A	Type A1a.1	G.651.1	TIA 492AAAB	OM2
50 µm	492AAAC-B	Type A1a.2	G.651.1	TIA 492AAAC	OM3
50 µm	492AAAD	Type A1a.3	G.651.1	TIA 492AAAD	OM4

The remaining sections of this document will reference the nomenclature adopted by ISO/IEC 11801 (OM1, OM2, OM3 and OM4) in differentiating the various grades of 62.5 and 50 µm MMF. The OM fiber classification is often referenced in both LAN and DC applications. In general, the higher the OM numerical digit, the higher the system performance one can expect from that particular fiber type. General guidelines and historical notes for OM fiber selection are provided below:

- OM1 legacy ("FDDI") grade fiber originally was designed for use with 1300 nm LEDs that operate at speeds of 100 Mbps (Million bits per second). Fiber Distributed Data Interface (FDDI) was a prevailing data transmission protocol when 62.5 µm MMF was introduced, but has since been displaced, primarily by Ethernet. Corning Cable Systems recommends 50 µm MMF (OM3 or OM4) for all new LAN/DC installations in lieu of LANscape 62.5 fiber types.

- OM2 fiber enables extension of legacy 50 µm MMF cabling. For entry-level One Gigabit (1 GbE) speed performance, Corning Cable Systems product offering is referred to as LANscape Pretium® 150 optical fiber. OM2 is no longer recommended for new installations due to the continued migration to 10 GbE and 10 Gbps Fibre Channel in data centers world-wide.

- OM3 laser-optimized fiber is the minimum recommended performance level for new LAN/DC installations today. Corning Cable Systems' **LANscape Pretium 300** is suitable for 10 Gbps data rates up to 300 m and emerging 40 and 100 Gbps data rates up to 100 m. OM3 is fully compatible with legacy OM2 installations.

- OM4 is a laser-optimized fiber that further extends the capabilities of OM3, and is fully compatible with legacy OM3 and OM2 installations. Corning Cable Systems' **LANscape Pretium 550** is suitable for 10 Gbps data rates up to at least 550 m and emerging 40 and 100 Gbps data rates up to 150 m. OM4 is recommended when OM3 distance ranges are exceeded, or it is anticipated they will be exceeded in the future.

MMF Industry Specification

Industry standard MMF specification includes dimensional (or geometry) requirements, mechanical requirements, optical transmission requirements, and even environmental requirements. Table 2 below provides a list of relevant parameters and attributes specified by prevailing industry standards:

Table 2: Multimode Fiber Industry Specifications

Dimensional Requirements	Units	Mechanical Requirements	Units
Cladding diameter	µm	Proof stress level	GPa
Cladding non-circularity	%	Strip force (average)	N
Core diameter	µm	Strip force (peak)	N
Core-cladding concentricity error	µm	**Environmental Requirements**	**Units**
Core non-circularity	%	Strip force tests	N
Primary coating diameter - uncolored	µm	Tensile strength tests	GPa
Primary coating diameter - colored	µm	Stress corrosion susceptibility	--
Primary coating-cladding concentricity error	µm	Transmission environmental	dB/km
Length	km	Temperature cycling	dB/km

Optical Transmission Requirements	Units
Maximum attenuation coefficient @850 nm	dB/km
Maximum attenuation coefficient @1300 nm	dB/km
Minimum modal bandwidth-length product for overfilled launch @850 nm	MHz●km
Minimum modal bandwidth-length product for overfilled launch @1300 nm	MHz●km
Minimum effective modal bandwidth-length product at 850 nm	MHz●km
Numerical aperture	Unitless
Maximum macrobending loss (as specified per number of turns and mandrel diameter)	dB
Zero dispersion wavelength, λ_0	nm
Zero dispersion slope, S_0	ps/nm2●km
Attenuation difference, 1380 - 1300 nm	dB/km
Point discontinuity at 850 & 1300 nm	dB/pt.

In selecting MMF, it is not necessary to understand every requirement listed in Table 2. The relevant differentiators in selecting MMF for today's networks can be found in the optical transmission requirements section. In particular, attenuation and bandwidth-length product are the primary determinants for overall system performance. The other requirements should not be ignored or dismissed. However, any fiber manufacturer and cabling system provider touting industry-standard fiber should be meeting relevant industry standards at a minimum, and such requirements do not explicitly factor into the overall calculations or analysis for system reach. For these reasons, the remaining sections of this AE Note will focus on attenuation and bandwidth considerations for selecting MMF.

MMF Transmission Distances

The proper choice of MMF essentially is reduced to a question of what distance can be reached at a particular data transmission speed with a specified amount of channel loss (in dB). The predominant data networking protocol in the LAN (and now encroaching on the wide area network (WAN) at large) is Ethernet. Storage Area Networks (SANs) predominantly rely on Fibre Channel. Tables 3 and 4 list prevailing implementations of Ethernet and Fibre Channel, respectively, with their corresponding wavelength of operation and distance capabilities for CCS fiber types. Highlighted rows and columns represent the recommended implementations in today's LANs and SANs. It is worth noting that 850 nm is the primary wavelength of operation due to the availability of low-cost 850 nm VCSELs.

Table 3: Ethernet Data Rates for LANs and DCs

	Data	Operation	Distance Capability Max. Channel Loss			
Network Protocol	**Rate (Gbs)**	**Wavelength**	**LANscape 62.5**	**Pretium 150**	**Pretium* 300**	**Pretium* 550**
"Fast" Ethernet: 10/100BASE-SX	0.1	850 nm	300 m (4.0 dB)	300 m (4.0 dB)	300 m (4.0 dB)	300 m (4.0 dB)
"Fast" Ethernet: 100BASE-FX	0.1	1300 nm	2000 m (11.0 dB)	2000 m (6.0 dB)	2000 m (6.0 dB)	2000 m (6.0 dB)
Gigabit Ethernet: 1000BASE-SX	1	850 nm	300 m (2.6 dB)	750 m (3.6 dB)	1000 m (4.5 dB)	1100 m (4.8 dB)
Gigabit Ethernet: 1000BASE-LX	1	1300 nm	550 m (2.3 dB)	600 m (2.3 dB)	600 m (2.3 dB)	600 m (2.3 dB)
10G Ethernet: 10GBASE-S	10	850 nm	33 m (2.6 dB)	150 m (2.6 dB)	**300 m (2.6 dB)**	**550 m (2.6 dB)**
10G Ethernet: 10GBASE-LX4	10	1300 nm	300 m (2.5 dB)	300 m (2.0 dB)	300 m (2.0 dB)	300 m (2.0 dB)
10G Ethernet: 10GBASE-LRM	10	1300 nm	220 m (1.9 dB)	220 m (1.9 dB)	220 m (1.9 dB)	220 m (1.9 dB)
40G Ethernet: 40GBASE-SR4	40	850 nm	--	--	**100 m (1.9 dB**	**150 m (1.5 dB**
100G Ethernet: 100GBASE-SR10	100	850 nm	--	--	**100 m (1.9 dB**	**150 m (1.5 dB**

***Note:** Pretium 300 (OM3) or Pretium 550 (OM4) are recommended for all new installations today. Distances and loss budgets presented are for system planning purposes only, and assume two standards-compliant connector pairs in a link. For deviations or specific guidance, Corning Cable Systems (CCS) can determine distance ranges based on specific channel configurations and maximum connector pair loss values. CCS's OM4 fiber is also available for extended distances. Please contact CCS for more information.

Table 4: Fibre Channel Data Rates for SANs and DCs

	Data	Operation	Distance Capability Max. Channel Loss			
Network Protocol	**Rate (MBs)**	**Wavelength**	**LANscape 62.5**	**Pretium 150**	**Pretium 300**	**Pretium 550**
1G Fibre Channel: 100-MX-SN-I	100	850	300 m (3.0 dB)	500 m (3.9 dB)	860 m (4.6 dB)	860 m (4.6 dB)
2G Fibre Channel: 200-MX-SN-I	200	850	150 m (2.1 dB)	300 m (2.6 dB)	500 m (3.3 dB)	500 m (3.3 dB)
4G Fibre Channel: 400-MX-SN	400	850	70 m (1.8 dB)	150 m (2.1 dB)	380 m (2.9 dB)	400 m (3.0 dB)
8G Fibre Channel: 800-MX-SN	800	850	21 m (1.6 dB)	50 m (1.7 dB)	150 m (2.0 dB)	190 m (2.2 dB)
8G Fibre Channel: 800-MX-SA	800	850	40 m (1.6 dB)	100 m (1.9 dB)	300 m (2.6 dB)	300 m (2.2 dB)
10G Fibre Channel: 1200-MX-SN-I	1200	850	33 m (2.4 dB)	82 m (2.2 dB)	300 m (2.6 dB)	450 m (3.1 dB)
16G Fibre Channel: 1600-MX-SN	1600	850	--	35 m (1.6 dB)	100 m (1.9 dB)	125 m (2.0 dB)
FDDI PMD ANSI X3.166	100	1300	2000 m (11.0 dB)	2000 m (6.0 dB)	2000 m (6.0 dB)	2000 m (6.0 dB)

In referencing Tables 3 and 4 above, it is important to understand that network communication channels can both be dispersion limited, as well as attenuation limited. Both dispersion (optical pulse broadening) and optical loss (whether it is fiber attenuation or passive component insertion loss) affect overall system bandwidth. Bandwidth is essentially the information capacity of the fiber, and defines the maximum data rate over a given operating distance. Table 5 provides the bandwidth and attenuation parameters for OM-compliant fiber types specified in Tables 3 and 4. For a fuller explanation of bandwidth characterization in MMF, please consult AE Note 81, "Multimode Optical Fiber Bandwidth Characterization". It is assumed that overall power budget requirements are met in reaching the distance capabilities specified in Tables 3 and 4 for the particular network protocol under consideration. These requirements may be specified by either the general specifications for that network protocol, or by the electronics manufacturer/vendor.

Table 5: Corning Cable Systems' Fiber (Cabled) Attenuation and Bandwidth Table

CCS Fiber Type	**Max α (dB/km) 850 nm**	**Max α (dB/km) 1300 nm**	**Min OFL BW (MHz•km) 850 nm**	**Min OFL BW (MHz•km) 1300 nm**	**Min EMB (MHz•km) 850 nm**
LANscape 62.5	3.4	1.0	200	500	220
Pretium 150	2.8	1.0	700	500	950
Pretium 300	2.8	1.0	1500	500	2000
Pretium 550	2.8	1.0	3500	500	4700

α: attenuation; BW: Bandwidth; OFL: Over-filled Launch; EMB: Effective Modal Bandwidth

Future-Proofing the Network

Although addressing current application requirements should be the imperative with initial selection criteria, future network growth and unanticipated upgrades, whether brought upon by advancements in technology or user population, should be considered. The small premium paid for a higher performance fiber type is worth the avoidance of having to re-cable later to support higher data rates. In addition, the incremental cost of spare fibers is also a wise safeguard against unpredictable network demand. Prevailing wisdom still dictates a minimum percentage allocation of extra fiber of no less than 25% for most networks*. In addition, it is at this time that many network planners make the decision to plan for potential single-mode fiber requirements. Although this AE note does not discuss SMF types specifically, standard single-mode fibers (non-dispersion shifted with a zero-dispersion wavelength of 1310 nm) is still the workhorse for most enterprise requirements today that are not met by MMF.

*Reference LANscape® Solutions Fiber Optic Design Guide for further guidance on spare fiber count allocations.

MMF Bend Performance

Another consideration with today's MMF selection involves macro-bend performance. Selecting a MMF that meets the challenges of typical enterprise-environment installation rigors is just as important as picking a MMF that meets electronics requirements. Tight bends, sharp edges and unorthodox cable securement practices (over-tight ty-wraps, staples, etc.) are commonplace in most cable routes, ladder rack and equipment frames, especially when balancing the need for greater densities and heat dissipation in modern data centers. Strong consideration should be given to selecting a fiber that offers bend radius protection down to 15 mm and below. Such fiber types are deemed "Bend-Insensitive" and should be compatible with current optical fibers, equipment, practices and procedures. Table 6 provides macro-bend loss requirements that meet Corning Cable Systems' Bend-Insensitive requirements. Discussion of bend-insensitive optical fiber standards started in IEC in 2010, but most of the technical work is now being completed by TIA.

Table 6: Bend-Insensitive Loss Requirements

Base Attenuation				Macrobend Loss			
Uncabled Fiber		**Cabled Fiber**		**Mandrel Radius (mm)**	**Number of Turns**	**Induced Attenuation (dB) 850 nm**	**1300 nm**
850 nm	**1300 nm**	**850**	**1300**	37.5	100	≤ 0.05	≤ 0.15
≤ 2.3	≤ 0.6	≤ 2.8	≤ 1.0	15	2	≤ 0.1	≤ 0.3
Attenuation (dB/km)				7.5	2	≤ 0.2	≤ 0.5

MMF in the Legacy LAN

Another consideration in choosing the correct fiber for a network is compatibility with any incumbent fiber that may already be installed (known as “legacy” fiber). Considering that many legacy systems contain OM1 (62.5 µm) MMF, guidelines should be established to extend these systems. First and foremost, performance incompatibility involving disparate MMF types should not be an issue if the different fiber types are isolated and segregated on different ports of the active electronics (hubs, switches, routers, etc), as the electronics perform any necessary electrical-to-optical (E/O) and/or O/E conversions making different fiber types a moot point.

However, connecting OM2, OM3, or OM4 with OM1 in the same passive channel is a different installation scenario altogether. Although Corning Cable Systems does not recommend mixing 62.5 µm and 50 µm MMF in the same channel, it is technically feasible. In theory, for an overfilled launch condition, the loss should be minimal when going from a smaller core (50 µm) to a larger core (62.5 µm), but considerably higher when light is passing in the opposite direction. A calculated value for the loss can be determined using the following formula:

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

Where:

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

When an LED transmits light from 62.5 µm MMF to 50 µm MMF, the maximum theoretical calculated power penalty is approximately 4.7 dB. It is important to realize that this is a one-time power loss, and is independent of the number of connectors, splices and subsequent fiber type changes that occur in the cable run. In actual deployments, typical power penalties can be lower (approximately 2 dB), because the LED mode power distribution is not always uniformly overfilled. When laser (VCSEL) transmitters are used, the coupling loss is even lower (< 0.50 dB) due to the smaller spot size and numerical aperture associated with such devices. This small loss is often covered by the excess power budget of systems, and is once again independent of the number of connectors and fiber type changes that occur in the channel.

MMF compatibility between MMFs with the same core size but different bandwidths is another potential challenge when integrating new MMF with legacy MMF installations. Per industry standards, MMF cable plants should once again maintain uniform fiber types throughout the entire operating channel (including the fiber link, and any connecting jumpers and/or patchcords). Corning Cable Systems also stands by this recommendation, but in situations where mixing fiber bandwidth types is required, it is possible to predict the expected performance deviation from uniform link specifications. Corning Cable Systems can provide general guidelines for such scenarios on a case-by-case basis. Please contact Corning Cable Systems’ Applications or Systems Engineering group for support on your particular application involving mixed fiber types.

MMF Selection in Summary

Selecting the appropriate MMF type for your application can be reduced to the following points and considerations:

1) Know which applications and protocols your network will be supporting today.
2) Examine which potential applications and protocols you will use in the future.
3) Find out which wavelengths of operation are specified for your end equipment.
4) Obtain relevant operating budget parameters, most notably maximum power loss allowed in the channel and distance reach specified for the given data rate.
5) Match the system and electronics requirements with the appropriate fiber type based on specified attenuation and bandwidth parameters.

In general, Corning Cable Systems recommends OM3 and OM4 MMF types, such as Pretium 300 and/or 550 for all new builds and installations to adequately meet the demands of today and the near future. Avoid mixed plant scenarios (involving 62.5 µm and 50 µm MMF together). Also, consider factoring in spare fiber counts for longer range future-proofing when in doubt about future network applications or size. For more detailed information please consult the reference documents section. For technical support regarding your specific application, please contact us at 1.800.743.2671 (U.S. and Canada) or 1.828.901.5000 (International) if you need additional technical assistance. Product information and this engineering note can also be accessed on the web at http://www.corning.com/cablesystems/nafta/en/index.aspx.

References:

For more information on MMF selection and MMF in general, please refer to the following documents:

1) AE Note 45: Single-mode Fiber Selection for Telecommunication Links

2) AE Note 68: Improving Multimode Fiber Testing Accuracy with Mandrel Wrapping

3) AE Note 81: Multimode Optical Fiber Bandwidth Characterization

4) AE Note 110: Considerations for Improved Bend Performance Optical Fibers

5) AE Note 131: Multimode Fiber Considerations for Test Jumpers

6) AN4245: A Simple Guide to Multimode Fibre, Sources, Measurements & Standards

7) AN4255: Application Engineering Note- Multimode Fiber in Bending

8) AN4256: Application Engineering Note- Multimode Fiber Compatibility

9) CO4261: A Brief Premises Fiber Selection Guide

10) CO6501: OM4 Frequently Asked Questions

11) WP1160: Fiber Selection Guide for Premises Networks

12) WP4044: 50 µm Optical Fiber Q&A

13) "The Evolution of Bend-Insenstive Multimode Optical Fiber", BICSI News Magazine, May/June 2011.