Fiber Selection and Standards Guide for Premises Networks

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Introduction

There are several types of optical fiber distinguished by design, characteristics, and subsequent operation with optical transceivers. These differences determine the application to which a given fiber is most appropriate. Some fiber types or specification differences that seem subtle can lead to large functional differences in a system and can directly affect the current and long-term performance of the network, as well as the cost. It is important that network designers and operators understand the fiber types and technologies available in order to make informed selection of fiber and interconnect technology for current and future application needs. This paper presents an overview of the important considerations for premises fiber selection such as fiber performance, reach, upgrade capability, flexibility, reliability, and relative system cost, and explains why Corning® ClearCurve® multimode optical fiber ensures high performance and reliability providing the most cost-effective choice for premises networks.

Premises Network Design Considerations - The Need for *Optical* Speed

System designers and consultants are faced with constructing communications networks that meet the current and future workload of their customers at the link lengths required for their facility or campus. Continued growth in subscriber demand for more sophisticated “smart” electronics devices and web-connected services increases demand for information storage and accessibility/transport infrastructure. These requirements drive the need for ultra-high-speed data interconnects and structured cabling fabric in premises networks such as Data Centers (DC), Storage Area Networks (SAN), clustered or supercomputing applications, and serve a wide range of sectors from financial and industrial to social networking and health. The interconnect media choices available for constructing such networks include wireless technology, copper cable, and optical fiber cable. Of these, optical fiber cable offers the highest bandwidth and lowest latency supporting the fastest data-rates over the longest link lengths, reliably and securely. The standardization of transmission protocols such as IEEE Ethernet is a key industry indicator of the pace of development in high-speed interconnect devices and network building blocks, which are facilitated by the capabilities of optical fiber (see Figure 1). Optical fiber is an easily-installed medium that is immune to electromagnetic interference and is also significantly more efficient in terms of power consumption. The latest trends in optical fiber cable interconnect infrastructure offer space and cost savings over copper cabling with higher cabling and port density and lightweight cables that contribute to better cooling efficiency and lower energy costs. The following sections of this paper provide an overview on key fiber performance and associated component characteristics to aid fiber-type selection process for premises networks.

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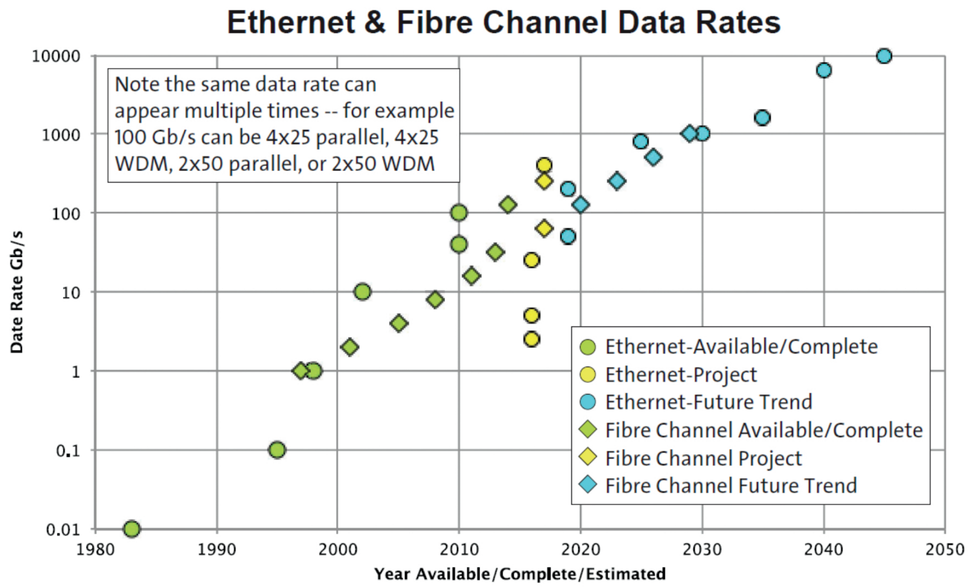
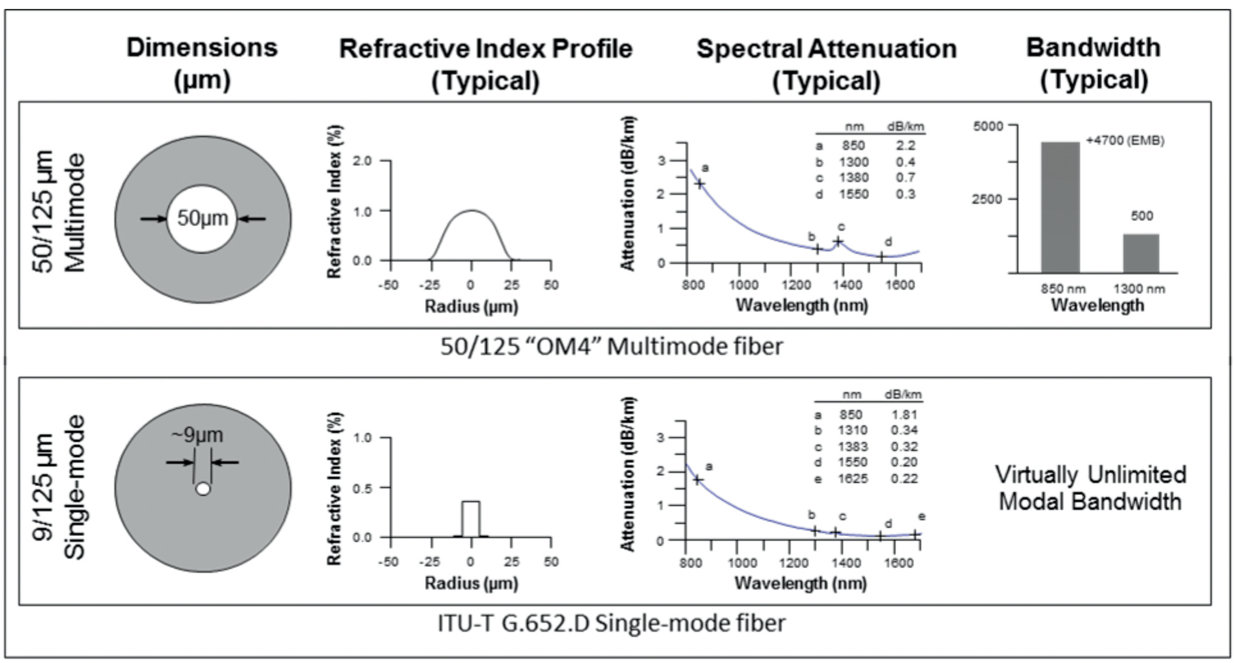


Optical Fiber Options

There are two main categories of optical fiber suitable for use within premise networks (Table 1):

- 50/125 µm multimode fiber
- Single-mode fiber

Note, 62.5/125 µm multimode fiber is no longer preferred for premise networks as it proved less optimal with vertical cavity laser-based transceivers (VCSELs) based systems.



Notes: 50/125 "OM4" featured for illustration, refer to Table 3 & 4 for all fiber type details, standards and application link lengths.

Table 1. Fundamental Optical Properties of Single-mode and Multimode Fiber Types

The numeric notation (e.g. 50/125 µm) signifies the diameter of the glass core, or light carrying region, (50 µm) and the outside glass cladding diameter (125 µm). This cladding diameter is common to all fiber categories in the industry and provides near identical mechanical properties for both fiber types. However, the different core diameters affect the optical properties significantly and, when balanced against network application needs, have a direct impact on system performance and system cost. The refractive index profile of each product is precisely designed to channel light down the fiber, optimizing certain attributes such as bandwidth, attenuation, and attenuation due to bending. Before comparing specific fiber types, it is first important to understand the two primary optical fiber attributes that have the biggest impact on system performance and cost:

The numeric notation (e.g. 50/125 µm) signifies the diameter of the glass core where the light travels (50 µm) and the outside glass cladding diameter (125 µm). This cladding diameter is common to all major fiber categories in the industry and provides near identical mechanical properties for the three fiber types. However the different core diameters of each fiber affect the optical properties significantly and have a direct impact on system performance and system cost when balanced against network application needs. The refractive index profile of each product is precisely designed to channel light down the fiber enhancing certain attributes such as bandwidth, attenuation and also fiber bending sensitivity. Before comparing specific fiber types, it is first important to understand the two primary optical fiber attributes that have the biggest impact on system performance and cost:

Attenuation is the decay of signal power (loss) as light travels through an optical fiber. Fiber cable attenuation coefficient is measured in decibels per kilometer (dB/km). A higher attenuation coefficient results in a higher rate of signal loss of a given fiber length. Insertion loss is the sum of the total attenuation from all sources and any reflection losses over a specific length. Single-mode fibers in premises networks generally operate at 1310 nm (for short reach applications), whereas 50/125 µm multimode fibers are optimized for 850 nm operation. Attenuation has rarely been a primary limiting factor in short-reach premises applications and where multiple connectors in the signal path are generally commonplace. However, in modern day, state-of-the-art high-speed interconnects (such as 100 Gb/s) the insertion loss performance of premises networks has become increasingly relevant.

Bandwidth quantifies the intrinsic information-carrying capacity of multimode fiber, given in units of megahertz-kilometer (MHz•km). Bandwidth behavior of multimode fibers arises from multi-modal dispersion (multi-path signal spreading) which occurs as the result of light traveling along different modes (paths) in the core of the fiber. The bandwidth specification or performance of a multimode fiber is verified through optical measurements during fiber manufacture. Actual system performance and data-rate capability is strongly bandwidth dependent but also governed by transceiver technology and device characteristics. Modal dispersion is suppressed in single-mode fibers by maintaining single-mode operation with the smaller core diameter. Chromatic dispersion is rarely a limiting factor for single-mode fiber when operated at 1310 nm (near zero dispersion) in premises networks.

Multimode fiber (50 µm) uses a graded index profile (i.e. parabolic in shape) to minimize modal dispersion. This design maximizes bandwidth while maintaining larger core diameters (as compared to single-mode) for simplified system assembly, ease of connectivity, and lower network costs. The bandwidth specification of multimode fibers is a major performance factor in network design. This has led the industry to exploit the higher intrinsic bandwidth potential of 50/125 µm fiber when developing higher-performance multimode fiber systems. Since the advent of the Gigabit Ethernet, standard low-cost VCSELs have been developed for multimode fibers operating at 850 nm and utilizing the greater bandwidth advantage of 50/125 µm fiber.

Fiber-Transceiver: Technology Evolution & Parallel Optics

An optical transceiver is a package, usually a pluggable module comprising of a) the optical light source(s) (typically a laser diode or in legacy applications, LED – light emitting diode) and b) optical receiver(s) (photo detector). Over the last decade, multimode bandwidth specifications and measurement methods have evolved alongside compatible transceiver technology, developed to keep pace with increasing transmission speeds. The transceiver-fiber combination is a major factor which determines a fiber's practical link length capability depending on the bit rate or application protocol speed. More importantly for high bit-rate applications (≥ Gigabit speeds), the component costs of transceiver devices dominate over the cost of passive interconnect hardware (cable and connectors). For 10G-based systems it is estimated that transceivers account for up to 15-20% of the total system cost, the passive optical cable and fiber technology accounts for approximately 5%, while the switch chassis accounts for the remainder. For short-range interconnects supporting high speeds above 10G, parallel optics solutions for multimode offer modular 10G and 25G "lanes" for transmission speeds of 40G and 100G Ethernet (see Figure 2).

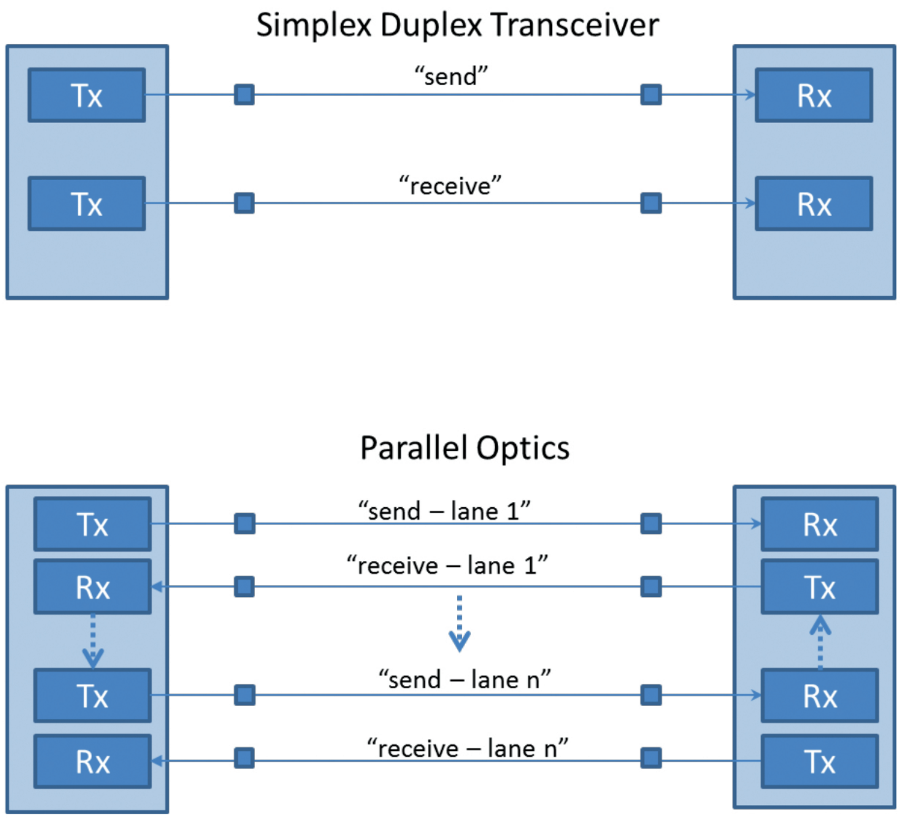


Figure 2. Transceiver - Fiber Connectivity for Duplex and Parallel Optics Schemes

System Costs: Single-mode vs. Multimode Fibers

Within premises networking applications, the most significant differences between single-mode and multimode optical fiber types are the core diameter size and primary operating wavelengths. These key factors impact associated transceiver technology, ease of connectivity, and cost. To utilize the fundamental attributes of single-mode fibers generally geared towards longer distance applications (multi-kilometer reach), transceivers must have lasers that operate at longer wavelengths with smaller spot-size and generally narrower spectral width. These transceiver characteristics combined with the need for higher-precision alignment and tighter connector tolerances to smaller core diameters result in significantly higher transceiver costs and overall higher interconnect costs for single-mode fiber interconnects. Fabrication methods for VCSEL based transceivers that are optimized for use with multimode fibers are more easily manufactured into array devices and are lower cost than equivalent single-mode transceivers. Despite the use of multiple fiber lanes and multi-transceivers arrays, there are significant cost savings over single-mode technology employing single or multichannel operation over simplex-duplex connectivity.

Transceivers utilizing low cost VCSEL technology developed for 50/125 µm multimode fibers take advantage of the larger core diameter enabling high coupling efficiency and accommodation of wider geometrical tolerances. Data rates from 10 Mb/s to 400 Gb/s are supported by the higher modal bandwidths offered by OM3 and OM4 50/125 µm multimode fibers which generally offer the lowest system cost and upgrade path to 400G and higher for standards-based premises applications using parallel-optic based interconnects.

Bend Insensitive Multimode Fiber (BIMMF)

Corning developed bend-insensitive ClearCurve® multimode fiber to withstand tight cable bends commonly found in the indoor “patching-interconnect” architecture prominent in applications such as data centers, enterprise networks, and local area networks. Excessive signal loss or increased attenuation due to tight bending can degrade signal quality and, if undetected, can impose severe restrictions on upgrade paths or lead to transmission reliability issues. The improved bend performance allows for greater positive spare margin (the difference between the power budget and the total losses induced in a link) which provides “network system protection” against unexpected or inadvertent cable bends that may occur during routine structured cabling operations, e.g. neighboring rack maintenance or MACs (moves, adds and changes). The fiber bending specifications (referred to in the industry as “macrobendloss”) for ClearCurve multimode fiber, shown in Table 2 below, reflect the improvement over legacy industry requirements.

Mandrel bending tests according to IEC 60793-1-47		IEC 60793-2-10	Corning ClearCurve Multimode Fibers OM2, OM3, OM4, & OM5
Number of turns	Bend radius (mm)		
100	37.5	≤ 0.5 dB	≤ 0.5 dB
2	15	≤ 0.1 dB	≤ 0.1 dB
2	7.5	≤ 0.2 dB	≤ 0.2 dB

Table 2. Macrobending Loss Specifications for Multimode Fiber (850 nm)

Multimode Fiber Cabling Standards

Multimode fibers are categorized according to bandwidth performance. These are commonly classified by the ISO/IEC OMx (optical multimode) designation. This indicates the class of fiber in terms of bandwidth as specified in the ISO/IEC 11801 and TIA 568 structured cabling standard. Various standards organizations have defined the relationship between transmission data rates, link length, and bandwidth for specific protocols, applications, and transceiver types. The standards are summarized in Tables 3 and 4. Table 3 outlines the most commonly used industry standards which describe the minimum specification requirements for multimode fibers for use in premises networks. This table also shows the Corning multimode fibers which correspond to and comply with each fiber category. Table 4 provides link lengths for Corning fiber types with the most popular multimode fiber application standards.

Table 3: Standardized Multimode Fiber Specifications

		International Standards Organization (ISO) OM - classification for multimode fiber				
Standards Body	**Document Number**	**OM1*** **	**OM2*** **	**OM3**	**OM4**	**OM5**
International Standards Organization (ISO)	ISO/IEC 11801	Type OM1 fiber: Legacy fibers with a nominal 200/500 MHz.km OFL* BW at 850/1300 nm	Type OM2 fiber: Legacy fibers with a nominal 500/500 MHz.km OFL BW at 850/1300 nm	Type OM3 fiber: Laser optimized 50 µm fibers with 2000 MHz.km EMB** at 850 nm	Type OM4 fiber: Laser optimized 50 µm fibers with 4700 MHz.km EMB at 850 nm	Type OM5 fiber: Laser optimized 50µm fibers with 4700 MHz.km EMB at 850 nm and 2470 MHz.km EMB at 953 nm
International Electrotechnical Commission (IEC)	IEC 60793-2-10	Type A1-OM1 fiber: Legacy 62.5/125 fibers with a range of bandwidth values: 200 MHz.km OFL at 850 nm 500 MHz.km OFL at 1300 nm	Type A1-OM2 fiber: Legacy 50/125 fibers with a range of bandwidth values: 500 MHz.km OFL at 850 nm 500 MHz.km OFL at 1300 nm	Type A1-OM3 fiber: Laser Optimized 50/125 fibers with 2000 MHz.km EMB at 850 nm 500 MHz.km OFL at 1300 nm	Type A1-OM4 fiber: Laser Optimized 50/125 fibers with 4700 MHz.km EMB at 850 nm 500 MHz.km OFL at 1300 nm	Type A1-OM5 fiber: Laser Optimized 50/125 fibers with 4700 MHz.km EMB at 850 nm 2470 MHz.km EMB at 953 nm 500 MHz.km OFL at 1300 nm
Telecommunications Industry Association, part of the Electronics Industries Alliance (TIA/EIA)	TIA/EIA 492AAA(A-D)	Type A1-OM1 492AAAF: Defines legacy 62.5/125 fibers with 160/500 MHz.km OFL BW at 850/1300 nm	Type A1-OM2 492AAAF: Defines legacy 50/125 fibers with 400/400 MHz.km OFL BW at 850/1300 nm	Type A1-OM3 492AAAF: Defines laser-optimized 50/125 fibers with 2000 MHz.km EMB at 850 nm	Type A1-OM4 492AAAF: Defines laser-optimized 50/125 fibers with 4700 MHz.km EMB at 850 nm	Type A1-OM5 492AAAF: Defines laser-optimized 50/125 fibers 4700 MHz.km EMB at 850 nm and 2470 MHz.km EMB at 953 nm
Corning Product Offering		**InfiniCor®300 Optical Fiber**	**ClearCurve® OM2 Optical Fiber**	**ClearCurve® OM3 Optical Fiber**	**ClearCurve® OM4 Optical Fiber**	**ClearCurve® OM5 Wide Band Optical Fiber**

Table 3. Standardized Multimode Fiber Specifications

***OFL:** Overfilled launch is the original standardized fiber bandwidth measurement where the source launches light uniformly into all modes of the multimode fiber. The launch condition of this measurement is similar to that of an LED source and hence this multimode fiber measurement gives a good indication of system performance when using legacy protocols utilizing LED sources.

****EMB:** Effective Modal Bandwidth is the bandwidth as seen in a system using a commercially available laser of known encircled flux (EF) and also fiber of known differential mode delay (DMD). Laser-based transceivers are required to support multi-gigabit transmission speeds for multimode fibers with EMB specifications.

***OM1 and OM2 are not recommended for new multi-gigabit structured cabling

Fiber Type		Link Lengths (m)			
		ClearCurve® Optical Fiber			SMF-28e+® Single-mode Optical fiber
		OM2	**OM3**	**OM4**	**OS1**
Wavelength		**850 nm**			**1310 nm**
Modal Bandwidth OFL (MHz.km)		**700**	**1500**	**3500**	**∞**
Modal Bandwidth EMB (MHz.km)		**950**	**2000**	**4700**	**∞**
Application Standard	**Nominal Speed (b/sec)**				
IEEE 802.3 series Ethernet					
10GBASE-SR	10G	82	300	400	-
10GBASE-ER	10G	-	-	-	30000
10GBASE-LRM	10G	220	220	-	-
25GBASE-SR	25G		70	100	-
25GBASE-LR	25G	-	-	-	10000
25GBASE-ER	25G	-	-	-	30000
40GBASE-SR4	40G	-	100	150	-
40GBASE-LR4	40G	-	-	-	10000
40GBASE-ER4	40G	-	-	-	30000
40GBASE-FR4	40G	-	-	-	2000
50GBASE-SR	50G	-	70	100	-
50GBASE-FR	50G	-	-	-	2000
50GBASE-LR	50G	-	-	-	10000
100GBASE-SR4	100G	-	70	100	-
100GBASE-LR4	100G	-	-	-	10000
100GBASE-ER4	100G	-	-	-	30000
100GBASE-SR10	100G	-	100	150*	-
100GBASE-SR2	100G	-	70	100	-
100GBASE-DR	100G	-	-	-	500
100GBASE-FR1	100G	-	-	-	2000
100GBASE-FR2	100G	-	-	-	10000
200GBASE-DR4	200G	-	-	-	500
200GBASE-FR4	200G	-	-	-	2000
200GBASE-LR4	200G	-	-	-	10000
200GBASE-SR4	200G	-	70	100	-
400GBASE-FR4	400G	-	-	-	2000
400GBASE-LR4	400G	-	-	-	10000
400GBASE-SR4	400G	-	70	100	-
400GBASE-DR4	400G	-	-	-	500
ANSI - INCITS - Fibre Channel					
400-MX-SN-I	4G	150	380	400	10000
800-MX-SN-I	8G	50	150	190	10000
1600-MX-SN-I	16G	35	100	125	10000
1600-MX-SN-S	32G	20	70	100	10000

Summary

Choosing the right fiber for your network application is a critical decision. Understanding your system requirements in order to select the appropriate fiber will maximize the value and performance of your cabling system and therefore network, now, and in the future. For premises networks, Corning ClearCurve multimode optical fibers provide the cost-effective combination of leading bandwidth performance and reliability due to Corning's bend-insensitive technology. Corning recommends ClearCurve OM4 multimode optical fibers for the most demanding high-speed interconnects at 400 Gb/s and beyond.

For further information on ClearCurve multimode fiber please visit the website at:
https://www.corning.com/optical-communications/worldwide/en/home/products/fiber/optical-fiber-products/clearcurve-multimode-fiber.html

References

Higher Bitrate MMF Systems using MMF
https://www.corning.com/media/worldwide/coc/documents/Fiber/RC-Application%20Notes/AN5227_3-17-2016.pdf

Corning® ClearCurve® Multimode Optical Fiber Product Information
http://www.corning.com/WorkArea/showcontent.aspx?id=36549

IEC 60793-2-10 Edition 7,2019 Optical fibres - Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres

492AAAF International standard ISO/IEC 11801: Information technology - Generic cabling for customer premises.

IEEE 802.3 American National Standard for Information Technology: Fibre Channel: Physical Interfaces (FC-PI-X)

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