

Fiber Selection and Standards Guide for Premises Networks

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Authors: Carl Roberts and Dr. Russell Ellis

Introduction

There are several main types of optical fiber and the way each is designed, the characteristics they possess and the way these cause the fiber to operate 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 the system that can directly affect the current and long-term performance of the network, as well as the cost. For this reason, it is important that network designers and network operators understand the fiber types and technologies available to make informed choices and select the correct fiber and interconnect technology for their 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 the demands on information storage and accessibility/transport infrastructure. These requirements drive the needs for ultra-high speed data interconnects and structured cabling fabric in premises networks such as: Data Centers (DC), Storage Area Networks (SAN) and clustered or supercomputing applications, serving 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 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, for example, is a key industry indicator as 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 also offer space and cost savings with higher cabling density and port density over copper cabling with 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 help in the fiber-type selection process for premises networks.

The Corning logo is a dark blue square with the word "CORNING" in white, uppercase, sans-serif font centered within it.

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Bandwidth Demand Trends - The Need for *Optical Speed*

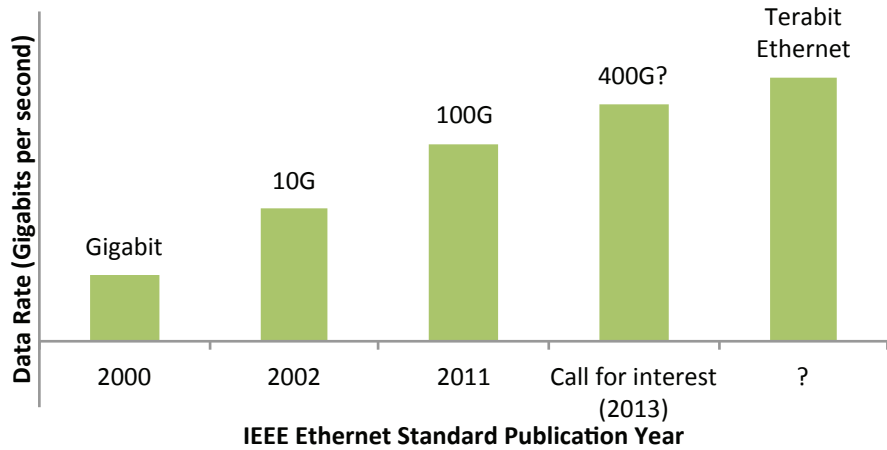
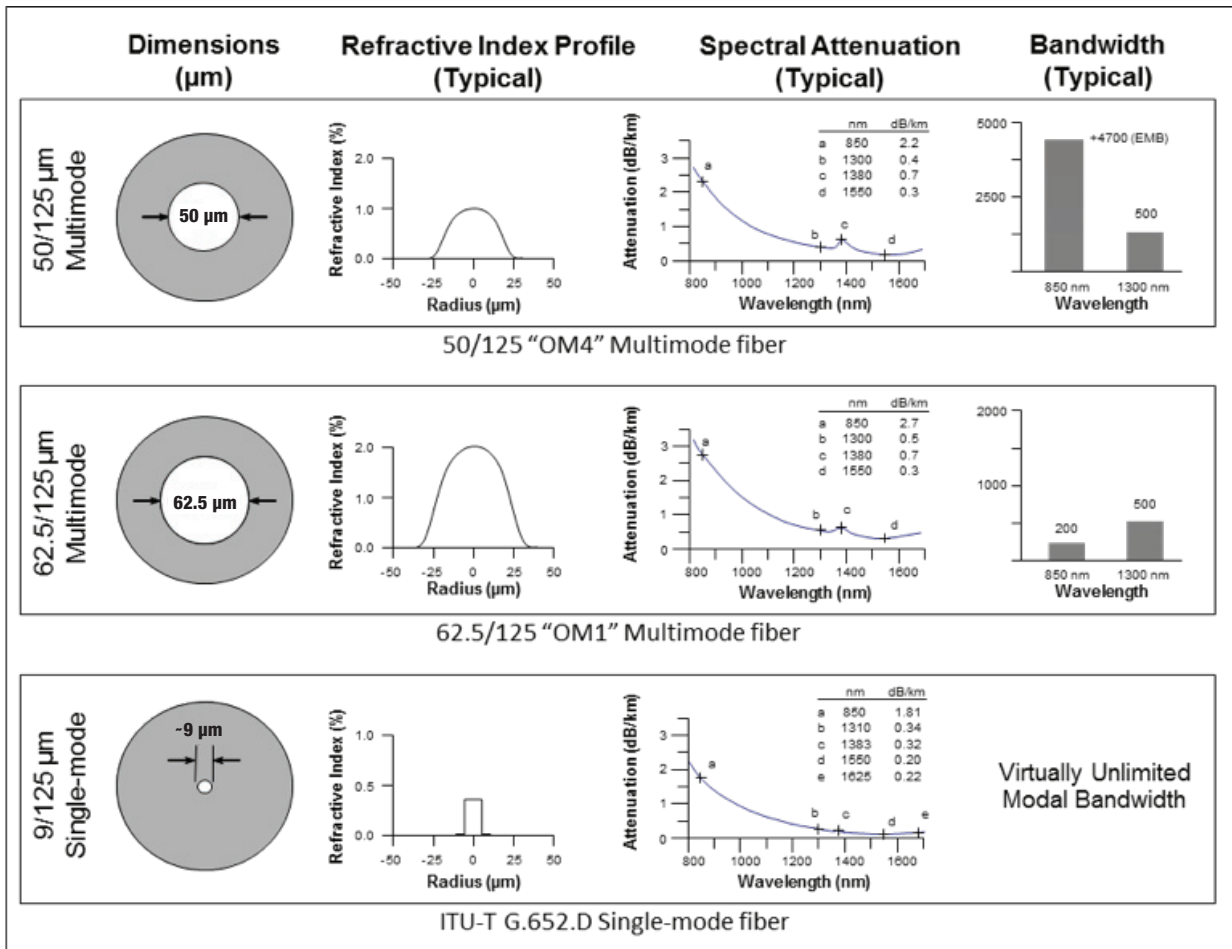


Figure 1. Publication Dates of Optical Fiber-Based IEEE Ethernet Networking Protocols

Optical Fiber Options

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

- 50/125 μm multimode fiber
- 62.5/125 μm multimode fiber
- Single-mode fiber



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 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 reduction of signal power, or loss, as light travels through an optical fiber. Fiber 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 total attenuation from all sources plus any reflection losses over a specific length. Single-mode fibers in premises networks generally operate at 1310 nm (for short reach applications) whereas multimode fibers are optimized for either 850 nm or 1300 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 have become increasingly relevant.

Bandwidth quantifies the intrinsic information-carrying capacity of multimode fiber, given in units of megahertz-kilometer (MHz \cdot 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 handling is strongly bandwidth dependent but also governed by transceiver technology and device characteristics. Modal dispersion is suppressed in single-mode fibers by the smaller core diameter. Waveguide chromatic dispersion is rarely a limiting factor for single-mode fiber when operated at 1310 nm (near zero dispersion) in premises networks.

Multimode fiber 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, 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 laser-based transceivers have been developed for multimode fibers operating at 850 nm and utilizing the greater bandwidth advantage of 50/125 μm fiber. This has led to the near obsolescence in applications and deployment of 62.5 μm multimode 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 delivery of higher transmission speeds. The combination of transceiver and fiber are major factors 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 \geq 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 the transceivers account for up to ~25% of the total cost of the physical interconnect and switch electronics, while the passive optical cable and fiber technology is less than 5%* (see figure 3).

For short-range interconnects supporting high speeds above 10G, parallel optics solutions for multimode offer modular 10G "lanes" for transmission speeds of 40G and 100G Ethernet (see Figure 2). Similar multi-lane transmission schemes are used by other interconnect protocols such as Infiniband (see Table 3).

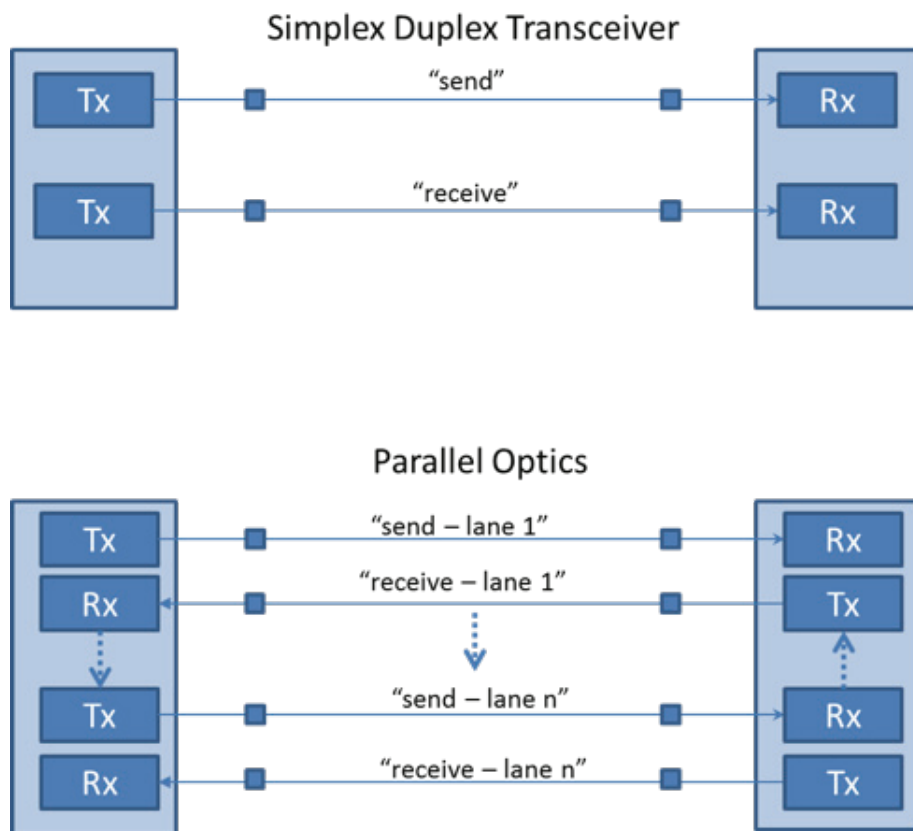


Figure 2. Transceiver - Fiber Connectivity for Duplex and Parallel Optics Schemes

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 therefore impact on associated transceiver technology, ease of connectivity and cost. To utilize the fundamental attributes of single-mode fibers, which are generally geared towards longer distance applications (multi-kilometer reach), requires transceivers with 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 (vertical-cavity surface emitting laser) 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 (Figure 3).

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 100 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 100G for standards-based premises applications using parallel-optic based interconnects.

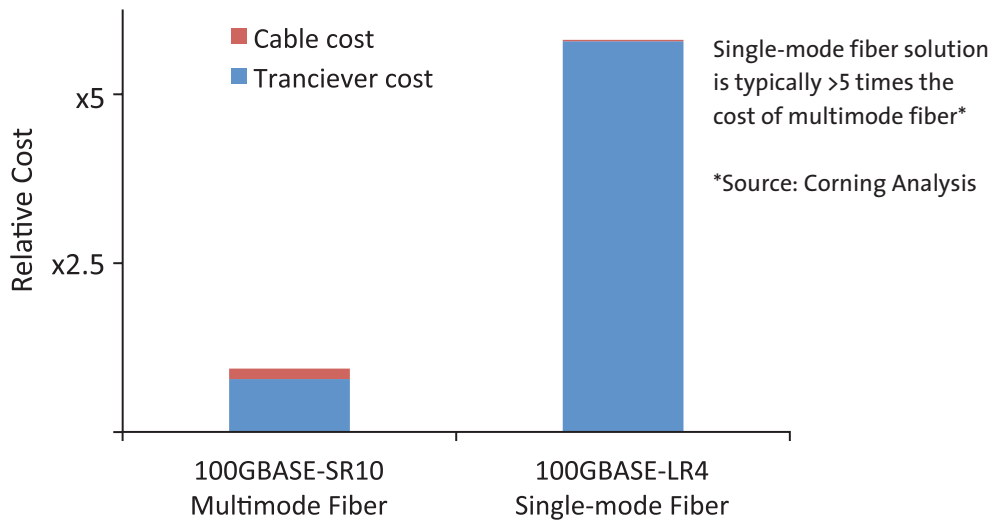


Figure 3. Relative Cost Comparison Between Multimode and Single-mode Fiber Using 100 Gb/s

Bend Insensitive Multimode Fiber (BIMMF)

Corning developed bend-insensitive ClearCurve multimode fiber to withstand tighter cable bends commonly found in the indoor “patching-interconnect” architecture that is prominent in applications such as data centers, enterprise networks and LANs. 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 “macrobending”) 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	ITU-T G.651.1	Corning ClearCurve Multimode Fibers OM2, OM3 & OM4
Number of turns	Bend radii (mm)			
100	37.5	0.5 dB	-	0.05 dB
2	15	-	1 dB	0.1 dB
2	7.5	-	-	0.2 dB

Note: Adoption of these tighter fiber bending specifications is under consideration by the major industry international standards bodies.

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

Multimode Standards

Multimode fibers are graded according to specification and chiefly by their bandwidth performance. These are commonly classified by the TIA/ISO OM (optical multimode) designation. This indicates the class of fiber in terms of bandwidth as specified in the ISO/IEC 11801 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 international 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.

International Standards Organization (ISO) OM- classification for multimode fiber					
Standards Body	Document Number	OM1	OM2	OM3	OM4
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 (no specification of core diameter, but typically 62.5 μm)	Type OM2 fiber: Legacy fibers with a nominal 500/500 MHz.km OFL BW at 850/1300 nm (no specification of core diameter but typically 50 μm)	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
International Electrotechnical Commission (IEC)	IEC 60793-2-10	Type A1b fiber: Legacy 62.5/125 fibers with a range of bandwidth values: 100 - 800 MHz.km OFL at 850 nm 200 - 1000 MHz.km OFL at 1300 nm	Type A1a.1 fiber: Legacy 50/125 fibers with a range of bandwidth values: 200 - 800 MHz.km OFL at 850 nm 200 - 1200 MHz.km OFL at 1300 nm	Type A1a.2 fiber: Laser Optimized 50/125 fibers with 2000 MHz.km EMB at 850 nm 500 MHz.km OFL at 1300 nm	Type A1a.3 fiber: Laser Optimized 50/125 fibers with 4700 MHz.km EMB at 850 nm 500 MHz.km OFL at 1300 nm
Telecommunications Industry Association, part of the Electronics Industries Alliance (TIA/EIA)	TIA/EIA 492AAA(A-D)	492AAAA: Defines legacy 62.5/125 fibers with 160/500 MHz.km OFL BW at 850/1300 nm	492AAAB: Defines legacy 50/125 fibers with 500/500 MHz.km OFL BW at 850/1300 nm	492AAAC: Defines laser-optimized 50/125 fibers with 2000 MHz.km EMB at 850 nm	492AAAD: Defines laser-optimized 50/125 fibers with 4700 MHz.km EMB at 850 nm
Corning Product Offering		InfiniCor®300 Optical Fiber	ClearCurve® OM2 Optical Fiber	ClearCurve® OM3 Optical Fiber	ClearCurve® OM4 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.

Fiber Type			Link Lengths (m)						
			ClearCurve® Optical Fiber				InfiniCor®300 Optical Fiber		SMF-28e+® Single-mode Optical fiber
			OM2	OM3	OM4	OM2,3&4	OM1		OS1
Wavelength Modal Bandwidth (MHz.km)			850 nm			1300 nm	850 nm	1300 nm	1310 nm
			850 EMB	2000 EMB ^[1]	4700 EMB ^[1]	500 OFL ^[2]	200 OFL ^[2]	500 OFL ^[2]	∞
Application Standard	Date Published	Nominal Speed (b/sec)							
IEEE 802.3 series Ethernet									
10GBASE-SR	2002	10G	150	300	550	-	33	-	-
10GBASE-LX	2002	10G	-	-	-	300	-	300	10000
40GBASE-SR4	2010	40G	-	140	170	-	-	-	-
40GBASE-LR4	2010	40G	-	-	-	-	-	-	10000
100GBASE-SR10	2010	100G	-	140	170	-	-	-	-
100GBASE-LR4	2010	100G	-	-	-	-	-	-	10000
100GBASE-ER4	2010	100G	-	-	-	-	-	-	30000
ANSI - INCITS Fibre Channel									
200-MX-SN-I	2000	2G	428	526	500	-	150	-	-
400-MX-SN-I	2002	4G	228	380	480	-	70	-	-
800-MX-SN-I	2003	8G	-	150	190	-	21	-	-
800-MX-SN-S	2003	8G	50	-	-	-	-	-	-
1600-MX-SN-I	2011	16G	-	100	125	-	15	-	-
1600-MX-SN-S	2011	16G	35	-	-	-	-	-	-
InfiniBand TA									
IB-1x-SDR-SX	2002	2G	250	500	700	-	125	-	-
IB-4x-SDR-SX	2002	8G	125	200	350	-	75	-	-
IB-8x-SDR-SX	2004	16G	125	200	350	-	75	-	-
IB-12x-SDR-SX	2002	24G	125	200	350	-	75	-	-
IB-1x-DDR-SX	2004	4G	125	200	350	-	65	-	-
IB-4x-DDR-SX	2004	16G	75	150	275	-	50	-	-
IB-8x-DDR-SX	2004	32G	75	150	275	-	50	-	-
IB-12x-DDR-SX	2004	48G	75	150	275	-	50	-	-
IB-1x-QDR-SX	2008	8G	82	300	500	-	33	-	-
IB-4x-QDR-SX	2008	32G	82	300	500	-	33	-	-
IB-12x-QDR-SX	2008	96G	82	300	500	-	33	-	-
IB-1x-FDR-SX	2011	14G	50	>50	>50	-	-	-	-
IB-4x-FDR-SX	2011	56G	50	>50	>50	-	-	-	-
IB-12x-FDR-SX	2011	168G	50	>50	>50	-	-	-	-
ITU/T Asynchronous Transfer Mode (ATM)									
	2001	1G	750	1000	1000	-	275	-	-
	2001	1G	-	-	-	550	-	550	5000
ITU/T - SONET/SDH OIF VSR									
OC-192 VSR4-01	2000	10G	750	1000	1000	-	500	300	-
OC-192 VSR4-02	2002	10G	-	-	-	-	-	-	600
OC-192 VSR4-03	2003	10G	375	620	810	-	-	-	-
OC-192 VSR4-04	2001	10G	150	300	500	-	33	33	-
OC-768 VSR5-01	2002	40G	150	300	500	-	-	-	-

^[1] EMB – Effective modal bandwidth measured in accordance with IEC 60793-1-49 and TIA/EIA-455-220

^[2] OFL – Over-filled launch bandwidth as measured in accordance with IEC 60793-1 and TIA/EIA-455-204

Table 4. Application Link Length for Corning Multimode and Single-mode Optical Fiber Types

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 which the capability of the network depends on, now and in the future. For premises networks, Corning ClearCurve multimode optical fibers provide the cost-effective combination of leading high bandwidth performance and increased reliability with Corning's bend-insensitive technology. Corning recommends ClearCurve OM4 multimode optical fibers for the most demanding high-speed interconnects up to 100 Gb/s and beyond.

For further information on Corning ClearCurve multimode fiber please visit the website at:

http://www.corning.com/opticalfiber/products/clearcurve/multimode_fiber.aspx

References

Corning® ClearCurve® Multimode Optical Fiber Product Information

<http://www.corning.com/WorkArea/showcontent.aspx?id=36549>

IEC 60793-2-10 Edition 4.0, 2001-03 Optical fibres - Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres

TIA/EIA 492AAAA, 492AAAB, 492AAAC, 492AAAD

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

ITU-T G.651 - Characteristics of a 50/125 µm multimode graded index optical fibre cable IEEE 802.3

American National Standard for Information Technology: Fibre Channel: Physical Interfaces (FC-PI-2)

InfiniBand™ Architecture Specification Volume 2 Release 1.2.1

ITU-T Rec. G.707/Y.1322, Network node interface for the synchronous digital hierarchy (SDH)

Corning Incorporated

www.corning.com/opticalfiber

One Riverfront Plaza
Corning, New York
USA

Phone: +1-607-248-2000 (U.S. and Canada)

Email: cofic@corning.com

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