IBM Z

Planning for Fiber Optic Links (FICON/FCP, Coupling Links, Open Systems Adapters, and zHyperLink Express)

GA23-1408-04

Note

Before you use this information and the product it supports, read the information in "Safety" on page vii, Appendix E, "Notices," on page 109, and *IBM Systems Environmental Notices and User Guide*, Z125-5823.

This edition, GA23-1408-04, applies to the IBM Z and IBM LinuxONE servers. This edition replaces GA23-1408-03.

There might be a newer version of this document in a **PDF** file available on **Resource Link**. Go to http://www.ibm.com/servers/resourcelink and click **Library** on the navigation bar.

Contents

Safety

Safety notices

Safety notices may be printed throughout this guide. **DANGER** notices warn you of conditions or procedures that can result in death or severe personal injury. **CAUTION** notices warn you of conditions or procedures that can cause personal injury that is neither lethal nor extremely hazardous. **Attention** notices warn you of conditions or procedures that can cause damage to machines, equipment, or programs.

World trade safety information

Several countries require the safety information contained in product publications to be presented in their translation. If this requirement applies to your country, a safety information booklet is included in the publications package shipped with the product. The booklet contains the translated safety information with references to the US English source. Before using a US English publication to install, operate, or service this product, you must first become familiar with the related safety information in the *Systems Safety Notices*, G229-9054. You should also refer to the booklet any time you do not clearly understand any safety information in the US English publications.

Laser safety information

All IBM Z® (Z) and IBM LinuxONE (LinuxONE) models can use I/O cards such as, ESCON, FICON®, Open Systems Adapter (OSA), InterSystem Channel-3 (ISC-3), RoCE Express, Integrated Coupling Adapter (ICA SR), IBM zHyperLink Express, or other I/O features which are fiber optic based and utilize lasers (short wavelength or long wavelength lasers).

Laser compliance

All lasers are certified in the US to conform to the requirements of DHHS 21 CFR Subchapter J for Class 1 or Class 1M laser products. Outside the US, they are certified to be in compliance with IEC 60825 as a Class 1 or Class 1M laser product. Consult the label on each part for laser certification numbers and approval information.

Laser Notice: U.S. FDA CDRH NOTICE if low power lasers are utilized, integrated, or offered with end product systems as applicable. Complies with 21 CFR 1040.10 and 1040.11 except for conformance with IEC 60825-1 Ed. 3., as described in Laser Notice No. 56, dated May 8, 2019.

CAUTION: Data processing environments can contain equipment transmitting on system links with laser modules that operate at greater than Class 1 power levels. For this reason, never look into the end of an optical fiber cable or open receptacle. (C027)

CAUTION: This product contains a Class 1M laser. Do not view directly with optical instruments. (C028)

About this publication

This publication provides information that can be used to plan for IBM Fiber Optic Links. This includes coupling facility links, Open Systems Adapter (OSA), zHyperLink Express®, and Fibre Connection (FICON) channels, which is IBM's implementation of the ANSI Fibre Channel Standard with additional support for multimode fibers. Although it contains general information relating to fiber optic cables, components, and optical fiber data processing environments, it includes only what is supported for these fiber optic links.

A technical change or illustration is indicated by a vertical line to the left of the change.

The Open Systems Adapter-Express (OSA-Express) Ethernet features conform to industry standards as defined herein. Contact your cable provider for further assistance. Refer also to Table 56 on page 97.

10 Gigabit Ethernet (10GBASE-LR, 10GBASE-SR)

IEEE 802.3ae
IEEE 802.1q
IEEE 802.3x - flow control
DIX Version 2 (DIX V2)

- Gigabit Ethernet (1000BASE-LX, 1000BASE-SX)

  IEEE 802.3ac
  IEEE 802.1q
  IEEE 802.3x - flow control
  IEEE 802.3z
  DIX Version 2 (DIX V2)
- Ethernet (1000BASE-T)

  IEEE 802.1p
  IEEE 802.1q
  IEEE 802.3ab
  IEEE 802.3ac
  IEEE 802.3u
  IEEE 802.3x - flow control
  DIX Version 2 (DIX V2)

The 10GbE RoCE Express feature conforms to industry standards as defined herein. Contact your cable provider for further assistance. Refer also to Table 56 on page 97.

- RoCE uses the InfiniBand Trade Association-defined (IBTA-defined) transport headers and invariant (end-to-end) cyclical redundancy checking (CRC) (adapter-to-adapter) to protect the InfiniBand transport payload. Refer to the supplement to the InfiniBand Architecture Specification Volume 1 Release 1.2.1, Annex A16 for details.
- RoCE uses the IEEE-assigned EtherType of 0x8915.
- The 10 GbE-capable switch must have Pause frame enabled as defined by the IEEE 802.3x standard.

10 Gigabit Ethernet (10GBASE-SR)

IEEE 802.3ae
IEEE 802.1q
IEEE 802.3x - flow control
DIX Version 2 (DIX V2)

10GbE RoCE Express

Remote Direct Memory Access (RDMA) over Converged Ethernet (RoCE) is part of the InfiniBand Architecture Specification that provides InfiniBand transport over Ethernet fabrics. It encapsulates

InfiniBand transport headers into Ethernet frames using an IEEE-assigned ethertype. One of the key InfiniBand transport mechanisms is RDMA, which is designed to allow transfer of data to or from memory on a remote system with low-latency, high-throughput, and low CPU utilization

Traditional Ethernet transports such as TCP/IP typically use software-based mechanisms for error detection and recovery and are based on the under-lying Ethernet fabric using "best-effort" policy. With the traditional policy the switches typically discard packets in the event of congestion and rely on the upper level transport for packet re-transmission. RoCE, however, uses hardware-based error detection and recovery mechanisms defined by the InfiniBand specification. A RoCE transport performs best when the under-lying Ethernet fabric provides a loss-less capability, where packets are not routinely dropped. This can be accomplished by using DEthernet flow control whereby Global Pause frames are enabled for both transmission and reception on each of the Ethernet switches in the path between the 10GbE RoCE Express features. This capability is enabled by default in the 10GbE RoCE Express feature.

Notes:

1. When the term FICON/FCP is used, it refers to FICON Express (LX and SX), FICON Express2 (LX and SX), FICON Express4 (LX and SX), FICON Express8 (LX and SX) and FICON Express8S (LX and SX) channels.
2. When the term OSA is used, it refers to OSA-Express, OSA-Express2 , OSA-Express3 and OSA-Express4S features.
3. This publication, in conjunction with the publication *Maintenance Information for Fiber Optic Links*, SY27-7696, replaces the publication *IBM 3044 Fiber-Optic Channel Extender Link Models C02 and D02: Fiber-Optic Cable Planning, Installation, and Maintenance Guide*, GC22-7130, and makes it obsolete.
4. This publication replaces *Cabling System Optical Fiber Planning and Installation Guide*, GA27-3943.
5. This publication replaces *Fibre channel Connection (FICON) I/O Physical Layer*, SA24-7172, and *Coupling Links I/O Physical Layer*, SA23-0395.

Organization of this publication

This publication is organized as follows:

- Chapter 1, "Introduction to fiber optic links (FICON/FCP, InfiniBand coupling links, and Open Systems Adapter)," on page 1 provides a brief introduction to fiber optic information transfer, lists the components that can be included in a fiber optic channel link, and shows an example of a fiber optic channel link.
- Chapter 2, "Link, trunk, and IBM jumper cable planning," on page 17 discusses fiber optic channel link planning tasks and contains considerations and recommendations related to planning for fiber optic channel links.
- Chapter 3, "Calculating the loss in a multimode link," on page 35 describes how to calculate the maximum allowable loss for a fiber optic channel link that uses multimode components. It shows an example of a multimode link and includes a completed work sheet that uses values based on the link example.
- Chapter 4, "Calculating the loss in a single mode link," on page 41 describes how to calculate the maximum allowable loss for a fiber optic channel link that uses single mode components. It shows an example of a single mode link and includes a completed work sheet that uses values based on the link example.
- Chapter 5, "Specifications," on page 47 lists the specifications and optical properties for a fiber optic channel link, IBM jumper cables, and trunk cable.
- Chapter 6, "FICON/FCP I/O physical layer: Introduction," on page 57 provides a brief introduction to fiber optic information transfer as it relates to FICON/FCP.
- Chapter 7, "Multimode physical layer," on page 59 describes the physical and optical requirements in a multimode link.

- Chapter 8, "Single Mode physical layer," on page 71 describes the physical and optical requirements in a single mode link.
- Chapter 9, "InfiniBand coupling links I/O physical layer: Introduction," on page 77 provides a brief introduction to fiber optic information transfer as it relates to InfiniBand coupling links.
- Chapter 10, "InfiniBand coupling link (12x IFB) 50 micron multimode physical layer," on page 79 describes the physical and optical requirements in a 12x InfiniBand multimode link.
- Chapter 11, "1x InfiniBand coupling link 9 micron single mode physical layer," on page 83 describes the physical and optical requirements in a 1x InfiniBand single-mode link.
- Chapter 12, "Integrated Coupling Adapter (24x PCIe) 50 micron multimode physical layer," on page 87 describes the physical and optical requirements in a 24x ICA-SR coupling link.
- Appendix A, "Measurement conversion tables," on page 95 contains conversion tables from English measurements to metric and metric measurements to English.
- Appendix B, "Fiber optic channel attachment options," on page 97 describes the history and future of fiber optics.
- Appendix C, "FICON/FCP I/O Physical Layer: Test methods and examples," on page 101 describes optical measurement procedures, and provides graphs referencing the maximum spectral width and center wavelength for 1.0625 Gbps.
- Appendix D, "Coupling links I/O physical layer: Test methods," on page 107 describes optical measurement procedures for coupling links.
- Appendix E, "Notices," on page 109 contains trademark and service mark information.

Prerequisite publications

- *Connectivity Handbook*, SG24-5444, provides connectivity alternatives available in the planning and design of a data center infrastructure to be found at http://www.redbooks.ibm.com.
- *FICON Implementation Guide*, SG24-6497, provides FICON and Fibre Channel architectures, terminology and supported technologies in the Library section on Resource Link® (http://www.ibm.com/servers/resourcelink).

Related publications

- *Enterprise Systems Connection Link Fault Isolation*, SY22-9533, contains information used to isolate link faults.
- *Maintenance Information for Fiber Optic Links*, SY27-7696, provides problem determination, verification, and repair procedures. This publication also contains information from *Maintenance Information for Fiber Distributed Data Interface Links*, SY27-0331, *Fibre channel Connection (FICON) I/O Physical Layer*, SA24-7172, and *Coupling Links I/O Physical Layer*, SA23-0395. This publication obsoletes form SY27-0331.
- *Introduction to IBM S/390 FICON*, SG24-5176, provides an overview of the Fibre Channel Connection (FICON).
- *Technical Service Letter No. 147 Fiber Optic Tools and Test Equipment*, (Revised 2/19/96 or later) contains a complete list of fiber optic support tools and test equipment.
- *Using the IBM Cabling System with Communications Products*, GA27-3620
- *IBM Cabling System Technical Interface Specification*, GA27-3773
- *Local Area Networks Concepts and Products*, SG24-4755
- *Coupling Link I/O Interface Physical Layer*, SA23-0395
- *Fibre Connection (FICON) I/O Interface Physical Layer*, SA24-7172
- *Planning for the System/390® Open Systems Adapter Feature*, GC23-3870

In addition to this document, you should be familiar with the following Electronics Industries Association (EIA) and Telecommunications Industry Association (TIA) standards. The following standards are published as American National Standards Institute (ANSI) Standards:

- *Commercial Building Telecommunications Wiring Standards*, (EIA/TIA 568)
- *Commercial Building Standards for Telecommunication Pathways and Spaces*, (EIA/TIA 569)
- *Telecommunications Administration Standard of Commercial Buildings* EIA/TIA Project number 2290 (currently available only as a draft)
- *Telecommunications Distribution Methods Manual - Building Industry Consulting Service International (BICSI)*

Coupling links are designed to be optically compatible with the F0 or physical layer industry standard *ANSI Fibre Channel Standard Physical and Signaling Interface (FC-PH)*, published by the *American National Standards Institute*, New York, NY.

The open fiber control (OFC) timing for 531 megabits per second links follows this ANSI standard. The OFC timing for 1.0625 gigabits per second links uses the same timing as specified in the ANSI standard for 266 megabits per second links, which enables longer distances for gigabit links.

Revisions

A technical change from the previous edition of this document is indicated by a thick vertical line to the left of the change.

Accessibility

Accessible publications for this product are offered in EPUB format and can be downloaded from Resource Link at http://www.ibm.com/servers/resourcelink.

If you experience any difficulty with the accessibility of any IBM Z® and IBM LinuxONE information, go to Resource Link at http://www.ibm.com/servers/resourcelink and click **Feedback** from the navigation bar on the left. In the **Comments** input area, state your question or comment, the publication title and number, choose **General comment** as the category and click **Submit**. You can also send an email to reslink@us.ibm.com providing the same information.

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Accessibility features

The following list includes the major accessibility features in IBM Z and IBM LinuxONE documentation, and on the Hardware Management Console and Support Element console:

- Keyboard-only operation
- Interfaces that are commonly used by screen readers
- Customizable display attributes such as color, contrast, and font size
- Communication of information independent of color
- Interfaces commonly used by screen magnifiers
- Interfaces that are free of flashing lights that could induce seizures due to photo-sensitivity.

Keyboard navigation

This product uses standard Microsoft Windows navigation keys.

Consult assistive technologies

Assistive technology products such as screen readers function with our publications, the Hardware Management Console, and the Support Element console. Consult the product information for the specific assistive technology product that is used to access the EPUB format publication or console.

IBM and accessibility

See http://www.ibm.com/able for more information about the commitment that IBM has to accessibility.

How to send your comments

Your feedback is important in helping to provide the most accurate and high-quality information. Send your comments by using Resource Link at http://www.ibm.com/servers/resourcelink. Click **Feedback** on the navigation bar on the left. You can also send an email to reslink@us.ibm.com. Be sure to include the name of the book, the form number of the book, the version of the book, if applicable, and the specific location of the text you are commenting on (for example, a page number, table number, or a heading).

Chapter 1. Introduction to fiber optic links (FICON/FCP, InfiniBand coupling links, and Open Systems Adapter)

This chapter provides a brief introduction to fiber optic information transfer, and lists the components that can be included in an IBM fiber optic channel link. These links include both Open Systems Adapter (OSA) and Fibre Connection (FICON) links.

With the development of products that use optical cable as a transmission medium, data processing centers and LANs are expanding beyond the limitations of copper cable. Optical cable allows attaching products to take advantage of the following benefits

- Extended distances
- Higher data rates
- Smaller and lighter cable
- Less susceptibility to radio frequency interference (RFI) and electromagnetic interference (EMI).

Because of the physical characteristics of optical cable and the products that use it, planning an optical fiber installation should be approached with a thorough understanding of this technology. This includes the factors associated with extended distance links (for example, right-of-way considerations) and using component and distribution hardware. To plan an installation that supports current products and future products, plan carefully and early. This chapter also shows an example of a fiber optic channel link.

Unidirectional fiber optic information transfer

Information transfer through an optical fiber usually occurs in only one direction by using a transmitter and a receiver Figure 1 on page 1. The transmitter accepts encoded digital information, converts it into an optical (light) signal, and sends it through the fiber. The receiver detects the optical signal, converts it into an electrical signal, and amplifies it. After being decoded, the digital output information is the same as the digital input.

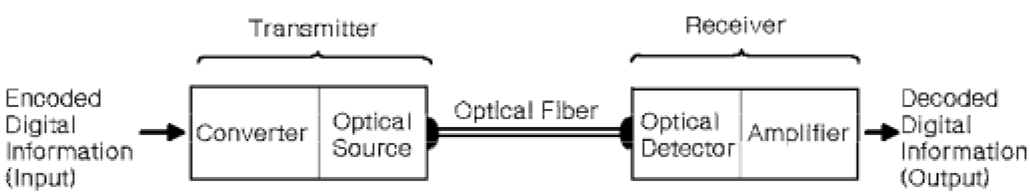


Figure 1. Unidirectional fiber optic Information transfer

Bidirectional fiber optic information transfer

Fiber optic information transfer can also occur in both directions simultaneously Figure 2 on page 2. This method uses two optical fibers contained in one duplex fiber optic cable and combines the transmitter, receiver, and duplex receptacle functions into one transmitter-receiver subassembly (TRS) in each device.

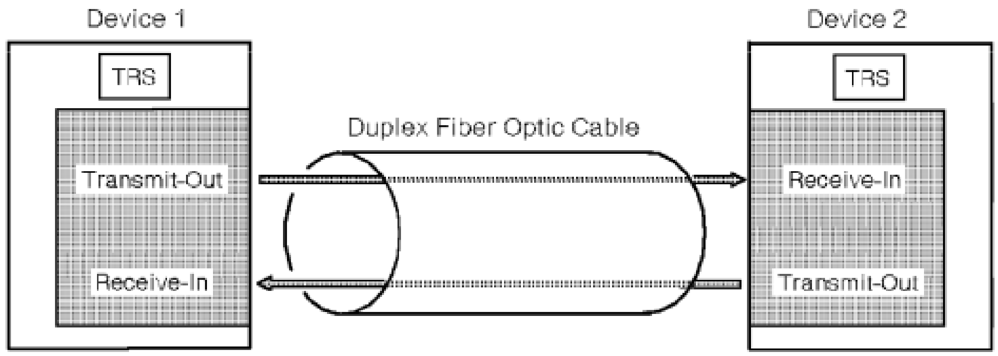


Figure 2. Bidirectional fiber optic information transfer

Optical fiber technology

Transmission of signals over optical fiber uses the phenomenon of total internal reflection to transmit data with rays of light through a strand of glass. This strand is called an optical fiber. Total internal reflection occurs because the *cladding* that surrounds the *core* of the optical fiber has a lower *index of refraction* than the core. This difference in index of refraction causes the light to be contained in the fiber as it travels from source to destination. See Figure 3 on page 3.

In optical fiber, *mode* describes the propagation of light rays in an optical fiber. Optical fiber supports many modes of propagation, depending on the size of the fiber.

When the core has a diameter that is large compared to the wavelength of the light signal, many modes of light are propagated. Such fiber is called *multimode* optical *fiber*. The different modes of light reach the end of the fiber at different times, because each mode takes a different path through the core. This causes the *pulse* to spread out; this is referred to as *modal dispersion*.

Optical fiber is usually referred to by the diameter of its core and cladding with its numerical aperture. For example, a multimode fiber with a diameter of 62.5 microns (millionths of a meter; hereafter, microns will be abbreviated as µm, which is the scientific notation) and a cladding diameter of 125 µm with a numerical aperture of .275, is designated as 62.5/125 NA .275 fiber (hereafter referred to as *62.5/125 fiber*). Based on the work of standards organizations, 62.5/125µm fiber was initially the recommended fiber cable for most multimode fiber applications. More recently, 50/125 NA .2 fiber (hereafter referred to as *50/125µm fiber*) has become the multimode fiber of choice. Multimode optical fiber is available with core diameters that range from 50 to 200 µm. Although other fiber sizes are supported by IBM, their use should be based on the requirements of the attaching products and is not recommended for new installations.

Most multimode optical fiber is *graded-index fiber*, which is manufactured with a gradually changing refractive index, instead of an abrupt change between the core and the cladding. This gradually changing refractive index allows for lower modal dispersion and thus a higher bandwidth. See Figure 3 on page 3 for an example of how the light in multimode optical fiber is propagated through a graded-index fiber.

In single mode fiber, light is propagated as only one mode. This mode travels in both the core and the cladding, with most of the light within a diameter of 9 to 10 µm (9 to 10 µm being the mode field diameter). This fiber is called single mode optical fiber. Single Mode optical fiber eliminates modal dispersion consideration.

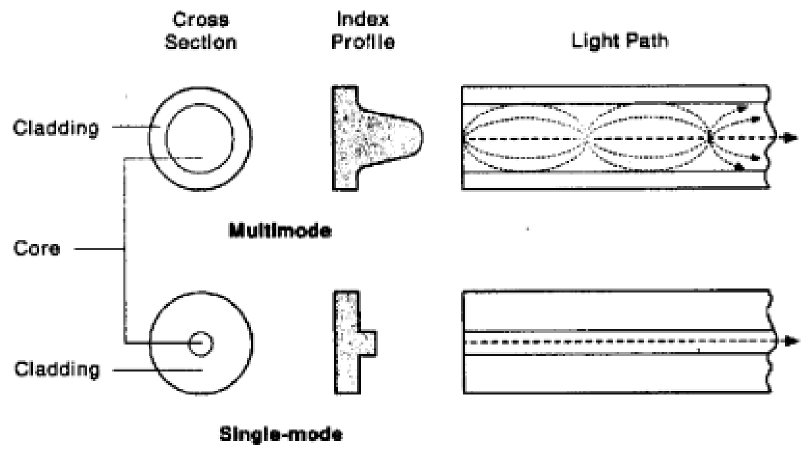


Figure 3. Single Mode and multimode optical fiber

Multimode fiber is usually used with a short wave length laser light source, whereas single mode fiber is usually used with long wavelength laser light source. Because of the laser light source and the propagation of a single mode of light, single mode fiber provides longer transmission distances and faster data rates.

Optical fiber elements and optical cable

The fiber element within an optical cable usually consists of a core and a cladding Figure 4 on page 4. The core provides the light path, the cladding surrounds the core, and the optical properties of the core and cladding junction cause the light to remain within the core.

Although the core and the cladding diameters, expressed in micrometers (µm), are often used to describe an optical cable, they actually indicate the physical size of the fiber element. For example, a fiber element having a core diameter of 62.5 µm and a cladding diameter of 125 µm is called 62.5/125-µm fiber.

In an optical cable, the core and cladding are typically surrounded by other layers (such as a primary and secondary buffer), a strength member, and an outer jacket (Figure 4 on page 4) that provide strength and environmental protection. It is possible to transmit multiple data channels over a single optical fiber by sending each data stream at a different optical wavelength. This is known as Wavelength Division Multiplexing (WDM). For more information, see the following red papers that describe several products offered by IBM strategic partners:

Adva http://www.redbooks.ibm.com/redpapers/pdfs/redp3903.pdf

Nortel http://www.redbooks.ibm.com/redpapers/pdfs/redp3904.pdf

Cisco http://www.redbooks.ibm.com/redpapers/pdfs/redp3905.pdf

Lucent http://www.redbooks.ibm.com/redpapers/pdfs/redp3906.pdf

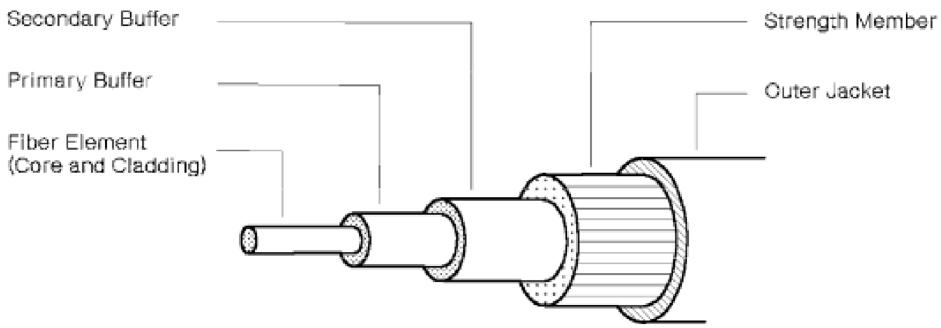


Figure 4. Optical cable elements (typical)

Because information transfer usually occurs in only one direction through an optical fiber, various fiber types have been developed for different applications. The optical properties and specifications of a fiber determine many characteristics. For example, **single mode** fiber (nominally about 9.0 µm) provides one high-bandwidth information "path". Single Mode fiber is usually used to transfer information over greater distances compared to **multimode** fiber (50.0 µm, for example), which provides multiple paths and has a lower bandwidth. The terms single mode and multimode are often used to describe the optical fiber and optical cable types.

Generally, long wavelength (LX or 1300 nm) laser diodes use single mode fiber to transmit information, while long wavelength light-emitting diodes (LEDs) or short wavelength (SX or 850 nm) lasers use multimode fiber. In a data processing environment using optical fiber, product, distance, and right-of-way considerations usually determine if single mode or multimode fiber is used.

Optical cable connectors

Optical cable connectors allow manual coupling and uncoupling of the fibers, but contribute to link attenuation (loss). Although several connector types have been developed to minimize this loss, all can be classified as either physical contact or nonphysical contact.

Physical-contact connectors

Physical-contact connectors, sometimes referred to as butt-coupled connectors, have a polished end-face surface with a slight outward (convex) curvature. When inserted into the receptacle, the fibers are precisely aligned and touch each other, thereby allowing maximum light transfer and minimum return loss. The IBM duplex connectors, the ST connector, the SC Duplex connector, the FC/PC connector, the MT–RJ connector, and the LC Duplex are types of physical-contact connectors.

Note: For more information on MT–RJ and LC Duplex interfaces, see the Planning section for the zSeries 900 on Resource Link at *http://www.ibm.com/servers/resourcelink*.

IBM duplex connectors, which combine the transmit and receive signals in one housing, provide high reliability and have low loss characteristics. They are keyed to provide correct orientation and use release tabs to prevent accidental removal.

Some IBM duplex connectors and receptacles used for single mode fiber have additional keying. This prevents the plugging of multimode IBM duplex connectors into IBM products having single mode receptacles.

The SC Duplex connector is another type of connector which may be keyed to prevent accidental plugging of a multimode fiber into a single mode receptacle, and to provide correct orientation to the TRS.

The MT–RJ connector has distinct male ends (with metal guide pins) and female ends (with guide holes). Only male to female connections will transmit optical signals. Since all MT–RJ transceivers have a male interface, only female jumper cables are required for most installations.

Nonphysical-contact connectors

Nonphysical-contact connectors do not allow the fiber end-faces to touch. Because an air gap exists, these connectors typically have a higher interface loss compared to physical-contact connectors. The biconic connector used by IBM, which is equivalent to AT&T part number 1006A, is an example of a nonphysical-contact connector.

Connector color coding

IBM simplex connectors use color-coding to show the direction that light travels through a link ("Light propagation in an IBM link" on page 23). These connectors are black (or use a black marking) and white (or use a white marking).

IBM duplex cable connectors use color-coding to differentiate between multimode and single mode. Multimode cables have black or beige connectors and single mode cables have grey or blue connectors. They do not require color coding to determine the direction that light travels, or propagates, through the cable because the connectors are physically keyed. This provides proper orientation and allows the fibers to be labeled "A" and "B", which is shown on the connector. See "Light propagation in an IBM jumper cable" on page 23.

The SC Duplex connector is an industry standard optical connector (as defined in *ANSI Fibre Channel Standard Physical and Signaling Interface (FC-PH)*, published by the *American National Standards Institute*. Since it may be purchased from a variety of vendors, there is no consistent scheme of color coding or labeling the ends of a simplex cable with SC Duplex connectors. These connectors can be identified by their shape (Figure 6 on page 5) and the direction of light propagation must be verified from the vendor specifications. For IBM supplied cables, the single mode SC Duplex jumper has a gray or blue connector and a yellow cable jacket, while the multimode has a black or beige connector with an orange jacket.

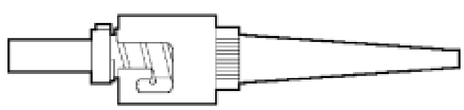


Figure 5. ST Physical-Contact Connector

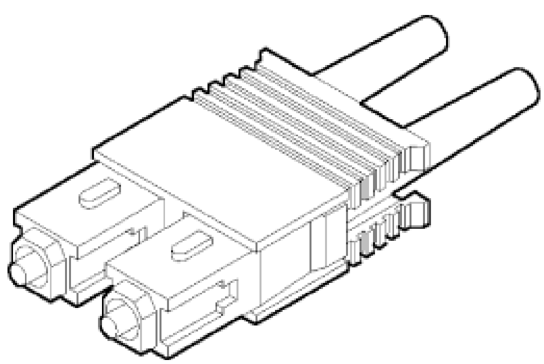


Figure 6. SC Duplex Connector

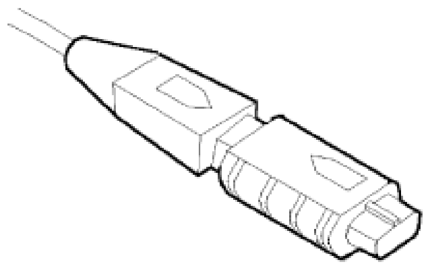


Figure 7. Multifiber Terminated Push-on Connector (MTP). Twelve fiber connector available on FTS-III Direct Attach trunk cables and harnesses. This connector is also used for 12x InfiniBand optical (IFB-O) cable but is referred to as an MPO connector.

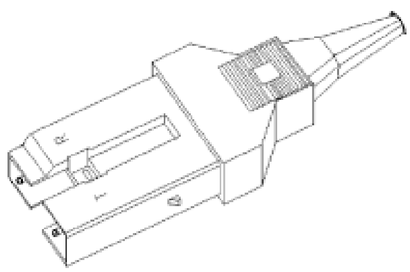


Figure 8. MIC Connector

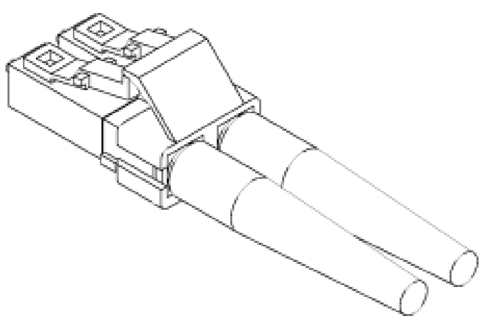


Figure 9. LC Duplex Connector

IBM jumper cables

IBM provides both single mode (yellow) and multimode (orange or aqua) jumper cables, which attach either between two devices or between a device and a distribution panel.

Note: Single Mode and multimode cables cannot coexist in the same fiber optic channel link. Additionally, we recommend that multimode cables of different core sizes (62.5µm and 50µm,) should not coexist in the same link. See “Mode Conditioning Patch cable (MCP)” on page 13.

The elements in an IBM duplex cable (Figure 10 on page 7) consist of two tight-buffered optical fibers (core and cladding) surrounded by a strength member, all of which are encased in a common flexible jacket. Duplex cables for coupling facility channels are similar, see Figure 11 on page 7, except that they are not encased in a single jacket. Both single mode and multimode jumper cables have a cladding diameter of 125 µm. single mode cable has a mode field diameter (MFD) of about 9 µm; multimode cable has a core diameter of 62.5 µm or 50.0 µm.

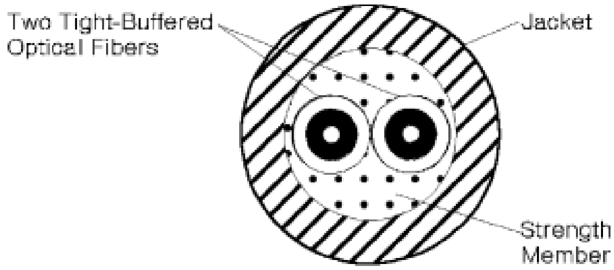


Figure 10. IBM Duplex Jumper Cable Elements

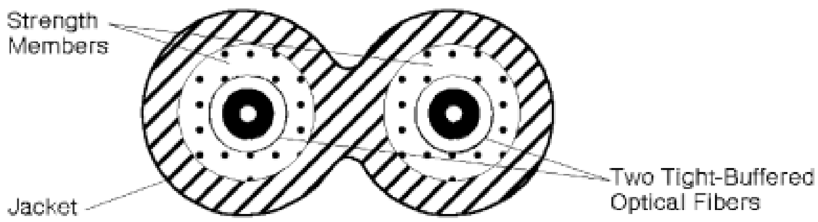


Figure 11. Coupling Facility jumper cable elements. (Jumper cables which use FICON/FCP SC duplex connectors.)

All IBM jumper cables have a duplex connector on one end, which attaches to a FICON-capable device, or coupling facility channel. Attaching a jumper cable to a distribution panel, however, could require jumper cables with other connector types ("Optical cable connectors" on page 4). IBM offers these jumper cables:

- Single Mode and multimode applications:
  - Duplex-to-duplex jumper cables have an IBM duplex connector on both ends
  - Duplex-to-duplex jumper cables have an SC Duplex connector on both ends
  - Duplex-to-duplex jumper cables have an LC Duplex connector on both ends
  - Duplex-to-duplex jumper cable conversion kits:
    - IBM duplex receptacle on one end and an SC Duplex connector on the other end
    - An LC Duplex connector on one end and a SC Duplex receptacle on the other end
- Multimode applications only:
  - Duplex-to-ST jumper cables have a pair of color-coded, physical-contact ST connectors on one end.
  - Duplex-to-FC jumper cables have a pair of color-coded, physical-contact FC connectors on one end
  - Duplex-to-unterminated jumper cables have an unterminated end (no connector) that allows the attachment of any connector type
  - Duplex-to-duplex jumper cables with female MT–RJ on both ends
  - Duplex-to-duplex jumper cables with male MT–RJ on both ends

Jumper cable availability

Table 1 on page 7 shows the availability of IBM jumper cables according to, cable type (single mode [SM], or multimode [MM]), and connector type. Table 5 on page 9 shows the availability of IBM jumper cables according to cable length.

Standard length SC Duplex connector jumper cables are available from IBM.

Table 1. Available cable and connector types: FICON/FCP, Coupling Links, zHyperLink Express and OSA

Multimode 50 and 62.5 µm	**Single Mode**
LC Duplex-to-SC Duplex	LC Duplex-to-SC Duplex

Table 1. Available cable and connector types: FICON/FCP, Coupling Links, zHyperLink Express and OSA (continued)	
Multimode 50 and 62.5 µm	**Single Mode**
LC Duplex-to-ST	LC Duplex-to-ST
LC Duplex-to-LC	

Table 2. OM3 LC to LC multimode Jumpers

Fixed length part number	EC	Length
00LU872	N37066	256.5 mm +/- 5.5
00LU873	N37066	310 mm + 10
15R7094	G42638	500 mm / 1.64 ft
45D4773	G40909	1 m / 3.3 ft
45D2683	G36907	2 m / 6.6 ft
15R8846	G42864	3 m / 9.8 ft
45E9750	M10504	4.2 m / 13.8 ft
45D4774	G40909	5 m / 16.4 ft
41V2120	G40437	10 m / 32.8 ft
15R8847	G42864	15 m / 49.2 ft
41V2121	N37299	20 m / 65.6 ft
15R8848	G42864	25 m / 82.0 ft
41T9514	G37408	30 m / 98.43 ft
41V2122	G40437	40 m / 131.2 ft
41V2123	G40437	80 m / 262.5 ft
46K3445	G37722	100 m / 328.1 ft
41V2124	G40437	150 m / 492.1 ft
45D2688	G36907	Custom

Table 3. OM4 LC to LC multimode Jumpers

Fixed length part number	EC	Length
00LT909	N36702A	500 mm / 1.64 ft
00LT910	N36702A	1 m / 3.3 ft
00LT911	N36702A	2 m / 6.6 ft
00LT912	N36702A	3 m / 9.8 ft
00LT913	N36702A	5 m / 16.4 ft
00LT914	N36702A	10 m / 32.8 ft
00LT915	N36702A	15 m / 49.2 ft
00LT916	N36702A	20 m / 65.6 ft

Table 3. OM4 LC to LC multimode Jumpers (continued)		
Fixed length part number	**EC**	**Length**
00LT917	N36702A	25 m / 82.0 ft
00LT918	N36702A	30 m / 98.43 ft
00LT919	N36702A	40 m / 131.2 ft
00LT920	N36702A	80 m / 262.5 ft
00LT921	N36702A	100 m / 328.1 ft
00LT922	N36702A	150 m / 492.1 ft

Table 4. OM5 LC to LC multimode Jumpers		
Fixed length part number	**EC**	**Length**
01PP370	N36754	1 m / 3.3 ft
01PP371	N36754	2 m / 6.6 ft
01PP372	N36754	3 m / 9.8 ft
01PP373	N36754	5 m / 16.4 ft
01PP374	N36754	8 m / 26.2 ft
01PP375	N36754	10 m / 32.8 ft
01PP376	N36754	13 m / 42.7 ft
01PP377	N36754	15 m / 49.2 ft
01PP378	N36754	20 m / 65.6 ft
01PP379	N36754	40 m / 131.2 ft
01PP380	N36754	80 m / 262.5 ft
01PP381	N36754	120 m / 423.2 ft
01PP382	N36754	150 m / 492.1 ft
01PP383	N36754	Custom

Table 5. Available lengths		
All FICON/FCP, Coupling Links, OSA, and multimode jumpers	**Single Mode jumpers**	**PSIB**
7 m (20 ft)	4 m (12 ft)	
13 m (40 ft)	13 m (40 ft)	
22 m (70 ft)	22 m (70 ft)	
31 m (100 ft)	31 m (100 ft)	
46 m (150 ft)	61 m (200 ft)	
61 m (200 ft)	92 m (300 ft)	150m (492 ft)
custom	122 m (400 ft)	

Table 5. Available lengths (continued)		
All FICON/FCP, Coupling Links, OSA, and multimode jumpers	**Single Mode jumpers**	**PSIB**
Notes: 1. Before ordering, consider length requirements for future equipment relocation. 2. The maximum total jumper cable length cannot exceed 244 meters (800 ft) when using either 50/125 µm trunk fiber or when a 62.5/125 µm link exceeds 2 kilometers (1.24 miles). 3. English distances are approximate. 4. Custom lengths are available in 0.5 meter increments from 4 meters (12 ft) to 500 meters (1640 ft).		

Jumper cable labels

Each IBM jumper cable has a jacket marking that contains the part number, EC number, length in meters and feet, and manufacturing/warranty data. Additional jacket markings may be added by the suppliers.

```
PN VVVVVVV/FFFFFFF EC1234567 31 m 100.0 ft 11210005 BAR CODE DATE CODE SNUM
```

Where V = variable length part number, F = fixed length part number. Manufacturing and warranty data includes: BAR CODE INFO

1
: Vendor code

1
: Last digit of year manufactured

210
: Day-of-year manufactured (Julian date)

005
: Sequence number

The above is bar code information for reference.

Trunk cable

Fiber optic trunk cable is generally used for longer links, such as between floors or buildings. It should also be used in single-floor coupling link environments when many jumper cables and connections are required. If trunk cable is used, distribution panels must provide the hardware used to attach IBM jumper cables.

A trunk cable typically contains from 12 to 144 fibers and has a strength member and an outer jacket. The physical trunk cable configuration varies and depends on user requirements, environmental conditions, and the type of installation required (for example, above ground or underground).

Splices

Fiber optic trunk cables can be joined by two splicing methods. Either method, when performed by a trained technician using high-quality materials, can produce a splice having a very low optical power loss.

- Fusion splices are joined by an electric arc.
- Mechanical splices are joined within a holder and sometimes use epoxy to bond the fibers.

Distribution panels

Many types of distribution panels exist. They are available in various sizes and styles and are called different names, depending primarily on their application or use. For example, they can be called central distribution panels, main distribution panels, zone panels, patch panels, building interface panels, enclosures, or cabinets. In a fiber optic channel link, they provide the hardware attachment capability between trunk cables and IBM jumper cables. They can also be used for floor-to-floor cable connections within a building or for connections between buildings. For more information about distribution panel requirements, contact your IBM marketing representative.

Couplers and adapters

Distribution panels must provide couplers or adapters to allow attachment of IBM jumper cables. Couplers join the same connector types, while adapters join different connector types.

- IBM duplex coupler
- ST coupler
- FC/PC coupler
- MT-RJ duplex coupler (joins male to female MT-RJ)
- LC duplex coupler
- IBM duplex-to-ST adapter
- IBM duplex-to-FC/PC adapter
- FICON duplex-to-duplex coupler
- FICON duplex-to-ST adapter
- FICON duplex-to-FC adapter
- MTP-to-MTP coupler

Note: IBM recommends using IBM duplex-to-duplex jumper cables between FICON SC Duplex-to-duplex jumper cables, between coupling link devices or FICON devices and distribution panels, and IBM duplex-to-ST or IBM duplex-to-FC/PC adapters in distribution panels.

Other adapters for patch panels may be available as RPQs.

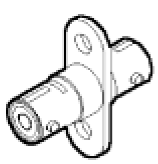


Figure 12. ST coupler

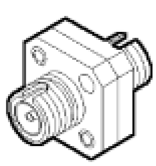


Figure 13. FC/PC coupler

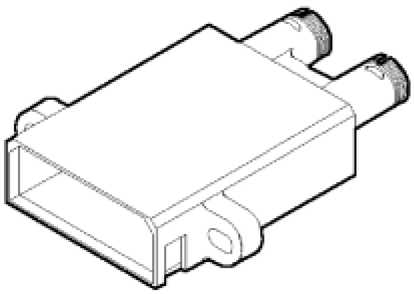


Figure 14. IBM Duplex-to-FC/PC adapter

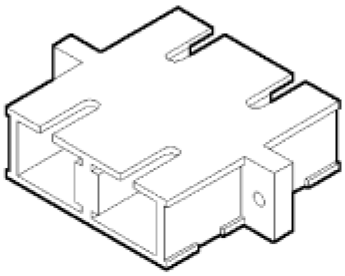


Figure 15. FICON Duplex-to-Duplex coupler

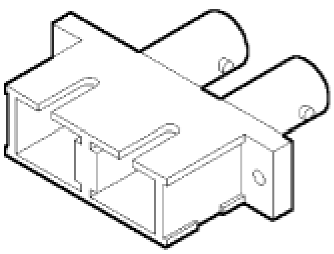


Figure 16. FICON SC Duplex-to-ST adapter

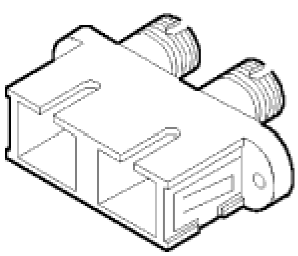


Figure 17. FICON SC Duplex-to-FC adapter

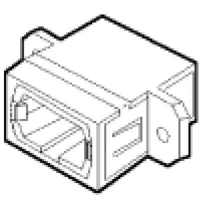


Figure 18. MTP-to-MTP coupler

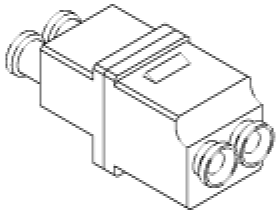


Figure 19. LC Coupler

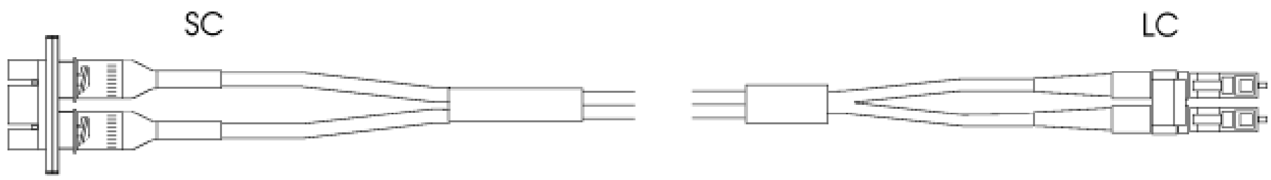


Figure 20. LC-to-SC duplex receptacle conversion kit

Mode Conditioning Patch cable (MCP)

In some fiber optic applications, it is possible to use a long wavelength (1300 nm) single-mode transceiver with multimode fiber by placing a special device known as a mode conditioning patch (MCP) cable at both ends of the link. The MCP cable resembles a standard 2 meter jumper cable.

Because of the bandwidth limitations of multimode fiber, future multi-gigabit fiber optic interconnects will likely be based on single mode fiber cables. However, many current applications use multimode fiber extensively. There is a need to re-use the large installed base of multimode fiber as long as possible; the ability to continue using installed fiber with new adapter cards also facilitates migration to higher data rate links. The need to migrate from multimode to single mode fiber affects all of the major datacom applications:

- Using MCPs, it is possible to run LX FICON channels over multimode fiber at reduced distances [550 meters (.31 miles)]. Although FICON is available in both multimode (SX) and single mode (LX) versions, future FICON enhancements which extend this protocol to multi-gigabit data rates will also require single mode fiber for distances beyond a few hundred meters.
- Coupling links for Parallel Sysplex® were originally offered as either 50 Mbyte/s data rates over 50 micron multimode fiber (using short wavelength 850 nm lasers) or 100 Mbyte/s data rates over single mode fiber (using long wavelength 1300 nm lasers). In May 1998 support for multimode fiber was withdrawn. There is a need to support 100 MByte/s adapter cards over the installed 50 micron multimode fiber to facilitate migration from the 50 Mbyte/s links.

This support will continue on coupling links using the LC interface; an MCP which adapts single mode LC to multimode SC Duplex is available for compatibility mode (1 Gbit/s) links.

The MCP is installed on both ends of a link, and occupies the same space as a standard 2 meter jumper cable. Adapter kits containing the MCPs are available with either SC Duplex connectors (to support coupling links) or ESCON connectors (to support ESCON-to-FICON migration). Different MCP adapter kits are required for 50 or 62.5 micron fiber. Using the MCPs reduces the maximum link distance to 550 meters for gigabit links (Chapter 5, "Specifications," on page 47). The maximum supported distances and fiber types for OSA follow industry standards (Table 56 on page 97). Optical mode conditioners are supported for FICON, coupling links, and OSA (see Table 6 on page 14). ESCON links using 62.5 micron jumpers and trunks can support FICON by plugging existing ESCON cables into the appropriate MCP. Note that some ESCON installations use 62.5 µm jumper cables with a 50 µm trunk, which is a supported configuration provided that this is the only transition from 50 to 62.5 micron fiber in the link and the maximum distance does not exceed 2 km. However, transitions between 50 µm and 62.5 µm fiber are not supported in applications which use MCPs. If you are planning to migrate an application with 50 micron trunks from ESCON to FICON using MCPs, then the jumper cables must be replaced with 50 micron jumper cables as well. Since IBM does not support 50 micron ESCON jumpers, the use of 50 micron SC

Duplex jumper cables is required (in other words, the 62.5 micron ESCON jumpers must be replaced with 50 micron SC Duplex jumpers). The appropriate MCPs and jumper cables are available from IBM.

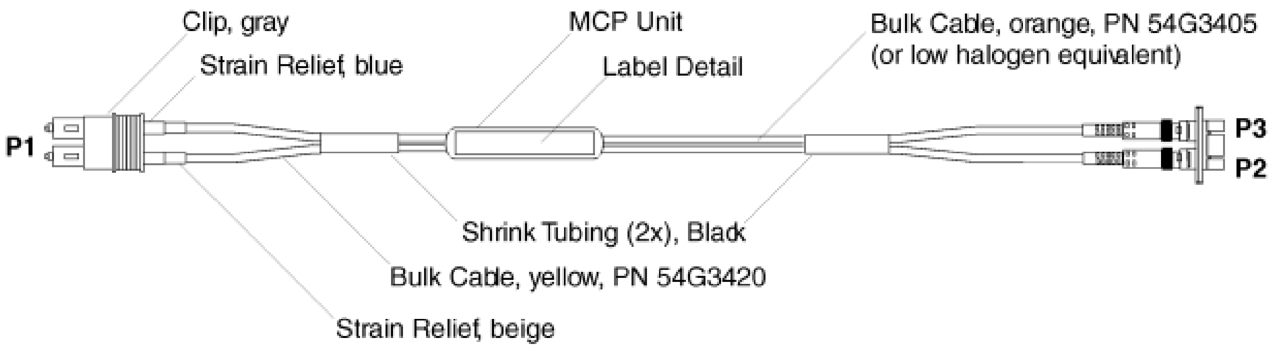


Figure 21. Mode Conditioner Patch cable (MPC) connections P2 and P3 may be terminated with either an SC Duplex or an ESCON duplex coupler. Connector P1 is available on either an SC Duplex or LC Duplex connector.

Table 6. Applications that support MCPs

Data Rate	Fiber type	Connectors for MCP	Maximum distance/link loss with MCP
FICON 1.06 Gbit/s	62.5 µm	SC Duplex	550 meters/5 dB
FICON 1.06 Gbit/s	50.0 µm	SC Duplex	550 meters/5 dB
FICON Express	62.5 µm	LC Duplex	550 meters/5 dB
FICON Express	50.0 µm	LC Duplex	550 meters/5 dB
CF links 1.06 Gbit/s	50.0 µm	SC Duplex (single mode connections available in either SC Duplex or LC Duplex)	550 meters/5 dB
Gigabit Ethernet LX 1.25 Gbit/s	62.5 µm	SC Duplex	550 meters/5 dB
Gigabit Ethernet LX 1.25 Gbit/s	50.0 µm	SC Duplex	550 meters/5 dB

Fiber optic channel link configuration

Note: IBM offers assistance in planning, design, and installation of fiber optic channel links through their Connectivity Services offering of IBM Global Services Advanced Connectivity System (IACS). For more details, contact your IBM marketing representative. Also, IBM's Fiber Transport Services (FTS) provides planning assistance, commodities, and installation for a multimode and single mode fiber trunk system. .

Fiber optic links, which use one optical fiber for sending and another for receiving, use IBM duplex connectors, duplex jumper cables, and require two trunk fibers. A link could consist of only one jumper cable that connects two devices, or it could have many cables, distribution panels, adapters, couplers, and connectors.

Parallel Sysplex using InfiniBand (PSIFB) 12x links use 12x InfiniBand (12x IFB) 12x cables which package 12 fibers for transmit and 12 fibers for receive. The 12x IFB cables utilize the Multi-fiber Push-On (MPO) connector.

Regardless of the number of cables and components, a fiber optic channel link attaches two devices and **must consist entirely of either single mode or multimode cables and components**.

Figure 22 on page 15 shows an example of a fiber optic channel link consisting of:

- Two IBM duplex-to-duplex jumper cables
- Two distribution panels, each containing an IBM duplex-to-ST adapter
- Four ST connectors
- Two trunk cable fibers
- Four trunk cable splices

For detailed diagrams of fiber optic channel link configurations, see Figure 29 on page 38 (multimode) and Figure 30 on page 43 (single mode).

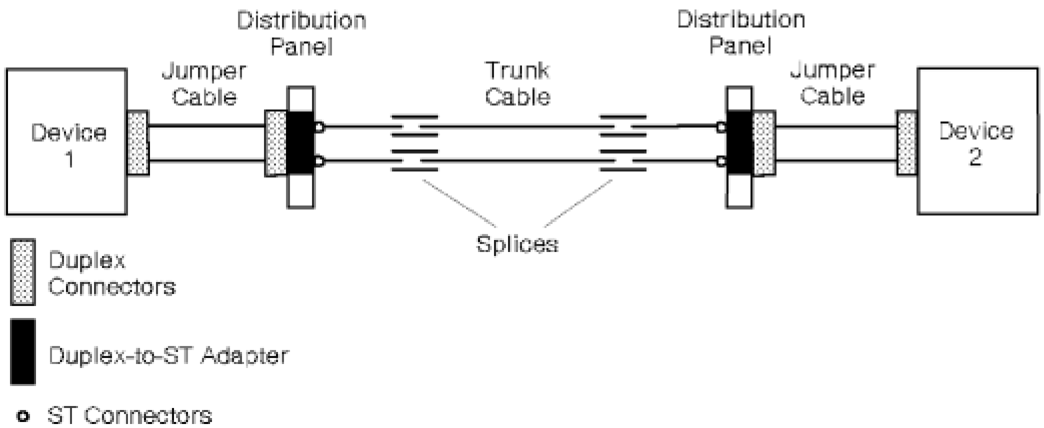


Figure 22. Example of components in a fiber Optic channel link

Chapter 2. Link, trunk, and IBM jumper cable planning

This chapter discusses fiber optic channel link planning tasks and also contains considerations and recommendations related to planning for fiber optic channel links. Refer to Chapter 5, “Specifications,” on page 47 for link specifications.

The physical location of the data processing equipment determines the link environment. This equipment can be located on a single floor within one building, on multiple floors or in multiple rooms within one building, between two or more buildings within a campus, or between two or more campuses. See “Link environments” on page 28 for a more detailed description.

IBM jumper cables are 9/125 µm, 50/125 µm, or 62.5/125 µm. Trunk cables used in a link can be 9/125 µm, 50/125 µm, or 62.5/125 µm. However, **a fiber optic channel link cannot use both 9-µm and 62.5-µm cable or both 9-µm and 50.0-µm cable.**

Certain IBM partners offer DWDM units to extend Coupling link distance beyond the 10 Km limit (6.2 miles). Please see your local IBM representative for more information.

The maximum OSA, FICON, or coupling link distance, which includes both jumper cables and trunk cables, is determined by product features and cable size.

- With 9-µm cable on a single_mode coupling link, the maximum link distance is 10km (6.2 miles)
- With 50-µm (2000MHz*km) IFB-O cable on a 12x InfiniBand coupling link, the maximum link distance is 150m (0.09 miles)
- With 9-µm cable on an LX FICON link, the maximum link distance is 4km or 10km (see Table 56 on page 97)
- With 50-µm cable on a SX FICON link, the maximum link distance is 70m to 860m (Table 56 on page 97)
- With 62.5-µm cable on a SX FICON link, the maximum link distance is 55m to 250m (Table 56 on page 97)
- With 62.5-µm cable on a SX OSA-Express2, OSA-Express3 and OSA-Express4S GbE links, the maximum link distance is 275 meters (0.17 miles)
- With 50-µm cable on a SX OSA-Express2, OSA-Express3 and OSA-Express4S GbE links, the maximum link distance is 550 meters (0.35 miles)
- With 50-µm OM4 cable on a SX OSA-Express3, OSA-Express4S and OSA-Express5S 10 GbE links, the maximum link distance is 400 meters (0.25 miles)
- With 50-µm OM5 cable on a SX OSA-Express3, OSA-Express4S and OSA-Express5S 10 GbE links, the maximum link distance is 400 meters (0.25 miles)

  Note: OM5 is Wide Band Multimode Fiber designed for increased data capacity using VCEL technology and SWDM (Short-Wavelength-Division-Multiplexing). It is designed to operate at wavelengths from 850-µm through 953-µm. It is backward compatible with OM4 applications. However, OM4 products are not compatible with OM5 wide band applications.
- With 9-µm cable on a LX OSA-Express2, OSA-Express3 and OSA-Express4S GbE links, the maximum link distance is 5 kilometers (3.17 miles)
- With 9-µm cable on a LX OSA-Express2, OSA-Express3 and OSA-Express4S 10GbE links, the maximum link distance is 10 kilometers (6.33 miles)

Certain IBM Partners offer DWDM units to extend Coupling link distances beyond the 10 Km limit. Contact the local IBM representative for more information.

Using an optical mode conditioner, the coupling links single_mode adapters may also operate over multimode fiber (50 µm) with a link range of up to 550 meters. Prior to May 1998, coupling facility channels were available for 50 µm multimode fiber at a range of 1 km; these have been discontinued.

Notes:

1. IBM will accept Request for Price Quotations (RPQs) for link distances greater than those specified above. Contact your marketing representative.
2. IBM does not accept Request for Price Quotations (RPQs) for Ethernet.
3. The distance between FICON capable devices can be greater than 10 km when using directors, channel extenders, or wavelength multiplexers. For more information, see *Introduction to IBM S/390® FICON*, SG24-5176.
4. The Fibre Channel Standard specifies a 4 hop limit for a network including directors.

IBM offers assistance in planning, designing, and installation of Fiber Optic links through its Connectivity Services offering of IBM Global Services Fiber Transport Services. For more details, contact your IBM marketing representative. Also, IBM's Fiber Transport Services (FTS) provides planning assistance, commodities, and installation for a multimode or single mode fiber trunk system.

Planning considerations

Fiber optic link planning should be approached similar to planning for any other cabling system. Depending on the location of data processing equipment, links can consist of various combinations of optical cables and components. Fiber optic channel links will become an integral part of an IBM data processing system environment. They should, therefore, be considered a long-term investment in future communications requirements.

Links do not necessarily require distribution panels and trunk cables. For example, a link environment in one room could consist of only IBM duplex-to-duplex jumper cables. This method would not incur much additional cost because most devices are shipped with jumper cables. Because planning for links should include future growth, consider the following factors carefully.

Specifications

Links must operate within certain specifications to provide reliable transmission characteristics. See Chapter 3, "Calculating the loss in a multimode link," on page 35 for a multimode link loss calculation example, Chapter 4, "Calculating the loss in a single mode link," on page 41 for a single mode link loss calculation example, and Chapter 5, "Specifications," on page 47 for link and cable specifications.

Flexibility

Links should support installation and relocation of existing equipment and processes, while providing connectivity for future applications.

Growth

Links should support not only installation and relocation but system expansion as well. A FICON, or coupling link environment can extend well beyond the 122 meter (400 ft.) distance restriction of a data processing environment containing bus-and-tag cables. Migrating to a, FICON, or coupling link environment not only enhances growth potential, but growth can occur with minimum system disruption.

Cable installation

Fiber optic cable is much smaller and lighter than bus-and-tag cable. Only one duplex fiber optic cable is required for information transfer. This allows a reduction in under-floor cable congestion, thereby simplifying installation, migration, and greatly reducing cable weight.

The cable plant must satisfy the industry standard specification to minimize connector reflections and maintain link loss budget specification. See Table 56 on page 97.

It is highly recommended that the fiber optic link be thoroughly analyzed to ensure the cable plant specifications (total cable plant optical loss as well as connectors/splices return loss) are being met for that link length. For example, the Fibre Channel standard requires all connectors and splices to have a return loss greater than 26 dB as measured by the methods of IEC 61300-2-6.

The most common source of cable plant optical link problems is associated with the various connections and splices in the optical link. Dust, dirt, oil or defective connections may cause a problem with high speed channels, such as 8 Gbps, whereas, lower link data rates, such as 1, 2, or 4 Gbps may be unaffected.

Fiber optic cleaning

If you are experiencing excessive bit errors, it is recommended that you first clean and reassemble the connections, using the Fiber Optic Cleaning Procedure found in the *Maintenance Information for Fiber Optic Links*, SY27-7696. The information includes the procedure and materials required. The cleaning is best performed by skilled personnel. The cleaning procedure may need to be performed more than once to ensure all dust, dirt, or oil is removed. Fiber Optic link testing information is also contained in this publication.

Cost

Although FICON, FCP, and coupling links require an initial investment, they can provide long-term savings when considering the cost of future expansion and relocation of a data processing environment.

Right-of-ways

A right-of-way is a legal right of passage over another person's property. Right-of-way owners are usually government agencies or common carrier companies responsible for regulation of telecommunication facilities and could include public utilities, railroads, and state, city, or local governments. Because FICON, FCP and coupling links could require the use of one or more right-of ways, users must consider right-of-way access. Users may want to consider one of several qualified DWDM solutions from our IBM business partners for help in solving their right-of-way problems.

Homologation exemption

The Long Reach 1x InfiniBand feature (HCA3-O LR, FC 0170) uses an LC Duplex connector and jumper cable qualified by IBM. Only IBM qualified cables plugging directly into the optics modules on the Long Reach 1x InfiniBand feature are supported. These cables are for use within the building only and are not intended to go outside the building. All attachments to an outside cable plant (including public "dark fiber") are supported only through a patch panel or WDM unit.

Wavelength-division multiplexing (WDM)

WDMs are typically used in a multi-site Parallel Sysplex and GDPS® environment. IBM will only support WDM products qualified by IBM Z for usage in GDPS solutions. Clients must review and ensure that the vendor products they plan to use have been tested and qualified by IBM using the same laboratories and procedures used to test all aspects of a GDPS environment. A list of qualified WDM products that support GDPS can be found on Resource Link: https://www.ibm.com/servers/resourcelink/lib03020.nsf/pages/systemzQualifiedWdmProductsForGdpsSolutions?OpenDocument&pathID=.

If you are new to Resource Link, you can register free for an IBMid and password at: https://www.ibm.com/servers/resourcelink.

Link planning tasks

Consider the following link planning tasks only after determining data processing equipment needs and attachment requirements.

Physical layout

When planning the physical layout of data processing equipment, determine the:

- Location of the equipment
- Location of the users
- Number and location of the physical connections
- Availability and type of right-of-ways

Determine if the layout can be achieved by using only jumper cables or if it requires trunk cable and distribution panels. See "Link environments" on page 28 for a more detailed description.

Cabling requirements

After determining the logical link configuration, plan the cabling requirements:

1. Use a floor plan to assess the possible link paths; then:
   a. Determine the length and type of each link (for example, jumper only or jumper and trunk, and multimode or single mode).
   b. Identify and locate each connector, splice, and distribution panel.
2. Make sure that the:
   a. Link specifications agree with the fiber cable types. See Chapter 5, "Specifications," on page 47.
   b. Calculated link loss is within specifications. See Chapter 3, "Calculating the loss in a multimode link," on page 35 or Chapter 4, "Calculating the loss in a single mode link," on page 41.
   c. Links conform to national, state, and local building codes.
3. Determine a labeling scheme for ease of installation and future cable management considerations.

Installation planning

Before installing a link, consider the following:

- Cable routing diagrams
  - Location and length of each link
  - Type, location, and identification of connectors, adapters, and couplers
  - Locations of splices and distribution panels
- Manufacturer data sheets
  - Cables
  - Bend radius control
  - Connectors
  - Strain relief
  - Splices
  - Distribution panels
  - Attached devices
- Warranty statement (for new installations)
- Link verification. Contact IBM for more information.

The link must be compatible with the devices that attach to it. See Chapter 5, "Specifications," on page 47 for the cable specifications required to support FICON-capable, or coupling facility channel-capable devices.

Other devices and applications can also attach to a trunk cable. Refer to the appropriate planning publications for specific device and cable requirements.

Trunk cable planning recommendations

Trunk cable

Optical fiber trunk cable provides a connection between distribution panels and is used between floors and between buildings. It may also be used on the same floor where the number and complexity of connections require the use of multiple jumper cables. Such cabling is frequently referred to as *backbone cabling*.

Optical fiber trunk cables typically contain from 12 to 144 fibers (6 to 72 pairs) with a strengthening material and an outer jacket. The jacket material may be composed of metal sheathing, fabric, or any one of several man-made materials, depending on the degree of environmental protection required. The physical configuration of the trunk cables will vary depending on user requirements, environmental conditions, and the type of installation required (for example, aerial or underground).

IBM trunk cable recommendations

The 62.5/125µm multimode optical fiber was initially recommended by IBM and the American National Standards Institute (ANSI) as the fiber of choice for long wavelength applications. Single Mode fiber is now recommended for all new installations. For short wavelength applications at limited distances, 50/125µm multimode optical fiber is preferred.

Note: Single mode and multimode cables cannot coexist in the same fiber optic channel link. Additionally, we recommend that multimode cables of different core sizes (62.5µm and 50µm) should not coexist in the same link.

For short wavelength applications at limited distances, 50.0/125 multimode optical fiber may be used. See Chapter 5, “Specifications,” on page 47. Maximum distances vary based on application and fiber specifications. Obtain all attaching product specifications before selecting fiber for a trunk installation. Various IBM products can use other fiber sizes to accommodate customer requirements worldwide. For example, 50/125 multimode fiber is used extensively in Japan and some European countries. However, use of these alternative fibers may not optimize distance capabilities.

The 9- to 10- µm single mode optical fiber supports higher data rates and longer distances; therefore IBM considers it the direction for future products. See Chapter 5, “Specifications,” on page 47.

If you plan to install a multimode optical fiber trunk, IBM recommends that you also consider installing single mode optical fiber at the same time to support future high-bandwidth applications. See Appendix B, “Fiber optic channel attachment options,” on page 97.

Horizontal cable

Some applications may require optical fiber cable between the distribution panel and the work area. IBM recommends that such cabling be installed in addition to copper cable for data transmission and that the cable installed should follow the recommendations of the EIA/TIA-568 *Commercial Building Telecommunications Wiring Standard*. Horizontal cabling with optical fiber generally requires no more than four strands of fiber (often only two) and may effectively be placed as part of a hybrid or composite cable that may consist of other transmission media.

IBM recommends that a duplex optical fiber connector be used in the work area and at the distribution panel to assist in maintaining polarity.

Connectors

Trunk fibers should be attached to high-quality, low-loss, physical-contact connectors, which are provided by several manufacturers. The most common optical connectors used in the data communications industry include the ST and FC/PC physical-contact connectors. Both are available for single mode and multimode cables. IBM recommends using either ST or FC/PC physical-contact connectors for attaching trunk fibers to IBM duplex adapters installed in distribution panels. For equipment which is compatible with the FibreConnection (FICON) interface, the coupling link may provide connectivity with the industry-standard FICON SC Duplex connector, which is a physical contact connector available for both multimode and single mode cable applications.

Also available are Multifiber Terminated Push-on (MTP) connectors that are used for connecting FTS-III Direct Attach trunk cables to FTS-III Direct Attach harnesses.

Planning for future fiber requirements

Each link requires two trunk fibers. The cost of installing the trunk cable and cable conveyances usually far exceeds the cost of the cable. This is especially true when a trunk cable must enter or exit a building either above ground or underground. When planning the number of trunk fibers needed, therefore, consider allocating additional fibers for facility expansion and future data processing requirements. Each link and application should be considered individually to evaluate this recommendation.

Alternate trunks

Optical fiber allows much greater distances between devices than copper bus-and-tag cables. For this reason, link availability can be affected by more external factors, such as construction activities, extremes in temperature, and natural disasters. All trunk cable routing should therefore be reviewed for possibilities of interruption. If these interruptions can cause a critical situation, consider installing physically separate trunks. If one trunk becomes damaged, the other trunk can then be used to minimize interruption time.

Security

Although optical fiber is difficult to tap without being detected, it is possible. The level of data security needed should therefore determine the precautions taken to minimize this possibility.

Distribution panel planning recommendations

Trunk cables and jumper cables attach to a distribution panel through various connection methods. IBM offers 1) different types of distribution panels, 2) multimode jumper cables that have different connector types at the distribution panel end, and 3) adapters and couplers for the panel connections. See "Distribution panels" on page 11 and "Couplers and adapters" on page 11. Contact your IBM marketing representative for more information.

The following paragraphs describe recommendations for locating distribution panels and list some features that a panel should contain.

Panel locations

Distribution panels should be located to provide:

- An entry, exit, and connection point for trunk and jumper cables
- A concentration point for jumper cables to allow manual I/O reconfiguration

  Note: This requires additional jumper cables.
- An access point to service a zone or area of processors and devices

Because of fiber optic channel link distance capabilities, panels can also be located away from the processors and control units, thereby saving floor space.

Panel features

Distribution panels should contain an adapter and coupler panel, a splice tray, and a storage area for jumper cable slack. Its design should also provide strain relief and radius control for jumper cables.

- **Adapter and coupler panels** provide the hardware to join identical (coupler) or different (adapter) cable connectors. They can be used separately or in combination within the panel.

- **Splice trays** should have the same cable capacity as adapter and coupler panels and should be equipped with hardware to provide strain relief for all cables entering and exiting the tray.
- **Jumper cable slack storage** provides adequate organizing hardware and storage space for excess jumper cable. The hardware should allow identification and removal of an individual jumper cable, without having to disconnect or remove other jumper cables within the panel.
- **Jumper cable strain relief and radius control** provides hardware that prevents damage to the jumper cables caused by excessive bending or pulling of the cables.

Determining the direction of light propagation

In IBM applications, light travels (propagates) in only one direction within each fiber. The direction of light propagation must be considered when installing and connecting jumper and trunk cables. The following explains how to determine this direction for links that use trunk and IBM jumper cables.

The cables and connectors for the coupling facility channels are industry standard parts, and may not be supplied by IBM. Consult the manufacturer's specifications to determine the characteristics of this cable.

Light propagation in an IBM link

Figure 23 on page 23 shows the physical fiber connections for three links. Notice that an odd number of physical "crossovers" of each fiber must exist for correct light propagation to occur. IBM duplex-to-duplex jumper cables are keyed, which maintains the crossover requirement within the cable. When a link uses both trunk and jumper cables, the trunk connections must ensure that an odd number of crossovers exist.

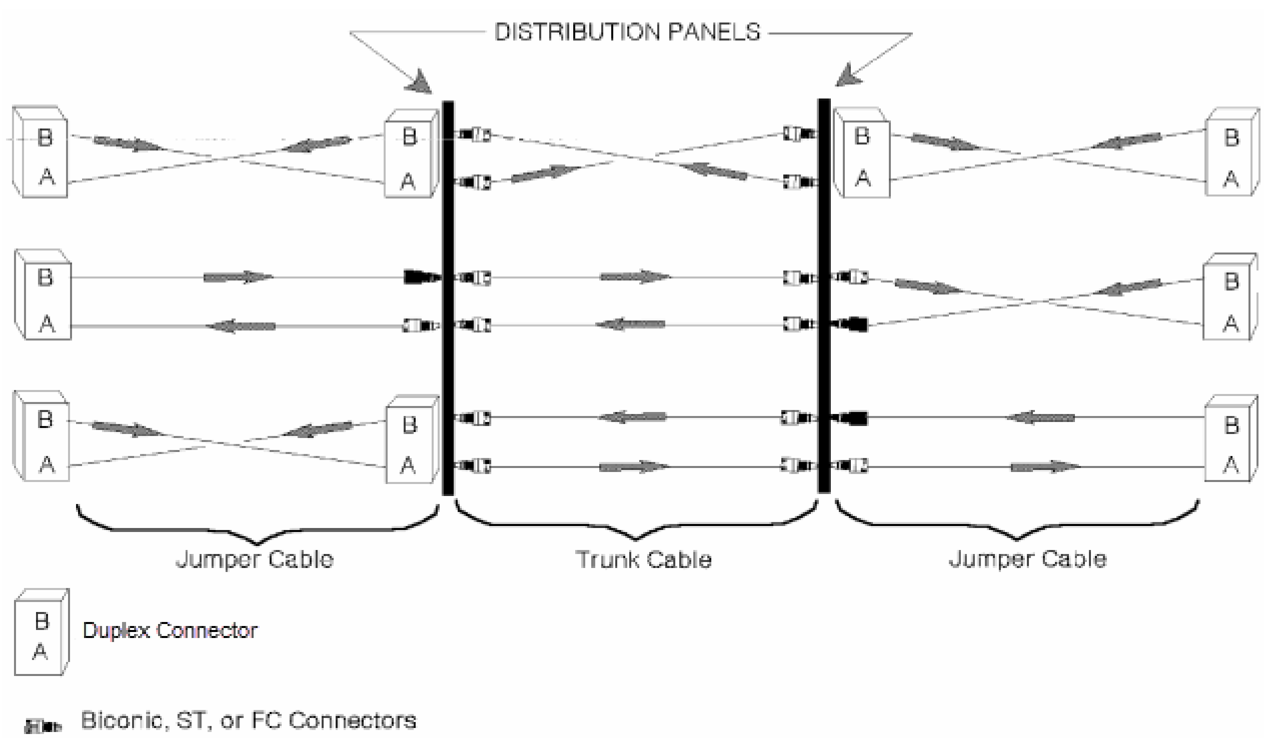


Figure 23. Determining direction of light propagation in a link

Light propagation in an IBM jumper cable

The transmitter (output) of each FICON capable, or coupling facility channel-capable device propagates light to the receiver (input) of the next device. IBM jumper cables provide a method to determine this direction:

- IBM duplex connectors have the letters A and B embossed on the plastic housing

- The connectors used on IBM's duplex-to-biconic, duplex-to-ST, and duplex-to-FC/PC cables are color-coded either by a white or black marking or by the connector color.
- 12x InfiniBand jumper cables contain two MPO connectors on each side, with one labeled TX for transmitter, the other RX for receiver. The ports on the Host Channel Adapter (HCA) cards also are labeled TX and RX. To properly attach the cables, connect the MPO connector labeled TX to the HCA port labeled TX, and connect the MPO connector labeled RX to the HCA port labeled RX. The maximum passive optical loss is limited to 2.06dB. There is no restriction placed on the number of intermediate connections for 12x InfiniBand coupling links, provided that the 2.06dB requirement is met.
- System z10® does support going through a patch panel with 12x InfiniBand links. It is highly recommended that there be no greater than 2 hops.

The direction of light propagation in an IBM duplex-to-duplex jumper cable is from B to A. In IBM's duplex-to-biconic, duplex-to-ST, and duplex-to-FC/PC jumper cables, this direction is from B to black.

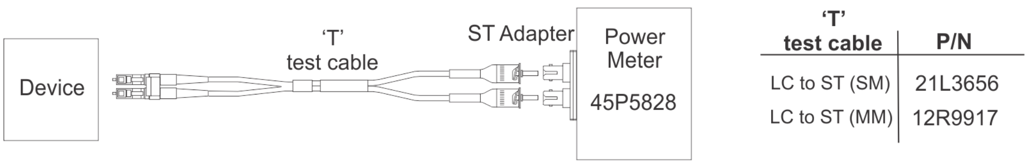


Figure 24. LC cable

Coexistence of jumper cables and bus-and-tag cables

Consider the information in the following paragraphs when installing fiber optic jumper cables in the same environment as copper bus-and-tag cables.

Physical characteristics

Similarities:

- Durable and rugged
- Highly reusable
- Withstands high tensile and compressive forces during installation and removal

Differences

- Bus-and-tag cable is about 75 times heavier and about five times the diameter of a jumper cable.
- Bus-and-tag cable has inherent radius control due to its stiffness, while jumper cable can be easily bent and requires radius control.

  Note: Minimum bend radius specifications also apply when handling fiber cable. If not handled properly, small fractures of the glass medium can result in high attenuation losses.

Cable installation considerations

Jumper cables could become tangled with bus-and-tag cables or connectors, which could cause damage to a jumper cable or connector when moving bus-and-tag cables. When all cables are routed properly and the cable environment is organized, no additional fiber cable protection is required. The amount of cable activity in a particular environment, however, should determine this need.

Cable design considerations

The skills required to design a cabling system are very different from those required to install optical fiber cable physically. A cabling system design must meet the requirements and limitations of its environment while satisfying the needs of the attaching products. The cabling system design must be completed before the physical installation can begin.

The expertise of the cabling system designer becomes more important with the increasing complexity of the cabling system. The designer needs to understand the needs of the customer and the products to be installed before deciding how the optical fiber cable will be distributed throughout the property. This will require an on-site evaluation of the premises. If the system will be installed in a new facility, the system designer should be involved before the system blueprints are completed.

Typical cabling system designs include the following:

- Building entrance specifications for the cables
- Number, location, size, and environmental requirements for telecommunications closets and equipment rooms
- Location, protection, size, and type specifications for the horizontal and vertical backbone system
- Distribution system type, specifications, and routing information
- Fire prevention, electrical, and mechanical requirements
- Conduit system installation requirements
- Component specifications and installation requirements
- Cable construction and fiber count
- Labeling and cable management criteria
- Installation verification criteria

Recommendations

Each data center must be carefully analyzed to determine the amount of cable activity or disruption that could occur under the raised floor. If the activity creates a significant exposure to the fiber cables, do any or all of the following:

- Consider using IBM's Fiber Transport Services (FTS) to:
  - Determine the minimum number of additional under-floor multimode cables required
  - Route as much under-floor trunk cable along the perimeter of the data center as possible
  - Provide an efficient use of conveyance systems for the jumper cables.
- Educate personnel about proper installation and handling procedures for fiber cables.
- Bundle the fiber cables. For example, use tie wraps to reduce the possibility of damage.
- Route the fiber cables to minimize the exposure caused by sharp edges, excessive bends, or congestion caused by bus-and-tag cables.

If the previous methods cannot be implemented and protection is necessary, IBM provides conveyance kits that are designed to protect fiber cables. Also, fiber cables can be installed in conduits, tubings, raceways, troughs, or other protective devices.

IBM design recommendations

The following list outlines IBM's basic design recommendations:

- Minimum of 10% spare fibers between distribution points for maintenance
- The use of physical-contact connectors
- Single Mode fiber installed for trunk cabling, if future need or long-distance links are foreseen
- A conduit system with interduct and pull-cords for future expansion
- Sufficient trunk fibers to accommodate short-term growth and migration.

Note: One way to determine the quantity of spare fiber for growth is to increase the planned quantity by 30%. If the future applications are unknown, plan multimode so that loss does not exceed 5 dB at 1300 nm. This level of loss will accommodate all current applications and leave a margin for future applications that may have more stringent attenuation requirements than those that are currently available.

Right-of-way planning considerations

The introduction of optical fiber into the data communications environment has provided extended distance connections. This sometimes results in a requirement to enter and exit other public and private rights-of-way not under your direct control. This added requirement to installation planning may be a new consideration for many customers. The extended links offered today require dedicated pairs of fiber cable from one end of the link to the other. These dedicated fibers are sometimes referred to as **dark fiber** in that there are no active components on the link other than the customer's equipment at each end. The requirement for dark fiber is new not only for the customer but also, in many cases, for the traditional providers of services between facilities. Therefore, it is important to use early planning and negotiation for rights-of-way for dark fiber to install extended distance links on schedule.

Because every installation has unique characteristics, it is not possible to provide one approach to meet all planning considerations. The following factors should be considered when planning for any right-of-way requirements:

- Fiber specifications (See Chapter 5, “Specifications,” on page 47).
- Growth and migration plans
- Numbers of fibers to include current, growth, and service spares.

  As a general rule, the total number of optical fibers installed should be equal to the sum of the following:

Requirement		Sum
Total number of fiber strands required immediately	=	______
Plus 10% (for spares)	=	______
Plus two terminated pairs (if spares are not terminated)	=	______
Plus 30% of the number required immediately (for future growth)		
Total fiber strands required	=	______

  Be prepared to increase the total optical fiber required if the environment seems to have a high chance of damage. Once a trunk cable is terminated and installed, opportunities for damage are substantially reduced.
- Physical routing considerations include
  - Redundancy and alternate cable installation

    Additional optical fiber may be needed (beyond that needed to meet requirements, spares, and projected growth). Because optical fiber allows for increased distances, all external cable routings should be reviewed for tolerance to interruption. If quick availability is critical, redundant cables and trunks in several locations may minimize system downtime during restoration activity.

    Major factors to be considered in this decision should include

    - Security from physical damage
    - Disaster recovery
    - Cost and time to repair (as opposed to initial installation costs)
    - Physical limitations and risks of the proposed right-of-way route
    - Post Telegraph Telephone (PTT, the National Post and Telecommunication Authority), contractor, and vendor capabilities
    - Serviceability – ease of access to the installed cable and trunk for inspection, repair, and restoration

- Environmental factors affecting long-term reliability. Adverse forces (such as extreme temperatures, precipitation, dust, chemicals, nuclear radiation, and construction activities) may degrade the installed cable.
  - Use new as opposed to existing facilities
  - Physical installation considerations
  - Reliability
  - Common carrier or governmental regulatory constraints
  - Tariffs
  - Incidental considerations (for example, removal and replacement of walkways and streets, relandscaping, and renegotiation of other utility rights-of-way).
- Building entry and exit
  - Connectors and adapters
  - Physical-contact connectors (SC, ST, or FC/PC) are recommended for trunk termination. Duplex-to-ST or Duplex-to-FC/PC adapters are recommended in distribution panels.
  - Selection of distribution panels
  - Interior building cable routing plans
  - Routing types (such as trays, conduit, and raceways)
  - Building and wiring codes (for example, National Fire Protection Association Codes (NFPA), National Electrical Codes (NECs), and local codes)
  - Cable densities, strain relief, bend radius control, splices, and considerations about storage of cable.
- Contractor selection and contract agreements.
- Labeling
  - Panel labeled with laser warning as required
  - Cable routing control
- Record keeping
  - Installed cable specification
  - Cables routing control
  - Serviceability
  - Warranty.
- Costs

  Installation costs as opposed to component costs must be balanced to accommodate growth and migration.
- Facility security requirements (such as lockable panels, lockable and controllable closets, security along rights-of-way, inspection schedules).
- Simultaneous use of optical fiber for video and voice is not an option for most data communications products at this time due to problems in multiplexing.
- Compatibility of all components is essential for reliability, serviceability, and aesthetics, especially in installations where optical fiber already exists.

Some skills required to install optical fiber components are different from those required to install copper. Contractors employed to install these components should have appropriate training and experience. This is especially important for optical fiber cable termination and splicing.

Correct handling procedures for optical fiber cable are identified by the manufacturer and should always be followed during installation. These specifications include minimum bend radius, maximum pulling tension, pulling lubricants allowed, and recommended pull-in procedure. The cable manufacturer should also recommend the correct procedures for cable sheath removal, stripping, and strain relief. The manufacturers of various types of connectors and splices ship instructions for the correct installation of their products (written for trained personnel).

Link environments

The physical location of the data processing equipment determines the link environment. This equipment can be located:

- On a single floor within one building
- On multiple floors or in multiple rooms within one building
- Between two or more buildings within a "campus"
- Between two or more campuses

The following paragraphs describe and show an example of each environment. The major differences are the type (single mode or multimode) and location of trunk fiber, the purpose of the distribution panels, and the cable routing from the panels. Figure 25 on page 29, Figure 26 on page 31, Figure 27 on page 33, and Figure 28 on page 34 show examples of the four fiber optic channel link environments. In these figures:

- Trunk cables (dotted lines) attach to distribution panels. IBM recommends use of ST or FC/PC physical-contact connectors.
- IBM jumper cables (solid lines) attach devices to distribution panels, using various combinations of connectors, adapters, and couplers within the panel.

Single-floor link environment

A single-floor link environment (Figure 25 on page 29) uses multiple, strategically placed distribution panels that are connected by trunk cable to a central distribution panel. This environment provides flexibility and growth because installation or relocation of equipment can be performed by using short multimode jumper cables, while causing little or no disruption to operations. After the equipment is relocated or installed, it can be reconnected into the closest distribution panel.

Other advantages include enhanced cable management capabilities and a more organized under-floor cable layout.

Consider the following when planning for a single-floor link environment:

- The Fiber Transport Services (FTS) offering of IBM Global Services Advanced Connectivity System (IACS) provides planning assistance, the required commodities, and the installation of this type of link environment. Contact your IBM marketing representative for more information.
- Place the distribution panels according to the location and number of devices and channels.
- Install enough spare trunk fibers for future growth. Although spare trunk fibers can remain unterminated without causing system disruption, installing connectors during trunk cable installation could be more cost-efficient and convenient.
- Each trunk connection and splice causes additional link attenuation (loss). The cabling design must consider the number of connectors and splices when calculating the link loss.
- This environment requires additional fiber optic jumper cables, which must be purchased separately.

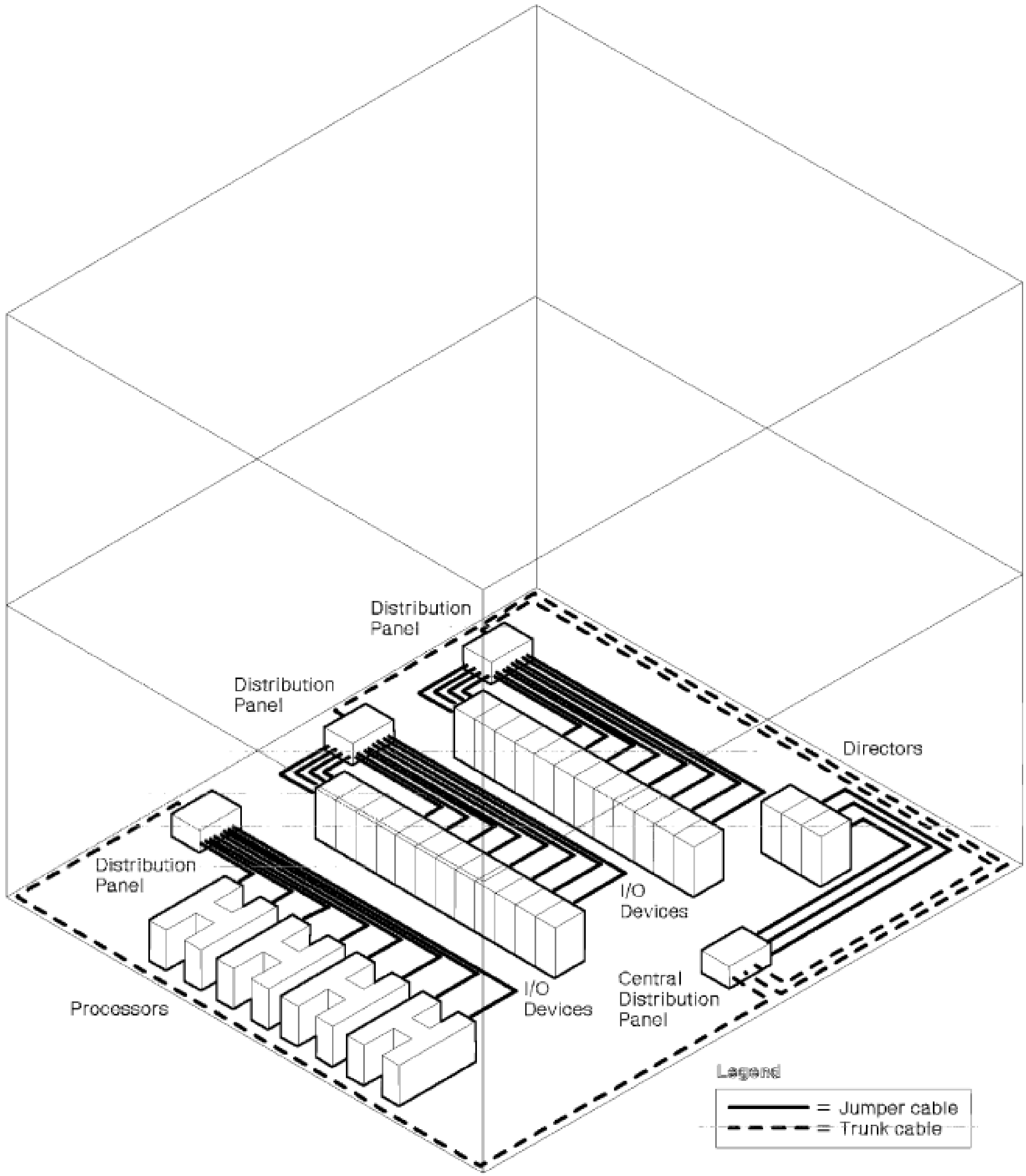


Figure 25. Example of a Single-floor link environment

Multifloor or multiroom link environment

Data processing equipment can be located on multiple floors or in multiple rooms. These could be adjacent rooms on a single floor, adjacent floors in a single building, or widely separated rooms or floors within a single building. This type of trunk system can be installed using 1x InfiniBand and FICON/FCP channels, since they support a maximum distance of 10 km (6.2 miles).

Although the cost is similar to a single-floor environment, the design factors could be more complex. For example, access between floors or rooms could require structural modification. Also, trunk fiber cable routing could be through hazardous areas or in areas where building wiring also exists. As the complexity of this environment increases, it becomes necessary to have a more organized arrangement of trunk cables and distribution panels.

The flexibility that exists when using distribution panels and trunk cables allows easier initial installation and reconfiguration. It also allows placement of trunk cables between the floors or rooms in a more permanent location. This environment involves additional factors, such as building codes, cable routing, contractor information, security, redundancy, and damage and disaster protection. Because these factors did not exist in single-floor environments, installation planning decisions become more important. Also, because this environment requires distribution panels and trunk cables, the number of connections for each link increases. This causes a higher link loss, thereby making link-loss calculations more critical.

A multifloor or multiroom link environment usually has more relocation activity within a floor or room, but not necessarily between floors or rooms. For example, consider a configuration that has I/O devices in one room or on one floor and processors in another room or on another floor. The I/O devices should have connection capability to multiple processors, and processors should have connection capability to other processors. The need to physically move more I/O devices to the processor area or a processor to the I/O area, however, might never be necessary.

The fiber cabling planned for this link environment cannot, therefore, provide a single solution consisting of only trunks and distribution panels. Cable planning must provide flexibility for adding and relocating jumper cables and to allow connection capability for many devices.

Figure 26 on page 31 shows a data processing configuration that occupies two floors (or rooms) within the same building. The first floor or room contains processors and I/O devices, while the second floor or room contains only I/O devices.

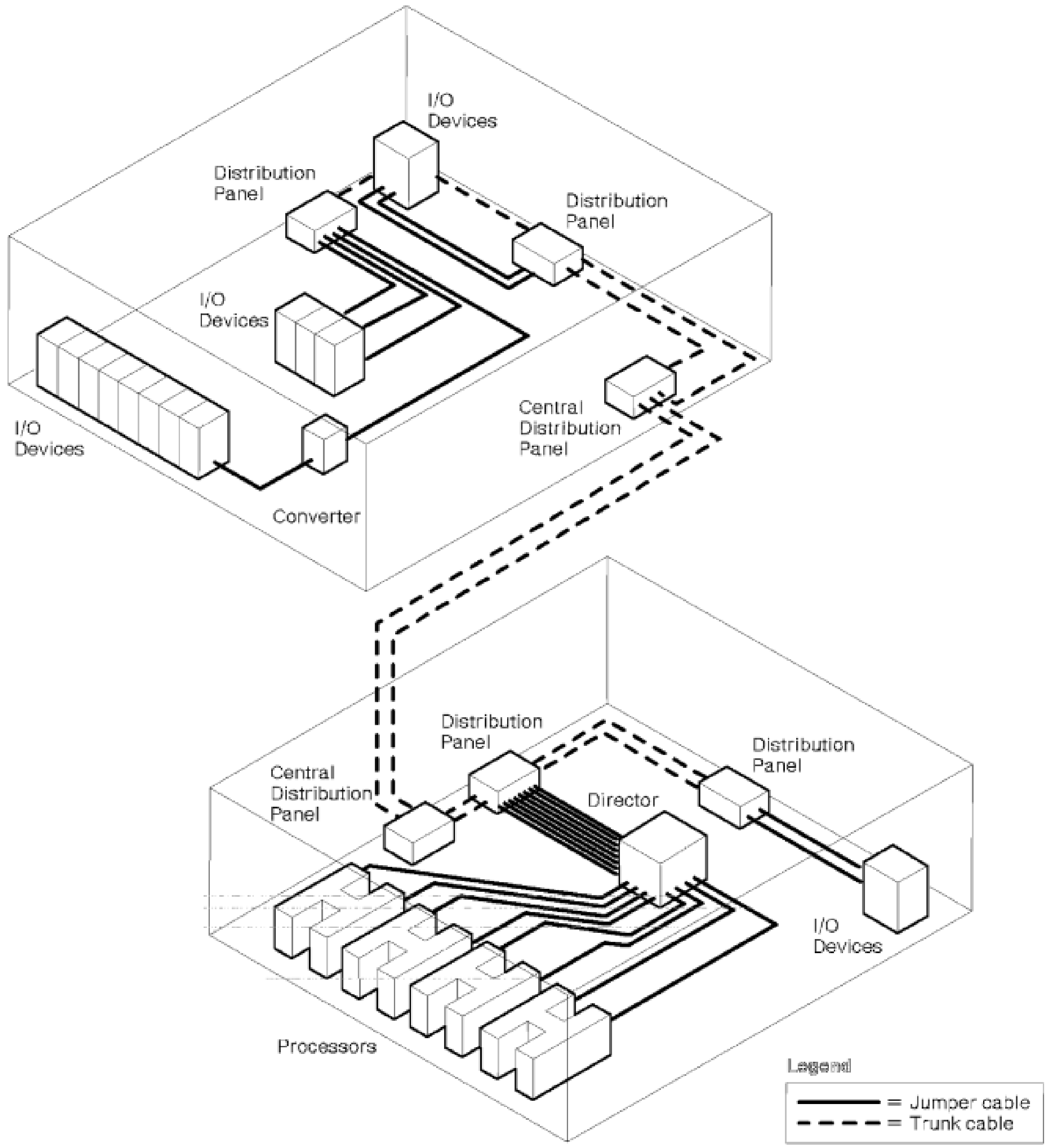


Figure 26. Example of a Multifloor or multiroom link environment

Single-campus link environment

Data processing equipment can be located in a multiple-building (campus) environment in which distances between buildings could vary greatly. The buildings could contain separate data centers, with each having distributed resources similar to a multiple-floor environment. The major planning factor in a single-campus is that the user controls all the land, and cable routing does not involve right-of-ways.

In addition to the considerations that exist for the single-building links, planning for a single-campus link environment involves outdoor trunk cables (above ground, underground, or both). This environment can use either multimode or single mode trunk cable. The major consideration for which trunk type to use is the link distance and product features.

For cable options seeTable 56 on page 97 Fiber optic channel attachment options

This environment could have existing facilities, such as utility poles or underground conduit, that can be used to install cables between buildings. When installing new trunk cable, only the building-to-building (interbuilding) facilities must be evaluated. If interbuilding trunk cable already exists, it must be evaluated and verified during cable installation planning. For example, users should supply information that specifies what cables, connectors, distribution panels, adapters and couplers are already installed. Interbuilding trunk cable installation could also involve using contractors who are familiar with installing and testing fiber optic cables.

Regardless of what facilities exist, each building in a single-campus link environment should contain a “building interface panel”. This panel provides a common access point for each building that can be used to splice trunk cable, prepare a fiber for installing a connector, and install connectors. Using a building interface panel is especially important when considering the possibility of damage to outdoor trunk cables caused by construction or some other activity. Using building interface panels, however, contributes to the total link loss because of additional connections. They should, therefore, be used only if the link loss introduced by additional connections will not exceed the maximum loss allowable for each link. If building interface panels are used, however, trunk fibers can be spliced at the panel rather than using connectors, thereby reducing the connection loss. See Chapter 5, “Specifications,” on page 47 for link specifications.

Figure 27 on page 33 shows an example of a data processing configuration that has two buildings within a campus. This environment uses building interface panels and includes two Directors.

- The two buildings are connected through an above ground or underground trunk cable, which enters both building interface panels.
- A trunk cable is installed in Building 001 (bottom of figure) between the distribution panel used for the I/O devices and another distribution panel attached to the building interface panel.
- Building 002 has a Director attached to the building interface panel that also attaches to another distribution panel.

This provides a common trunk (sometimes called a “backbone”) for these two buildings.

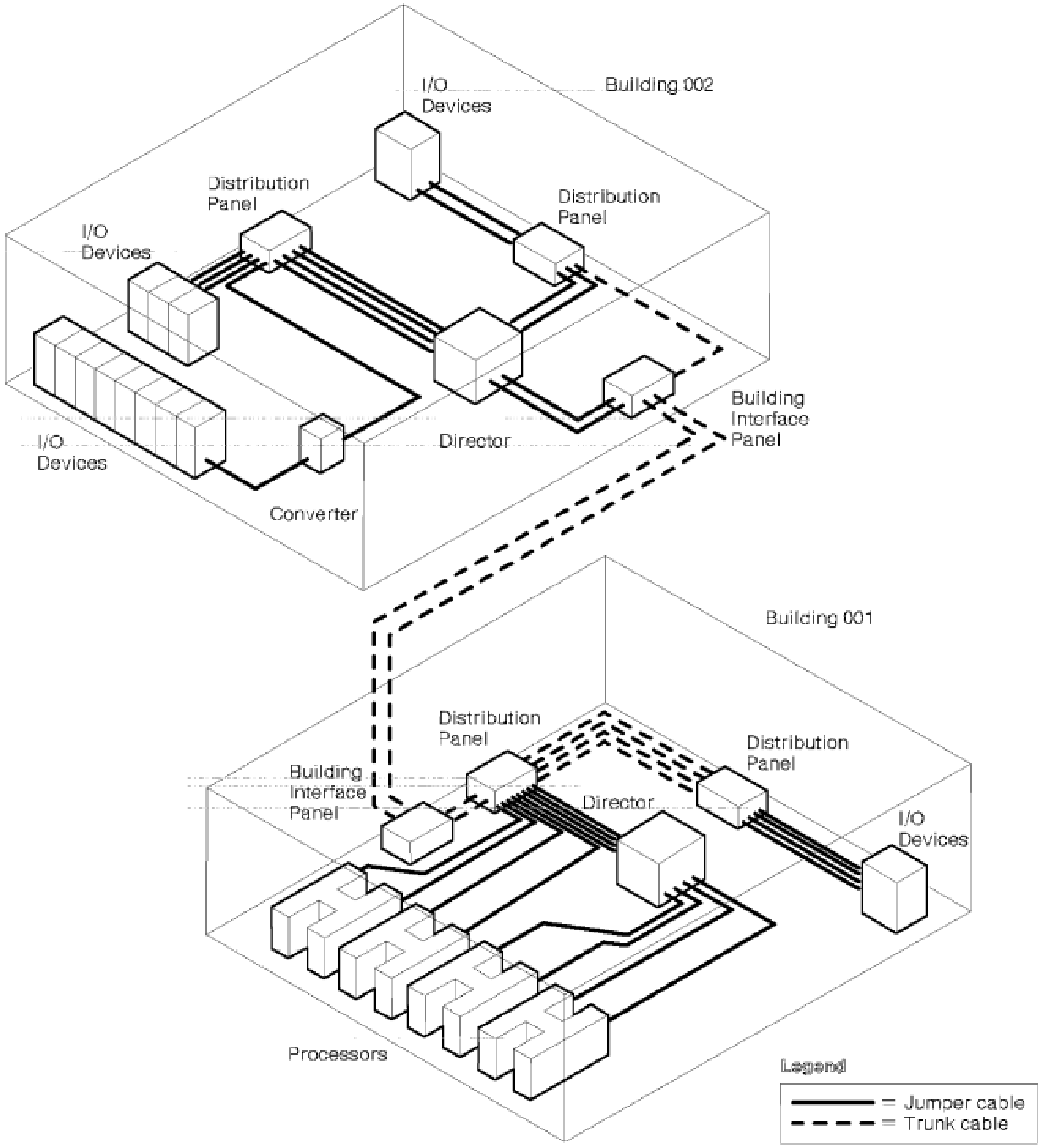


Figure 27. Example of a single-campus link environment between two buildings

Multicampus link environment

Planning for a multicampus link environment typically involves the same considerations as the other three environments and includes additional considerations. Multicampus links usually require single mode trunk cable because 1) the distance between buildings is greater than 3 kilometers (1.86 miles), and 2) the connections between buildings are outside the user's control, thereby requiring access to a right-of-way. Negotiation for using a right-of-way, however, can greatly extend the time required to plan a multicampus link and must be considered.

The following lists additional planning considerations for a multicampus link:

- Leasing of dark fiber

Most telecommunication facilities are terminated by data communications equipment (DCE) and have repeaters, conditioning, or exchanges within the link. A "dark" fiber has no active components either in the link or at the termination points.

- Increased number of connections

  When private contractors, common carrier companies, or governmental agencies install fiber cables across public right-of-ways, they sometimes connect the fibers to a building interface panel. This adds to the link loss because it induces additional connections.

- Common carrier regulatory constraints
- Governmental regulatory constraints
- Tariff zones
- Reliability, availability, and serviceability factors

Figure 28 on page 34 conceptually shows a multicampus environment. Notice that the figure does not indicate building boundaries. This is because a multicampus environment could be distributed over a wide geographical area and each building could have an unequal amount of data processing equipment. Contact your IBM marketing representative.

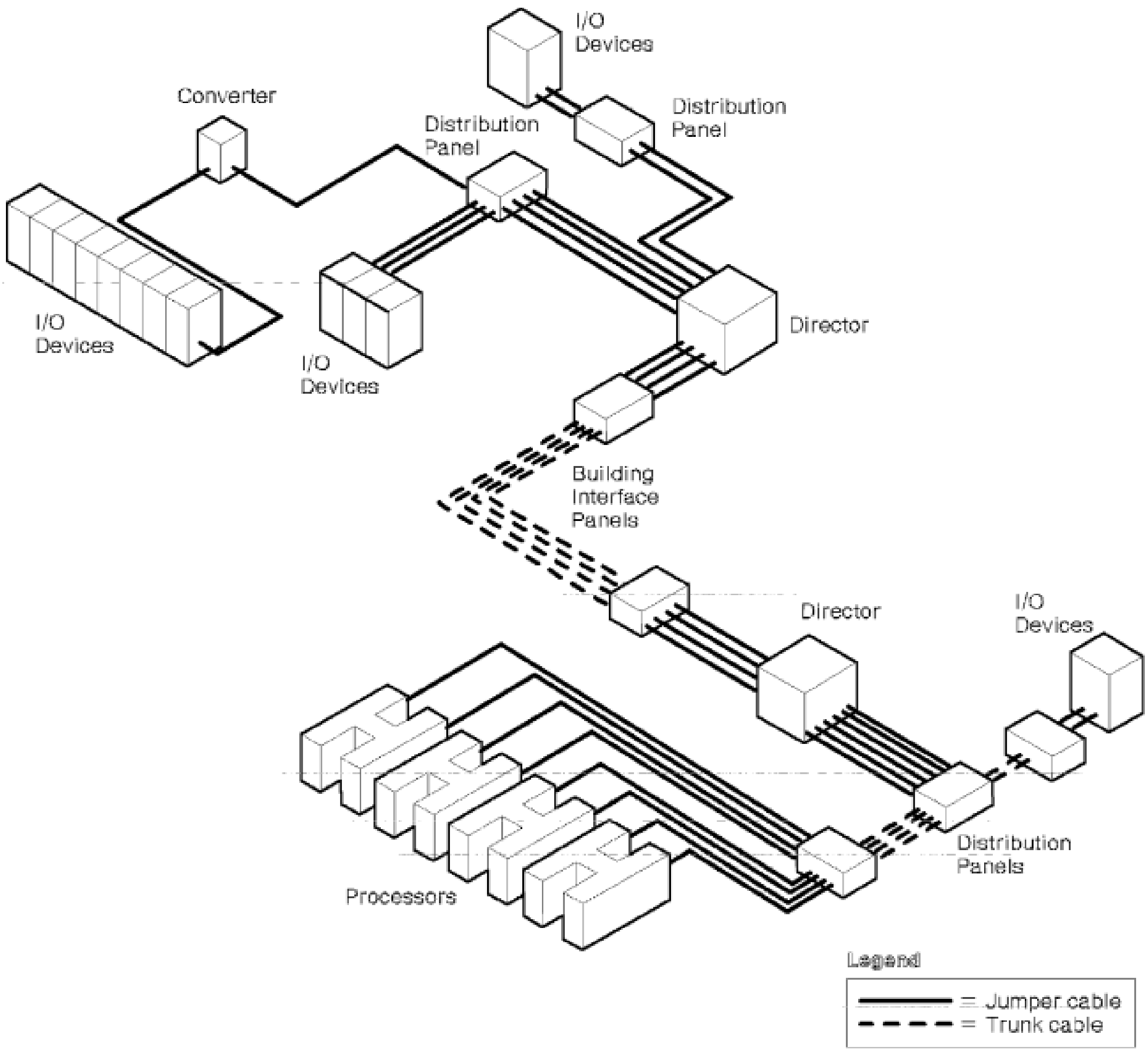


Figure 28. Example of a multicampus link environment

Chapter 3. Calculating the loss in a multimode link

This chapter describes how to calculate the maximum allowable loss for a FICON/FCP link that uses multimode components. It shows an example of a multimode FICON/FCP link and includes a completed work sheet that uses values based on the link example. Be sure to use the fiber loss corresponding to the proper wavelength for multimode links; refer to the FICON/FCP, and coupling link physical layer documents for more information. The use of an optical mode conditioner is considered to be an extension of the source and receiver, and does not enter into the link loss analysis.

Each link has a loss (attenuation) whose value depends on the loss induced by each cable, connector, and splice. This value, when calculated, cannot be greater than the maximum link loss.

Use the following explanation and refer to the configuration example (Figure 29 on page 38) and the work sheet example (Table 7 on page 38). Although actual values should be used if possible, this example uses the typical loss values shown in Table 19 on page 54.

Planning your individual optical fiber links involves:

- Determining the acceptable link loss of the supported products
- Calculating the link loss
- Determining whether new or existing fiber cable will be used
- Selecting jumper cables.

Prerequisites to link planning

You should obtain the following items when planning an optical fiber link:

- Cabling routing blueprints, which provide the following information
  - Location and length of each link segment
  - Type, location, and identification of connectors and splices
  - Locations of distribution, splice, and storage panels
- Manufacturer data sheets on the following link components
  - Cable
  - Connectors
  - Distribution, splice, and storage panels
  - Attached devices.
- Planning and installation guides specific to IBM products, available from your IBM marketing representative.
- Link measurements from the installer, if available.

Link configuration planning

Physical configuration is the actual path from one product to another.

- You will need the design plans for your facility to determine the following
  - The locations of data processing equipment
  - The locations of users who require links
  - The number and location of the physical connections of the cabling system.

Note: For optical fiber cabling requirements between telecommunications closets, you need two optical fibers for each device you want to connect plus 10% extra for maintenance and repair, at a minimum.

- Plan the paths for the cable link from the product location to attaching product location, and determine the following
  - Length and type of each segment of the link (such as jumper cable, or backbone)
  - Identification and location of each connector, splice, and distribution panel in the link.
- Check the design specifications (which are prepared for accepting bids) to verify that they contain at least the following information
  - Correct fiber cable type
  - Bandwidth requirements
  - Conformance to national, state, and local building codes.
- The physical configuration information is used during link loss calculations. The calculated loss budget for each link loss should become part of the design specifications. Installers should verify that the link loss budget has been met for each installed strand of optical fiber. Refer to the appropriate link loss calculation section for IBM product sets.

In the raised floor environment, the number and location of connection points can be large, which requires many long jumper cables. Consider installing a trunking system under the raised floor to facilitate the management of these connections.

When attaching other devices and applications to a common fiber trunk, first refer to each device's planning publication for specifications and cable requirements.

Completing a loss work sheet for a multimode link

Use Section A of the Link Loss Work Sheet to calculate the total component mean loss, Section B to calculate the component variance loss, and Section C to calculate the total link loss. When MCPs are used at either end of a link, it is only necessary to calculate the end-to-end link loss from one MCP to the other. You do not need to include the MCP loss in this calculation.

Section A: Calculating the multimode component mean loss

The fiber cable manufacturer should provide either the component mean (average) loss or worst-case specification data. If the mean value is not available, use the worst-case specification data to complete Section A. If the manufacturer's data is not available, use the typical component loss values from Table 19 on page 54.

Connections: Multiply the average connection loss value by the total number of connections in the link. Connections to coupling facility channel-capable or FICON-capable devices are included in the device specification and **should not** be included in the connection calculation.

Note: A link consisting of one IBM duplex-to-duplex jumper cable is considered to have no connections when calculating the link loss.

Splice Loss: Multiply the splice loss value by the total number of link splices. If the link has both mechanical and fusion splices, calculate the losses separately, then enter the total on the work sheet.

Jumper Cable Loss: Multiply the combined length of the jumper cables in kilometers by the jumper cable loss per kilometer.

Trunk Cable Loss: Multiply the total length of the trunk cable in kilometers by the cable loss per kilometer.

Section B: Calculating the Multimode Component Variance Loss

The fiber cable manufacturer should provide the values used to determine variance loss. This loss, attributable to manufacturing tolerances or installation methods (or both), is induced by connections and splices.

- If the manufacturer's data is not available, use the typical component loss values from Table 19 on page 54.
- If the manufacturer has provided only worst-case specification data, it includes the variance loss. Enter a value of zero on the work sheet for the Total Component Variance Loss.
- If the manufacturer provides a standard deviation (σ) value, use the square of this value to determine the component variance loss. For example, if σ equals 0.24, then enter a value of 0.06 (0.24 squared) on the worksheet for the Total Component Variance Loss.

Connections: Multiply the connection variance value by the total number of connections in the link. Connections to FICON-capable, or coupling facility channel-capable devices are included in the device specification and **should not** be included in the connection calculation.

Splice Variance: Multiply the splice variance value by the total number of splices in the link.

Section C: Calculating the total multimode link loss

The total calculated link loss includes the following values:

- All calculated component mean losses.
- Three times the square root of the sum of the calculated component variances.
- The higher-order mode loss. This loss, induced by the connectors and the first few hundred meters of each link, is assigned a constant value, depending on the trunk fiber size.
  - For 50.0-µm trunk fiber, use 1.5 dB.
  - For 62.5-µm trunk fiber, use 1.0 dB.

Loss calculation example for a multimode link

Figure 29 on page 38 shows a link example consisting of:

- Jumper Cable 1 (IBM duplex-to-duplex, multimode, 13 meters).
- Jumper Cable 2 (IBM duplex-to-duplex, multimode, 77 meters). (Combined jumper cable length = 90 meters or 0.09 km).
- 1.5 km of 50-µm trunk cable (bandwidth = 800 MHz·km).
- One 62.5-µm-to-50.0-µm physical-contact connection (in each fiber).
- One 50.0-µm-to-62.5-µm physical-contact connection (in each fiber).
- Six 50-µm mechanical splices (in each fiber).
- Trunk cable connectors are ST (physical contact).

Note: The example of a completed Calculated Link Loss Work Sheet (Table 7 on page 38) uses Table 19 on page 54, which lists typical values for currently used components. Use Table 19 on page 54 **only** if the manufacturer's specifications are not available.

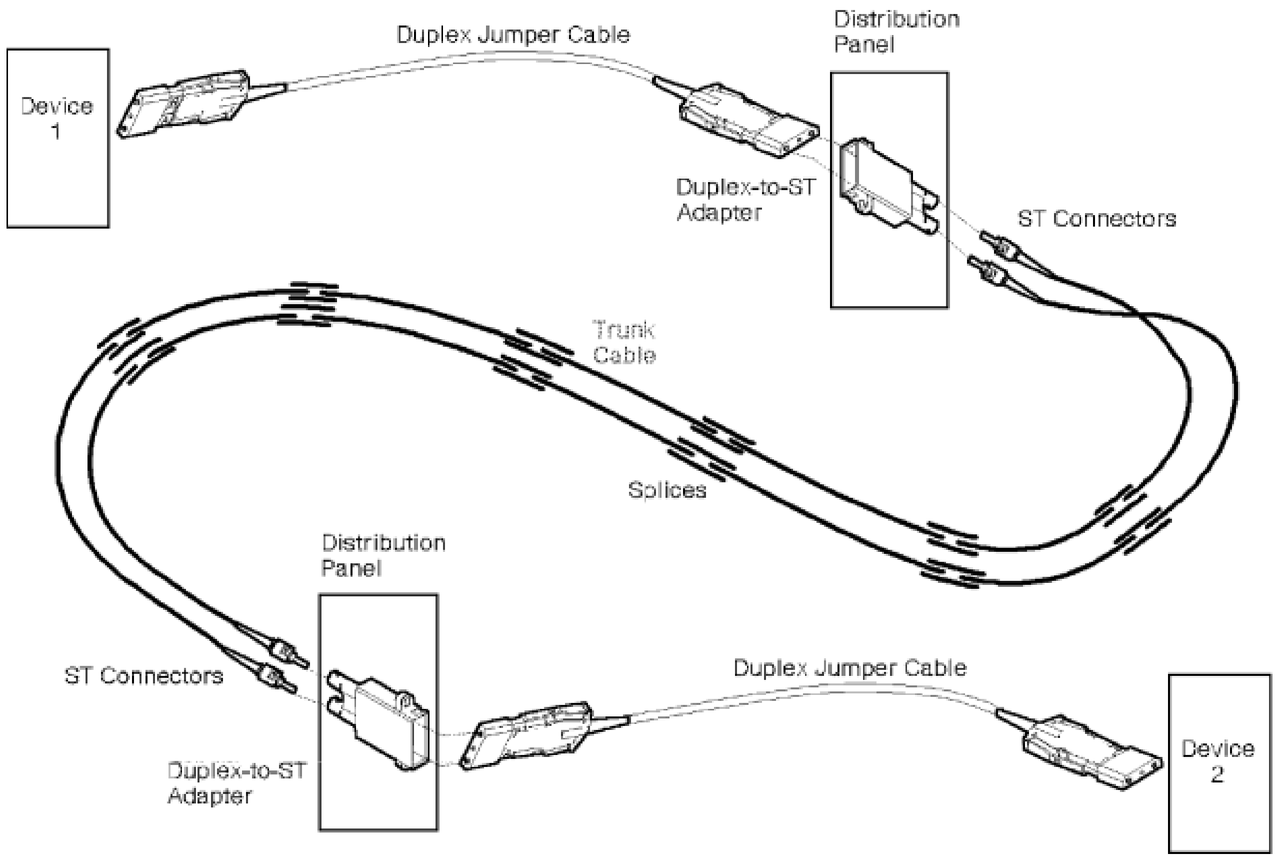


Figure 29. Example of a multimode link

Table 7. Example of a Completed Calculated Link Loss Work Sheet for a multimode link.

A. Calculating the multimode component mean loss					
Connection loss multiplied by the number of connections in the link:					
__**62.5**___- µm-to-__**50.0**__- µm connection:	__**2.10**__ dB	x	___**1**___	=	__**2.10**__ dB
__**50.0**___- µm-to-__**62.5**__- µm connection:	___**0**____ dB	x	___**1**____	=	___**0**____ dB
________- µm-to- _______- µm connection:	________ dB	x	_______	=	________ dB
Splice loss multiplied by total number of splices in the link:	__**0.15**__ dB	x	___**6**____	=	__**0.90**__ dB
Jumper cable loss multiplied by the combined length of the jumper cables:	__**1.75**__ dB/km	x	__**0.09**__ km	=	__**0.16**__ dB
Trunk loss per kilometer multiplied by the total trunk length (in km):	__**0.90**__ dB/km	x	__**1.5**___ km	=	__**1.35**__ dB
					(+) __________
			Total Component Mean Loss		__**4.51**__ dB
B. Calculating the multimode component variance loss					
Connection variance multiplied by the number of connections in the link:					
__**62.5**__- µm-to-__**50.0**__- µm	__**0.12**__ dB^2	x	____**1**___	=	__**0.12**__ dB^2

Table 7. Example of a Completed Calculated Link Loss Work Sheet for a multimode link. (continued)

A. Calculating the multimode component mean loss					
__**50.0**__- µm-to-__**62.5**__- µm connection:	__**0.01**__ dB^2	x	____**1**___	=	__**0.01**__ dB^2
_______- µm-to-________- µm connection:	________ dB^2	x	________	=	________ dB^2
Splice variance multiplied by total number of splices in the link:	__**0.01**__ dB^2	x	____**6**___	=	__**0.06**__ dB^2
					(+) __________
			Total Component Variance Loss		__**0.19**__ dB^2

C. Calculating the total multimode link loss				
Total component mean loss:			=	__**4.51**__ dB
Square root of total component variance loss multiplied by 3:	$\sqrt{\underline{\ 0.19\ }\ dB^2}$	= __**0.44**__ dB x 3	=	__**1.32**__ dB
High order mode loss:			=	___**1.5**__ dB
50.0-µm trunk = 1.5 dB				
62.5-µm trunk = 1.0 dB				(+) __________
		Calculated link loss		__**7.3**___ dB

Multimode Calculated Link Loss Work Sheet

A. Calculating the multimode component mean loss					
Connection loss multiplied by the number of connections in the link:					
________- µm-to-________- µm connection:	________ dB	x	________	=	________ dB
________- µm-to-________- µm connection:	________ dB	x	________	=	________ dB
Splice loss multiplied by total number of splices in the link:	________ dB	x	________	=	________ dB
Jumper cable loss multiplied by the combined length of the jumper cables:	________ dB/km	x	________ km	=	________ dB
Trunk loss per kilometer multiplied by the total trunk length (in km):	________ dB/km	x	________ km	=	________ dB
					(+) __________
			Total component mean loss		________ dB

B. Calculating the multimode component variance loss

A. Calculating the multimode component mean loss

Connection variance multiplied by the number of connections in the link:					
________- µm-to-________- µm	________ dB^2	x	________	=	________ dB^2
________- µm-to-________- µm connection:	________ dB^2	x	________	=	________ dB^2
Splice variance multiplied by total number of splices in the link:	________ dB^2	x	________	=	________ dB^2
					(+) __________
			Total component variance loss		________ dB^2

C. Calculating the total multimode link loss

Total component mean loss:				=	________ dB
Square root of total component variance loss multiplied by 3:	$\sqrt{\text{\_\_\_\_\_\_\_\_ } dB^2}$	=	________ dB x 3	=	________ dB
High order mode loss:				=	________ dB
50.0-µm trunk = 1.5 dB					(+) __________
62.5-µm trunk = 1.0 dB					
			Calculated link loss		________ dB

Chapter 4. Calculating the loss in a single mode link

This chapter describes how to calculate the maximum allowable loss for an FICON link that uses single mode components. It shows an example of a single mode FICON link and includes a completed work sheet that uses values based on the link example.

Each link has a loss (attenuation) whose value depends on the loss induced by each cable, connector, and splice. This value, when calculated, cannot be greater than the maximum link loss.

Use the following explanation and refer to the configuration example (Figure 30 on page 43) and the work sheet example (Table 8 on page 43). Although actual values should be used if possible, this example uses the typical loss values shown in Table 19 on page 54.

Completing a Loss Work Sheet for a single mode link

Use Section A of the Link Loss Work Sheet to calculate the total component mean loss, Section B to calculate the component variance loss, and Section C to calculate the total link loss.

Section A: Calculating the single mode component mean loss

The fiber cable manufacturer should provide either the component mean (average) loss or worst-case specification data. If the mean value is not available, use the worst-case specification data to complete Section A. If the manufacturer's data is not available, use the typical component loss values from Table 19 on page 54.

Connections: Multiply the average connection loss value by the total number of connections in the link. Connections to coupling facility channel-capable or FICON-capable devices are included in the device specification and **should not** be included in the connection calculation.

Notes:

1. A link consisting of one IBM duplex-to-duplex jumper cable is considered to have no connections when calculating the link loss.

Splice Loss: Multiply the splice loss value by the total number of link splices. If the link has both mechanical and fusion splices, calculate the losses separately, then enter the total on the work sheet.

Note: Because a single mode link can be up to 20 kilometers (12.4 miles) and fiber cable is available in reels of from 1 to 7 kilometers (0.62 to 4.35 miles), single mode trunk cable could require “reel-to-reel” splicing. If this loss is included in the trunk cable loss, **do not** include it in the splice loss calculation. If not certain about whether to include this value, contact your marketing representative.

Jumper Cable Loss: Multiply the combined length of the jumper cables in kilometers by the jumper cable loss per kilometer.

Trunk Cable Loss: Multiply the total length of the trunk cable in kilometers by the cable loss per kilometer.

Section B: Calculating the single mode component variance loss

The fiber cable manufacturer should provide the values used to determine variance loss. This loss, attributable to manufacturing tolerances or installation methods (or both), is induced by connections and splices.

- If the manufacturer’s data is not available, use the typical component variance loss values from Table 19 on page 54.
- If the manufacturer has provided only worst-case specification data, it includes the variance loss. Enter a value of zero on the work sheet for the Total Component Variance Loss.

- If the manufacturer provides a standard deviation (σ) value, use the square of this value to determine the component variance loss. For example, if σ. equals 0.24, then enter a value of 0.06 (0.24 squared) on the worksheet for the Total Component Variance Loss.

Connections: Multiply the connection variance value by the total number of connections in the link. Connections to coupling facility channel-capable or FICON-capable devices are included in the device specification and **should not** be included in the connection calculation.

Splice Variance Multiply the splice variance value by the total number of splices in the link.

Section C: Calculating the total single mode link loss

The total calculated link loss includes the following values:

- All calculated component mean losses.
- Three times the square root of the sum of the calculated component variances plus the jumper assembly variance loss (0.05 dB).
- The jumper assembly loss and the excess connector loss. For a 9-µm trunk cable, these values are:
  - Jumper assembly loss = 0.3 dB
  - Excess connector loss = 0.2 dB.

Loss calculation example for a single mode link

Figure 30 on page 43 shows a link example consisting of:

- Jumper Cable 1 (IBM duplex-to-duplex, single mode, 92 meters).
- Jumper Cable 2 (IBM duplex-to-duplex, single mode, 122 meters) (combined jumper cable length = 214 meters or 0.21 km).
- 19.76 km of 9-µm trunk cable.
- Two physical-contact ST connections (in each fiber).
- Two mechanical splices (in each fiber).

Note: The example of a completed Calculated Link Loss Work Sheet (Table 8 on page 43) uses Table 19 on page 54, which lists typical values for currently used components. Use Table 19 on page 54 **only** if the manufacturer's specifications are not available.

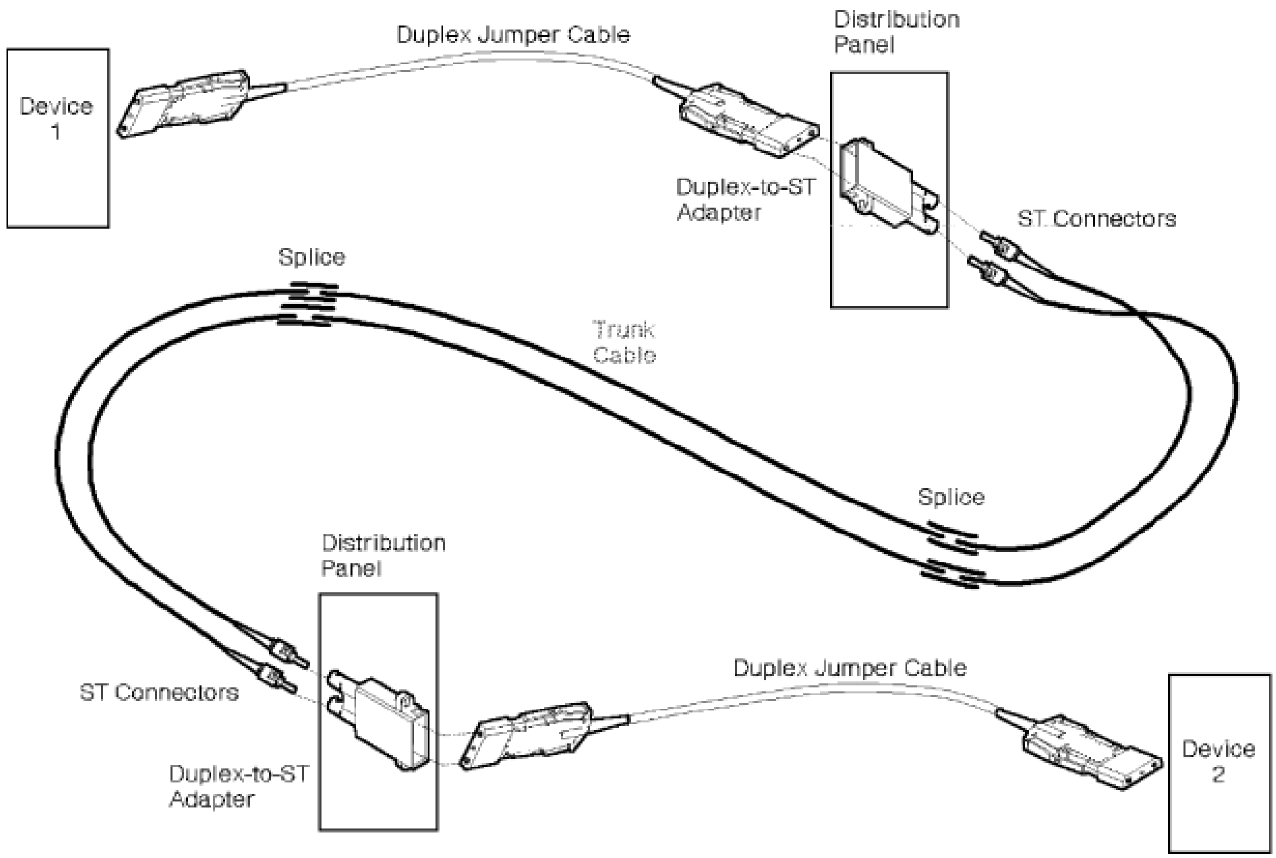


Figure 30. Example of a single mode link

Table 8. Example of a completed Calculated Link Loss Work Sheet for a single mode link

A. Calculating the single mode component mean loss					
Connection loss multiplied by the number of connections in the link:	**0.35** dB	x	**2**	=	**0.70** dB
Splice loss multiplied by total number of splices in the link:	**0.15** dB	x	**2**	=	**0.30** dB
Jumper cable loss multiplied by the combined length of the jumper cables:	**0.8** dB/km	x	**0.21** km	=	**0.17** dB
Trunk loss per kilometer multiplied by the total trunk length (in km):	**0.5** dB/km	x	**19.76** km	=	**9.88** dB
					(+)
			Total component mean loss		**11.05** dB

B. Calculating the single mode component variance loss					
Connection variance multiplied by the number of connections in the link:	**0.06**	x	**2**	=	**0.12** dB^2
Splice variance multiplied by total number of splices in the link:	**0.01** dB^2	x	**2**	=	**0.02** dB^2
					(+)
			Total component variance loss		**0.14** dB^2

Table 8. Example of a completed Calculated Link Loss Work Sheet for a single mode link (continued)

A. Calculating the single mode component mean loss					
C. Calculating the total single mode link loss					
Total component mean loss:				=	__**11.05**__ dB
Square root of total component variance loss plus system variance loss (0.04 dB) multiplied by 3:	$\sqrt{\underline{0.14} + 0.05\ dB^2}$	=	__**0.436**__ dB x 3	=	__**1.31**__ dB
Jumper assembly loss plus excess connector loss:				=	0.50 dB
					(+) __________
.			**Calculated link loss**		__**12.86**__ dB

Single Mode Calculated Link Loss Work Sheet

A. Calculating the single mode component mean loss					
Connection loss multiplied by the number of connections in the link:	________ dB	x	________	=	________ dB
Splice loss multiplied by total number of splices in the link:	________ dB	x	________	=	________ dB
Jumper cable loss multiplied by the combined length of the jumper cables:	________ dB/km	x	________ km	=	________ dB
Trunk loss per kilometer multiplied by the total trunk length (in km):	________ dB/km	x	________ km	=	________ dB
					(+) __________
			Total component mean loss		________ dB

B. Calculating the single mode component variance loss					
Connection variance multiplied by the number of connections in the link:	________ dB^2	x	________	=	________ dB^2
Splice variance multiplied by total number of splices in the link:	________ dB^2	x	________	=	________ dB^2
					(+) __________
			Total component variance loss		________ dB^2

C. Calculating the total single mode link loss					
Total component mean loss:				=	________ dB
Square root of total component variance loss multiplied by 3:	$\sqrt{\_\_\_\_\_\_ + 0.05\ dB^2}$	=	________ dB x 3	=	________ dB

A. Calculating the single mode component mean loss

Jumper assembly loss plus excess connector loss:	=	0.50 dB
		(+) __________
	Calculated link loss	________ dB

Chapter 5. Specifications

This chapter lists the specifications and optical properties for a fiber optic channel link, IBM jumper cables, and trunk cable.

Link specifications

The trunk to which the IBM jumper cables are connected must have optical properties that conform to the specifications in the table.

Table 9. Maximum coupling link loss (at 1300-nanometer wavelength)

Maximum link length in km (Miles)	Maximum link loss (dB)	Trunk size (µm)	Minimum trunk modal bandwidth (MHz•km)
≤ 10 (6.2)	7	9 to 10	N/A to single mode fiber
≤ 0.550* (.31)	5	50	500

* Requires mode conditioning patch cables on both ends of the link (1 Gbit/s links only).

Note: Coupling links which support 1 km (0.62) with 50 µm fiber; 8 dB loss at 850 nm wavelength have been discontinued effective May 1998.

Table 10. Maximum FICON/FCP link loss (at 1300-nanometer wavelength at 1, 2, 4, 8, 16, or 32 Gbit/s)

Data Rate	Maximum Link Length in km (Miles)	Maximum Link Loss (dB)	Trunk Size (µm)	Minimum Trunk Modal Bandwidth (MHz•km)
1 Gbit/s	10.00 (6.21)	7.80	9	N/A to single mode fiber
1 Gbit/s	0.550 (0.34)	5.00	62.5*	200
1 Gbit/s	0.550 (0.34)	5.00	50*	500
2 Gbit/s	10.00 (6.21)	7.80	9**	N/A
4 Gbit/s	10.00 (6.21) ***	7.80	9**	N/A
4 Gbit/s	4.00 (2.48) ***	4.80	9**	N/A
8 Gbit/s	10.00 (6.21)***	6.4	9**	N/A
16 Gbit/s	10.00 (6.21)***	6.4	9**	N/A
32 Gbit/s	10.00 (6.21)***	6.34	9**	N/A

Notes:

* Mode Conditioner Cable (FC0106) required for Trunk Fiber reuse. All Fiber between mode conditioners must be 62.5 µm. Requires matching LX optics.

** Use of Mode Conditioner Patch cables for MM Trunk Fiber reuse is not supported for 2/4 Gbit/s.

*** IBM supports interoperability of 10 km transceivers with 4 km transceivers provided the unrepeated distance between a 10 km transceiver and a 4 km transceiver does not exceed 4 km (2.5 miles).

Table 11. Maximum FICON/FCP link loss (at 850-nanometer wavelength)

Data rate	Maximum link length in km (Miles)	Maximum link loss (dB)	Trunk size (µm)	Minimum trunk modal bandwidth (MHz•km)
1 Gbit/s	0.860 (0.53)	4.62	50	2000

Table 11. Maximum FICON/FCP link loss (at 850-nanometer wavelength) (continued)				
Data rate	**Maximum link length in km (Miles)**	**Maximum link loss (dB)**	**Trunk size (µm)**	**Minimum trunk modal bandwidth (MHz•km)**
1 Gbit/s	0.500 (0.31)	3.85	50	500
1 Gbit/s	0.300 (0.19)	3.00	62.5	200
1 Gbit/s	0.250 (0.16)	2.80	62.5	160
2 Gbit/s	0.500 (0.31)	3.31	50	2000
2 Gbit/s	0.300 (0.19)	2.62	50	500
2 Gbit/s	0.120 (0.07)	2.10	62.5	200
4 Gbit/s	0.400 (.248)	2.95	50	4700
4 Gbit/s	0.380 (0.23)	2.88	50	2000
4 Gbit/s	0.150 (0.09)	2.06	50	500
4 Gbit/s	0.070 (0.04)	1.78	62.5	200
8 Gbit/s	0.190 (.118)	2.19	50	4700
8 Gbit/s	0.150 (0.09)	2.04	50	2000
8 Gbit/s	0.050 (0.03)	1.68	50	500
8 Gbit/s	0.021 (0.01)	1.58	62.5	200
16 Gbit/s	0.125 (.077)	1.95	50	4700
16 Gbit/s	0.100 (.062)	1.86	50	2000
16 Gbit/s	0.035 (.021)	1.63	50	500
16 Gbit/s	0.015 (.009)	1.56	62.5	200
32 Gbit/s	0.100 (.062)	1.86	50	4700
32 Gbit/s	0.070 (0.04)	1.75	50	2000
32 Gbit/s	0.020 (0.01)	1.57	50	500

Multimode trunk cable optical specifications

The following specifications for multimode trunk cable support attachment of FICON SX-capable, or coupling facility channel-capable devices. Use of trunk fiber having different specifications significantly alters link characteristics. Be sure to use the specification corresponding to the operating wavelength of the channel.

62.5/125-µm Multimode trunk cable	
Type of fiber	Graded index with glass core and cladding
Core diameter[1]	62.5 ±3.0 µm
Core noncircularity	6% maximum
Cladding diameter[2]	125 ±3.0 µm
Cladding noncircularity	2% maximum
Core and cladding offset	3µm maximum
Numerical aperture[3]	0.275 ± 0.015

62.5/125-µm Multimode trunk cable	
Minimum modal bandwidth[4]	500 MHz· km at ≤ 2 km at 1300 nm or 160 MHz· km at 850 nm 800 MHz· km at > 2 km and ≤ 3 km at 1300 nm
Attenuation (See note)	1.0 dB/km at 1300 nm 4.0 dB/km at 850 nm
50.0/125-µm Multimode Trunk Cable	
Type of fiber	Graded index with glass core and cladding
Core diameter [1]	50.0 ±3.0 µm
Core noncircularity	6% maximum
Cladding diameter[2]	125 ±3.0 µm
Cladding noncircularity	2% maximum
Core and cladding offset	3µm maximum
Numerical aperture[3]	0.200 ± 0.015
Minimum modal bandwidth[4]	800 MHz• km at ≤ 2 km at 1300 nm or 500 MHz• km at ≤ 1 km at 850 nm
Attenuation (See note)	0.9 dB/km at 1300 nm or 3.0 dB/km at 850 nm

Note: This attenuation is a typical value rather than a specification. Use the actual dB/km attenuation value when completing the Calculated Link Loss Work Sheet.

Notes:

1. Measured in accordance with EIA 455 FOTP 58, 164, 167 (or equivalent).
2. Measured in accordance with EIA 455 FOTP 27, 45, 48 (or equivalent).
3. Measured in accordance with EIA 455 FOTP 47 (or equivalent).
4. Measured in accordance with EIA 455 FOTP 51 (or equivalent).

Single Mode trunk cable optical specifications

The following specifications for single mode trunk cable support attachment of FICON-capable, or coupling facility channel-capable devices. Use of trunk fiber having different specifications significantly alters link characteristics. These specifications conform to CCITT recommendation G.652.

Table 12. Single Mode trunk cable optical specifications

Type of fiber	**Dispersion unshifted**
Mode field diameter[3]	9.0 to 10.0 µm ± 10%
Core concentricity error[4]	1.0 µm maximum
Cladding diameter[4]	125 ±2.0 µm
Cladding noncircularity[4]	2% maximum
Zero dispersion wavelength[5]	1295-1322 nm
Zero dispersion slope[5]	0.095 ps/(nm^2•km) maximum
Cutoff wavelength (λ_c)[6]	1280 nm maximum
Cutoff wavelength (λ_{cc})[7]	1260 nm maximum
Attenuation above normal (See note 1)	0.06 dB/km maximum

Table 12. Single Mode trunk cable optical specifications (continued)

Type of fiber	Dispersion unshifted
Attenuation (See note 2)	0.5 dB/km at 1310 nm

Notes:

1. Maximum attenuation for wavelengths from 1270 to 1340 nm must not exceed the attenuation at 1310 nm by more than 0.06 dB/km. Typically, this specification can be met by fiber with 1383-nm OH absorption peaks below 2 dB/km.
2. This attenuation is a typical value rather than a specification. Use the actual dB/km attenuation value when completing the Calculated Link Loss Work Sheet.
3. Measured in accordance with EIA 455 FOTP 164, 167 (or equivalent).
4. Measured in accordance with EIA 455 FOTP 45, 48 (or equivalent).
5. Measured in accordance with EIA 455 FOTP 168 (or equivalent).
6. Measured in accordance with EIA 455 FOTP 80 (or equivalent).
7. Measured in accordance with EIA 455 FOTP 170 (or equivalent).

IBM multimode jumper cable specifications (62.5 µm)

Optical specifications

Table 13. IBM multimode jumper cable specifications (62.5 µm): Optical Specifications

Specification	Details
Core diameter[1]	62.5 ±3.0 µm
Cladding diameter[2]	125 ±2.0 µm
Numerical aperture[3]	0.275 ± 0.015
Minimum modal bandwidth[4]	OM2 - 500 MHz·Km at 1300 nm or 850 nm OM3 - 1,500 MHz·Km at 850 nm, 500 MHz·Km at 1300 nm Note: EMB is 2000 MHz·Km at 850 nm for OM3
Optical loss	1.75 dB/km maximum at 1300 nm 4.0 dB/km maximum at 850 nm

Notes:

1. Measured in accordance with EIA 455 FOTP 58 (or equivalent).
2. Measured in accordance with EIA 455 FOTP 27, 45, 48 (or equivalent).
3. Measured in accordance with EIA 455 FOTP 47 (or equivalent).
4. Measured in accordance with EIA 455 FOTP 51 (or equivalent).

Physical specifications

Table 14. IBM Multimode jumper cable specifications (62.5 µm): Physical specifications

Specification	Details
Connector color	Black or Beige

Specification	Details
Jacket color	OM2 - Orange OM3 - Aqua
Jacket outside diameter	4.8 mm (0.189 in.), SC Duplex; 2 mm (0.08 in.) MT–RJ
Weight (see note [for information only])	20 grams per meter (0.013 pound per foot)
Installation tensile strength (see note)	1000 newtons (225 lbf) maximum
Minimum bend radius (during installation)	4.0 mm (0.157 in.); 5 seconds maximum at 400 newtons (90lbf)
Minimum installed bend radius:	
No load	12 mm (approx. 0.5 in.)
Long-term residual	25 mm (approx. 1.0 in.) at 89 newtons (20 lbf) maximum
Flammability	Underwriters Laboratory-rated OFNR (Optical Fiber Nonconductive, Riser) UL-1666 (Plenum UL-910 is also acceptable)
Crush resistance	500 newtons per centimeter (286 lbf per inch) maximum
Maximum unsupported vertical rise	100 meters (328 feet)
Note: Cables only; connectors not included	

Table 14. IBM Multimode jumper cable specifications (62.5 µm): Physical specifications (continued)

Environmental specifications

Specification	Details
Operating environment	Inside buildings only
Operating temperature	10°C to +60°C (+40°F to +140°F)
Operating relative humidity	5% to 95%
Storage and shipping temperature	-40°C to +60°C (-40°F to +140°F)
Lightning protection	None required
Grounding	None required

IBM multimode jumper cable specifications (50 µm)

Optical specifications

Table 15. IBM multimode jumper cable specifications (50 µm): Optical specifications

Specification	Details
Core diameter[1]	50.0 ±3.0 µm
Cladding diameter[2]	125 ±2.0 µm

Specification	Details
Numerical aperture[3]	0.200 ± 0.015
Minimum modal bandwidth[4]	500 MHz•km at 1300 nm or 850 nm
Optical loss	1.75 dB/km maximum at 1300 nm 4.0 dB/km maximum at 850 nm

Table 15. IBM multimode jumper cable specifications (50 µm): Optical specifications (continued)

Notes:

1. Measured in accordance with EIA 455 FOTP 58 (or equivalent).
2. Measured in accordance with EIA 455 FOTP 27, 45, 48 (or equivalent).
3. Measured in accordance with EIA 455 FOTP 47 (or equivalent).
4. Measured in accordance with EIA 455 FOTP 51 (or equivalent).

Physical specifications

Table 16. IBM multimode jumper cable specifications (50 µm): Physical specifications

Specification	Details
Connector color	Black or Beige
Jacket color	Orange
Jacket outside dimensions	Zip cord
Installation tensile strength (see note)	800 newtons (180 lbf) maximum
Minimum bend radius (during installation)	50 mm (1.969 in.); 5 seconds maximum at 100 newtons (22.5lbf)
Minimum installed bend radius:	
No load	30 mm (approx. 1.2 in.)
Long-term residual	50 mm (approx. 2.0 in.) at 80 newtons (18 lbf) maximum
Flammability	Underwriters Laboratory-rated OFNP (Optical Fiber Nonconductive, Plenum) UL-910
Crush resistance	888.8 newtons per centimeter (508 lbf per inch) maximum[2]

Notes:

1. Cables only; connectors not included.
2. Measured in accordance with EIA 455-41.

Environmental specifications

Specification	Details
Operating environment	Inside buildings only
Operating temperature	10°C to +60°C (+40°F to +140°F)
Operating relative humidity	5% to 95%
Storage and shipping temperature	-40°C to +60°C (-40°F to +140°F)

Specification	Details
Lightning protection	None required
Grounding	None required

IBM single mode jumper cable specifications

Optical specifications (at 1300-nm wavelength)

Table 17. IBM single mode jumper cable specifications: Optical specifications

Specification	Details
Operating wavelength	1270 to 1355 nm
Mode field diameter[1]	8.7 to 10 µm
Zero dispersion wavelength[2]	1310 ± 10 nm
Dispersion (1270-1340 nm)[2]	3.5 ps/(nm·km) maximum
Cutoff wavelength[3]	1260 nm maximum
Attenuation (1270-1340 nm)[4]	0.8 dB/km maximum

Notes:

1. Measured in accordance with EIA 455 FOTP 164, 167 (or equivalent).
2. Measured in accordance with EIA 455 FOTP 168 (or equivalent).
3. Measured in accordance with EIA 455 FOTP 80 (or equivalent).
4. Measured in accordance with EIA 455 FOTP 78 (or equivalent).

Physical specifications

Table 18. IBM single mode jumper cable specifications: Physical specifications

Specification	Details
Connector color	Grey or Blue
Jacket material	Yellow polyvinyl chloride (PVC)
Jacket outside dimensions	Zip cord
Weight[2]	20 grams per meter (0.013 pound per foot)
Installation tensile strength[2]	1000 newtons (225 lbf) maximum
Minimum bend radius (during installation)	50 mm (1.969 in.); 5 seconds maximum at 100 newtons (22.5lbf)
Minimum installed bend radius:	
No load	30 mm (approx. 1.2 in.)
Long-term residual	50 mm (approx. 2.0 in.) at 80 newtons (18 lbf) maximum
Flammability	Underwriters Laboratory-rated OFNR (Optical Fiber Nonconductive, Riser) UL-1666 (see note 1)

Table 18. IBM single mode jumper cable specifications: Physical specifications (continued)	
Specification	**Details**
Crush resistance	889 newtons per centimeter (199.9 lbf per inch) maximum[3]
Maximum unsupported vertical rise	100 meters (328 feet)

Notes:

1. Contact your account representative for availability of plenum and halogen-free cables (UL-910).
2. Cables only; connectors not included.
3. Measured in accordance with EIA 455-41.

Environmental specifications

Specification	Details
Operating environment	Inside buildings only
Operating temperature	0°C to +60°C (+32°F to +140°F)
Operating relative humidity	8% to 95%
Storage and shipping temperature	-40°C to +60°C (-40°F to +140°F)
Lightning protection	None required
Grounding	None required

Typical optical component loss values

The following loss values are typical for optical components used in the data communication industry. Use the manufacturer's loss values if available.

Note: Optical loss is not the only consideration in a link. Dispersion increases with distance and its effects increase with data rate.

Table 19. Typical Optical Component Loss

Component	Description	Size (μm)	Mean loss	Variance (dB^2)
Connector[Note 1]	Physical contact	62.5 to 62.5	0.40 dB	0.02
		50.0 to 50.0	0.40 dB	0.02
		9.0 to 9.0[Note 2]	0.35 dB	0.06
		62.5 to 50.0[Note 3]	2.10 dB	0.12
		50.0 to 62.5	0.00 dB	0.01
Connector[Note 1]	Nonphysical contact	62.5 to 62.5	0.70 dB	0.04
	(Multimode only)	50.0 to 50.0	0.70 dB	0.04
		62.5 to 50.0[Note 3]	2.40 dB	0.12
		50.0 to 62.5	0.30 dB	0.01
Splice	Mechanical	62.5 to 62.5	0.15 dB	0.01

Table 19. Typical Optical Component Loss (continued)

Component	Description	Size (µm)	Mean loss	Variance (dB^2)
		50.0 to 50.0	0.15 dB	0.01
		9.0 to 9.0 Note 2	0.15 dB	0.01
Splice	Fusion	62.5 to 62.5	0.40 dB	0.01
		50.0 to 50.0	0.40 dB	0.01
		9.0 to 9.0 Note 2	0.40 dB	0.01
Cable	IBM Multimode jumper	62.5	1.75 dB/km	NA
	IBM Multimode jumper	50.0	3.00 dB/km at 850 nm	NA
	IBM Single Mode jumper	9.0	0.8 dB/km	NA
	Trunk	62.5	1.00 dB/km	NA
	Trunk	50.0	0.90 dB/km	NA
	Trunk	9.0	0.50 dB/km	NA

Notes:

1. The connector loss value is typical when attaching identical connectors. The loss can vary significantly if attaching different connector types.
2. Single Mode connectors and splices must meet a minimum return loss specification of 28 dB.
3. Connecting 62.5 to 50.0 with no mode conditioning patch cable is not recommended. It can cause modal noise in addition to the loss.

Chapter 6. FICON/FCP I/O physical layer: Introduction

This publication applies to both single mode and multimode fibre channel links. There are two distinct physical layers that can be used as part of a fiber optic channel link: multimode and single mode. The multimode physical layer is intended for use with either 62.5/125-micrometer or 50/125-micrometer multimode fiber optic cable. The single mode physical layer is intended for use with dispersion-unshifted, single mode fiber optic cable. Each physical layer provides a common, compatible I/O interface that products can use to communicate with each other through light pulses sent over multimode or single mode optical transmission fibers.

Fiber optic information transfer

Generally, an individual link consists of a transmitter and receiver at each device capable of sending and receiving optical data pulses over a duplex fiber transmission cable. A duplex link uses one fiber to transmit data to a device and the other fiber to receive data from a device. Both fibers in the link are simultaneously active.

Typically, a point-to-point link uses a trunk cable, with short sections of duplex jumper cable, either SC Duplex or LC Duplex, at either end of the trunk for routing within the building or machine room (see Figure 31 on page 58). A point-to-point link is not required to be constructed with this configuration and can have alternate forms. For example, a short link could have only one jumper cable and no trunk cable. Distribution panels provide a central location for attachment of trunk and jumper cables and can be mounted in a rack, wiring closet, or on a wall.

For attachment to a fibre channel link device, the end of the transmission cable is terminated in a duplex connector that mates with a duplex receptacle on the device. When attached, the connector is optically coupled to the transmitter and receiver, and the device can send and receive optical signals over the cable.

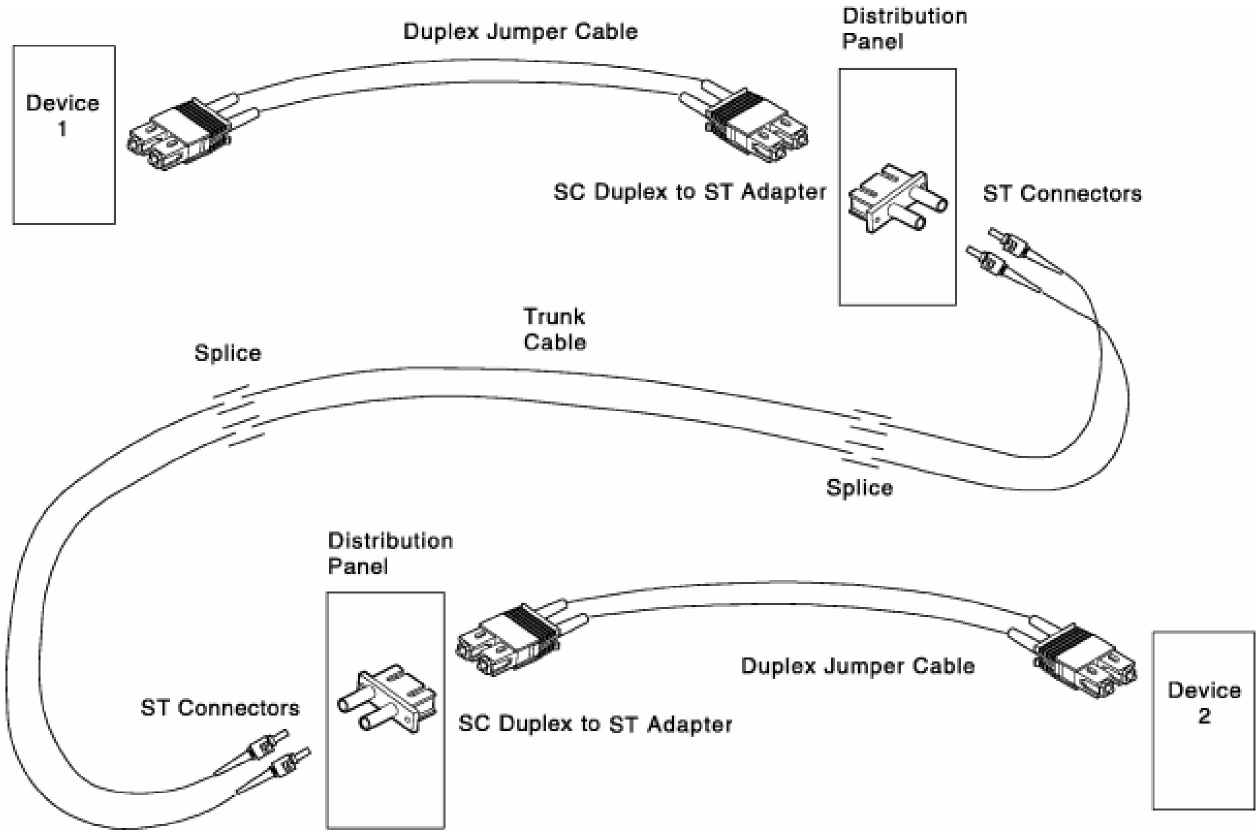


Figure 31. Example of a fiber optic link

Data transmission

The data transmitted over a link is based on an 8-bit/10-bit nonreturn-to-zero code. For 16G links the data is encoded using a 64B/66B scheme. In the 8B/10B transmission code, the high optical power level designates a 1-bit, while the low optical power level designates a 0-bit. The idle function or one of the sequence functions is sent repetitively during periods when information is not being sent. The data-transmission rates on both multimode and single mode channels are:

- 1.0625 Gbps, which is equivalent to 100 MBytes
- 2.1250 Gbps, which is equivalent to 200 MBytes.
- 4.2500 Gbps, which is equivalent to 400 MBytes.
- 8.5000 Gpbs, which is equivalent to 800 MBytes.
- 14.0250 Gbps, which is equivalent to 1600 MBytes.
- 28.05 Gbps, which is equivalent to 3200 MBytes.

Devices exist that only work at 1.0625 Gbps. Later devices only work at 1.0625 Gbps and 2.125 Gbps. The newest devices that function at 4.25 Gbps also work at the slower data rates. They will autonegotiate with the attached device to choose the fastest common data rate.

Chapter 7. Multimode physical layer

The multimode physical layer allows the operating distances outlined in Table 10. It is important that a multimode link consist of only one fiber type; for example, all 50/125 micron fiber or all 62.5/125 micron multimode fiber. Mixed fiber types in a multimode link are not supported. The 50/125 micron fiber is now available in both standard (500 MHzvkm) and high bandwidth (2000 MHzvkm). Mixing the two is not supported.

Table 20. Multimode cable plant for OM2 limiting variants

FC-0	**400-M5-SN-I**	**800-M5-SN-S**	**1600-M5-SN-S**	**3200-M5E-SN-I**
Data rate (MB/s)	400	800	1600	3200
Operating range (m)	0.5 - 150	0.5 - 50	0.5 - 35	0.5 - 20
Loss Budget (dB)	2.06	1.68	1.63	1.57

Table 21. Multimode cable plant for OM3 limiting variants

FC-0	**400-M5E-SN-I**	**800-M5E-SN-I**	**1600-M5E-SN-I**	**3200-M5E-SN-I**
Data rate (MB/s)	400	800	1600	3200
Operating range (m)	0.5 - 380	0.5 - 150	0.5 – 100	0.5 - 70
Loss Budget (dB)	2.88	2.04	1.86	1.75

Table 22. Multimode cable plant for OM4 limiting variants

FC-0	**400-M5F-SN-I**	**800-M5F-SN-I**	**1600-M5F-SN-I**	**3200-M5E-SN-I**
Data rate (MB/s)	400	800	1600	3200
Operating range (m)	0.5 - 400	0.5 - 190	0.5 – 125	0.5 - 100
Loss Budget (dB)	2.95	2.19	1.95	1.86

Table 23. Multimode cable plant for OM5 limiting variants

FC-0	**400-M5F-SN-I**	**800-M5F-SN-I**	**1600-M5F-SN-I**	**3200-M5E-SN-I**
Data rate (MB/s)	400	800	1600	3200
Operating range (m)	0.5 - 400	0.5 - 190	0.5 – 125	0.5 - 100
Loss Budget (dB)	2.95	2.19	1.95	1.86

The use of LX multimode fiber links will require the appropriate mode conditioning patch cable or equivalent installed on both ends of a duplex link (the mode conditioner must be plugged directly into the optical transceiver on the adapter card, it cannot be inserted at a patch panel or elsewhere in the middle of a link). The mode conditioning patch cable is a special fiber optic jumper cable which contains both single mode (yellow jacket) and multimode (orange or aqua jacket) optical fiber. A different mode conditioner is required for operation with 50/125-µm or 62.5/125-µm multimode trunk fiber cable. These cables, along with the appropriate duplex adapters, are available from IBM.

Note: In some fiber optic applications, it is possible to use a long wavelength (1300 nm) single mode laser adapter with multimode fiber by placing a special device known as an optical-mode conditioner at both ends of the link. The optical mode conditioner resembles a standard 2 meter jumper cable, and is sometimes known as a mode conditioning patch (MCP) cable. Note that MCP is only supported at 1.0625 Gbps. As shown in Figure 32 on page 60, the MCP is unique in that it contains both single mode (yellow) and multimode (orange or aqua) fibers in a single jumper cable assembly. Without the MCP, it is not possible to use a single mode laser transmitter over multimode fiber because the laser source does not launch an equal amount of optical power into all modes of the fiber; this leads to excessive dispersion of the data pulses, and the link will not function. The MCP is designed to "condition" the laser launch so that the optical power fills all modes of the fiber equally

The MCP is installed on both ends of a link, and occupies the same space as a standard 2 meter jumper cable. Adapter kits containing the MCPs and suitable duplex couplers for attachment to the existing multimode cable infrastructure are available from IBM. Different MCPs are required for 50.0 micron or 62.5 micron multimode fiber.

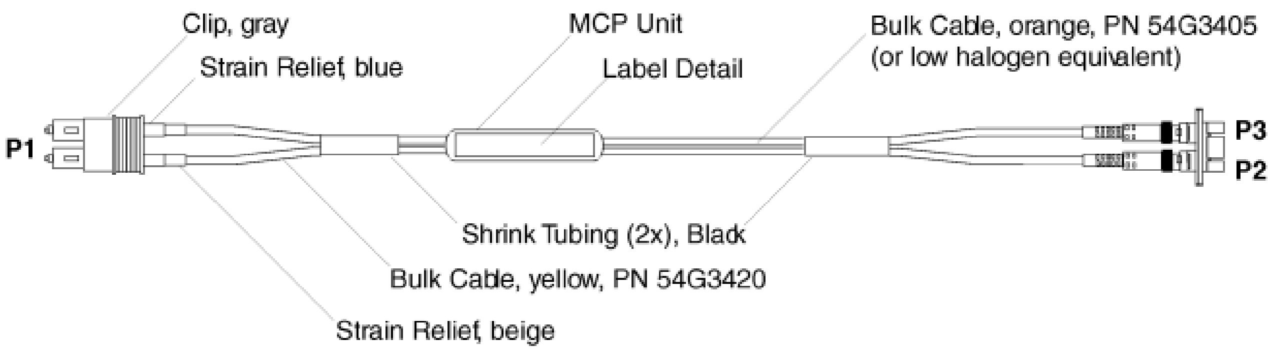


Figure 32. Mode conditioner patch (MCP) cable

SX multimode output interface

Table 24 on page 60 defines the serial optical signal at the multimode duplex receptacle when coupled into a multimode duplex jumper cable. The parameters specified are based on the requirement that the bit error rate does not exceed 10^{-12}, including operation at the minimum interface power level. The use of a *coherent* light source, such as a laser diode, is required.

Table 24. SX 50/125 µm and 62.5/125 µm multimode output interface optical signal

Parameter	Unit	100-M5-SN-I (1.0625 Gbps)	200-M5-SN-I (2.125 Gbps)	400-M5-SN-I (4.250 Gbps)	800-M5-SN-S (8.500 Gbps)	1600-M5-SN-I (14.025 Gbps)	3200-M5-SN-I (28.05 Gbps)
Average power, maximum[1]	dBm						
Average power, minimum [2]	dBm	-10	-10	-9	-8.2	-7.8	-6.2
Center wavelength, minimum [3]	nm	770	830	830	840	840	840
Center wavelength, maximum	nm	860	860	860	860	860	860
RMS spectral width, maximum	nm	1.0	0.85	0.85	0.65	.59	.57

Table 24. SX 50/125 µm and 62.5/125 µm multimode output interface optical signal (continued)

Parameter	Unit	100-M5-SN-I (1.0625 Gbps)	200-M5-SN-I (2.125 Gbps)	400-M5-SN-I (4.250 Gbps)	800-M5-SN-S (8.500 Gbps)	1600-M5-SN-I (14.025 Gbps)	3200-M5-SN-I (28.05 Gbps)
Rise/Fall Time (20-80%), maximum [4]	ps	300	150	90	Note[7]	Note[7]	Note[7]
Optical Modulation Amplitude (OMA), maximum [5]	mW	0.156	0.196	0.247	0.302	0.331	0.479
Relative intensity noise (RIN_{12}) [6]	dB/Hz	-116	-117	-118	-128	-128	-129

Notes:

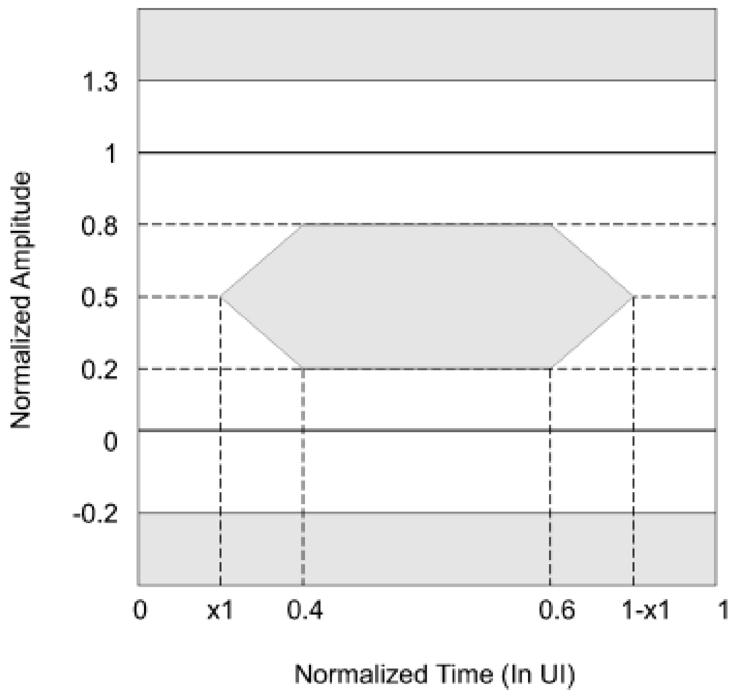
1. Lesser of class 1 laser safety limits (CDRH and EN 60825) or receiver power, maximum.
2. Based on any valid 8B/10B code pattern. The minimum length of a SM jumper cable between the output interface and the instrumentation is 2 meters.
3. If using the higher bandwidth cable option of 2000 MHz•km in (see *ANSI FC-PI-2*), the center wavelength minimum is further restricted to 840 nm.
4. Optical rise and fall time specifications are based on the unfiltered waveforms. For the purpose of standardizing the measurement method, measured waveforms shall conform to the Transmitter Eye Diagram Mask as defined in ANSI FC-PI-2. If a filter is needed to conform to the mask, the filter response effect should be removed from the measured rise and fall times using the equation: $T_{RISE/FALL} = [(T_{RISE/FALL\_MEASURED})^2 - (T_{RISE/FALL\_FILTER})^2]^{1/2}$

   The optical signal may have different rise and fall times. Any filter should have an impulse response equivalent to a fourth order Bessel-Thomson Filter. See the *ANSI FC-PI-2* standard.
5. Optical Modulation Amplitude (OMA) values are peak-to-peak. OMA is defined in terms of Extinction Ratio (ER) and optical average power (Pavg), which can be derived from the equation OMA = 2Pavg ((ER-1)/(ER +1)). The specified OMA at 1.0625 Gbps is equivalent to an average power of -9 dBm at ER = 9.
6. See "Test methods" on page 101.
7. Transmitter deterministic performance is controlled by TWDP.

Multimode eyemask diagram, LX and SX

The transmitter and receiver output signals must conform to the eyemask defined in Fibre Channel FC-PI Rev. 12 for 1062.5 Mbps data rates. The fibre channel eyemask follows. A low-pass filter is recommended for the transmitter (between scope and O/E converter), in order to eliminate the relaxation oscillation of the laser during measurement. A fourth-order Bessel Thompson filter is recommended for this measurement with cutoff frequency equal to 0.75 times the bit rate.

The mask of the transmitter eye diagram is shown in Figure 33 on page 62.



Note: x1 shall be half the value given for total jitter at the gamma T point. The test or analysis shall include the effects of a single-pole, high-pass frequency-weighting function that progressively attenuates jitter at 20 dB/decade below a frequency of bit rate/1 667. The value of x1 applies at a total jitter probability of 10-12. At this level of probability, direct visual comparison between the mask and actual signals is not a valid method for determining compliance with the jitter output requirements.

Figure 33. Eyemask diagram

SX multimode input interface

Table 25 on page 62 specifies the input interface requirements. To assist in fault isolation, the input interface activates a loss-of-signal (LOS) state when the optical data cannot be detected.

Table 25. SX 50/125 µm and 62.5/125 µm multimode input interface characteristics

Parameter	Unit	100-M5-SN-I (1.0625 Gbps)	200-M5-SN-I (2.125 Gbps)	400-M5-SN-I (4.250 Gbps)	800-M5-SN-S (8.500 Gbps)	1600-M5-SN-I (14.025 Gpbs)	3200-M5-SN-I (28.05 Gpbs)
Saturation level (Pavg received), maximum [1]	dBm	0	0	0	0	0	2.0
Optical Modulation Amplitude (OMA) (sensitivity), minimum [3]	mW	0.031	0.049	0.061	0.076	0.089	0.095
Return loss, minimum [2]	dB	12	12	12	12	12	12

Parameter	Unit	100-M5-SN-I (1.0625 Gbps)	200-M5-SN-I (2.125 Gbps)	400-M5-SN-I (4.250 Gbps)	800-M5-SN-S (8.500 Gbps)	1600-M5-SN-I (14.025 Gpbs)	3200-M5-SN-I (28.05 Gpbs)

Table 25. SX 50/125 µm and 62.5/125 µm multimode input interface characteristics (continued)

Notes:

1. Based on any valid 8B/10B code pattern measured at, or extrapolated to, 10^{-12} BER. Must meet this specification with worst-case conditions as specified in Table 24 on page 60 for the output interface and Table 26 on page 63 for the fiber optic link.
2. This measurement is made using a 2 meter (minimum length) single mode duplex jumper cable and includes only the power in the fundamental mode of the single mode fiber.
3. FC-PI specifies receiver Optical Modulation Amplitude (OMA) instead of sensitivity and Extinction Ratio (ER). Receiver sensitivity is the minimum optical average power (Pavg) required, which can be derived from the equation Pavg = OMA ((ER+1)/2 x (ER-1)). The specified OMA at 1.0625 Gbps is equivalent to an average power of -17 dBm at ER=9dB.

SX multimode link specifications

Table 26 on page 63 lists the specifications for links using multimode fiber cable. The trunk cable to which the IBM jumper cables are connected must have optical properties that conform to the specifications in the table.

Table 26. Maximum link loss (at 850 nanometer (nm) wavelength)

Link/fiber type	Maximum Link Length[1, 2] in Meters (Miles)	Maximum Link Loss (dB)	Trunk Size (µm)	Minimum Trunk Modal Bandwidth (MHzvkm)
Multimode SX 1 Gbps (100-M6-SN-I) (OM1)	300 (0.186)	3.00	62.5	200
Multimode SX 2 Gbps (200-M6-SN-I) (OM1)	150 (0.093)	2.10	62.5	200
Multimode SX 4 Gbps (400-M6-SN-I) (OM1)	70 (0.043)	1.78	62.5	200
Multimode SX 8 Gbps (800-M6-SN-I) (OM1)	21 (0.013)	1.58	62.5	200
Multimode SX 1 Gbps (100-M5-SN-I) (OM2)	500 (0.311)	3.85	50	500
Multimode SX 2 Gbps (200-M5-SN-I) (OM2)	300 (0.186)	2.62	50	500

Table 26. Maximum link loss (at 850 nanometer (nm) wavelength) (continued)				
Link/fiber type	**Maximum Link Length[1, 2] in Meters (Miles)**	**Maximum Link Loss (dB)**	**Trunk Size (µm)**	**Minimum Trunk Modal Bandwidth (MHzvkm)**
Multimode SX 4 Gbps (400-M5-SN-I) (OM2)	150 (0.093)	2.06	50	500
Multimode SX 8 Gbps (800-M5-SN-I) (OM2)	50 (0.031)	1.68	50	500
Multimode SX 16 Gbps (1600-M5-SN-I) (OM2)	35 (0.022)	1.63	50	500
Multimode SX 32 Gbps (3200-M5-SN-I) (OM2)	20 (0.0124)	1.57	50	500
Multimode SX 1 Gbps (100-M5-SN-I) (OM3)	860 (0.534)	4.62	50	2000
Multimode SX 2 Gbps (200-M5-SN-I) (OM3)	500 (0.311)	3.31	50	2000
Multimode SX 4 Gbps (400-M5-SN-I) (OM3)	380 (0.237)	2.88	50	2000
Multimode SX 8 Gbps (800-M5-SN-I) (OM3)	150 (0.094)	2.04	50	2000
Multimode SX 16 Gbps (1600-M5-SN-I) (OM3)	100 (0.062)	1.86	50	2000
Multimode SX 32 Gbps (3200-M5-SN-I) (OM3)	70 (.043)	1.75	50	2000
Multimode SX 16 Gbps (1600-M5-SN-I) (OM4)	125 (0.78)	1.95	50	4700
Multimode SX 32 Gbps (3200-M5-SN-I) (OM4)	100 (0.062)	1.86	50	4700

Link/fiber type	Maximum Link Length[1, 2] in Meters (Miles)	Maximum Link Loss (dB)	Trunk Size (µm)	Minimum Trunk Modal Bandwidth (MHzvkm)
Multimode SX 16 Gbps (1600-M5-SN-I) (OM5)	125 (0.78)	1.95	50	4700

Table 26. Maximum link loss (at 850 nanometer (nm) wavelength) (continued)

Notes:

1. The maximum link length includes both jumper and trunk cables.
2. If the customer uses IBM's Fiber Transport Services (FTS), contact the marketing representative for distance considerations.

LX multimode output interface

Table 27 on page 65 identifies the serial optical signal at the multimode duplex receptacle when coupled into a multimode duplex jumper cable. The parameters specified are based on the requirement that the bit error rate does not exceed 10^{-12}, including operation at the minimum interface power level. The use of a *coherent* light source, such as a laser diode, is required.

Note: MCP is only supported at 1.0625 Gbps data rate.

Table 27. Multimode output interface optical signal

Parameter	Unit	Minimum	Maximum
Average Power to SMF [1]	dBm	-9.5	-4
Center wavelength [4]	nm		
Spectral width (RMS) [4]	nm		
Rise/Fall time (20-80%) [1,2]	ps		320
Optical Modulation Amplitude [5]	mW		0.189
Relative intensity noise (RIN_{12}) [3]	dB/Hz		-116

Notes:

1. Based on any valid 8B/10B code pattern. The length of jumper cable between the output interface and the instrumentation is 4 meters.
2. The minimum frequency response bandwidth range of the optical waveform detector is 800 kHz to 1 GHz.
3. See "Relative Intensity Noise (RIN) measurement" on page 101.
4. Spectral width may be increased based on center wavelength and distance trade-offs. Link budget analysis is required for any such change. Trade-offs are available between spectral width, central wavelength, and minimum Optical Modulation Amplitude (OMA). See "Spectral width and center wavelength examples" on page 102.
5. Optical Modulation Amplitude (OMA) is defined in terms of Extinction Ratio (ER) and optical average power (Pavg), which can be derived from the equation OMA = 2Pavg ((ER-1)/(ER+1)). The specified OMA is equivalent to an average power of -9 dBm at ER = 9dB.

LX multimode input interface

Table 28 on page 66 specifies the input interface requirements. To assist in fault isolation, the input interface activates a loss-of-signal (LOS) state when the optical data cannot be detected.

Table 28. Multimode input interface characteristics

Parameter	Unit	Minimum	Maximum
Saturation level [1]	dBm		-3
Optical Modulation Amplitude (sensitivity) [3]	mW	0.015	
Return Loss [2]	dB	12	

Notes:

1. Based on any valid 8B/10B code pattern measured at, or extrapolated to, 10^{-12} BER. Must meet this specification with worst-case conditions as specified in Table 27 on page 65 for the output interface and Table 29 on page 66 for the fiber optic link.
2. This measurement is made using a 4-meter single mode duplex jumper cable and includes only the power in the fundamental mode of the single mode fiber.
3. FC-PI specifies receiver Optical Modulation Amplitude (OMA) instead of sensitivity and Extinction Ratio (ER). Receiver sensitivity is the minimum optical average power (Pavg) required, which can be derived from the equation Pavg = OMA ((ER+1)/2 *(ER-1)). The specified OMA is equivalent to an average power of -20 dBm at ER = 9dB.

LX multimode link specifications

Table 29 on page 66 lists the specifications for links using multimode fiber cable. The trunk cable to which the IBM jumper cables are connected must have optical properties that conform to the specifications in the table.

Table 29. Maximum link loss (at 1300-nanometer wavelength)

Maximum Link Length in km (Miles)	Maximum Link Loss (dB)	Trunk Size (µm)	Minimum Trunk Modal Bandwidth (MHzvkm)
0.55 (0.34)	5.0	50.0	500
0.55 (0.34)	5.0	62.5	500

Note: The maximum link length includes both jumper cables and trunk cables.

Multimode trunk cable optical specifications

These specifications are for multimode trunk cable support attachment of fibre channel devices:

Table 30. 62.5/125-µm multimode trunk cable

Specification	Details
Type of Fiber	Graded index with glass core and cladding
Operating wavelength	1300 nm or 850 nm
Core diameter [1]	62.5 ± 3.0 µm
Core noncircularity	6% maximum

Table 30. 62.5/125-μm multimode trunk cable (continued)

Specification	Details
Cladding diameter [2]	125 ± 3.0 μm
Cladding noncircularity	2% maximum
Core and cladding offset	3 μm maximum
Numerical aperture [3]	0.275 ± 0.015
Minimum modal bandwidth [4]	200 MHz·km
Attenuation [5]	0.5 dB/km at 1300 nm 4.0 dB/km at 850 nm

Notes:

1. Measured in accordance with EIA 455 FOTP 58, 164, 167, or equivalent.
2. Measured in accordance with EIA 455 FOTP 27, 45, 48, or equivalent.
3. Measured in accordance with EIA 455 FOTP 47 or equivalent.
4. Measured in accordance with EIA 455 FOTP 51 or equivalent.
5. This attenuation is a typical value, not a specification. Use the actual dB/km attenuation value when completing a Calculated Link Loss Work Sheet. The total link loss, however, cannot exceed specifications in this manual.

Table 31. 50/125-μm multimode trunk cable

Specification	Details
Type of Fiber	Graded index with glass core and cladding
Operating wavelength	1300 nm or 850 nm
Core diameter [1]	50.0 ± 3.0 μm
Core noncircularity	6% maximum
Cladding diameter [2]	125 ± 3.0 μm
Cladding noncircularity	2% maximum
Core and cladding offset	3 μm maximum
Numerical aperture [3]	0.200 ± 0.015
Minimum modal bandwidth [4]	500 MHz·km
Attenuation [5]	0.5 dB/km at 1300 nm 4.0 dB/km at 850 nm

Notes:

1. Measured in accordance with EIA 455 FOTP 58, 164, 167, or equivalent.
2. Measured in accordance with EIA 455 FOTP 27, 45, 48, or equivalent.
3. Measured in accordance with EIA 455 FOTP 47 or equivalent.
4. Measured in accordance with EIA 455 FOTP 51 or equivalent.
5. This attenuation is a typical value, not a specification. Use the actual dB/km attenuation value when completing a Calculated Link Loss Work Sheet. The total link loss, however, cannot exceed specifications in this manual.

Multimode duplex jumper cable specifications

These specifications are for multimode duplex jumper cable support attachment to fibre channel devices:

Table 32. Multimode duplex jumper cable

Specification	Details
Type of Fiber	Graded index with glass core and cladding
Operating wavelength	1300 nm or 850 nm
Core diameter [1]	62.5 ± 3.0 µm or 50.0 ± 3.0 µm
Cladding diameter [2]	125 ± 3.0 µm
Ferrule outer diameter	2.4985 ±0.0016 mm
Numerical aperture [3]	0.200 ± 0.015
Minimum modal bandwidth [4]	500 MHz·km
Attenuation	0.5 dB/km maximum at 1300 nm 4.0 dB/km maximum at 1300 nm
Connector Color	Beige
Jacket color	Orange or Aqua

Notes:

1. Measured in accordance with EIA 455 FOTP 58, 164, 167, or equivalent.
2. Measured in accordance with EIA 455 FOTP 27, 45, 48, or equivalent.
3. Measured in accordance with EIA 455 FOTP 47 or equivalent.
4. Measured in accordance with EIA 455 FOTP 51 or equivalent.

Multimode interface connection

Some multimode FICON links use the multimode fibre channel standard SC Duplex connector. This connector is polarized to prevent inverting the fiber connection to the interface. It is mechanically retained in a duplex receptacle by a latch that engages the receptacle when the connector is inserted.

Some multimode FICON links use the LC Duplex connector. This connector is polarized to prevent inverting the fiber connection to the interface. It is mechanically retained in a duplex receptacle by an RJ-45 type latch that engages the receptacle when the connector is inserted. Adapter kits are available from IBM to convert between SC Duplex and LC Duplex interfaces.

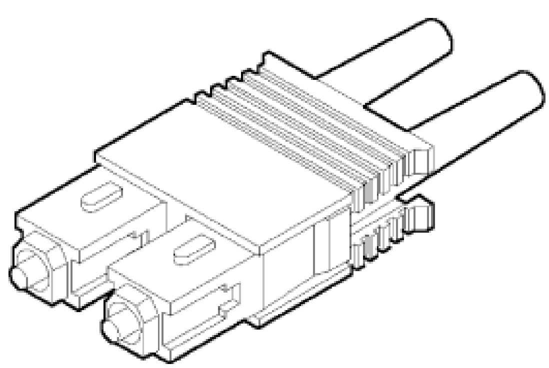


Figure 34. Multimode fibre channel standard SC Duplex connector

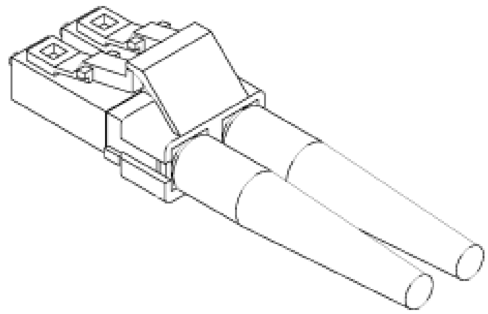


Figure 35. LC Duplex connector

Class 1 laser safety

Meeting the requirements for Class 1 certification is very important for an optical interconnect system in a computer environment due to the potential for customer exposure to laser radiation.

Chapter 8. Single Mode physical layer

The fibre channel single mode physical layer allows links to extend up to 10 km (6.20 miles), without retransmission, using dispersion-unshifted, single mode trunk fiber cable.

Single Mode output interface

Table 33 on page 71 defines the serial optical signal at the single mode duplex receptacle when coupled into a single mode duplex jumper cable. The parameters specified in this section are based on the requirement that the bit-error rate does not exceed 10^{-12}, including operation at the minimum interface power level.

Table 33. Single Mode output interface optical signal

Parameter	Unit	100-SM-LC-L (1.0625 Gbps)	200-SM-LC-L (2.125 Gbps)	400-SM-LC-L (4.250 Gbps)	400-SM-LC-M (4.250 Gbps)	800-SM-LC-L (8.500 Gbps)	1600-M5-SN-I (8.500 Gbps)	3200-M5-SN-I (28.05 Gbps)
Distance, maximum	km	10	10	10	4	10	10	10
Average power, maximum [1]	dBm					.5	2	2
Average power, minimum [2]	dBm	-9.5	-11.7	-8.4	-11.2	-8.4	-5.0	-5.0
Center wavelength, minimum [5]	nm					1260	1260	1295
Center wavelength, maximum [5]	nm					1360	1360	1325
RMS spectral width, maximum [5]	nm							
Rise/Fall Time (20-80%), maximum [3]	ps	320	160	90	90			
Optical Modulation Amplitude (OMA), maximum [5]	mW							
Relative intensity noise (RIN_{12}) [4]	dB/Hz	-116	-117	-118	-120	-128	-128	-130

Parameter	Unit	100-SM-LC-L (1.0625 Gbps)	200-SM-LC-L (2.125 Gbps)	400-SM-LC-L (4.250 Gbps)	400-SM-LC-M (4.250 Gbps)	800-SM-LC-L (8.500 Gbps)	1600-M5-SN-I (8.500 Gbps)	3200-M5-SN-I (28.05 Gbps)

Table 33. Single Mode output interface optical signal (continued)

Notes:

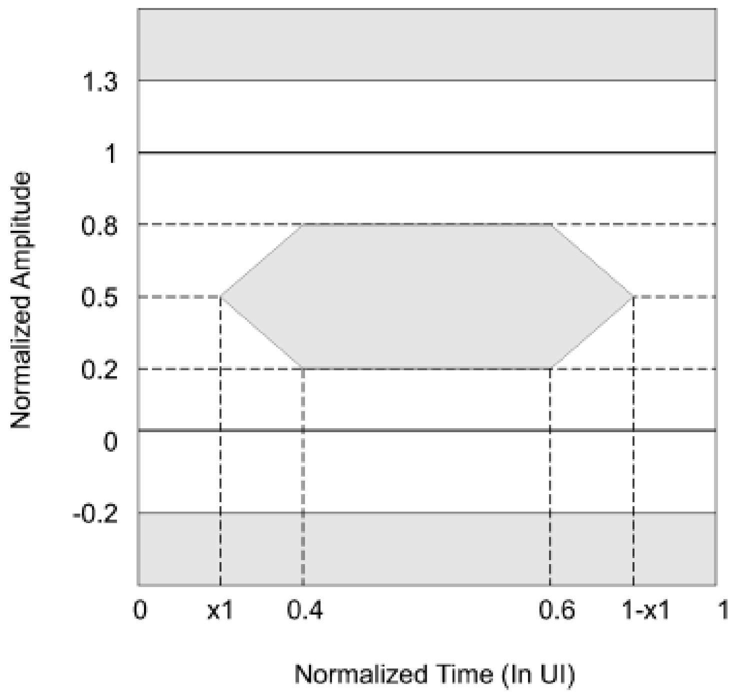
1. Lesser of class 1 laser safety limits (CDRH and EN 60825) or receiver power, maximum.
2. Based on any valid 8B/10B code pattern. The length of jumper cable between the output interface and the instrumentation is 2 meters (6.56 feet).
3. Optical rise and fall time specifications are based on the unfiltered waveforms. For the purpose of standardizing the measurement method, measured waveforms shall conform to the mask as defined in Figure 36 on page 73. If a filter is needed to conform to the mask, the filter response effect should be removed from the measured rise and fall times using the equation: $T_{RISE/FALL} = [(T_{RISE/FALL\_MEASURED})^2 - (T_{RISE/FALL\_FILTER})^2]^{1/2}$

   The optical signal may have different rise and fall times. Any filter should have an impulse response equivalent to a fourth order Bessel-Thomson Filter.
4. See "Test methods" on page 101.
5. Spectral width may be increased based on center wavelength and distance trade-offs. Link budget analysis is required for any such change. Trade-offs are available between spectral width, central wavelength, and minimum Optical Modulation Amplitude (OMA). See "Spectral width and center wavelength examples" on page 102.

Eyemask diagram

The transmitter and receiver output signals must conform to the eyemask defined in Fibre Channel FC-PI Rev. 12 for 1062.5 Mbps data rates. The fibre channel eyemask follows. A low-pass filter is recommended for the transmitter (between scope and O/E converter), to eliminate the relaxation oscillation of the laser during measurement. A fourth-order Bessel Thompson filter is recommended for this measurement with cutoff frequency equal to 0.75 times the bit rate.

The mask of the transmitter eye diagram is shown in Figure 36 on page 73.



Note: x1 shall be half the value given for total jitter at the gamma T point. The test or analysis shall include the effects of a single-pole, high-pass frequency-weighting function that progressively attenuates jitter at 20 dB/decade below a frequency of bit rate/1 667. The value of x1 applies at a total jitter probability of 10-12. At this level of probability, direct visual comparison between the mask and actual signals is not a valid method for determining compliance with the jitter output requirements.

Figure 36. Eyemask diagram

Single Mode input interface

Table 34 on page 73 specifies the input interface requirements.

Table 34. Single Mode input interface characteristic

Parameter	Unit	100-SM-LC-L (1.0625 Gbps)	200-SM-LC-L (2.125 Gbps)	400-SM-LC-L (4.250 Gbps)	400-SM-LC-M (4.250 Gbps)	800-SM-LC-L (4.250 Gbps)	800-SM-LC-L (8.500 Gbps)	1600_SM-LC-L (14.025 Gbps)	3200-SM-LC-L (28.05 Gbps)
Saturation level (Pavg received), maximum[1]	dBM	-3	-3	-1	-1	-0.5	+0.5	+2.0	+2.0
Optical Modulation Amplitude (OMA) (sensitivity), minimum [3]	mW	0.015	0.015	0.029	0.029	0.042	0.042	0.089	0.072
Return loss, minimum [2]	dB	12	12	12	12	12	12	12	26

Parameter	Unit	100-SM-LC-L (1.0625 Gbps)	200-SM-LC-L (2.125 Gbps)	400-SM-LC-L (4.250 Gbps)	400-SM-LC-M (4.250 Gbps)	800-SM-LC-L (4.250 Gbps)	800-SM-LC-L (8.500 Gbps)	1600_SM-LC-L (14.025 Gbps)	3200-SM-LC-L (28.05 Gbps)

Table 34. Single Mode input interface characteristic (continued)

Notes:

1. Based on any valid 8B/10B code pattern measured at, or extrapolated to, 10^{-12} BER. Must meet this specification with worst-case conditions as specified in Table 33 on page 71 for the output interface and Table 35 on page 74 for the fiber optic link.
2. This measurement is made using a 4-meter single mode duplex jumper cable and includes only the power in the fundamental mode of the single mode fiber.
3. FC-PI specifies receiver Optical Modulation Amplitude (OMA) instead of sensitivity and Extinction Ratio (ER). Receiver sensitivity is the minimum optical average power (Pavg) required, which can be derived from the equation Pavg = OMA ((ER+1)/2*(ER-1)). The specified OMA at 1.0625 Gbps is equivalent to an average power of -17 dBm at ER=9dB.

Single Mode link specifications

Table 35 on page 74 lists the specifications for links using 9/125-µm fiber cable. The trunk cable to which the IBM jumper cables are connected must have optical properties that conform to the specifications in the table.

Table 35. Maximum link loss (at 1300-nanometer wavelength)

Link Type	Maximum Link Length in km (Miles)	Maximum Link Loss (dB)	Trunk Size (µm)
fibre channel	10	7.8	9~10

Notes:

1. The maximum link length includes both jumper cables and trunk cables.
2. Single Mode connectors and splices must meet a minimum return loss specification of 12 dB.
3. In a single mode jumper cable, the minimum distance between the connectors or splices is 2 meters (6.56 feet).
4. In a single mode trunk cable, the distance between the connectors or splices must be sufficient to ensure that only the lowest-order bound mode propagates.

Single Mode trunk cable specifications

These are specifications are for single mode trunk cable support attachment to fiber optic channel devices:

Table 36. Specifications for single mode trunk cable support attachment to fiber optic channel devices

Specification	Details
Type of fiber	Dispersion unshifted
Operating wavelength	1270 to 1355
Mode field diameter [1]	8.7 to 10.0
Core concentricity error [2]	1.0 µm maximum
Cladding diameter [2]	125 ±2.0 µm
Cladding noncircularity [2]	2% maximum

Table 36. Specifications for single mode trunk cable support attachment to fiber optic channel devices (continued)	
Specification	**Details**
Zero dispersion wavelength [3]	1300-1322 nm (nominal 1310 nm)
Zero dispersion slope [3]	0.095 ps/(nm2-km) maximum
Cutoff wavelength (λc) [4]	1280 nm maximum
Cutoff wavelength (λcc) [5]	1260 nm maximum
Attenuation above nominal [6]	0.06 dB/km maximum
Attenuation [7]	0.5 dB/km at 1300 nm

Notes:

1. Measured in accordance with EIA 455 FOTP 164, 167, or equivalent.
2. Measured in accordance with EIA 455 FOTP 45, 48, or equivalent.
3. Measured in accordance with EIA 455 FOTP 168 or equivalent.
4. Measured in accordance with EIA 455 FOTP 80 or equivalent.
5. Measured in accordance with EIA 455 FOTP 170 or equivalent.
6. The maximum attenuation for wavelengths from 1270 to 1355 nm must not exceed the attenuation at 1310 nm by more than 0.06 dB/km. (Typically, this specification can be met by fiber with 1383-nm OH absorption peaks below 2 dB/km.)
7. This attenuation is a typical value, not a specification. Use the actual dB/km attenuation value when completing a Calculated Link Loss Work Sheet. The total link loss, however, cannot exceed 7 dB for an fibre channel link.

Single Mode duplex jumper cable specifications

These are specifications for single mode duplex jumper cable support attachment to fiber optic channel devices:

Table 37. Specifications for single mode duplex jumper cable support attachment to fiber optic channel devices

Specification	Details
Type of fiber	Dispersion unshifted
Operating wavelength	1270 to 1355 nm
Mode field diameter [1]	8.7 to 10 µm
Ferrule outer diameter	2.499 ±0.0005 mm
Zero dispersion wavelength [2]	1310 to 1322
Dispersion (1285-1300 nm) [2]	3.5 ps/(nm-km) maximum
Cutoff wavelength [3]	1260 nm maximum
Attenuation (1300 nm) [4]	0.5 dB/km maximum
Connector color	Blue
Jacket color	Yellow

Table 37. Specifications for single mode duplex jumper cable support attachment to fiber optic channel devices (continued)	
Specification	**Details**
Notes: 1. Measured in accordance with EIA 455 FOTP 164, 167, or equivalent. 2. Measured in accordance with EIA 455 FOTP 168 or equivalent. 3. Measured in accordance with EIA 455 FOTP 80 or equivalent. 4. Measured in accordance with EIA 455 FOTP 78 or equivalent.	

Single Mode interface connection

Some single mode FICON links use the single mode fibre channel standard SC Duplex connector. This connector is polarized to prevent inverting the fiber connection to the interface. It is mechanically retained in a duplex receptacle by a latch that engages the receptacle when the connector is inserted.

Some single mode FICON links use the LC Duplex connector. This connector is polarized to prevent inverting the fiber connection to the interface. It is mechanically retained in a duplex receptacle by an RJ-45 type latch that engages the receptacle when the connector is inserted. Adapter kits are available from IBM to convert between SC Duplex and LC Duplex interfaces.

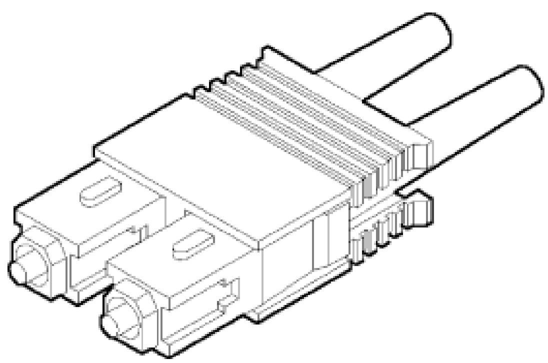


Figure 37. Fibre channel single mode duplex connector

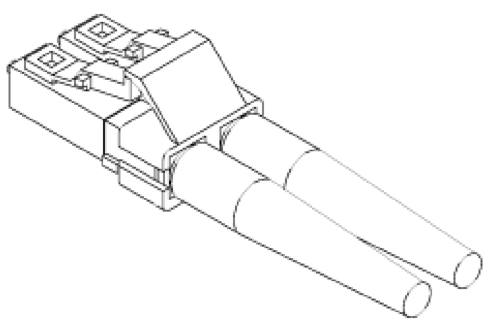


Figure 38. Fibre channel single mode duplex connector

Class 1 laser safety

Meeting the requirements for Class 1 certification is very important for an optical interconnect system in a computer environment due to the potential for customer exposure to laser radiation.

Chapter 9. InfiniBand coupling links I/O physical layer: Introduction

This chapter applies to fiber optic channel links, which includes both single mode and multimode coupling links. Parallel sysplex coupling links are also known as hyperlinks. There are two distinct physical layers that can be used as part of a fiber optic channel link: multimode and single mode. The multimode physical layer is intended for use with 50/125-micrometer multimode fiber optic cable. The single mode physical layer is intended for use with dispersion-unshifted, single mode fiber optic cable. Each physical layer provides a common, compatible I/O interface that products can use to communicate with each other through light pulses sent over multimode or single mode optical transmission fibers.

Fiber optic information transfer

Generally, an individual link consists of a transmitter and receiver at each device capable of sending and receiving optical data pulses over a duplex fiber transmission cable. A duplex link uses one fiber to transmit data to a device and the other fiber to receive data from a device. Both fibers in the link are simultaneously active.

Typically a point-to-point link uses a trunk cable, with short sections of duplex jumper cable at either end of the trunk, for routing within the building or machine room (Figure 39 on page 78). A point-to-point link is not required to be constructed with this configuration and can have alternate forms. For example, a short link could have only one jumper cable and no trunk cable. Distribution panels provide a central location for attachment of trunk and jumper cables and can be mounted in a rack, wiring closet, or on a wall.

For attachment to a fiber optic channel link device, the end of the transmission cable is terminated in a duplex connector that mates with a duplex receptacle on the device. When attached, the connector is optically coupled to the transmitter and receiver, and the device can send and receive optical signals over the cable.

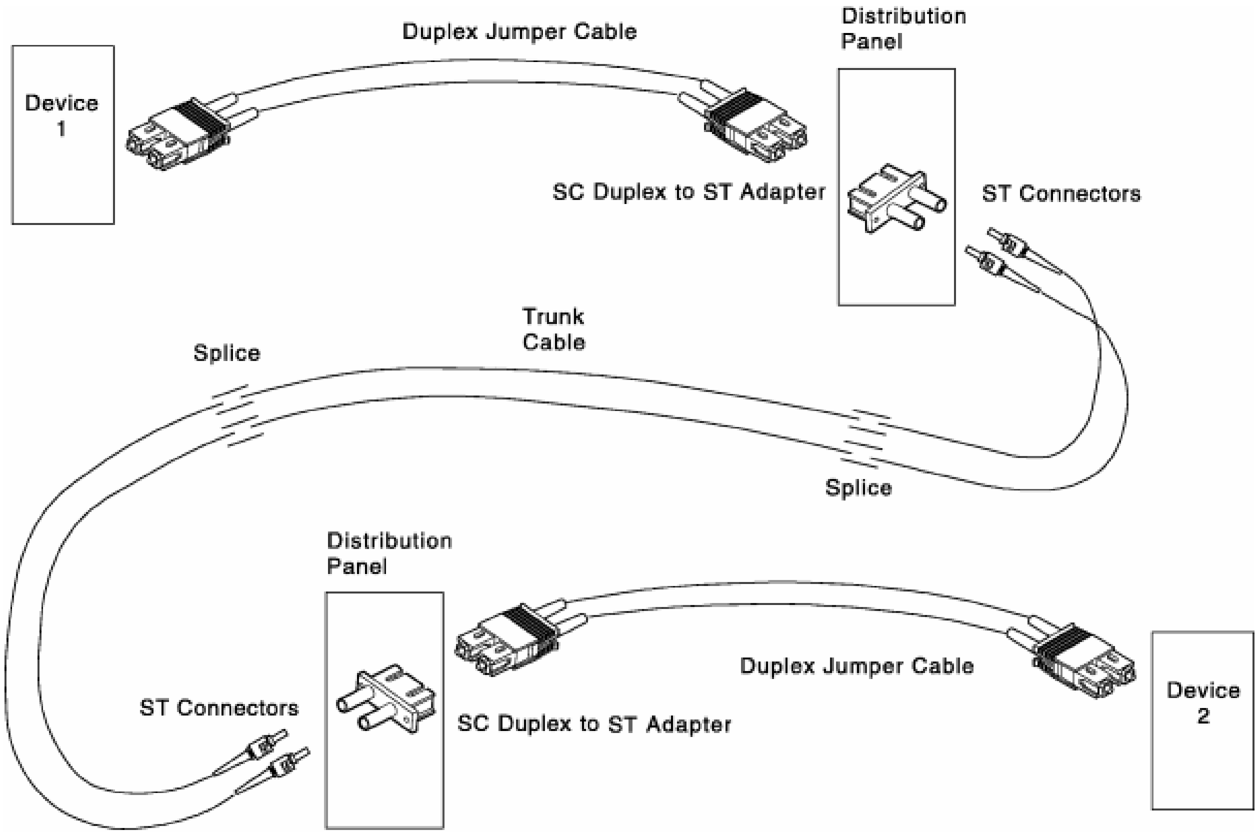


Figure 39. Example of a fiber optic link

Data transmission

The data transmitted over a link is based on an 8-bit/10-bit nonreturn-to-zero code. In the 8B/10B transmission code, the high optical power level designates a 1-bit, while the low optical power level designates a 0-bit. The idle function or one of the sequence functions is sent repetitively during periods when information is not being sent. The data transmission rate on multimode fiber optic channel links is 531 ±0.05 Mb (Mb equals 1 000 000 bits) per second, while the data transmission rate on single mode channels is either 1 062.50 ±0.10 megabits per second or 2 125 ±0.20 megabits per second.

Chapter 10. InfiniBand coupling link (12x IFB) 50 micron multimode physical layer

This interface information applies to 12x InfiniBand-SDR coupling links operating at 3 GBps (2.5 Gbps per lane, 12 lanes in each direction) used to connect System z9® Servers to System z10, zEnterprise® 196, or zEnterprise 114 servers. The 12x InfiniBand-DDR coupling links operating at 6 GBps (5.0 Gbps per lane, 12 lanes in each direction) are used to connect System z10 servers to zEnterprise 196, zEnterprise 114, or zEnterprise EC12 servers.

12x InfiniBand coupling link 50 micron multimode output interface

The 12x InfiniBand multimode links are 12x, meaning that there are 12 fibers in each direction to make up one link. To state it another way, there are 12 lanes with each lane including a transmit and receive fiber pair. Table 38 on page 79 specifies the optical signal requirements on each lane at the Multi-fiber Push-On (MPO) connector when coupled into a 12x InfiniBand cable. The parameters specified are based on the requirement that the bit error rate does not exceed 10^{-12}, including operation at the minimum interface power level.

Table 38. OM3 50 micron multimode output interface

Parameter	Minimum	Maximum	Units
Average power [1]	-5.40	-2.00	dBm
Optical modulation amplitude [3]	0.224		mW
Center wavelength (λ) [1]	830	860	nm
RMS spectral width[1]		0.85	nm
Rise time (T_r) (20-80%) [1]		75	ps
Fall time (T_f) (80-20%) [1]		75	ps
Relative intensity noise (RIN_{12}) [2]		-122	dB/Hz
Total jitter at TP2 [1]		0.443	UI

Notes:

1. Based on any valid 8B/10B code pattern. Every lane of the 12x interface must meet this criteria.
2. See Appendix D, “Coupling links I/O physical layer: Test methods,” on page 107.
3. Measurement can be made with a dc-coupled optical waveform detector that has a minimum bandwidth of 800 MHz and whose gain flatness and linearity over the range of optical power being measured provide an accurate measurement of the high and low optical power levels.

12x InfiniBand coupling links 50 micron multimode input interface

Table 39 on page 79 specifies the input interface requirements.

Table 39. OM3 50 micron multimode input interface characteristics

Parameter	Minimum	Maximum	Units
Average power	-11.00	+1.5	dBm

Table 39. OM3 50 micron multimode input interface characteristics (continued)			
Parameter	**Minimum**	**Maximum**	**Units**
Total jitter at TP3 (see note)		0.538	UI
Note: Based on any valid 8B/10B code pattern measured at, or extrapolated to, 10^{-12} BER. Must meet this specification with worst-case conditions as specified in Table 38 on page 79 for the output interface and "12x InfiniBand coupling links 50 micron multimode link specifications" on page 80 for the fiber optic link. The minimum average power input to the receiver is referred to as the sensitivity of the receiver. The maximum average power input to the receiver is referred to as the saturation of the receiver.			

12x InfiniBand coupling links 50 micron multimode link specifications

Table 40 on page 80 lists the specifications for the required physical media, 12x InfiniBand 50/125 micron multimode fiber optic cable with MPO connector. Each section of the link must conform to these properties, including 50-µm fiber with less than 2000 MHz-km. The maximum link loss is end-to-end from transmit of HCA fanout to receive of HCA fanout.

Note: 62.5-µm multimode fiber is not supported.

Table 40. Maximum link loss (at 850-nanometer wavelength)

Maximum Link Length in km (Miles)	Maximum Passive Link Loss (dB)	Trunk Size (µm)	Minimum Trunk Modal Bandwidth (MHz-km)
0.150	2.06	50.0	2000

12x InfiniBand coupling links 50 micron multimode trunk cable optical specifications

These specifications are for multimode trunk cable support attachment of fiber optic channel devices:

50/125-µm Multimode Trunk Cable	
Operating wavelength	850 nm
Core diameter	50.0 µm
Cladding diameter	125 µm
Numerical aperture	0.20 ±0.015
Minimum modal bandwidth	2000 MHz-km at 850 nm
Attenuation	<2.3 dB/km at 850 nm

12x InfiniBand coupling links 50 micron multimode MPO jumper cable specifications

These specifications are for multimode duplex jumper cable support attachment to fiber optic channel devices:

Table 41. 50 micron multimode MPO jumper cable

Specification	Details
Operating wavelength	850 nm
Core diameter	50.0 µm
Cladding diameter	125 µm
Numerical aperture	0.20 ±0.015

Table 41. 50 micron multimode MPO jumper cable (continued)	
Specification	**Details**
Minimum modal bandwidth	2000 MHz-km at 850 nm
Attenuation	<2.3 dB/km at 850 nm
Jacket color	Aqua blue

12x InfiniBand coupling links available cable lengths, OM3 50/125 µm MMF

These specifications are for multimode duplex jumper cable support attachment to fiber optic channel devices:

Table 42. Duplex 24-fiber cable Assemblies

Description	Length Meters	Length Feet	Connector Type
Duplex 24-fiber cable Assembly	10.0 m	32.8 f	MPO-MPO
Duplex 24-fiber cable Assembly	13.0 m	42.7 f	MPO-MPO
Duplex 24-fiber cable Assembly	15.0 m	49.2 f	MPO-MPO
Duplex 24-fiber cable Assembly	20.0 m	65.6 f	MPO-MPO
Duplex 24-fiber cable Assembly	40.0 m	131.2 f	MPO-MPO
Duplex 24-fiber cable Assembly	80.0 m	262.4 f	MPO-MPO
Duplex 24-fiber cable Assembly	120.0 m	393.7 f	MPO-MPO
Duplex 24-fiber cable Assembly	150.0 m	492.1 f	MPO-MPO
Duplex 24-fiber cable Assembly	Custom	N/A	MPO-MPO

12x InfiniBand coupling links 50 micron multimode interface connector

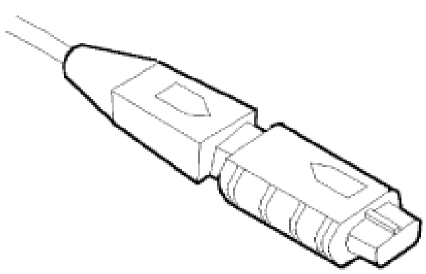


Figure 40. 12x InfiniBand multimode interface with MPO connector

Class 1M laser safety

Meeting the requirements for a Class 1M classification is very important for an optical interconnect system in a computer environment due to the potential for customer exposure to laser radiation. The "Laser compliance" on page vii details the compliance certification of the coupling links.

The 12x IFB coupling links achieved Class 1M laser certification through numerous design safeguards. Whenever a duplex link is opened for any reason (such as broken fiber or unplugged connectors) the link detects this condition and reduces the optical power emissions from the transmitter on both ends of the link to levels below the class 1M international safety limits. The power is reduced quickly enough to prevent any possible injury to the operator. When the link is in this mode, the transmitter continues to pulse at a very low duty cycle. When the link is restored, the transmitter automatically performs a handshake and reactivates both ends of the link.

Chapter 11. 1x InfiniBand coupling link 9 micron single mode physical layer

This interface information applies to InfiniBand coupling links operating at 2.5 Gbps per lane (SDR) and at 5.0 Gbps per lane (DDR) and supports a distance of 10 Km (6.2 miles), without retransmission.

1x InfiniBand coupling link micron single mode output interface

The 1x InfiniBand single mode fiber optic links are 1x, meaning that there is one signal lane (1 fiber) in each direction to make up one link. Table 28 specifies the optical signal requirements on each lane using a LC Duplex connector. The parameters specified in Table 28 are for both SDR (2.5 Gbps) and DDR (5.0 Gbps) operation, and are based on the requirement that the bit error rate does not exceed 10-12, including operation at the minimum interface power level. The parameters are specified at the output of a 2 m single mode jumper cable connected to the output interface.

Table 43. Single Mode fiber optic output interface

Parameter	Minimum	Maximum	Units
Average power into SMF [1]	-7.0	+0.5	dBm
Optical modulation amplitude [3]	0.29		mW
Center wavelength (λ) [1]	1260	1360	nm
Rise time (20-80%) [1]		75	ps
Fall time (80-20%) [1]		75	ps
Relative intensity noise (RIN_{12}) [2]		-128	dB/Hz
Total jitter at TP2 [1]		90.4	ps

Notes:

1. Based on any valid 8B/10B code pattern. Every lane of the 1x interface must meet this criteria.
2. Measurement can be made with a dc-coupled optical waveform detector that has a minimum bandwidth of 800 MHz and whose gain flatness and linearity over the range of optical power being measured provide an accurate measurement of the high and low optical power levels.

1x InfiniBand coupling link 9 micron single mode input interface

Table 44 on page 83 specifies the input interface requirements.

Table 44. 9 micron single mode input interface characteristics

Parameter	Minimum	Maximum	Units
Average power	-13.00		dBm
RX OMA	0.03		mW
Total jitter at TP3 (see note)		0.066	UI

Table 44. 9 micron single mode input interface characteristics (continued)			
Parameter	**Minimum**	**Maximum**	**Units**
Note: Based on any valid 8B/10B code pattern measured at, or extrapolated to, 10^{-12} BER. Must meet this specification with worst-case conditions as specified in Table 43 on page 83 for the output interface and "1x InfiniBand coupling link 9 micron single mode link specifications" on page 84 for the fiber optic link. The minimum average power input to the receiver is referred to as the sensitivity of the receiver. The maximum average power input to the receiver is referred to as the saturation of the receiver.			

1x InfiniBand coupling link 9 micron single mode link specifications

Table 45 on page 84 lists the specifications for the required physical media, 1x InfiniBand 9/125 micron single mode fiber optic cable with LC Duplex connector. Each section of the link must conform to these properties. The maximum link loss is end-to-end from transmit of HCA fanout to receive of HCA fanout.

Table 45. Maximum link loss (at 1300-nanometer wavelength)

Maximum Link Length in km (Miles)	Maximum Passive Link Loss (dB)	Trunk Size (µm)
10 (6.2)	6.0	9.0

1x InfiniBand coupling link 9 micron single mode LC jumper cable specifications

The specification below is for a single mode fiber duplex jumper cable attachment to DWDM devices, which uses an industry standard Duplex LC Duplex connector:

Table 46. 1x InfiniBand coupling link 9 micron single mode LC jumper cable specifications

Specification	Details
Type of fiber	Dispersion unshifted
Operating wavelength	1270 to 1355 nm
Mode field diameter [1]	8.7 to 10.0 µm
Zero dispersion wavelength [2]	1310-1322 nm
Dispersion (1285-1330 nm) [2]	3.5 ps/(nm-km) maximum
Cutoff wavelength [3]	1260 nm maximum
Attenuation (1300 nm)[4]	0.5 dB/km at 1310 nm
Connector color	Blue
Jacket color	Yellow

Notes:

1. Measured in accordance with EIA 455 FOTP 164, 167, or equivalent.
2. Measured in accordance with EIA 455 FOTP 168 or equivalent.
3. Measured in accordance with EIA 455 FOTP 80 or equivalent.
4. Measured in accordance with EIA 455 FOTP 78 or equivalent.

Note:

The fiber optic cabling is the same as used with FICON LX, 10 GbE LR, and GbE LX.

1x InfiniBand DDR 9 micron single mode trunk cable optical specifications

These specifications are for single mode trunk cable support attachment of fiber optic channel devices:

Table 47. 1x InfiniBand DDR 9 micron single mode trunk cable optical specifications

Specification	Details
Type of fiber	Dispersion unshifted
Operating wavelength	1270 to 1355 nm
Mode field diameter [1]	8.7 to 10.0 µm
Core concentricity error [2]	1.0 µm maximum
Cladding diameter [2]	125 ±2.0 µm
Cladding noncircularity [2]	2% maximum
Zero dispersion wavelength [3]	1295-1322 nm (nominal 1310 nm)
Zero dispersion slope [3]	0.095 ps/(nm^2-km) maximum
Cutoff wavelength (λ_c) [4]	1280 nm maximum
Cutoff wavelength (λ_{cc}) [5]	1260 nm maximum
Attenuation above nominal [6]	0.06 dB/km maximum
Attenuation [7]	0.5 dB/km at 1310 nm

Notes:

1. Measured in accordance with EIA 455 FOTP 164, 167, or equivalent.
2. Measured in accordance with EIA 455 FOTP 45, 48, or equivalent.
3. Measured in accordance with EIA 455 FOTP 168 or equivalent.
4. Measured in accordance with EIA 455 FOTP 80 or equivalent.
5. Measured in accordance with EIA 455 FOTP 170 or equivalent.
6. The maximum attenuation for wavelengths from 1270 to 1355 nm must not exceed the attenuation at 1310 nm by more than 0.06 dB/km. (Typically, this specification can be met by fiber with 1383-nm OH absorption peaks below 2 dB/km.)
7. This attenuation is a typical value, not a specification. Use the actual dB/km attenuation value when completing a Calculated Link Loss Work Sheet. The total link loss, however, cannot exceed 6.0 dB for a coupling link.

1x InfiniBand coupling links 9 micron single mode interface connector

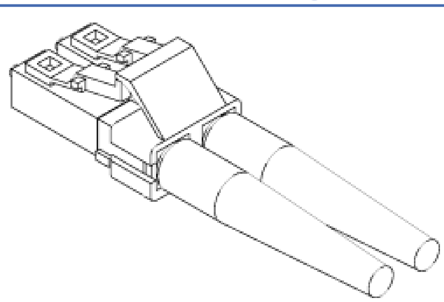


Figure 41. 1x InfiniBand single mode interface connector

Class 1M laser safety

Meeting the requirements for a Class 1M classification is very important for an optical interconnect system in a computer environment due to the potential for customer exposure to laser radiation. The "Laser compliance" on page vii details the compliance certification of the coupling links.

The 1x IFB coupling links achieved Class 1M laser certification through numerous design safeguards. Whenever a duplex link is opened for any reason (such as broken fiber or unplugged connectors) the link detects this condition and reduces the optical power emissions from the transmitter on both ends of the link to levels below the class 1M international safety limits. The power is reduced quickly enough to prevent any possible injury to the operator. When the link is in this mode, the transmitter continues to pulse at a very low duty cycle. When the link is restored, the transmitter automatically performs a handshake and reactivates both ends of the link.

Chapter 12. Integrated Coupling Adapter (24x PCIe) 50 micron multimode physical layer

This interface information applies to 24x ICA-SR coupling links and zHyperLink Express, operating at 8 GBps (8 GBps per lane, 8 lanes in each direction), which are used to connect the IBM Z and IBM LinuxONE Emperor servers.

24x ICA coupling link 50 micron multimode output interface

The 24x ICA multimode links are 24x, meaning that there are 24 fibers, 12 in each direction, to make up one link. To state it another way, there are 12 lanes with each lane including a transmit and receive fiber pair. Table 48 on page 87 specifies the optical signal requirements on each lane at the Multi-fiber Push-On (MPO) connector when coupled into a 24x ICA cable. The parameters specified are based on the requirement that the bit error rate does not exceed 10^{-12}, including operation at the minimum interface power level.

Table 48. Transceiver optical transmitter characteristics

Parameter	Minimum	Maximum	Units
Center wavelength	840	860	nm
RMS spectral width		0.65	nm
Average launch power, each lane	-7.6	2.4	dBm
Optical Modulation Amplitude (OMA), each lane	-5.6	3	dBm
Difference in launch power (OMA) between any two lanes		4	dB
Peak power, each lane		4	dBm
Launch power in OMA minus TDP, each lane	-6.5		
Transmitter and dispersion penalty (TDP), each lane		3.5	dB
Extinction ratio	3		dB
Optical bit skew between any two lanes, due to transmitter		125	ps
Optical return loss tolerance		12	dB
Encircled flux[1]	>/=86% at 19 µm </=30% at 4.5 µm		
Transmitter eye mask definition[2]: {X1, X2, X3, Y1, Y2, Y3} (Hit ratio 5x10-5 hits per sample)	Specification values: 0.23, 0.34, 0.43, 0.27, 0.35, 0.4		
Average launch power of OFF transmitter, each lane		030	dBM

Table 48. Transceiver optical transmitter characteristics (continued)			
Parameter	**Minimum**	**Maximum**	**Units**

Notes:

1. If measured into type A1a.2 50 µm fiber in accordance with IEC 61280-1-4.
2. In accordance with 802.3ba, Clause 86.8.4.6.1.

24x ICA coupling links 50 micron multimode input interface

Table 49 on page 88 specifies the input interface requirements.

Table 49. Transceiver optical receiver characteristics

Parameter	Minimum	Maximum	Units
Center wavelength	8.40	860	nm
Damage threshold	3.4		dBm
Average power at receiver input, each lane	-9.5	2.4	dBm
Receiver reflectance		-12	dB
Optical Modulation Amplitude (OMA), each lane		3	dBm
Stressed receiver sensitivity in OMA, each lane[1]		-5.4	dB
Peak power, each lane		4	dBm
Receiver jitter tolerance in OMA, each lane[2]		-5.4	dBm

Notes:

1. Measured with conformance test signal for a BER = 10^{-12} and conditions as specified in 802.3ba, Clause 86.7.3.
2. Measured in accordance with receiver conditions as specified in 802.3ba, Clause 86.7.3.

zHyperLink and 24x ICA coupling links 50 micron multimode link specifications

Table 50 on page 88 lists the specifications for the required physical media, 24x ICA-SR 50/125 micron multimode fiber optic cable with MPO connector. Each section of the link must conform to these properties, including 50-µm fiber with less than 2000 MHz-km. The maximum link loss is end-to-end from transmit of ICA to receive of ICA.

Note: 62.5-µm multimode fiber is not supported.

Table 50. Maximum link loss (at 850-nanometer wavelength)

Maximum Link Length in meters	Maximum Passive Link Loss (dB)	Trunk Size (µm)	Minimum Trunk Modal Bandwidth (MHz-km)
100	2.06	50.0	2000 (OM3)

Table 50. Maximum link loss (at 850-nanometer wavelength) (continued)			
Maximum Link Length in meters	**Maximum Passive Link Loss (dB)**	**Trunk Size (µm)**	**Minimum Trunk Modal Bandwidth (MHz-km)**
150	2.00	50.0	4700 (OM4)
150	2.00	50.0	4700 (OM5)

zHyperLink and 24x ICA coupling links 50 micron multimode trunk cable optical specifications

These specifications are for multimode trunk cable support attachment of fiber optic channel devices:

50/125-µm Multimode Trunk Cable		
Operating wavelength	850 nm	850 nm
Core diameter	50.0 µm	50.0 µm
Cladding diameter	125 µm	125 µm
Numerical aperture	0.20 ±0.015	0.20 ±0.015
Minimum modal bandwidth	2000 MHz-km at 850 nm	4700 MHz-km at 850 nm
Attenuation	<2.3 dB/km at 850 nm	<2.3 dB/km at 850 nm

zHyperLink and 24x ICA coupling links 50 micron multimode MPO jumper cable specifications

These specifications are for multimode duplex jumper cable support attachment to fiber optic channel devices:

Table 51. 50 micron multimode MPO jumper cable		
Specification	**Details for 2000 MHz-km at 850 nm minimum modal bandwidth**	**Details for 4700 MHz-km at 850 nm minimum modal bandwidth**
Operating wavelength	850 nm	850 nm
Core diameter	50.0 µm	50.0 µm
Cladding diameter	125 µm	125 µm
Numerical aperture	0.20 ±0.015	0.20 ±0.015
Minimum modal bandwidth	2000 MHz-km at 850 nm	4700 MHz-km at 850 nm
Attenuation	<2.3 dB/km at 850 nm	<2.3 dB/km at 850 nm
Jacket color	Aqua	Aqua
SKEW (max)	10 ps/m, 400 ps max	10 ps/m, 400 ps max

zHyperLink and 24x ICA coupling links available cable lengths, OM3, OM4, and OM5 50/125 um MMF

These specifications are for multimode duplex jumper cable support attachment to fiber optic channel devices:

Table 52. Single MTP 24 to single MTP 24 fiber optic ASM (OM3)		
P/N	**EC level**	**Length (M)**
00JJ544	N37116	1.0
00JJ545	N37116	2.0
00JJ546	N37116	3.0
00JJ547	N37116	5.0
00JJ548	N37116	8.0
00LU290	N37116	10.0
00LU291	N37116	13.0
00JJ549	N37116	15.0
00JJ550	N37116	20.0
00LU292	N37116	40.0
00LU293	N37116	80.0
00LU294	N37116	100.0
00LU295	N37116	Custom

Table 53. Single MTP 24 to single MTP 24 fiber optic ASM (OM4)		
P/N	**EC level**	**Length (M)**
00JA683	N37116	1.0
00JA684	N37116	2.0
00JA685	N37116	3.0
00JA686	N37116	5.0
00JA687	N37116	8.0
00LU282	N37116	10.0
00LU283	N37116	13.0
00JA688	N37116	15.0
00JA689	N37116	20.0
00LU284	N37116	40.0
00LU285	N37116	80.0
00LU286	N37116	120.0
00LU287	N37116	150.0
00LU288	N37116	Custom

Table 54. Single MTP 24 to single MTP 24 fiber optic ASM (OM5)		
P/N	**EC level**	**Length (M)**
01PP094	N37743	1.0
01PP095	N37743	2.0

Table 54. Single MTP 24 to single MTP 24 fiber optic ASM (OM5) (continued)

P/N	EC level	Length (M)
01PP096	N37743	3.0
01PP097	N37743	5.0
01PP098	N37743	8.0
01PP099	N37743	10.0
01PP0100	N37743	13.0
01PP0101	N37743	15.0
01PP0102	N37743	20.0
01PP0103	N37743	40.0
01PP0104	N37743	80.0
01PP0105	N37743	120.0
01PP0106	N37743	150.0
01PP0107	N37743	Custom*
*Custom length can not exceed 150M.		

Cable Distributors:

- Global support ID for cabling support:

  Functional ID Name: Global Cabling Support/India/IBM
  Functional ID Shortname: cabling@in.ibm.com
- Anixter: ibmcabling@anixter.com, or 877-747-2830
- IBM Global Technology Services® (GTS): Visit http://www.ibm.com and search for Facility Cabling Services.
- For Corning cable support, contact cabling@in.ibm.com.

IBM Qualified Cable Suppliers:

- Computer Crafts Inc.: http://www.computer-crafts.com
- Fujikura: RBFiber@fujikura.com

24x ICA coupling links 50 micron multimode interface connector

Figure 42 on page 92 illustrates a 24x ICA multimode interface with MPO connector.

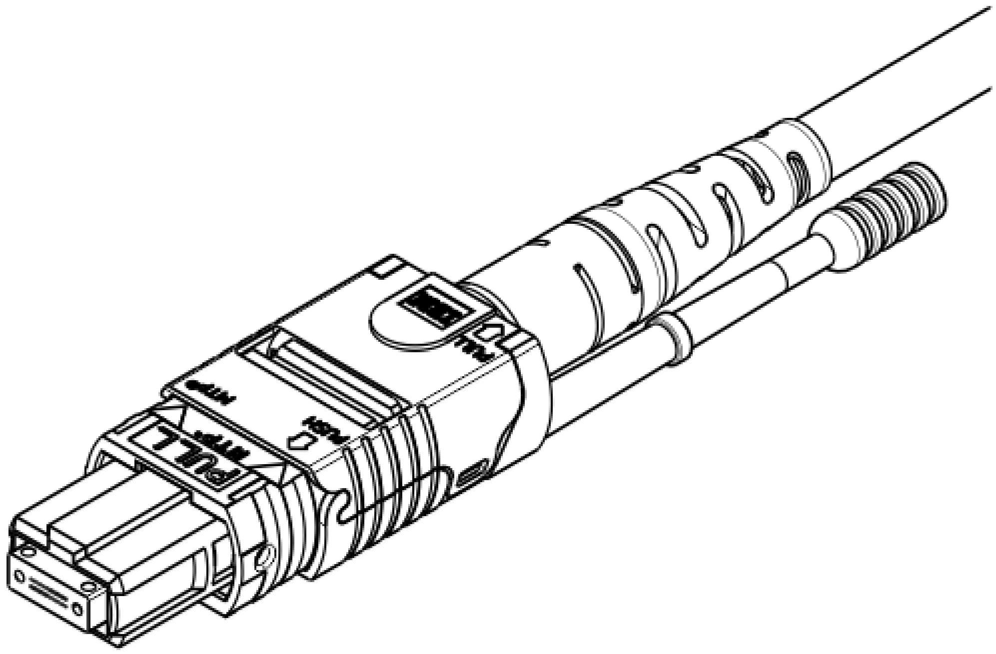


Figure 42. 24x ICA multimode interface with MPO connector

Chapter 13. Coupling Express LR feature

General information

The Coupling Express LR is a two-port, Ethernet-based, long-distance coupling card. The Coupling Express LR is designed to drive distances up to 10 km unrepeated and up to 100 km with a qualified dense wavelength division multiplexing (DWDM) device. Coupling Express LR supports a link data rate of 10 Gbps.

Table 55. Coupling Express LR - single mode LC jumper cable specifications

Specification	Details
Type of fiber	Dispersion unshifted
Operating wavelength	1270 to 1355 nm
Mode field diameter [1]	8.7 to 10.0 µm
Zero dispersion wavelength [2]	1310-1322 nm
Dispersion (1285-1330 nm) [2]	3.5 ps/(nm-km) maximum
Cutoff wavelength [3]	1260 nm maximum
Attenuation (1300 nm)[4]	0.5 dB/km at 1310 nm
Connector color	Blue
Jacket color	Yellow

Notes:

1. Measured in accordance with EIA 455 FOTP 164, 167, or equivalent.
2. Measured in accordance with EIA 455 FOTP 168 or equivalent.
3. Measured in accordance with EIA 455 FOTP 80 or equivalent.
4. Measured in accordance with EIA 455 FOTP 78 or equivalent.

Appendix A. Measurement conversion tables

This appendix contains conversion tables from English measurements to metric and metric measurements to English.

English-to-metric conversion table

English value	Multiplied by	Equals metric value
Fahrenheit	(°F -32) x 0.556	Celsius
Inches	2.54	Centimeters (cm)
Inches	25.4	Millimeters (mm)
Feet	0.305	Meters (m)
Miles	1.61	Kilometers (km)
Pounds	0.45	Kilograms (kg)
Pound force (lbf)	4.45	Newtons (N)

Metric-to-english conversion table

English value	Multiplied by	Equals metric value
Celsius	(°C x 1.8) + 32	Fahrenheit
Centimeters (cm)	0.39	Inches
Millimeters (mm)	0.039	Inches
Meters (m)	3.28	Feet
Kilometers (km)	0.621	Miles
Kilograms (kg)	2.20	Pounds
Newtons (N)	0.225	Pound force (lbf)

Appendix B. Fiber optic channel attachment options

Fiber optic channel attachment options

This table lists maximum unrepeated distance and link budget for each type of channel; longer distances are possible using repeaters, switches, or channel extenders. Minimum bandwidth requirement to achieve these distances is listed for multimode fiber only, this specification does not apply to single mode fiber. MCP denoted mode conditioning patch cable, which is required to operate some links over multimode fiber. Bit rates given below may not correspond to effective channel data rate in a given application due to protocol overheads and other factors. SC Duplex connectors are keyed per the ANSI Fibre Channel Standard specifications. Deviations from these specifications, including longer distances, may be possible and are evaluated on an individual basis by submitting a Request for Price Quote (RPQ) to IBM. Various types of non-fiber optic interconnects are also supported, including 10 Mbps, 100 Mbps, and 1000 Mbps Ethernet using 1000BASE-T Ethernet over Category 5 or Category 6 copper cabling.

Note: Any reference to FICON Express could apply to FICON Express, FICON Express2, FICON Express4, FICON Express8, and FICON Express8S. Any reference to OSA-Express could apply to OSA-Express, OSA-Express2, OSA-Express3, or OSA-Express4S

Table 56. Fiber optic channel attachment options

Channel Type	Fiber	Connector	Bit Rate	Distance/Bandwidth	Link Loss Budget
FICON (LX) at 1 Gbps	Single Mode	SC Duplex or LC Duplex	1.06 Gbit/s	10 km	7.8 dB
	Multimode 62.5 (With MCP)	SC Duplex	1.06 Gbit/s	550 meters/ 500 MHz-km	5 dB
	Multimode 50.0 (With MCP)	SC Duplex	1.06 Gbit/s	550 meters/ 400 MHz-km	5 dB
FICON Express (LX) at 2Gbps	Single Mode	LC Duplex	2.13 Gbit/s	10km	7.8 dB
FICON Express (LX) at 4 Gbps	Single Mode	LC Duplex	4.25 Gbit/s	10 km	7.8 dB
	Single Mode	LC Duplex	4.25 Gbit/s	4 km	4.8 dB
FICON Express (LX) at 8Gbps	Single Mode	LC Duplex	8.5 Gbit/s	10 km	6.4 dB
FICON Express (LX) at 16 Gbps	Single Mode	LC Duplex	14.025 Gbit/s	10 km	6.4 dB
32G FCP (LX)	Single Mode	LC Duplex	28.05 Gbit/s	10 km	6.34 dB[Note 1]

Table 56. Fiber optic channel attachment options (continued)					
Channel Type	**Fiber**	**Connector**	**Bit Rate**	**Distance/Bandwidth**	**Link Loss Budget**
FICON (SX) at 1 Gbps	Multimode 62.5 Note 2	SC Duplex or LC Duplex	1.06 Gbit/s	300 meters/ 200 MHz-km	3.0 dB
	Multimode 50.0 Note 2	SC Duplex or LC Duplex	1.06 Gbit/s	500 meters/ 500 MHz-km 860 meters/ 2000 MHz-km	3.85 dB 4.62 dB
FICON Express (SX) at 2 Gbps	Multimode 62.5	LC Duplex	2.13 Gbit/s	150 meters/ 200 MHz-km	2.10 dB
	Multimode 50.0	LC Duplex	2.13 Gbit/s	300 meters/ 500 MHz-km 500 meters/ 2000 MHz-km	2.62 dB 3.31 dB
FICON Express (SX) at 4 Gbps	Multimode 62.5	LC Duplex	4.25 Gbit/s	70 meters/ 200 MHz-km	1.78 dB
	Multimode 50.0	LC Duplex	4.25 Gbit/s	150 meters/ 500 MHz-km 380 meters/ 2000 MHz-km 400 meters/ 4700 MHz-km	2.06 dB 2.88 dB 2.95 dB
FICON Express (SX) at 8 Gbps	Multimode 62.5	LC Duplex	8.5 Gbit/s	21 meters/ 200 MHz-km	1.58 dB
	Multimode 50.0	LC Duplex	8.5 Gbit/s	50 meters/ 500 MHz-km 150 meters/ 2000 MHz-km 190 meters/ 4700 MHz-km	1.68 dB 2.04 dB 2.19 dB
FICON Express (SX) at 16 Gbps	Multimode 50.0	LC Duplex	14.025 Gbit/s Note 3	35 meters/ 500 MHz-km 100 meters/ 2000 MHz-km 125 meters/ 4700 MHz-km	1.63 dB 1.86 dB 1.95 dB
32G FCP (SX)	Multimode 50.0	LC Duplex	28.05 Gbit/s Note 3	35 meters/ 500 MHz-km 100 meters/ 2000 MHz-km 125 meters/ 4700 MHz-km	1.57 dB Note 4 1.75 dB Note 4 1.86 dB Note 4
OSA- Express GbE LX	Single Mode	LC Duplex	1.25 Gbit/s	5 km	4.6 dB
	Multimode 50.0 (with MCP)	LC Duplex	1.25 Gbit/s	550 meters/ 500 MHz-km	2.4 dB
OSA- Express GbE SX	Multimode 62.5	LC Duplex	1.25 Gbit/s	275 meters/ 200 MHz-km	2.6 dB
	Multimode 50.0	LC Duplex	1.25 Gbit/s	550 meters/ 500 MHz-km	3.6 dB
	Multimode 50.0	LC Duplex	1.25 Gbit/s	550 meters/ 2000 MHz-km	3.6 dB
OSA- Express 10GbE (LR)	Single Mode	LC Duplex	10.0 Gbit/s	10 km	6.0 dB
OSA- Express 10GbE (SR)	Multimode 62.5	LC Duplex	10.0 Gbit/s	33 meters/ 200 MHz-km	1.6 dB
	Multimode 50.0	LC Duplex	10.0 Gbit/s	82 meters/ 500 MHz-km	1.8 dB
	Multimode 50.0	LC Duplex	10.0 Gbit/s	300 meters/ 2000 MHz-km	2.6 dB
	Multimode 50.0	LC Duplex	10.0 Gbit/s	400 meters/ 4700 MHz-km	2.9 dB

Table 56. Fiber optic channel attachment options (continued)					
Channel Type	**Fiber**	**Connector**	**Bit Rate**	**Distance/Bandwidth**	**Link Loss Budget**
OSA- Express 25 GbE SR	Multimode 50.0	LC Duplex	25.78125 Gbit/s	OM3 (.5 - 70m) 2000 MHz-km OM4 (.5 - 100m) 4700 MHz-km	1.8.dB 1.9 dB
Coupling Express (LR)	Single Mode	LC Duplex	10.0 Gbit/s	10 km	6.0 dB
RoCE 10GbE (SR)	Multimode 62.5	LC Duplex	10.0 Gbit/s	33 meters/ 200 MHz-km	1.6 dB
	Multimode 50.0	LC Duplex	10.0 Gbit/s	82 meters/ 500 MHz-km	1.8 dB
	Multimode 50.0	LC Duplex	10.0 Gbit/s	300 meters/ 2000 MHz-km	2.6 dB
	Multimode 50.0	LC Duplex	10.0 Gbit/s	400 meters/ 4700 MHz-km	2.9 dB
PSIFB (1x IFB)	Single Mode	LC Duplex	2.5 / 5.0 Gbit/s	10 km	5.66 dB
PSIFB (12x IFB)	Multimode 50.0	12x MPO	3.0 GB/s	150 meters/ 2000 MHz-km	2.06 dB
	Multimode 50.0	12x MPO	6.0 GB/s	150 meters/ 2000 MHz-km	2.06 dB
ICA and zHyperLink	Multimode 50.0	24x MPO	8.0 GB/s	100 meters/ 2000 MHz-km	1.9 dB[Note 5]
	Multimode 50.0	24x MPO	8.0 GB/s	150 meters/ 4700 MHz-km	1.5 dB[Note 6]

Notes:

1. Link loss assumes 2 dB connection loss. For other connection loss, please see Table 57 on page 99.
2. Indicates channels which use short wavelength (850 nm) optics; all link budgets and fiber bandwidths are measured at this wavelength. Unless noted, all other links are long wavelength (1300 nm).
3. Mbit/s, reduced to an effective data rate of 100 Mbit/s by protocol overhead.
4. For max operating distance and loss budget for different connection losses, see Table 57 on page 99.
5. 1.5 dB is allocated for connection loss.
6. 1.0 dB is allocated for connection loss.

Table 57. 3200-SN maximum operating distance and loss budget for different connection losses					
Distance (m) / Loss Budget (dB)					
Fiber Type	**Connection loss**				
	3.0 dB	2.4 dB	2.0 dB	1.5 dB	1.0 dB
M5F (OM4)	20 / 3.04	65 / 2.64	80 / 2.36	100 / 1.86	110 / 1.48
M5E (OM3)	12 / 3.03	45 / 2.64	60 / 2.24	70 / 1.87	80 / 1.41
M5 (OM2)	NA	15 / 2.52	15 / 2.52	20 / 2.02	25 / 1.29
OS1 / OS2	8250 / 6.52	9250 / 6.42	10000 / 6.34	11000 / 6.21	11750 / 6.11

Appendix C. FICON/FCP I/O Physical Layer: Test methods and examples

Test methods

A.1 Eye-window measurement

The output interface optical eye-window (EW) measurement involves measuring the open eye-window on a bit-by-bit basis, using a BERT (bit error rate test) test set. The bit error rate (BER) is measured at various *T* sub $_d$'s (decision points) within the eye pattern to ensure conformance to the eye-window specification.

The eye-window is given by:

$EW = | T_d (max) - T_o | + | T_o - T_d (min) |$

Where:

T_o = Center of the baud interval
T_d = BER decision point as referenced from T_o
T_d (max) = Rightmost decision point
T_d (min) = Leftmost decision point

For each position of T_d from T_d(min) to T_d(max), a BER measurement is taken, giving the probability of error at the T_d position. In effect, T_d is swept across the eye pattern, measuring the probability of error at each point in the eye. The range of T_d values that result in a BER ≤ 10^{-12} establishes the eye-window, and the smallest range from T_o must be ≥ half the appropriate eye-window specification.

In practice, a BERT test set is used to generate and sweep the decision point (using the BERT clock in conjunction with a precise delay generator), to make the bit-by-bit error count and to calculate the measured BER. The center of the baud interval (T_o) pattern is the midpoint between positioning T_d to the left and right edges of the eye to achieve a BER > 10^{-2} while transmitting a square wave pattern. Subsequent measurements are made while transmitting allowed 8/10 code patterns. The measured BER at T_o, T_d (max), T_d (min) must be ≤ 10^{-12} and the values of both (T_d (max) - T_o) and (T_o - T_d (min)) must be greater than or equal to half the appropriate eye-window specification. All measurements are made with respect to a linear phase, low-pass filter with a 3 dB cutoff frequency of 800 MHz for single mode fiber optic channel links and 300 MHz for multimode fiber optic channel links. It is important that the BERT retiming data latch be significantly faster than the timing resolution of interest.

A common practice used to save time is to measure the eye-window at higher probabilities (for example, 10^{-6}) and then extrapolate to the eye-window at a 10^{-12} probability.

Relative Intensity Noise (RIN) measurement

When lasers subject to reflection-induced noise effects are operated in a cable plant with a low optical return loss, the lasers will produce an amount of noise which is a function of the magnitude and polarization state of the reflected light. For fibre channel standards, the magnitude of the reflected light can be 12 dB, resulting in the notation of RIN_{12} for the relative intensity noise.

An example of a RIN test arrangement is shown in Figure 43 on page 102. The test cable between the device under test (DUT) and the detector forms an optical path having a single discrete reflection at the detector with the specified optical return loss. There must be only one reflection in the system because the polarization rotator can only adjust the polarization state of one reflection at a time. The polarization rotator should be adjusted to maximize the noise read by the power meter.

Two measurements are made by the photodetector: average optical power and noise. The average optical power is determined by measuring the average current (Ipd) through the detector. The noise is measured by ac-coupling the detector into the high frequency electrical power meter. A low-pass filter is used between the photodetector and the power meter to limit the noise measured to 800 MHz for single mode fiber optic channel links and 300 MHz for multimode links.

In order to measure the noise, the modulation to the DUT must be turned off. You can calculate the RIN from the observed detector current and electrical noise using this equation:

$$RIN = 10 \log\left(\frac{P_e}{BW\ 25\ I_{pd}^2}\right) - G \quad dB/Hz$$

Where:	**Is:**
I_{pd}	= Current through the detector in amps
P_e	= Electrical noise power in watts
BW	= Bandwidth of the measuring system in hertz
	= Low pass bandwidth of filter; high-pass bandwidth of dc blocking capacitor
G	= Gain in dB of any amplifier in the noise measurement path

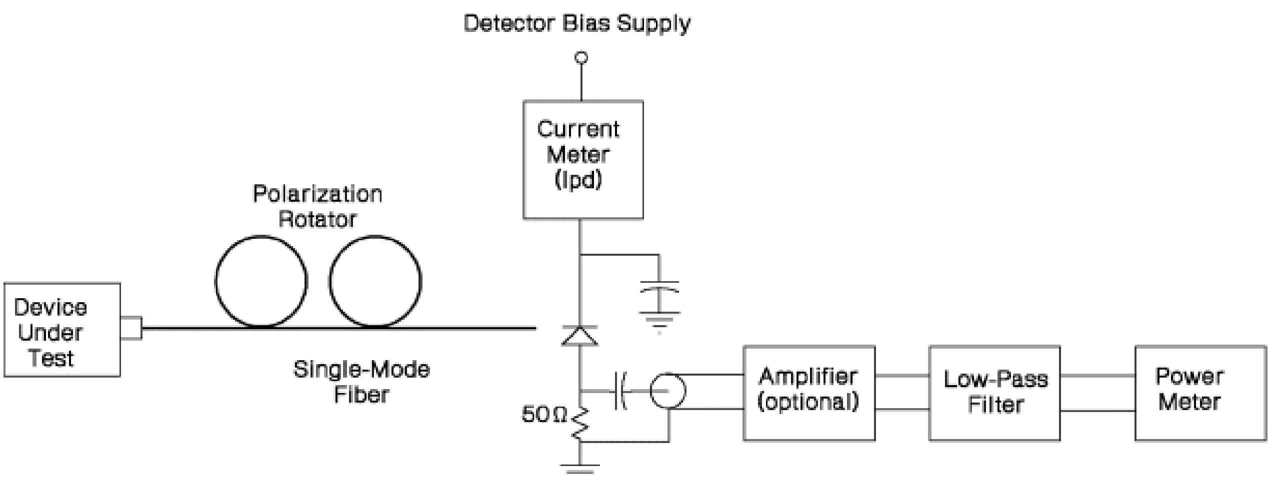


Figure 43. Example of a RIN test setup

Spectral width and center wavelength examples

To meet the link power budget, the transmitter can trade-off OMA, spectral width, and center wavelength as show in the following.

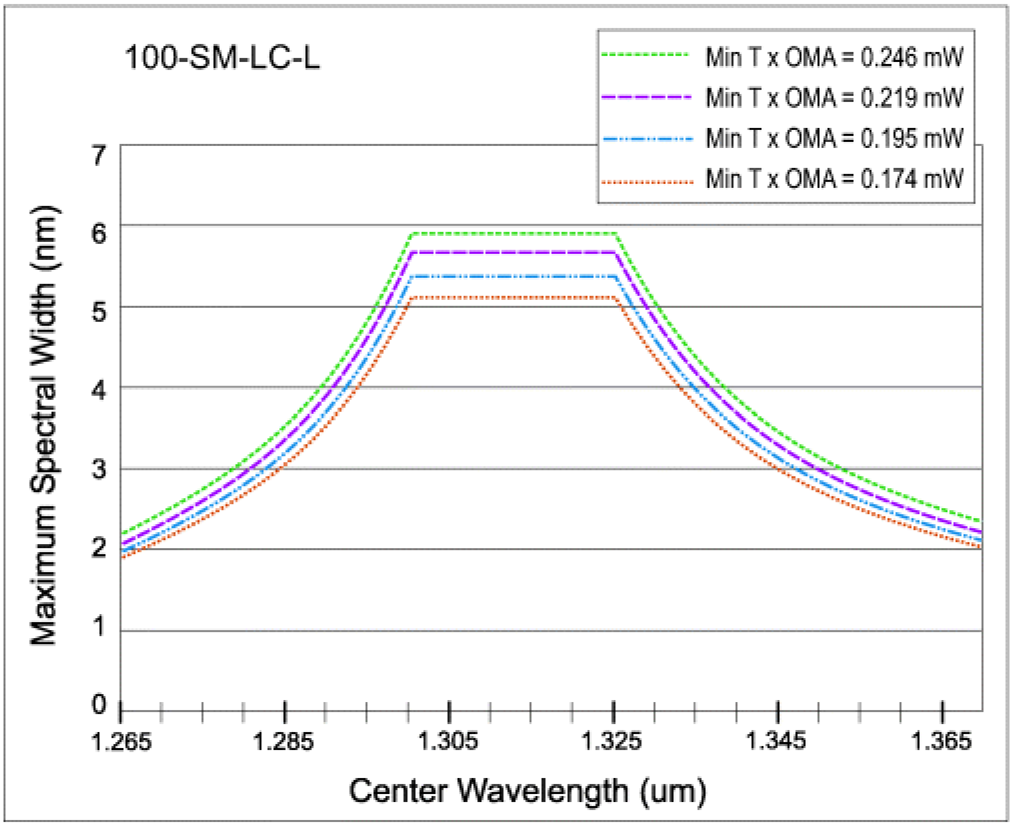


Figure 44. 1.0625 Gbps single mode 10 km link

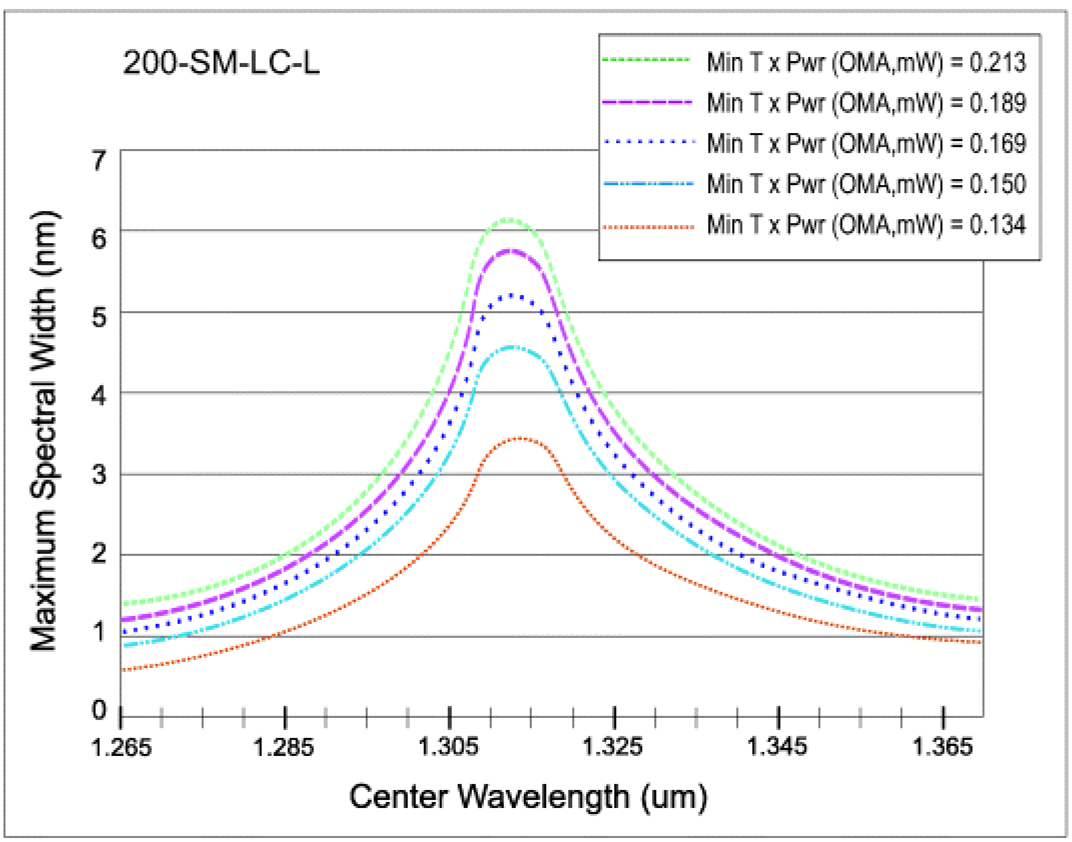


Figure 45. 2.125 Gbps single mode 10 km link

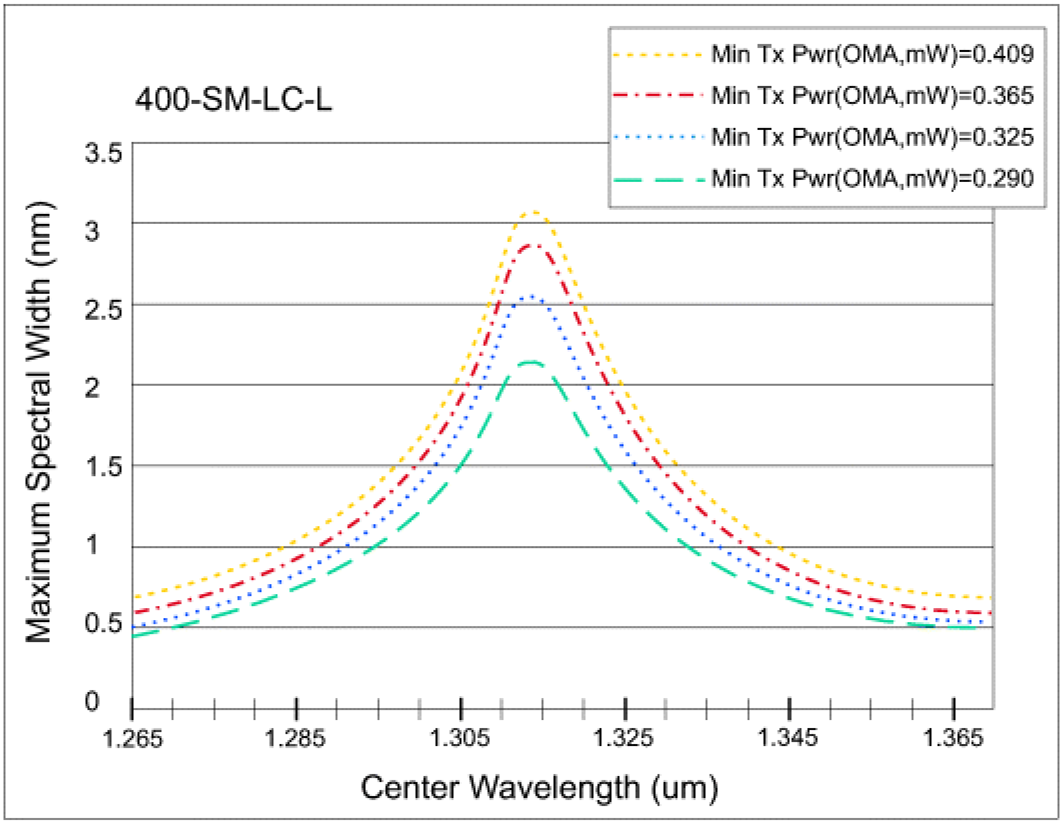


Figure 46. 4.25 Gbps single mode 10 km link

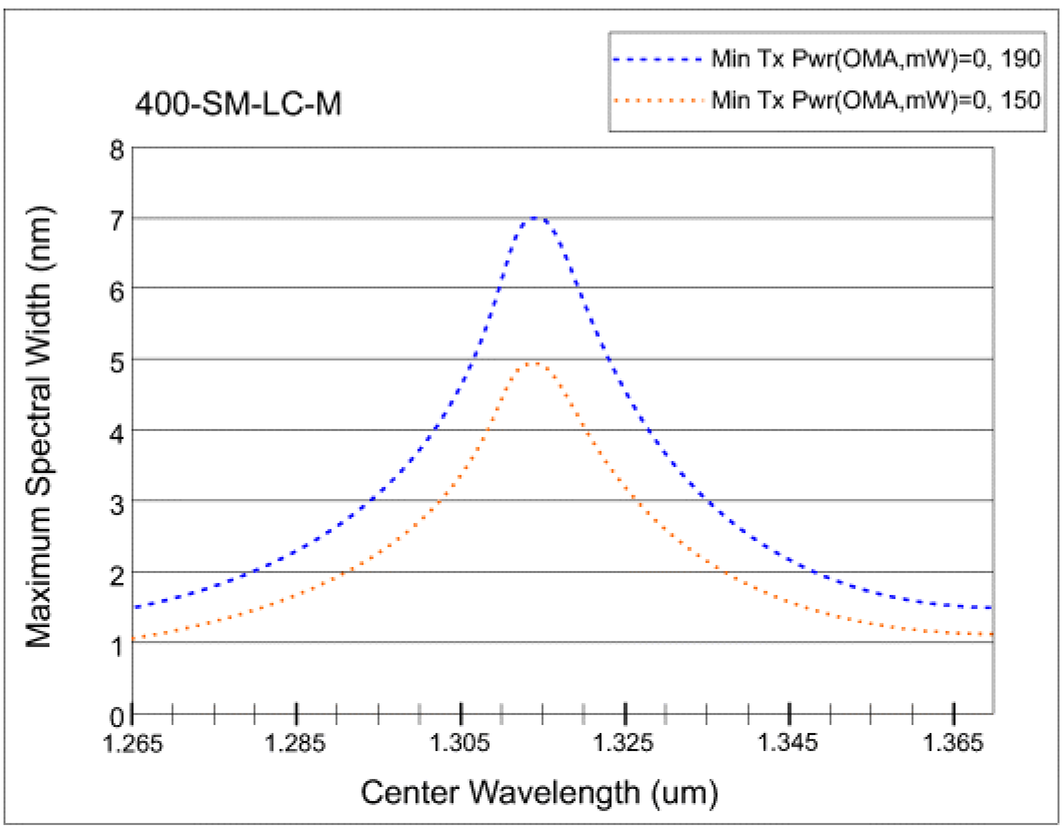


Figure 47. 4.25 Gbps single mode 4 km link

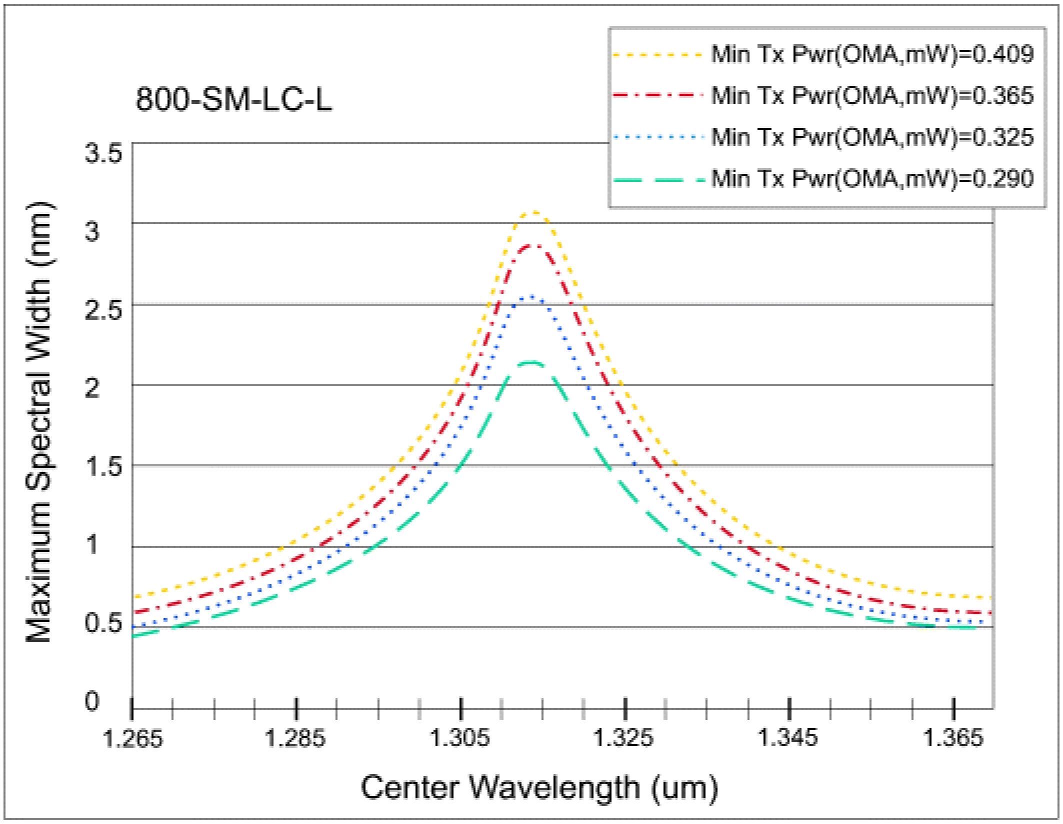


Figure 48. 8.5 Gbps single mode 4 km link

Normative references

The following standards contain provisions that, through reference in this text, constitute provisions of this publication. These documents are subject to change and may be revised, replaced, or supplemented. Consult the latest available revisions or supplements.

Equivalent EIA test procedures as specified in CCITT G.651 or G.652 can be used.

All FOTPs are EIA/TIA-455-XXX.

- FOTP-27 Methods for Measuring Outside (Uncoated) Diameter of Optical Waveguide Fibers
- FOTP-30 Frequency Domain Measurement of Multimode Optical Fiber Information Transmission Capacity
- FOTP-45 Microscopic Method for Measuring Fiber Geometry of Optical Waveguide Fibers
- FOTP-47 Output Far-Field Radiation Pattern Measurement
- FOTP-48 Measurement of Optical Fiber Cladding Diameter Using Laser-Based Instruments
- FOTP-51 Pulse Distortion Measurement of Multimode Glass Optical Fiber Information Transmission Capacity
- FOTP-54 Mode Scrambler Requirements for Overfilled Launching Conditions to Multimode Fibers
- FOTP-58 Core Diameter Measurement of Graded-Index Optical Fibers
- FOTP-80 Cutoff Wavelength of Uncabled Single-Mode Fiber by Transmitted Power
- FOTP-107 Return Loss for Fiber Optic Components
- FOTP-127 Spectral Characteristics of Multimode Lasers
- FOTP-164 Single-Mode Fiber, Measurement of Mode Field Diameter by Far-Field Scanning
- FOTP-167 Mode Field Diameter Measurement - Variable Aperture Method in the Far-Field

- FOTP-168 Chromatic Dispersion Measurement of Multimode Graded-Index and Single-Mode Optical Fibers by Spectral Group Delay Measurement in the Time Domain
- FOTP-170 Cable Cutoff Wavelength of Single-Mode Fiber by Transmitted Power
- FOTP-171 Attenuation by Substitution Measurement - for Short-Length Multimode Graded-Index and Single-Mode Optical Fiber Cable Assemblies Short-Length Multimode Graded-Index and Single-Mode Optical Fiber Cable Assemblies
- FOTP-176 Measurement Method of Optical Fiber Geometry by Automated Grey-Scale Analysis
- FOTP-177 Numerical Aperture Measurement of Graded-Index Optical Fibers

Copies can be obtained by writing to:

Director of Technical Programs
Information and Telecommunication Technologies
Electronic Industries Association
2001 Eye Street N.W.
Washington, D.C. 20066

Appendix D. Coupling links I/O physical layer: Test methods

Eye-window measurement

The output interface optical eye-window (EW) measurement involves measuring the open eye-window on a bit-by-bit basis, using a BERT (bit error rate test) test set. The bit error rate (BER) is measured at various T_d's (decision points) within the eye pattern to ensure conformance to the eye-window specification.

The eye-window is given by: EW = | T_d (max) - T_o | + | T_o - T_d (min) |

Where:

T_o = Center of the baud interval
T_d = BER decision point as referenced from T_o
T_d (max) = Rightmost decision point
T_d (min) = Leftmost decision point

For each position of T_d from T_d(min) to T_d(max), a BER measurement is taken, giving the probability of error at the T_d position. In effect, T_d is swept across the eye pattern, measuring the probability of error at each point in the eye. The range of T_d values that result in a BER ≤ 10^{-12} establishes the eye-window, and the smallest range from T_o must be ≥ half the appropriate eye-window specification.

In practice, a BERT test set is used to generate and sweep the decision point (using the BERT clock in conjunction with a precise delay generator), to make the bit-by-bit error count and to calculate the measured BER. The center of the baud interval (T_o) pattern is the midpoint between positioning T_d to the left and right edges of the eye to achieve a BER > 10^{-2} while transmitting a square wave pattern. Subsequent measurements are made while transmitting allowed 8/10 code patterns. The measured BER at T_o, T_d (max), T_d (min) must be ≤ 10^{-12} and the values of both (T_d (max) - T_o) and (T_o - T_d (min)) must be greater than or equal to half the appropriate eye-window specification. All measurements are made with respect to a linear phase, low-pass filter with a 3 dB cutoff frequency of 800 MHz for single mode fiber optic channel links and 300 MHz for multimode fiber optic channel links. It is important that the BERT retiming data latch be significantly faster than the timing resolution of interest.

A common practice used to save time is to measure the eye-window at higher probabilities (for example, 10^{-6}) and then extrapolate to the eye-window at a 10^{-12} probability.

Relative Intensity Noise (RIN) measurement

When lasers subject to reflection-induced noise effects are operated in a cable plant with a low optical return loss, the lasers will produce an amount of noise which is a function of the magnitude and polarization state of the reflected light. For coupling links, the magnitude of the reflected light can be 12 dB, resulting in the notation of RIN_{12} for the relative intensity noise.

An example of a RIN test arrangement is shown in Figure 49 on page 108. The test cable between the device under test (DUT) and the detector forms an optical path having a single discrete reflection at the detector with the specified optical return loss. There must be only one reflection in the system because the polarization rotator can only adjust the polarization state of one reflection at a time. The polarization rotator should be adjusted to maximize the noise read by the power meter.

Two measurements are made by the photodetector: average optical power and noise. The average optical power is determined by measuring the average current (Ipd) through the detector. The noise is measured by ac coupling the detector into the high-frequency electrical power meter. A low-pass filter is used between the photodetector and the power meter to limit the noise measured to 800 MHz for single mode fiber optic channel links and 300 MHz for multimode links.

In order to measure the noise, the modulation to the DUT must be turned off. You can calculate the RIN from the observed detector current and electrical noise using this equation:

$$RIN = 10 \log\left(\frac{P_e}{BW\ 25\ I_{pd}^2}\right) - G \ \ dB/Hz$$

Where:	Is:
I_{pd}	= Current through the detector in amps
P_e	= Electrical noise power in watts
BW	= Bandwidth of the measuring system in hertz
	= Low pass bandwidth of filter; high-pass bandwidth of dc blocking capacitor
G	= Gain in dB of any amplifier in the noise measurement path

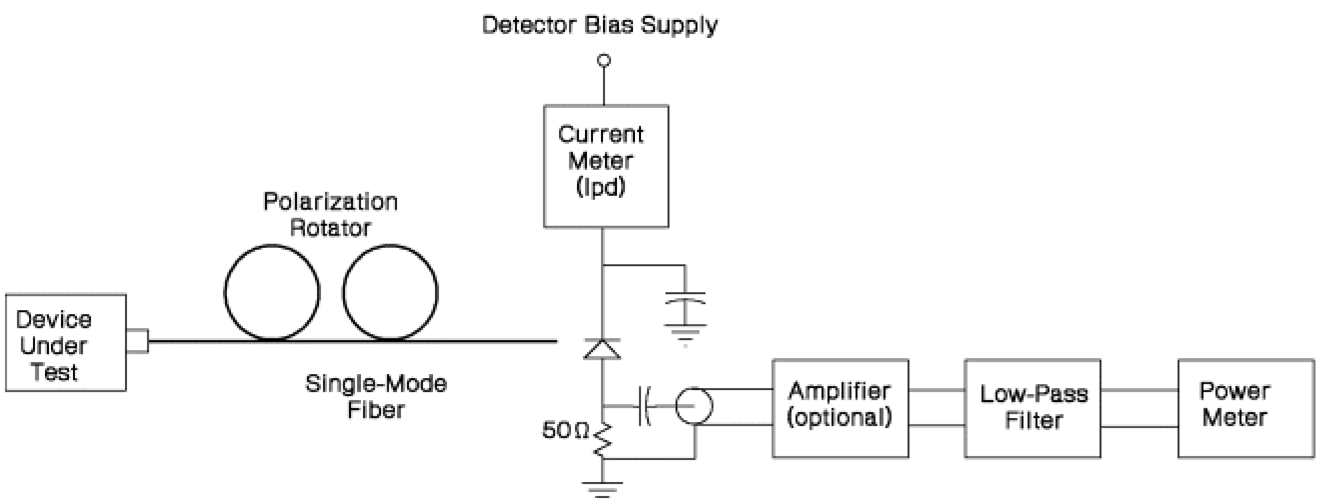


Figure 49. Example of a RIN test setup

Link loss verification

See *Maintenance Information for Fiber Optic Links* for details on the link loss verification procedure for multimode and single mode coupling links.

Appendix E. Notices

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要領に基づく定格入力電力値： Knowledge Centerの各製品の
仕様ページ参照

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