Fibre Channel Fiber Cabling

OVERVIEW

This paper will discuss the Fibre Channel standards for fiber cables at both 1Gb and 2Gb speeds, and also some discussion of "departures from standard." Items discussed will be cable types, plug types, speed, distance, and the various "coupling cables" available from IBM. Discussion of shortwave vs. longwave will also be included.

In the future, a list of supported distances will be available on the web with links from the various supported server sites.

NOTE: The spelling "Fibre" refers to the Fibre Channel standard which can run over different cables including copper cables. The spelling "Fiber" refers to glass strands only.

GLASS, CONNECTORS, AND OPTICS

Any fiber cable has as specific kind of glass strand, and on each end a specific kind of connector. Typically a fiber cable will have identical male connectors on both ends to plug into devices that have the matching female socket, but the two cable ends do not need to be the same connector type or gender. Any of the connector types mentioned in this paper can be used with any of the cable types. The cable type represents the kind of glass that is used, the connector type represents what the end(s) of the cable look like, or the port the cable plugs into.

Cable Types

Multimode fiber (MMF) allows light to disperse in the fiber so that it takes many different paths, bouncing of the edge of the fiber repeatedly to finally get to the other end (multimode means multiple paths for the light). The light taking these different paths gets to the other end of the cable at slightly different times (different path - different distance - different time). The receiver has to figure which signals go together as they all come flowing in, so the total distance is limited by how "blurry" the original signal has become. The thinner the glass the less the signals "spread out" and the further you can go and still figure out what is what on the receiving end.

This dispersion (called Modal Dispersion hence the name multi**mode**) is more important in determining the distance a high speed signal can go than any attenuation of the signal. From an engineering standpoint it is easy enough to crank up the power level of your transmitter and/or the sensitivity of your receiver, but too much dispersion cannot be decoded no matter how strong all the incoming signals are.

Singlemode fiber (SMF) is so thin (9 microns) that the light "can barely squeeze through" and basically tunnels through middle of the fiber using only one path or mode. There are reasons for this having to do with complex optics/physics. Plenty of documentation is available on the Internet explaining this phenomenon, so this paper will not go into this. However, since there is only one path that the light takes to the receiver, there is no "dispersion confusion" at the receiver. The main concern with singlemode fiber is attenuation of the signal.

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NOTE: Many vendors offer longer than standard distances over singlemode fiber, because it is easy enough to transmit at high power while listening with high sensitivity. The 1Gb Fiber Channel standard for singlemode fiber is 10km, but that is easily exceeded with higher-output lasers. The newer 2Gb standard has much lower distances for multimode fiber - where dispersion is an issue - but supports the same 10km for 2Gb over singlemode fiber by ensuring enough power in the signal.

The advantage to multimode fiber is that it is usually the least expensive way to go if the distance required is not great. However, signal speeds keep increasing, which reduces the distance you can go on multimode fiber, and at some point it will be a "niche connectivity option" much like Fibre Channel over copper is today. (Copper wire allows the least distances of all, unless you split the signal and use multiple pairs of wires, but that is beyond the scope of this paper, and today IBM does not support Fibre Channel over copper.)

Current Fiber Types

There are three basic fiber cable types primarily in use in Fibre Channel today. They are typically identified by the width of the glass used to carry the light signals as follows:

- 62.5 micron fiber - This is multimode fiber and can go the least distance. However, due to its extensive use in networking and ESCON infrastructures there is a lot of 62.5 micron fiber already in place.
- 50 micron fiber - Also multimode, but thinner and thus can go longer distances.
- 9 micron fiber - singlemode fiber that can go much longer distances, especially with high output lasers

NOTE: Fibre Channel devices/adapters that support multimode fiber can have either 50 micron or 62.5 micron fiber plugged into them, just as long as any single link between a transmitter and a receiver (between a server and a switch or between two switches or between a storage device and a switch) is the same width all the way through. Splicing 62.5 and 50 micron fiber - even through a patch panel - is a bad idea. Splicing in general is rarely worth the trouble.

Connector Types

A connector type defines the particular kind of "plug" you have at the end of a cable, or on a device. Typically, devices have female connectors that the cable's male end plugs into, but occasionally a cable will have a female connector so that it can be jumpered directly to another cable, or sometimes "gender benders" are used which are connectors with two male or two female
Ends. The connector types typically found for fiber cables are:

SC - This connector type is the most prevalent today, and almost all devices supporting 1Gb Fibre Channel have this kind of receptacle. Each cable strand is terminated with a square plug that fits into - naturally - a square hole on the device.

LC - This is a new connector type - it is much smaller allowing higher port densities - and is found almost everywhere 2Gb speeds are supported. (Some devices that are 1Gb only still use LC plugs - see product websites for plug information.) The plugs and receptacles are still square, but they are much smaller than SC.

ST - This is an older fiber connector that is not seen on Fibre Channel devices, but mentioned because a lot of “legacy cable” uses this kind of connector in patch panels. ST connectors are just like coax connectors in that the cable has a round “cup” that twists (and locks) on a barrel protruding from either a device or a patch panel.

Jumper cables

Jumper cables are merely cables that have different kinds of connectors on either ends to handle whatever endpoints they are using. For instance, when SC devices came out, and were used with patch panels using ST connectors, an SC/ST jumper cable was made that went from the SC device the to the ST patch panel. Jumper cables can be any combination, the important thing is that the link must be the same width cable end-to-end (with a couple of exceptions referred to later). End to end means between devices that regenerate a signal. Here are a a few examples.

The following two examples are valid because the switch is re-driving the signal over the different-width cable. You can even use singlemode fiber between the switch and a server or device. The actual cables are in bold print:

SERVER/**SC--62.5 micron--ST**/PATCH PANEL/**ST--62.5--SC**/SWITCH/**SC--50 micron--SC**/DEVICE

SERVER/**SC--62.5 micron--SC**/SWITCH/**SC--50 micron--ST**/PATCH PANEL/**ST---50---SC**/DEVICE

The following examples are *not valid.* You cannot change cable widths going through a patch panel.

SERVER/**SC--62.5 micron--ST**/PATCH PANEL/**ST--50 micron--SC**/SWITCH/**SC--50--SC**/DEVICE

SERVER/**SC--62.5 micron--SC**/SWITCH/**SC--62.5 micron--ST**/PATCH PANEL/**ST--9--SC**/DEVICE

Lasers

There are basically two kinds of laser light used with Fibre Channel fiber, often referred to as shortwave or longwave laser. Shortwave laser uses a wavelength of approximately 850 nm and longwave laser has a wavelength of about 1300nm. (The lasers are never exact, just within a tolerance.)

In Fibre Channel products today you only see shortwave lasers used with multimode fiber, and longwave lasers used with singlemode fiber. In principle, you could run either laser over any fiber, but the other combinations never caught on. (Longwave over multimode is sometimes used with Gigabit Ethernet, however.)

You **cannot** mix and match shortwave and longwave lasers on either end of a link. The optics always come with a receiver designed for the same light that the laser transmits. If you go through a switch you can come in shortwave and go out longwave on a different port because they are on two different links.

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NOTE: The second invalid example above shows 62.5 multimode going into a patch panel and coming out 9 micron. Not only is this bad from a simple cabling standpoint, but you would also have a shortwave laser on one side and a longwave laser on the other side so it is hopeless for two reasons.

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Distance

Now for any given combination of optics and fiber and signaling speed, there is a maximum distance specified in the Fibre Channel standard.

Fiber type	Speed	Max Distance
9 micron SMF (longwave)	1Gb	10km
9 micron SMF (longwave)	2Gb	2km
50 micron MMF (shortwave)	1Gb	500m
50 micron MMF shortwave	2Gb	300m
62.5 micron MMF (shortwave)	1Gb	175m/300m
62.5 micron MMF (shortwave)	2Gb	90m/150m

This table may look a little curious, but let's go through it. First of all, in going from 1Gb to 2Gb the distance for singlemode fiber seems to change dramatically. Actually, this was just a guess by the standards at what would be needed/possible. All vendors today of 2Gb products support 2Gb speeds at 10km over singlemode fiber.

This is primarily because singlemode fiber is mostly affected by signal attenuation (there is no dispersion to deal with because the light only takes one path through the fiber.) The 10km spec for 1Gb was conservative. It specified a range of transmitter power and a range of receiver sensitivity. Most optics were manufactured to transmit at maximum power and to be able to receive at minimum power. This allows distances well beyond 10km all by itself. (IBM FICON offers 20km over "normal optics" with an RPQ that basically checks the fiber and equipment to verify it is all up to spec.) Many vendors offer higher-output lasers that can be used at much longer distances - up to 100km for a single non-repeated hop. So when going to 2Gb it was easy enough to come up with optics that would allow this faster signal to go the same 10km.

50 micron fiber matches the intuitive guess. If you double the speed you probably halve the distance. All vendors support the standard distance for 50 micron fiber at 1Gb and 2Gb.

62.5 micron shows two different distances and this has been a huge source of confusion for everyone. This is because there are two grades of 62.5 fiber depending on the quality of the glass. The main difference is in a property called Modal Bandwidth, or sometimes Optical Bandwidth. A discussion of this follows:

THE SAGA OF 62.5 MICRON FIBER

The early wide use of 62.5 micron fiber was to extend LAN segments. Token-Ring and Ethernet customers installed fiber to extend LAN segments in various parts of a building to a central point. (Often "fiber risers" were used to get from one floor to another.) This early fiber was also used for FDDI, ATM, and ESCON connections, and has been called "FDDI grade" in some contexts. Since all of these speeds are about an order of magnitude less than Fibre Channel (or slower), there was no pressing need for "better glass" as long distances could be achieved anyway.

With the advent of Gigabit Ethernet, however, some manufacturers started producing 62.5 fiber in which the index of refraction varied from the center of the fiber to the edge. This changed the way light bounced around in the glass making the different modes arrive at the endpoint closer together than before. There was less Modal Dispersion and thus longer distances could be used.
The way this was measured was with the previously mentioned metric - Modal Bandwidth.

Modal Bandwidth

Modal Bandwidth is a measure of the total bandwidth available in a kilometer of fiber. Modal Dispersion restricts the bandwidth that is available, thus the less Modal Dispersion, the more Modal Bandwidth. (If you use a shorter fiber, there is less dispersion and more bandwidth available at the end of the fiber. Modal Bandwidth is listed as MHz-km - bandwidth at 1 km.)

62.5 micron fiber Modal Bandwidth

The older 62.5 micron fiber ("FDDI grade") has a Modal Bandwidth of at least 160MHz-km. The newer, better 62.5 micron fiber has a Modal Bandwidth of 200 MHz-km. Thus the two different distances listed for 62.5 micron for any given signal represent the two grades of 62.5 fiber. The longer distance is always for the 200MH-km Modal Bandwidth fiber.

MODAL BANDWIDTH IN THE FIBRE CHANNEL STANDARD

While Gigabit Ethernet vendors will often list two distances for 62.5 micron fiber - distinguishing between the two grades of 62.5 micron fiber - Fibre Channel vendors rarely mention this, and it is buried in the standards documents. ANSI Fibre Channel standards documents mention 160 MHz-km and the shorter distances in some sections of the documents, and in other sections will show tables with longer distances over 62.5 micron fiber. It can be a little tricky to tease this out.

What is most important, of course, is what distance is supported by any given vendor. Vendors who quote the longer distances have probably tested with the better fiber, and vice versa. It is not uncommon for vendors to support the lower distance at one speed and the higher distance at another speed, causing a great deal of confusion. The answer, of course, is to "know your fiber."
Your 62.5 fiber vendor should be able to tell you what the Modal Bandwidth of your fiber is, and then appropriate decisions can be made from there.

INTEROPERABILITY BETWEEN 1Gb and 2Gb devices

The Fibre Channel standard specifies a procedure for speed auto-detection. Thus, if a 2Gb port on a switch or device is connected to a 1Gb port it will negotiate down and run the link at 1Gb. If there are two 2Gb ports on either end of a link then the negotiation will end up running the link at 2Gb if the link is up to spec. A link that is too long, or "dirty" could end up running at 1Gb even with 2Gb ports at either end so watch your distances and make sure your fiber is good!