APPENDIX C

Differential Mode Delay

When an unconditioned laser source (1000BASE-LX/LH GBIC) designed for operation on single-mode fiber (SMF) cable is directly coupled to an MMF cable, differential mode delay (DMD) can occur. DMD can degrade the modal bandwidth of the fiber-optic cable, causing a decrease in the link span (the distance between the transmitter and the receiver) that is reliably supported.

The Gigabit Ethernet specification (IEEE 802.3z) outlines parameters for Ethernet communications at a gigabits per second rate. The specification offers a higher speed version of Ethernet for backbone and server connectivity using existing deployed MMF cable. To accomplish this, the specification requires the use of laser-based optical components to propagate data over MMF cable.

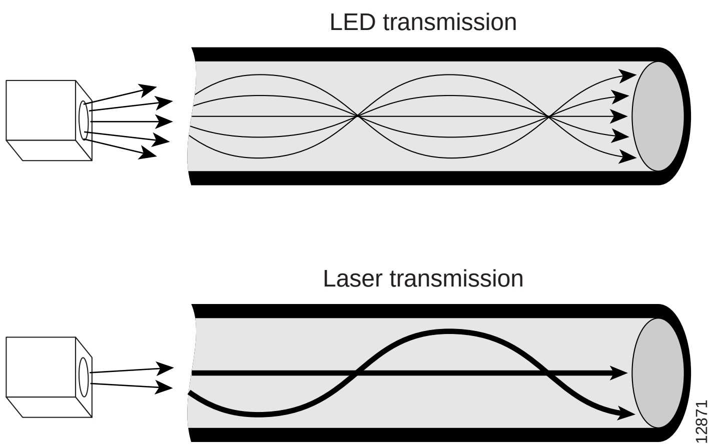
Lasers function at the baud rates and longer distances required for Gigabit Ethernet. The IEEE 802.3z Gigabit Ethernet Task Force has identified the DMD condition that occurs in certain circumstances with particular combinations of lasers and MMF cable. The resulting characteristics create an additional element of “jitter” that limits the reach of Gigabit Ethernet over MMF cable.

With DMD, a single laser light pulse excites a few modes equally within an MMF cable. These modes, or light pathways, then follow two or more different paths. These paths may be of different lengths and have different transmission delays as the light travels through the cable. With DMD, a distinct pulse propagating down the cable no longer remains a distinct pulse or, in extreme cases, can become two independent pulses. Strings of pulses tend to interfere with each other, making it difficult to recover data in a reliable fashion.

DMD does not occur in all deployed fibers. It occurs with certain combinations of worst-case fibers and worst-case transceivers. Gigabit Ethernet is the first technology to experience this problem because of its very high baud rate and its long MMF cable lengths. SMF cable and copper cable are not affected by DMD.

MMF cable has only been tested for use with LED sources. LEDs create a condition within a fiber-optic cable referred to as an *overfilled launch condition*. The overfilled launch condition describes the way LED transmitters couple light into the fiber-optic cable in a broad spread of modes. Similar to a light bulb radiating light into a dark room, the generated light shines in multiple directions that “overfill” the existing cable space and “excites” a large number of modes. (See Figure C-1.)

Figure C-1 LED Transmission Compared to Laser Transmission



Lasers launch light in a more concentrated fashion. Typically, a laser transmitter couples light into only a fraction of the existing modes or optical pathways in the fiber-optic cable (see Figure C-1).

The solution to DMD is to condition the laser light launched from the source (transmitter) so it spreads the light evenly across the diameter of the fiber-optic cable, making the launch look more like an LED source to the cable. The objective is to scramble the modes of light to distribute the power more equally in all modes. This prevents the light from being concentrated in just a few modes. This is in contrast to an unconditioned launch, which, in the worst case, might concentrate all of its light in the center of the fiber-optic cable, thereby exciting only two or more modes equally.

A significant variation in the amount of DMD is produced from one MMF cable to the next. No reasonable test can be performed to survey an installed cable plant to assess the effect of DMD. Therefore, you must use the mode-conditioning patch cords for all 1000BASE-LX/LH GBICs using MMF when the link span exceeds 984 feet (300 meters). For link spans less than 300 meters, you can omit the patch cord.