TYCO ELECTRONICS eDIGEST

A series of technology briefs spanning Tyco Electronics' product portfolio

Advances in High Density Optical Interconnects

Background

It is no secret that the internet and wireless technologies are dramatically enhancing our ability to connect to people and information. The unseen consequence of exponential growth on a global scale is the demand for infrastructure to support traffic generated by hundreds of millions of users (see Figure 1). Billions of packets of digital data wend their way around the world, through switches, long haul optical fibers, metro rings, and assorted other access topologies. At each node incoming fibers are patched from entrance closets to equipment and back again.

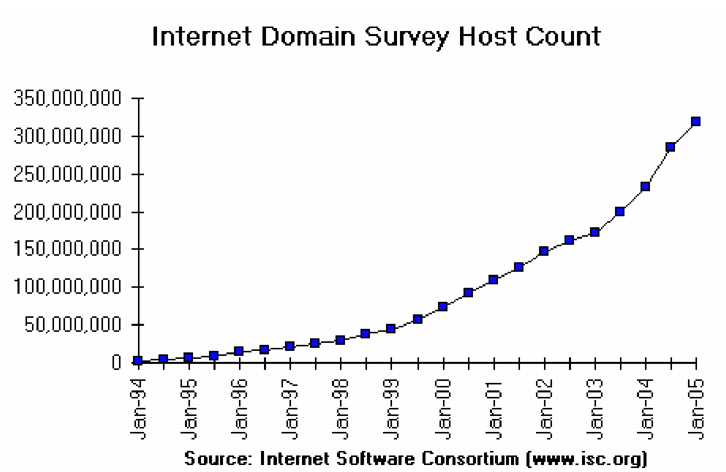

Figure 1 – Number of Hosts attached to the Internet
Source: Internet Software Consortium, Inc. (http://www.isc.org)

Since optical fibers are extremely small (even with protective coatings they are only 250 microns in diameter…about 4 times the diameter of a human hair), hundreds of fibers can be installed in cables taking relatively little space. However, terminating these fibers with connectors increases the space used 20 to 50 fold. While Moore's Law is driving up the channel count of switch and PHY chips, connector technology is struggling to keep up.

Optical connectors need to be at least a certain size to be compatible with human fingers. Coupling and retention mechanisms, which are adequately strong, also take some space. Therefore, the logical way to increase density is to put multiple fibers together in one ferrule. (As an historical aside, we note that various dictionary definitions of the word ferrule invariably imply a cylindrical part. In single fiber connectors, the piece into which the fiber is terminated is indeed cylindrical. Multi-fiber connectors generally involve fibers arranged in arrays, and therefore the parts are generally blocky or rectangular, but the term "ferrule" is still used, even though the parts are no longer cylindrical.)

Silicon V-grooves

Silicon V-groove arrays were used in some early multi-fiber connectors. This offered the precision of semiconductor fabrication processes and predictable angles of crystallographic planes. They are relatively expensive, however, and have largely given way to the molded MT ferrule.

MT

Connectors based on the MT ferrule, particularly the MPO have come to dominate the multi-fiber connector market. Originally developed by NTT for multiple fiber splicing, the fiber count has grown from single rows of 4, 8, or 12 fibers to versions with 2 or 6 rows of 12 fibers. Although the 2.5 mm and then the 1.25 mm ceramic cylindrical were the kernels for several different connectors, the MT has become the de-facto standard multi-fiber ferrule (see Figure 2).

Figure 2 – MT Ferrule (Photo courtesy of US Connec Ltd.)

MT Ferrules are available from a number of vendors in both multimode and single mode (SM) tolerance grades. Likewise, cable assemblies are available from a variety of sources, and have been in use for years in storage and network applications.

Key Attributes

Alignment is provided by precision pins in 0.7 mm diameter guide holes. The datum for optical alignment is centered in the part which minimizes distance for tolerance accumulation, and the distance between guide holes does not affect datum location. Elasticity of the pins and ferrule material absorb manufacturing tolerance variations, although advances in materials and molding technology have made these quite small. Key to achieving low insertion loss is the ability to measure true position of the fiber holes. MT ferrules are molded with a flat end face perpendicular to the guide holes. This facilitates inspection, since all the features are in a single plane and the holes are circular. Polishing processes remove some ferrule material, so it is important that the true position be maintained for 100 microns or more below the surface. This is especially important for SM ferrules, where the polish process creates an 8 degree angle. It is doubly important for multi-row ferrules, where the 8 degree angle over the distance between the rows results in 70 microns difference in elevation.

72 Fiber

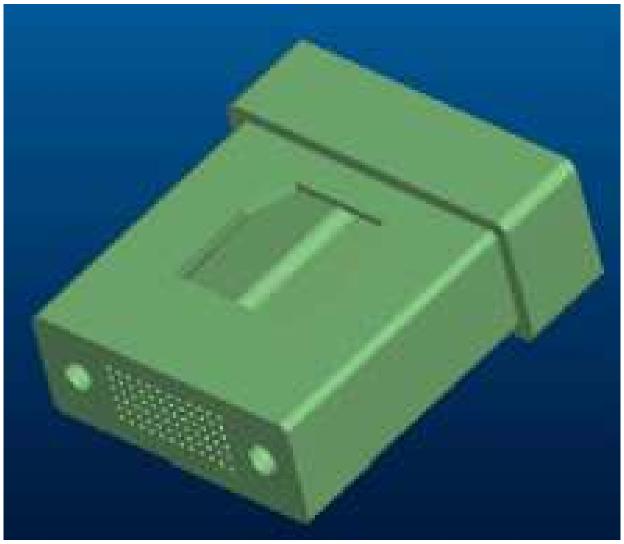

Figure 3 – 72 Fiber MT ferrule

Currently 72 fiber MPO (or MTP® as it is called by US Connec Ltd.) is available only in multimode grades. However, given the trends and past history, SM should follow. The MPO connector is designed to provide positive contact for up to 12 fibers. In addition, the 72 fiber MPO has a slightly modified spring to provide more room for the stack of ribbons, as well as increased normal force since it is spread out over a larger number of fibers. Even so, achieving PC performance with higher fiber counts requires more precise control of the polish process to ensure better co-planarity. Tyco Electronics has done extensive development work in polishing processes and high density connector development (see Figure 4). This is controlled by polish process and fixtures, and verified via interferometric end face scans (see Figure 5).

**Figure 4 – Tyco Electronics PARA-OPTIX™
72 Channel MPO Style Connector**

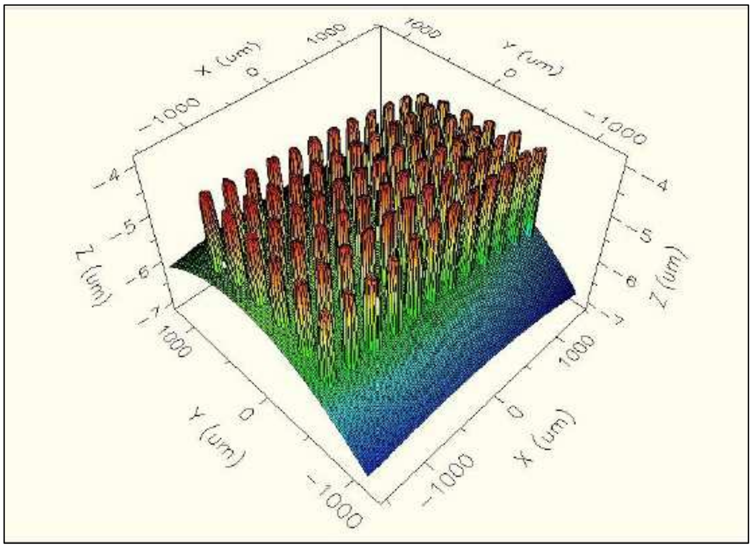

Figure 5 – End face scan of 72 fiber MT ferrule

There is already a developing infrastructure to support cable assembly vendors, such as specialized instruments to measure end face geometry and high channel count insertion loss testers (see Figure 6). Evolved from systems to measure lower fiber count ferrules, this kind of equipment has the necessary optical field of view and software to measure all 72 fibers at one time.

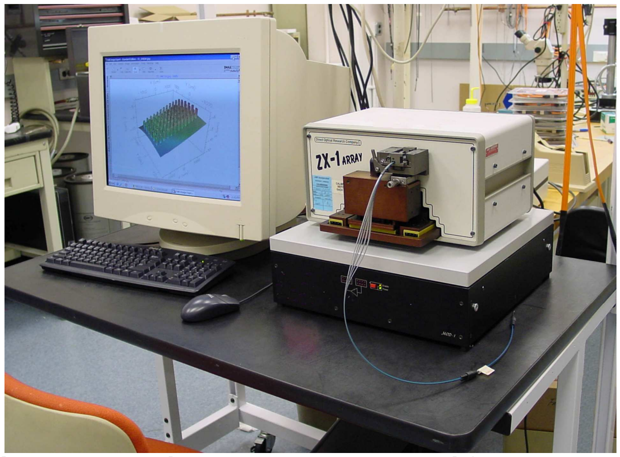

Figure 6 – Equipment to measure end face geometry

Optical Performance

The performance of high density connectors lags behind that of single fiber connectors. This is largely due to the technology maturity; however, statistics also come into play. Single fiber ferrules can be inspected to truncate the manufacturing distribution at any desired eccentricity values to limit insertion loss. With MT ferrules, ALL fiber holes need to be located within a few microns of their ideal position. The more holes there are, the higher the tolerance for the worst hole. Put another way, if a ferrule is rejected due to one hole out of tolerance, 71 good holes are thrown away as well. Therefore, typical insertion loss for multi-fiber ferrules tends to be higher than that of single fiber connectors.

Another difference between traditional single-fiber and MT-based connectors is tune-ability. To achieve lowest possible loss, single mode connectors such as SC and LC are tuned to orient any remaining core offset towards the key. This tightens the distribution of core offset, thereby minimizing insertion loss. This ability to tune derives from the circular symmetry of the cylindrical ferrule, which the MT design does not possess. Therefore insertion loss is determined solely by the “as produced” true position of the fiber holes, combined with the core eccentricity tolerance of the fiber.

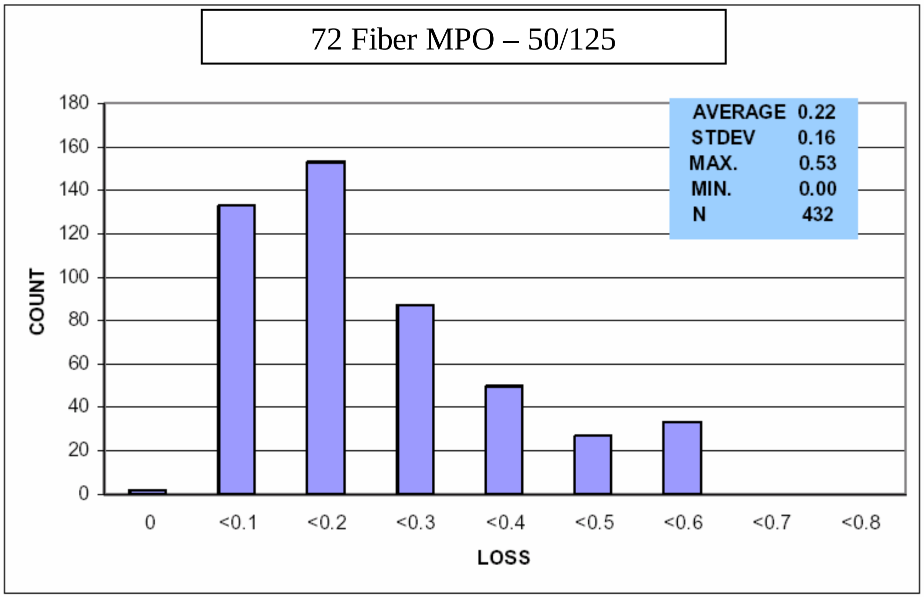

Figure 7 – 72 Fiber MPO Insertion Loss

Compatible Transceivers

Although there has been a shakedown in the multi-fiber transceiver industry beginning with the burst of the telecom bubble in 2000, there remain a number of vendors supplying single-row devices.

Multi-row transceivers have yet to become commonly available; however, there are a number of vendors providing single row receivers and transmitters. These can be mounted away from the board edge, with optical jumpers connecting to high density connectors such as the 72 fiber MPO. This maximizes the use of valuable board edge front panel real estate.

As with conventional single channel transceivers, there are multi-source agreements for parallel optic devices. POP4 (http://www.popoptics.org) describes a transceiver which utilizes a 12-fiber connector with 4 fibers transmitting, 4 fibers receiving and the 4 fibers in the middle not used, but rather simply separating the Tx and Rx circuits to minimize crosstalk. SNAP12 (http://www.snapoptics.org) devices utilize the same physical form factor, but define separate transmitter and receiver modules, each having 12 channels.

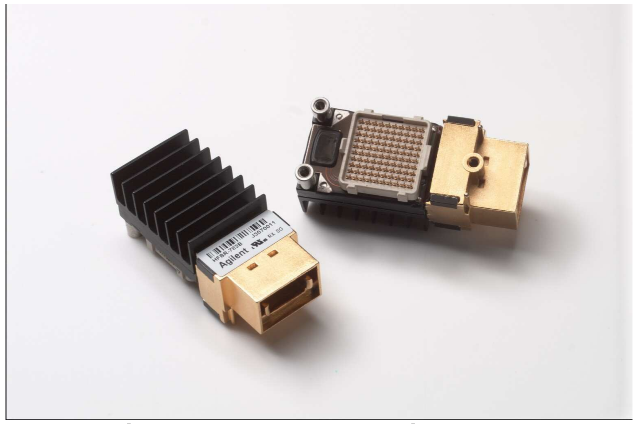

Figure 8 – SNAP 12 Device
(Photo courtesy of Agilent Technologies, Inc.)

Applications

As a general rule, any application involving large numbers of fibers is a candidate for high density interconnects. This includes facilities such as data centers and storage facilities, premise cabling, and the upcoming FTTx infrastructure. Equipment that involves large numbers of ports such as switches and routers is also a candidate. For instance, Infiniband (http://www.infinibandta.org/) 4X and 12X variants utilize the MPO interface.

Port Density is Key

SFF connector battles in the late 90's were driven by need for higher port density. While semiconductor technology continues to evolve with ever higher levels of integration in switch and PHY chips, connectors have not kept up with Moore's law (see Figure 9).

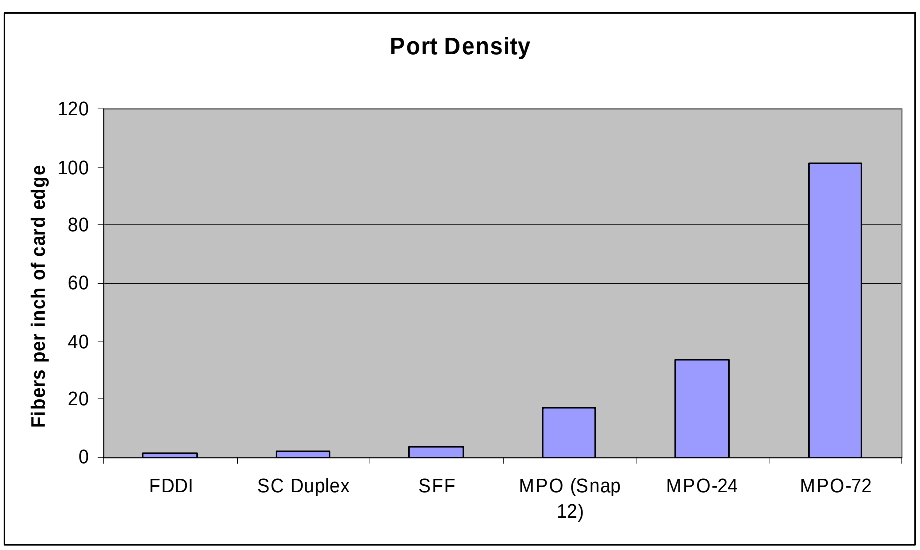

Figure 9 – Port Density for common connector styles

Summary

Traditionally, the width needed for optical transceivers was approximately the same as the width of the optical connectors. As the number of fibers in an MT ferrule increases, other issues, such as size of the transceiver electrical connector or heat dissipation, become the gating items. One approach that de-couples the transceiver size from port density is to place the transceivers inboard, with short fiber jumpers to high density connectors on the card edge. This solution has the added appeal of placing transceivers close to the chips with which they communicate, minimizing trace length which facilitates higher speeds and lower power consumption.

In many applications scalability of both port count and speed is desirable. High density fiber interfaces are appealing for intra- and inter-rack links because the cables are an order of magnitude smaller (and lighter) than copper, and can scale to higher speeds with the electronics. If there is a socially acceptable addiction in life, it is the desire for higher bandwidth. Who among us wants to go back to using a 1200 baud modem, let alone the 300 baud teletypes of yore? The proliferation of DSL, cable modems, as well as the increasing adoption of FTTx are driving both availability and demand for high bandwidth applications such as VoIP and video on demand. Couple this with the double digit growth in internet access in countries such as India and China, and it is clear that scalability is not only desirable…it is imperative. High density connectors based on MT technology provide the solution to one piece of the scalability dilemma.

For additional technical information, contact your local Tyco Electronics Sales Engineer, or visit http://www.tycoelectronics.com/fiberoptics .