The Optical Fiber Ribbon Solution for the 10G to 40/100G Migration
Bill Charuk, SR Product Manager, Data Center Solutions

Introduction

With the advent of data centers in communication infrastructure, various network protocols have evolved to meet the data rates necessary to handle the required amount of data transfer efficiently. Part of this evolution, of course, was installing fiber optics in more and more network interconnection scenarios in place of copper cable. With end-user connectivity now possible through various user devices, fiber optic cables have become the ubiquitous transport medium in the data center network. The number and type of fibers, their long term viability, and value to the user are paramount considerations to handle today’s rapidly increasing data rates and exponential growth of data traffic.

A large majority of the increased bandwidth requirements satisfied by new fiber will occur in existing buildings and support structures, such as trays and duct banks. The question for network and data center managers will be, “Is there enough physical space to install the fibers I need?” Additionally, “Can I install the topology needed and still provide room for future expansion and ensure adequate fiber protection?” The answers to these questions are multifaceted to be sure.

To address these challenges and questions, it is important to examine and consider both how and why an optical fiber ribbon cabling solution should be deployed for new 40Gbs/100Gbs installations and upgrades of existing 1Gbs/10Gbs infrastructures. This in-depth examination is backed by compelling technical reasons and step by step techniques to achieve optimum data center installation speed, high performance, connectivity, and cost efficiencies.

Over the past decade, the movement of data has become crucial for businesses and individuals alike, particularly through the rise of social networking, big data, mobile
communications and the infrastructure necessary to support them. Cisco, a world leader in transceiver equipment, recently published a study that shows expected growth in data transmission in the coming years for mobile data traffic alone (see Figure 1).

![Figure 1](image)

As the demands on the network infrastructure continue to increase, more and more servers, routers and network switches will be added to individual data centers to handle the increased data traffic. As these increase, the amount of installed optical fiber will also increase and may be mitigated by a shift from multimode to single-mode fiber.

**Data Center Requirements**

Many typical data centers today utilize 1Gbs and 10Gbs infrastructures. The next generation, depending on the timing of its next upgrade, will be to 40Gbs or 100Gbs. The backbone (inter-building), which connects MDF (main distribution frame) to MDF, is
more than likely a single-mode network. Therefore, the amount of space needed for the
cables and future growth should be available, unless the network has been engineered
as a retrofit solution for existing duct space already in use for other cable requirements.
In such cases, any additional cable added should have the highest fiber density available
for a given fiber count to maximize the use of the duct space.

Inside the buildings (our primary focus) where the MDF is linked to distribution switches,
OM3 or OM4 multimode fiber is typically used. Again, the network planners need to be
cognizant of fiber density in a given space because of the impact to airflow and power
consumption, and hence, cable diameter. Also of concern is the ability to provide
adequate cable management for all the cable assemblies needed to fully connect the
system.

So, what does all this mean with regard to the cable plant? Ideally, the cable plant
design needs to meet the best possible of the following criteria, regardless of the next
generation data rate to be supported. The physical plant should maximize the use of
available duct space to ensure that all fiber routing for present and any future builds can
be supported. Also, the cable plant should not be an impediment to the airflow
necessary to cool the racks of electronics in the data center. A well designed cable
plant will improve the operation of the electronics potentially, as well as minimize the
amount of power required for air conditioning. Of course, the cable plant must be within
the established budget for the project, as well.

**Fiber Requirements**

For every optical network, standards for fiber performance must be followed to ensure
proper operation under planned conditions of the network. Typically, this means that
both distance and link loss budgets must be established for the data center
infrastructure. Two standards define the fiber performance that must be adhered to in
the data center. They are the IEEE802.3ba standard for 40/100Gbs Ethernet and the
TIA-942 Telecommunications Infrastructure Standard for Data Centers. Table 1 shows
the distance and loss limitations for 10Gbs to 100Gbs links.
Currently, both 1 and 10Gbs systems use a single fiber to transmit data at the requisite speed. This means one fiber and one connection each per transmit and receive signal channel. The process is accomplished using LC duplex connectors on a two fiber optical patch cord for one channel connection that can be applied to 1 and 10Gbs systems.

Based on the limitations outlined in Table 1, designers should limit the maximum distance for any link to less than 100 meters. This distance will allow 40Gbs to be fully supported using OM3 fiber and to have a higher link loss budget. However, when upgrading to 40Gbs, other factors must be taken into account also. For example, a 40Gbs network should be able to upgrade to next level 100Gbs or 400Gbs with minimal impact on the overall infrastructure.

**Form Factors**

The transceiver form factor will be different as speeds increase. In Table 2, we see that different data transmission schemes in the leftmost column are supported by various form factors. The form factors, themselves, are spelled out by industry Multi-Source Agreements (MSA’s). When reviewing the table, it is apparent that there are different form factors available to support 40G and 100G systems. Since both 40G and 100G solutions can be installed using “4 by” parallel optics (i.e. four separate channels transmitting and receiving) it may be prudent for the data center manager to select a form factor for “future proofing” that uses this protocol, so that little or no changes are needed.
Table 2

The green box in Table 2 contains the “standard” transceiver in use today for 40Gbs. As previously noted, it uses 4 parallel fibers for transmission and 4 lanes. The red box outlines a four lane solution for 100Gbs systems. Obviously, if the distance and link loss requirements are met, a 100Gbs upgrade from 40Gbs should be a straightforward process.

Connectivity
MPO connectors will be the most prevalent connector type used in the system. Figure 2 shows a standard 12F MPO and the fiber lane configuration required by standards. As the figure shows, 4 fibers will be used for transmission and 4 fibers will be used for the receive function. The four fibers in the middle are unused or “dark” fibers.
This scenario could be a major cost issue in some data centers if steps are not taken to fully utilize the installed fiber base when retro fitting systems, since the dark fibers are essentially useless. If the system is further upgraded to 100G with a similar 4X25Gbs scheme, then the same fiber arrangement can be used. Through the use of conversion harnesses or interconnect modules, all 12 fibers of a ribbon can be utilized until the interconnection with optical modules is required.

The use of ribbons allow for easier connectorization (less opportunity to cross fibers in an MPO connector), and perhaps more importantly, achieve easier polarization continuity regardless of the polarity method selected for the system.

**Cable Considerations**

As with any cable installation, several considerations must be taken into account prior to deciding on a cable design. Several areas to consider are listed below:

- Adequate fiber count for foreseeable need
- Available duct/conduit space
- Installation path
- Ruggedness of design
- Termination method
- Fire codes
- Cost
While all of these factors are important, the end user is responsible for determining the importance each issue has when designing a specific network.

Ribbon cables have been used in the telecom industry for over twenty years. They were introduced to increase the fiber density in a given cable and to reduce cable costs. Initial designs were built to outside plant fiber cable standards. The designs then migrated to include armored versions, dry outside plant cables, and riser and plenum rated indoor cables.

The fiber density, particularly as fiber counts increase in the data center, is a very attractive feature of these types of cables. For a typical fiber optic cable design, Figure 3 below shows the comparative size of riser rated cable types. Note that for a 48F cable ribbon design the outside diameter is approximately 40% of the OD for the interlocked armor design of the same fiber count and only 16% larger in diameter than a cable of reduced diameter design.
Furthermore, the issue with cable diameter is significant when the cable is installed, as it often is, in a conduit system. The fill ratio, or the amount of space the cable occupies versus the amount of available space in a given duct, is defined by the following formula:

\[
\frac{d_1^2 + d_2^2 + d_3^2}{D^2}
\]

Where \(d^2\) refers to individual cable diameters installed and \(D^2\) refers to the inside diameter of the conduit in which the cable(s) are to be installed. In the chart below, it can easily be seen that if higher fiber count cables of various designs are installed in conduit, the fill ratios for these designs indicate that some installations may be problematic. To be able to install three cables and make maximum use of a conduit, a typical limit of 40% of the available cross sectional area should be used. Figure 4 below shows the various fill ratios for 1, 2 and 4 inch EMT conduit using riser rated ribbon cables of various fiber counts.

![Figure 4: Riser Ribbon Fill Ratios - 3 Cables](chart.png)
In comparison, the fill ratio for interlocked armor cable with three cables installed is shown in Figure 5. The amount of "headroom" for the installation using a ribbon cable design is evident.

Since every building has varying conduit space available, the number of cables installed will depend on a variety of factors. Ultimately, the ease of installation and the likelihood of damage to the installed cables and the cable being installed are determined by the contractor and installers working with the network infrastructure.
Of course, if cable size were the only determining factor in the selection of a cable construction for a data center, then the smallest cable diameter would be the determining factor. However, this is not the only detail to be considered when installing cables in a network. For example, every cable installation is not the same length or has the same number of bends at the same angles. Installation methodologies are different and depending on the length of cable, its weight, and the aforementioned run factors, tensile strength must also be taken into consideration. Figure 6 below illustrates the difference in tensile strength of various designs.

![Cable Comparison – Tensile (Lbs.)](image)

Figure 6

The chart shows the difference between a ribbon cable and often deployed interlocked armor cables. It must be noted that there are various cable designs that have differing tensile load ratings, such as 300 lbs. The chart shows also the relative difference between the industry standard cable and those designed for “lighter” duty. Clearly, the tensile strength differences must be taken into account during an installation. Ribbon cables are flexible and strong, lessening the likelihood that problems will arise during the cable pull process.
Since cables were first installed inside of buildings, and more importantly, under data center (or communication room) floors, IT managers have been concerned with the possibility of fibers being damaged by technicians and installers walking on cables while working underneath removable floor panels. To ensure the long term viability of cables and the fibers they contain, interlock armor with the appropriate jacket material became a widely used cable design. Figure 7 measures the crush resistance of the cables being reviewed. Obviously, the interlocked armor crush specification is double that of an industry standard ribbon riser cable and almost 10X that of the smaller diameter plenum cable.

![Crush Resistance Chart](image)

**Figure 7**

The operating environment helps to determine the cable of choice at least as it relates to where the cable is located. In most modern data centers, however, cable is no longer installed under floor plenum environments; rather, they are installed in overhead cable trays. Cable installed in cable trays would significantly reduce the likelihood of cables being crushed from installations going on nearby. If the data center manager can control the amount of foot traffic in the cable trays, then the interlocked armor solution may be overkill in both size and cost. On the other hand, the ribbon design has a very good crush resistance, as well. In this case, ribbon can be considered an excellent choice in the data center environment. Finally, the reduced subunit cables, if
undisturbed, could also be a viable alternative. However, it must be noted that over the lifetime of the network the possibility of damage to this cable is higher than the other designs because of the significantly lower mechanical crush resistance.

For every installation, the cost of the components is always a factor in the choice of components that comprise a system. In Figure 8 below, the relative costs of the designs under review are shown for the same fiber counts. The interlocked armor, due to the additional material costs of the armor and over jacketing, is the most costly to produce. The ribbon design is very cost effective and, at higher fiber counts, is actually the most cost effective design. It must be noted that at higher fiber counts (in this case the chart is depicting 48F cables in comparison) the cost of termination is also significantly less, since ribbons can easily be terminated with field installable splice-on MPO connectors.
Conclusion

The ultimate choice of which cable to deploy in the data center rests with the person responsible for execution of a network’s infrastructure build plan. Many factors should be considered prior to purchasing, installing, terminating, and testing a fiber optic cable. When reviewing the major factors that typically are considered for a cable installation, it is clear that ribbon cable designs should be seriously considered for use in data center builds. The overall combination of ruggedness of the ribbon design, fiber density, size, and relative cost points to ribbon as being most suited to both new and retrofit installations in the data center. Additionally, the ribbons in fiber optic cables are best suited for future expansion, since the transmission protocols progress to higher and higher data rates. Long term, this characteristic, alone, saves the user time and money when upgrades are performed on existing data center end equipment—while ensuring optimum data center installation speed, performance, connectivity, and cost efficiencies that simultaneously prepare the data center for today and tomorrow.