Multimode Fibre

for High Data Transmission and Energy Efficient Next-Generation Data Centre

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Global Internet Protocol (IP) traffic has been skyrocketing in the cloud and in enterprise data centres (DCs), driven by the growing number of internet users and connected devices, faster broadband access, high-quality video streaming, metaverse connectivity and ubiquitous social networking. And this trend has only accelerated during the COVID-19 pandemic as people rely more on the internet to share bandwidth at home with family, make video conference calls with colleagues, and upload short videos or other content sharing into the cloud.

Figure 1 highlights selected macro trends: Global peak internet traffic has increased by 47% [1]; Facebook witnessed an instant messaging frequency jump of 50% [2]; And since the pandemic began in early 2020, 23% of U.S. consumers have added at least one new paid streaming video service, which are largely delivered by optical fibre [3].

To support fast-growing cloud-based services, data centres are being built globally to provide necessary computing, storage, and content delivery services to enterprise and cloud users.

Over the past two decades, the data centre market has become one of the most dynamic, fastest-growing markets driving innovation in many technical fronts. Data centre

Figure 1: Global IP Traffic Growing Trend Accelerated During the Pandemic

operators are striving to build faster, denser, easier-to-install, more-cost effective and more power-efficient data centres, with resiliency and sustainability first and foremost.

Outlook of multimode fibre market

As data centre traffic continues to grow, hyperscale and enterprise data centres are constantly upgrading their infrastructure by deploying higher and higher speed ethernet transceivers. With the industry excited about market growth of single-mode fibre-based solutions, primarily driven by emerging silicon photonics (SiP) technology, multimode fibre solutions, unfortunately, are often underestimated.

The multimode-based solution remains an important option for data centre operators. Transceiver shipments are often used as a key indicator of market trends. As illustrated in Figure 2, multimode fibre transceiver shipments are anticipated to continue to grow for the foreseeable future [4]. Specifically, we conclude that:

- The sales of multimode fibre transceivers are projected to contribute over 45% of all transceiver shipments [4], indicating that a significant portion of data centre infrastructure buildout will be based on multimode solutions.
- Higher speed multimode fibre transceiver shipments will dominate multimode fibre growth in the next five years as DC operators evolve to higher speed. For example, 100G and 400G multimode fibre transceiver shipment volumes are expected to outnumber 10G and 40G multimode fibre transceiver shipments combined by 2025.

The robust growth of multimode solutions is mainly driven by enterprise DCs in North America and big cloud DCs in China. Unlike their North American hyperscale DC counterpart, who typically spread the DC campus over the size of a stadium, cloud DCs in China are typically located in multi-storey buildings with a much smaller footprint. Given this, a 100m link length is sufficient to cover most of the switch-to-switch interconnect, which is ideal for a multimode fibre-based solution. It is therefore widely expected that Chinese big cloud DCs will deploy a large volume of 200G and 400G multimode fibre-based solutions in the next five years.

Technoeconomic analysis

Multimode fibre has played an essential role in modern data centre systems thanks to its natural compatibility with cost-effective Vertical-Cavity Surface-Emitting Laser (VCSEL) sources at 10G and 40G speeds. As data centres evolve to higher data rates, and the industry prepares to deploy next-generation 400G transceivers, can multimode fibre still maintain cost-effectiveness over a single-mode solution, especially given that SiP technology has significantly reduced single-mode transceiver cost today?

To quantitatively compare the 400G first-installed cost of multimode and single-mode solutions, we established a cost model that includes optical transceivers, structured cables, and connectivities. Specifically, we consider commercially available 400G transceiver types including 400G SR8 (multimode fibre, parallel) and 400G DR4 (single-mode, parallel) and 400G FR4 (single-mode fibre, duplex). Corning EDGE™ Solutions are included as connectivity solutions to match each transceiver

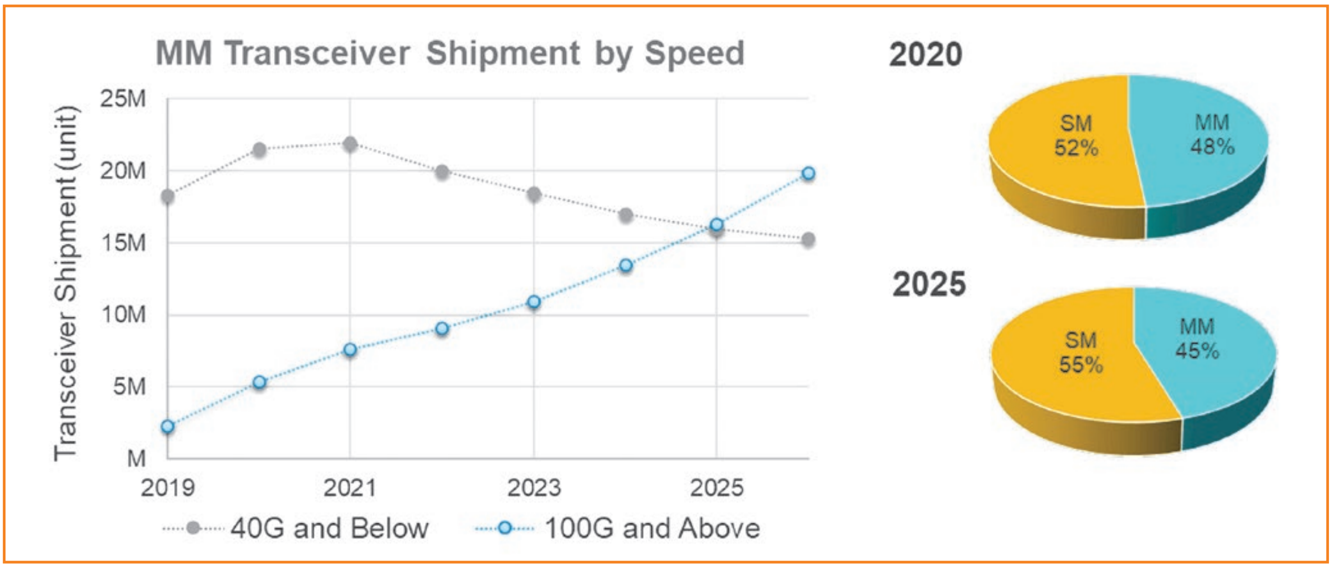

Figure 2: Multimode Fibre Transceiver Shipments Are Projected to be Significant in the Future

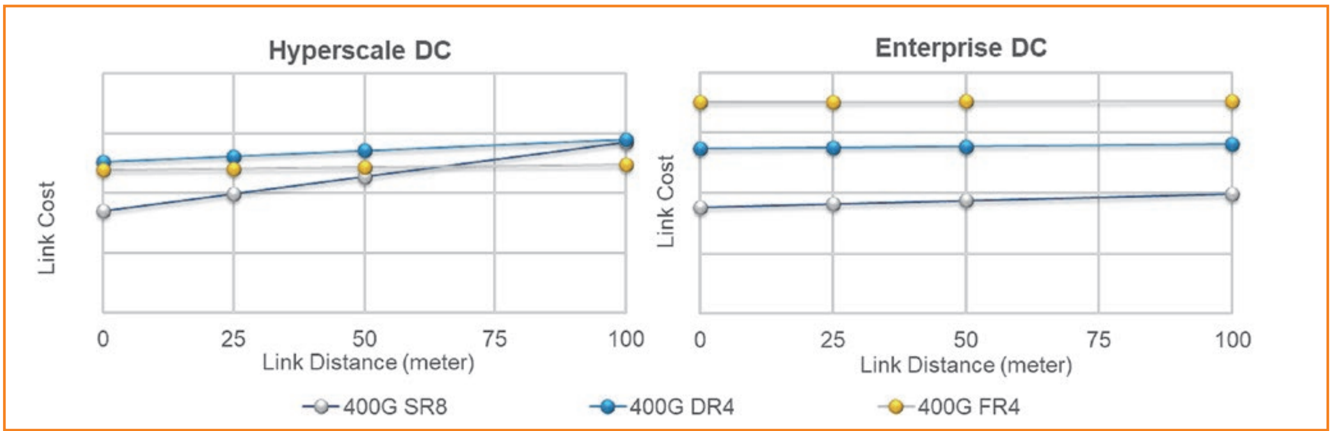

Figure 3: Link Cost Analysis for Hyperscale DC and Enterprise DC

type, respectively. In addition, the trunk cable is based on OM4 fibre, which offers an effective modal bandwidth of 4700MHz·km (defined by IEC 60793) to ensure 100m reach. It is worth noting that we consider different transceiver prices in the cost model for hyperscale and enterprise DCs, to reflect the fact that hyperscale and enterprise DCs follow vastly different business models in terms of procurement and operation. Based on the analysis, as illustrated in Figure 3, we conclude that:

For Hyperscale DCs:

- Multimode 400G SR8 is the most cost-effective solution in most of the short-reach applications.
- Single-mode 400G FR4 solution is slightly more cost-effective than a multimode-based solution (400G SR8) for 100m.
- Duplex 400G single-mode fibre (FR4) is lower cost than Parallel 400G single-mode fibre (DR4) due to highly efficient connectivity usage.

For Enterprise DCs:

- Multimode 400G SR8 delivers 20%+ cost benefit over single-mode solutions (FR4 and DR4).
- Parallel single-mode 400G DR4 is more cost effective than Duplex single-mode 400G FR4.

Clearly, the cost advantage of multimode fibre-based solutions is still viable at 400G for the majority of data centre applications. We therefore expect stability or growth for the OM4 multimode fibre market.

Power consumption considerations

Global data centre electricity use in 2020 was 200-250TWh, or around 1% of global electricity demand [5], and this is only anticipated to grow with one prediction suggesting an increase to 8% by 2030 [6]. To reduce this, and avoid the harmful emission of greenhouse gases (GHGs) associated with the production of electricity, achieving greater DC energy efficiency is critical. How can we achieve this by transitioning to a multimode fibre solution?

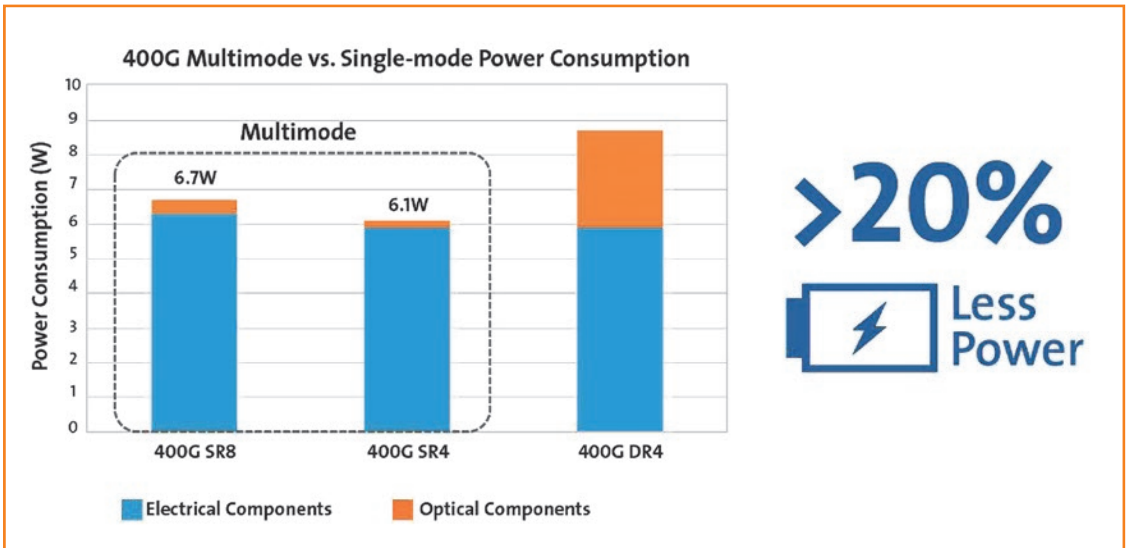

Figure 4. Multimode vs. Single-mode 400G Transceiver Power Consumption Comparison

	Electricity Reduction	Estimated Electricity Cost Savings	GHG Emissions Reduction	Carbon Sequestered by Acres of US Forests in 1 Year
1 Year	500,000 KWh	$35,000	354 mt CO2e	434
5 Year	2,500,000 KWh	$177,000	1,772 mt CO2e	2,171
10 Year	5,000,000 KWh	$353,000	3,543 mt CO2e	4,341

Assume a Data Center with 500 switches
CO_2 equivalencies source: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Corning Analysis

Figure 5: Reduction in Power Consumption and GHG Emissions Offered by Multimode Fibre-based Solution Over the Single-mode Counterpart

From a transmission technology standpoint, multimode fibre exhibits more energy efficient operation in data centres, which is associated with the lower power consumption of VCSEL-based multimode transceivers. Compared to a single-mode based 400G DR4 transceiver, multimode fibre-based 400G transceivers (eg. 400G SR8) deliver more than 20% power savings.

Although both transceivers types require power-hungry digital-signal-processors (DSPs), VCSELs in an SR8 transceiver enable a two watt power reduction compared to 400G DR4 single-mode transceivers. For the 400G SR4 transceiver that is under development (future-generation multimode fibre 400G option suggested by IEEE 802.3db), the power advantage is projected to be even higher, as the number of optical components and transimpedance amplifier (TIA) is cut in half.

A data centre potentially deploys tens of thousands of optical transceivers, meaning that the choice of a more energy efficient transmission solution could result in a significant reduction in GHG emissions. Deploying a 400G multimode transceiver in a DC with 500 switches, as detailed in Figure 5, not only reduces electricity costs, but also helps to reduce GHG emissions. For example, in a 10-year period, the multimode solution delivers a five million kWh energy savings, which translates into approximately 3,543 metric tons less carbon dioxide equivalent (CO_2e) emitted, as estimated using the United States Environmental Protection Agency GHG equivalencies calculator [7]. To put that into perspective, this equates to the carbon sequestered by 4,341 acres of US forests in one year. When compared with single-mode fibre, the multimode fibre solution offers a distinct opportunity to reduce the power consumption of today's data centres.

Why Corning® ClearCurve® Multimode Fibre?

Laser-optimised 50 µm-core multimode fibres are widely deployed with higher modal bandwidth to enable high data rate multimode applications.

In the world of multimode fibre, the IEEE 802.3bm task force defined the capability for multimode VCSEL at 25Gb/s transmission over multimode fibre, where 850nm multimode VCSEL and OM4/OM5 can meet the 100m link distance requirement. As data centre optics evolve to higher data rates, IEEE recently approved IEEE 802.3db, paving the way for 200G and 400G Ethernet options based on a 100G/lane multimode solution. To achieve 100G/lane operation over 100m multimode fibre, a high effective link bandwidth (BW_{eff}) of multimode fibre is required to enable sufficient headroom for system transmission performance. In principle, BW_{eff} depends on both the fibre modal dispersion and chromatic dispersion [8], namely:

$$BW_{eff} = \frac{1}{\sqrt{EMB^{-2} + BW_{CD}^{-2}}}$$

where EMB is the TIA-defined worst case Effective Modal Bandwidth, and BW_{CD} is the chromatic dispersion limited bandwidth, which is determined by both the chromatic dispersion slope and zero dispersion (λo) wavelength range.

	ClearCurve® OM4 fiber	Standard OM4 fiber
Lambda0 (nm)	$1295 \leq \lambda 0 \leq 1315$	$1297 \leq \lambda 0 \leq 1328$
Maximum Zero Dispersion Slope	0.101	0.105
Maximum D at 850nm (ps/nmkm)	-101.5	-110.6
Effective Bandwidth for 100m link (BW_{eff} in GHz)	25.7	24.2
Performance Margin	7%	0%

Figure 6: OM4 Fibre Effective Link Bandwidth and Reach Extension Comparison

Since the worst case EMB are characterised at the same level for any standardized OM3 or OM4 fibre, the BW_{eff} is determined by chromatic dispersion performance, which differentiates Corning® ClearCurve® multimode fibre from its peers. In Figure 6, we list the dispersion slope and λo range of ClearCurve® OM4 fibre in comparison with IEC standard OM4 multimode fibre.

ClearCurve® OM4 fibre offers the most ideal chromatic dispersion at 850nm wavelength with the tightened λo range and flattened dispersion slope, which in turn optimizes chromatic dispersion contributed bandwidth (BWCD). Engineered chromatic dispersion in ClearCurve® OM4 fibre therefore delivers higher effective link bandwidth, capable of supporting up to a 7% performance margin.

Summary

Multimode fibre-based solutions will remain an important option for data centre operators, and the expected multimode market growth is mainly driven by enterprise DCs in North America and big cloud DCs in China. Techno-economic analysis predicts that the cost advantage presented by multimode fibre solutions persists at 400G data rate for the majority of applications. From a power consumption perspective, multimode solutions help deliver significant advantages by reducing electricity use and greenhouse gas emissions. Therefore, we expect the multimode market, especially OM4 fibre, will see sustained adoption for the foreseeable future. By optimising the chromatic dispersion, Corning® ClearCurve® multimode fibre delivers the highest effective link bandwidth, which ensures superior transmission performance with 7% more headroom than standard compliant products.

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