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Demystifying the Bandwidth Requirements for 100G/lane Multimode Fiber Operation

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Introduction

For multimode fiber (MMF) applications, the industry has traditionally adhered to 100-meter OM4 and 70-meter OM3 as link guidance for fiber deployment selections in short-reach data center applications. While these benchmarks served industries well in the past, as we move into an era of 100G/lane or higher data rate applications, it's time to reassess MMF bandwidth requirements to sustain MMF's role in such applications.

The Dynamics of Fiber Bandwidth Requirements

OM3 fiber and OM4 fiber are both laser-optimized multimode fibers with 50 µm fiber cores, designed to meet the ISO 11801 standard. IEC guidance outlines the minimum Effective Modal Bandwidth (EMB) requirements for OM3 and OM4 [1], as shown in Fig.1. OM4 meets or exceeds modal bandwidth of 4700 MHz·km at 850 nm.

Historically, almost all MMF solutions follow these benchmarks to define the reach specification. For example, popular multimode transceiver protocols such as 100G SR4, 100G BiDi, 400G SR8, and 400G SR4.2 all define 100 m reach using OM4 and 70 m reach using OM3. Until now, fiber bandwidth has not been a bottleneck to achieving these reach specifications.

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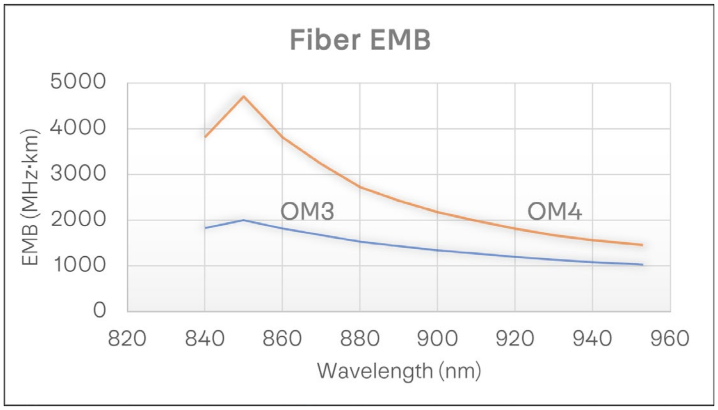

Figure 1: Standard OM3 and OM4 EMB wavelength dependance.

In the era of 100G/lane or higher-data-rate multimode applications, the paradigm has shifted. In practice, many of the high-speed VCSEL transceivers available in the market incorporate Indium into the quantum well to enhance device bandwidth, which effectively shifts the operating wavelength upward from 850 nm to the 860-870 nm range. This shift can affect the EMB value at 860-870 nm when using standard OM4 fiber, raising questions about whether the fiber bandwidth can support 100 m reach at 100G/lane speed.

In MMF transmission systems, the transmission performance is driven by the effective link bandwidth BW_{eff}, which is defined as $\boldsymbol{BW_{eff}} = \left(\frac{1}{EMB^2} + \frac{1}{BW_{CD}{}^2}\right)^{-1/2}$. For 100G/lane transmission, the required link bandwidth is specified as 18GHz [2]. As the VCSEL wavelength shifts toward the 860 nm-870 nm range, the link bandwidth typically declines below 18GHz, as is shown in Fig 2.

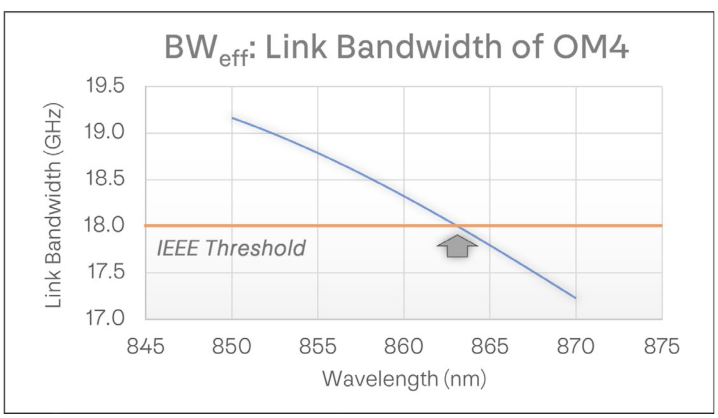

Figure 2: Link bandwidth may fall below 18GHz by using standard OM4.

Intuitively, one may suppose the EMB must increase to bring the performance (link bandwidth) back to 18GHz.

However, it's important to note that the effective link bandwidth BW_{eff} is a function of not only EMB, but also chromatic dispersion and laser linewidth-contributed bandwidth (BW_{CD}). Here BW_{CD} is related to both the chromatic dispersion value and the root mean square (RMS) linewidth. For most of the commercially deployed VCSEL transmission applications, the RMS linewidth is primarily specified at 0.6 nm.

As the wavelength increases, chromatic dispersion drops, resulting in a higher BW_{CD}, as demonstrated in Fig.3. This implies that a lower EMB value might be sufficient to achieve the same link bandwidth as the wavelength increases. Since link bandwidth BW_{eff} is the measure that affects the transmission performance, it's more effective to assess link performance based on BW_{eff} rather than solely on the EMB value.

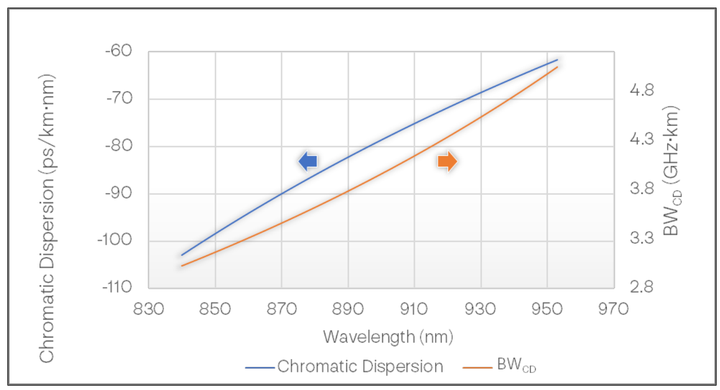

Figure 3: CD contributed bandwidth BW_{CD} increases as wavelength shifts to longer wavelength.

By considering both modal bandwidth and chromatic dispersion, required EMB values to meet 100 m reach capability can be calculated (Table 1).

SPEC	OPERATIONS		
Wavelength	850 nm	860 nm	870 nm
EMB in MHz·km	4700	4500	4200
BW_{eff} margin* in GHz	1.2	1.5	1.5

Table 1: Fiber bandwidth requirement for 100 m 100G/lane operation at various wavelengths.

Clearly, to achieve a 100-meter reach at 100G/lane, the multimode fiber must deliver a minimum EMB value of 4500 MHz·km at 860 nm and 4200 MHz·km at 870 nm. This ensures optimal performance with sufficient margin (*margin over 18 GHz of link bandwidth requirement).

Meeting and exceeding bandwidth requirements with Corning® ClearCurve® multimode optical fiber

Does Corning offer a multimode fiber that can meet or even exceed bandwidth requirements for short-reach data center applications? The answer is yes. An optimized ClearCurve® OM4 fiber is the ideal solution for the 100G/lane applications, readily accommodating any potential wavelength shift toward 870 nm operation.

Additionally, Corning introduced a high-data-rate optimized multimode fiber in 2023, ClearCurve® OM4 XT fiber, which defines EMB values of 4700 MHz·km for 850 nm and 3100 MHz·km for 910 nm. Through Monte Carlo simulation, we analyze the EMB distribution of ClearCurve® OM4 XT fiber, focusing on the wavelength dependence curve of this MMF [3].

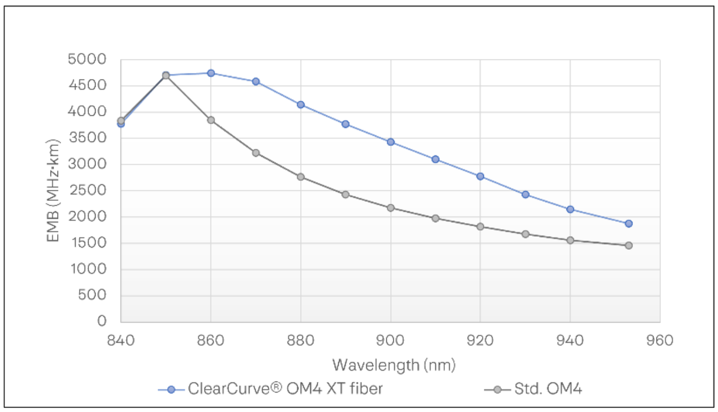

Figure 4: ClearCurve® OM4 XT fiber wavelength dependence curve.

The wavelength dependence curve, illustrated in Fig.4, indicates that ClearCurve® OM4 XT fiber has much higher bandwidth margins than the requirements shown in Table 1 above. Ultimately, Corning ClearCurve® Multimode fiber assists customers in delivering the necessary performance for up to 100 m in data center or AI cluster links at 100G/lane multimode, while maintaining low-cost and low-power operation.

References

[1] IEC guidance: IEC document with EMB guidance curves 60793-2-10_ed7_2019.pdf.

[2] IEEE Std 802.3dbTM-2022.

[3] Xin Chen et al. Wavelength Dependence of Modal Bandwidth of Multimode Fibers for High Data Rate Transmission and Its Implications, Photonics 2024, 11(7).