Proposed Options for a 1060 nm Optimized MMF

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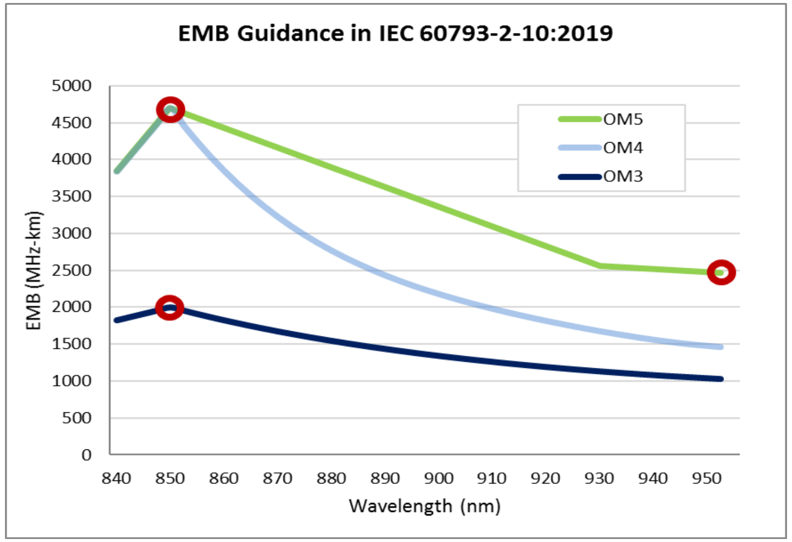
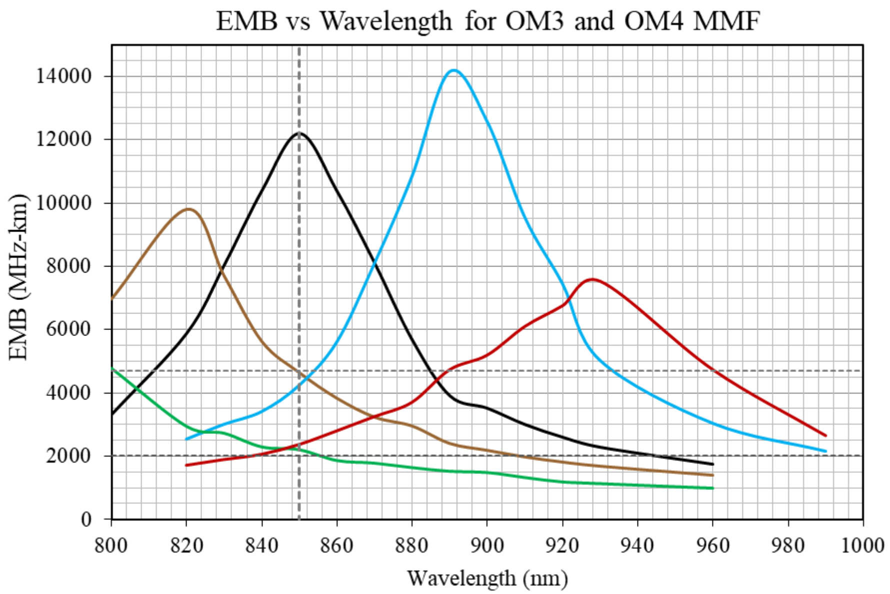
Supporters

Standardized Multimode Fiber: A Review

- Multimode fibers (MMFs) are classified as OM3/OM4/OM5 based on effective modal bandwidth (EMB) at selected spectral regions as shown in the figure:
  - Upper: OM3, OM4 and OM5 minimum modal BW requirements
  - Lower: Measured OM3 and OM4 EMBs vs wavelength
- OM5 is the latest MMF type, intended to support higher bandwidth at longer wavelengths and multiwavelength operation from 850 nm to 953 nm.
- However, OM5 does not improve modal bandwidth sufficiently enough beyond 953 nm
  - For example, at 850 nm it remains similar to OM4 (4700 MHz-km), and while the bandwidth at longer wavelengths (e.g., 953 nm) is improved, it is not enough to support ≥200Gbps per lane for required reaches.

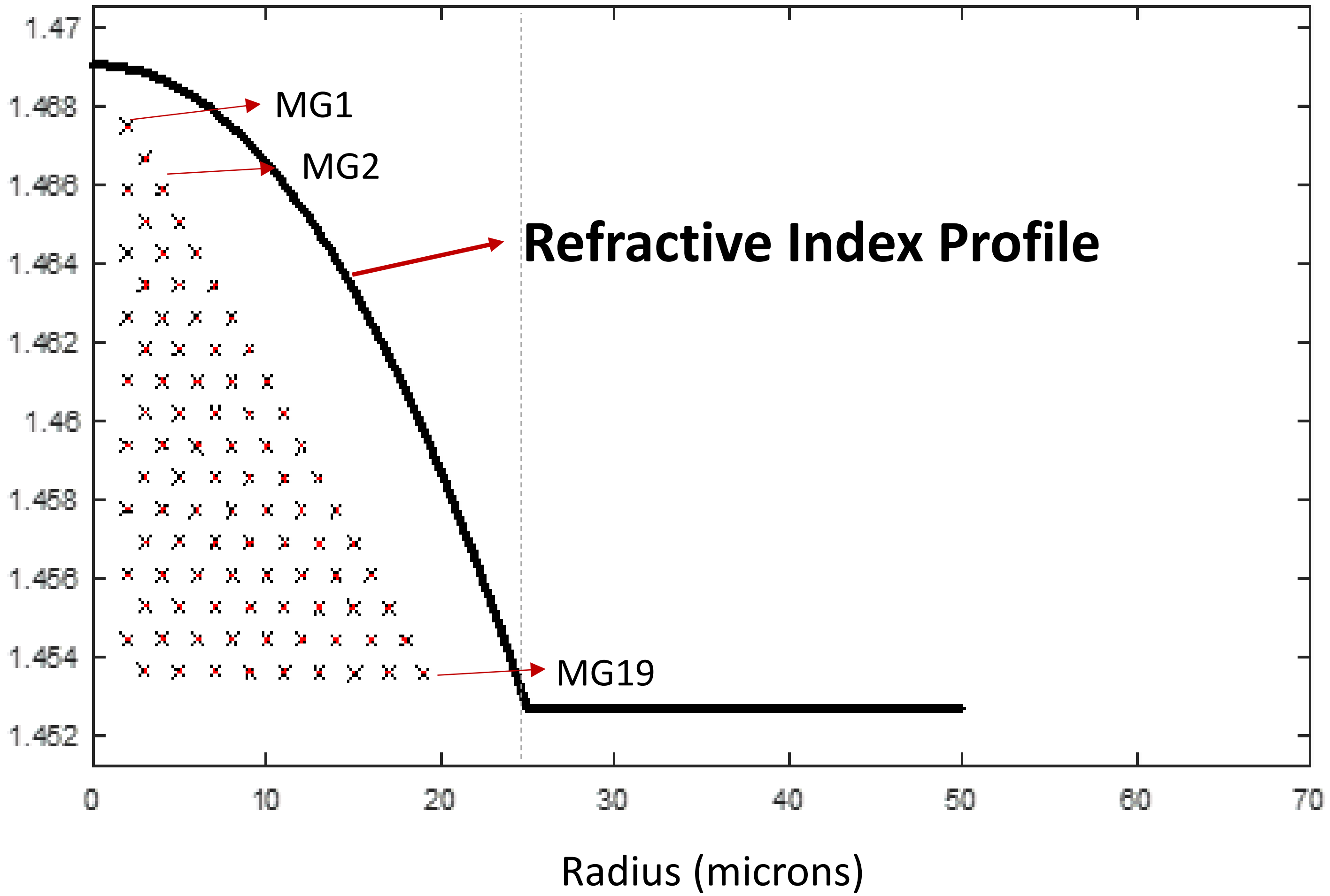


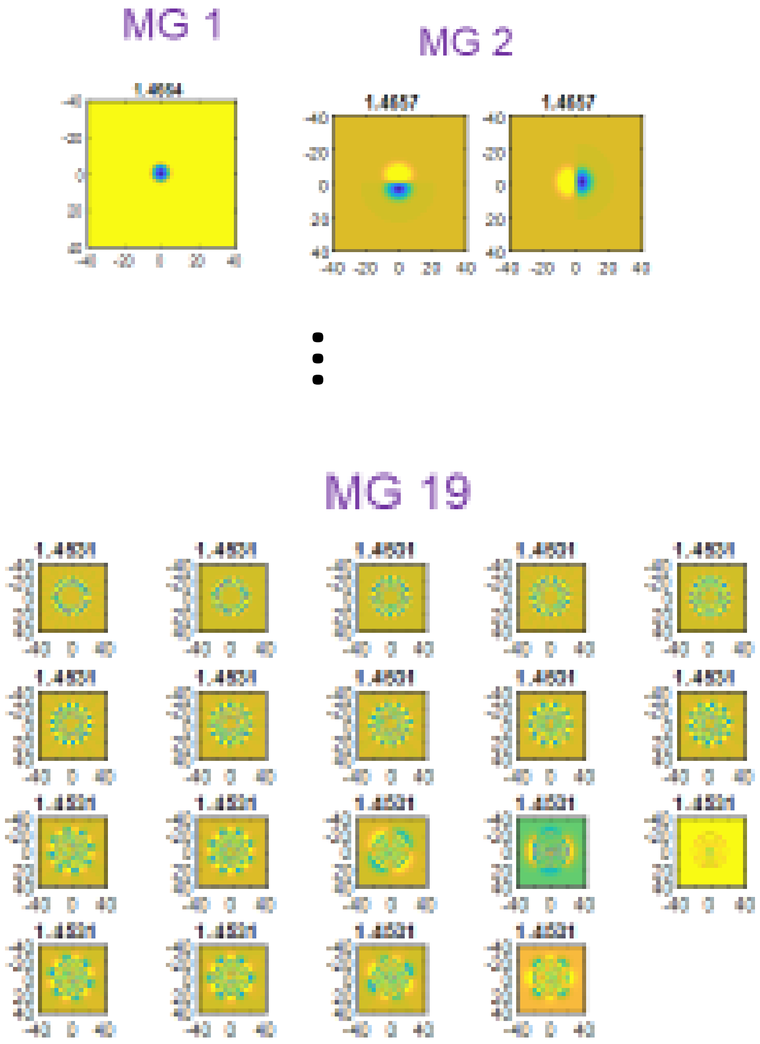


Motivation

- 1060 nm VCSELs can potentially improve bandwidth and energy efficiency.
- However, standard multimode fibers (MMF) such as OM3/OM4 or OM5—designed for 850 nm operation—have insufficient bandwidth at 1060 nm for high-speed interconnects.
- To enable efficient optical interconnects, a fiber optimized for longer wavelengths is required.
- If backward compatibility is no longer a requirement, then higher performing multimode fibers are unlocked providing key advantages:
  - A larger core diameter than SMF reduces sensitivity to misalignment and contamination.
  - Significantly lower chromatic dispersion increasing the channel bandwidth while potentially resulting in a lower the fiber cost relative to the cost of standard OM4/OM5 fiber.
- 1060 nm VCSELs with an optimized MMF can provide robust, high-bandwidth interconnections for next-generation AI networks (scale-up and scale-out).
- In this presentation, we discuss options and a draft proposal for a new fiber.

Parameter to Optimize Modal Bandwidth

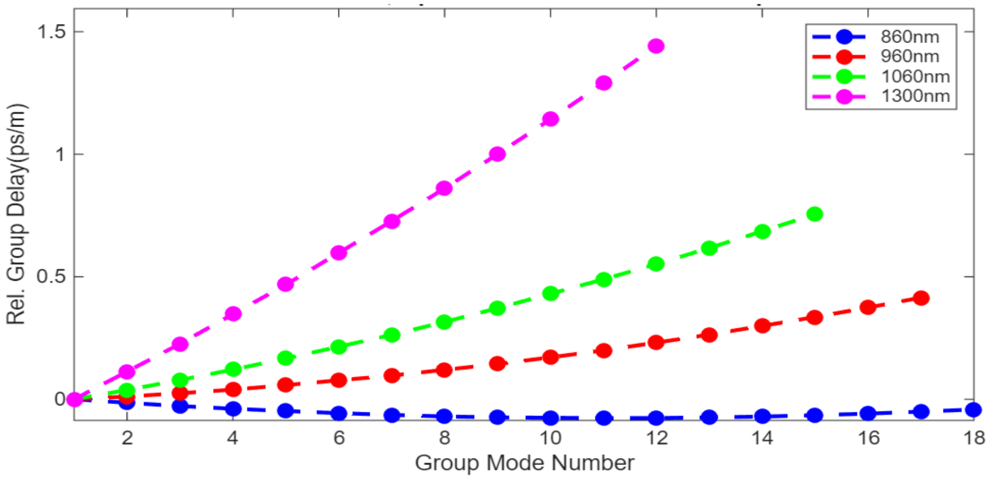




Group Delays vs Wavelength

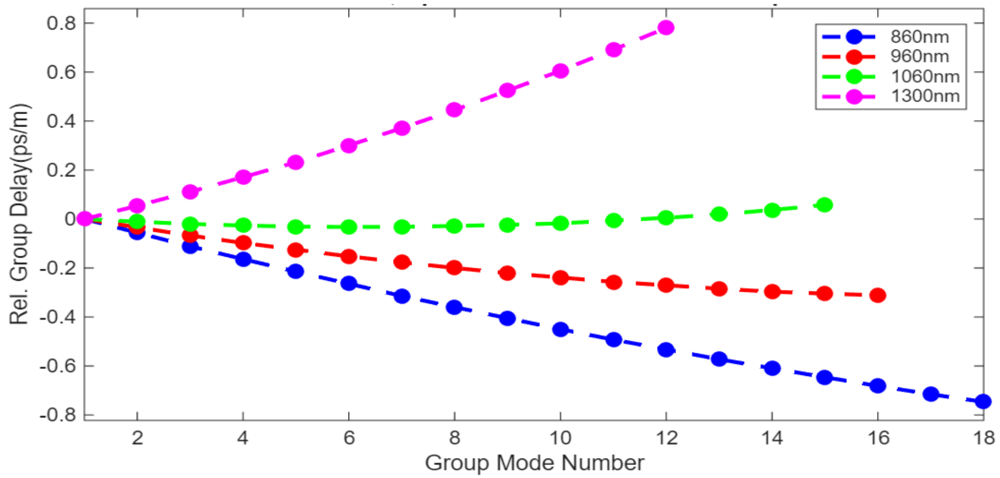
High Bandwidth OM4

Fiber: 50 microns Tuned to Peak BW at 850 nm



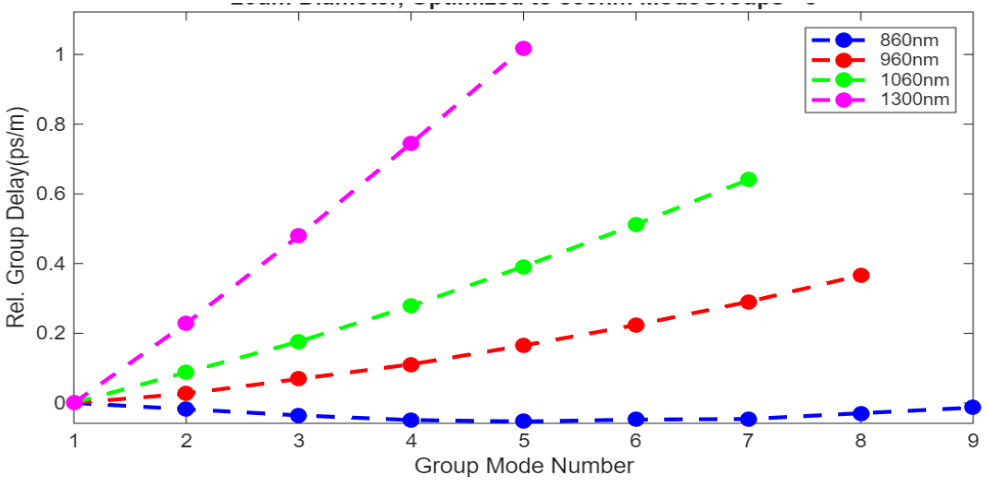
Option A

Fiber: 50 microns Tuned to Peak BW at 1060 nm



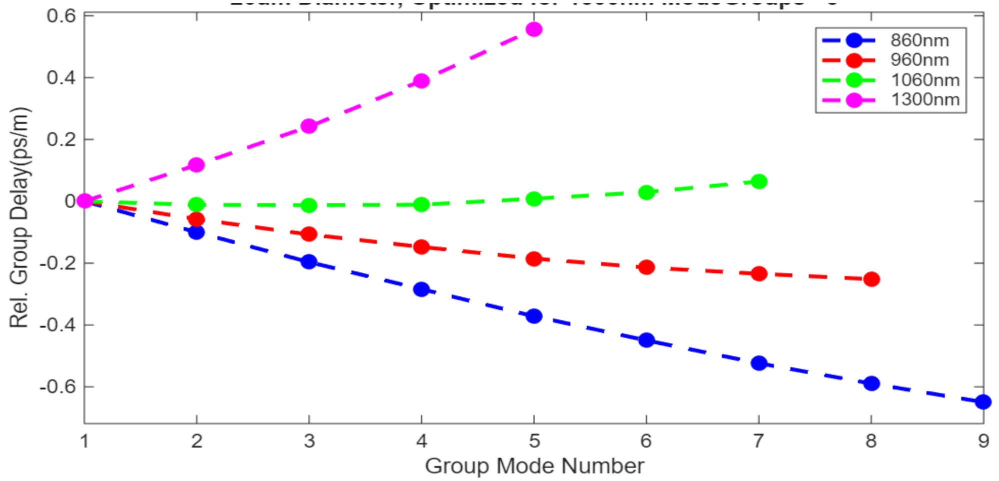
Example to illustrate the impact of diameter

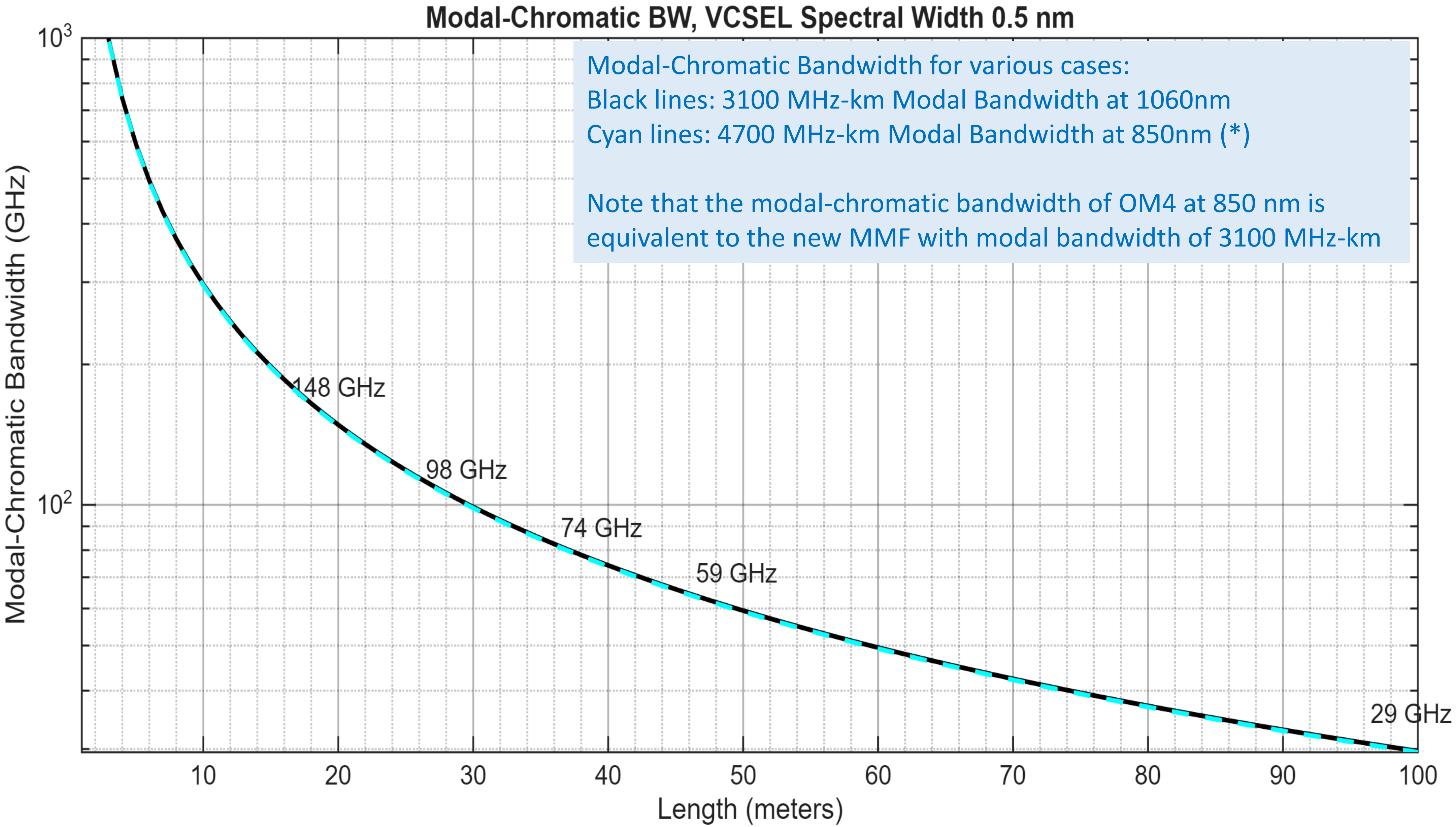
Fiber: 26 microns Tuned to Peak BW at 850 nm



Option B

Fiber: 26 microns Tuned to Peak BW at 1060 nm





*** The worst-case EMB for OM4/5 MMF is set at 3840 MHz-km at 840 nm for 0.60 nm spectral width, so the “equivalent” EMB of 3100 MHz-km at 1060 nm may overestimate the actual required modal BW of the proposed 1060 MMF**

Fiber Options: Technical Comparison

Parameter	OM4	MMF Option A	MMF Option B
Core Diameter	50 µm	50 µm	≃26 µm
Refractive Index Profile	Tuned to 850 nm	Tuned to 1060	Tuned to 1060
Numerical Aperture	0.20	0.20	0.20
Macrobending Losses	As defined in ANSI/TIA-492AAAF standard	Similar to OM4	Similar or close to OM4
IL	2.5 dB/km	~ 0.9 dB/km	~ 0.9 dB/km
Modal Bandwidth	4700 (MHz-km) @ 850nm	3100 (MHz-km) @ 1060 nm (TBD*)	3100 (MHz-km) @ 1060 nm (TBD*)
CD	- 98 ps/(nm·km)	> -36 ps/(nm·km)	> -36 ps/(nm·km)
Total Bandwidth			
Spectral width: 0.5nm	2950 (MHz-km) @ 850nm	<2970 (MHz-km) @ 1060 nm	<2970 (MHz-km) @ 1060 nm
Spectral width: 0.6nm	2630 (MHz-km) @ 850nm	<2920 (MHz-km) @ 1060 nm	<2920 (MHz-km) @ 1060 nm

*It depends on the channel bandwidth and distance targets, and on what is economically viable given the modal-bandwidth/yield tradeoff.

Comparison of the MMF Options

Parameters at 1060 nm	Option A	Option B
Diameter	50 microns	~26 microns
Modal Bandwidth	3100 MHz-km (TBD *)	3100 MHz-km (TBD*)
Modal-Chromatic BW at 50m and 30m	59GHz (50m) / 98 GHz (30m)	59GHz (50m) / 98 GHz (30m)
Coupling to VCSEL /Detectors	Similar to OM4	Smaller lenses/tapers **
Connectivity	Robust to misalignment and contamination	TBD
Development by fiber vendors	Simpler than option B, since it only requires tuning the refractive-index profile	Changing the core diameter and the refractive-index profile is more complex
Standardization	Potentially faster since the diameter has not changed. We still need alignment from the fiber vendors and the ecosystem within the standards TIA/IEC.	It needs alignment from the fiber vendors and the ecosystem within the TIA/IEC standards. It might require more time due to fiber diameter changes.
Testing	BW testing needs to be re-evaluated	Needs development

*It depends on the channel bandwidth and distance targets, and on what is economically viable given the modal-bandwidth/yield tradeoff.
**Photodetector with smaller diameter improve bandwidth. Assuming PD diameter of 20 microns and 26-micron diameter fiber can potentially interface directly with small or no lenses.

Economic Feasibility Consideration

- Lower chromatic dispersion at 1060 nm allows reduced modal bandwidth while maintaining total bandwidth at least equivalent to the current OM4
- Relaxed modal bandwidth can improve manufacturing yield and shorten development cycles
- 1060 nm MMF potentially supports a more sustainable business model and has broad market potential
- Smaller core design can make coupling to fast photodetectors easier
- Smaller core design reduces germanium usage – an important factor amid rising Ge prices and potentially large demands of optical connectivity by scale-up and scale out AI DC infrastructure
- The smaller core option facilitates future compact, dense solutions possibly including Multi-Core Fiber (MCF)

Summary & Discussion

- VCSELs and MMF operating at 1060 nm could potentially provide energy efficient and economically feasible short-reach links for AI scale-up and scale out applications
- The options presented for an MMF optimized for operation at 1060 nm include fibers with 50 µm and ~26 µm core diameters, summarizing the merits and challenges of each.
  - A smaller-core fiber (~26 µm), with a refractive-index profile optimized for 1060 nm, could provide additional benefits such as easier coupling to photodiode, and lower fiber cost relative to the cost of 50 µm-core MMF
  - However, a smaller-core MMF may increase the complexity of fiber development, testing, and standardization
- 1060 MMFs with higher modal bandwidths can potentially support future higher speeds (e.g. 400G) and longer reaches
- Input from transceiver and fiber subject matter experts is needed to narrow down the options, and converge on requirements for the new fiber