

Measurement and Analysis of 1060 nm Optimized Fiber Bandwidth

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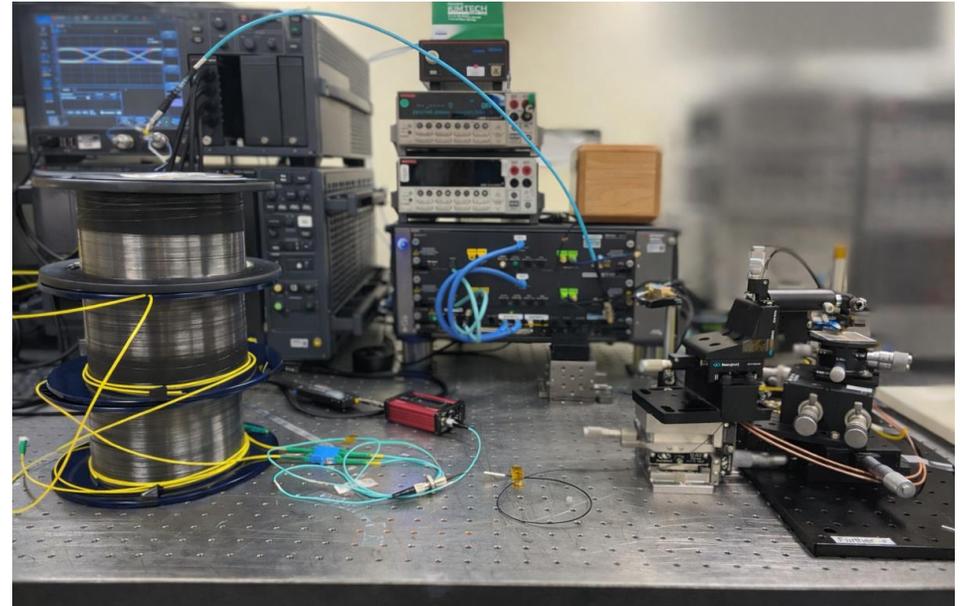
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Outline

- **Measurements:** Bandwidth of 1060 nm optimized fibers
- **Analysis:** Fiber EMB requirements
- **Future Outlook:** Extended reach and 400G

Measurement Setup

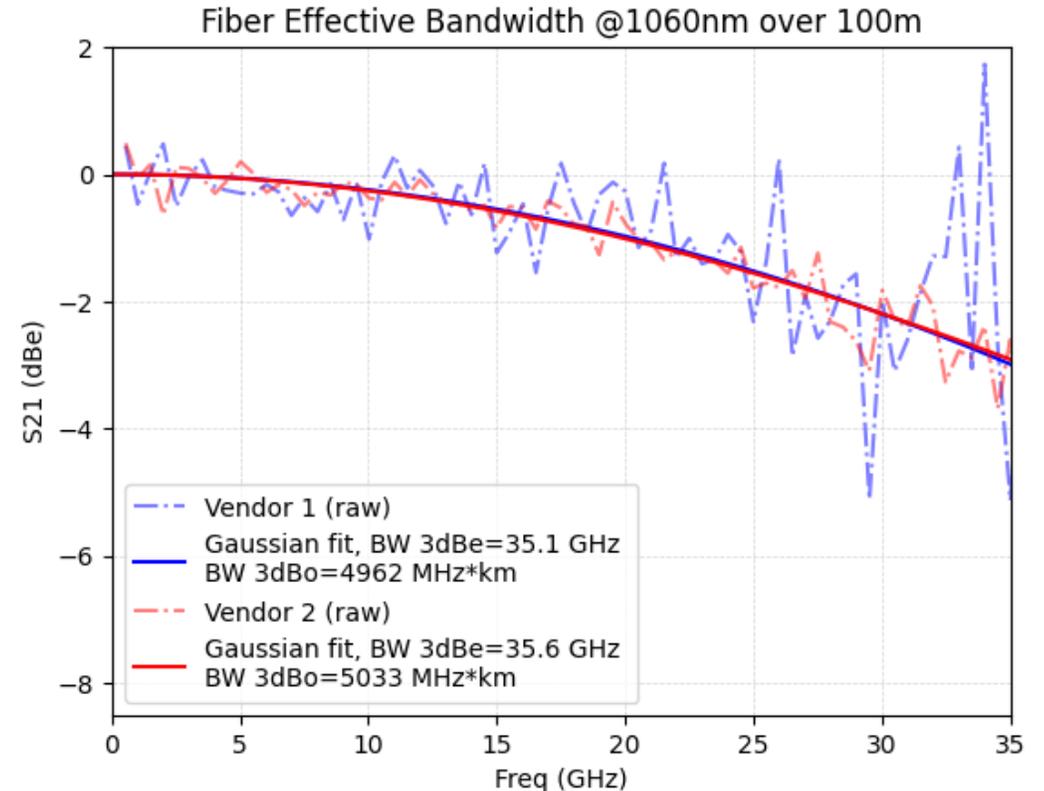
- An Arbitrary Waveform Generator (AWG) generates sinusoidal tones to drive a 1060 nm VCSEL.
- The signal is detected by a photodiode, and the amplitude is measured using a Digital Communication Analyzer (DCA). Measurements are taken both with and without the fiber spool.
- The difference between the two measurements is used to calculate the fiber bandwidth.



Keysight AWG → Bias-Tee + VCSEL → 1m patchcord+ OM1060 Fiber Spool → Photodetector → Keysight DCA

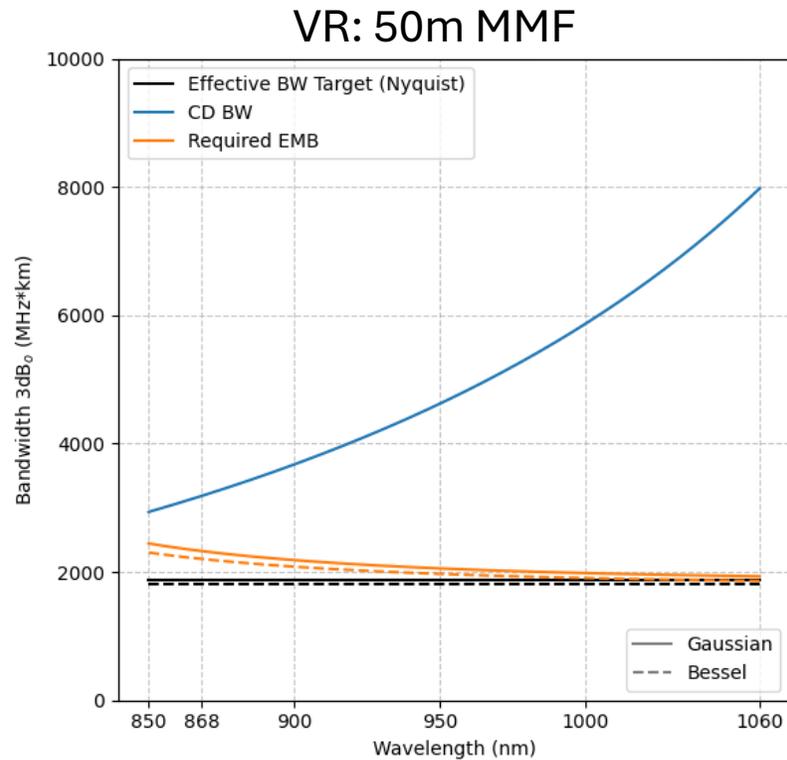
Measurement Results

- Measurements were taken on 100-meter fiber spools of 50 um core fiber from two different vendors.
- Gaussian fitting was applied to the measurements to mitigate test noise and provide a more accurate bandwidth calculation.
- After de-embedding, the 3 dB electrical bandwidth was measured at 35.1 GHz for Vendor 1 and 35.6 GHz for Vendor 2.
- These results correspond to an equivalent 3 dB optical bandwidth of approximately 5000 MHz*km for both vendors.

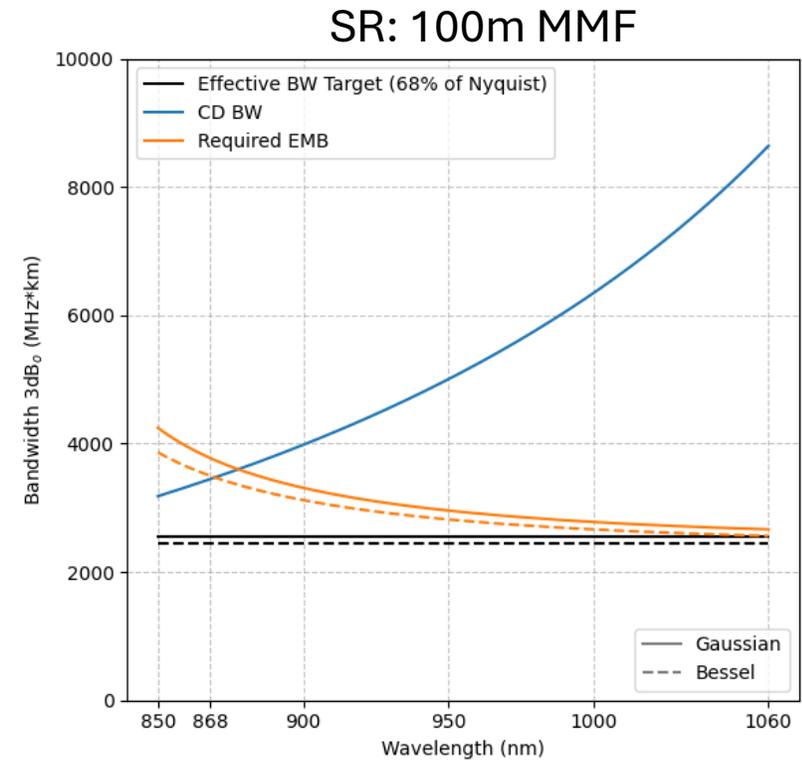


100Gb/s PAM4 Fiber EMB Requirement

- To maintain Effective Modal Bandwidth (EMB) requirements below the OM4 specification limit (4700 MHz*km), the 100G-SR standard had to reduce the effective channel bandwidth specification below the Nyquist frequency.



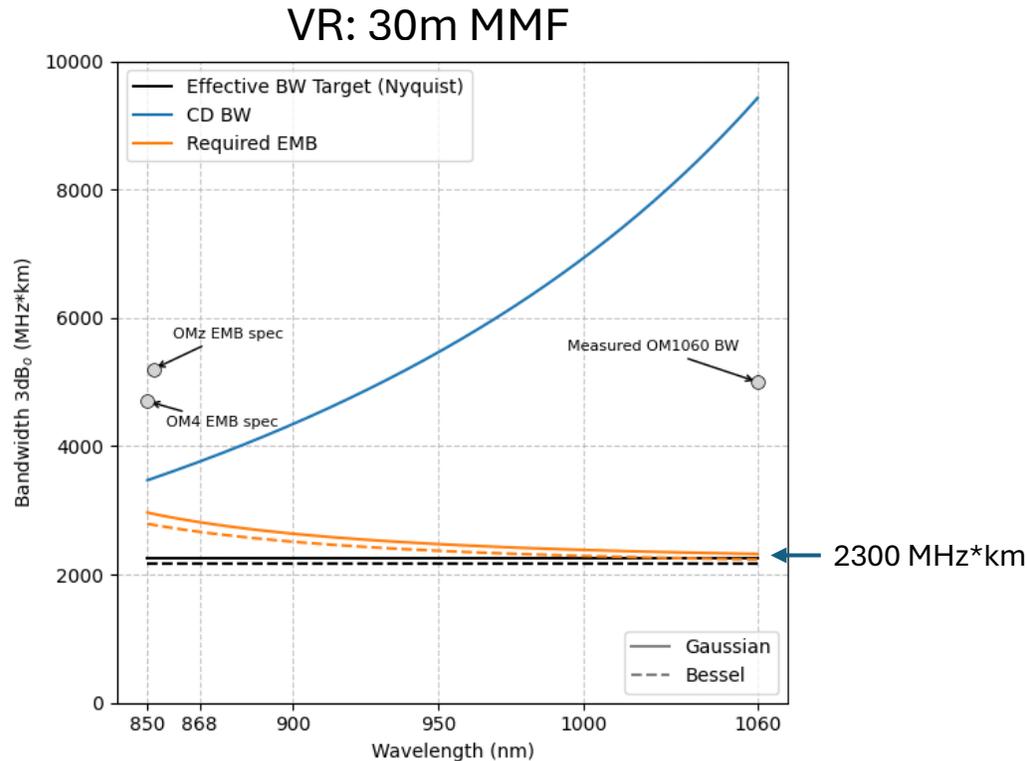
Fiber EMB required at 106 Gb/s PAM4 over 50 m MMF for a total channel 3dBe bandwidth target of 26.6 GHz with a spectral width of 0.65 nm



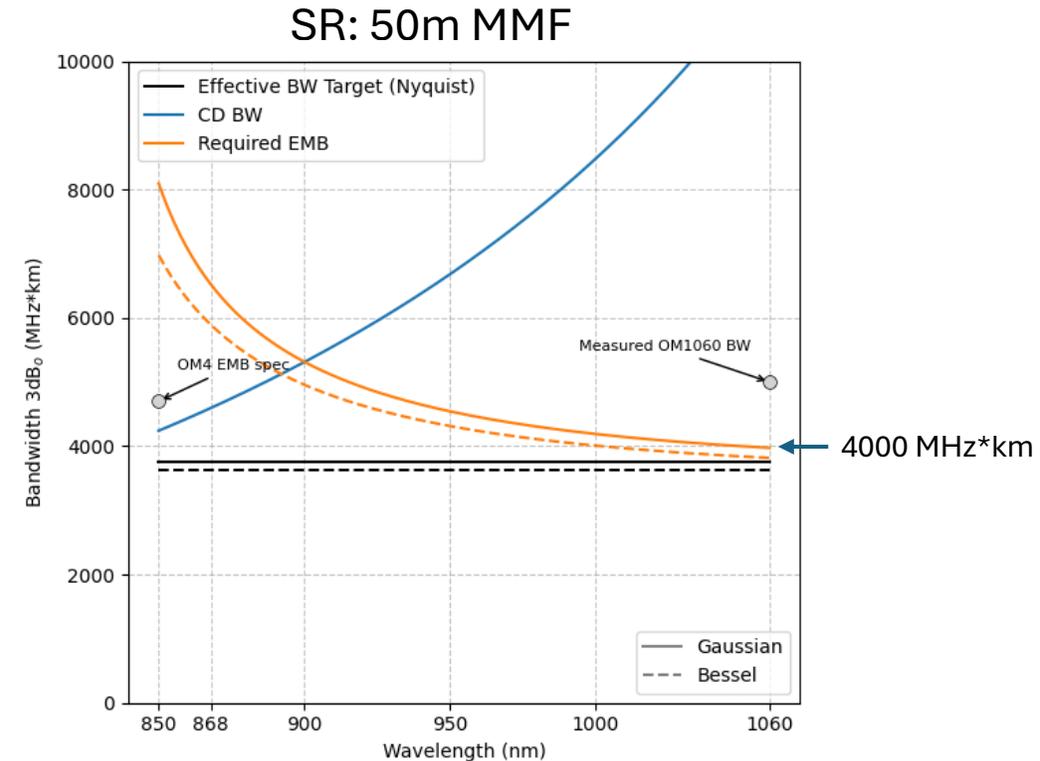
Fiber EMB required at 106 Gb/s PAM4 over 100 m MMF for a total channel 3dBe bandwidth target of 18.0 GHz with a spectral width of 0.60 nm

200Gb/s PAM4 Fiber EMB Requirement

- At 200 Gb/s, the effective fiber bandwidth specification cannot be significantly reduced below the Nyquist frequency due to bandwidth limitations in other link components.
- Consequently, the standard OM4 specification no longer meets the required EMB for 200G-SR.
- However, the modal bandwidth requirement is significantly lower at 1060 nm, resulting in more relaxed bandwidth specifications for both fiber and laser manufacturers.

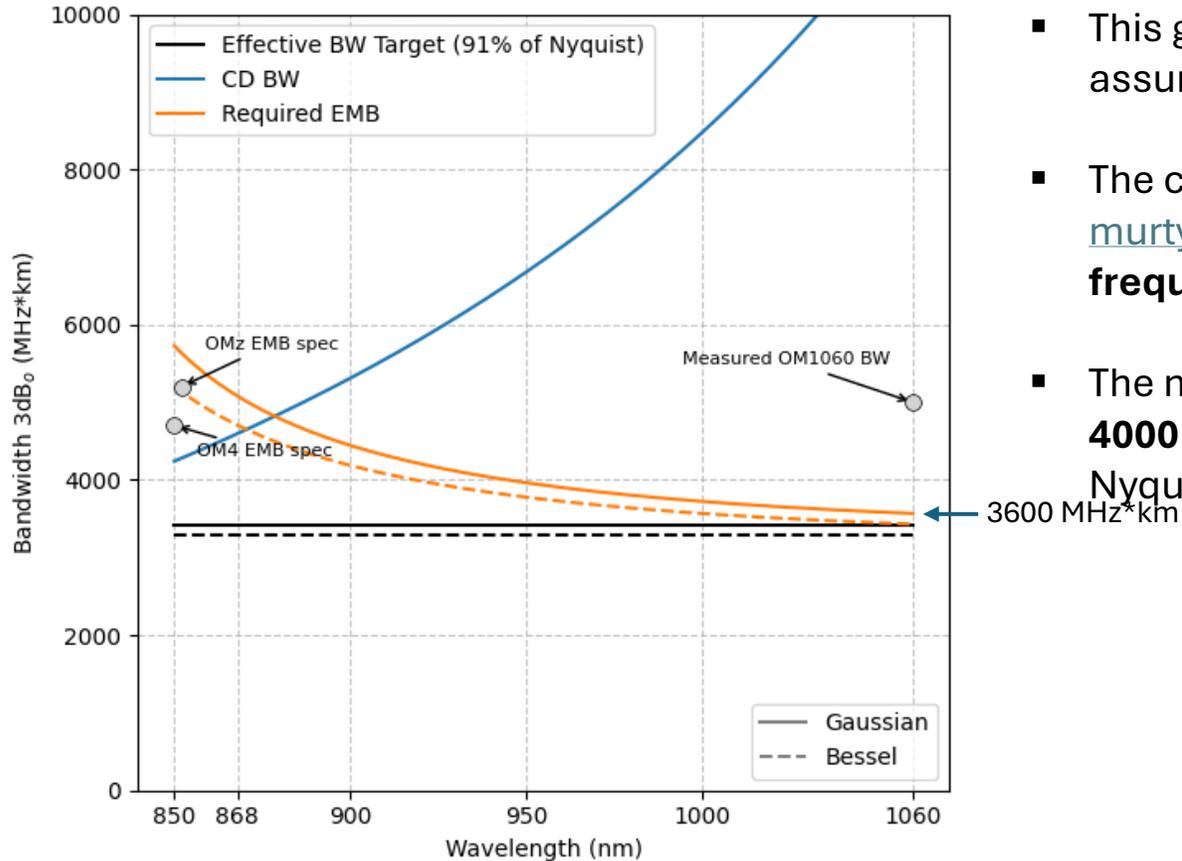


Fiber EMB required at 212 Gb/s PAM4 over 30 m MMF for a total channel 3dBe bandwidth target of 53.1 GHz with a spectral width of 0.55 nm



Fiber EMB required at 212 Gb/s PAM4 over 50 m MMF for a total channel 3dBe bandwidth target of 53.1 GHz with a spectral width of 0.45 nm

200Gb/s PAM4 Fiber EMB Requirement for < Nyquist channel BW

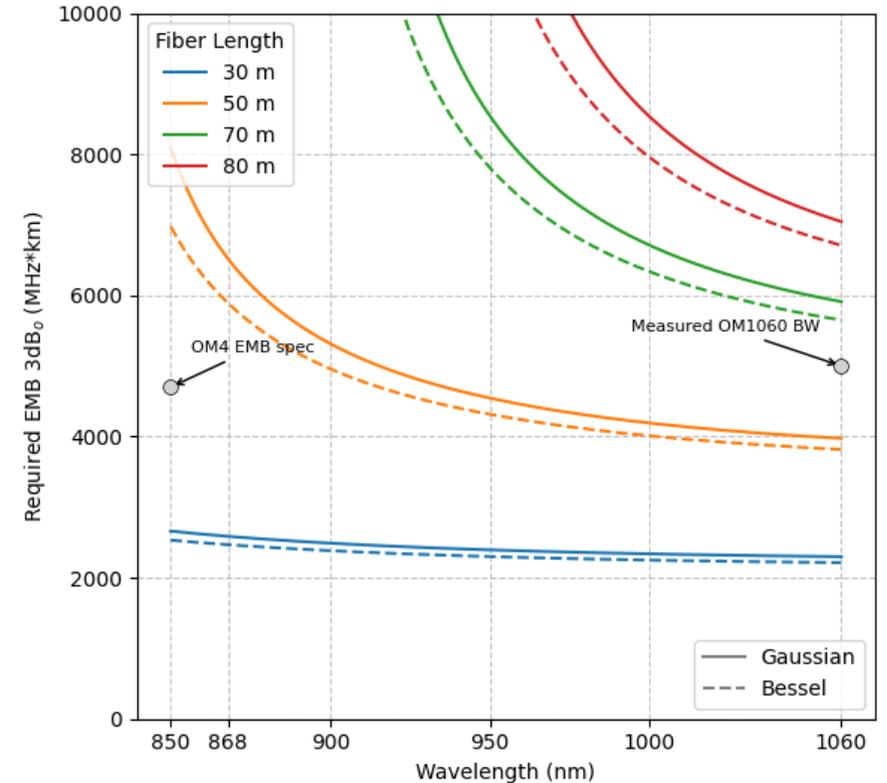


- This graph is equivalent to one shown in the previous slide, except it assumes a channel -3 dBc bandwidth lower than the Nyquist frequency.
- The channel effective -3 dBc bandwidth is **48.2 GHz**, proposed in [murty_3ds_02b_2603](#) which corresponds to **91% of the Nyquist frequency**.
- The new **1060 nm optimized fiber EMB** should be in the range of **3600–4000 MHz·km**, depending on the ratio of channel bandwidth to the Nyquist frequency.

Fiber EMB required at 212 Gb/s PAM4 over 50 m MMF for a total channel 3dBc bandwidth target of 48.2 GHz with a spectral width of 0.45 nm

Extending Reach Beyond 50m

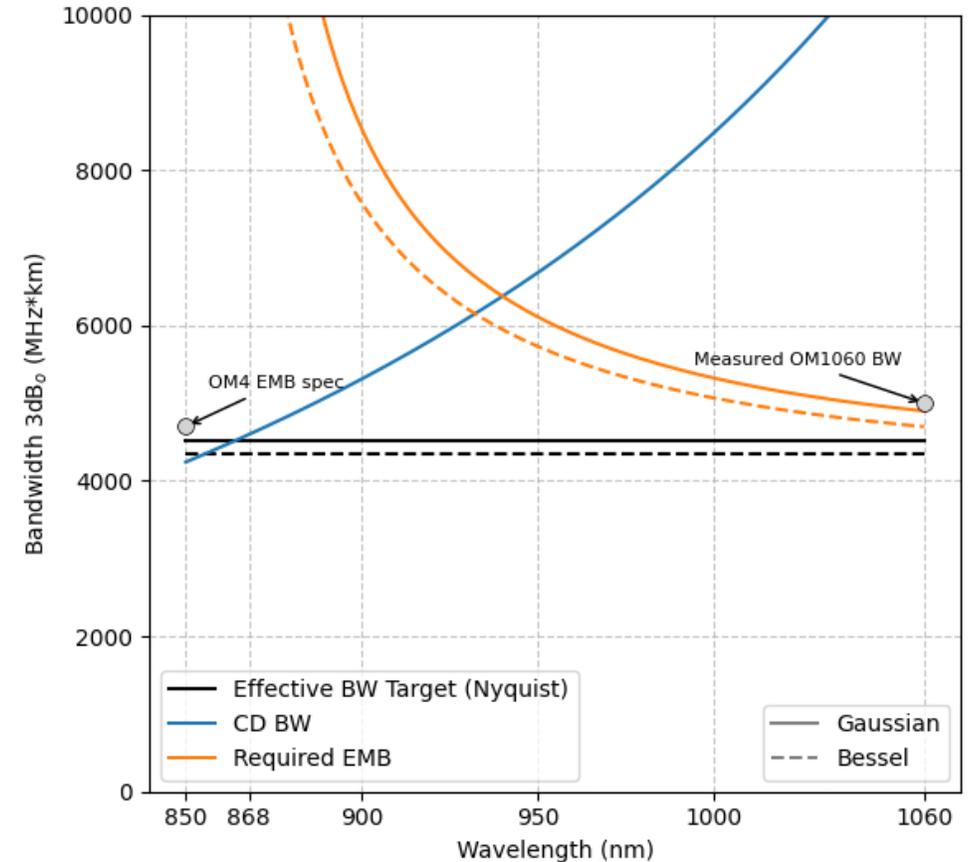
- The reduction in modal bandwidth requirements at 1060 nm creates the possibility to extend the reach beyond 50 meters.
- Additionally, smaller core fibers would feature fewer modes and mode groups, making them easier to design to achieve higher bandwidth to potentially reach 80+ meters.



Fiber EMB required at 212 Gb/s PAM4 for a total channel 3dBe bandwidth target of 53.1 GHz with a spectral width of 0.45 nm

Path to 400G PAM4

- Furthermore, 1060 nm fiber bandwidth will be sufficient to support at least a 30-meter reach at future 400G data rates



Fiber EMB required at 425 Gb/s PAM4 over 30 m MMF for a total channel 3dBe bandwidth target of 106.2 GHz with a spectral width of 0.45 nm

Conclusion

- Our analysis demonstrates that 1060 nm wavelength offers significant bandwidth improvements.
- These improvements result in relaxed fiber EMB requirements for a 50-meter reach. We propose a **target EMB** for new 1060nm optimized fiber between **3600 to 4000 MHz*km**
- The measured performance of OM1060 fiber shows a comfortable margin for meeting the fiber bandwidth requirements for 50 meter objective.
- Reaches longer than 50 meters are achievable with higher EMB target
- Future 400 Gb/s data rates will be able to support at least 30 meters of fiber at 1060 nm.
- Future work will include measuring and analyzing the performance of smaller core fibers.