Transceiver Impact on MMF Modal Bandwidth for 200G/Lane Links at 850nm and 1060nm

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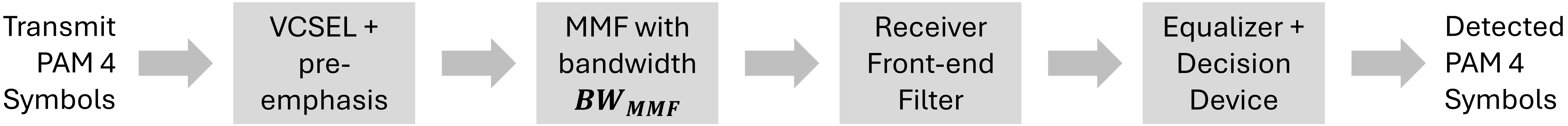
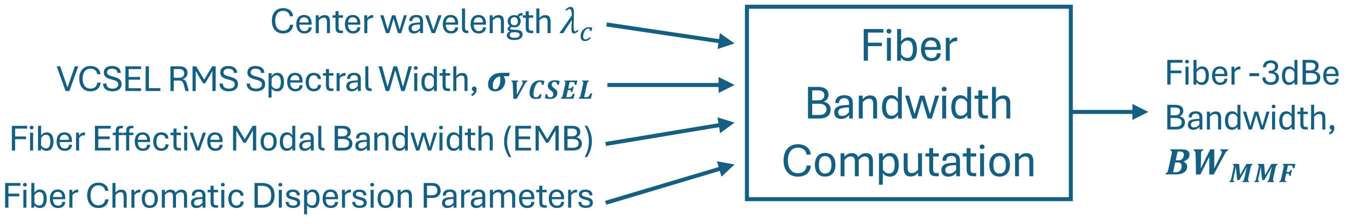
Supporters

Motivation



- Fiber Bandwidth BW_{MMF} : -3dBe bandwidth due to a combination of modal and chromatic dispersion



All bandwidths are -3dBe

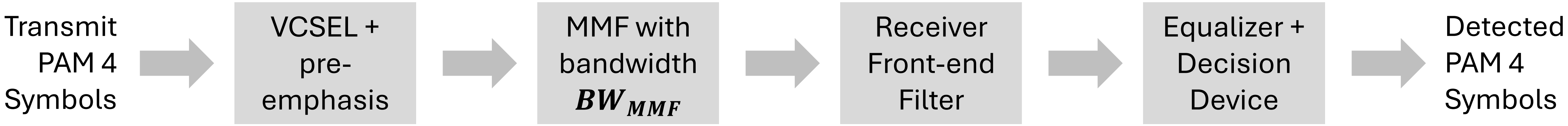
Can get Fiber EMB for any given Fiber -3dBe BW

king_3cm_adhoc_01_062818.pdf

abbott_3db_adhoc_01_080620.pdf

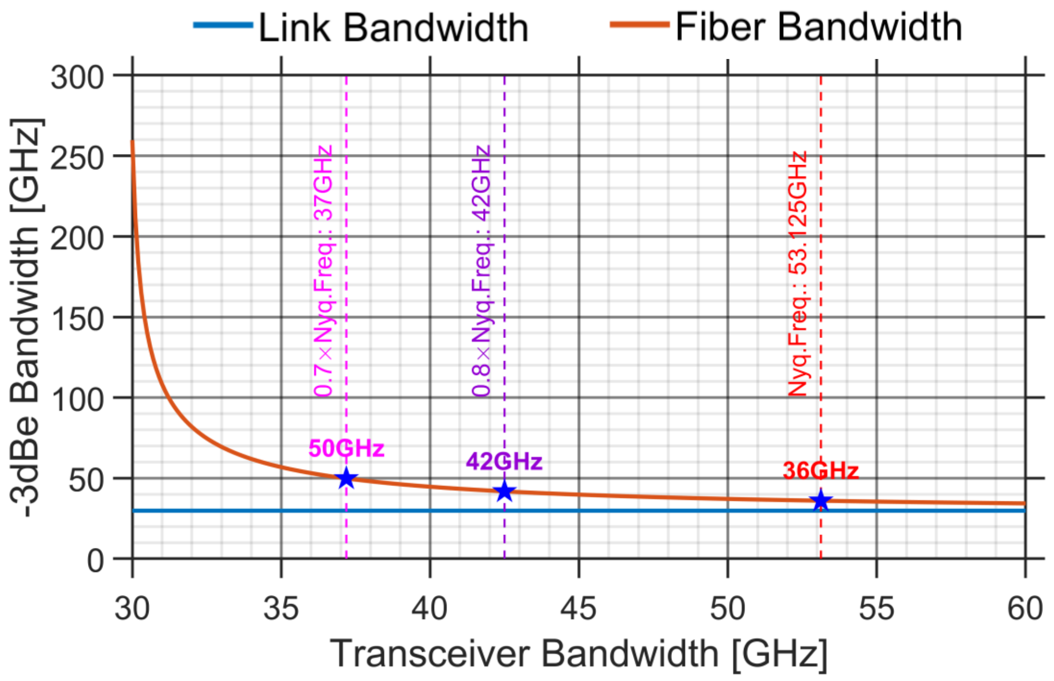
- Actual conversations:
  - If for a 50m link BW_{MMF} = 39.4GHz, can you tell me if it will close the link for 200G/lane transmission?
  - Why do we need higher BW_{MMF} = 60.7GHz for 30m but a lower BW_{MMF} = 50.2GHz for 50m?
  - murty_3ds_adhoc_01_260303.pdf
- This contribution:
  - Provides a simple framework that helps answer above questions → brings out important underlying parameters
  - Enable discussions around optimal trade-off between transceiver and fiber properties among manufacturers

A Tale of Two Bandwidths: Transceiver Bandwidth and Fiber Bandwidth



- **Transceiver Bandwidth** BW_{XCVR} = BW due to filtering components of transceiver (like VCSEL/pre-emphasis, receiver Front-end filter etc)
- **Link Bandwidth** (seen by equalizer block) = BW due to transceiver & MMF, $BW_{link} = 1/\sqrt{BW_{XCVR}^{-2} + BW_{MMF}^{-2}}$
- Reference Link: IEEE802.3db 100G/lane over 100m, relative to Nyquist Frequency (=26.5625GHz):
  - $BW_{XCVR,ref} \approx 1$, $BW_{MMF,ref} \approx 0.68$ (murty_200gmmf_adhoc_01_250904.pdf) → $BW_{link,ref} \approx 0.5623$
- Assumption: For similar TDECQ, the link bandwidth should remain the same (relative to Nyquist Frequency)
- Required MMF bandwidth from $BW_{MMF} = 1/\sqrt{BW_{link,ref}^{-2} - BW_{XCVR}^{-2}}$ → fiber EMB for any transceiver BW

Fiber -3dBe Bandwidth for 200G/lane

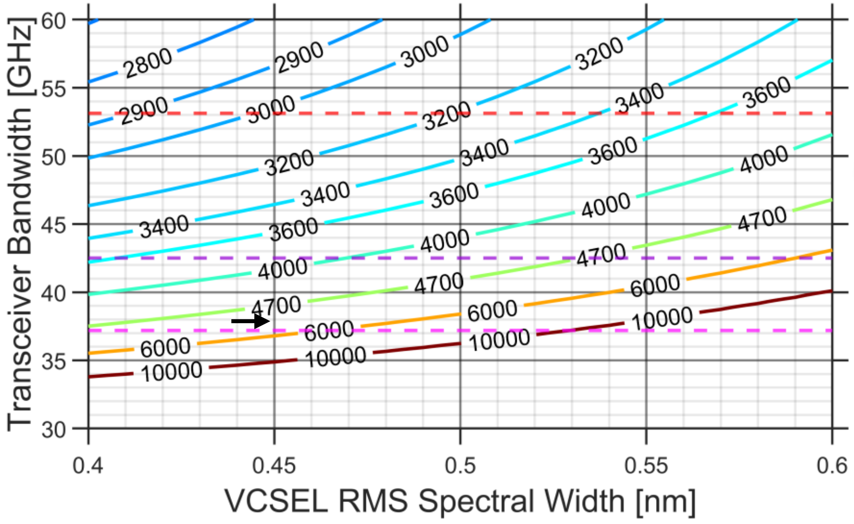


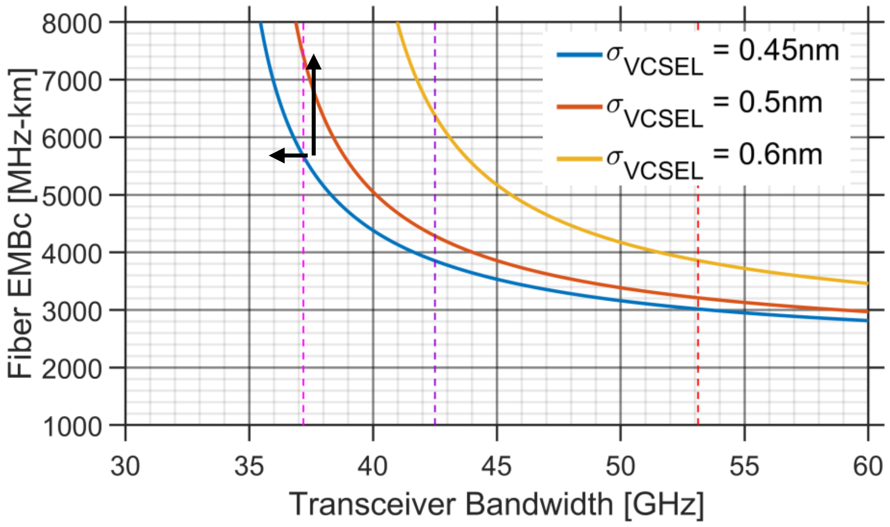
- Fiber -3dBe BW independent of wavelength: applies to both the 850nm and the 1060nm bands
- For 200G/lane, at 850nm, transceivers bandwidth up to $\approx 0.7 \times$ Nyquist Frequency ($\approx$ 37GHz) achievable
  - murty_200gmmf_adhoc_01_250904.pdf
  - Results in Fiber -3dBe BW of $\approx$ 50GHz

- Answer: Will a 50m link at 868nm with σ_{VCSEL} = 0.45nm and fiber 3dBe BW = 39.4GHz close at 200G/lane?
  - Expected BW_{XCVR}= 45.5GHz $\approx$ 0.856 × Nyq. Freq. → link won't close with typical $\approx 0.7 \times$ Nyq. Freq. BW transceiver
- Prior contributions report EMB for closing link based on fiber -3dBe bandwidth
  - murty_200gmmf_adhoc_01_250904.pdf, castro_3ds_01_2601.pdf, murty_3ds_adhoc_01_260303.pdf, lewis_3ds_adhoc_01_260303.pdf among others
- Proposal: make transceiver BW the relevant parameter rather than the fiber -3dBe BW while reporting EMB

Xcvr Impact on Fiber EMB: **850nm Band, 50m, 200G/lane**

- - Nyquist Frequency: 53.125GHz
- - 0.8×Nyquist Frequency: 42GHz
- - 0.7×Nyquist Frequency: 37GHz

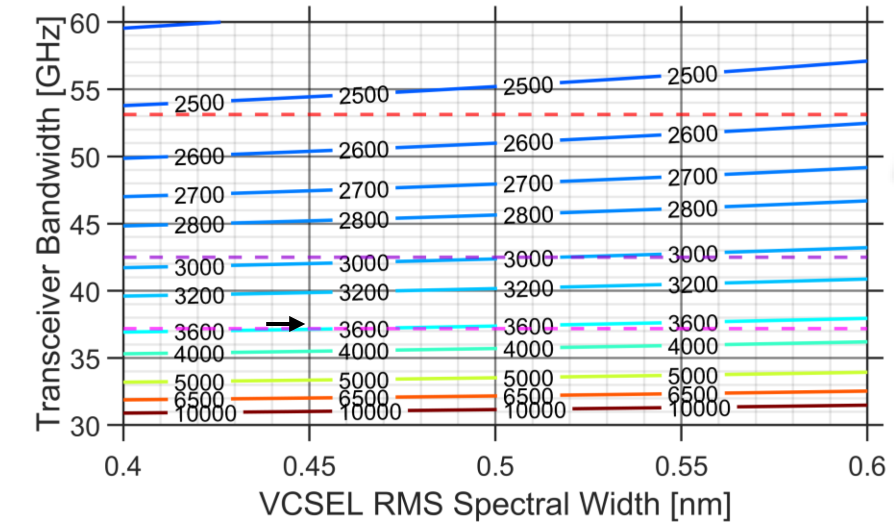


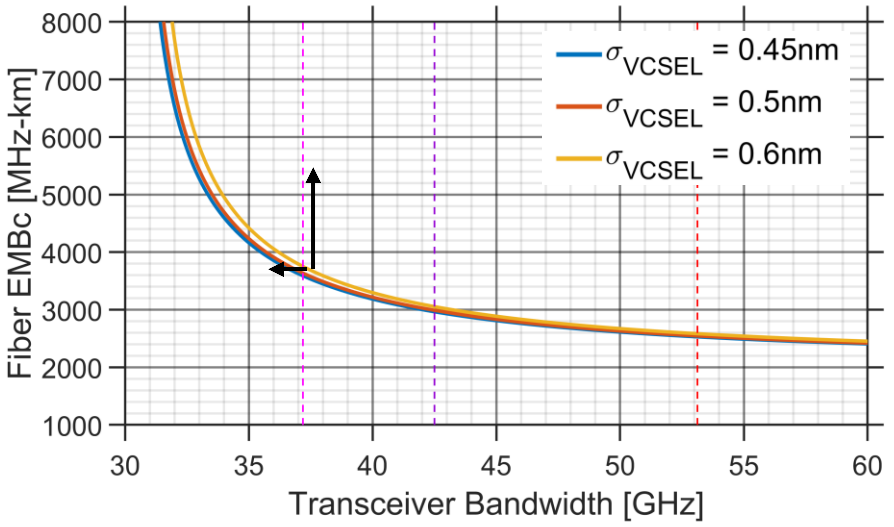


- Fiber EMB [MHz-km] contours for 50m @ 852nm
- With 37GHz transceivers, even with σ_{VCSEL} = 0.45nm, modal bandwidth needs to be at least 5200MHz-km
  - higher than peak OM4 EMB (4700MHz-km) → lower fiber yield
- 850nm band soln. sensitive to VCSEL spectral width:
  - Spectral width increase from 0.45nm → 0.5nm results in a ~2000MHz-km increase in EMB
  - Necessary to have VCSEL spectral width ≤ 0.45nm for reasonable fiber EMB
- 850nm band soln. sensitive to transceiver bandwidth:
  - Transceiver BW drop from 37GHz → 36GHz results in ~1100MHz-km increase in EMB (@ 0.45nm σ_{VCSEL})

Xcvr Impact on Fiber EMB: **1060nm Band, 50m, 200G/lane**

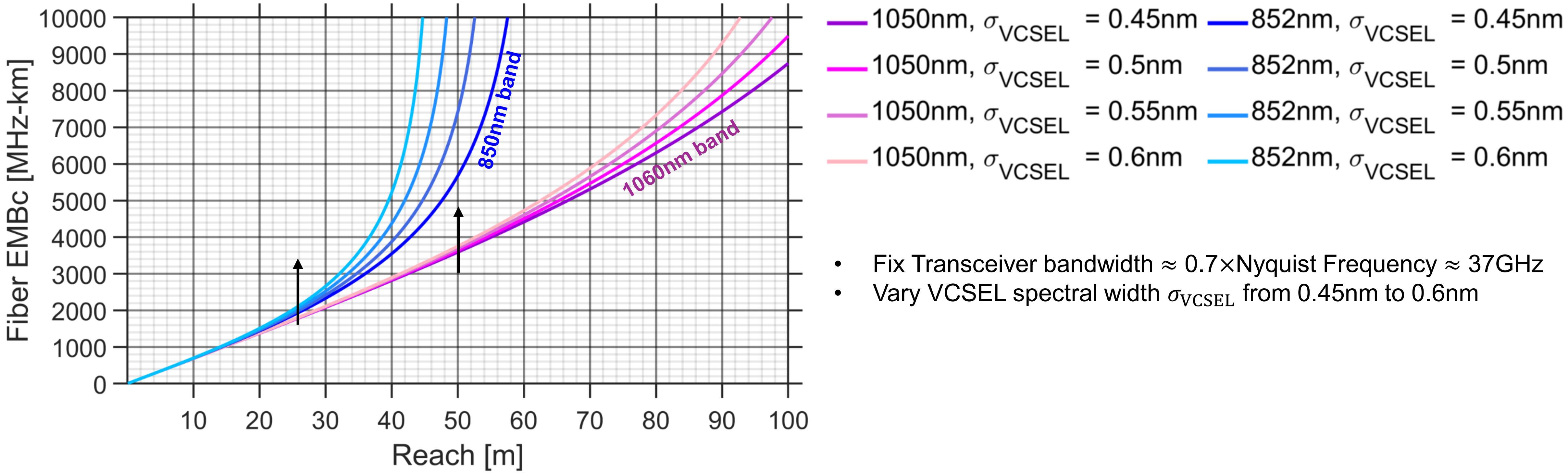
- Nyquist Frequency: 53.125GHz
- 0.8×Nyquist Frequency: 42GHz
- 0.7×Nyquist Frequency: 37GHz





- Fiber EMB [MHz-km] contours for 50m @ 1050nm
- With 37GHz transceivers, with σ_{VCSEL} = 0.45nm, modal bandwidth needs to be at least 3600MHz-km
  - lower than in the 850nm band (~5200MHz-km) → higher fiber yield
- 1060nm band soln. NOT sensitive to VCSEL spectral width:
  - Spectral width increase from 0.45nm → 0.5nm results in a ~50MHz-km increase in EMB
  - Works with VCSELS with spectral widths up to 0.6nm with almost the same EMB (already low)
- 1060nm band soln. less sensitive to even transceiver bandwidth:
  - Transceiver BW drop from 37GHz → 36GHz results in ~230MHz-km increase in EMB (@ 0.45nm σ_{VCSEL})

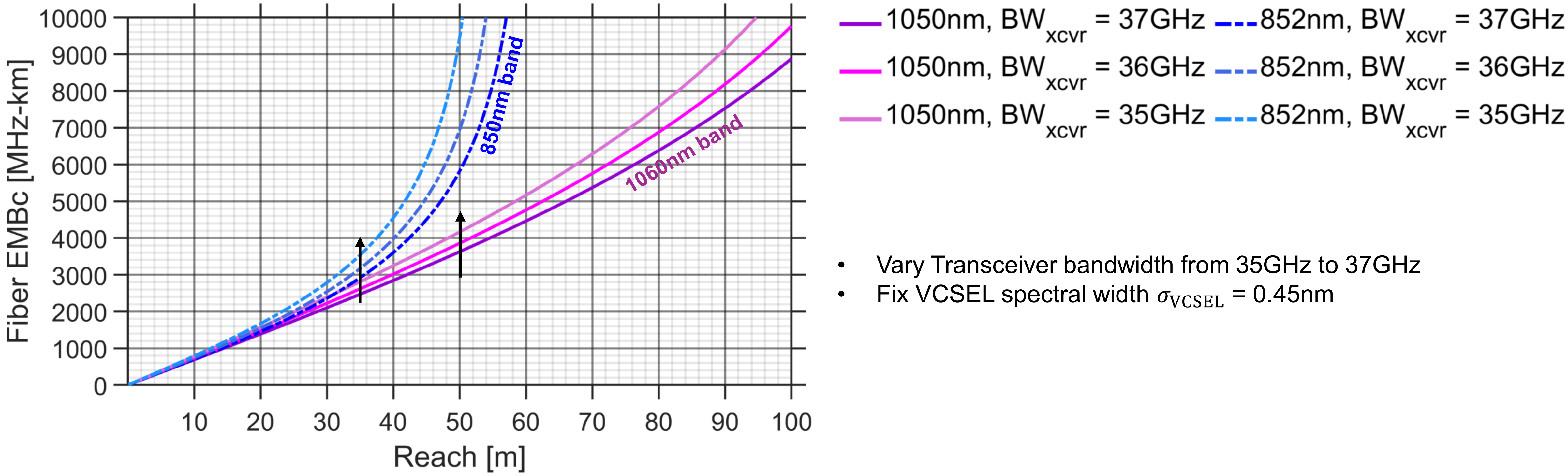
VCSEL Spectral Width Impact on Fiber EMB: 200G/lane at different reaches



- Fix Transceiver bandwidth ≈ 0.7×Nyquist Frequency ≈ 37GHz
- Vary VCSEL spectral width σ_{VCSEL} from 0.45nm to 0.6nm

- For the same reach, 1060nm band requires lower fiber EMB than 850nm band soln. → higher fiber yield
- 1060nm band soln. is relatively insensitive to VCSEL Spectral Width for longer reaches w.r.t. 850nm soln.
  - 850nm band soln.: relatively insensitive up to 25m reach
  - 1060nm band soln.: relatively insensitive up to 50m reach

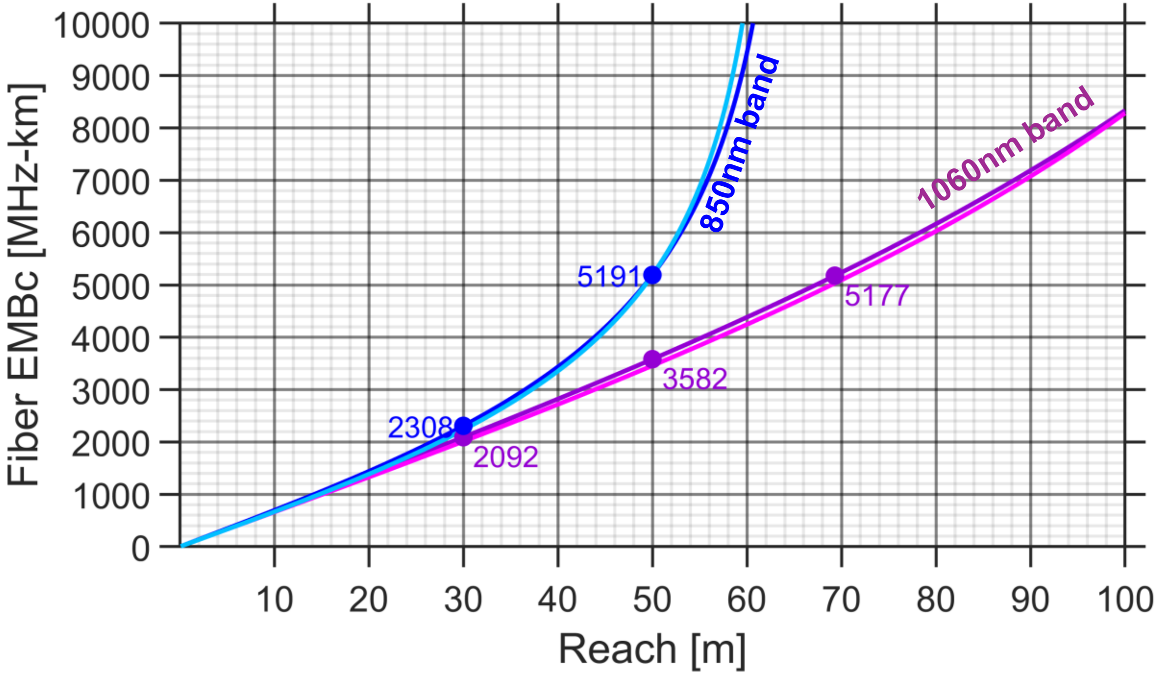
Transceiver Bandwidth Impact on Fiber EMB: 200G/lane at different reaches



- Vary Transceiver bandwidth from 35GHz to 37GHz
- Fix VCSEL spectral width σ_{VCSEL} = 0.45nm

- 1060nm band soln. is relatively insensitive to transceiver BW for longer reaches w.r.t. 850nm soln.
  - 1060nm band soln. as sensitive at 50m reach as the 850nm band soln. is at 33m reach

Transceiver Bandwidth can be adjusted to make the required EMB across uniform across the wavelength band



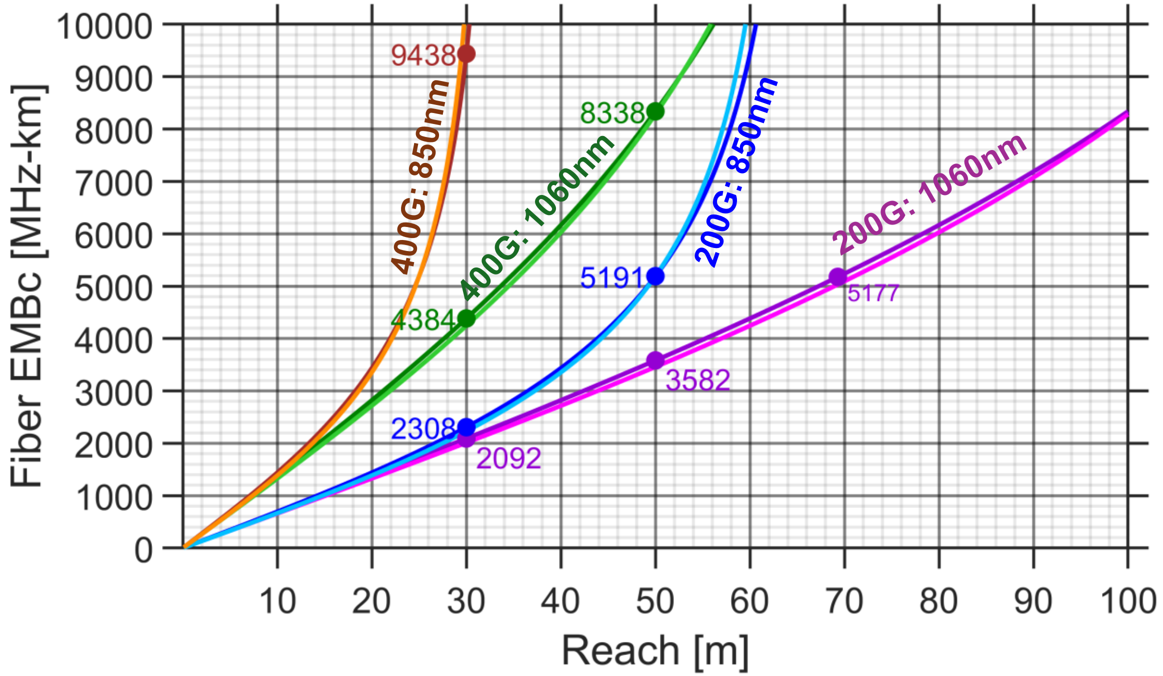
1070nm, BW_{xcvr} = 37.0GHz, BW_{MMF} = 50.2GHz
1050nm, BW_{xcvr} = 37.9GHz, BW_{MMF} = 48.2GHz
868nm, BW_{xcvr} = 37.0GHz, BW_{MMF} = 50.2GHz
852nm, BW_{xcvr} = 37.9GHz, BW_{MMF} = 48.2GHz

VCSEL spectral width σ_{VCSEL} = 0.45nm

Required Fiber EMB at 30m, 50m and ~70m are shown

- Use higher bandwidth transceiver at shorter λs, to get almost the same fiber EMB across the wavelength band
  - At longer λs (868nm or 1070nm), use 37GHz transceiver BW → fiber -3dBe BW ≈ 50.2GHz
  - At shorter λs (852nm or 1050nm), use 37.9GHz transceiver BW → fiber -3dBe BW ≈ 48.2GHz
  - Corresponding fiber -3dBe bandwidths (50.2GHz and 48.2GHz) consistent with murty_3ds_adhoc_01_260303.pdf
  - → Uniform Fiber EMB required across the wavelength band for both 850nm and 1060nm solutions
- For the same ~5200MHz-km EMB, 1060nm soln. can support ~70m reach compared to only 50m for 850nm soln.

Feasibility of 400G/lane Transmission



VCSEL spectral width σ_{VCSEL} = 0.45nm

Required Fiber EMB at 30m, 50m and ~70m are shown

- Assumes transceiver BW of up to 0.7× Nyquist Frequency are still achievable at 2x the baud rate
- Both 850nm and 1060nm band solutions support 25m reach with the same EMB as with 200G/lane, 50m
  - Different comparative fiber yields
- 1060nm band supports 30m reach with ~4400MHz-km EMB whereas 850nm cannot
  - 850nm band solution requires ~9500MHz-km EMB fiber at 30m reach
- **Will ~74-76GHz bandwidth transceivers be possible in the future?**

Conclusions

- Proposal: make transceiver BW the relevant parameter instead of fiber -3dBe BW while reporting EMB
  - Have shown why using transceiver BW while reporting fiber EMB provides better clarity than the fiber -3dBe BW
  - For 200G/lane transmission, ≈37GHz transceivers require ≈50GHz Fiber -3dBe BW
- For 200G/lane VCSEL-MMF links, 1060nm band solution seems to be a better engineered solution
  - Fiber EMB: 1060nm band soln. requires lower EMB Fibers than 850nm band soln. → higher fiber yield

Fiber EMB [MHz-km]	**850nm Band Soln. σ_{VCSEL} = 0.45nm**		**850nm Band Soln. σ_{VCSEL} = 0.5nm**		**1060nm Band Soln. σ_{VCSEL} = 0.45nm**		**1060nm Band Soln. σ_{VCSEL} = 0.5nm**	
Transceiver BW, BW_{XCVR}	**37GHz**	**35GHz**	**37GHz**	**35GHz**	**37GHz**	**35GHz**	**37GHz**	**35GHz**
30m Fiber EMB	≥ 2310	≥ 2700	≥ 2400	≥ 2820	≥ 2100	≥ 2400	≥ 2100	≥ 2400
50m Fiber EMB	≥ 5200	≥ 7300	≥ 6210	≥ 11500	≥ 3600	≥ 4100	≥ 3620	≥ 4150

  - For the same 5200MHz-km EMB in the 850nm band (50m reach), the 1060nm solution supports ~70m reach
  - Degradation in transceiver bandwidth and/or VCSEL rms spectral width:
    - Does not impact required fiber EMB in the 1060nm band much
    - Requires significantly higher EMB fiber in the 850nm band for 50m links → lower fiber yield
- For 400G/lane links, 1060nm band solution seems to support 30m reach, 850nm not feasible
  - 1060nm would require fiber EMB ~4400 MHz-km → commercially viable
  - 850nm would require fiber EMB ~9500 MHz-km → commercially challenging
  - Provided ~74-76GHz bandwidth can be realized!