Design considerations towards smaller-core 1060 nm MMF

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IEEE P802.3ds 200 Gb/s per Wavelength MMF PHYs Task Force

November 10, 2026

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Background and motivation

- **Support convergence on smaller-core 1060 nm MMF**
  - Contributions presented to the Task Force support a 25–29 µm design space, consistent with proposed nominal core diameter of 27 ± 2 µm as presented in ransford_3ds_01a_2609 [ieee802.org].
- **Extend the analysis beyond core diameter**
  - Calculate the impact of other fiber design parameters on the modal bandwidth
  - Evaluate fiber design compatibility through bend loss and coupling efficiency
- **Evaluate lower-NA designs**
  - Preliminary simulations indicate that reducing core NA can improve EMB
  - Coupling calculations assess compatibility with representative VCSEL beams and launch conditions
- **Improve tolerance to profile variation**
  - The modeled lower-NA design provides a wider alpha-parameter window while maintaining the selected EMB threshold

Design objective and criteria

Objectives:

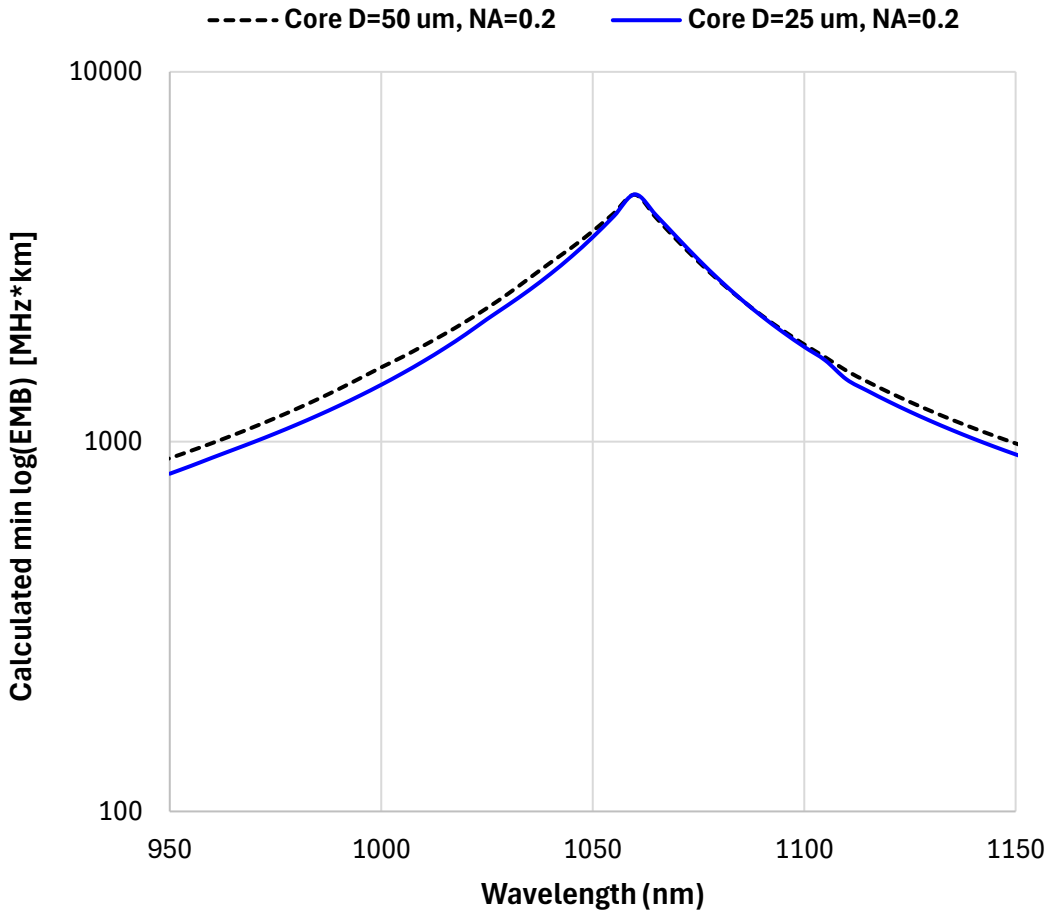
- Audit MMF design parameters to target a compatible integration with 1060 nm VCSEL while reducing the core diameter of the MMF.
- Provide a design that can be manufactured, measured, and ultimately validated

- Fiber design parameters:
  - Core diameter, core NA, alpha parameter

- Deployment conditions:
  - Fiber bending
  - VCSEL coupling conditions
  - Support practical VCSEL launch and coupling

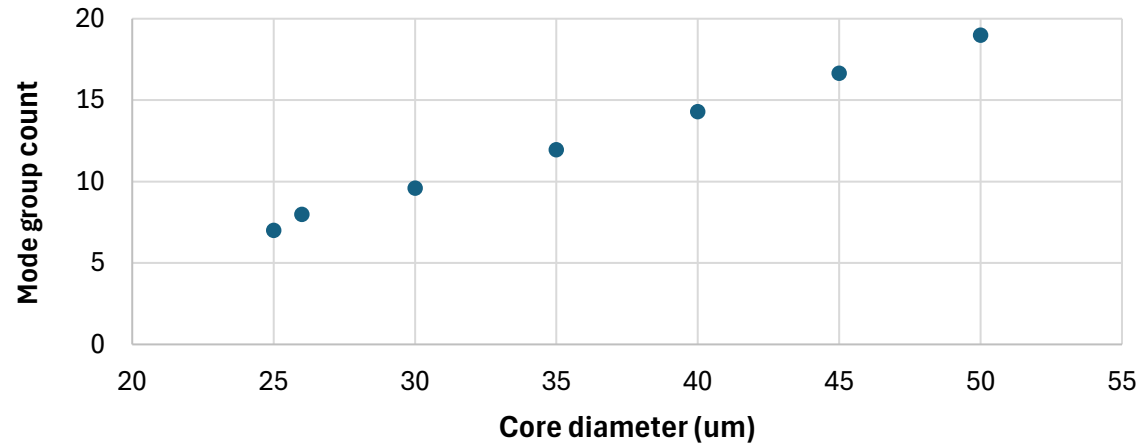
Baseline: 50 and 25 µm core MMF are capable of delivering similar modal bandwidth at 1060 nm

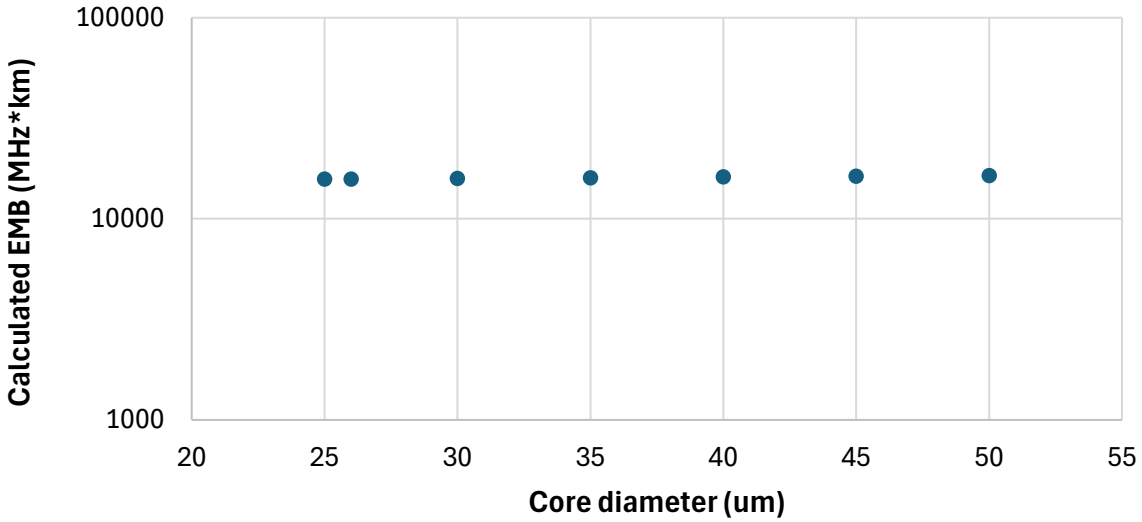
- A baseline MMF profile is used throughout this study to benchmark the simulation.
- Scaling the MMF core diameter from 50 to 25 µm reduces the transverse mode content (LP modes from ~ 220 to 56).
- The calculated min EMB as a function of wavelength indicates that both core diameters are capable of the same performances at 1060 nm



The number of modes decreases for a 25 µm core diameter while EMB remains high

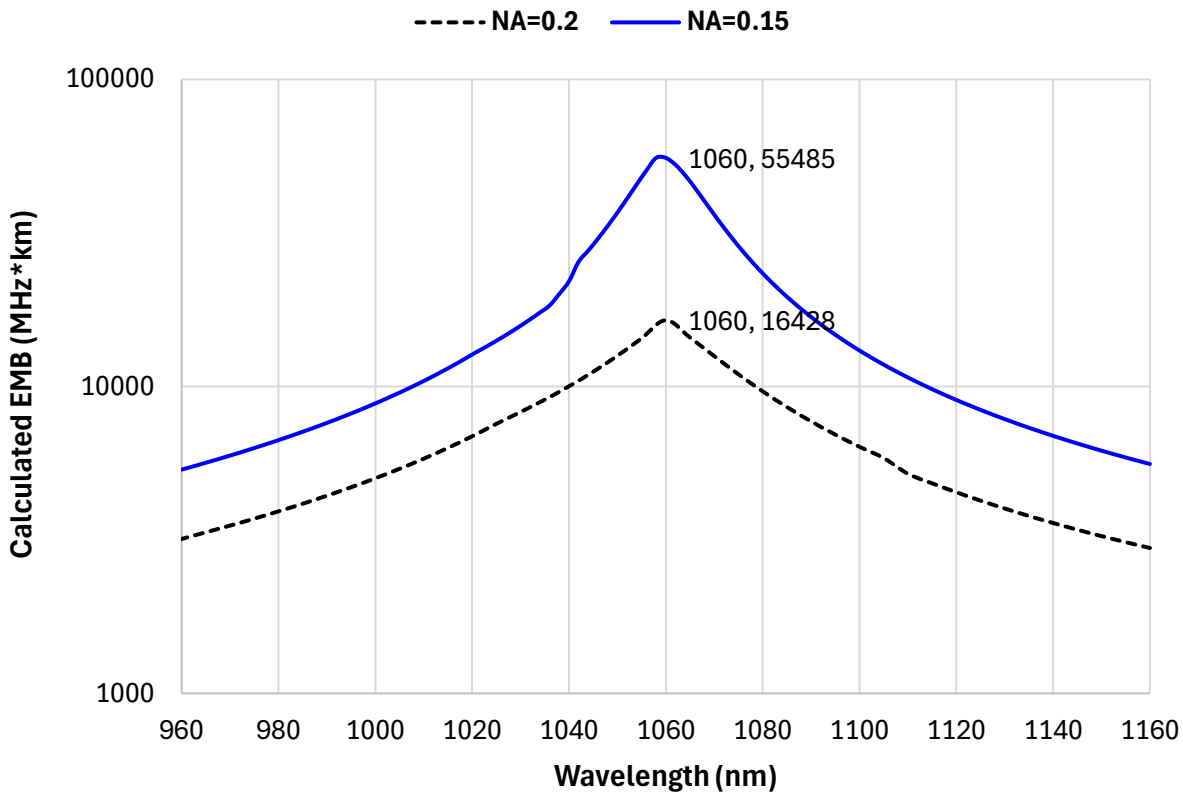
- At 1060nm, 25 µm core MMF (0.2 NA) supports 7 mode groups, while 50 µm core MMF (0.2 NA) supports 19 mode groups.
- At 1060nm, the calculated EMB for both core diameters show no significant difference, indicating both fibers are capable of similar bandwidth performances
- MMF with core diameter comprised within 27 µm +/- 2 are capable of similar bandwidth performances as the 50 µm reference





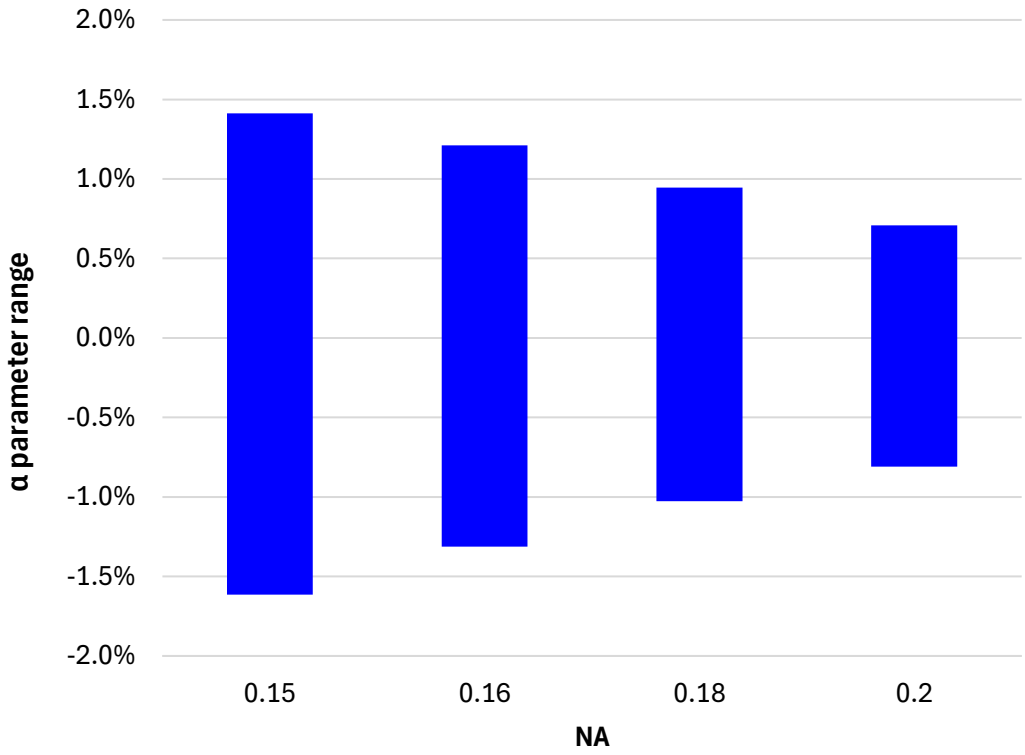
Impact of the core NA on 25 µm core MMF performances

- To study the impact of the fiber design on the performances, a set of simulations is carried for a lower NA.
- At 1060nm, reducing the core NA from 0.2 to 0.15 decreased the number of modes from 56 (7 group modes) to 30 (5 group modes).
- At 1060 nm, simulation results show that EMB increases 3.3 times for 0.15 NA compared to 0.2 NA



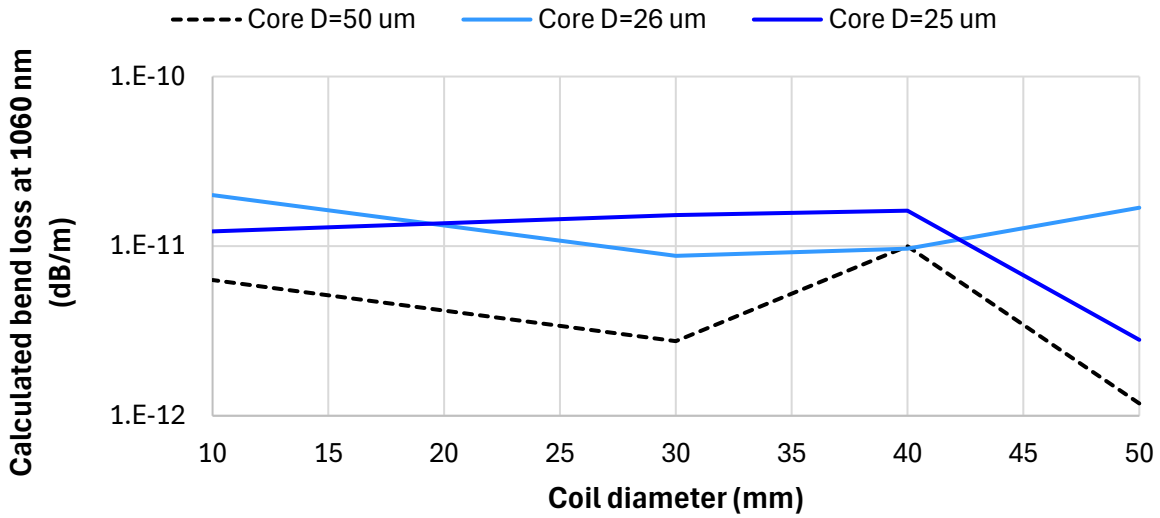
Reducing the core NA to 0.15 increases the MMF manufacturability by 2x

- At 1060nm, the tolerance of the fiber to maintain its EMB performances is studied.
- The core diameter is fixed at 25 µm and the NA is varied from 0.2 down to 0.15.
- The range of index profile alpha parameter capable of achieving EMB ≥ 4,700 MHz*km is calculated for each NA depicted on the graph.
- At 1060, the lower the core NA, the wider is the alpha-parameter range required to ensure a min EMB value.
- Simulation results suggest that a 2x wider manufacturing window is achievable by reducing the core NA closer to 0.15

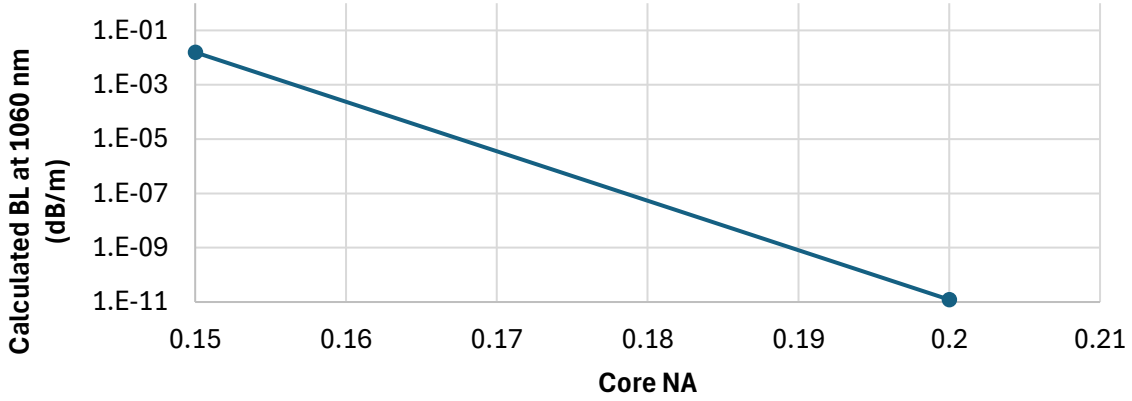


Study the impact of 25 µm core MMF with 0.15 NA on bending loss during deployment

- At 1060nm, for a fixed 0.2 core NA, the calculated bend loss as a function of core diameter, as small at 25 µm remains very small 9within the accuracy range of the simulation.



- At 1060nm, the 25 µm core diameter MMF deployed at 10 mm coil diameter is expected to experience significantly higher bend loss.
- Additional simulations with optimization of the trench is needed to identify if a suitable MMF design is feasible



Study the VCSEl coupling condition into the MMF and its impact on coupling loss

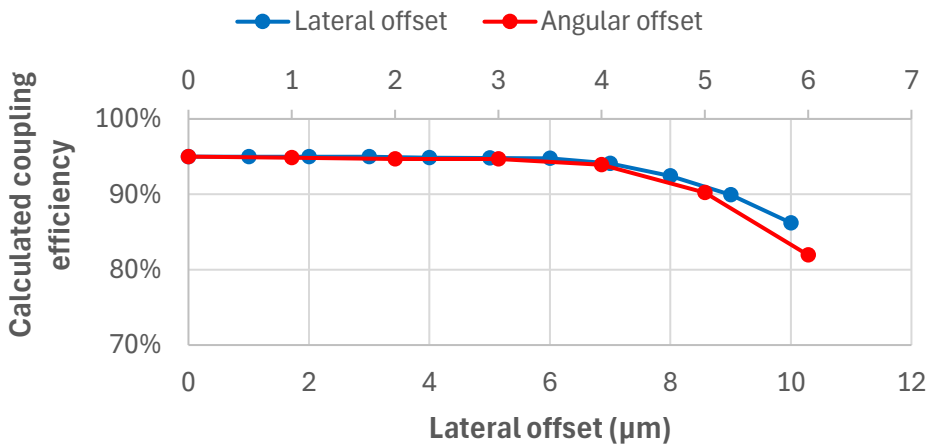
- For a 25 µm core diameter, the calculated Mode Field Diameter (MFD) values at 1060 nm were calculated.

Core NA	MFD (µm)
0.2	9.2
0.15	10.6

- Measured VCSEL beams were used to calculate the coupling efficiency into a 25 µm core MMF, 0.2 core NA
- More than 95% coupling efficiency is achievable with a 25 µm core diameter MMF

VCSEL launch	Coupling efficiency
With collimation	~95%
Without collimation	~70%

- Coupling efficiency is not affected by lateral offset of the launch light into the MMF, if the offset is less than 6 µm



Conclusion

Key observations

- Simulation results supports smaller-core 1060 nm MMF: a 25 µm core can preserve modal bandwidth comparable to a 50 µm reference.
- Coupling calculations indicate that efficient VCSEL launch into a 25 µm core is feasible with appropriate collimation.
- Core diameter alone does not determine performance. Lower-NA designs demonstrate higher calculated EMB and a wider allowable index-profile alpha window.
- Lower NA introduces a bandwidth–bend-loss tradeoff that requires further trench optimization and validation.

Recommendations

- Support the proposed nominal core diameter of **27 ± 2 µm** as the basis for convergence at this stage of the draft.
- Preserve flexibility in NA and refractive-index-profile design rather than prematurely exclude technically viable solutions.
- Refine NA, launch and bend-performance requirements as additional VCSEL, fiber and system-level data become available.