Design and optimization of an Er-doped Al_2O_3 adiabatic waveguide taper for double layer integration with Si_3N_4 platform

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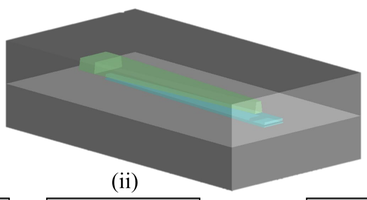
Abstract

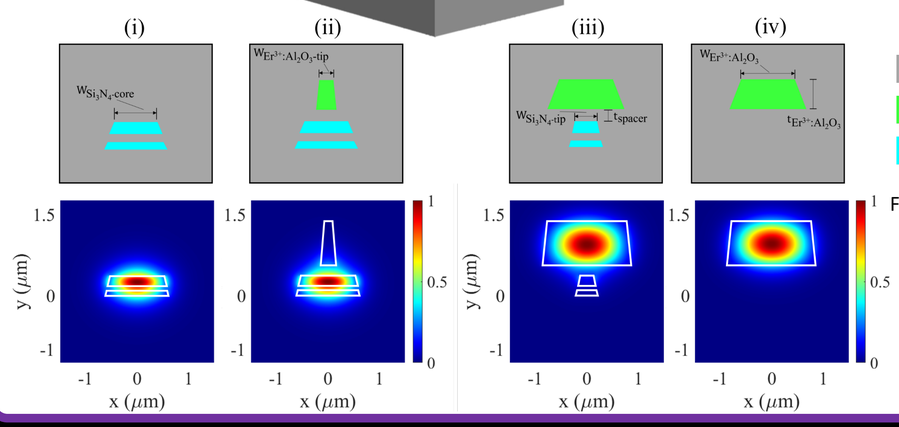
The integration of active-passive material platforms is needed to increase the number of optical components on-chip, i.e. achieve more functionalities on PICs. Adiabatic waveguide tapers are of great interest for applications that require short and low-loss transitions between different material platforms. In this work, an Er-doped Al_2O_3 adiabatic waveguide taper is designed for the integration with the standard asymmetric double stripe (ADS) Si_3N_4 TriPleX technology. The tolerance of the taper design to fabrication variations is studied in the wavelength range of 980 nm – 1630 nm. The simulated total loss of the final taper design is ≤ 0.1 dB per coupler.

Adiabatic coupler design

- Er-doped Al_2O_3 separated from Si_3N_4 by SiO_2 spacer (100-300 nm).
- Both waveguides are tapered laterally.
  - Taper angles of 0.039° (Si_3N_4) and 0.057° (Er^{3+}:Al_2O_3)
- Taper tips are limited by fabrication resolution.
  - Si_3N_4 → Stepper lithography (≈ 300 nm)
  - Er^{3+}:Al_2O_3 → Electron beam lithography (≈ 150 nm)



Material	λ = 980 nm	λ = 1480 - 1630 nm
Er^{3+}:Al_2O_3	1.726	1.720 ± 0.001
Si_3N_4	1.993	1.983 ± 0.001
SiO_2	1.455	1.452 ± 0.001

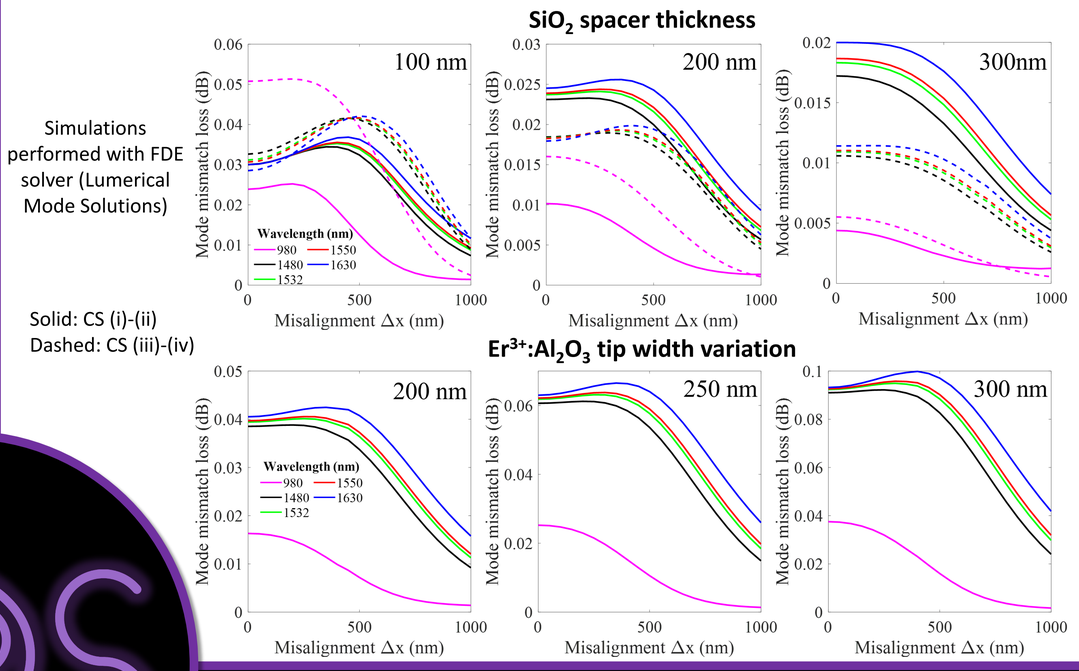


Mode mismatch loss

- Change in effective refractive index in CS(i)-(ii) and CS(iii)-(iv), result in a mode mismatch loss.
- Mode mismatch loss as a function of misalignment, variations in SiO_2 spacer thickness and Er^3+:Al_2O_3 taper width.

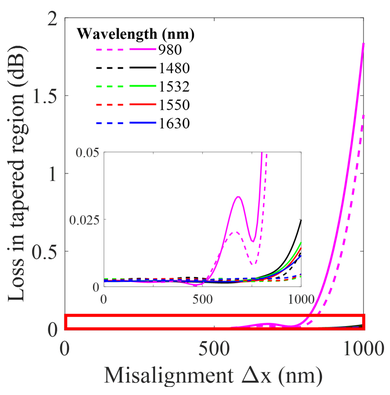
Simulations performed with FDE solver (Lumerical Mode Solutions)

Solid: CS (i)-(ii)
Dashed: CS (iii)-(iv)

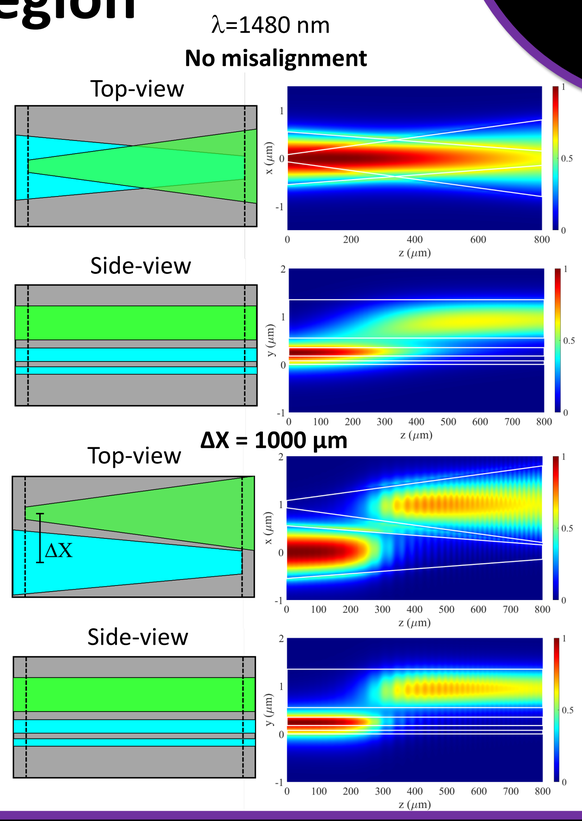


Loss in tapered region

- Power transition loss from CS (ii) to CS (iii).
- Tolerance to lateral misalignment increases for longer wavelengths.



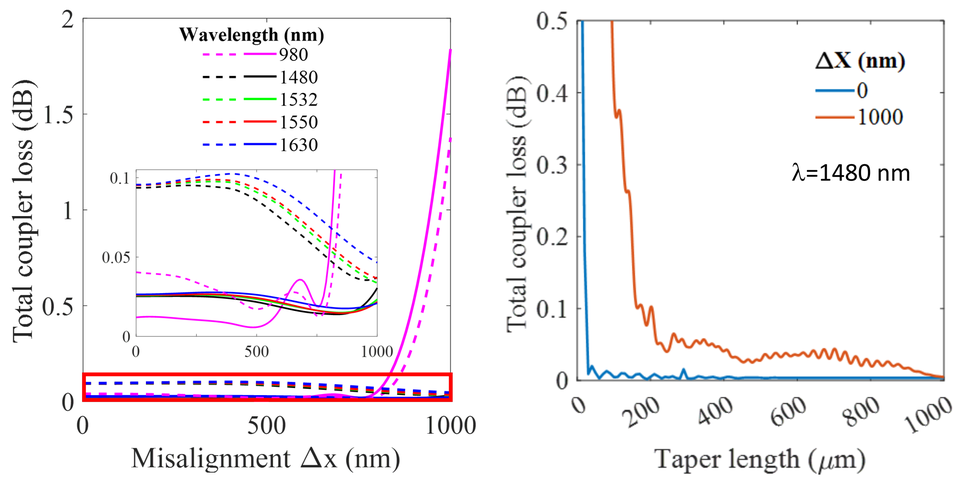
Solid: 150 nm Er^{3+}:Al_2O_3 taper tip width
Dashed: 300 nm Er^{3+}:Al_2O_3 taper tip width



Simulations performed with EME solver (Lumerical Mode Solutions)

Total coupler loss

- Sum of losses due to mode mismatch at the taper tips and coupling loss in tapered region.
- For misalignments < 0.8 μm the total coupler loss is < 0.1 dB for tolerant range of Er^{3+}:Al_2O_3 taper width.
- Taper length can be reduced while still having a total loss < 0.1 dB



Solid: 150 nm Er^{3+}:Al_2O_3 taper tip width
Dashed: 300 nm Er^{3+}:Al_2O_3 taper tip width

150 nm Er^{3+}:Al_2O_3 taper tip width
200 nm SiO2 spacer

Conclusion

- Adiabatic coupler design for double layer integration of Er^{3+}:Al_2O_3 in the commercial Si_3N_4 TriPleX platform.
- Low-loss (≤ 0.1 dB) over a broad wavelength range (980 nm – 1630 nm).
- High fabrication tolerance to EBL misalignment, Er^{3+}:Al_2O_3 taper tip width variations, and thickness variations in the SiO_2 spacer.
- Possible to reduce the taper length to achieve compact devices.
- Explore different taper geometries.

References

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