EUROPEAN CONFERENCE ON INTEGRATED OPTICS

ophellia

Optical gain via multilayer monolithic integration of Si_3N_4 with $Al_2O_3:Er^{3+}$ waveguide amplifiers

ECIO Integrated photonic technologies and platforms – 20th April 2023

C. E. Osornio-Martinez, D. B. Bonneville, M. Dijkstra and S. M. García-Blanco

UNIVERSITY OF TWENTE.

MESA+ INSTITUTE FOR NANOTECHNOLOGY

INTEGRATED OPTICAL SYSTEMS

https://lidar-ophellia.eu

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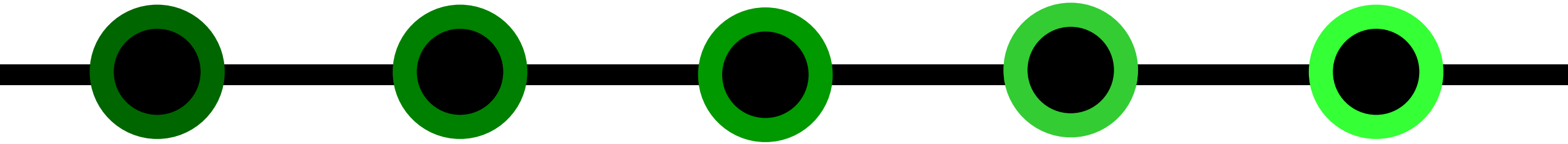
Content



Introduction

Al_2O_3 as photonic platform

Monolithic integration with Si_3N_4

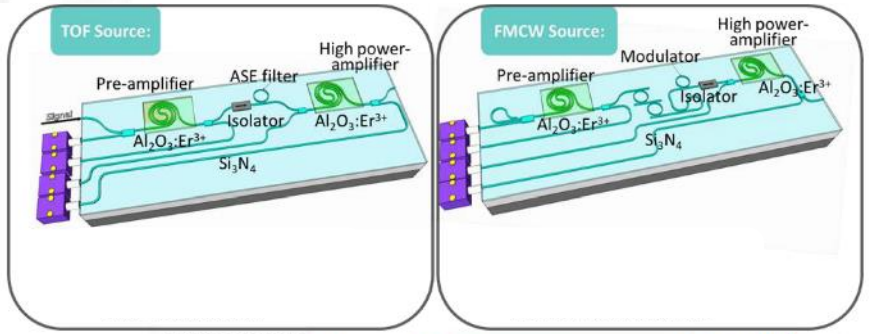
EDWA measurements

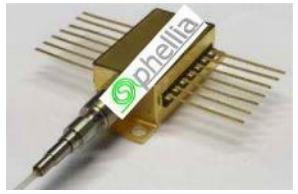
Summary

MOTIVATION

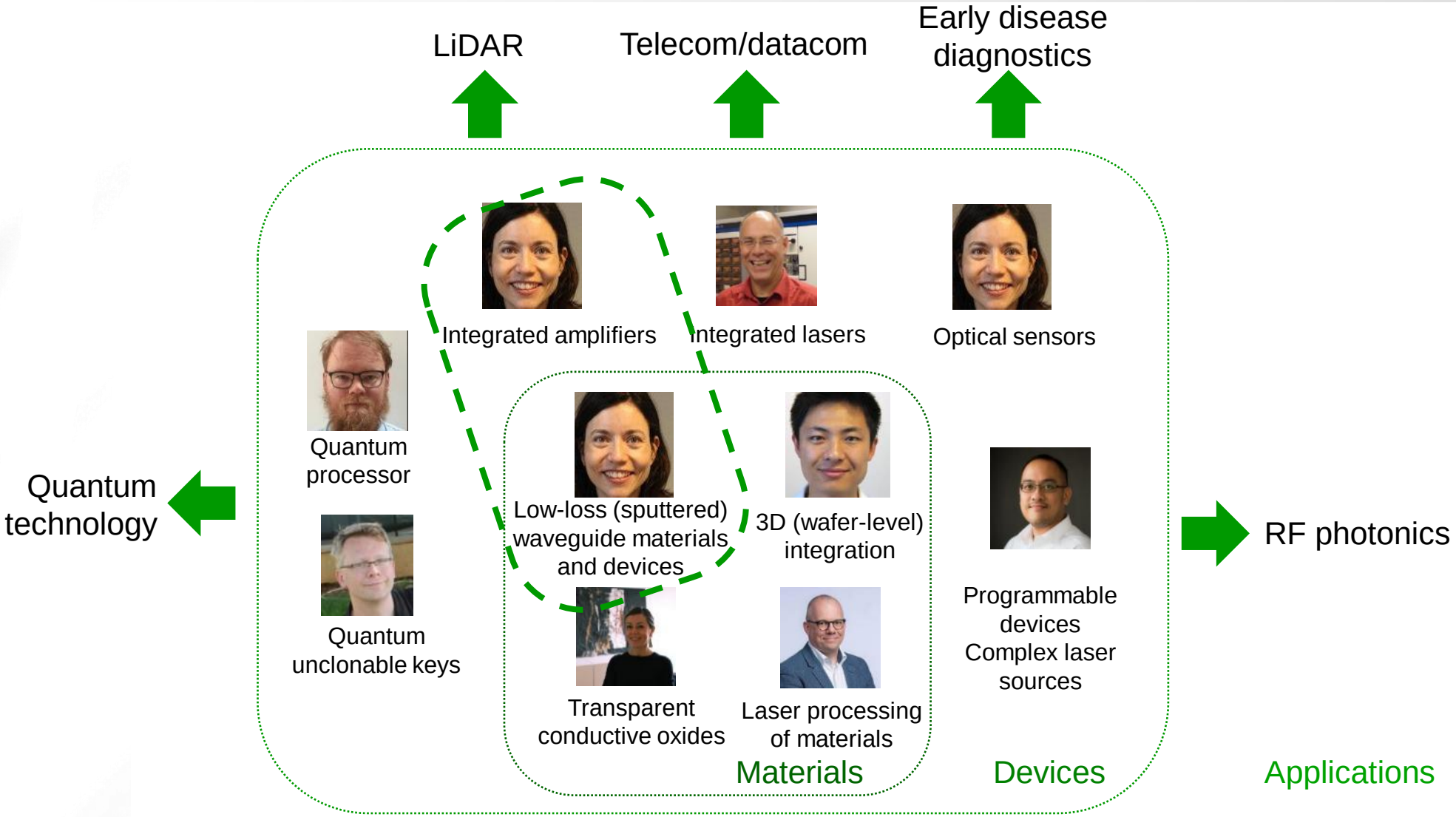
- Develop novel materials and integration technologies for laser sources for LiDAR applications.
- **Low cost, low size** and **lightweight** → high **chip integration** and **tolerant packaging** technology.

Photonic Integrated Circuits (PICs) are **essential** to achieve this goal





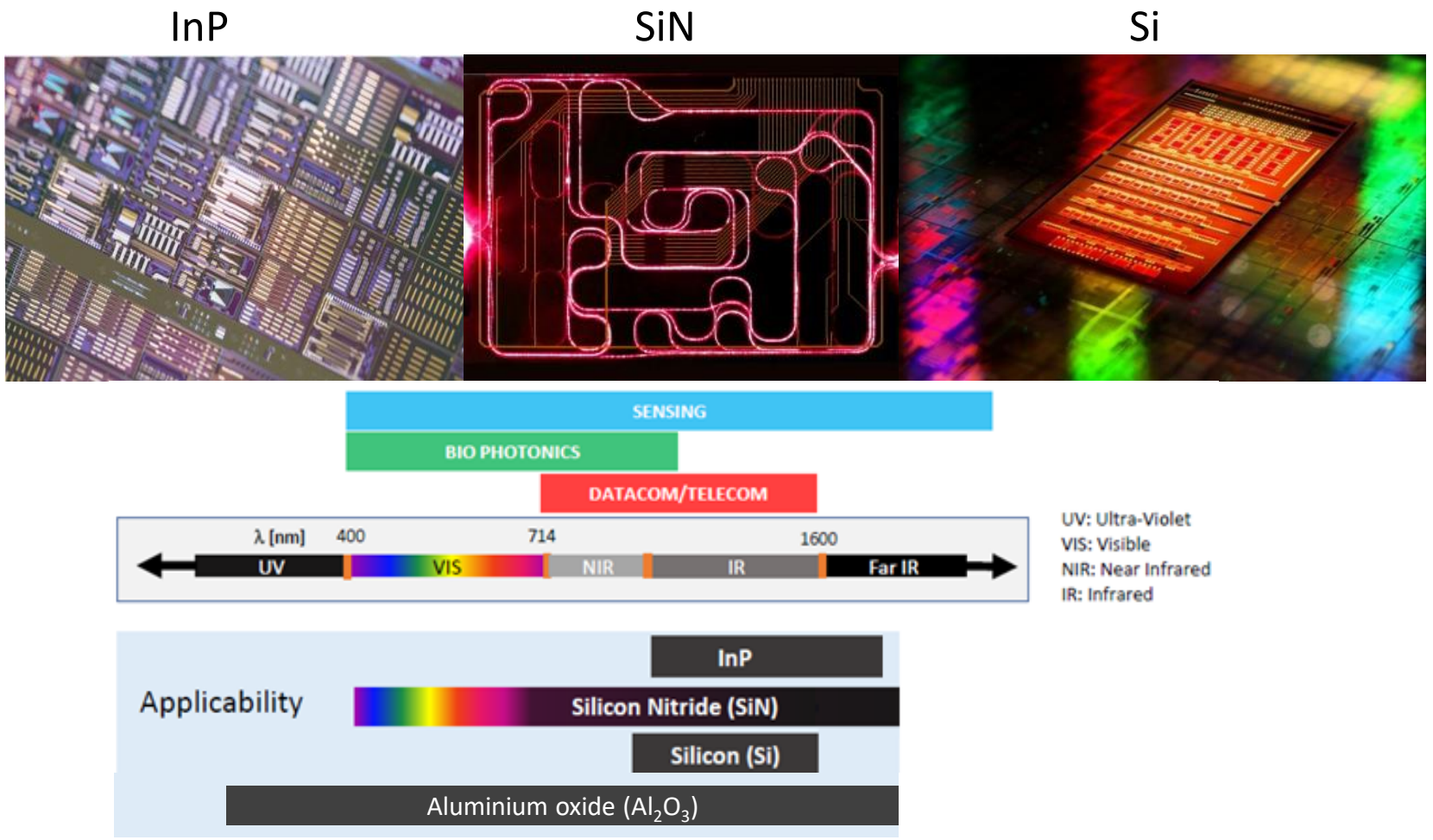
INTEGRATED PHOTONICS IN TWENTE



MESA+ INSTITUTE - NANOLAB

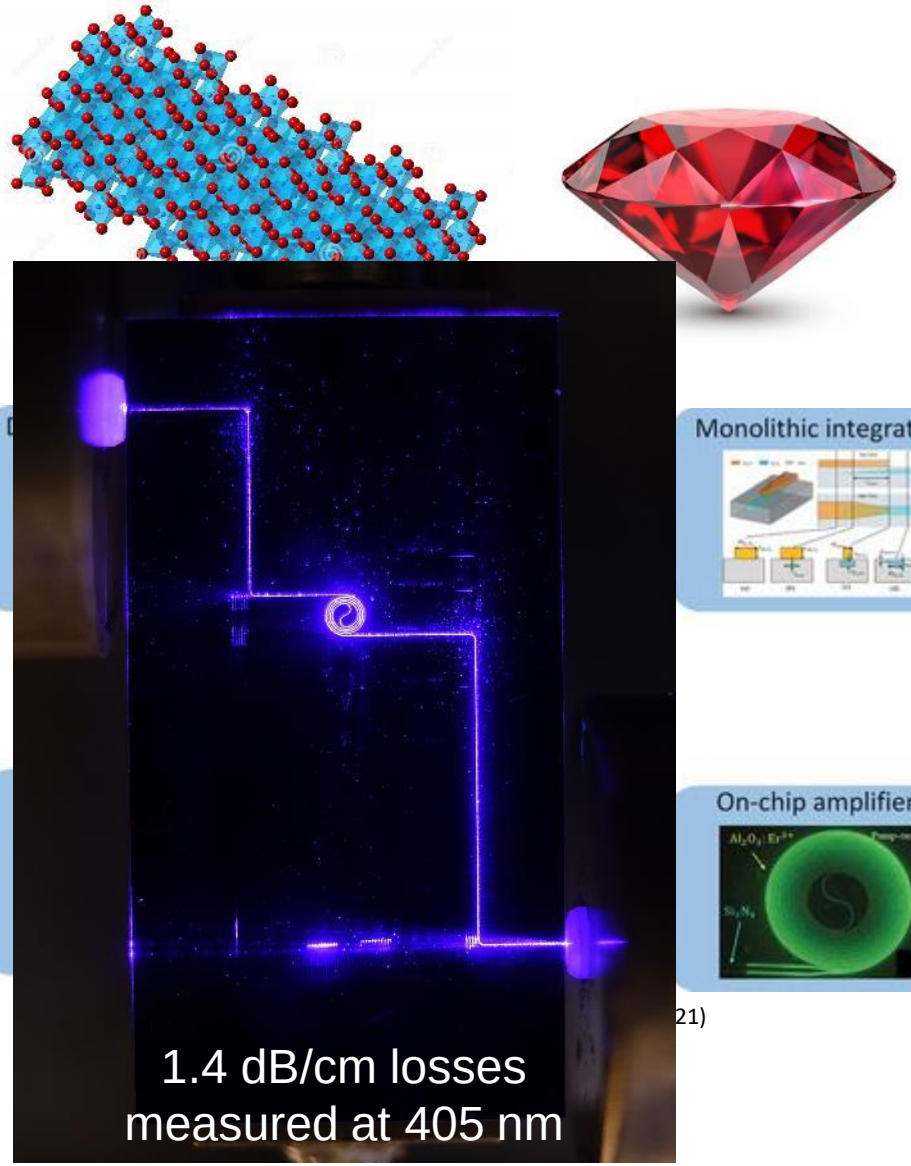
- 1250 m^2 cleanroom
- 1000 m^2 for specialized equipment
- Deposition (PVD + CVD), lithography, E-beam, etching, dicing, SEM, TEM, XRD, annealing etc.

INTEGRATED PHOTONIC PLATFORMS



Al_2O_3 AS A PHOTONIC PLATFORM

- Naturally occurring in crystalline state as corundum, forming popular gems such as ruby and sapphire
- Large transparency window: UV-mid-IR
- Low propagation losses: 5 dB/m
- Moderate refractive index: ~1.72 @1550 nm
- Wafer level deposition
- High rare-earth ion solubility
- In the Nanolab→ RF reactive sputtering



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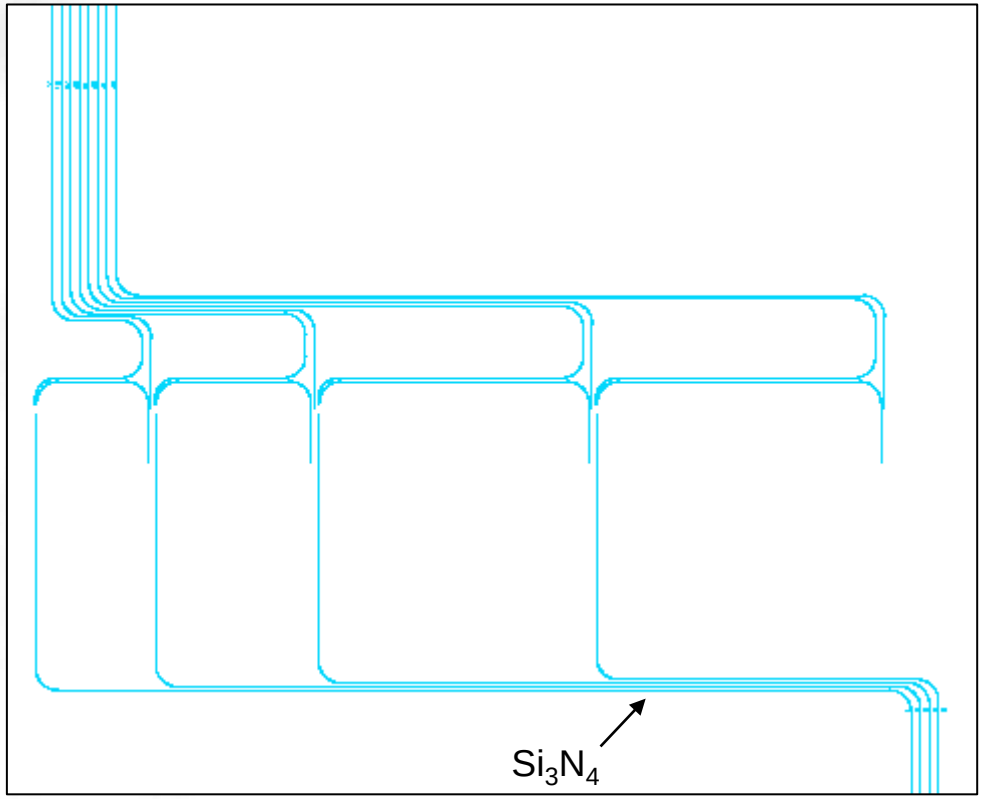
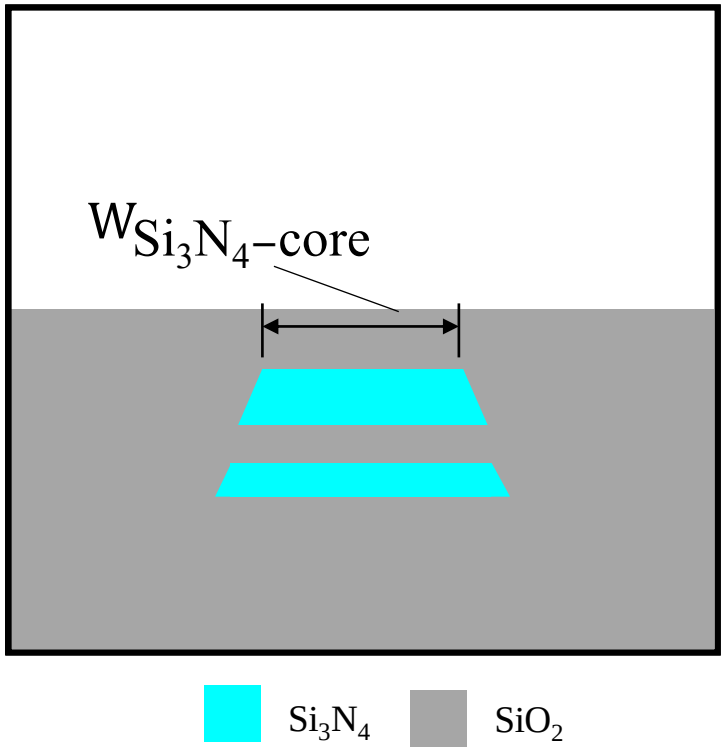
Al_2O_3-Si_3N_4 AMPLIFIERS – MONOLITHIC INTEGRATION

- Chip layout and building blocks
  - Si_3N_4 TriPleX input/output couplers
  - 50/50 splitter
  - Reference branch



Cross-section



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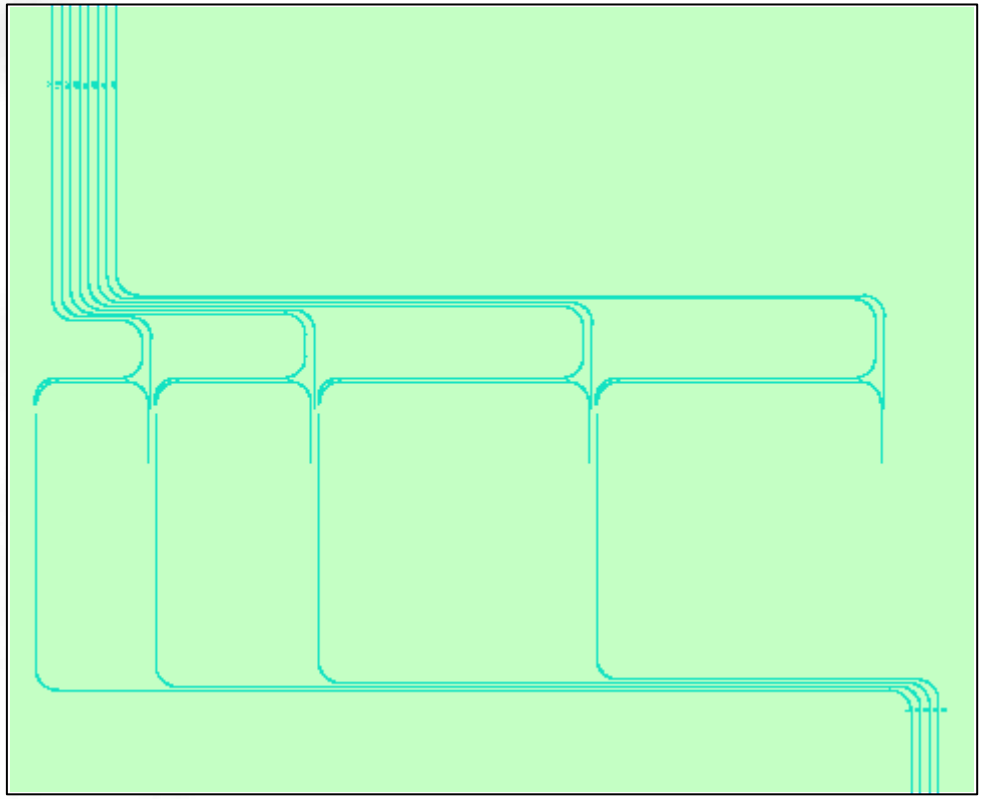

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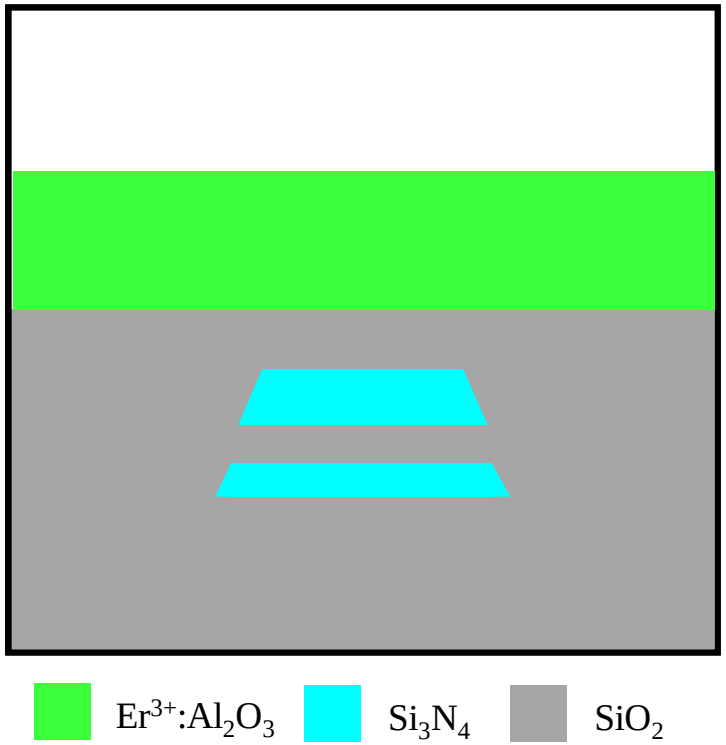

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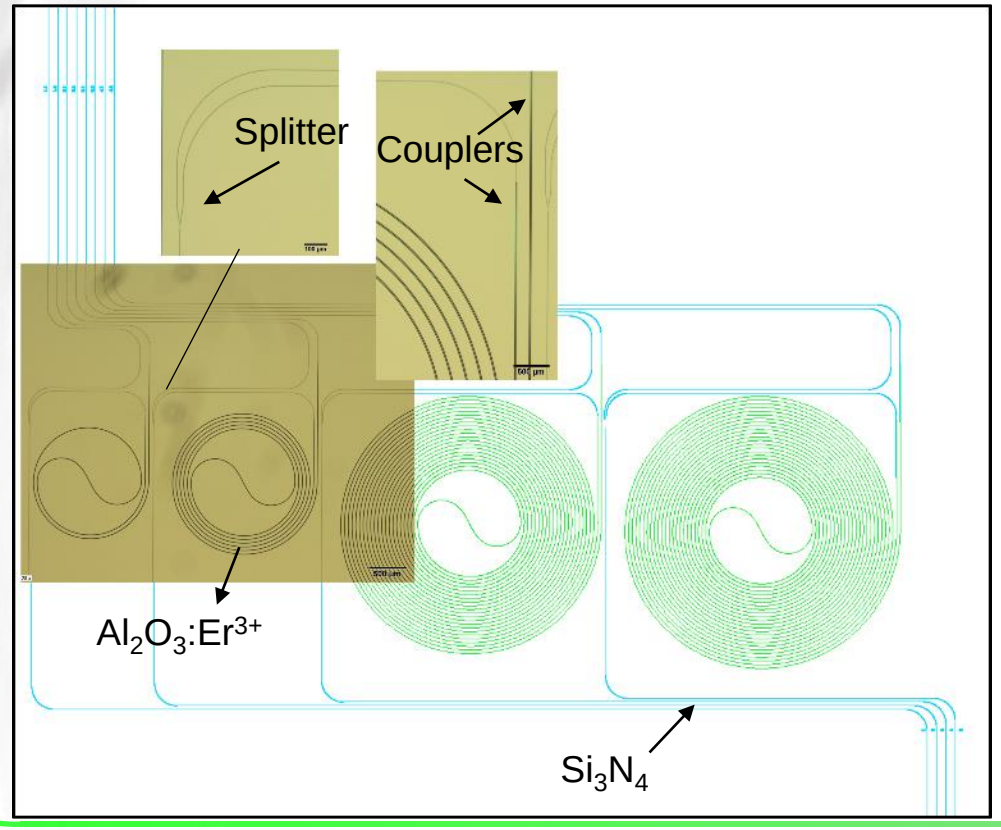
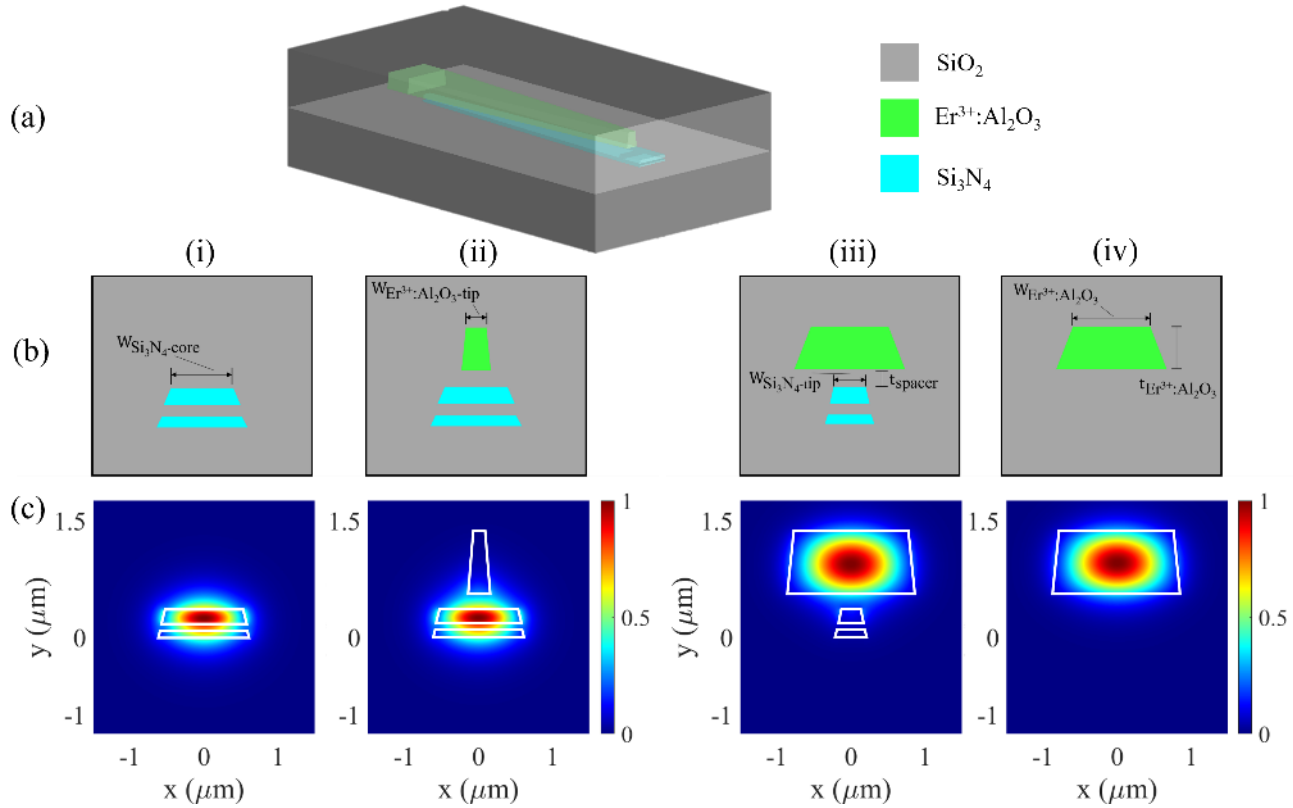
  - Si_3N_4 – Al_2O_3 coupler + amplifier



Vertical adiabatic taper – Passive / Active coupling



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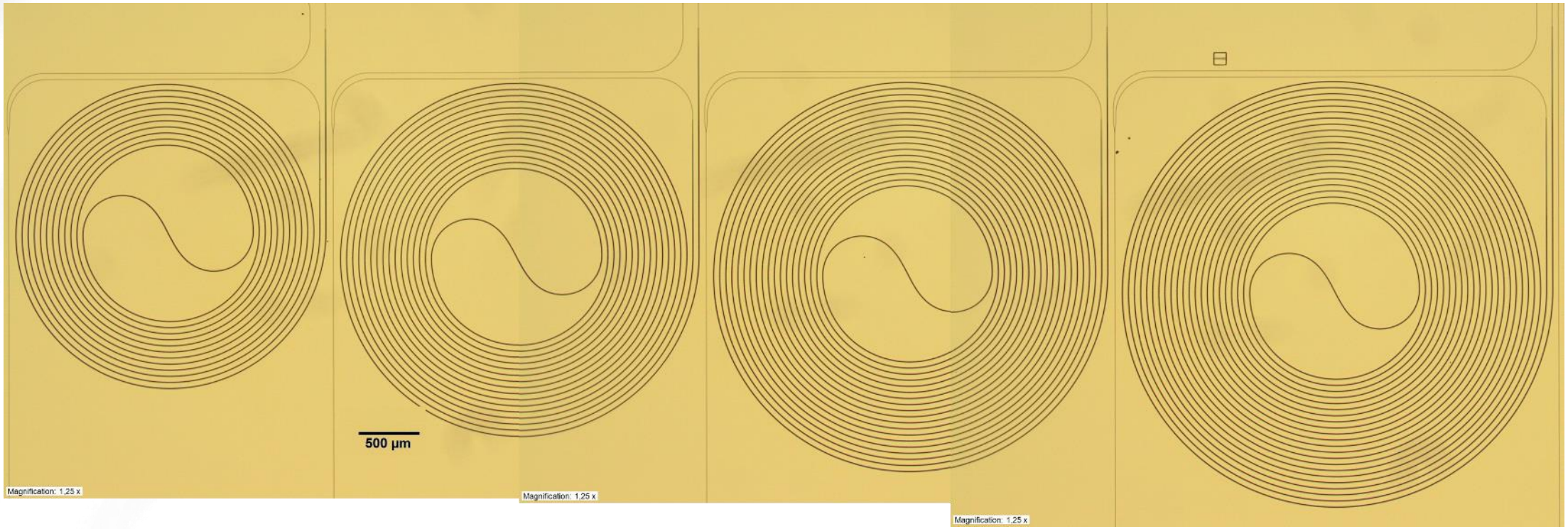
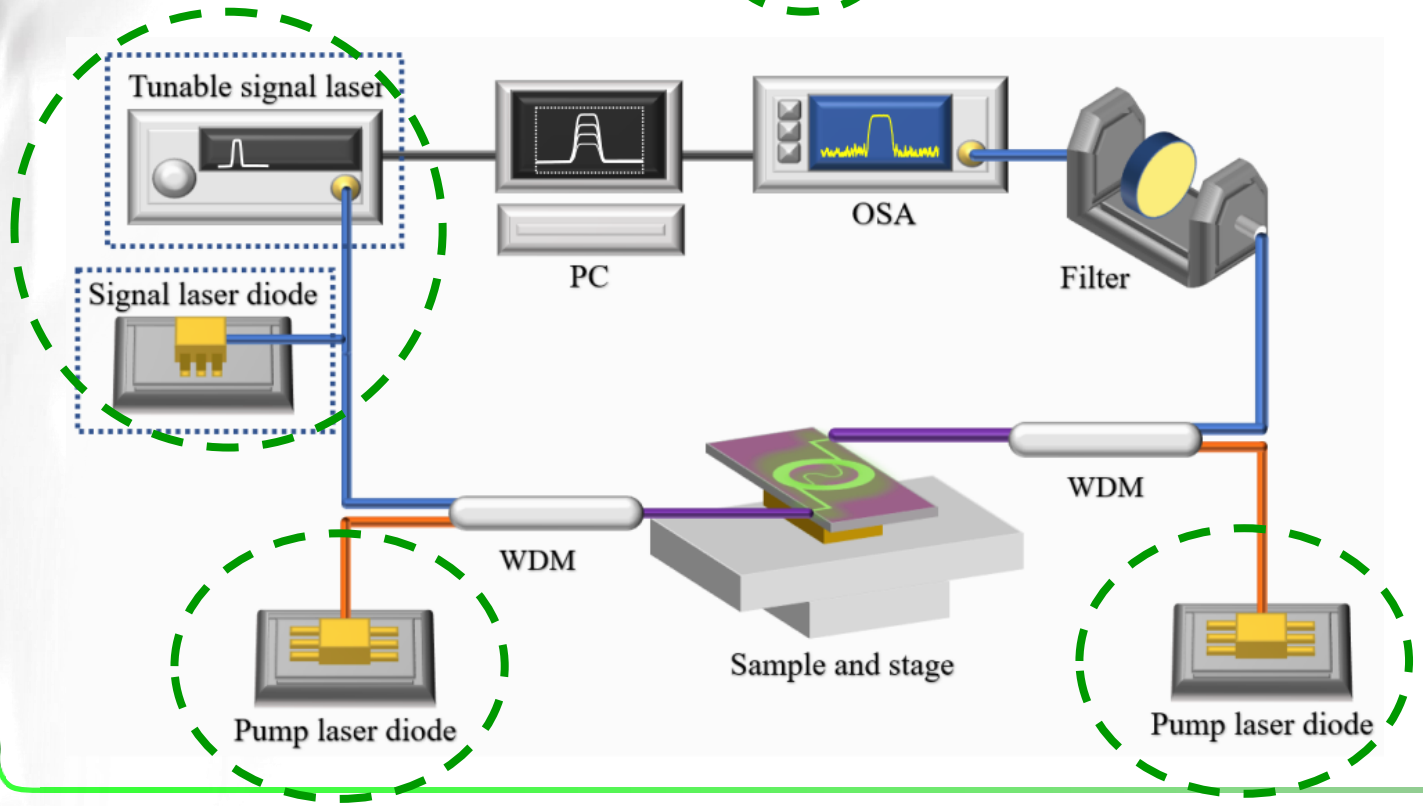
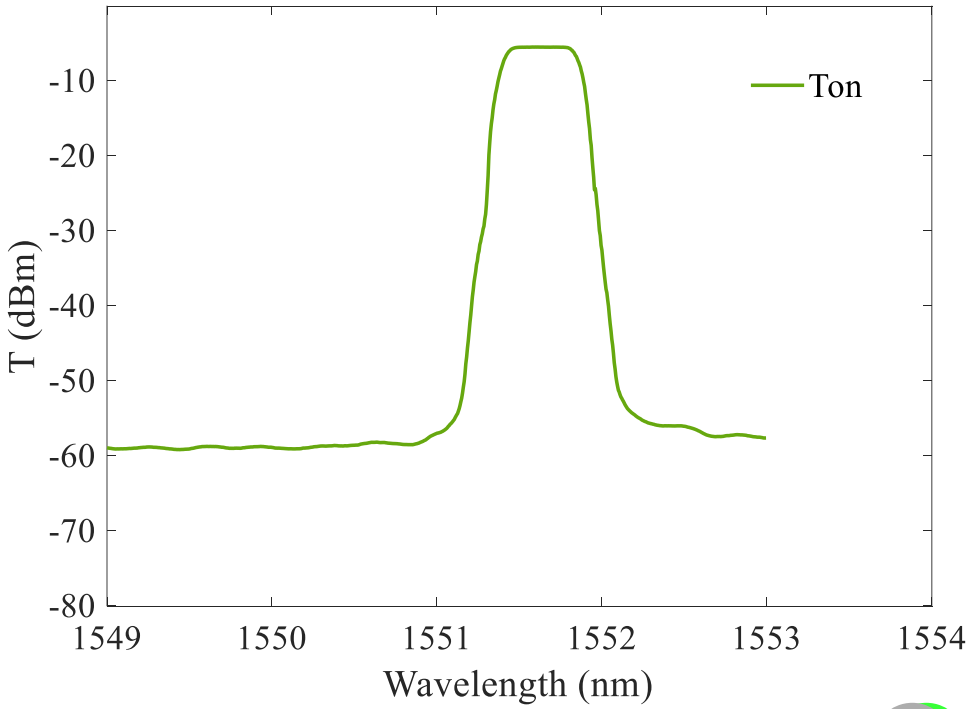


Al_2O_3-Si_3N_4 AMPLIFIERS – GAIN MEASUREMENTS

- Gain with reference branch method
  - Measure amplified signal in amplifier branch (T_{on})
  - Measure signal in reference branch (T_{ref})

$$g_{global} = T_{on} - T_{ref}$$





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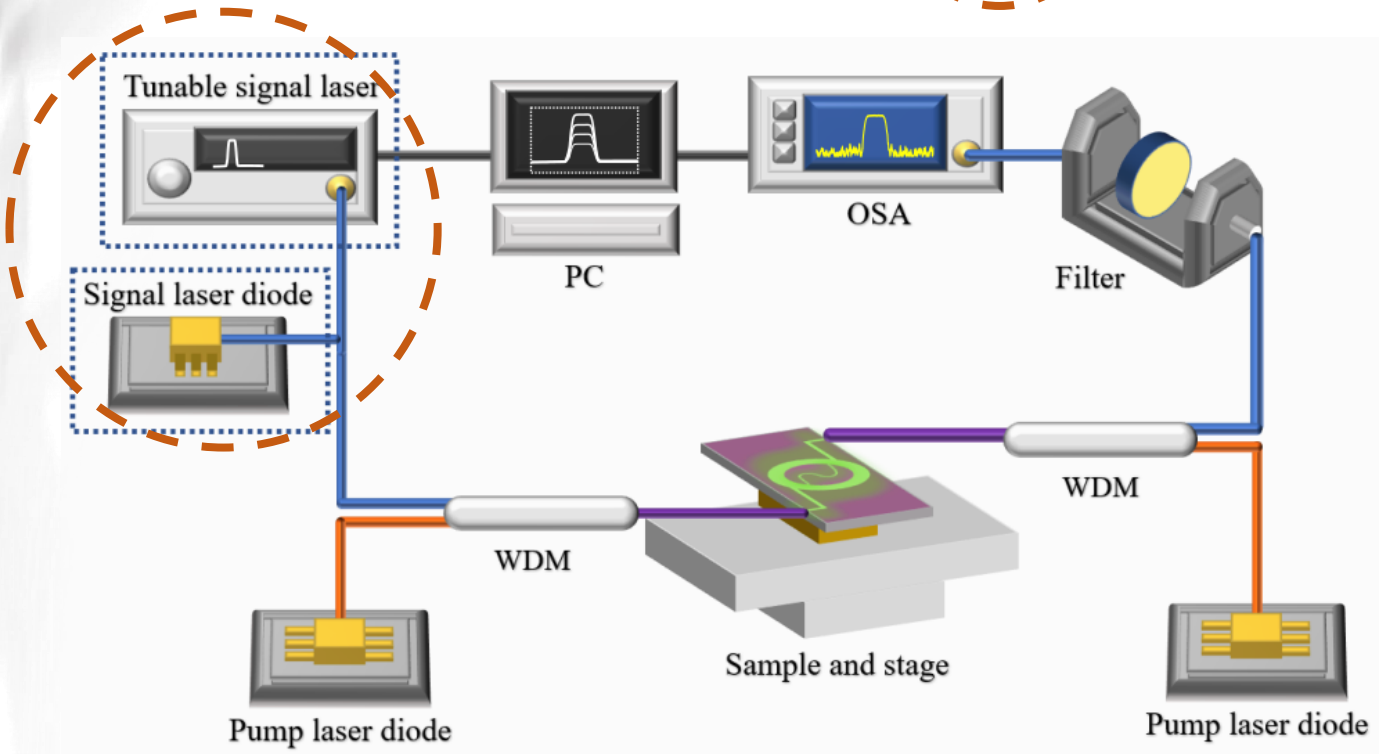
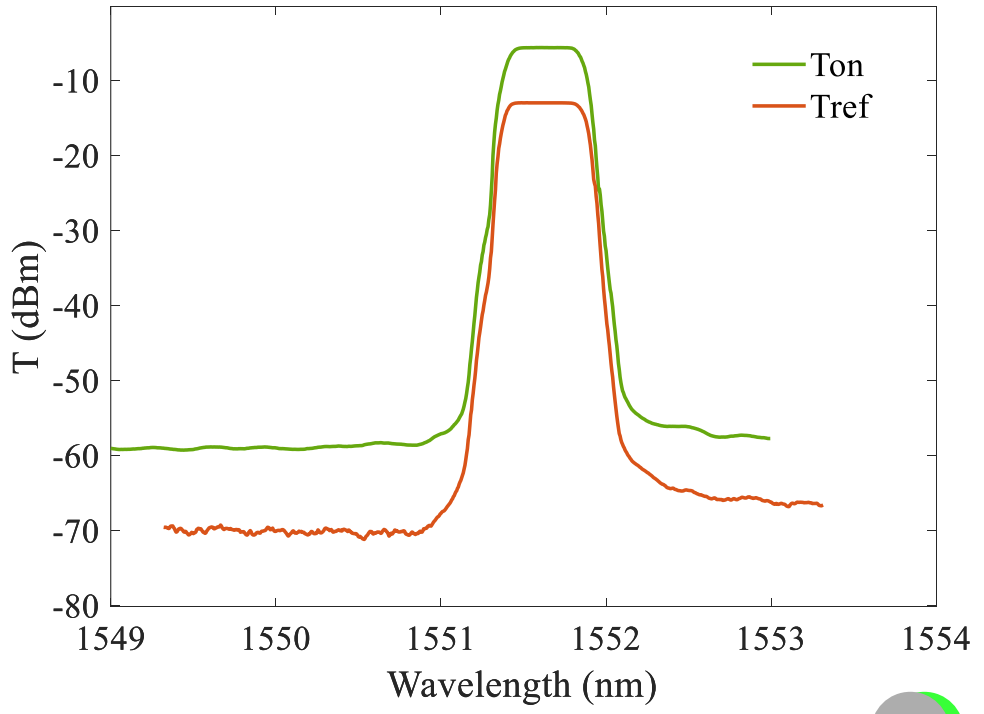
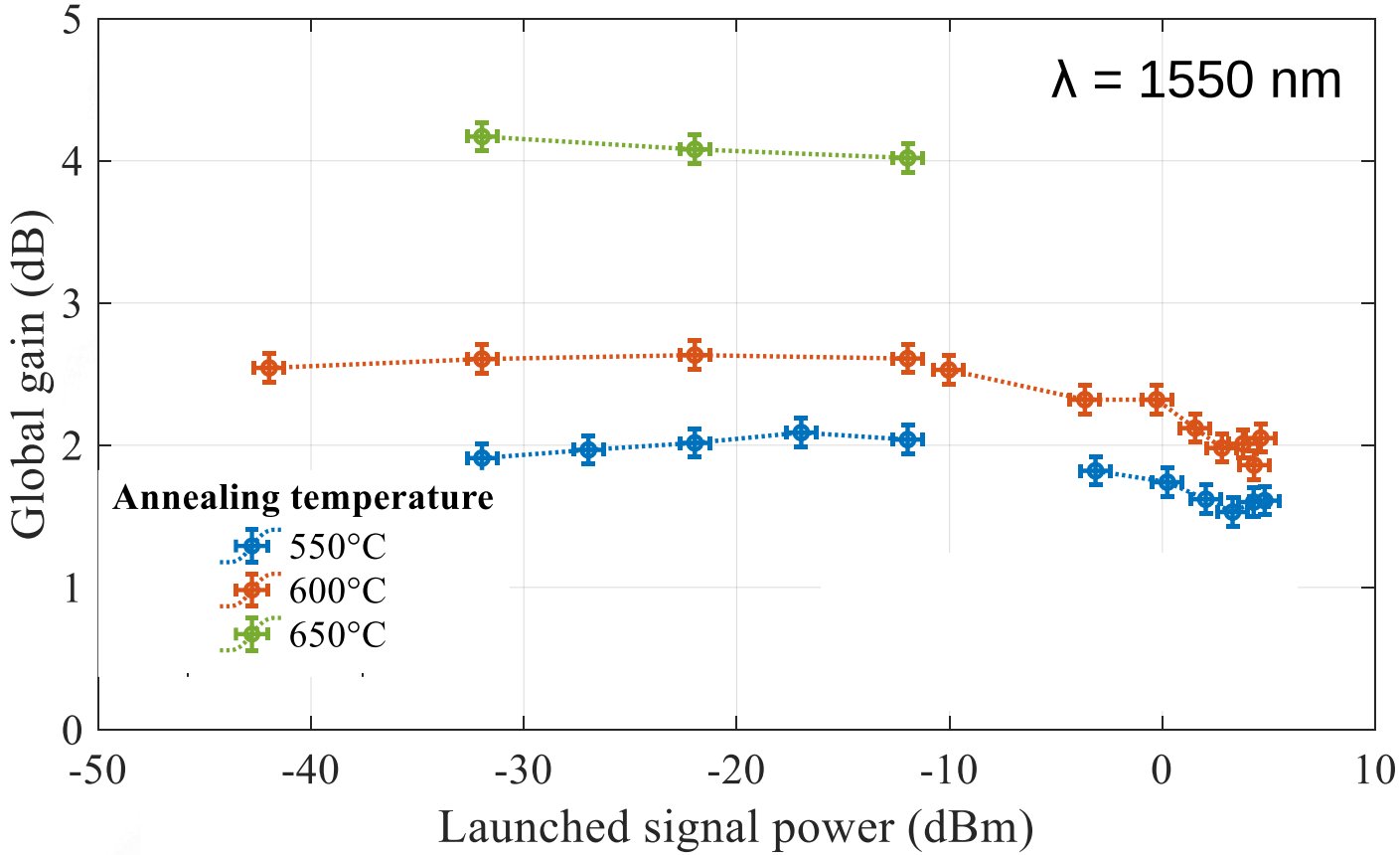


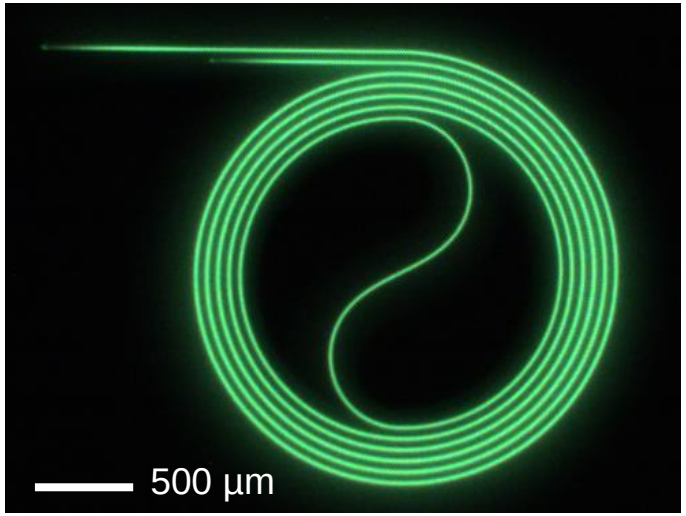


Al_2O_3-Si_3N_4 AMPLIFIERS – GAIN MEASUREMENTS

- Influence of annealing on the gain
  - Annealing show increase in gain*



On-chip pump power (~240 mW)



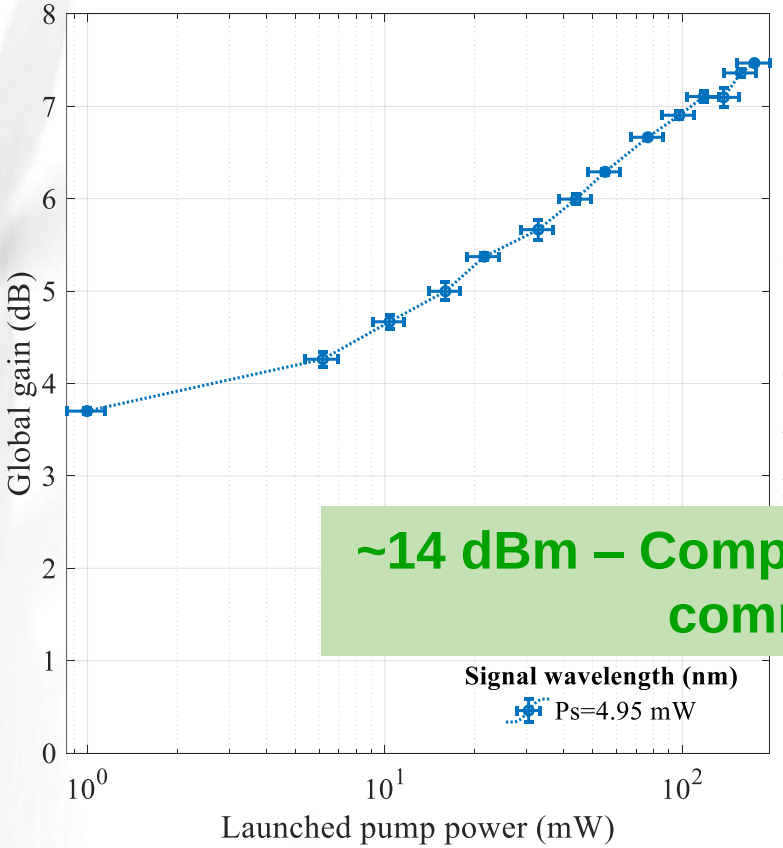
Amplifier length = 3.19 cm

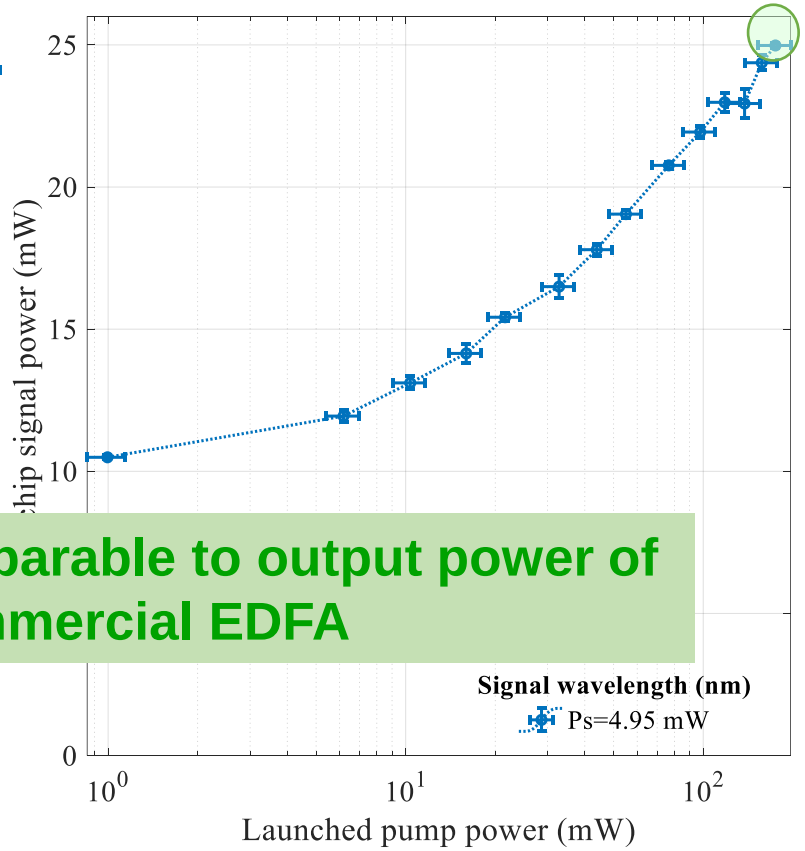
Er^{3+} concentration ~$1.5x10^{20}$ ion/cm^3

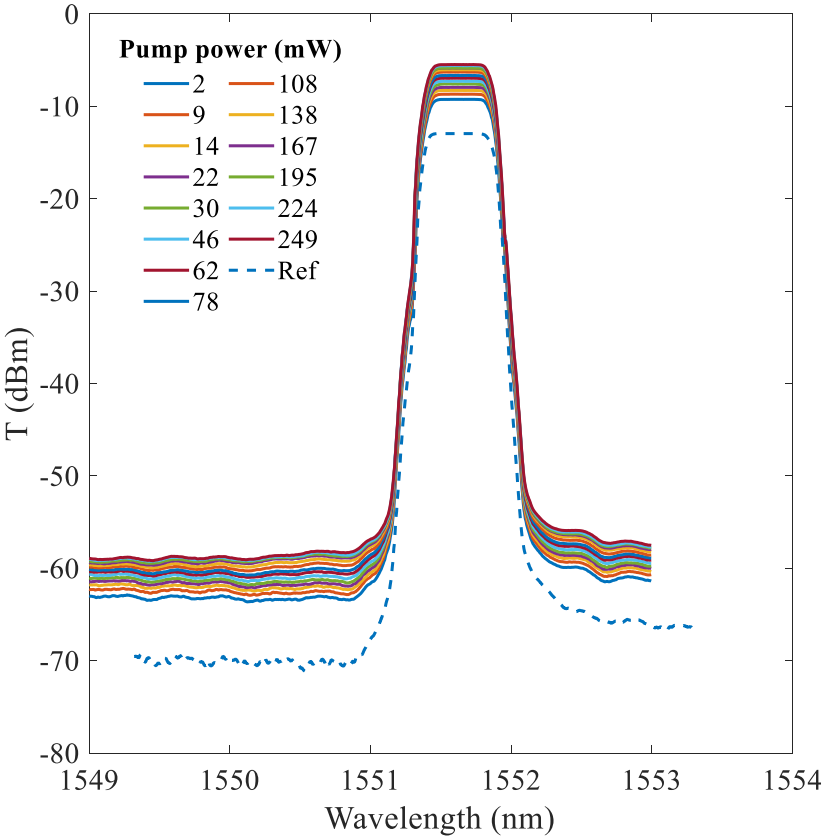
*variable optimum temperature depending on concentration

Al_2O_3-Si_3N_4 AMPLIFIERS – GAIN MEASUREMENTS

- Gain vs pump power







~14 dBm – Comparable to output power of commercial EDFA

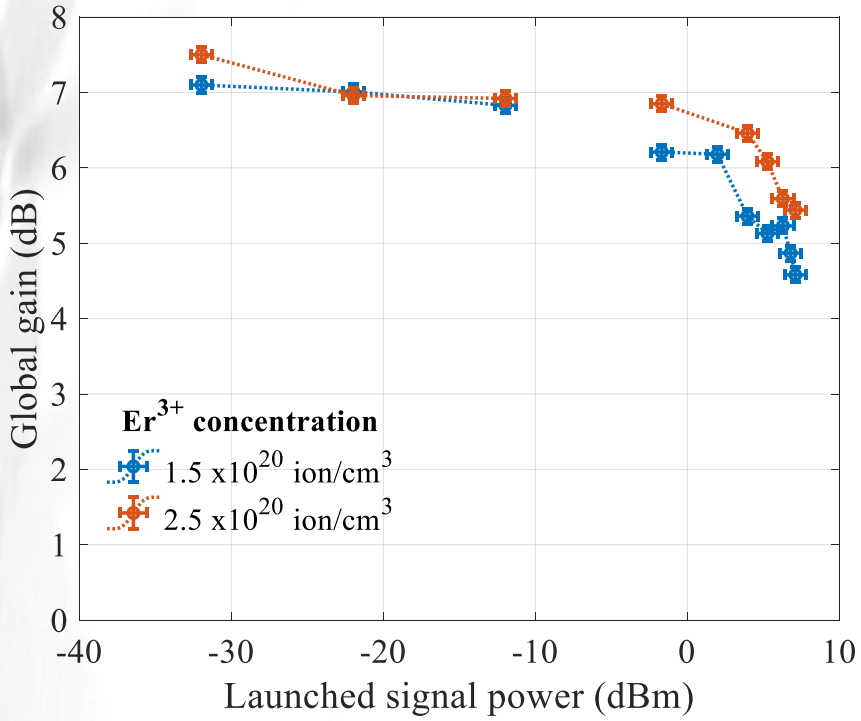
Amplifier length = 4.48 cm

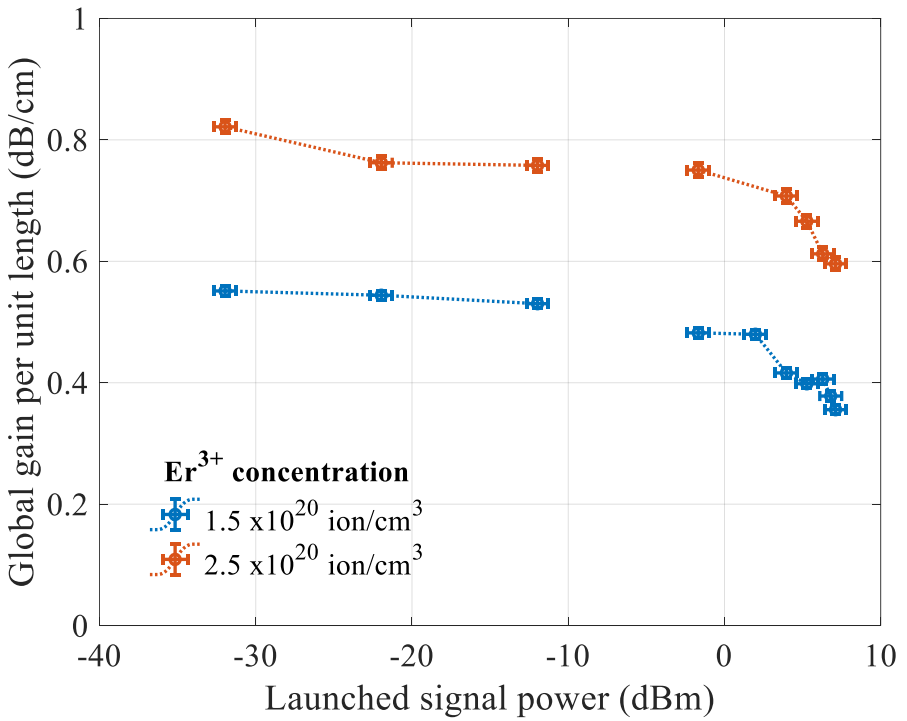
Er^{3+} concentration ~$1.5x10^{20}$ ion/cm^3

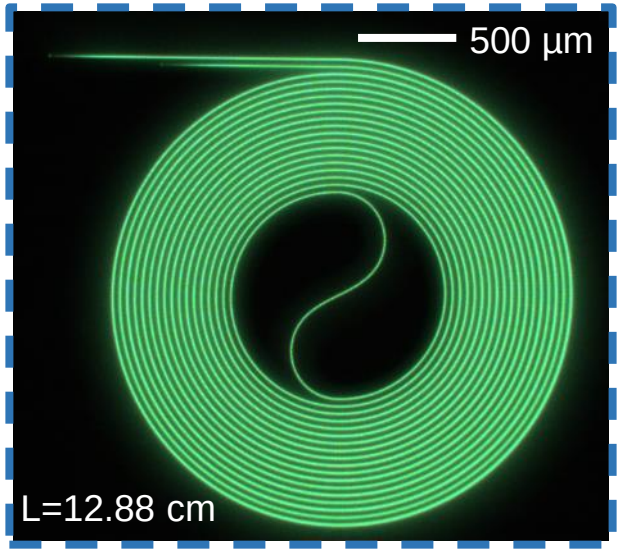
Al_2O_3-Si_3N_4 AMPLIFIERS – GAIN MEASUREMENTS

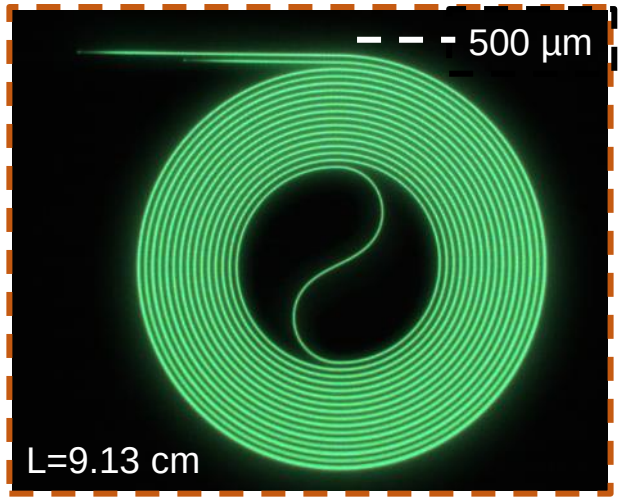
- Gain vs signal power
  - Concentration comparison

λ = 1550 nm





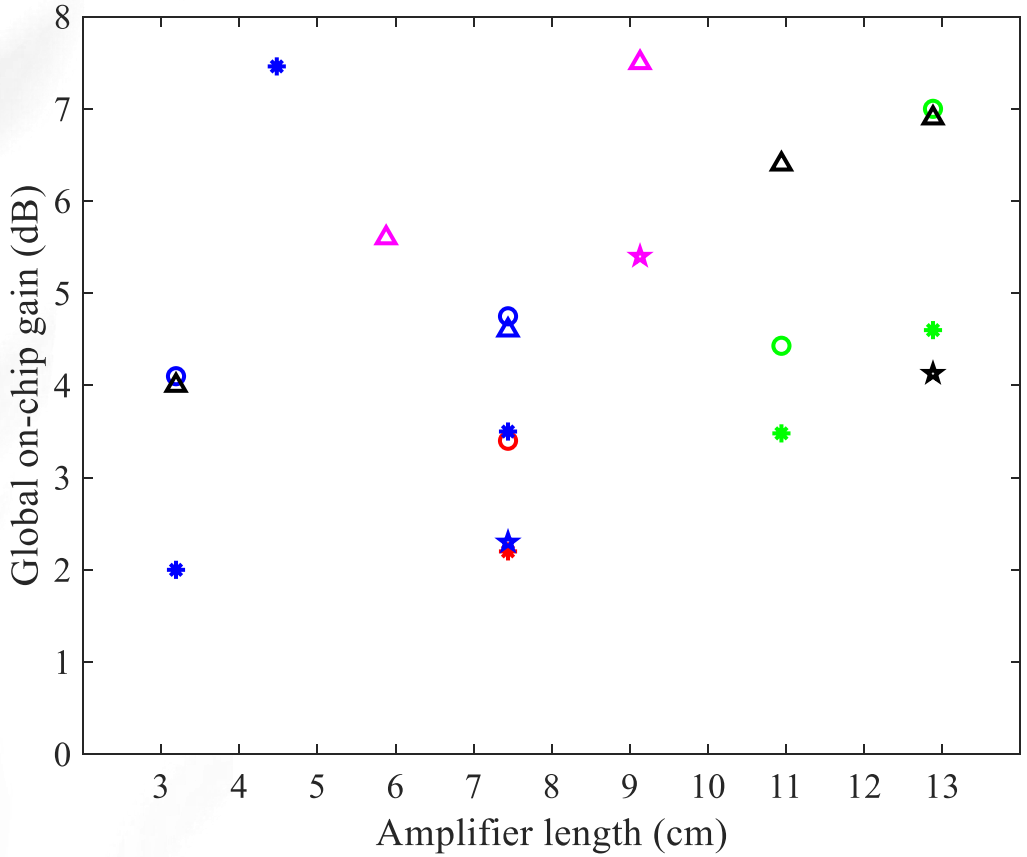


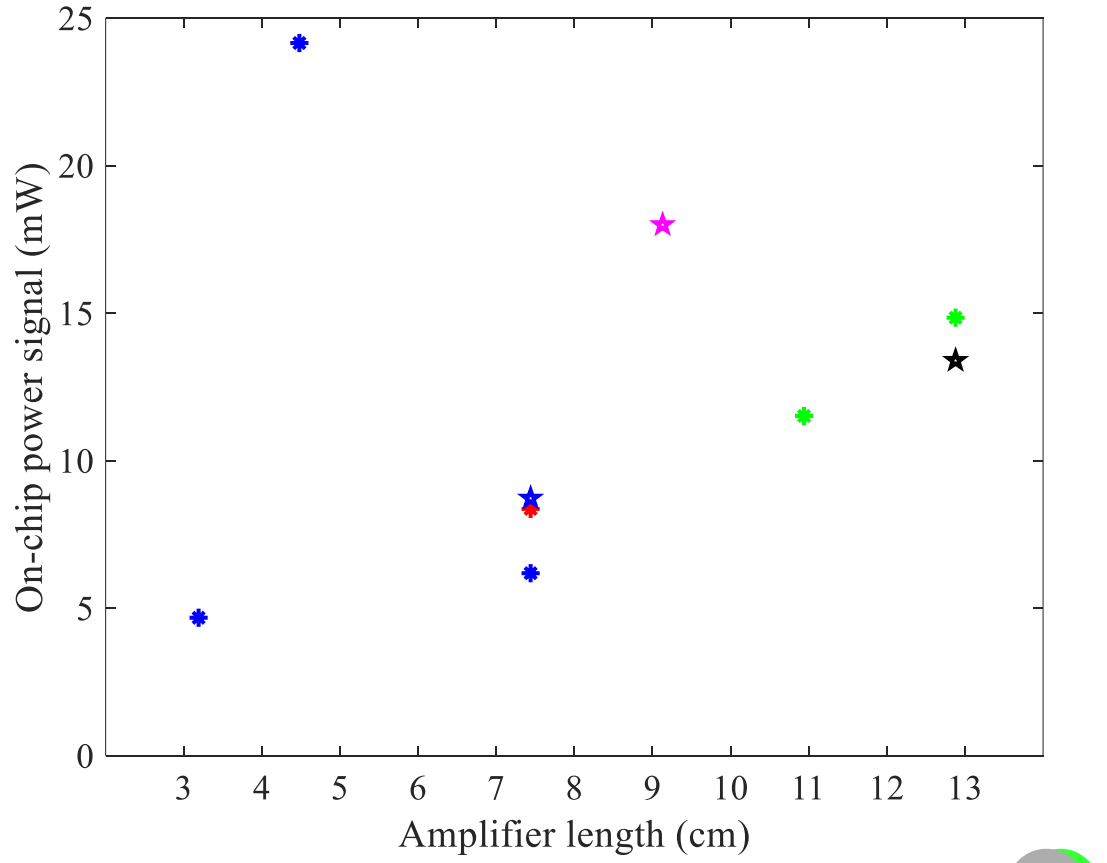


On-chip pump power ~240 mW

Al_2O_3-Si_3N_4 AMPLIFIERS – SUMMARY

- Gain summary
  - Various lengths, widths, concentrations and signal powers





*Highest signal power available with laser diodes

Thank you for your attention!