

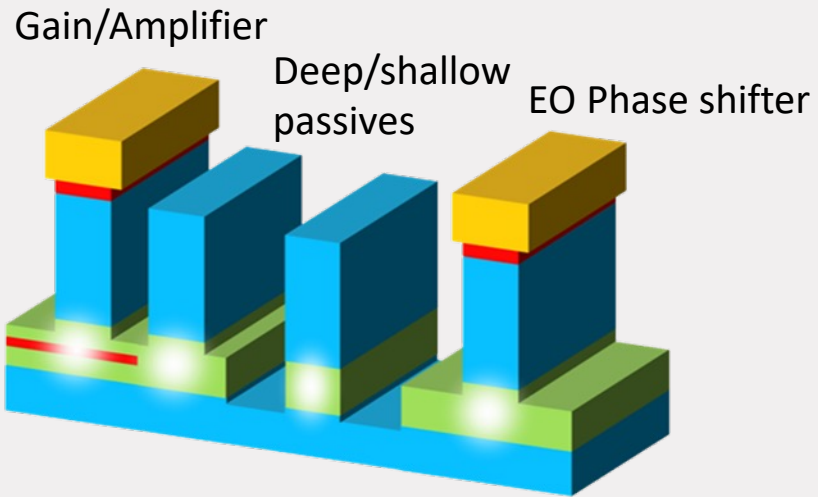
InP membrane technology platform for large scale photonic integration

Yuqing Jiao

Outline

- Introduction
- Laser integrated nanophotonics platform
- Key components for large scale and high capacity
- Summary

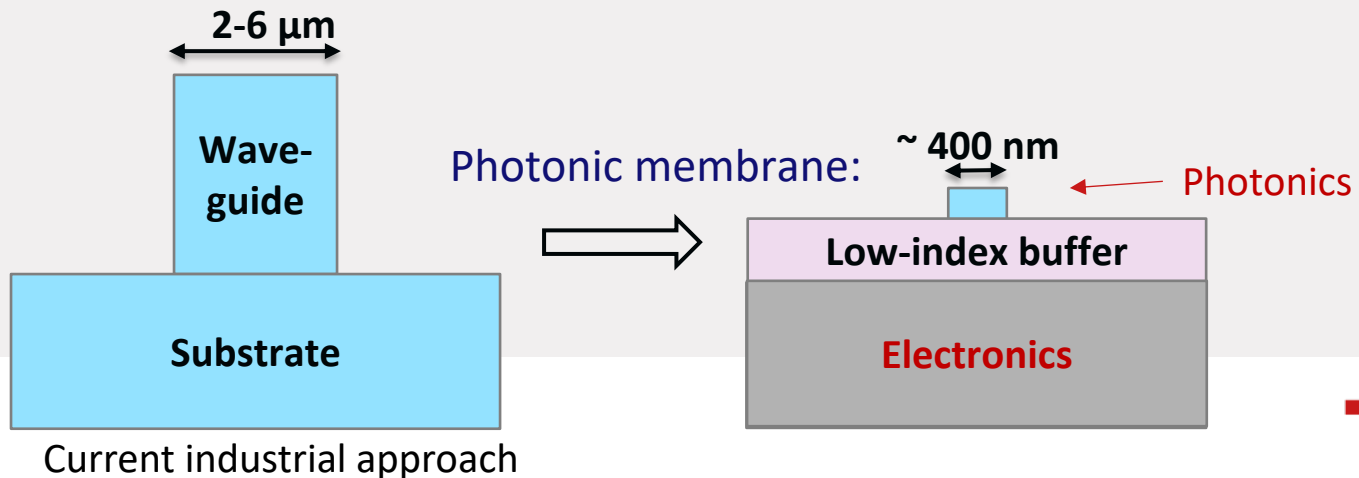
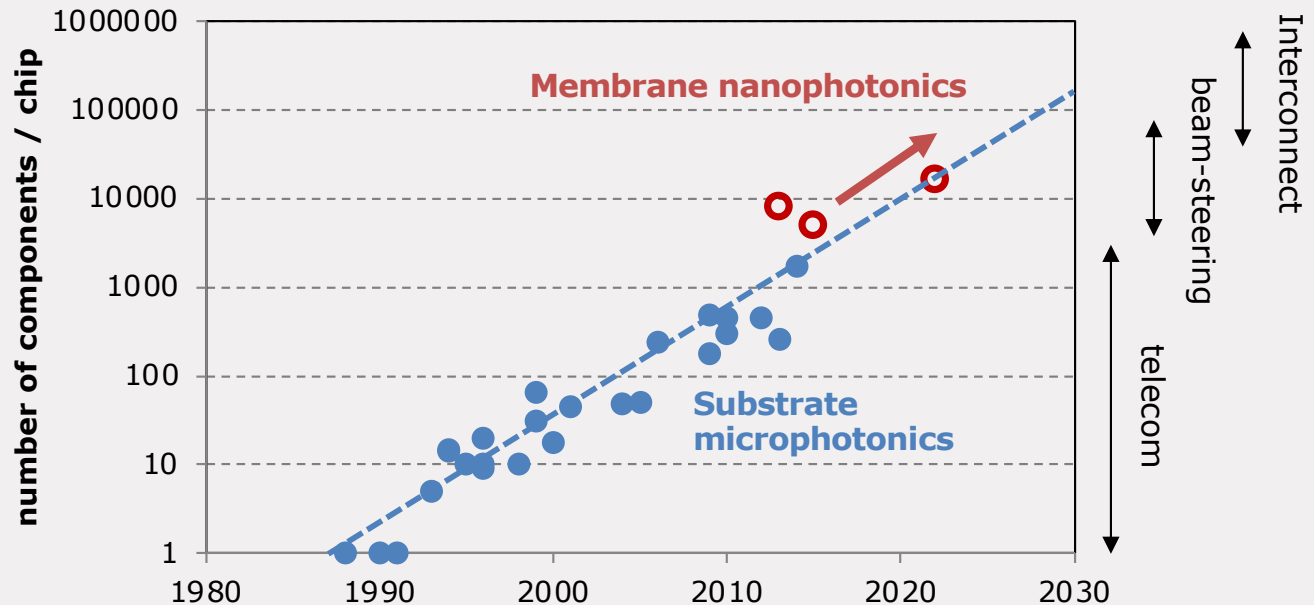
Photonic integration on InP



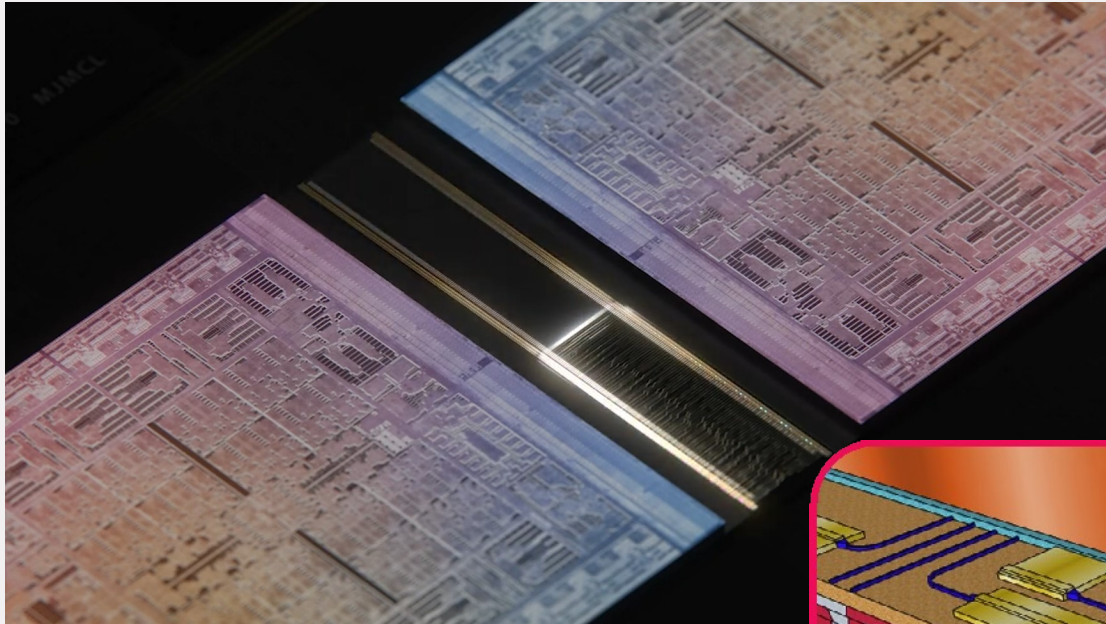
From micro to nano integration

Driving force:

- Functionality
- Speed
- Energy efficiency

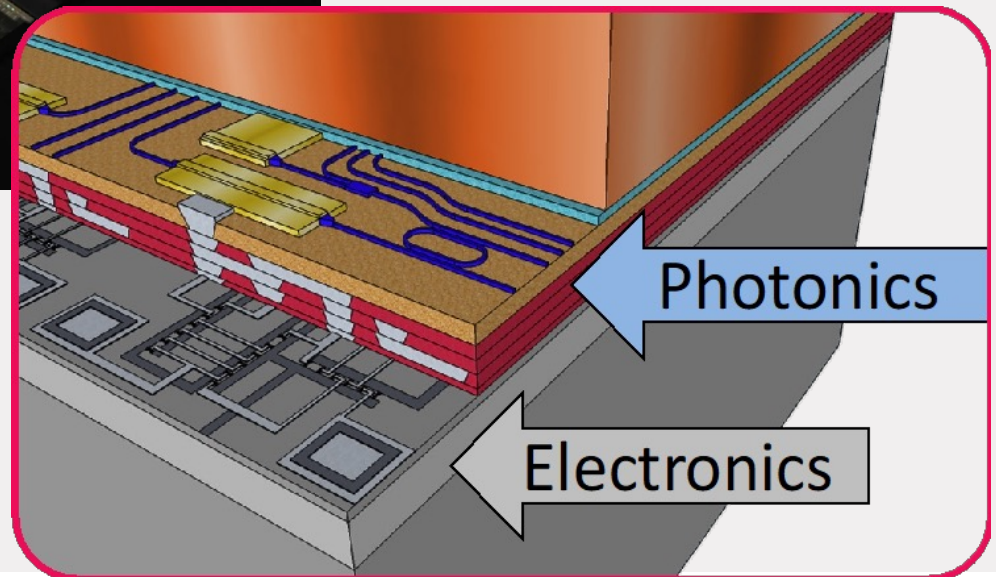


Heterogeneous co-integration

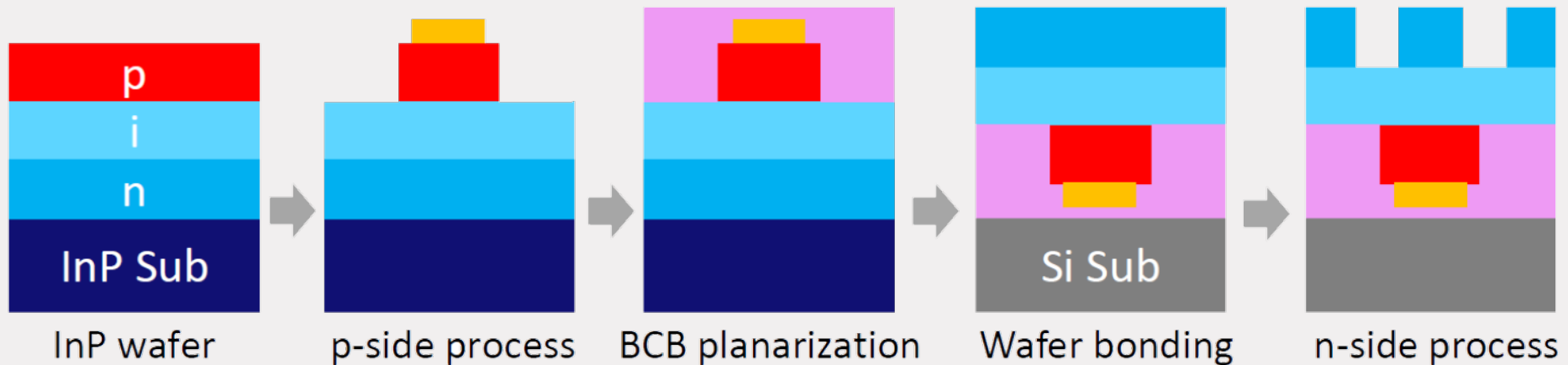


Apple/TSMC ultra-fusion
interconnects
2.5 TB/s from massive
parallelism

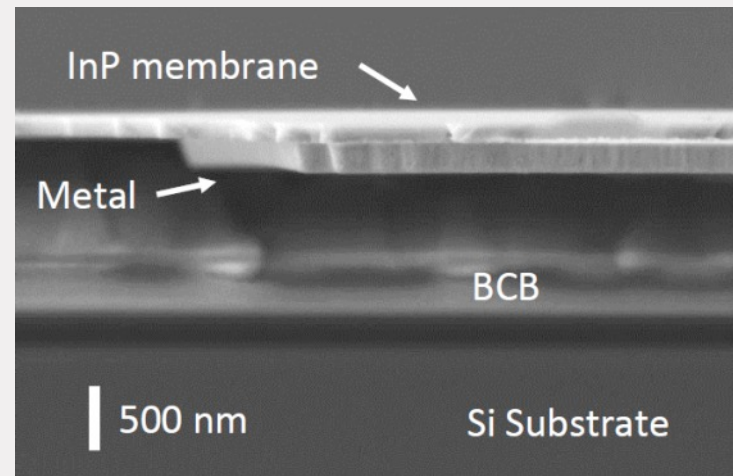
Nanophotonic interconnects
Potential TB/s per channel
(principle demonstrated in fibers)



Double-sided InP membrane

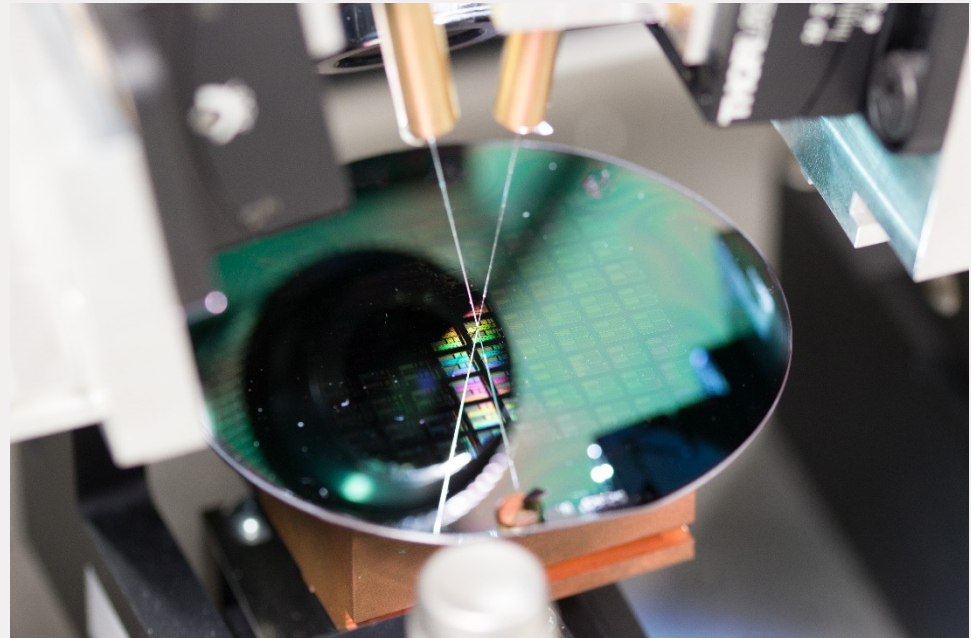
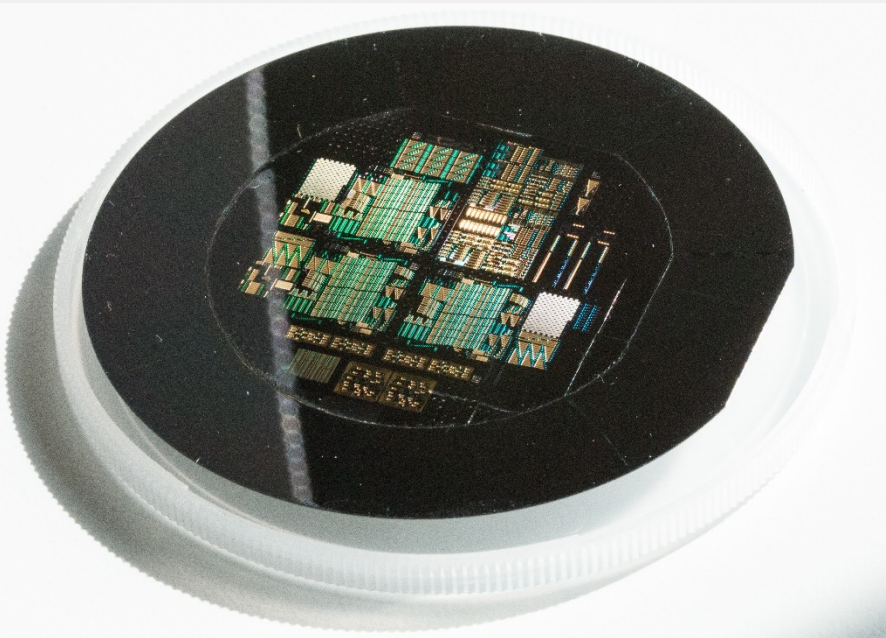


- x2 times ultra-flat surfaces for highest lithography precision
- enable deep UV 193nm scanner process (CD 100 nm)
- design freedom for optimal optical and electrical performances



Wafer-scale integration for membrane

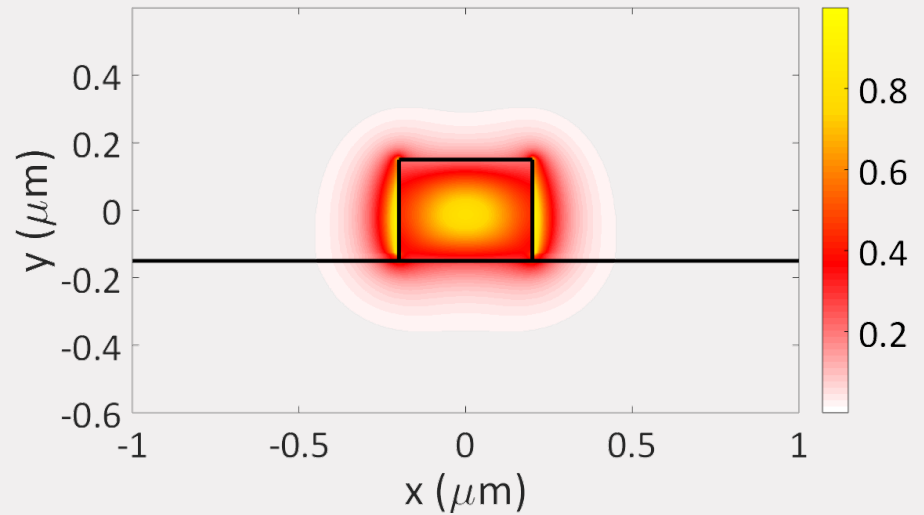
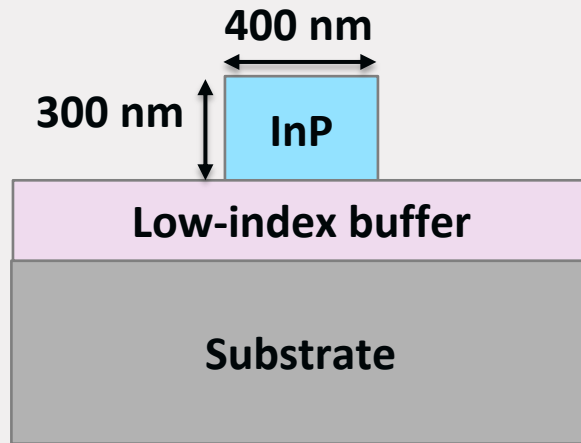
- Wafer-to-wafer bonding



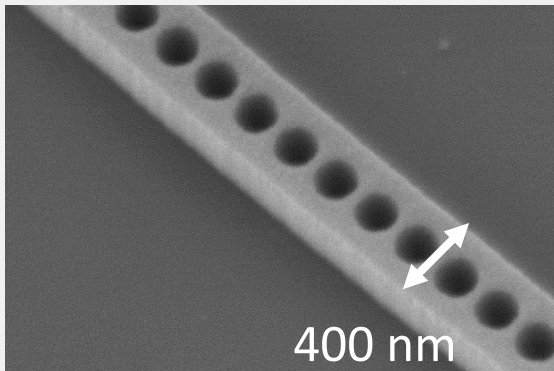
- 2-inch wafer scale
- A/P membrane 1.5 μm thick
- Patterned with EBL

- Full 3-inch wafer scale
- Membrane only 300 nm thick
- Patterned with ASML DUV scanner
- Route to sub-dB/cm loss

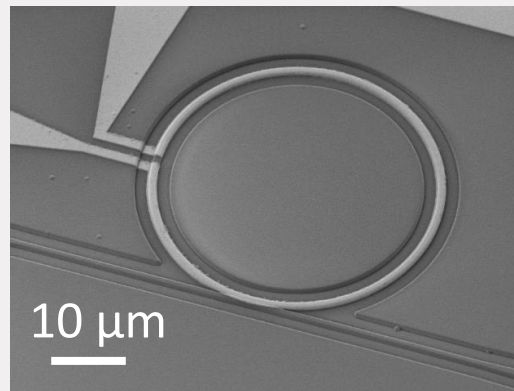
High optical confinement in InP



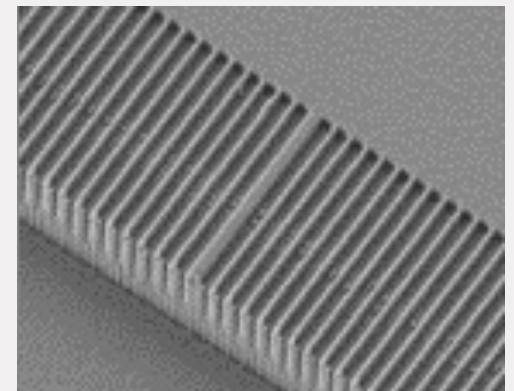
Enabling high-performance laser cavities:



$R > 98\%$ PhC mirrors ($L = 3 \mu\text{m}$)



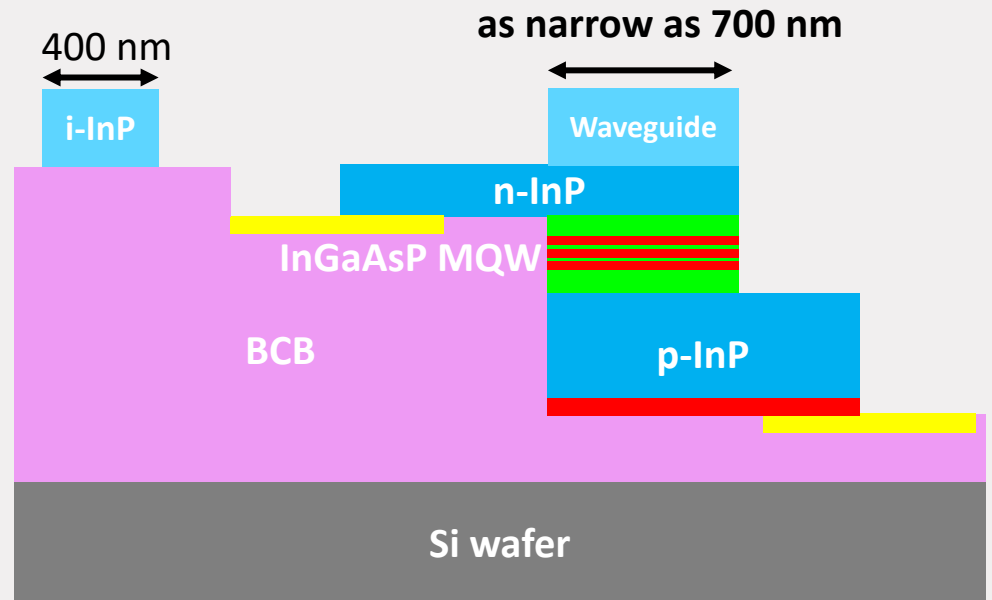
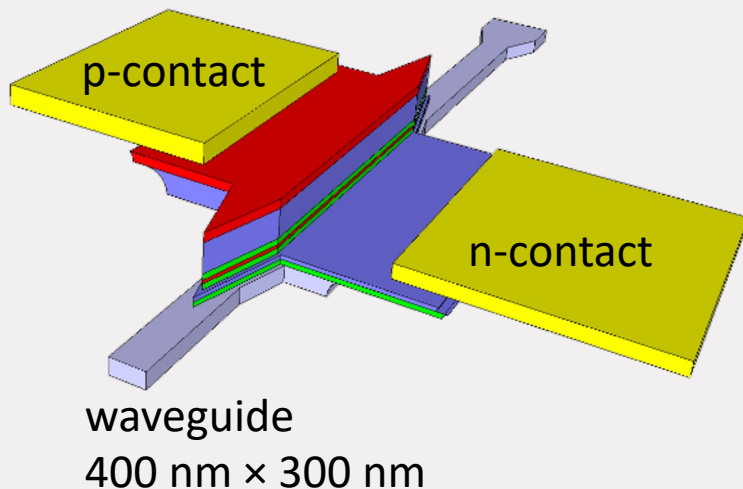
$Q > 60,000$ resonators



Distributed feedback mirrors

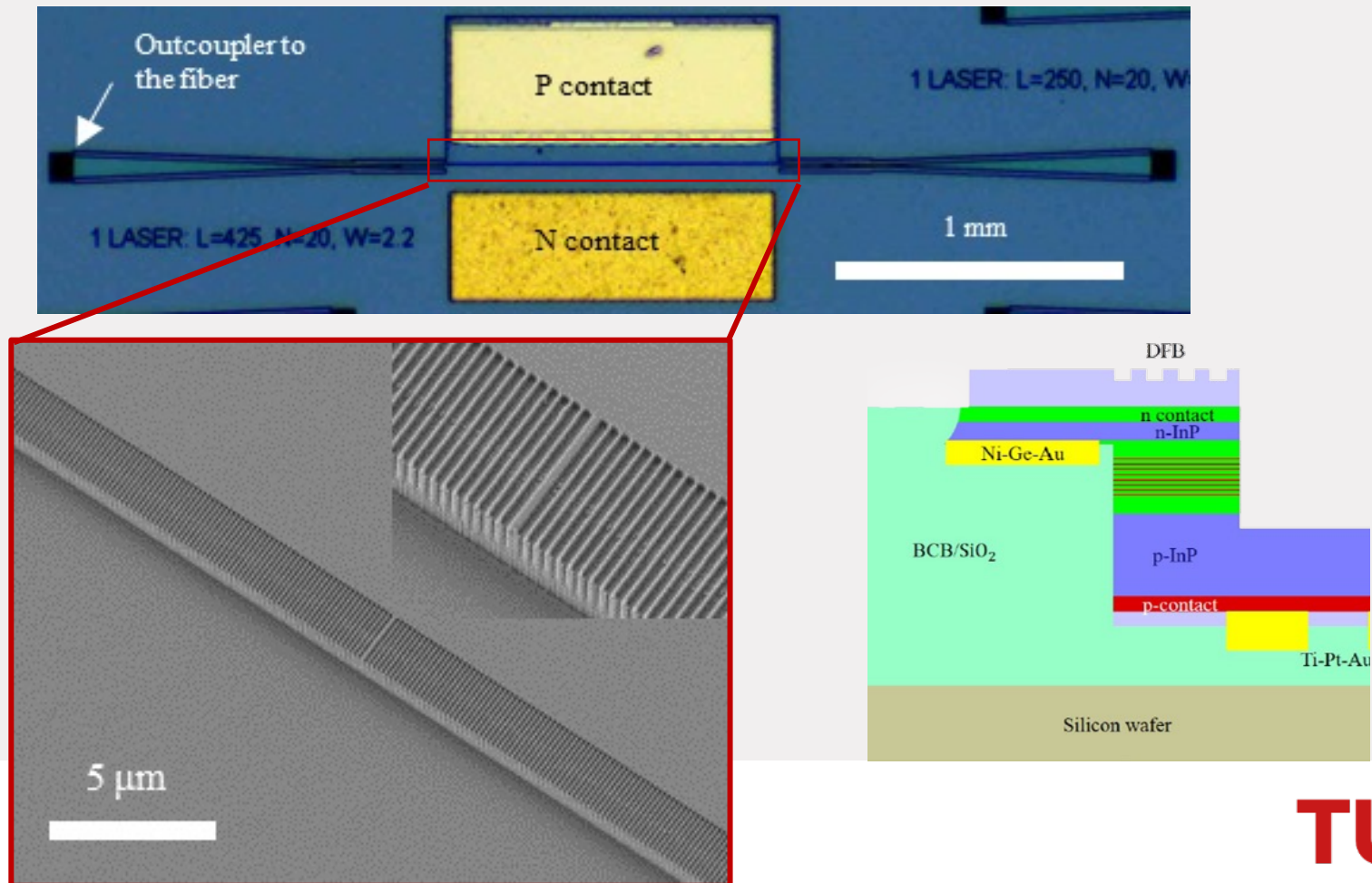
Native gain in nanophotonic waveguides

- S-shaped amplifier/laser for tighter confinement
- Improve optical mode matching
- No critical alignment (lithography overlay accuracy)



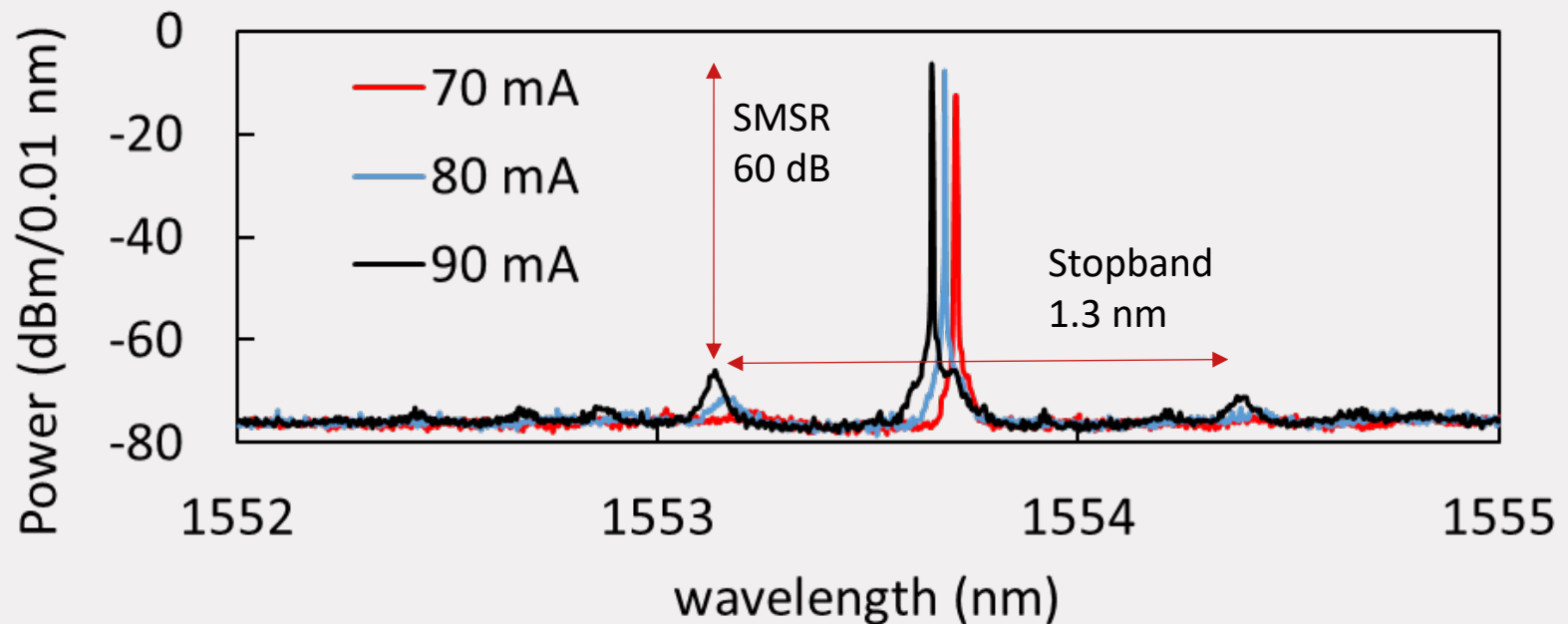
DFB lasers

- Quarter- λ shifted DFB cavity (1 mm long)



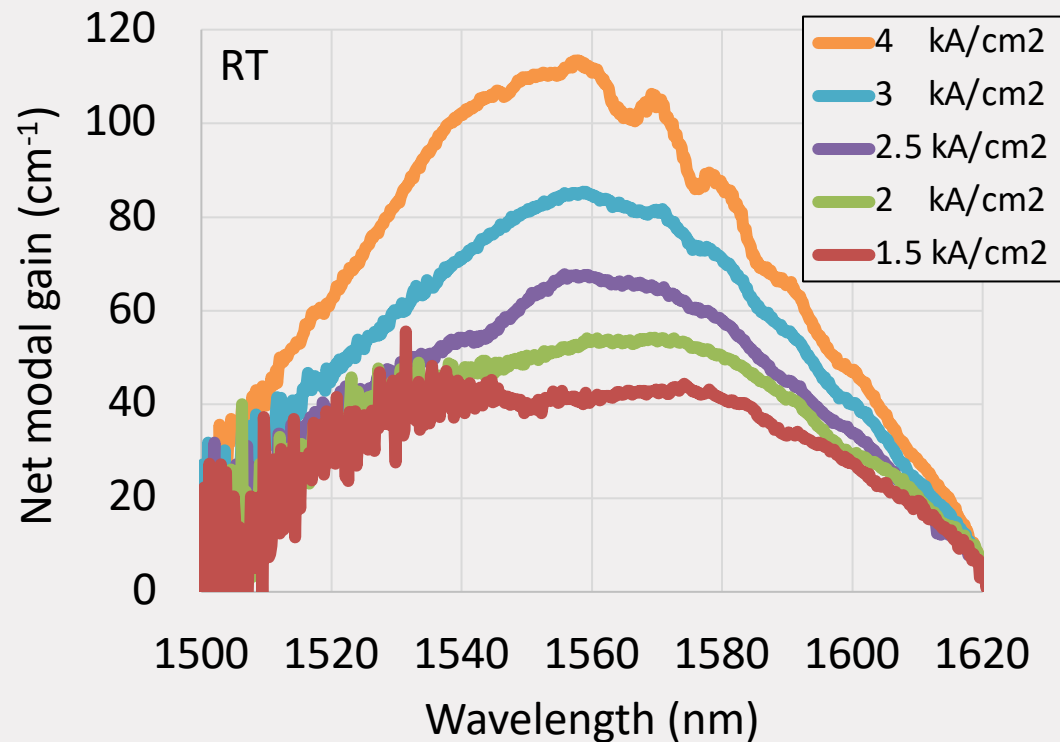
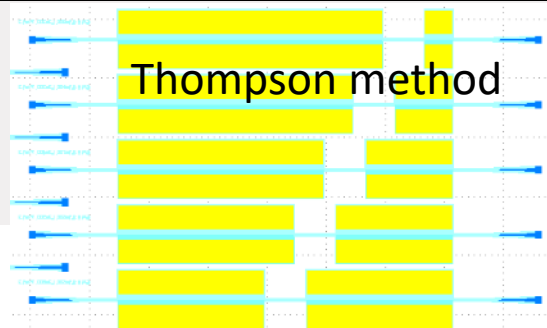
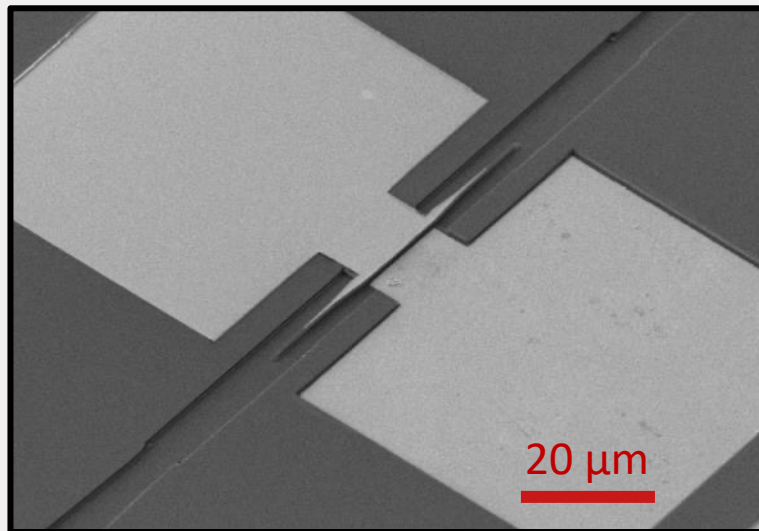
DFB lasers

- 50mA threshold current (2.5 kA/cm^2)
- 1 mW in fiber (10 mW in waveguide)
- Very high SMSR $> 60\text{dB}$

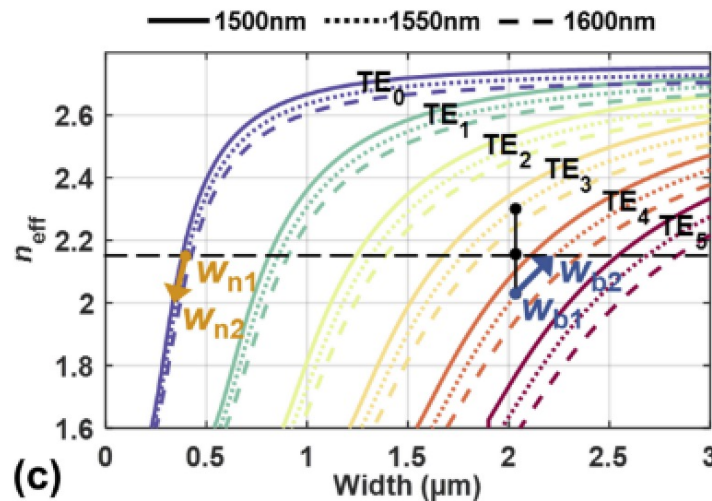
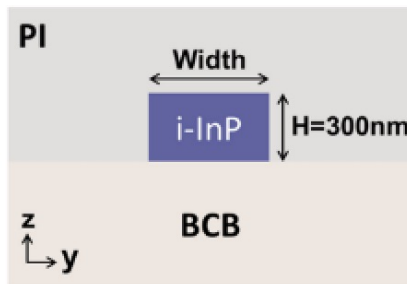
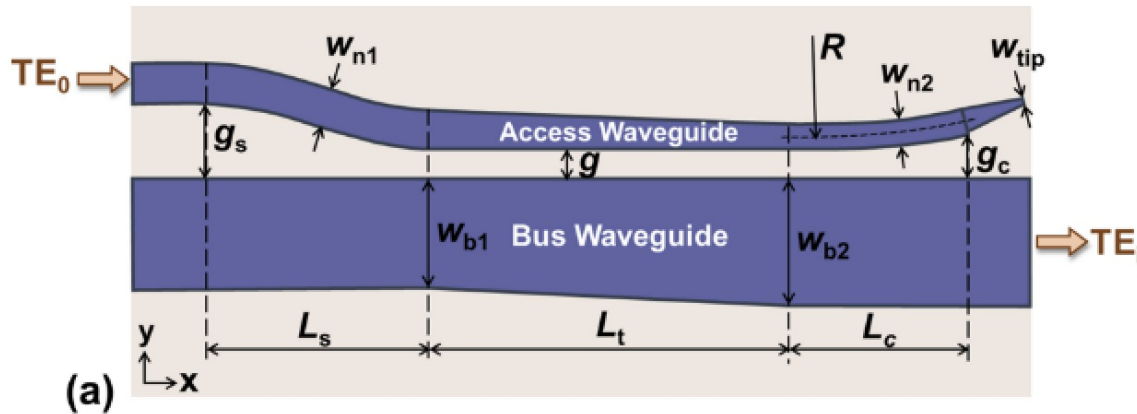


Membrane amplifier

- 4 / 8 multi-quantum wells (MWQ) design
- 110 cm^{-1} gain @ 4 kA cm^{-2} (8 MQW)



Multimode multiplexing



5-mode multiplexer on InP

EL < 1 dB, XT < -14 dB with 50nm width variation

Broadband ($\sim 100\text{nm}$)

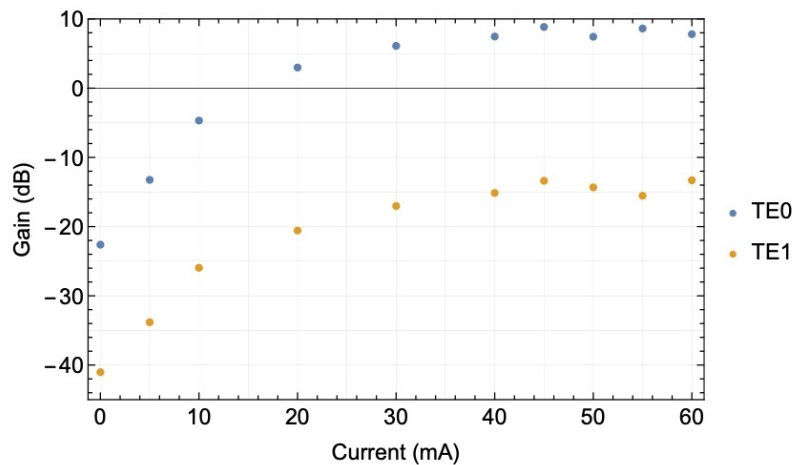
Highest tolerance reported thanks to moderate index contrast

Multimodal amplification

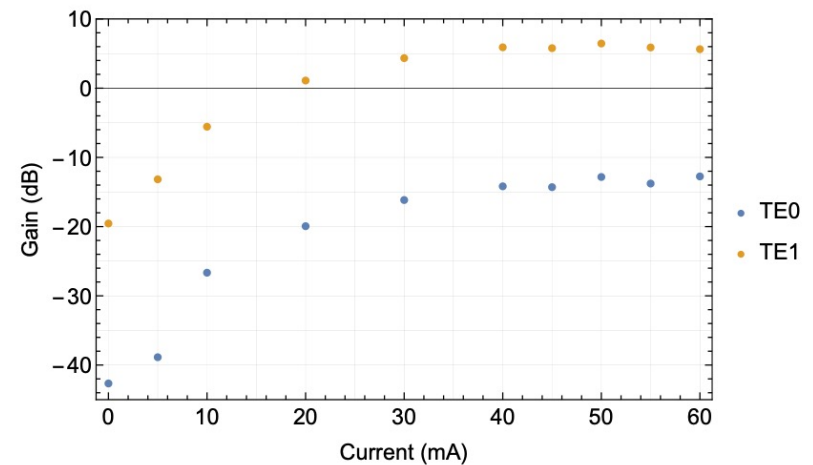


Preliminary results of a test amplifier (500um) for TE0 and TE1
8 dB gain for TE0, 6 dB for TE1 @ 50mA injection

TE0 input



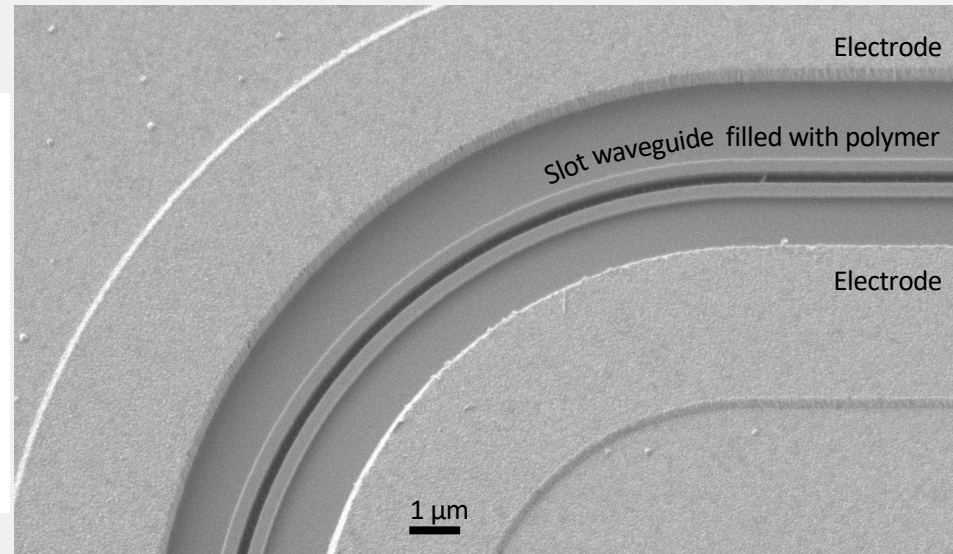
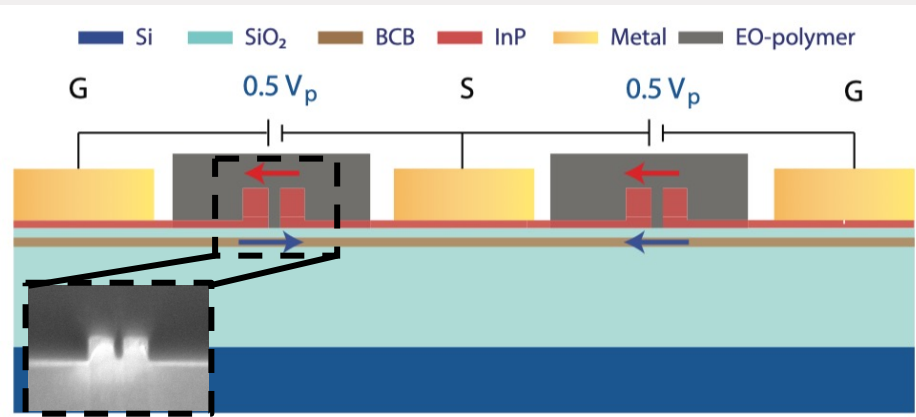
TE1 input



First EO polymer modulator on InP

InP has 3x lower optical loss and 8x higher electron mobility than Si, at same doping level ($1\text{e}18\text{ cm}^{-3}$)

First electro-optic polymer modulator on InP

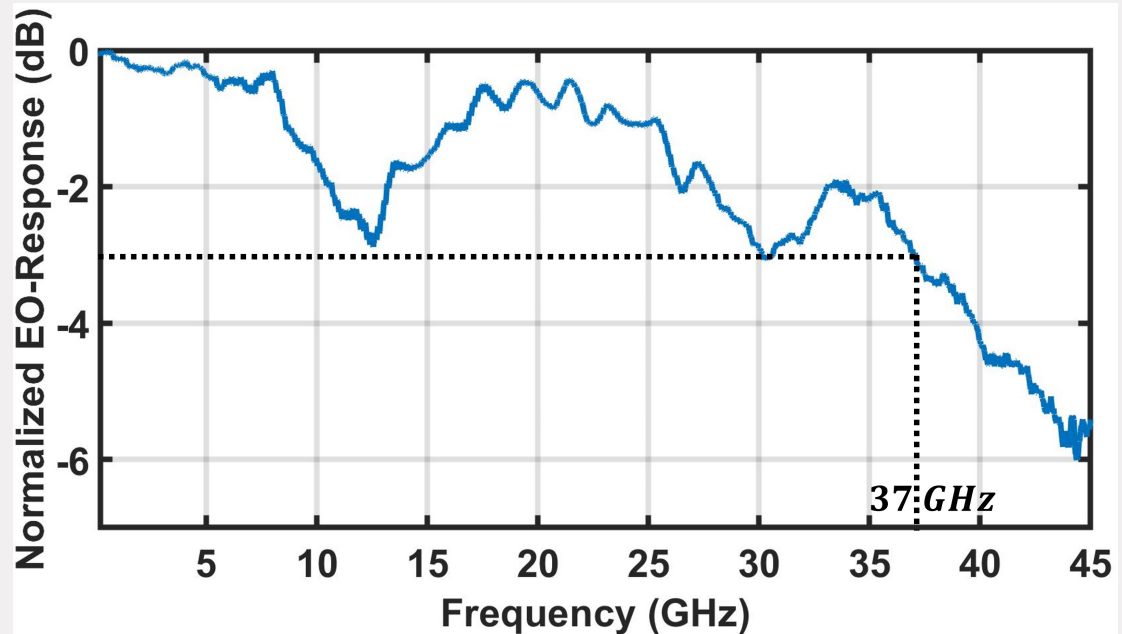
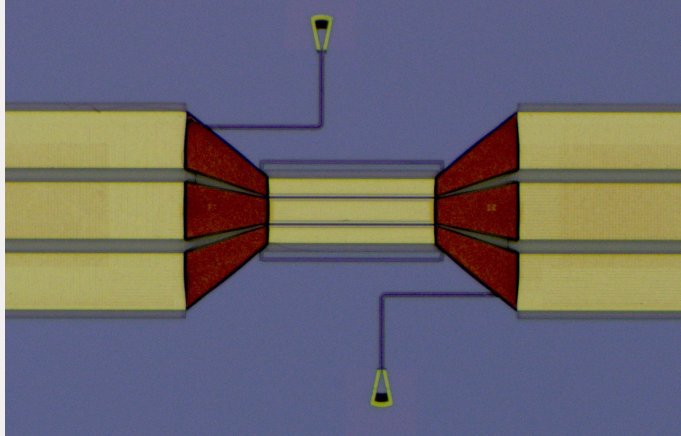


First EO polymer modulator on InP

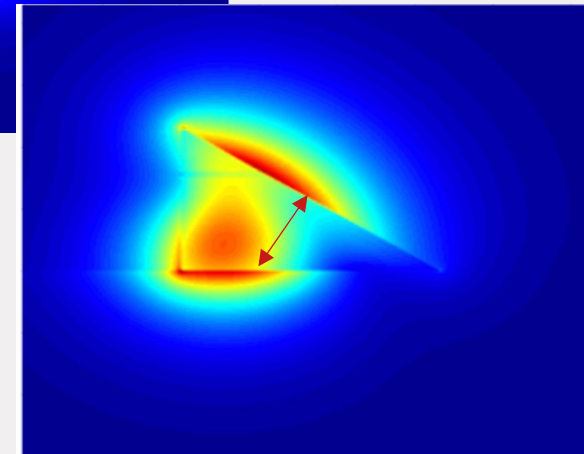
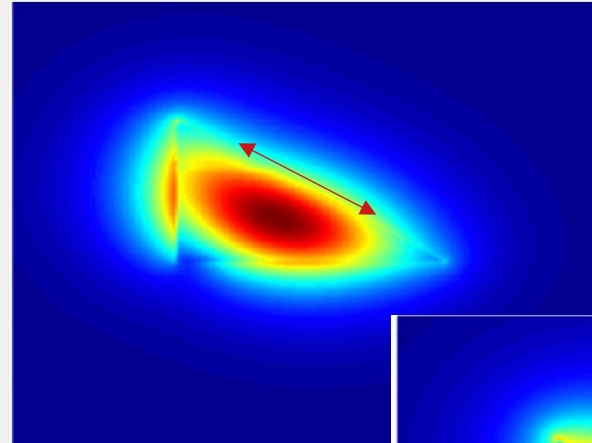
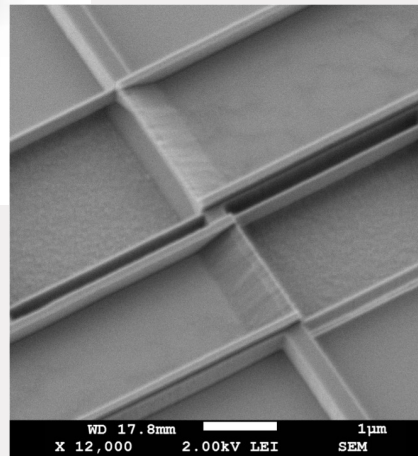
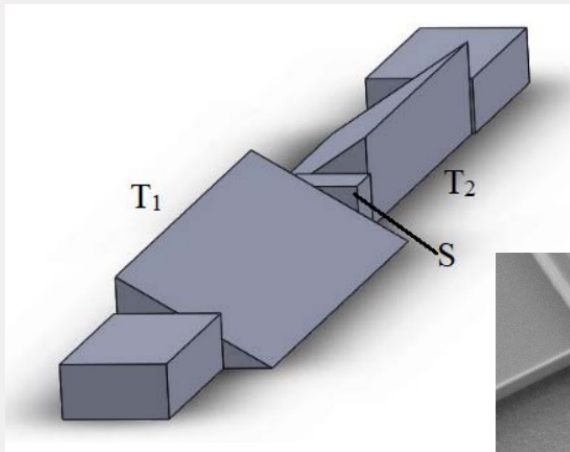
Conservative material choice: bulk r_{33} coefficient 110 pm/V ,

Effective r_{33} in slot 25 pm/V due to surface effects

37GHz bandwidth & 4.5 V.mm achieved



On-chip polarization handling



Triangular waveguide for extremely efficient polarization rotation

High fab tolerances by exploiting natural “slow-etch” crystal plane

Full TE/TM conversion ($> 99\%$) within **4.2 μm** length (record small)

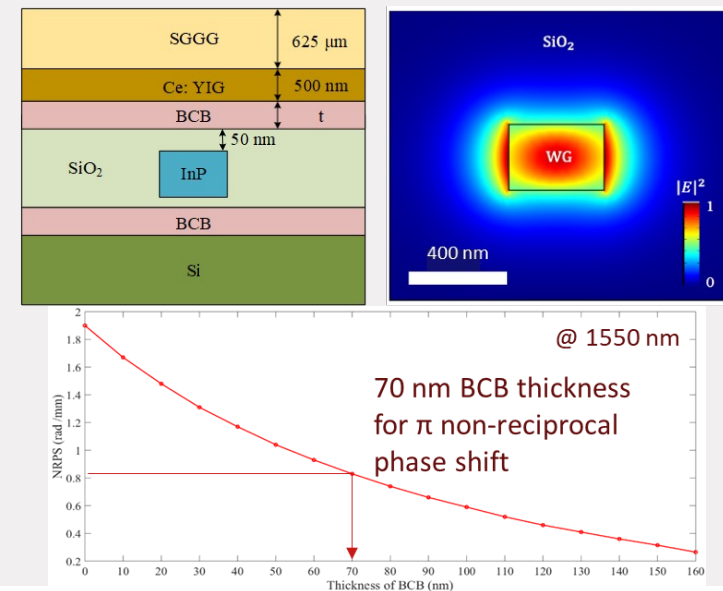
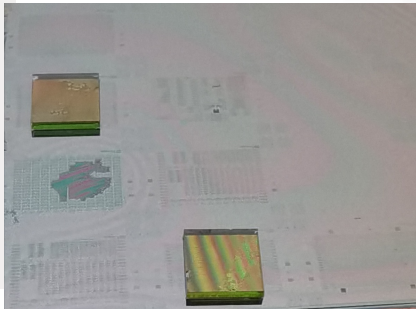
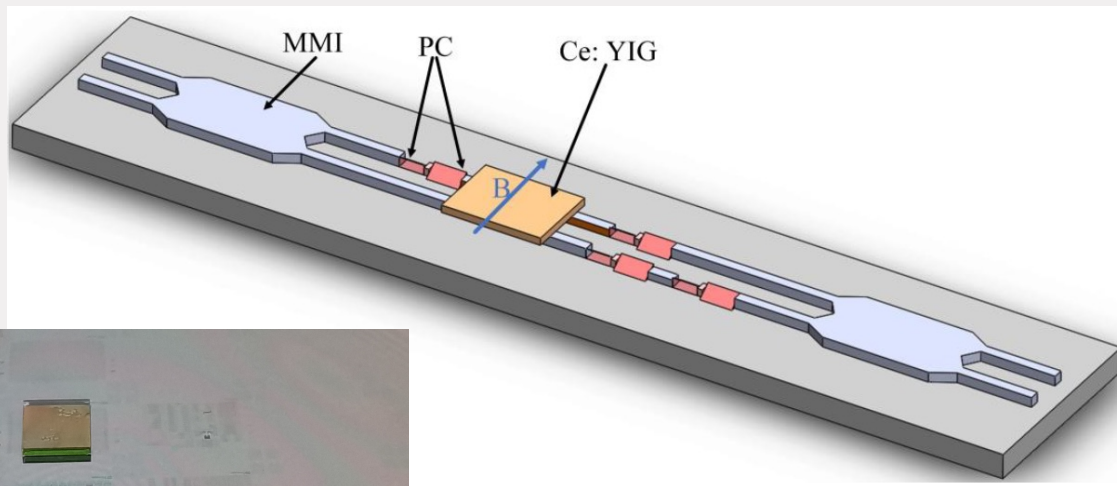
Integrated isolator/circulator

First on-chip isolator on InP PICs (37 dB isolation demonstrated)

Direct integration right next to the InP lasers

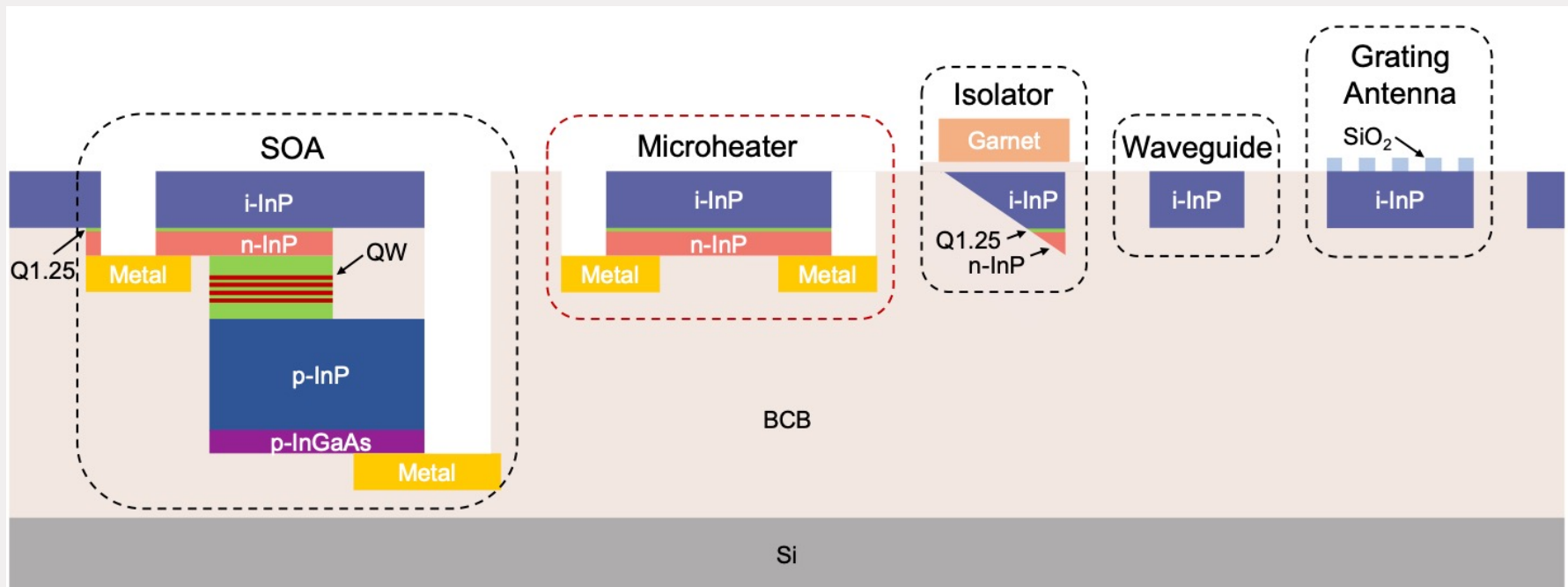
Novel polarization insensitive design

First technological success in 3D integration (YIG + InP + Si)



The platform

- One-stop shop to access amplifier/laser, (slot) waveguides, polarization controllers, microheaters, resonators and more.
- Officially a JePPIX product. Please visit JePPIX booth at ECOC2022

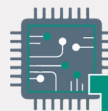


Summary

- Active-passive photonic integration on an InP membrane
- InP membrane enables fab-tolerant components, efficient gain and flexible material integration
- A viable technology towards very-large-scale integration



Gravitation



TWILIGHT

EU H2020



PHOTONICS²¹
PHOTONICS PUBLIC PRIVATE PARTNERSHIP