From Communications to Quantum Technology and Sensing

The Versatility of Hybrid Photonic Integration Technologies

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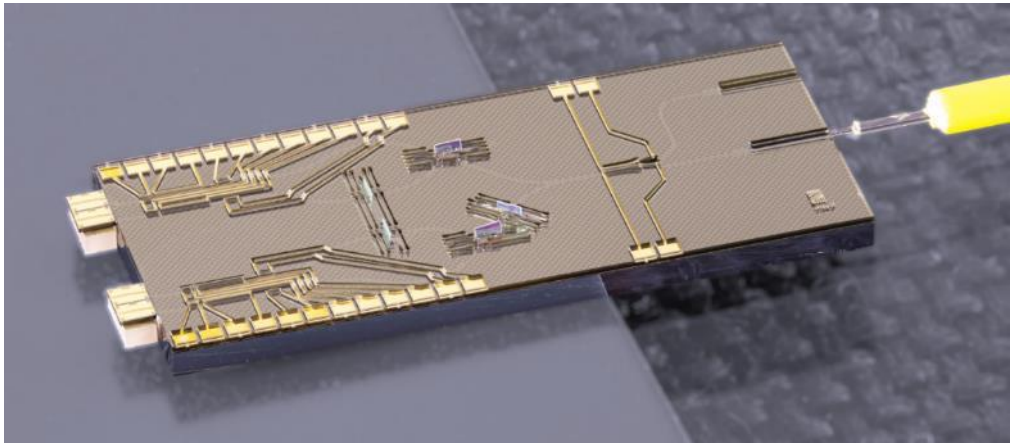

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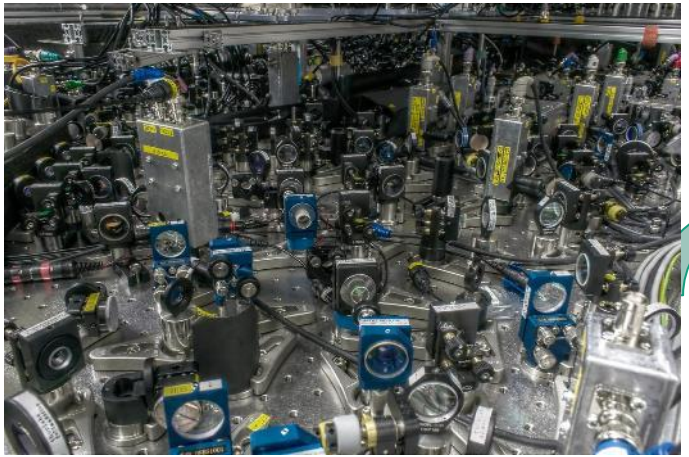
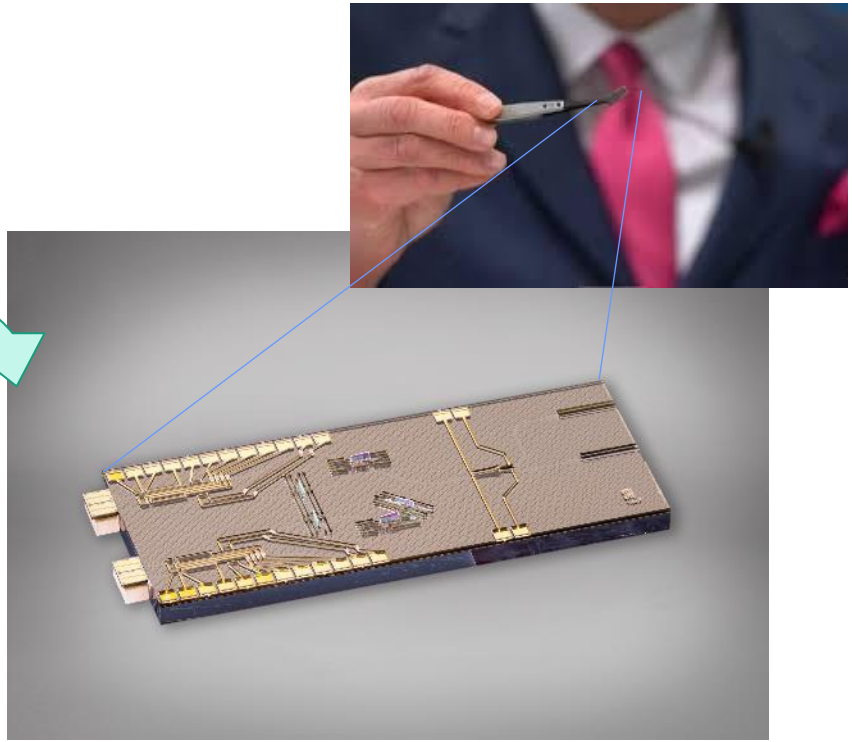
Photonic Integration





Integration of lasers, detectors, waveguides, filters, ...

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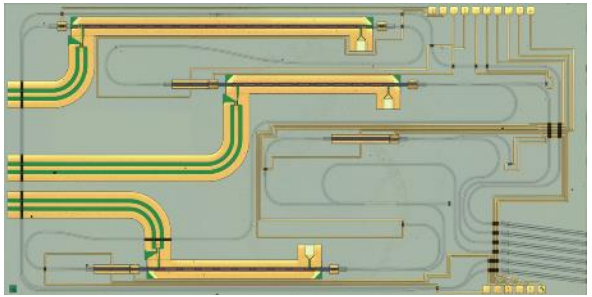
Photonic Integration



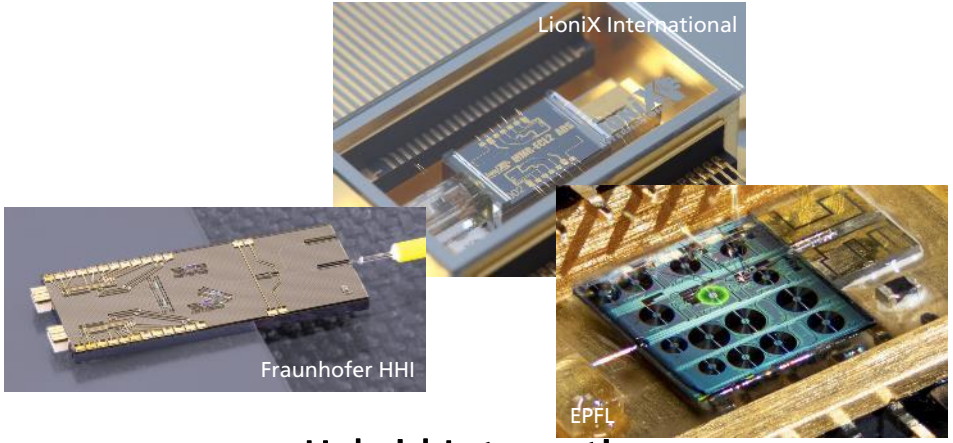
Monolithic Integration

Waveguides and actives on same die

→ Semiconductor material system, mostly InP

\+ Optical sub-assembly = fabricated chip

\- Limited by properties of material



Hybrid Integration

Waveguides and actives on separate dies

→ actives: semiconductor

→ passives: Silica, Si_3N_4, polymer, TFLN, …

→ NLO: ppLN, ppKTP, …

\- Additional assembly necessary

\+ Combination of optimal components and novel functionalities

\+ Yield management → known good dies

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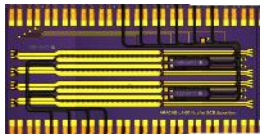
Hybrid Photonic Integration at HHI

Laser

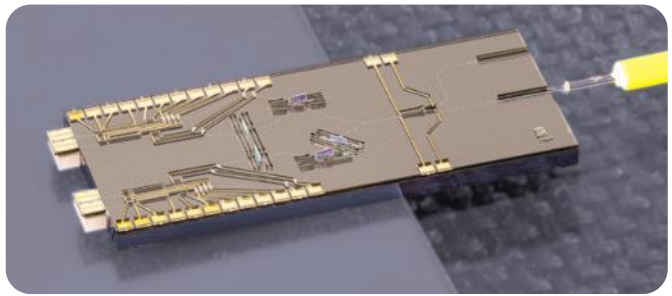
Receivers & Detectors



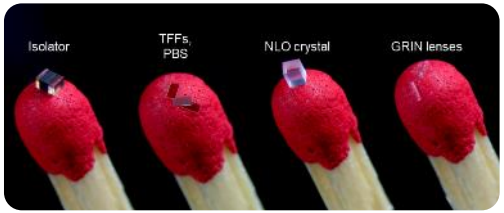
Modulators

SPADs

Single components



Hybrid PIC – PolyBoard



Micro-optical elements

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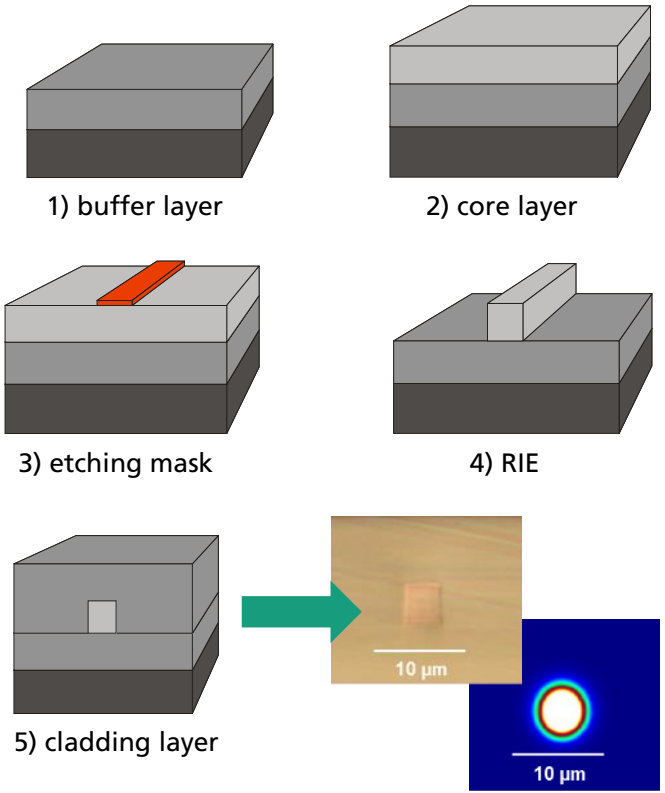
The PolyBoard Platform

HHI's polymer-based photonic technology PolyBoard

- **4" and 6" wafer** technology
  → scaling to 8" in the roadmap
- **Single-mode waveguides**
- **Refractive index contrast between Δn = 0.005 and Δn = 0.030**
- **No coating / polishing required**

Δn	Fiber butt coupling loss	Min. bend radius	Waveguide cross section
0.005	0.1 dB	15.0 mm	7.3 µm x 7.3 µm
0.011	0.6 dB	6.0 mm	6.0 µm x 6.0 µm
0.030	1.0 dB	1.5 mm	3.2 µm x 3.2 µm



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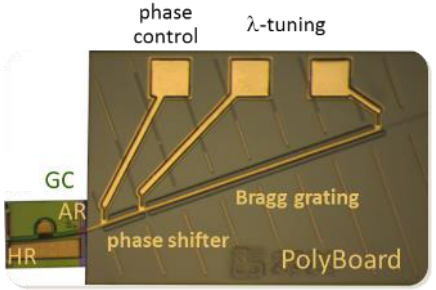
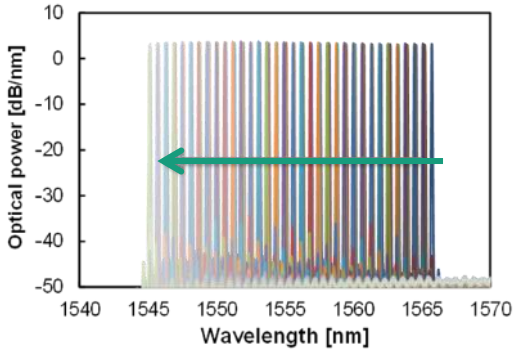
Hybrid Tunable Lasers

Flexible integrated light sources

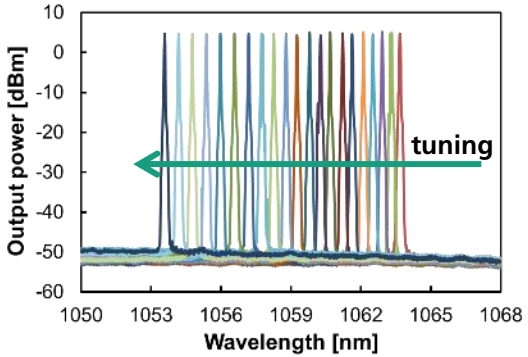
- Single photons via weak coherent pulses
- Integrated pump for non-linear optics
- Laser concept can be transferred into VIS → gain chip material



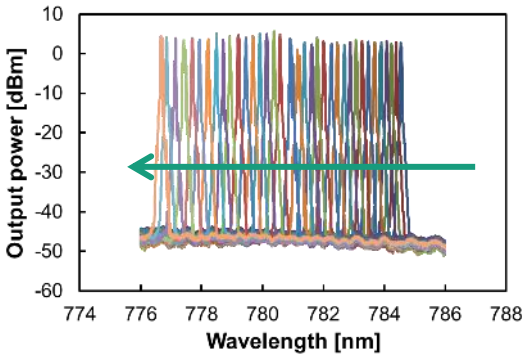
C band → InP gain chip



1064 nm → GaAs gain chip



785 nm → GaAs gain chip



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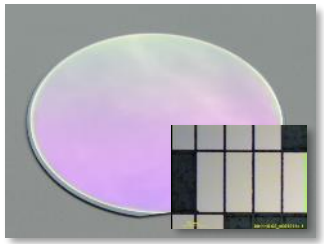
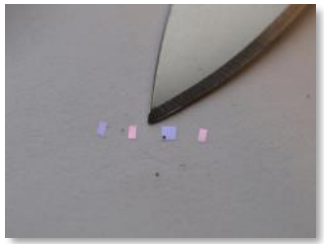
Slots & Thin Film Elements

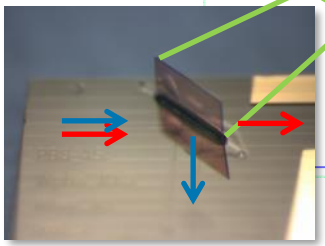
Efficient on-chip filtering

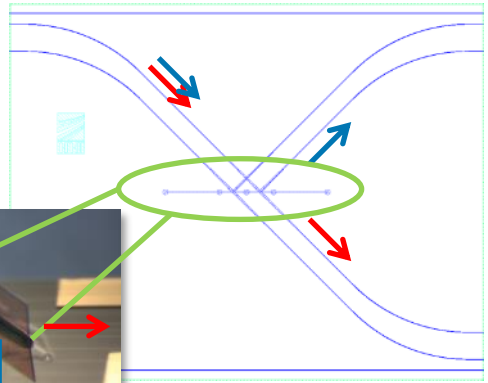
Thin-film elements are based on dielectric layer stacks

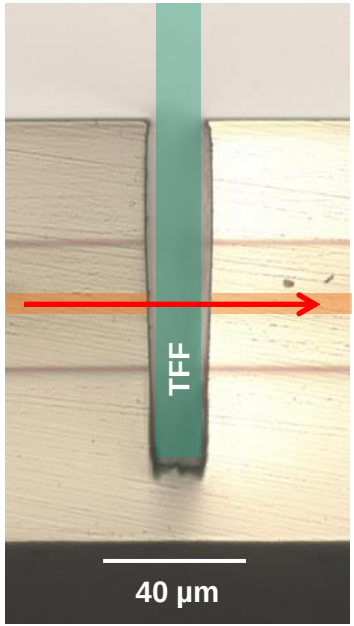
- Various efficient filter characteristics
  → wavelength, polarization etc.
- Small footprint
- Temperature-insensitive











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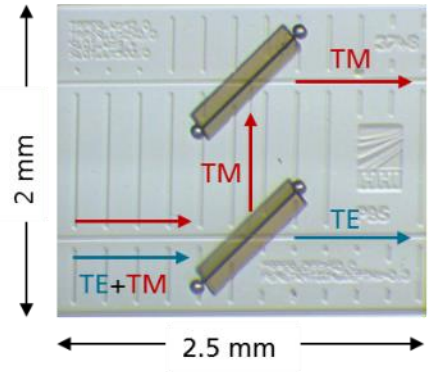
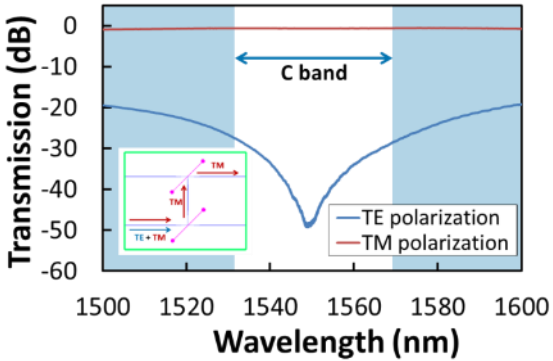
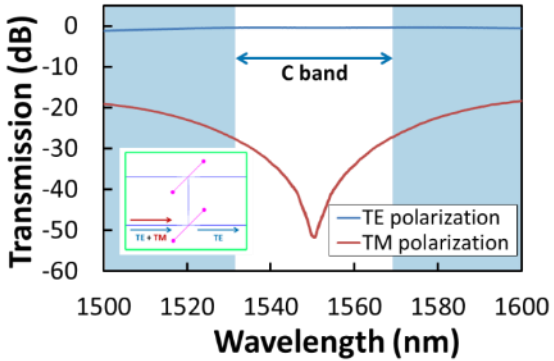
Slots & Thin Film Elements

Example: Efficient polarization splitter

- Footprint: some mm²,
- Total insertion loss: <0.7 dB (fiber-chip-fiber)







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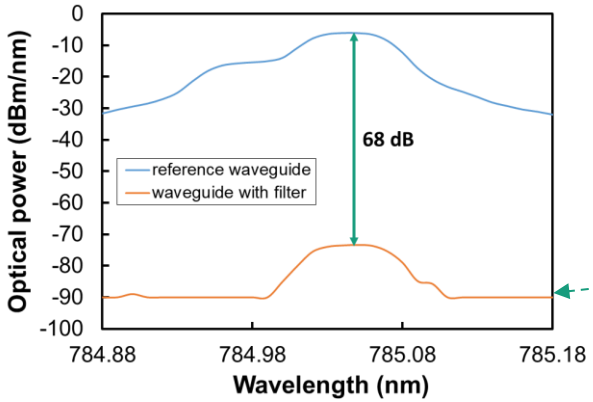
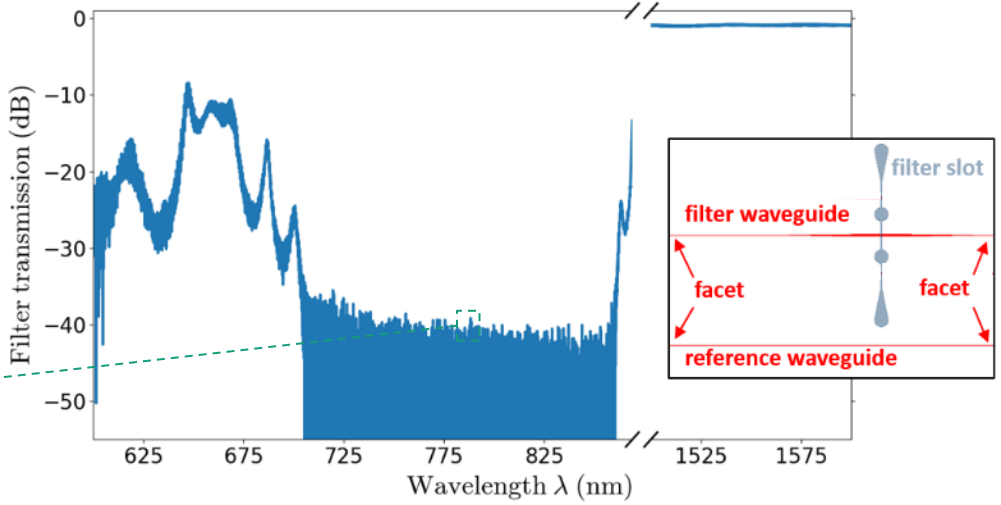
Slots & Thin Film Elements

Example: Pump suppression filter

- Pass: C band / stop: around 785 nm
- 68 dB pump suppression on chip





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UNIQORN Affordable Quantum Communication for Everyone

QUANTUM FLAGSHIP

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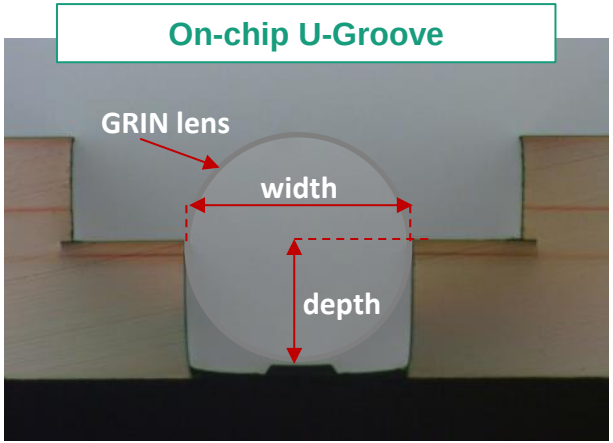
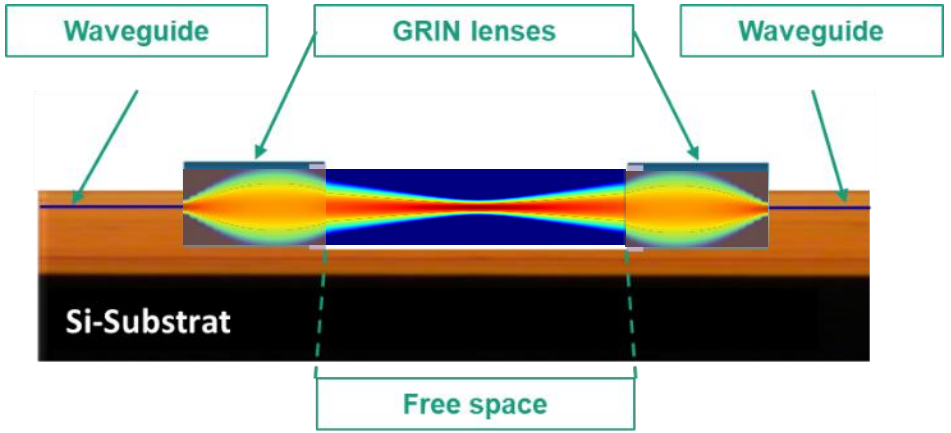
Micro-Optical Bench

On-chip free-space sections

Beam collimation with GRIN lenses in on-chip U groove





Free-space sections with lengths up to 10 mm
→ insertion of non-linear + non-reciprocal crystals

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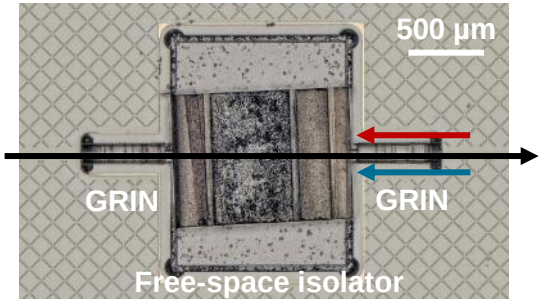
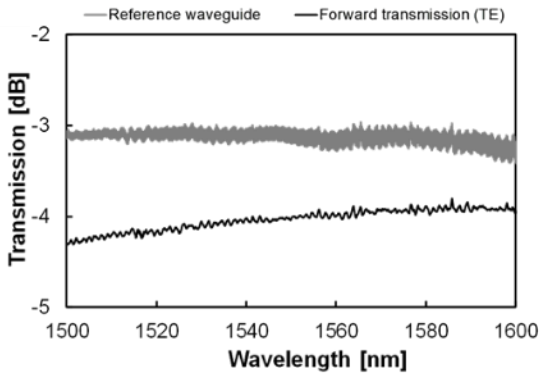
Micro-Optical Bench

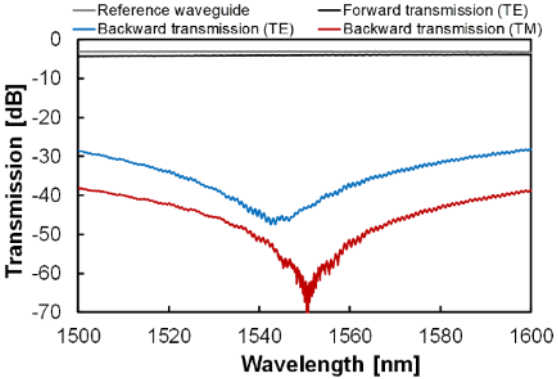
Example: Integrated optical free-space isolator



On-chip integrated free-space isolator



<1 dB on-chip loss in forward transmission



>40 dB peak isolation

<1 dB @1550 nm // > 28 dB isolation over 100 nm bandwidth

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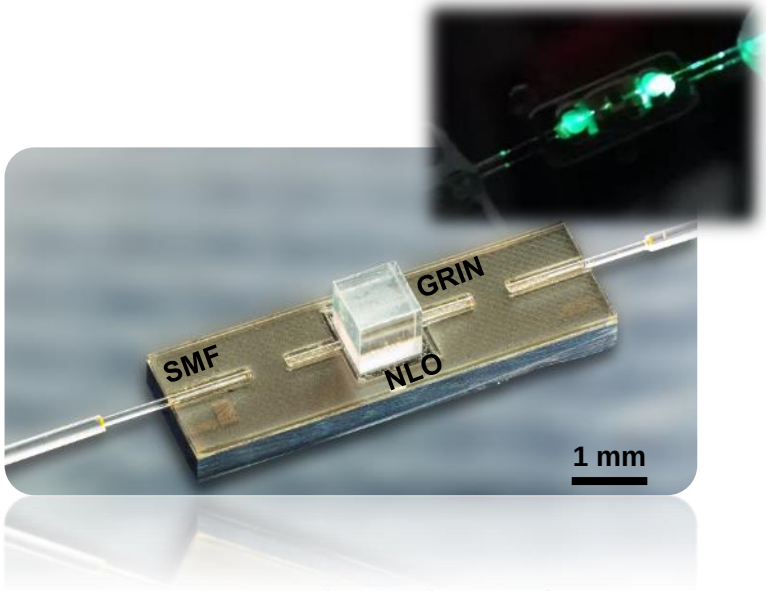
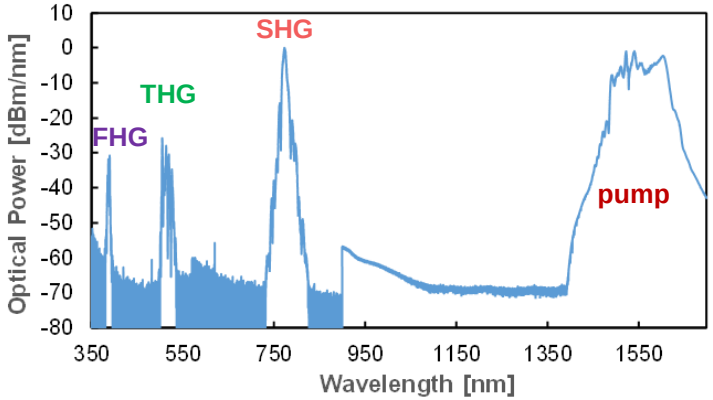
Micro-Optical Bench

Example: Non-linear optics with bulk crystals



NLO crystal in PolyBoard



Higher harmonic generation

1550 nm → 775 nm + 515 nm + 387 nm

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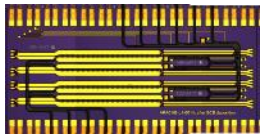
Hybrid Photonic Integration at HHI

Laser

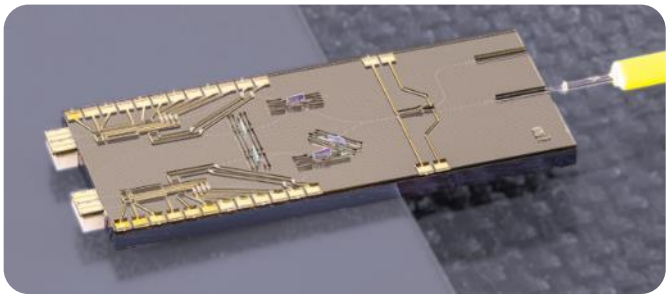
Receivers & Detectors



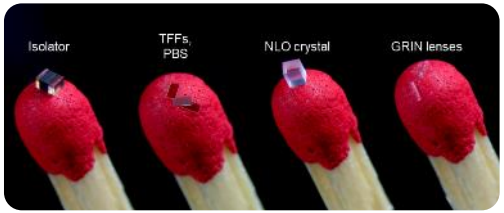
Modulators

SPADs

Single components



Hybrid PIC – PolyBoard



Micro-optical elements

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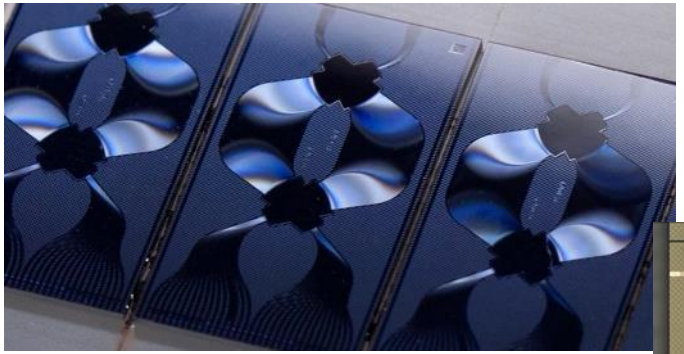
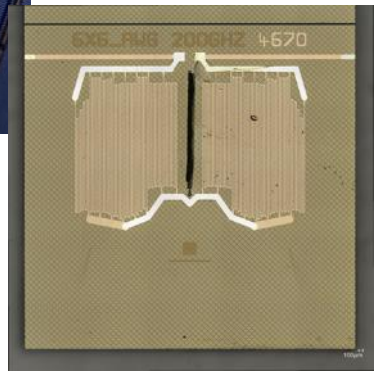
The Photonic Engine for Transceivers

PolyBoard AWGs for MUX/DEMUX

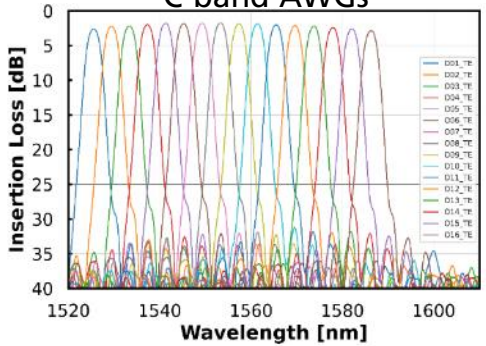
Tx & Rx AWGs on the same chip



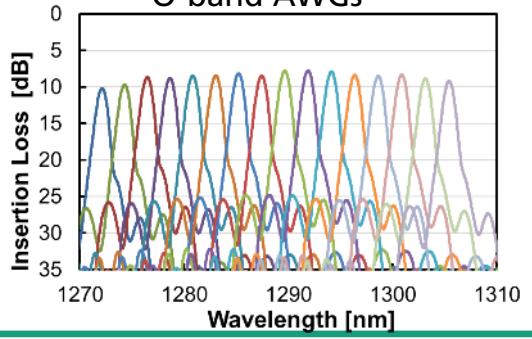
Possibility of tuning channels w/ µ-heaters



C-band AWGs



O-band AWGs



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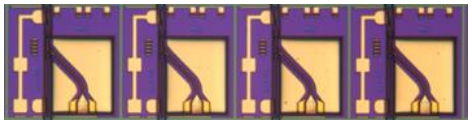
Putting all the Building Blocks Together TRx

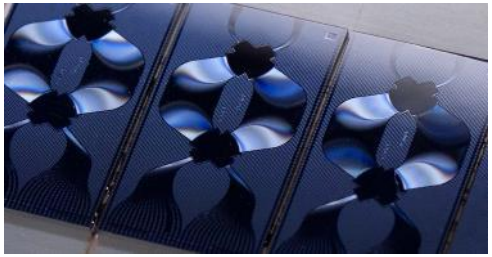
PolyBoard-based hybrid PIC for WDM Transceivers

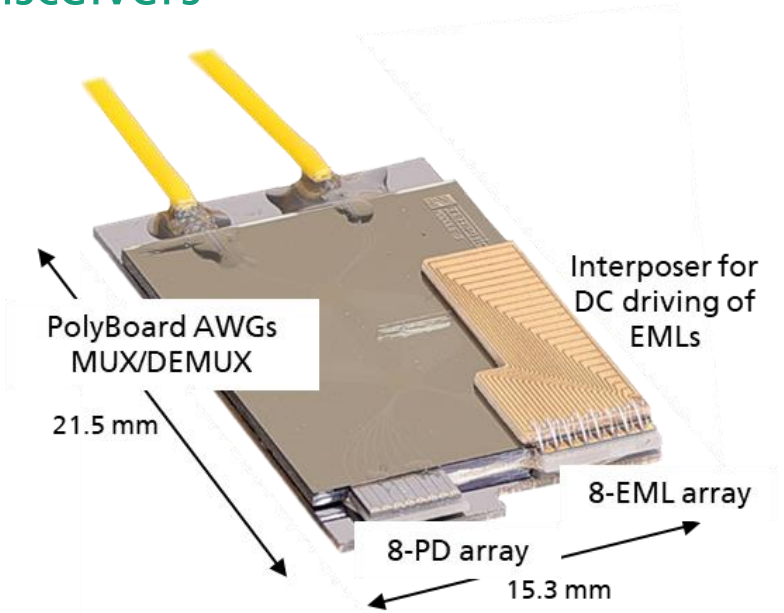
EML Arrays



Waveguide PD Array

PolyBoard AWGs





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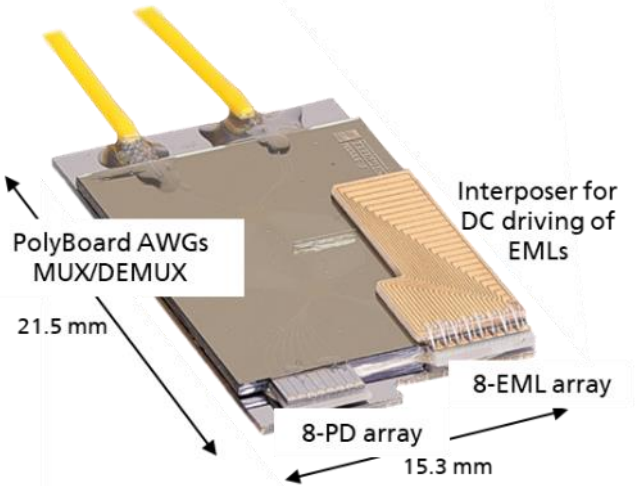
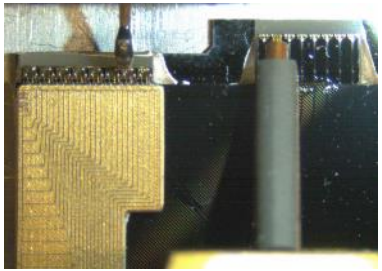
800 Gb/s Hybrid PIC Transceiver

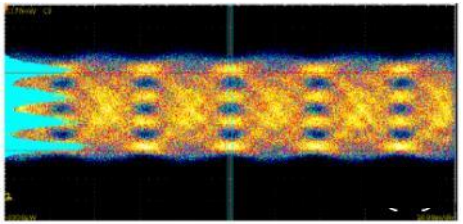
8-Channel
(1x 8-fold EML/PD arrays)



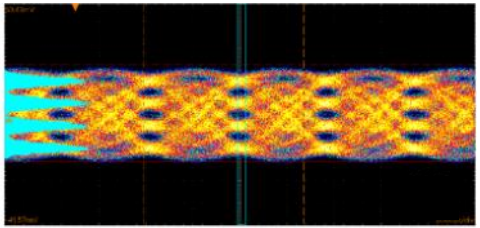
On-PIC testing



Tx: Real-time Eye of 50 Gbaud PAM-4 (B2B)



Rx: Real-time Eye of 50 Gbaud PAM-4 (B2B)



Capability of 800 Gb/s demonstrated

JOCN, 2024

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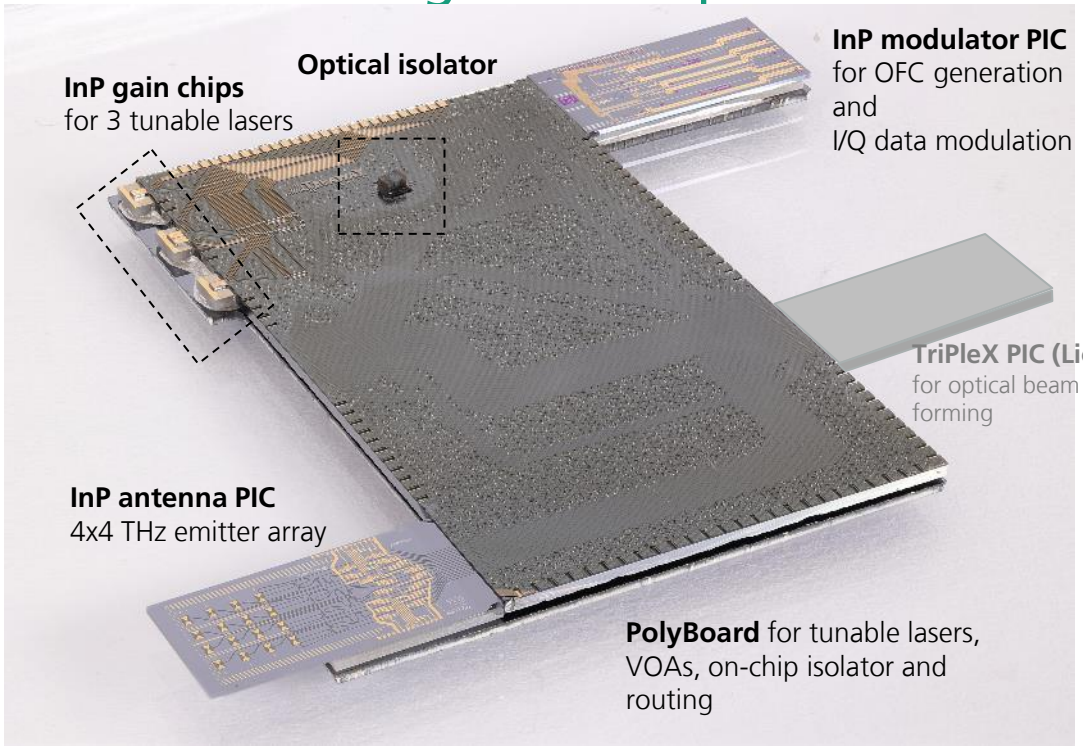
Beam Steerable Tx for Wireless Communications

Hybrid PICs Including THz components



EuMW 2024, Paris

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TERAWAY

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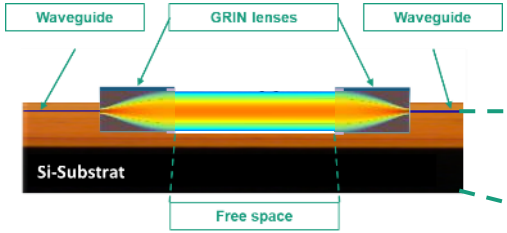
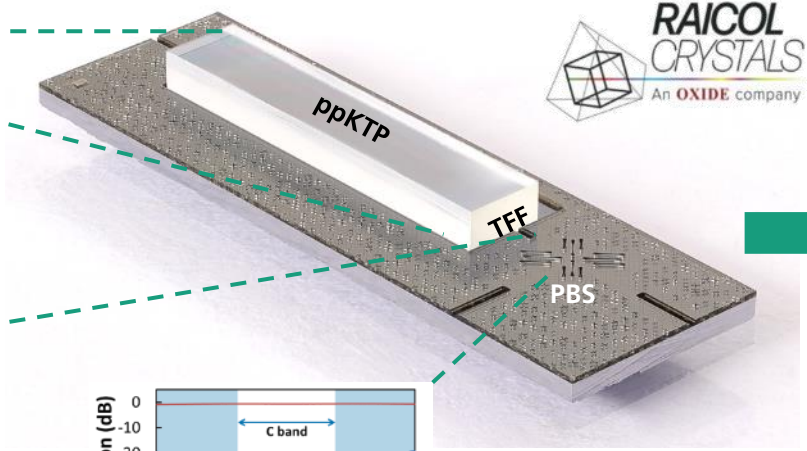
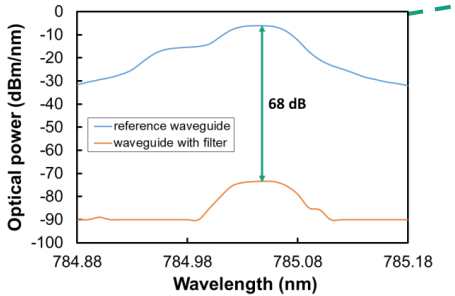
Integrated 1550 nm Photon Pair source

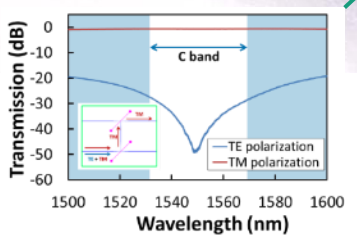
Enabled by micro-optical bench and hybrid integration



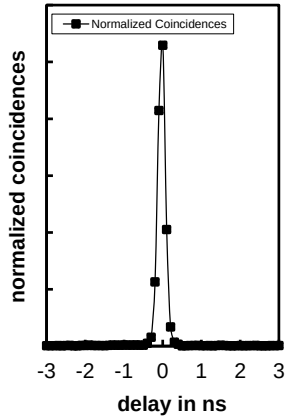


RAICOL CRYSTALS
An OXIDE company





Photon pairs
→ bunching



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WE PUT SCIENCE INTO ACTION.

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