PHOTONICS ASSEMBLY

Integrated Photonics Status and Challenges in Quantum

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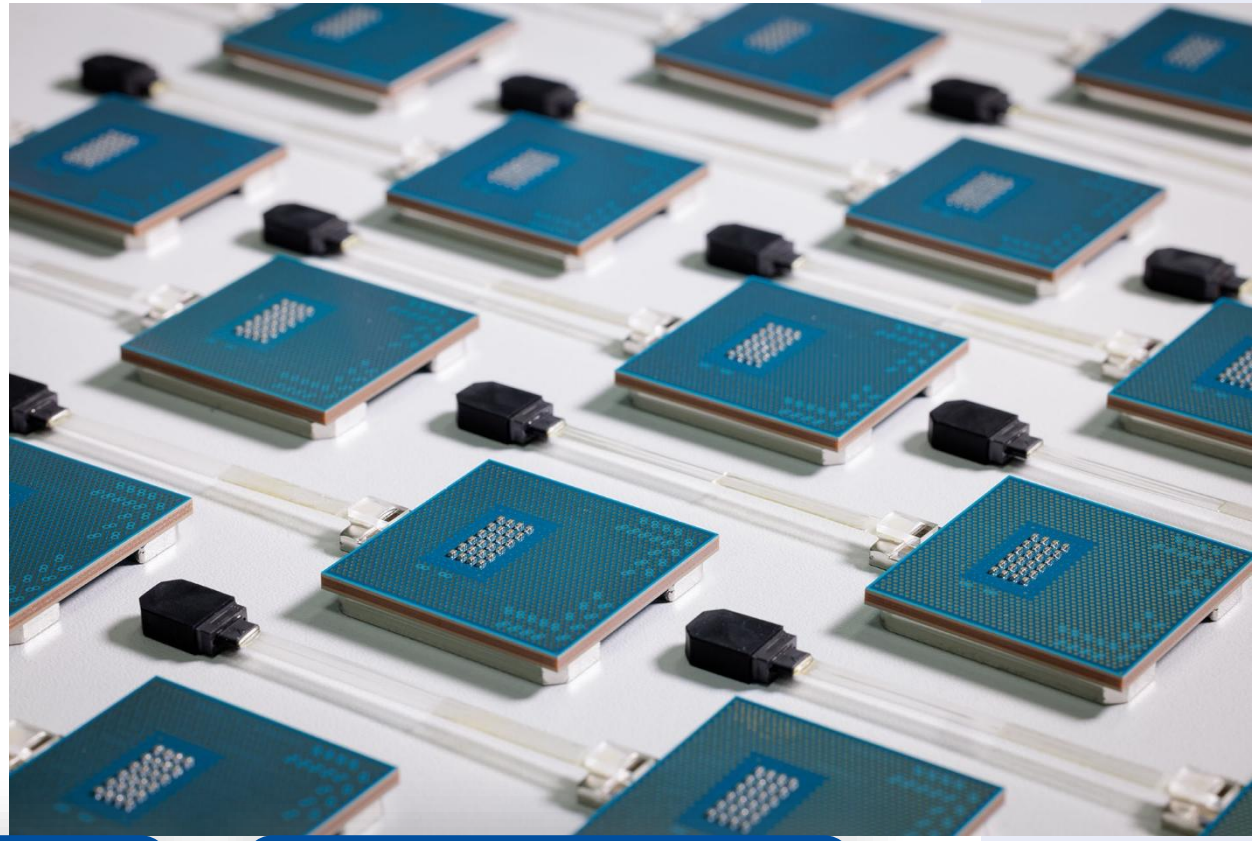
EPIC ONLINE TECHNOLOGY MEETING – PHOTONICS FOR QUANTUM INDUSTRY

MAY 11, 2026

PHIX Photonics Assembly

Large scale assembly and packaging foundry for photonic integrated circuits (PICs)

We have state-of-the-art facilities in the Netherlands and the United States from which we supply PIC and MEMS based components and modules in scalable production volumes.



All PIC platforms

Silicon photonics, silicon nitride, indium phosphide, thin-film lithium niobate, and many more.

From prototype to volume

We help optimize your PIC design and module BOM for smooth scale-up to large manufacturing volumes.

World leading expertise

We’re specialized in hybrid PIC assembly, fiber attachment, and (ultra-high frequency) electronics interfacing.

Core Expertise

Optical Interfaces

- Low loss and reliable: fiber to chip (F2F), chip to chip (C2C)
- Mode field adapters: SiN, lenses, phase
- Lens printing

Material Integration

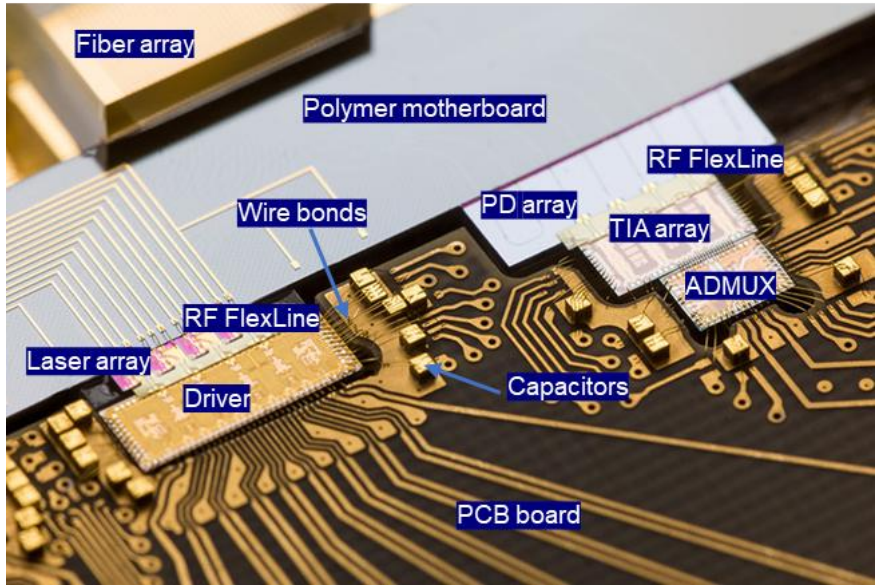
- Hybrid integration
- Flip chip

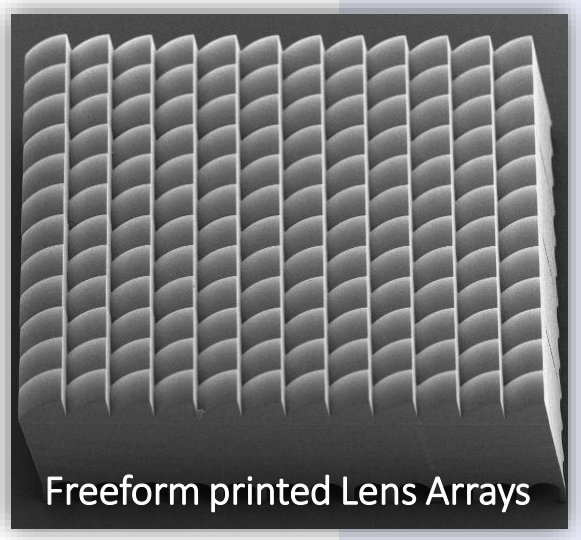
Electrical

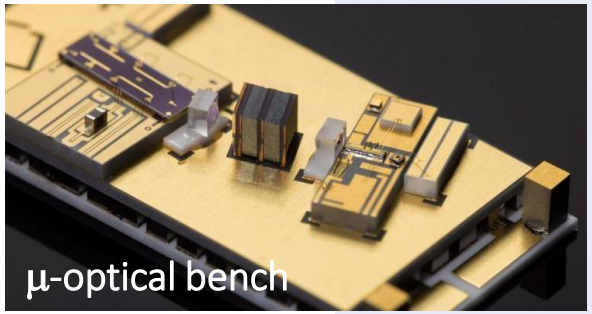
- High density DC
- RF up to 140 GHz

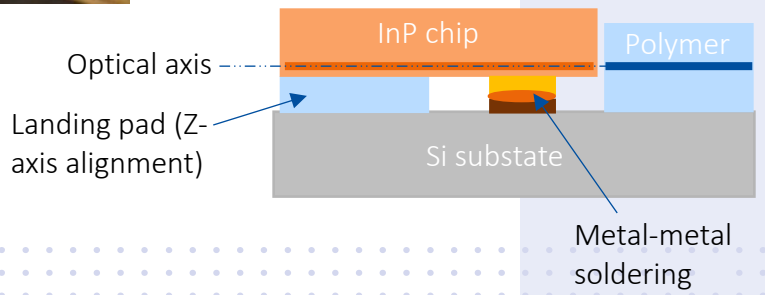
System Integration

- Optical, mechanical, electrical & thermal
- Design, supply chain, assembly









PICs in Quantum

Market

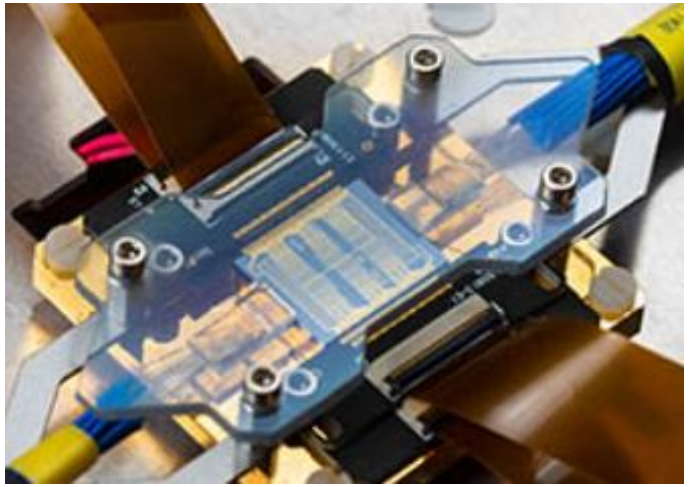
- Compute (photonic)
- Sensing: PNT, healthcare
- Communication: QKD

Technology

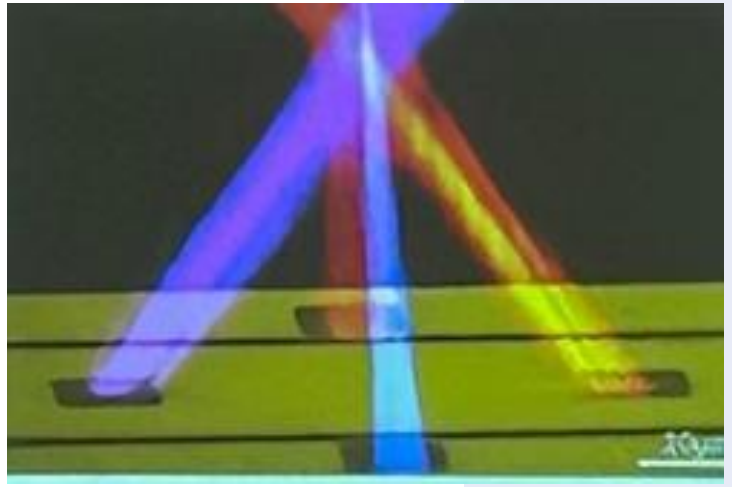
- Atomic clock / frequency combs
- Ion / neutral atom traps
- Narrow linewidth, tunable laser
- Low loss optical interfaces

Challenges

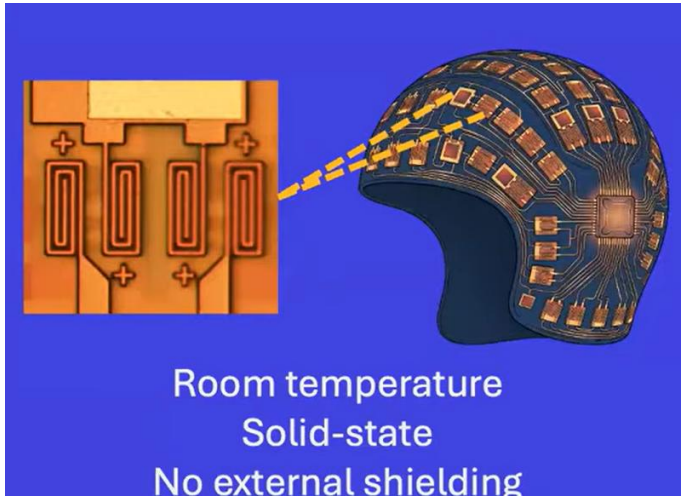
- Complex photonic circuitry
- Multiple wavelengths, beam steering,..
- Scalability



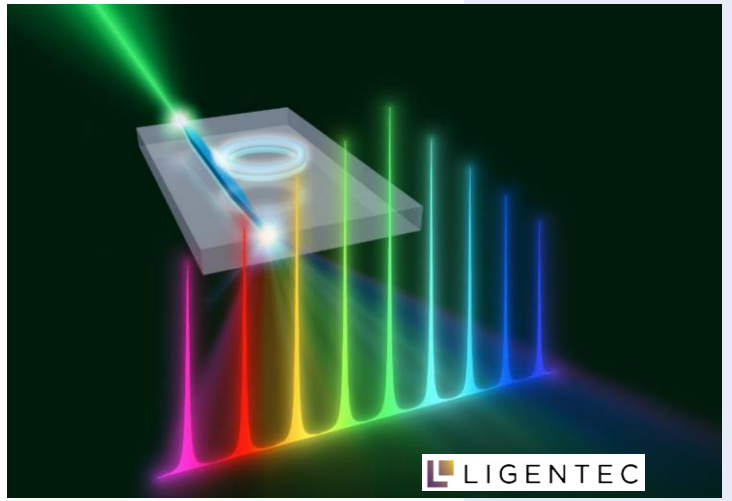
Photonic Quantum Processor



Ion Trap (schematics)



Brain Activity Sensor (magnetic)



Frequency Comb

Photonic Enablers - Lasers & Traps

<u>Laser w/ high quality Photons</u>

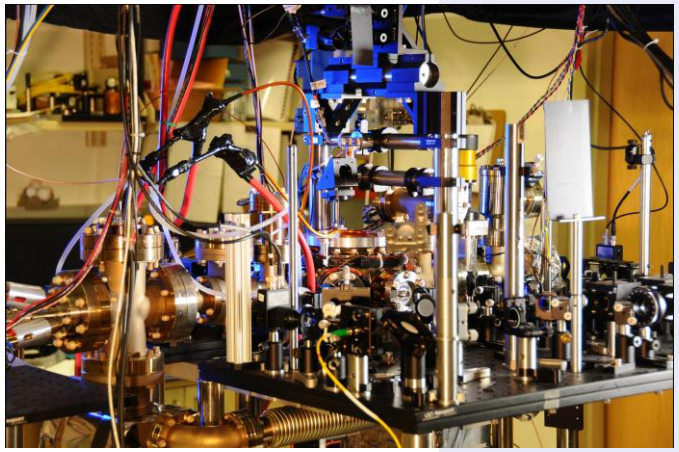
- Initializing, manipulating, reading of atoms / ions
- Low linewidth, low noise, tunable, stable operation
- Wide wavelength range from 0.2 um to 4 um
- Power from mW to W

Requirements for read / write

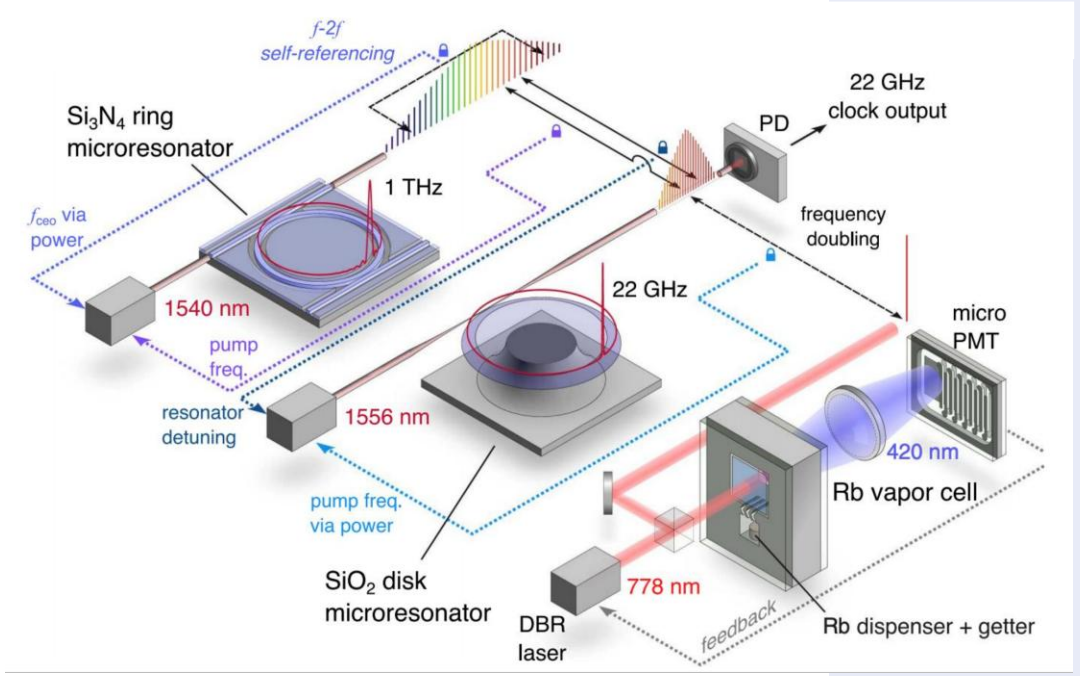
- Multi-beam localization of atoms, ions
- Precise “tweezers”
- Cryo environment

<u>Opportunities enabled by photonic integration</u>

- Integration -> Scalability



Yb atomic clock @ NIST

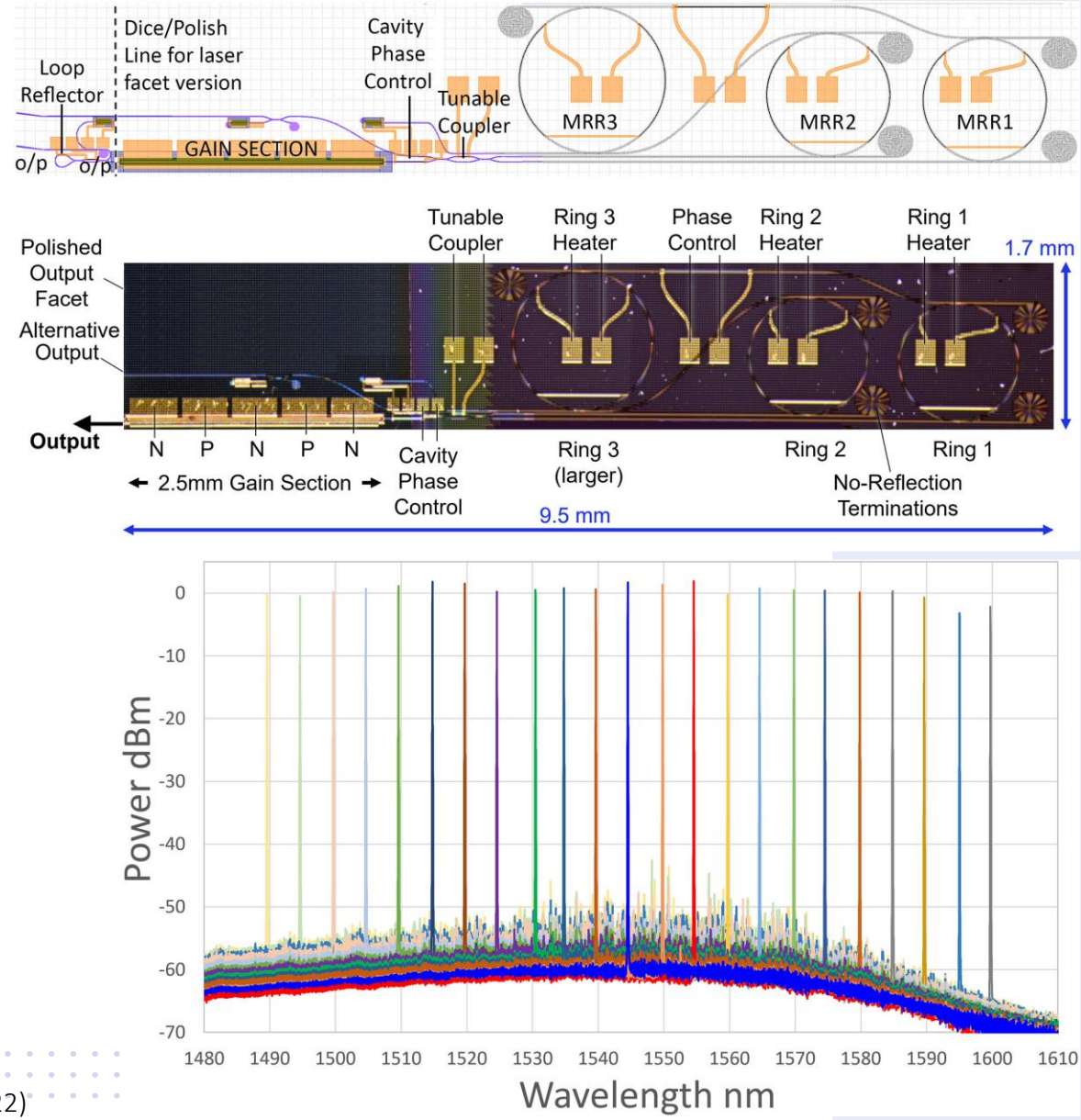


PIC based atomic clock

High Quality Photons – Integrated Laser

- ECL (External Cavity Laser)
  - Integrated Coherent Tunable Laser
  - < 100 Hz Lorentzian linewidth
  - -155 dBc/Hz RIN
  - 120 nm tuning range
  - VIS toNIR
  - 15 mW output power
- Power Scaling
  - Serial amplification, also scales noise

  -> Coherent beam combining on the chip

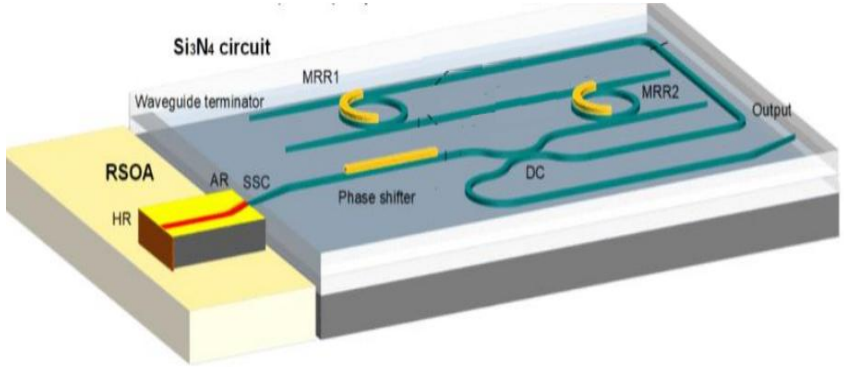


P.Morton et al., Journal of Lightwave Technology, Vol.40, NO.6 (March 2022)

Scalable Manufacturing of Laser

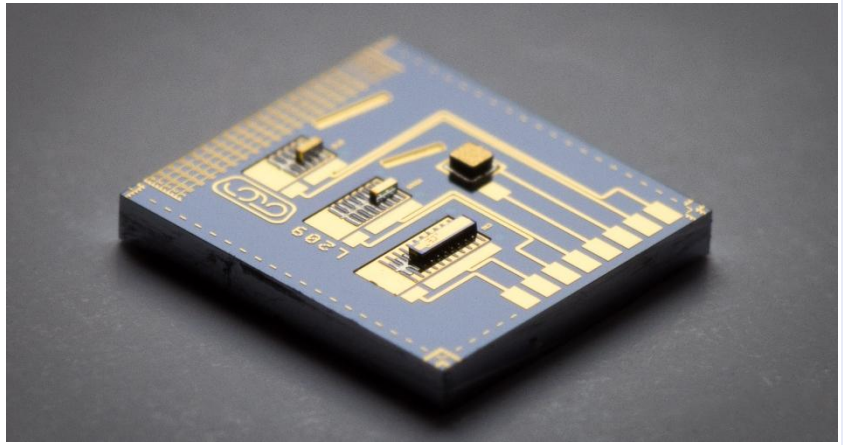
Technology

- SOA with broad gain
- PIC defines:
  - narrow linewidth (kHz) & tuning range (~100 nm)
  - stable wavelength over temperature (10 kHz)
  - Comb laser w/ narrow channel spacing (<<25 GHz)
  - Fast modulation thru heterogenous integration of TFLN



Manufacturing

- Flip chip bonding of lasers on PIC
- Multiple wavelengths on one PIC
- Highly scalable, testing can be challenging
- Other applications have similar needs, i.e. AR/VR



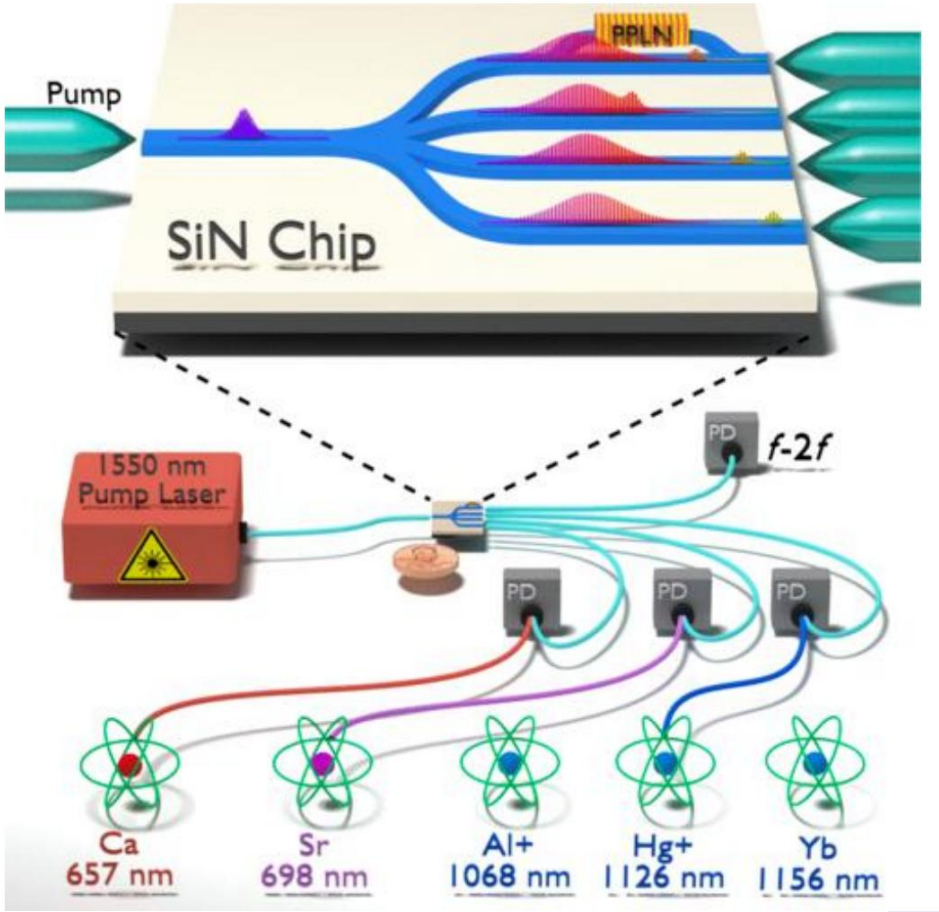
Supercontinuum Laser based on PIC

Technology

- PPLN on SiN
- 50 mW output power
- 900 nm wide spectrum

Applications

- Spectroscopy
- Precision agriculture
- Environmental Imaging
- Bio-medical imaging
- …



D. Carlson, et al. Phys. Rev. Applied (2017)

Conclusion

Market

- Quantum is built on photonics
- Strong investments from government and private equity
- Highly fragmented, emerging markets

Technology

- Lasers & traps are basic building blocks
- PICs need complex photonic circuitry with active / passive integration from ~0.4 um to ~ 1.5 um
- Low loss optical interface from ~0.1dB to 1.0 dB
- Scalable manufacturing enabling >10,000 Qbit hardware

Industry needs & PHIX offer

- Entrepreneurs addressing emerging markets
- Extend supply chain: optical isolator in VIS, PIC in VIS, multilayer waveguide PIC, low loss optical interconnect,..
- PHIX is packaging partner from prototype to high volume w/ expertise in lasers & PIC from VIS to NIR