Dominic Schulz, Fraunhofer HHI

Photonic Quantum Devices

EPIC Online Technology Meeting on Photonics for Quantum Industry, 11. May 2026

Agenda

- Introduction
- Motivation & Market projection for Quantum Technologies
- Photonic Components and PICs (monolithic / hybrid) for Quantum
- Future Challenges for Quantum Technologies

dominic.schulz@hhi.fraunhofer.de

Fraunhofer-Gesellschaft

Europe’s largest research organization

75
Institutes in Germany

Worldwide
research collaborations

Fraunhofer HHI

140+ Mio € Budget
1000+ people
80% self-financed

More than
32.000
employees

3,6
Billion euros Budget

- Video Compression & AI
- 5G, 6G & Photonic Networks
- Photonic Components & PICs

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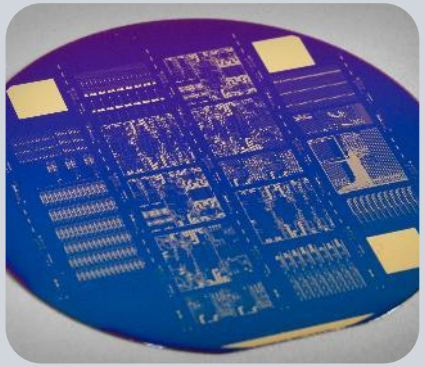
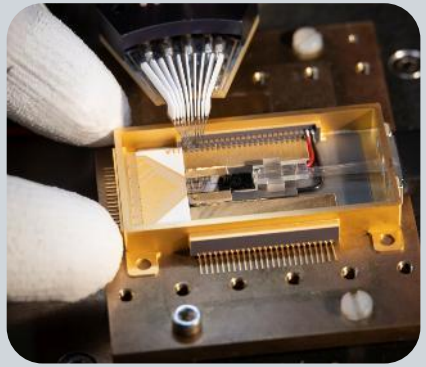
Fraunhofer HHI's Photonic Solutions

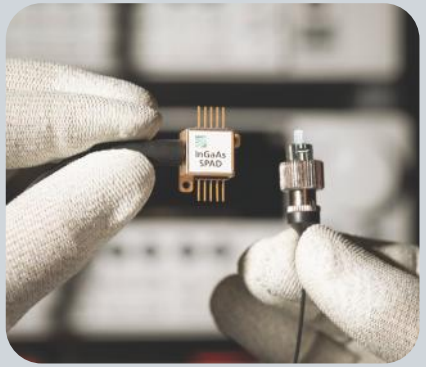
Covering the entire photonics value chain from design to system



Foundry Services, Chips & PICs



Hybrid & Heterogeneous Photonic Integration



Photonic Modules

Sub Systems

Turnkey Systems

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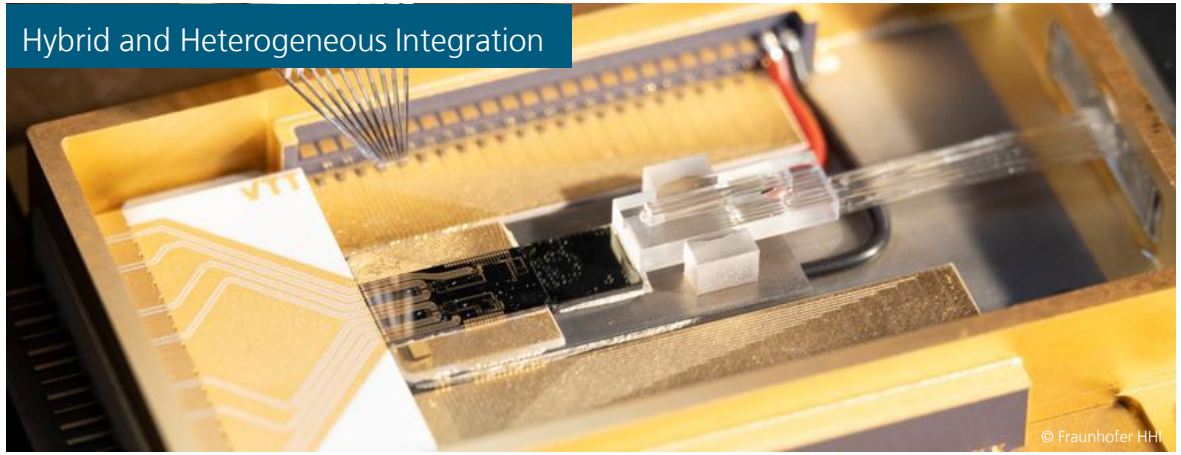
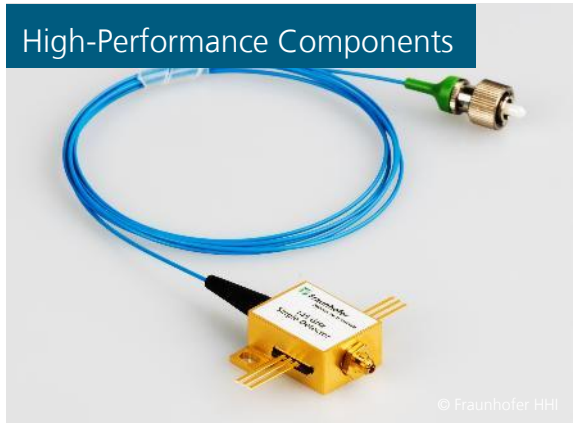
Photonic Expertise

Customized designs available for dedicated applications

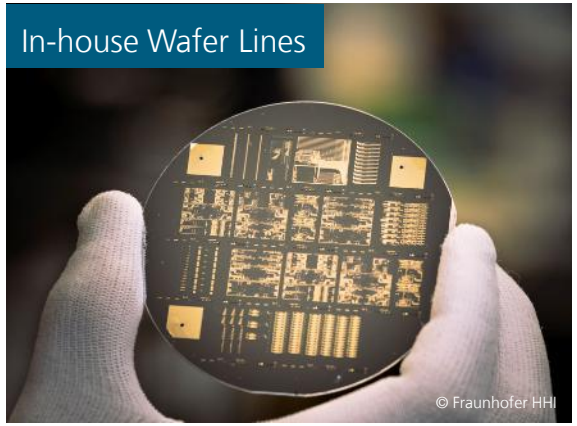
Hybrid and Heterogeneous Integration



High-Performance Components



In-house Wafer Lines



Photonics at Fraunhofer HHI

- 40+ years experience in design & processing, complete wafer process line
- Design and fabrication of complex PICs, including hybrid & heterogeneous active-passive integration
- Assembly and packaging for photonic modules

Highest performance in photonics

InP (MPW), TFLN (MPW), Si_3N_4, Polymer

Wavelength range:	450 – 4500 nm
Quantum efficiencies:	up to 99%
Bandwidths:	up to 145 GHz
Optical powers:	up to 4.9 W
Data rates:	up to 1,6 Tbit/s

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Applications & Markets for Photonics

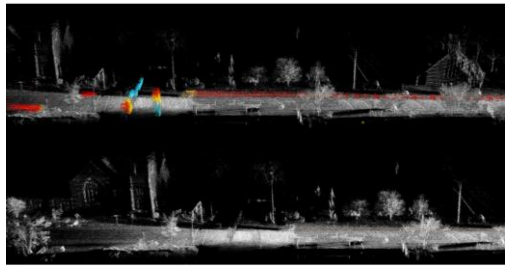
Estimated tenfold growth of quantum communication market in next decade

Data- & Telecom

Quantum

Medical

Mobility



6G

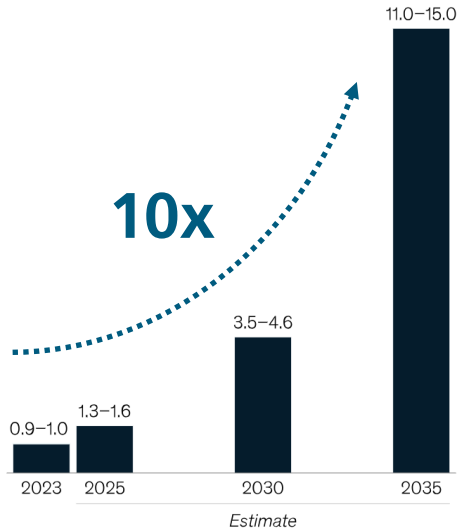
Climate

Security

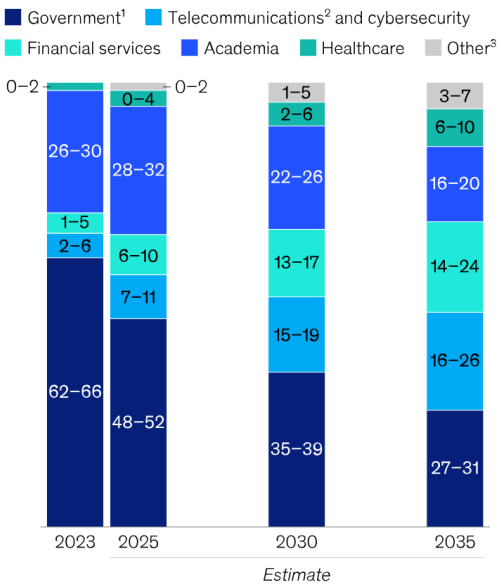
Production

The quantum communication market is projected to reach $11 billion to $15 billion by 2035.

Quantum communication market size, $ billion



Quantum communication market breakdown by customer type, %



[1]Includes defense.
[2]Includes public cloud providers.
[3]Includes manufacturing, automative, insurance, etc.
Source: Press search; McKinsey analysis

McKinsey & Company

McKinsey & Company, The Year of Quantum: From concept to reality in 2025 June 23, 2025 | Report

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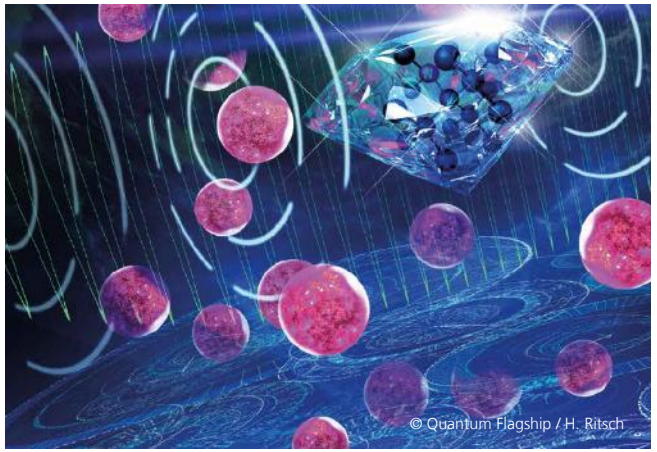
Quantum Technologies

Manipulation of photons is key for many applications

Quantum Communications

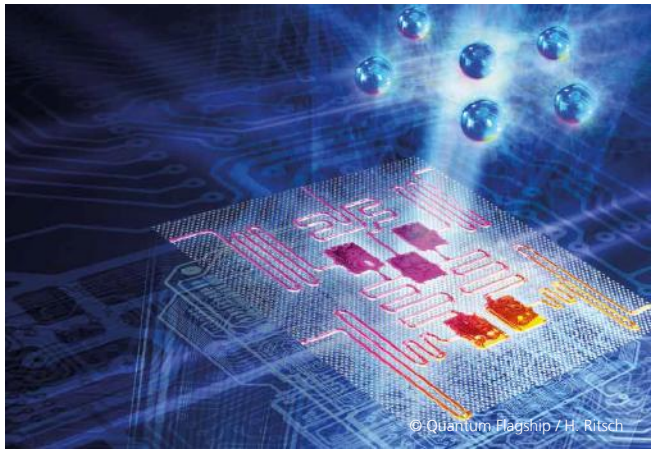
→ Quantum Key Distribution (QKD) with single photons

→ Exchange of quantum states with entangled photons



Quantum Sensing

→ Atomic and solid-state quantum systems für optical clocks, magnetometers, gravimeters, …



Quantum Computing

→ Qubits for parallel Information processing in superpositions (superconducting, ion traps, atoms or photons)

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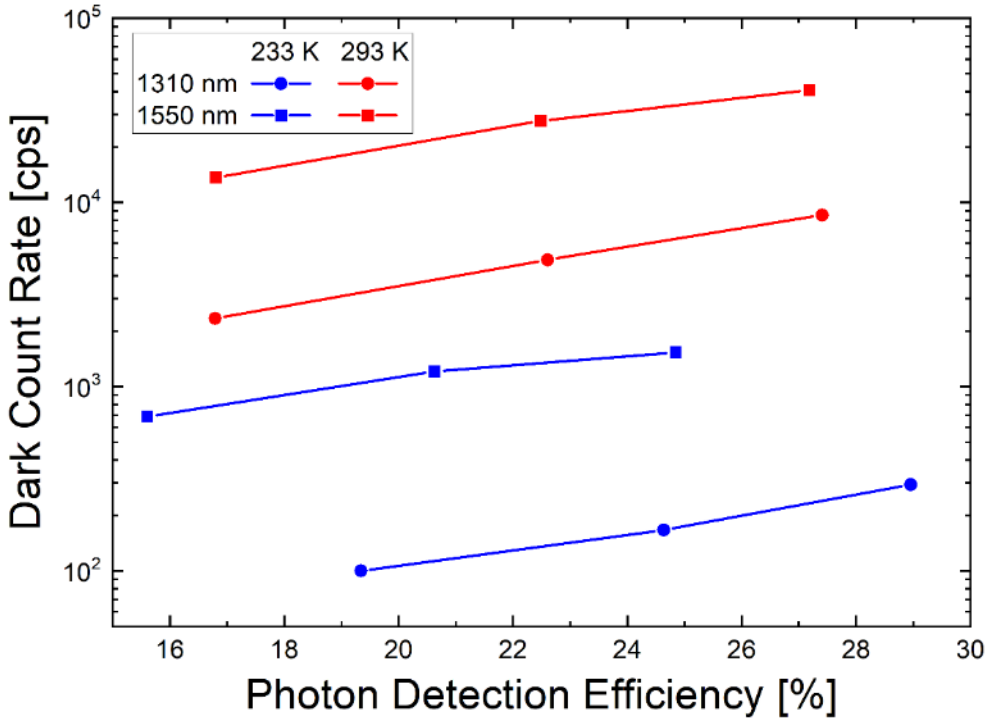
InGaAs Single Photon Avalanche Diode for SWIR

Packaged chips for optimum performance in O- and C-band

SPAD Chip

SPAD Module



- Design and fabrication of InGaAs SPADs in Europe
- Drop-in compatible to existing SPAD modules from Asia
- SPADs now available as O- and C-band option

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Photonic Integrated Circuits (PICs)

Monolithic vs. hybrid integration approaches

Monolithic Integration

Waveguides and actives on same die
→ Semiconductor material system

\+ Optical sub-assembly = fabricated chip

\- Limited by properties of material

Hybrid Integration

Passives, actives and NLO in separate dies
→ actives: semiconductor
→ passives: Silica, Si_3N_4, polymer
→ NLO: ppLN, ppKTP, …

\+ Combination of optimal components and novel functionalities

\- … but assembly steps necessary

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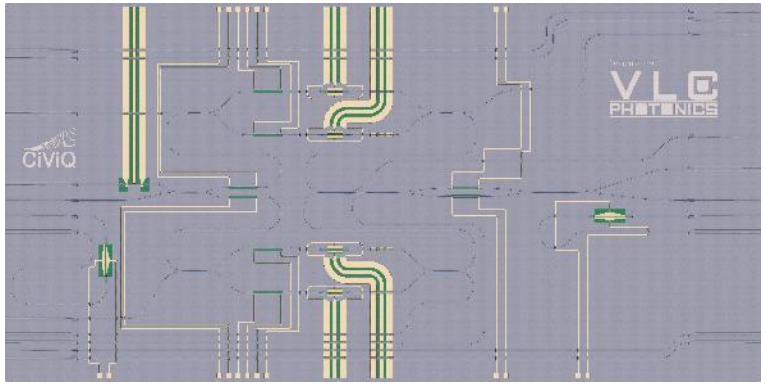
Photonic Integrated Circuits (PICs)

Monolithic vs. hybrid integration approaches

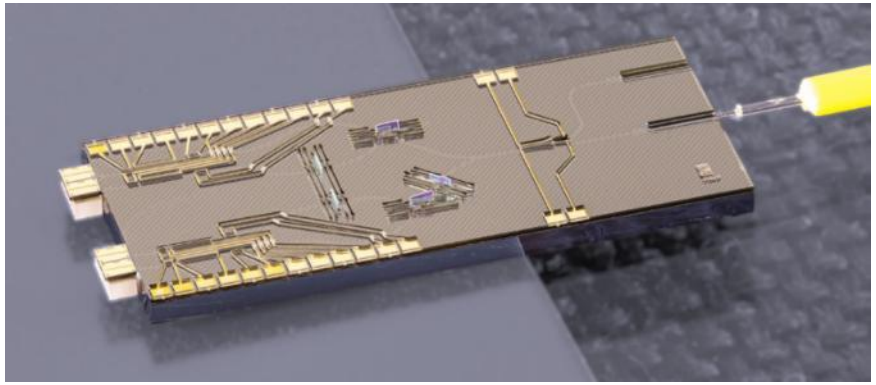
Monolithic Integration



CV-QKD-Tx

→ Monolithic InP PIC

Hybrid Integration



DV-QKD-Tx

→ Hybrid InP + Polymer PIC

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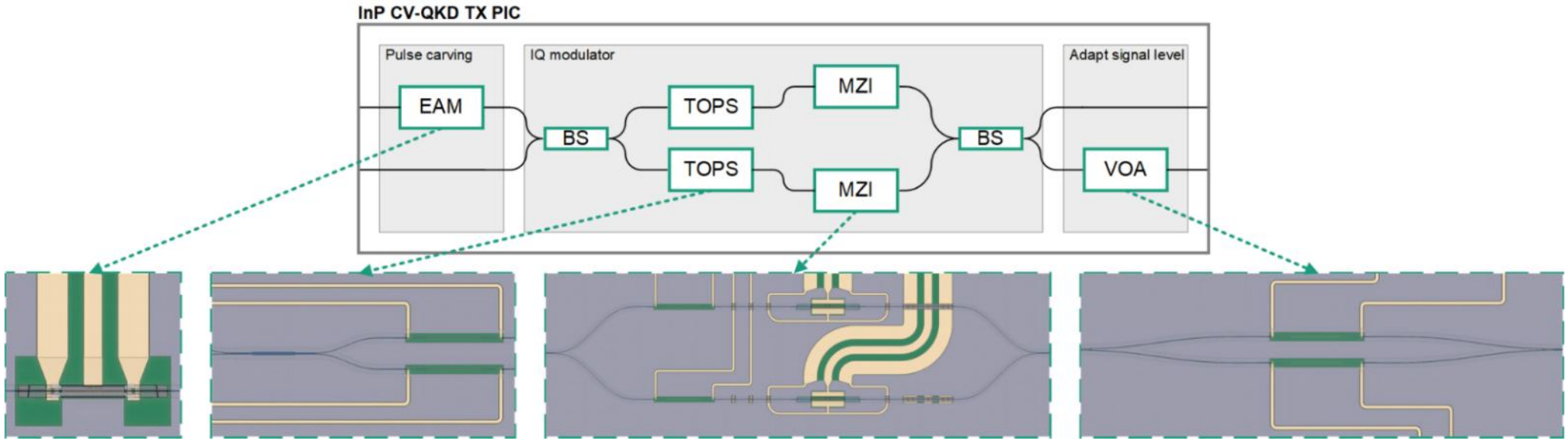
Quantum PICs on InP MPW Runs

Monolithic integration of standard functionalities

- Continuous-Variable Quantum Key Distribution Transmitter (CV-QKD TX)
  - Includes several actives (EAM, TOPS, CIPS) and passives (waveguides, spot-size converters, MMI)
  - Designed with PDK and fabricated on HHI InP transceiver MPW platform



J. Aldama et al., "Integrated InP-based transmitter for continuous-variable quantum key distribution," Opt. Express 33, 8139-8149 (2025)

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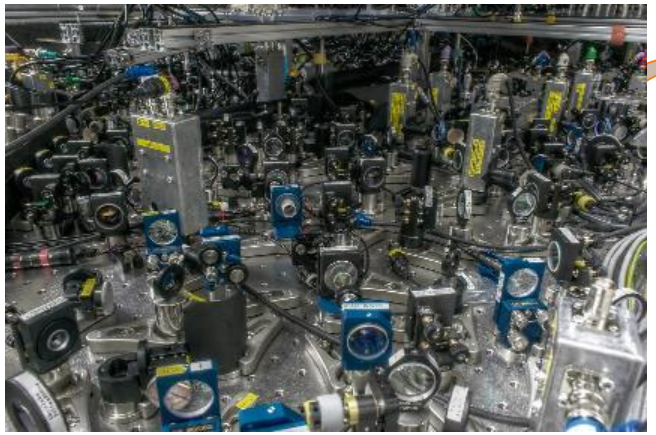
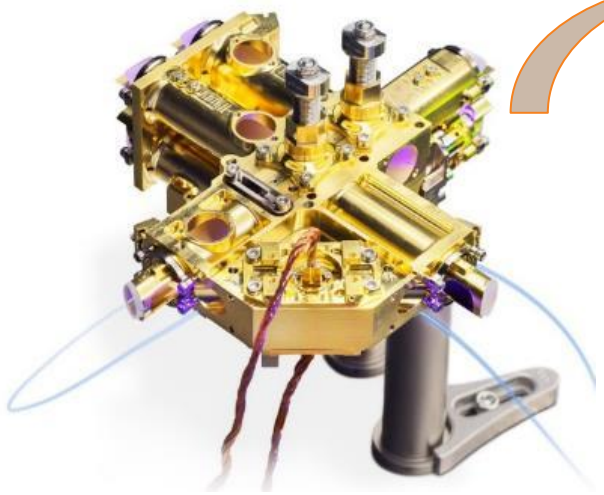
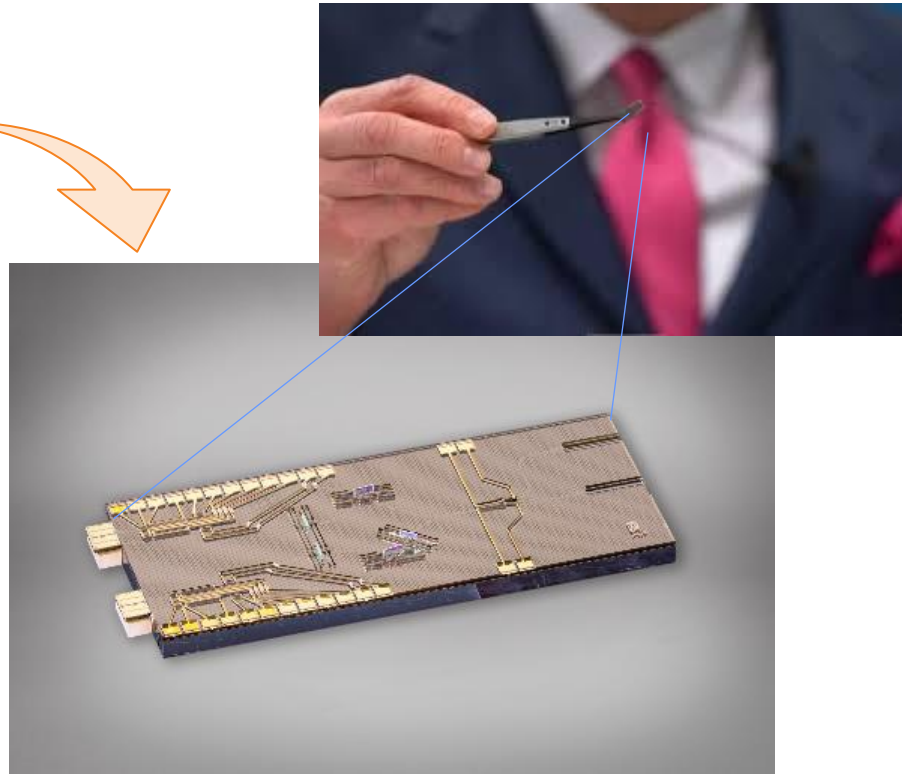
Photonic Integration for Quantum Technologies







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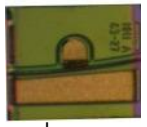
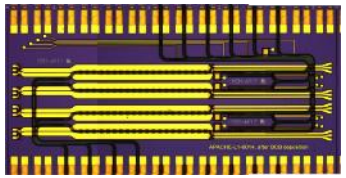
Hybrid PICs for Quantum

Multiple wafer technologies (hybrid), but also µ-optics



Laser

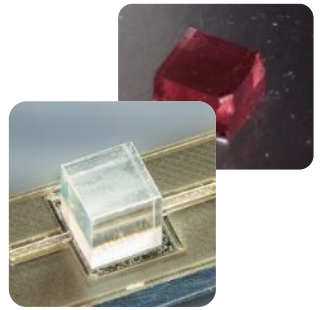
Receivers & Detectors



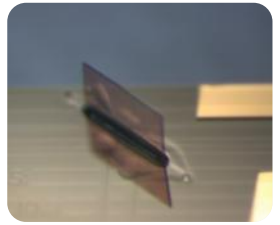
Modulators

SPADs

Single components

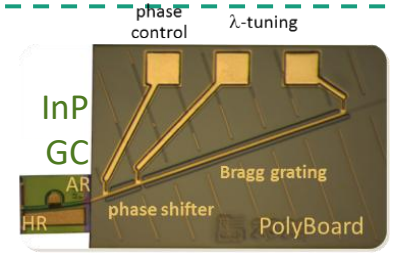


Crystals

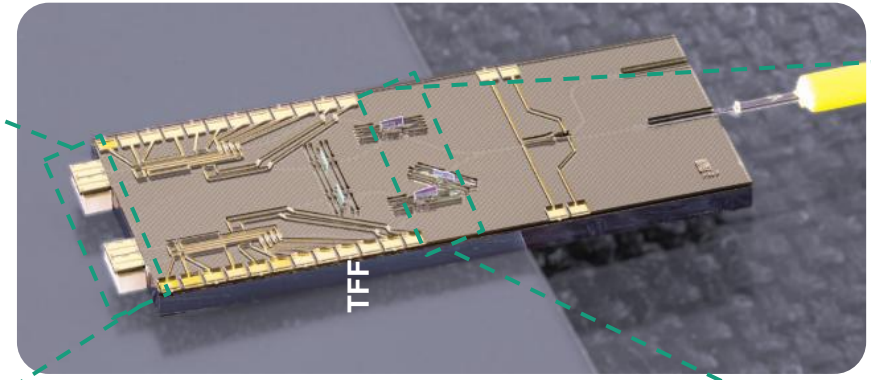


Filters

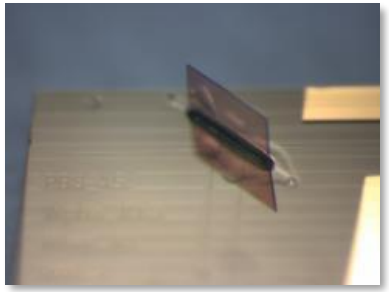
Micro-optical elements



20 nm tuning range //
10 Gbit/s direct modulation



Hybrid PIC



> 45 dB max. polarization extinction ratio

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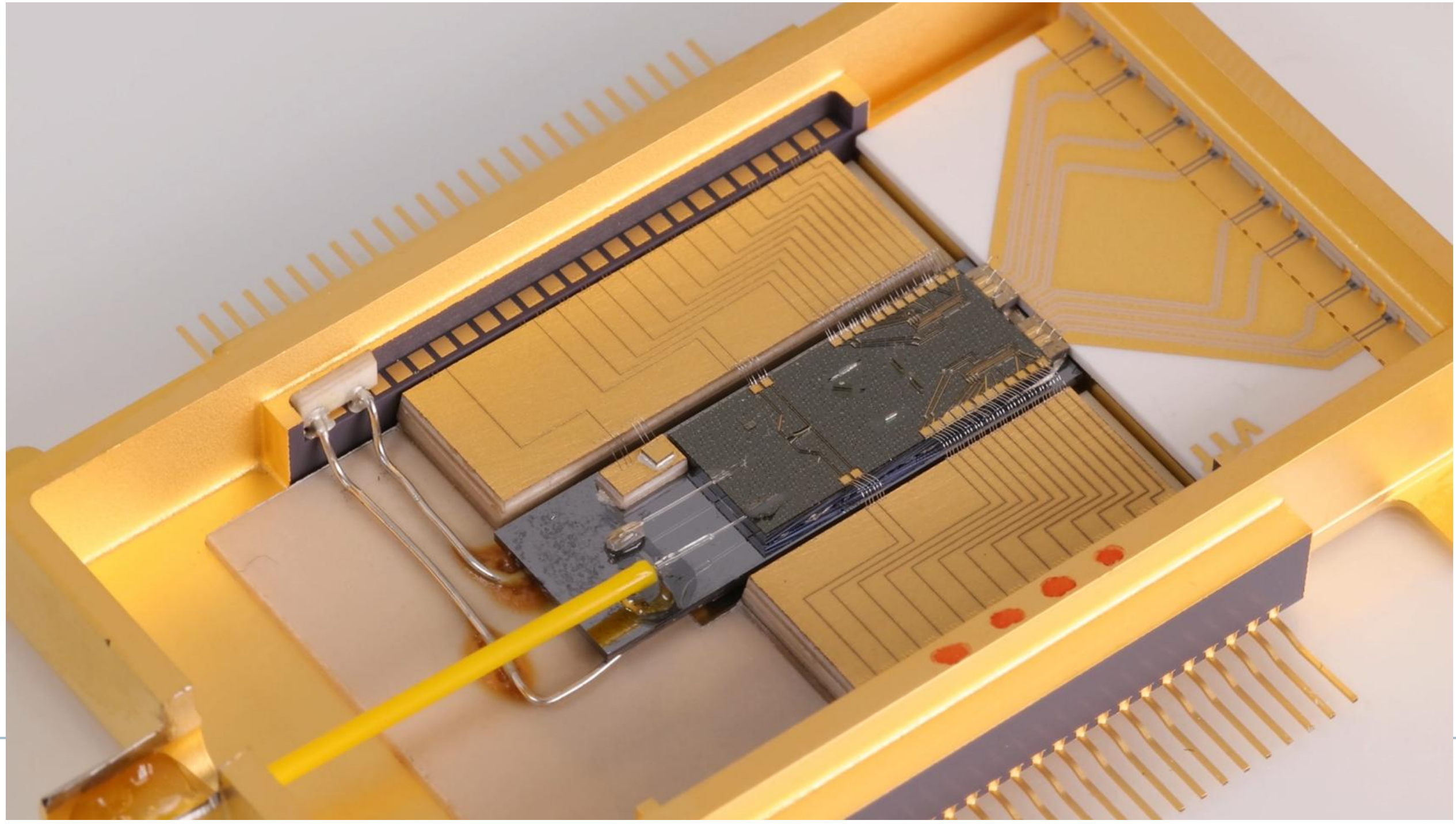
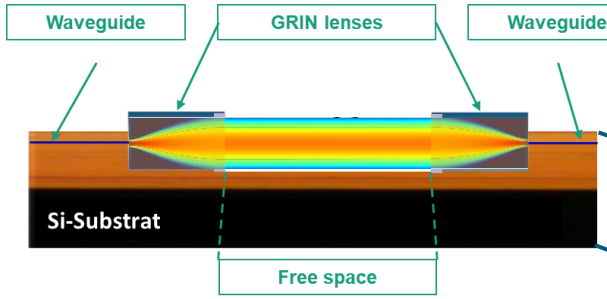
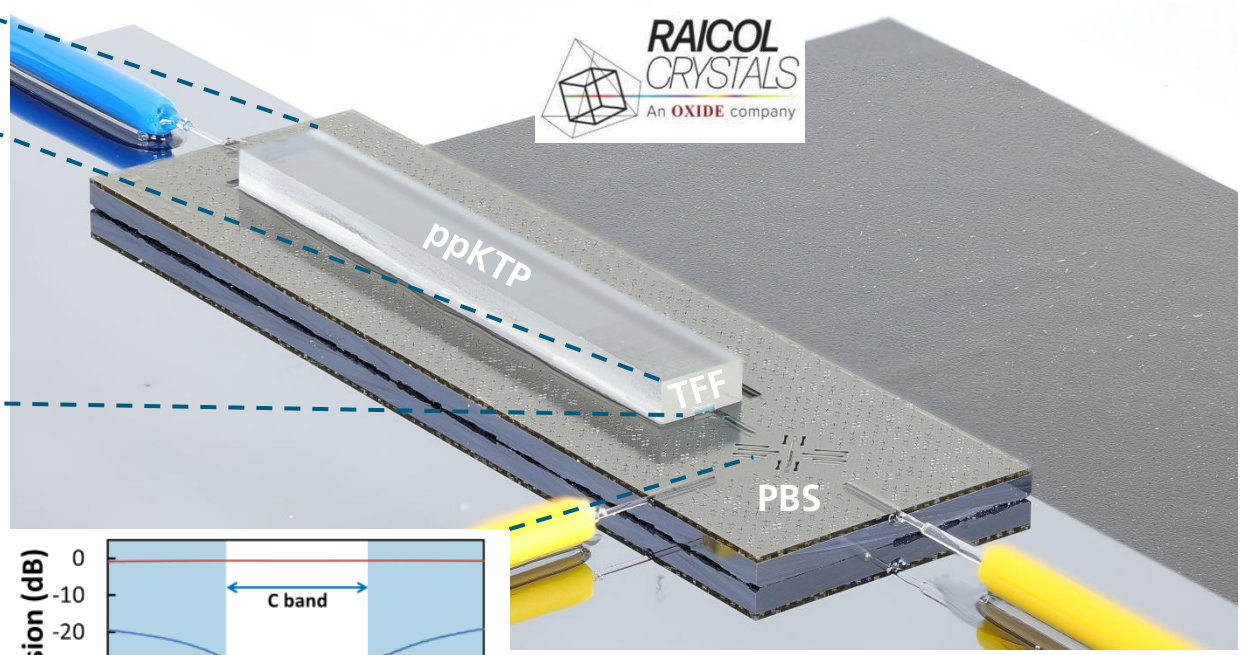
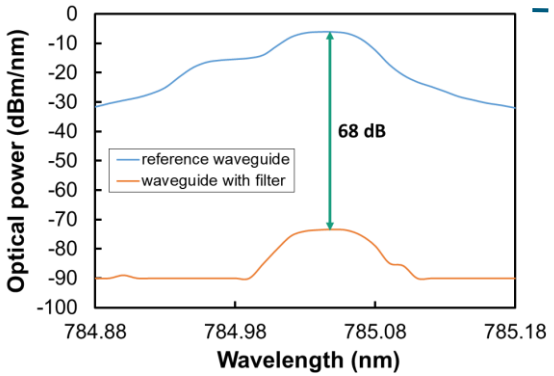


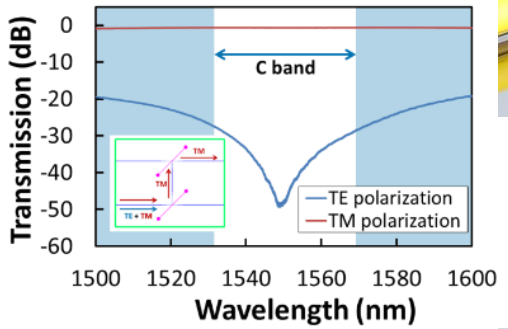
Integrated 1550 nm photon pair source

Enabled by micro-optical bench and hybrid integration

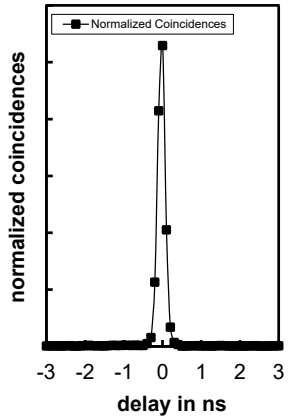








Photon pairs → bunching



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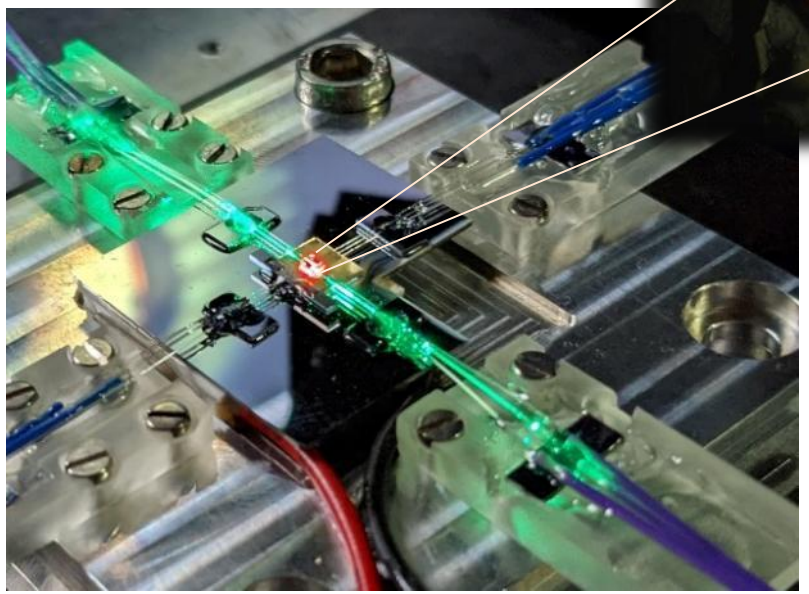
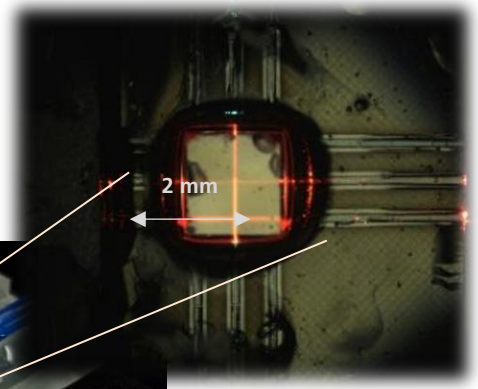
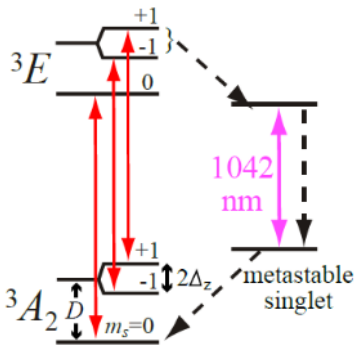
PICs for Quantum Sensing

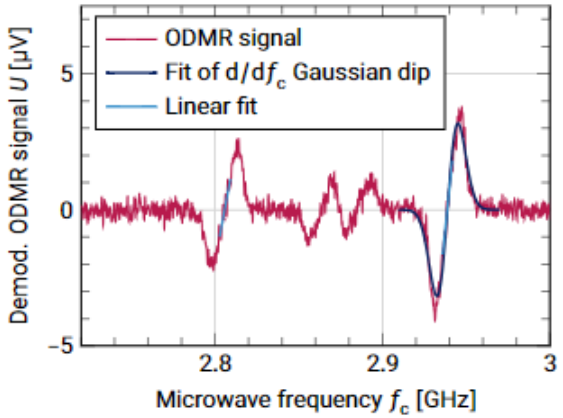
Magnetometry with NV centers for GNSS-denied environments

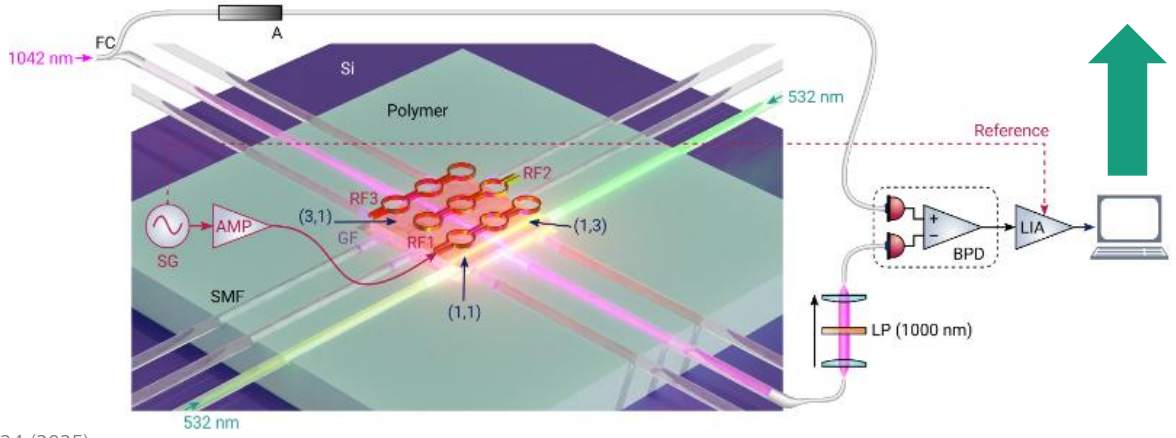
- 3x3 Pixel Array
  - Pump: 532 nm
  - Read-out: 1042 nm
- Signal: 1042-nm absorption











Julian M. Bopp et al.: Diamond-on-chip magnetic field camera for mobile imaging, Phys. Rev. Applied 23, 034024 (2025)

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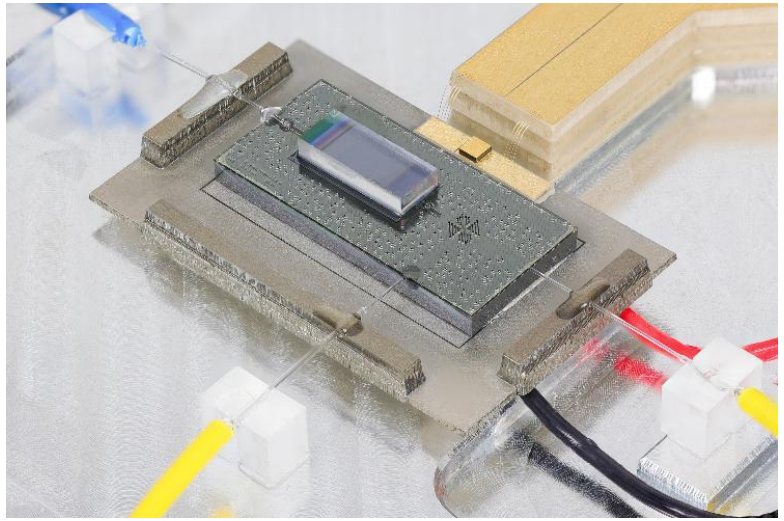
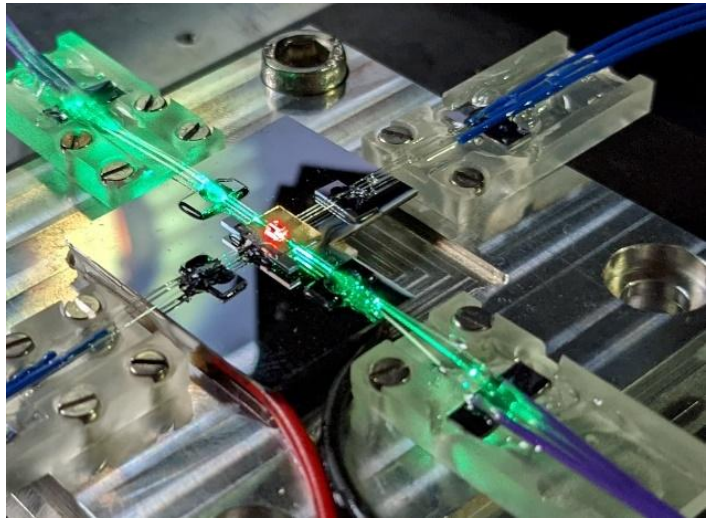
Photonics for Quantum Applications

Challenges for quantum communication, sensing and computing



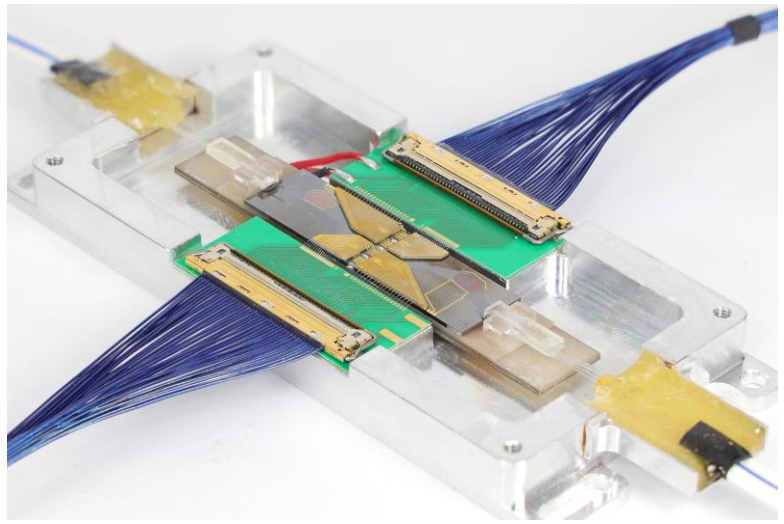
Q-Communication

- Photon loss in fiber and free-space links
- Quantum repeaters
- Source and detector performance
- Integration with classical telecom infrastructure
- Cost and deployment complexity



Q-Sensing

- Maintaining quantum coherence outside laboratories
- Miniaturization of quantum sensors
- Environmental noise sensitivity
- System robustness for field deployment



Q-Computing

- Scalability
- Robustness
- Low-loss photonic circuits
- Large-scale error correction
- SWaP-C

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Thank you
for your attention.

Dr.-Ing. Dominic Schulz, MBA
dominic.schulz@hhi.fraunhofer.de

Fraunhofer Heinrich Hertz Institute, HHI
Einsteinufer 37
10587 Berlin
Germany

www.hhi.fraunhofer.de