QUANDELA

Towards fault tolerant photonic quantum computing

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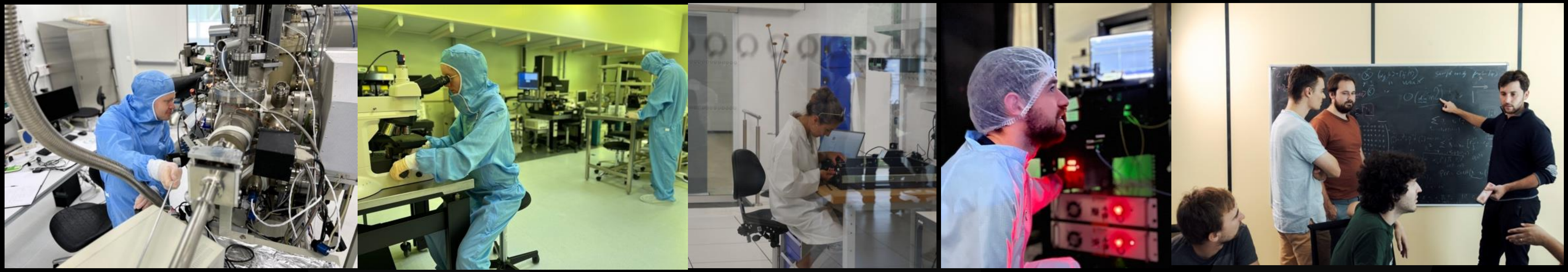
07/04/2025

Photonic Quantum Computing leader in EU with a large team of experts in quantum photonic technologies

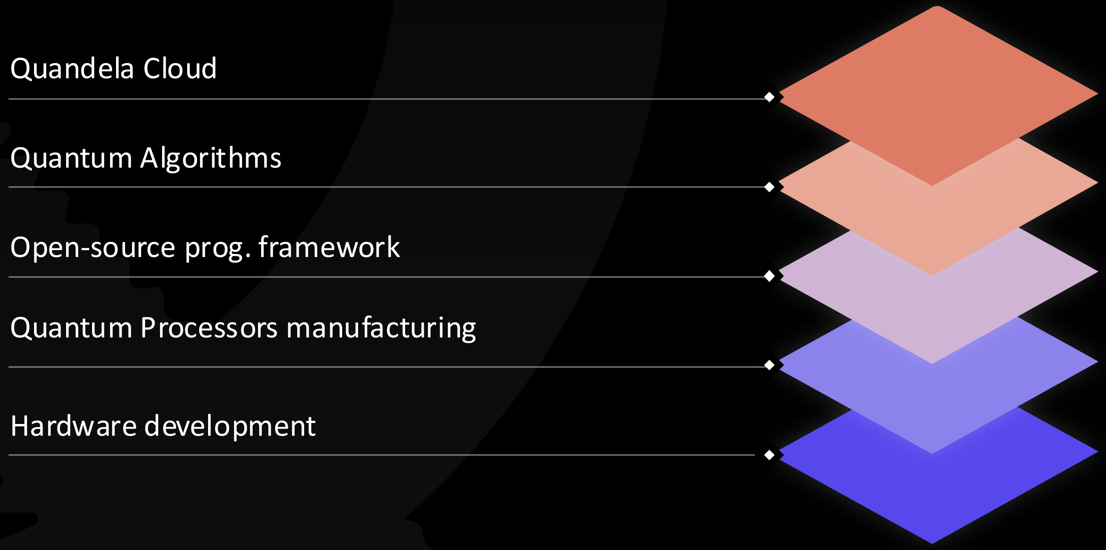


R&D Centers

Production Centers

Offices based in
Paris
Munich
Seoul
Montreal

Quandela's full-stack approach empowers enterprises with holistic quantum computing solutions



Photonic quantum computing

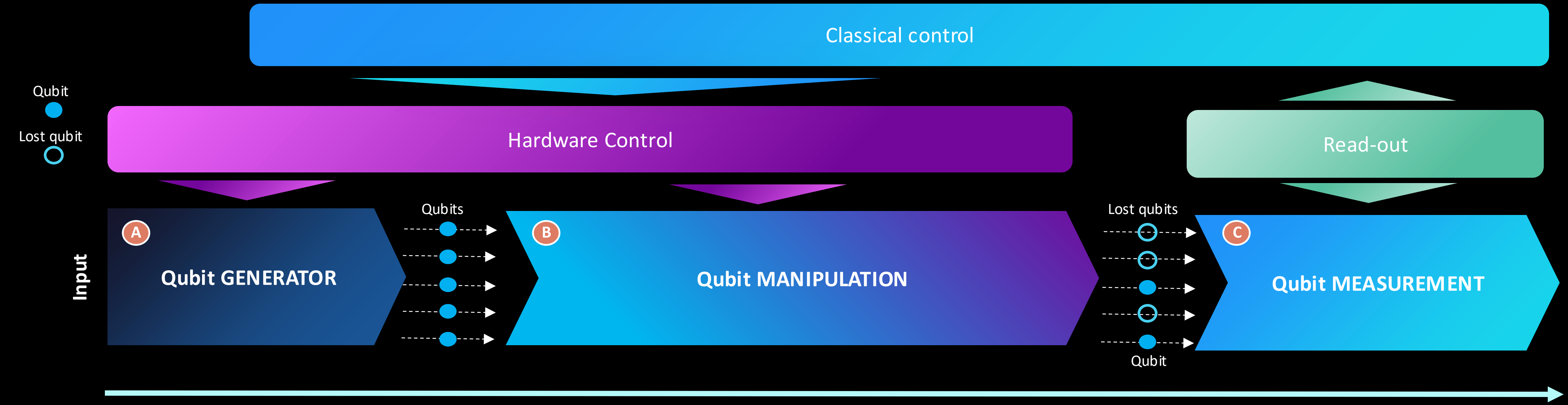
Single photons as quantum information carriers

- Ease of manipulation and addressability
- Modular architectures
- Negligible decoherence at room temperature

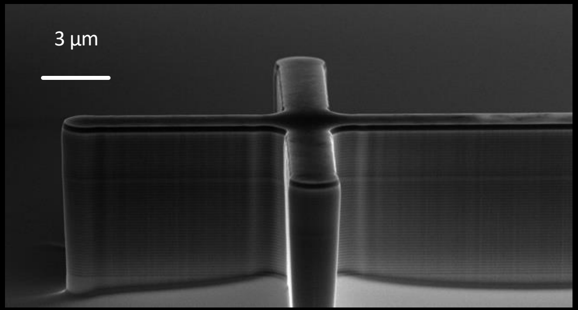
Challenges

- **Loss** is the main source of error
- Probabilistic nature of linear optical gates

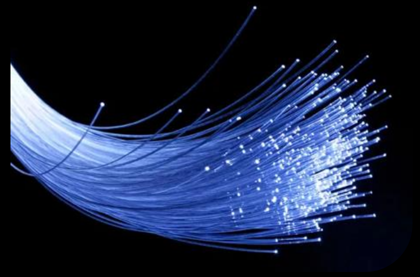
Photonic quantum computing



Quandela:
Solid-state emitters = <u>on-demand</u> process



Integrated photonics, fibers and detectors



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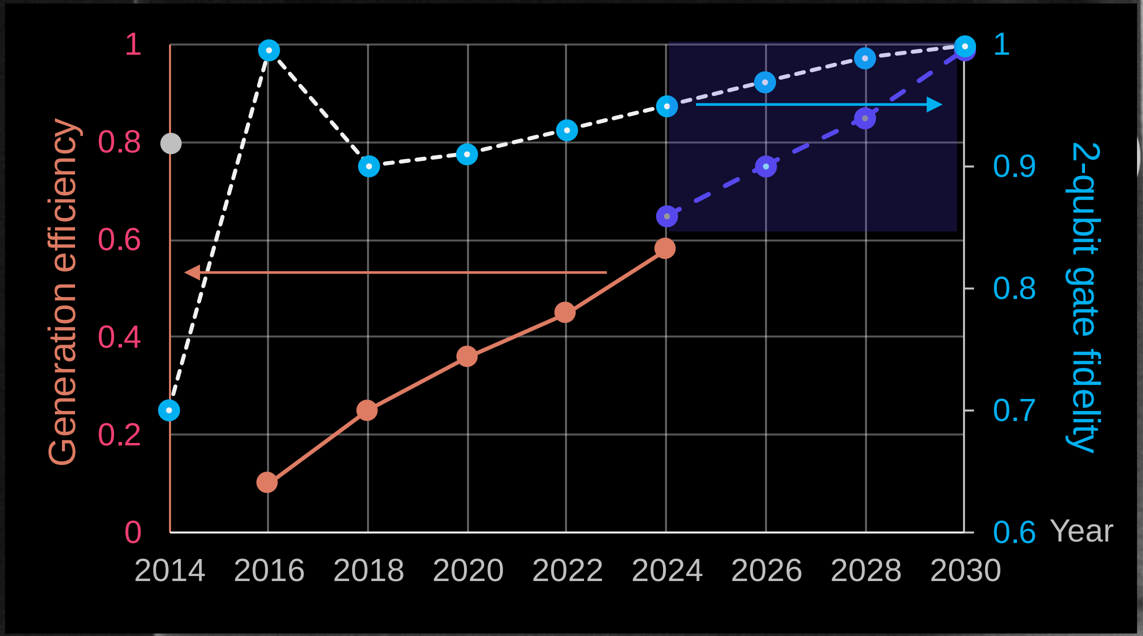
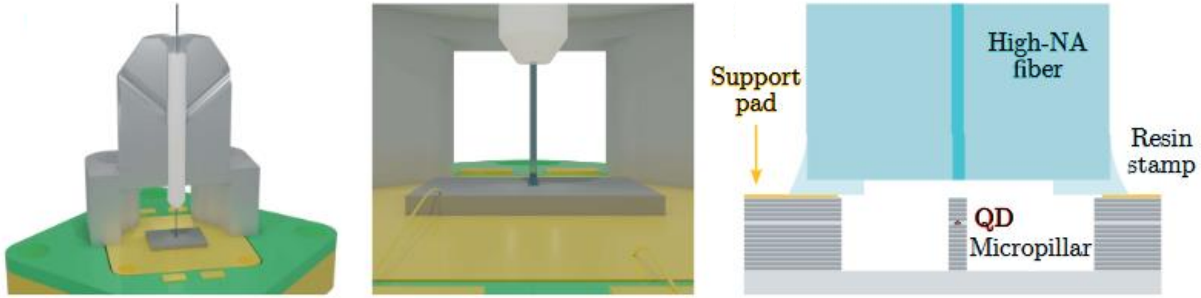
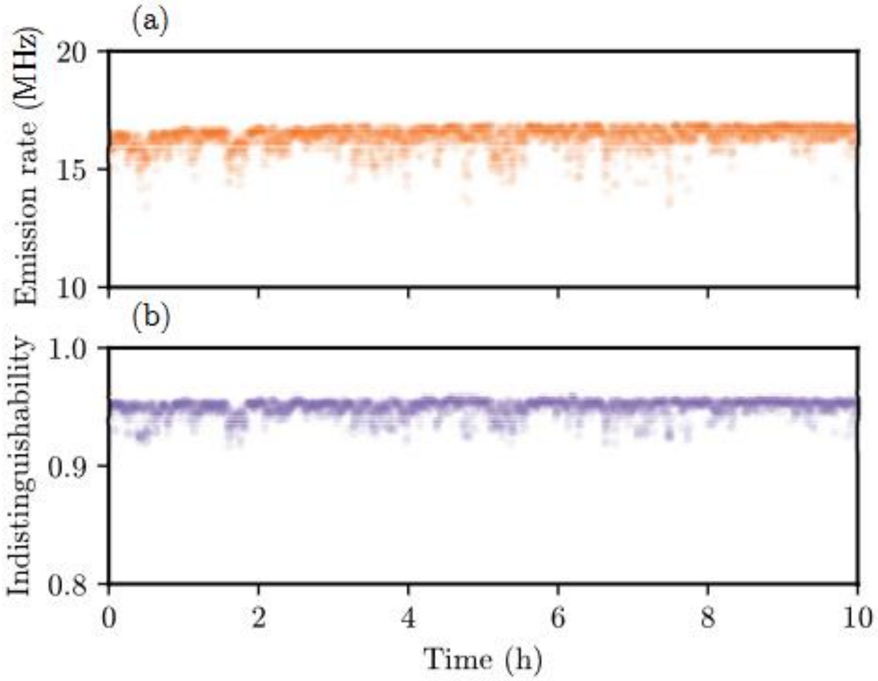
5 µm

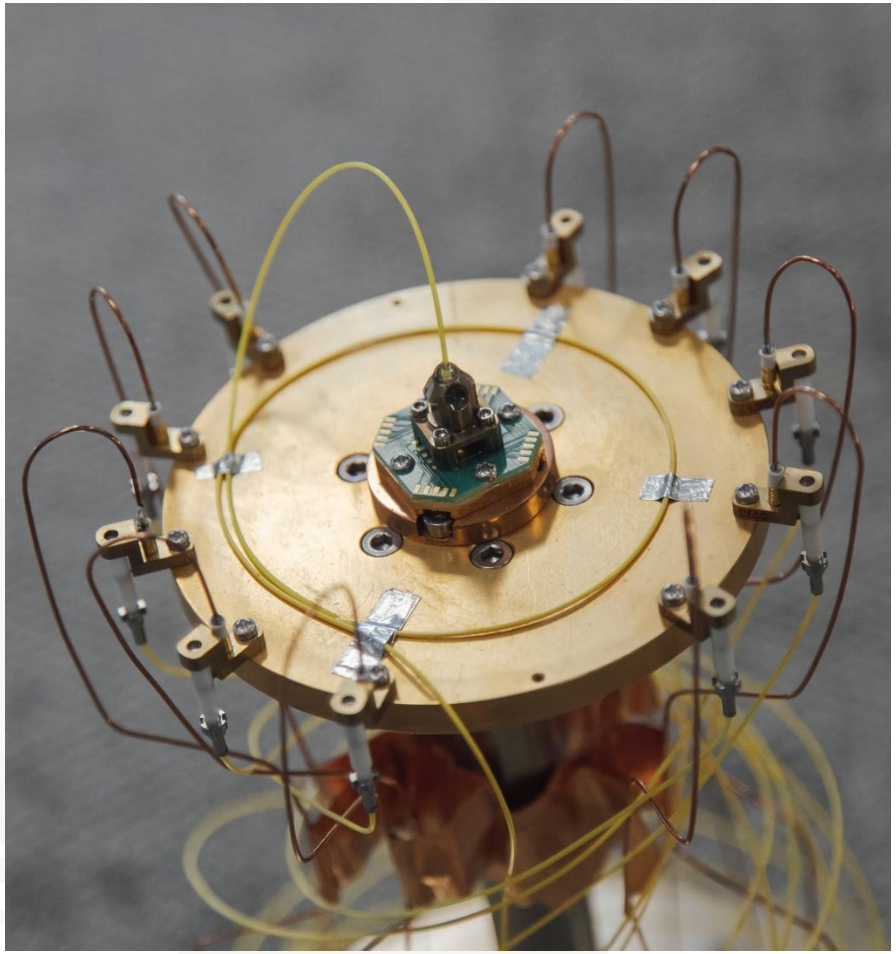
Wavelength	925-930 nm
Indistinguishability	**M_s > 94%**
Brightness	**B ~50%**
Operating temperature	4 K



Fiber pigtailed single photon source

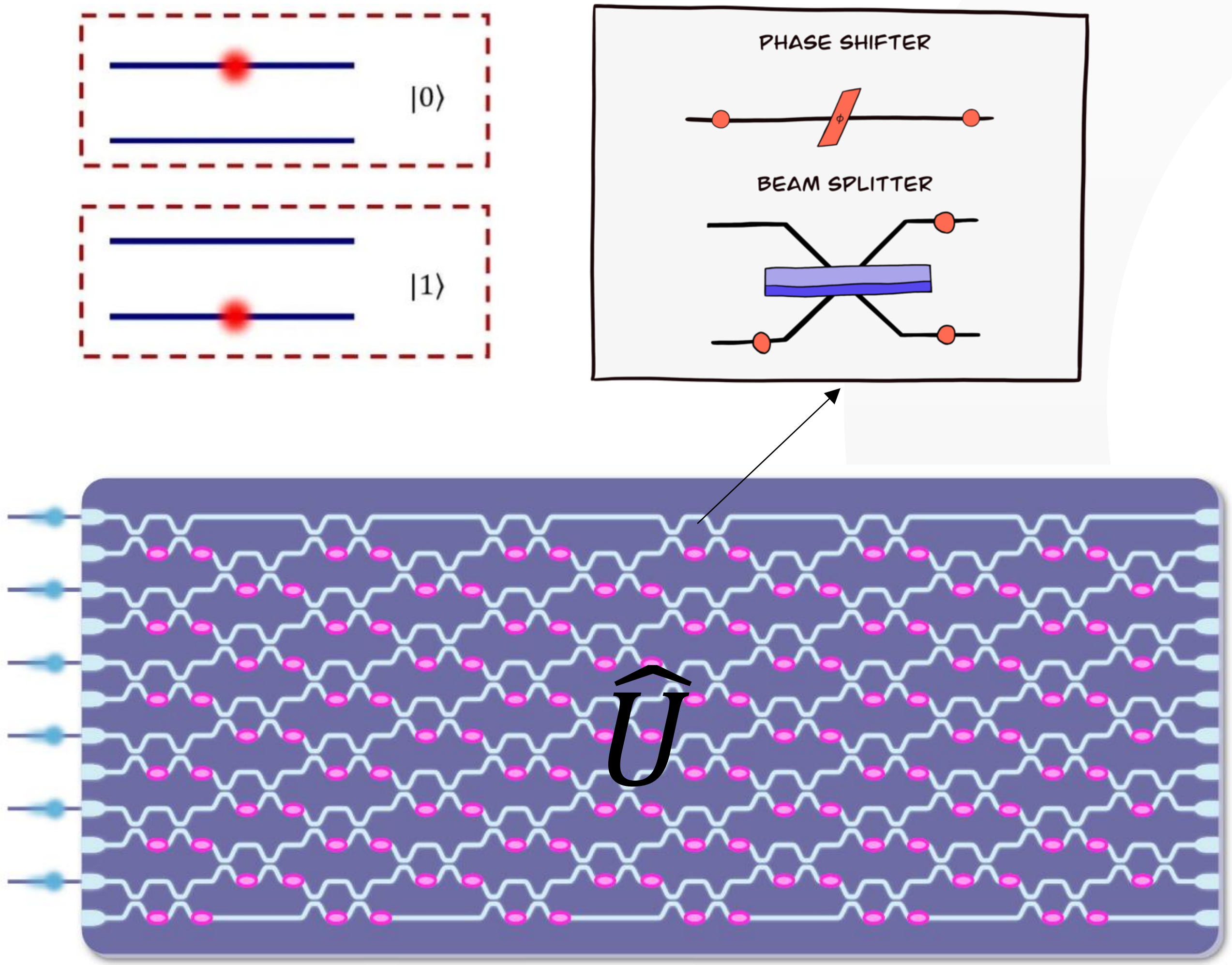






Margaria, N., et al. *Arxiv,* arXiv:2410.07760v1 (2024)

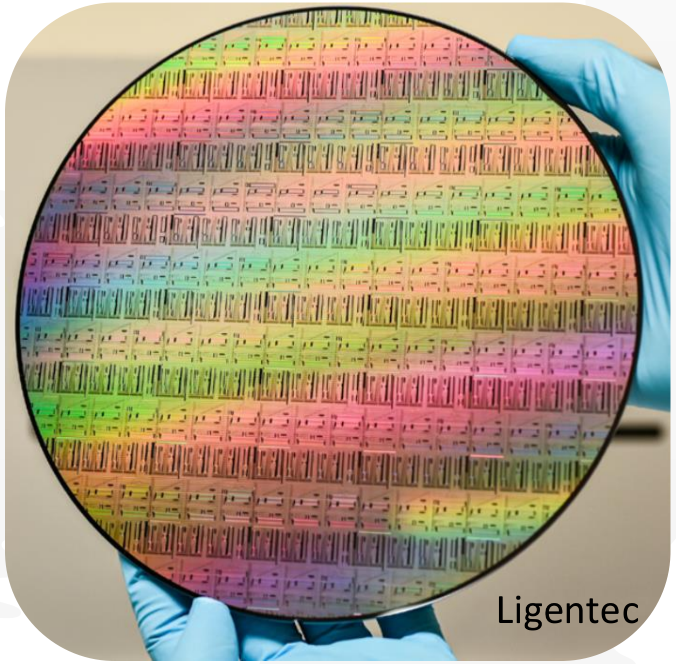
Optical processing – Linear optical circuits



Unitary matrix

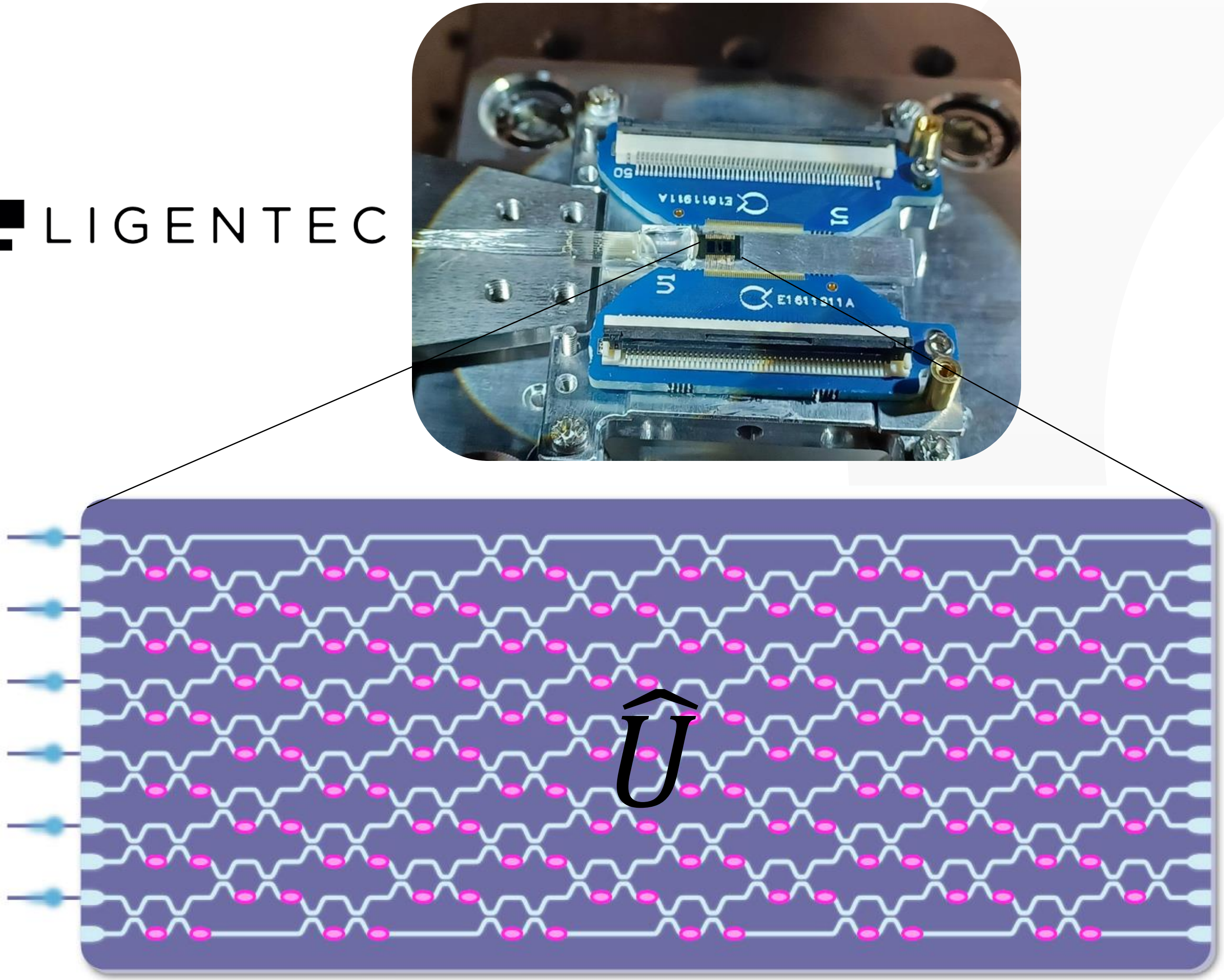
Silicon Nitride platform

- Ultra-low loss @925 nm (<0.1 dB/cm)
- High volume manufacturing
- Active and low loss components integration
  - Phase shifters
  - Single photon detectors



High fidelity optical processing

LIGENTEC

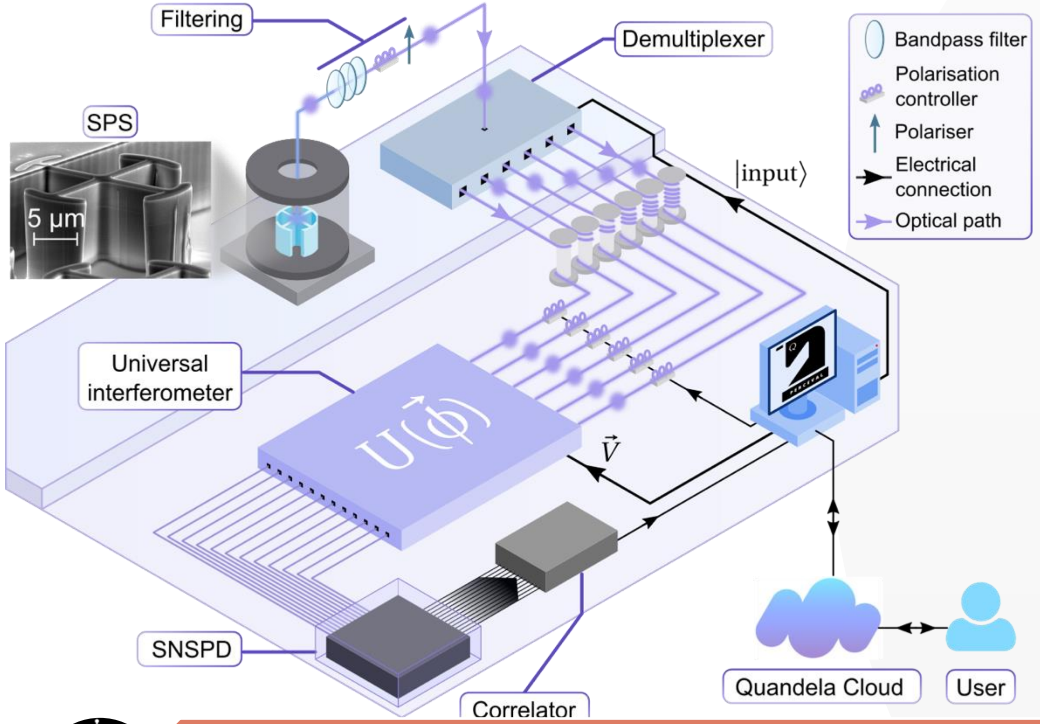


Average fidelity of 99.77%
(100 Haar-random unitary matrices)

- High quality components design and manufacturing
- Machine learning based calibration of components behavior and error mitigation

Scalable machine learning-assisted clear-box characterization for optimally controlled photonic circuits. A. Fyrillas et al. arXiv preprint arXiv:2310.15349 2024

Data center compatible quantum processors



Design any type of linear optics circuit

And bridge with other frameworks

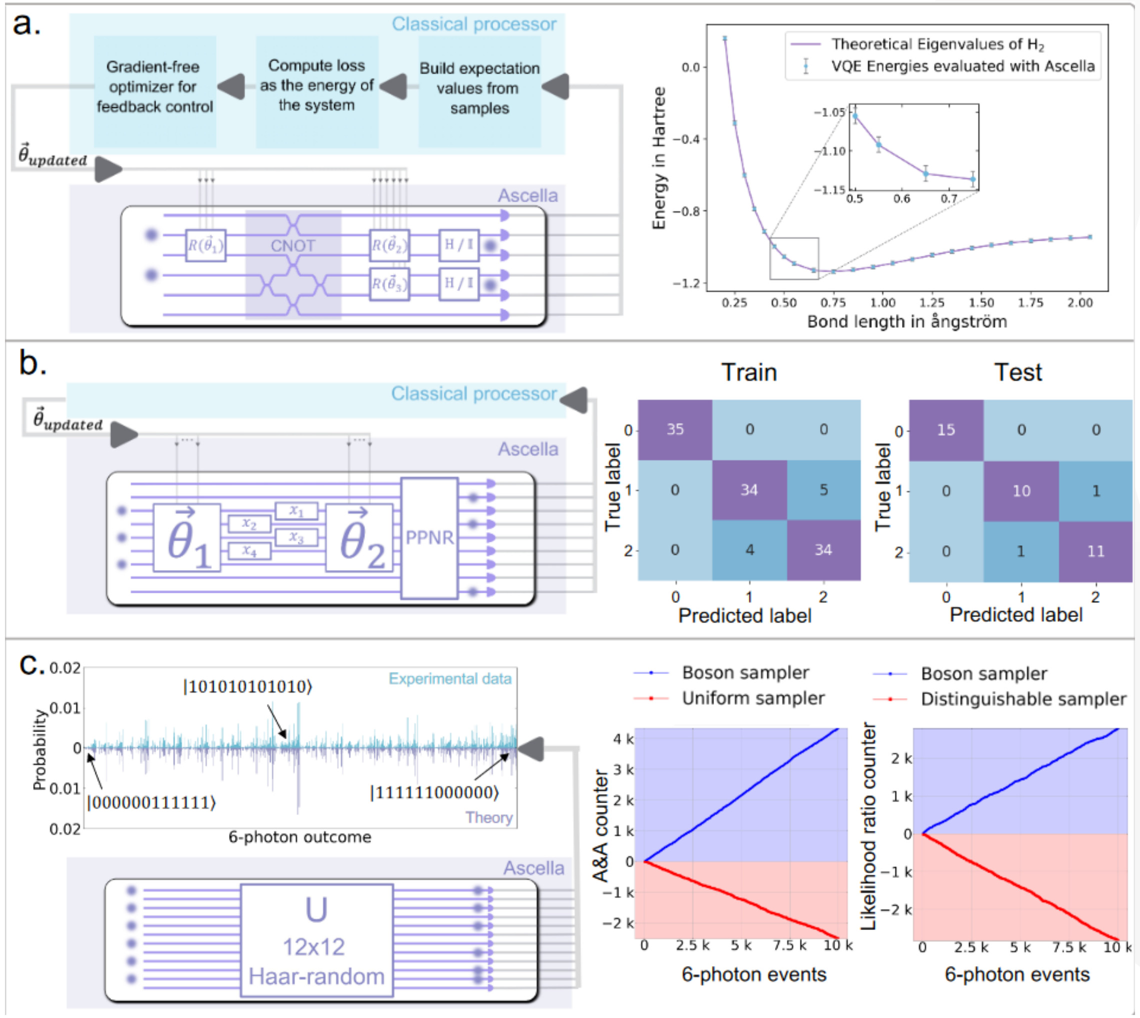
Simulate and test algorithms with perfect and noisy devices

Execute and compile any circuit to available hardware

- 12 photons quantum processing unit
- Modular and fully integrated for data center compatibility
- Low consumption 3-4kW
- >90% availability
- 2 Qubit gate fidelity >90%

https://cloud.quandela.com/

Small scale Photon-native computation

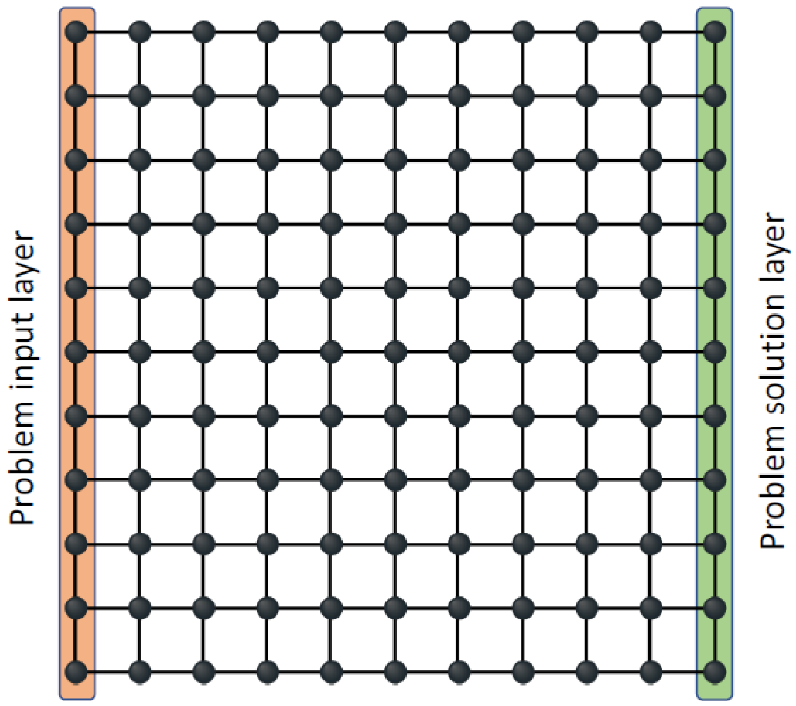


Hybrid variational quantum eigensolver

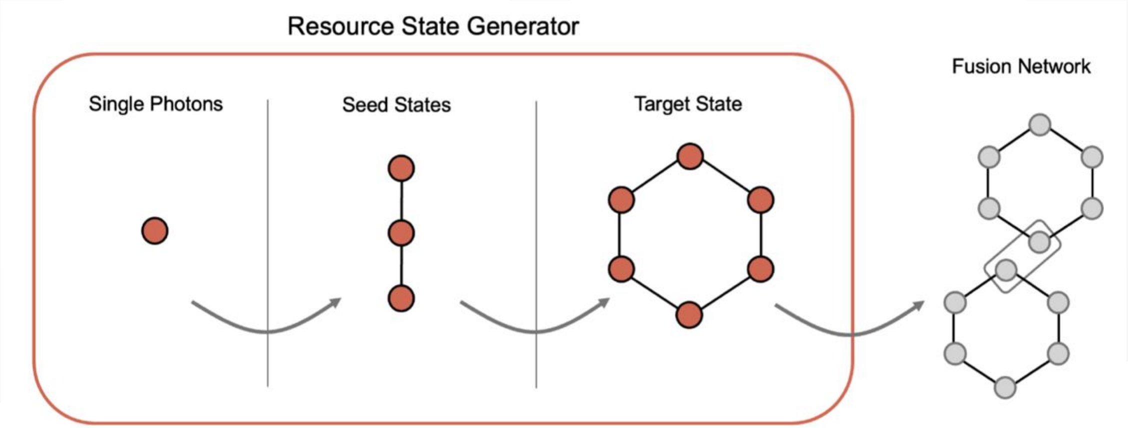
Quantum neural network

6 single-photon Boson Sampling

General purpose quantum computing
Fault tolerant architectures



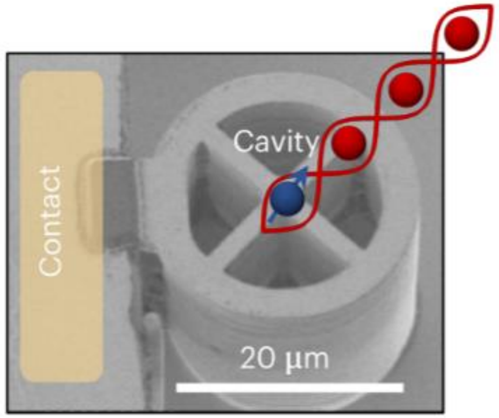
- **Photonic graph states** where multiple photons are mutually entangled
- Multi-qubit logical gates with single / two qubit gates and measurements
- Base of **error correction architectures such as FBQC**

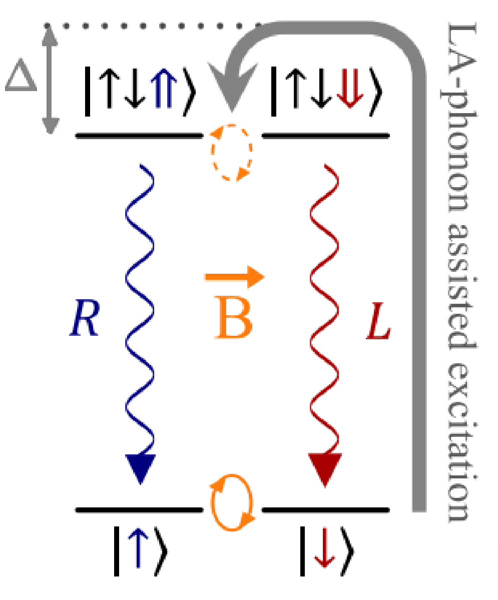


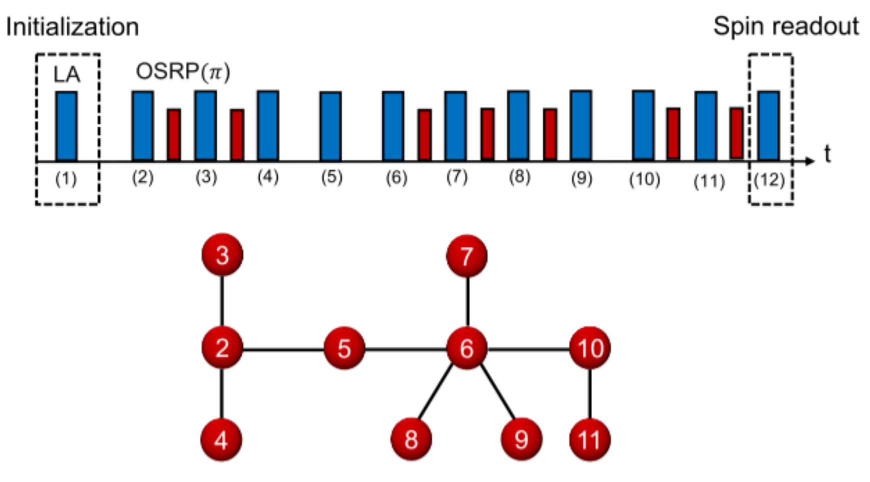
Raussendorf R. and Briegel H. Phys. Rev. Lett. 86, 5188 (2001)

Source: S. Bartolucci et al., Nat. Commun. 14, 612 (2023)

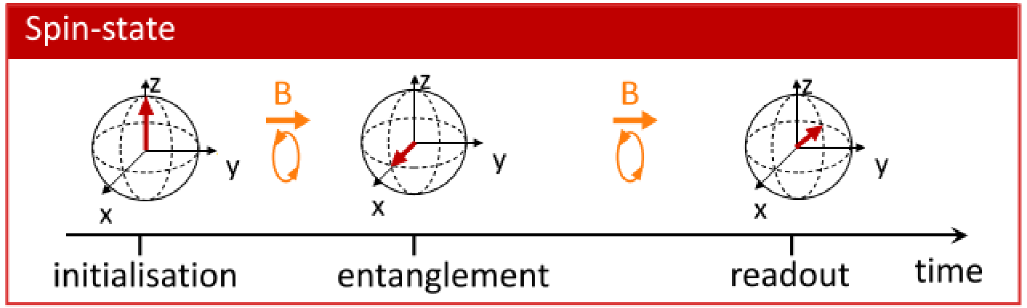
On demand spin – photon entanglement







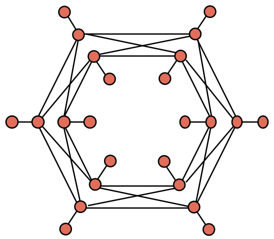
Caterpillar state



- Deterministic entanglement mediated by the spin of a quantum emitter
- On-demand reconfigurability of the entanglement generation

H. Huet et al. (2024) arXiv:2410.23518v1

Generation cost for the building block of fault-tolerant computing



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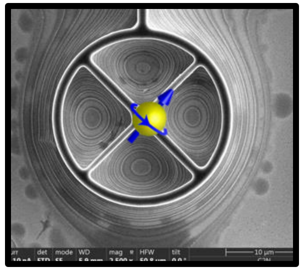
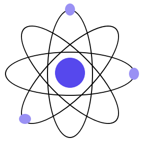
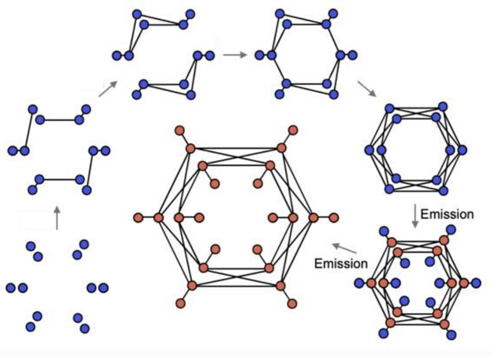
Hybrid →

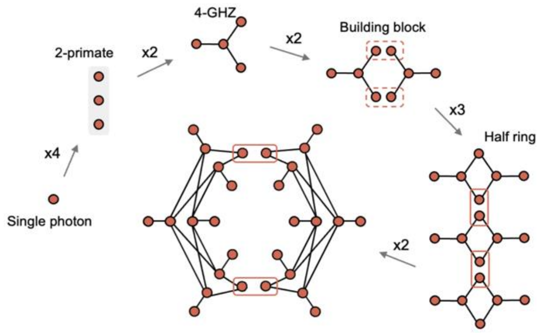






OTHER PHOTONIC PLATFORMS

Pure photonic →



12 sources

24 detectors

24 beam-splitt.

Improvement of x**100 000 factor**

96% Efficiency for the required source

1,000,000 sources

>1,000,000 detectors

>1,000,000 beam-splitt.

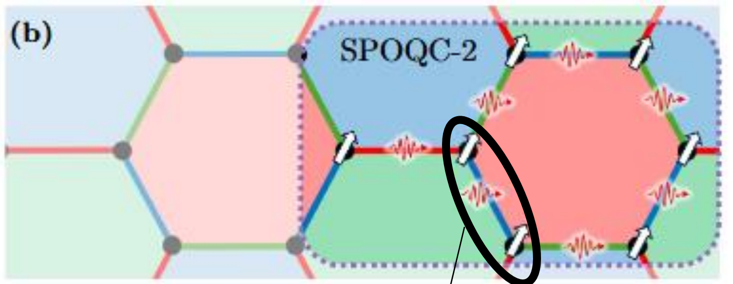
99% Required efficiency at the source

Source: S.C. Wein et al. arXiv:2412.08611 (2024)

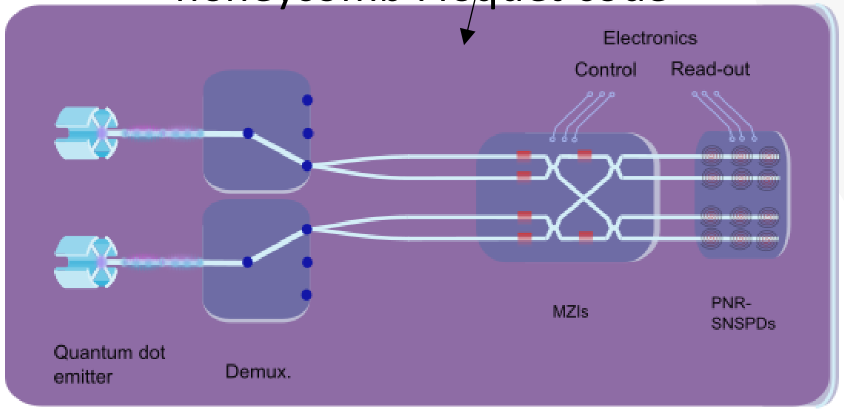
SPOQC Architecture

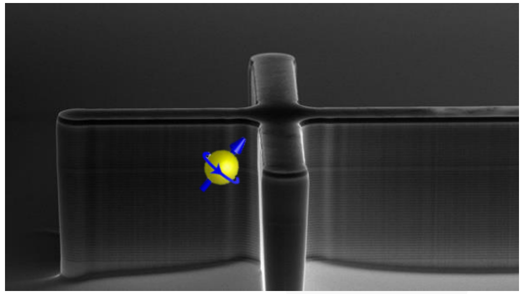
A Spin-Optical Quantum Computing Architecture

Grégoire de Gliniasty[1,2], Paul Hilaire[1], Pierre-Emmanuel Emeriau[1], Stephen C. Wein[1], Alexia Salavrakos[1], and Shane Mansfield[1]

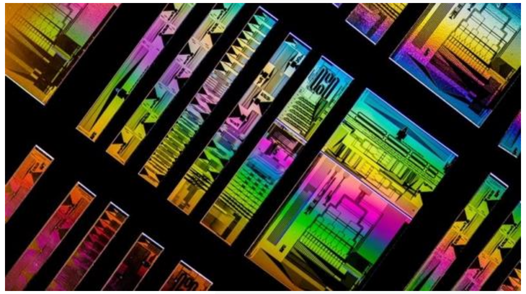


honeycomb Floquet code





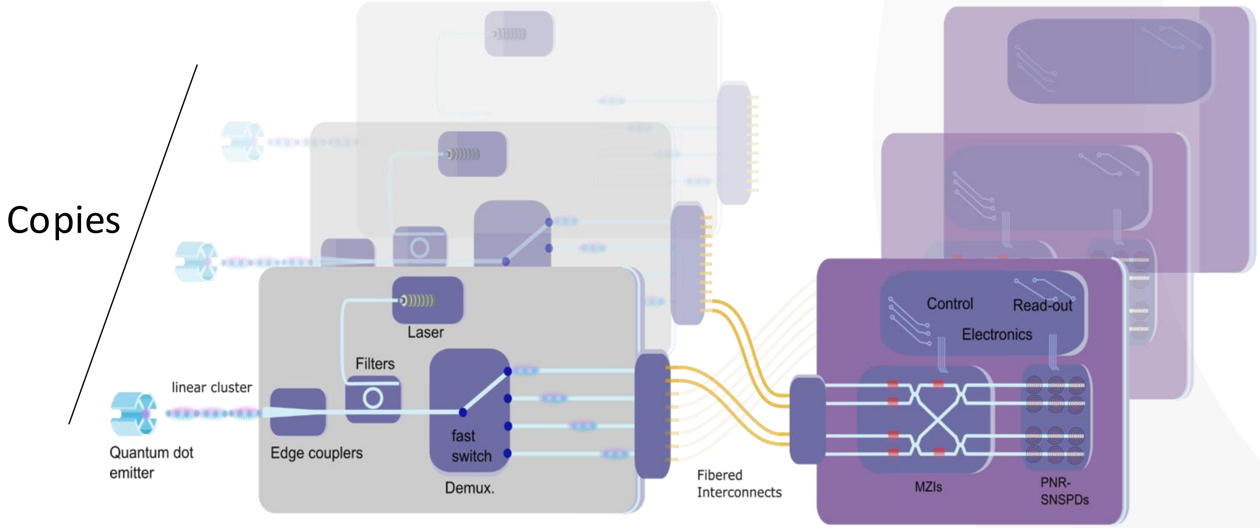
Quantum Dot
Spin - Photon interface



Linear optics

- Allows for quantum error correction with a **loss tolerance threshold of 6.4%**

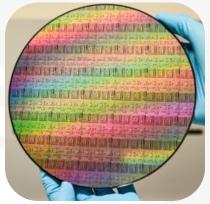
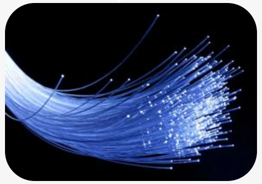
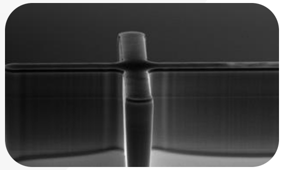
Hardware requirements



Modular architecture

New ingredients

- Large indistinguishable resource states generation
- High volume and low-loss PICs manufacturing
    - High speed phase reconfigurability
    - Photon Number resolving and high efficiency detection
- Low-loss fiber interconnects
- GHz rate ps pulsed lasers
- Low latency read-out & control electronics
- Cryogenics

Thank you!