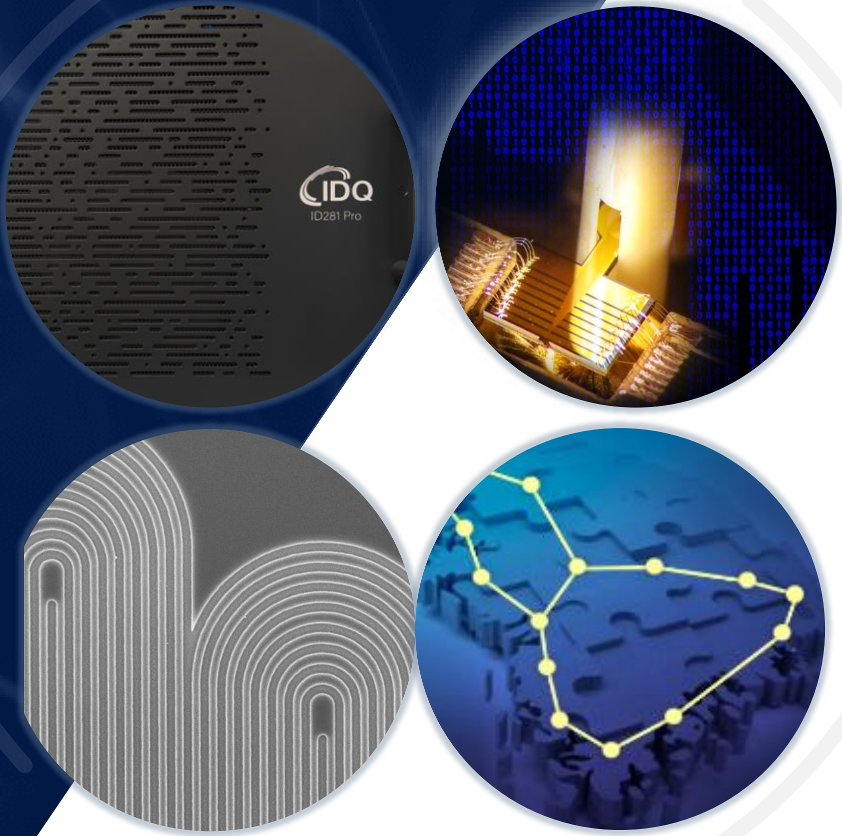
20 YEARS
QUANTUM INNOVATION

Enabling quantum computers, networks and communication with high-performance single-photon detectors



Félix Bussières, *VP Quantum Detection*

ID Quantique

AIDAinnova training course – CERN – January 2025

ID Quantique

Founded in 2001

Team of > 120

Geneva, Seoul, Boston, Austria

Two complementary BUs

Quantum-safe networks

Quantum detection systems

Quantum-safe networks

QKD and key management

QKD system for today's quantum-safe secure networks with KMS for end-to-end security

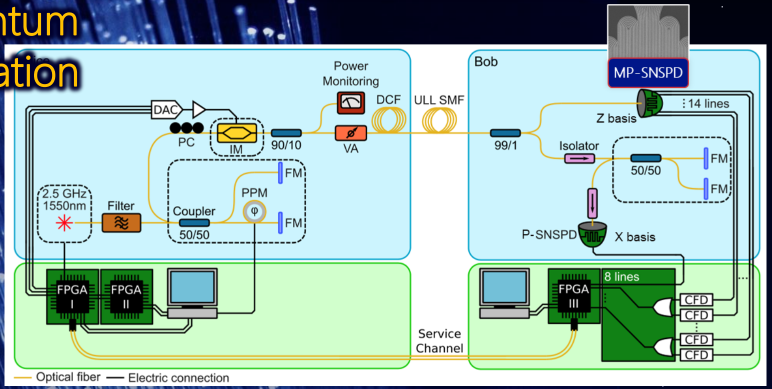
Markets

- Telecoms
- Government
- Bank and Finance
- Critical Infrastructure
- Healthcare
- Academia

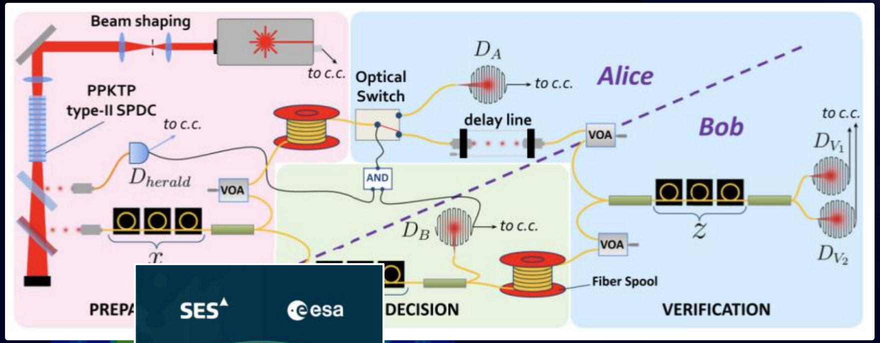
IDQ's Quantum detection systems :

Enabling the *Quantique* in networks, computers and science

Quantum communication



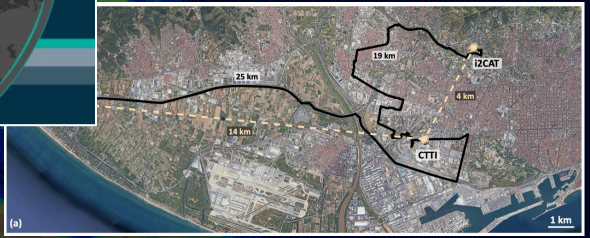
Grunfelder et al, Nat. Photon. 17, 422 (2023)



Neves et al, Nat. Comm. 14, 1855 (2023)

Quantum networks

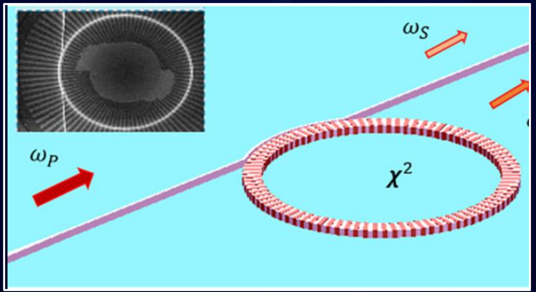
Pelet et al., Phys. Rev. Applied 20, 044006 (2023)



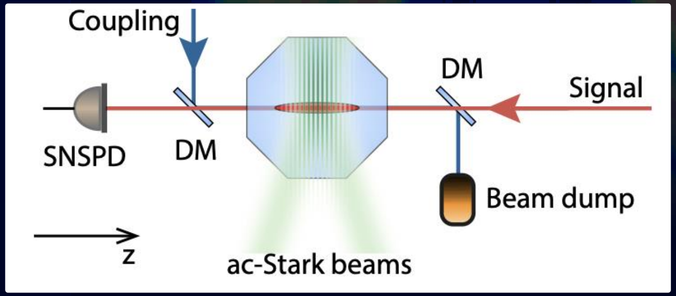
Rakonajac et al, Optica Quantum 1, 94 (2023)

Quantum computing

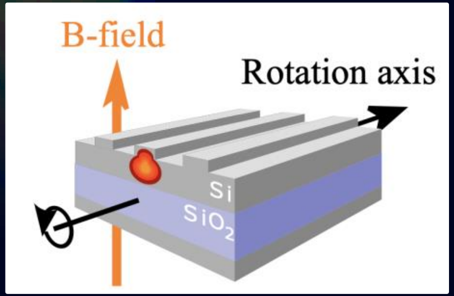
Quantum photonics
Quantum emitters
Material science



Zhaohui et al., PR Applied 20, 044033 (2023)

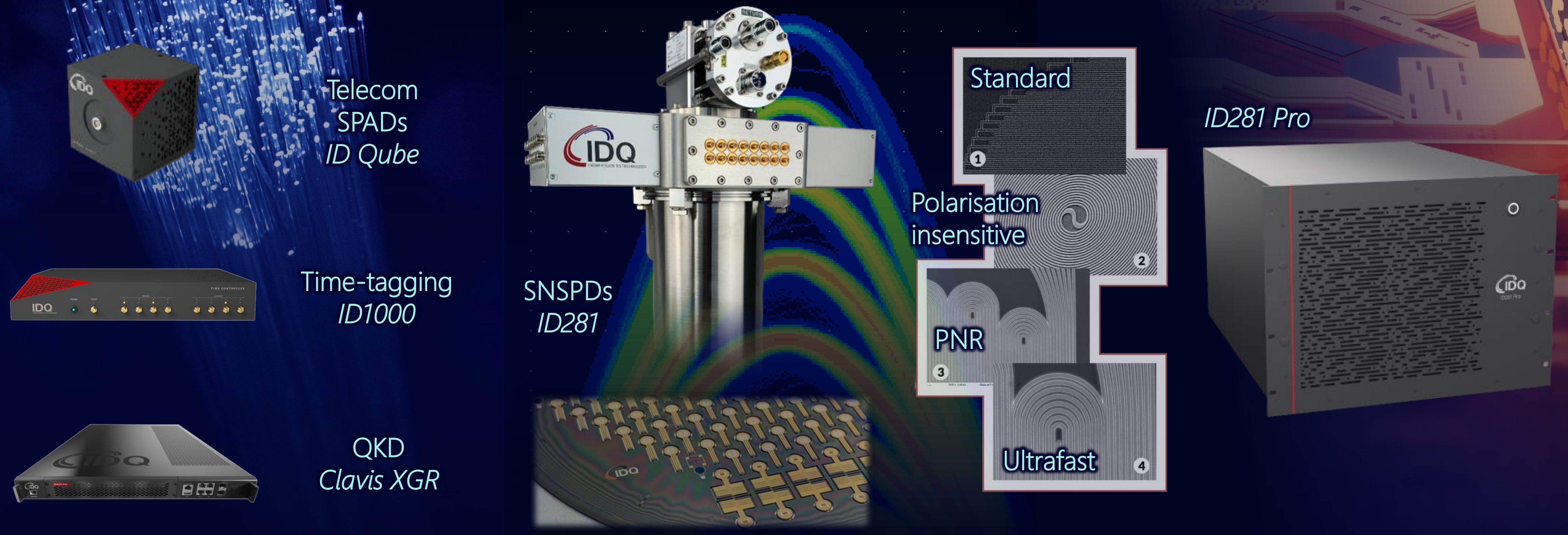


Kurzyna et al, arXiv:2402.06513 (2024)



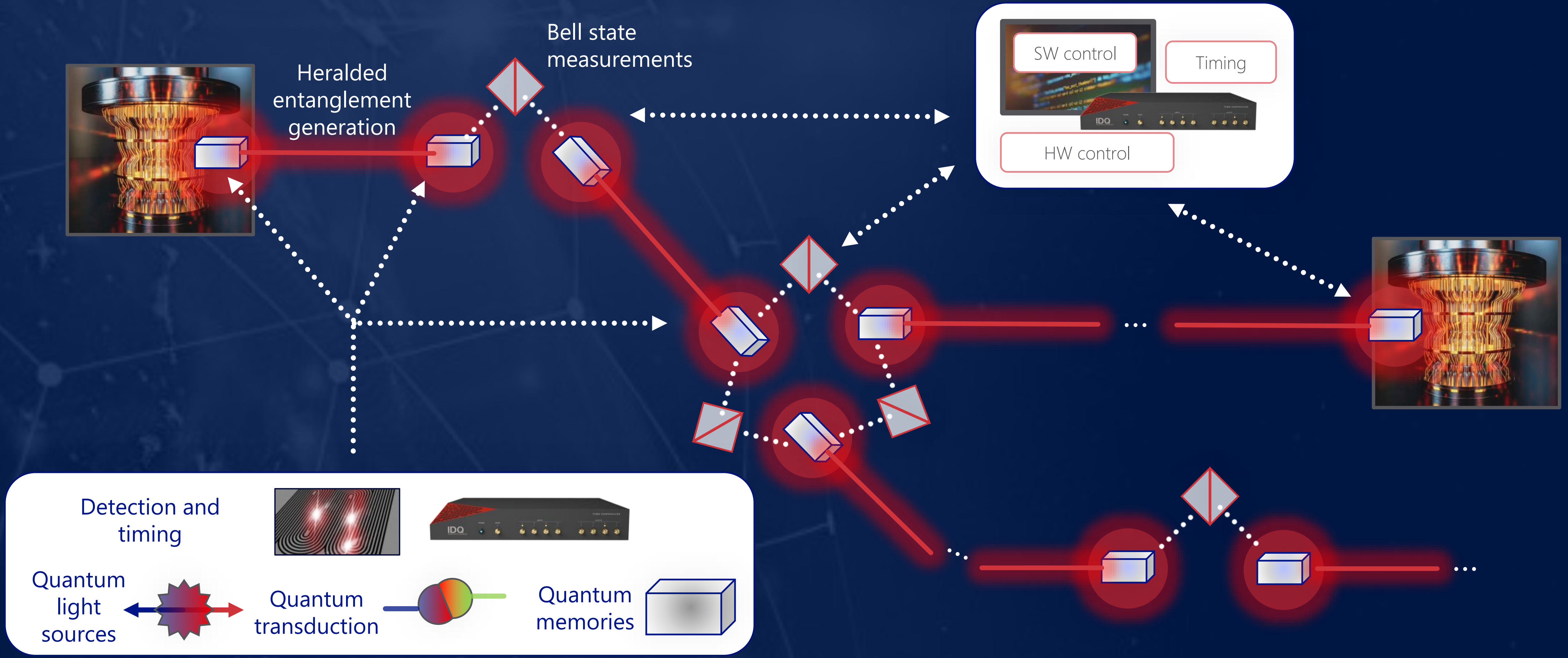
Holzapfel et al, arXiv:2409.06571 (2024)

We develop and deliver state-of-the-art & industry-ready quantum detection systems to spark technological progress



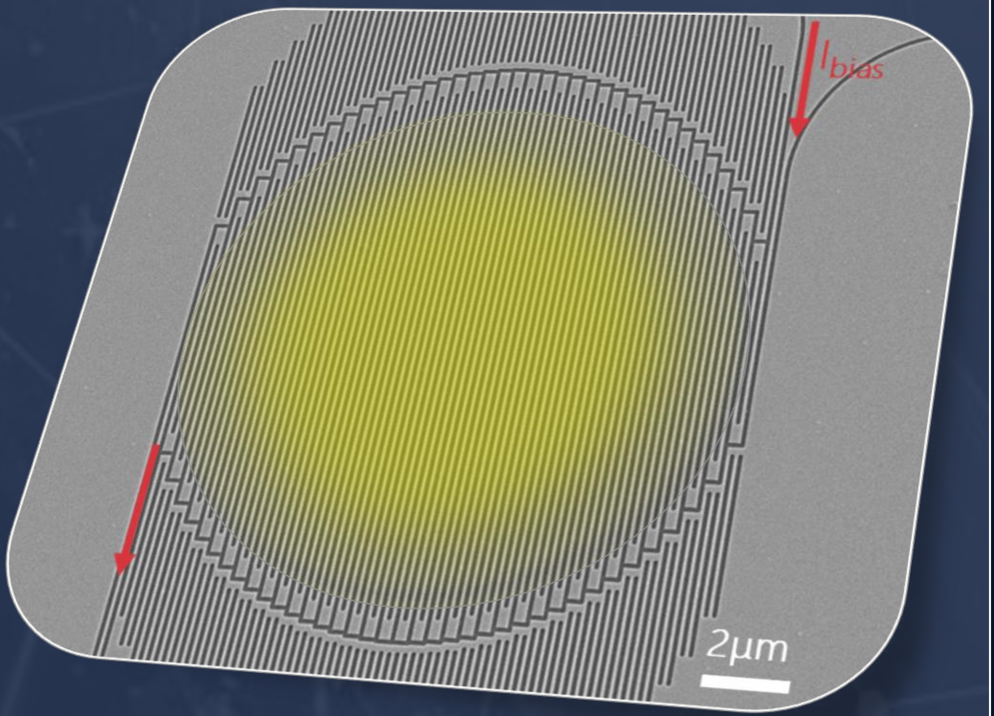
Quantum networks in 20...

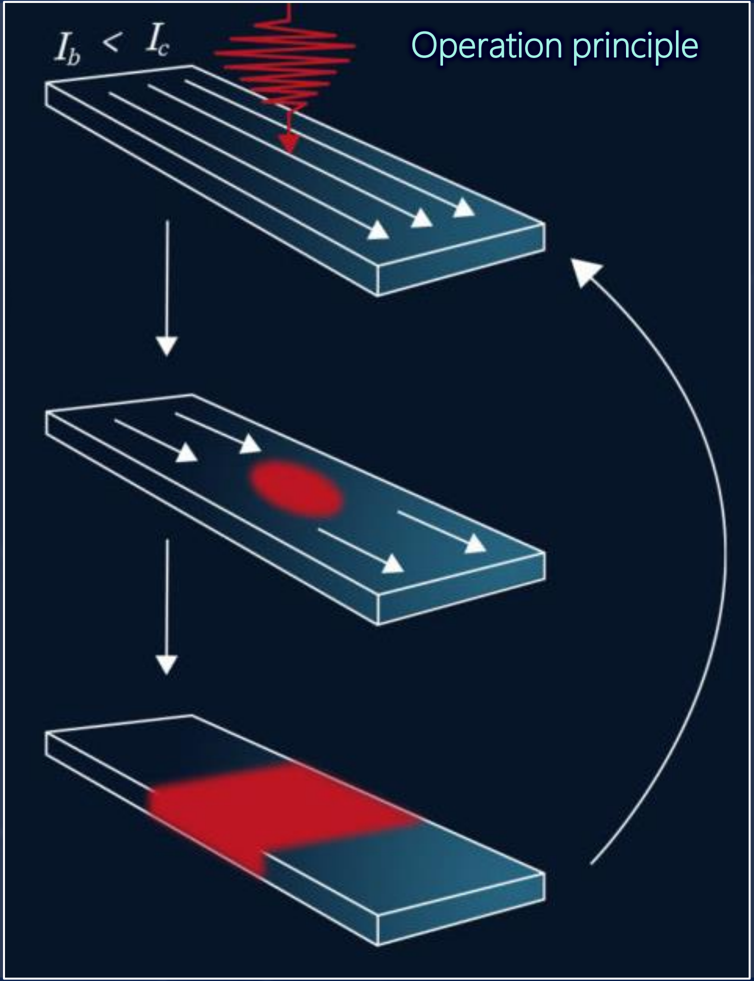
Towards a generalized "Quantum Internet" to distribute and use entanglement



Superconducting nanowire single-photon detectors technology

The very best in single-photon detection

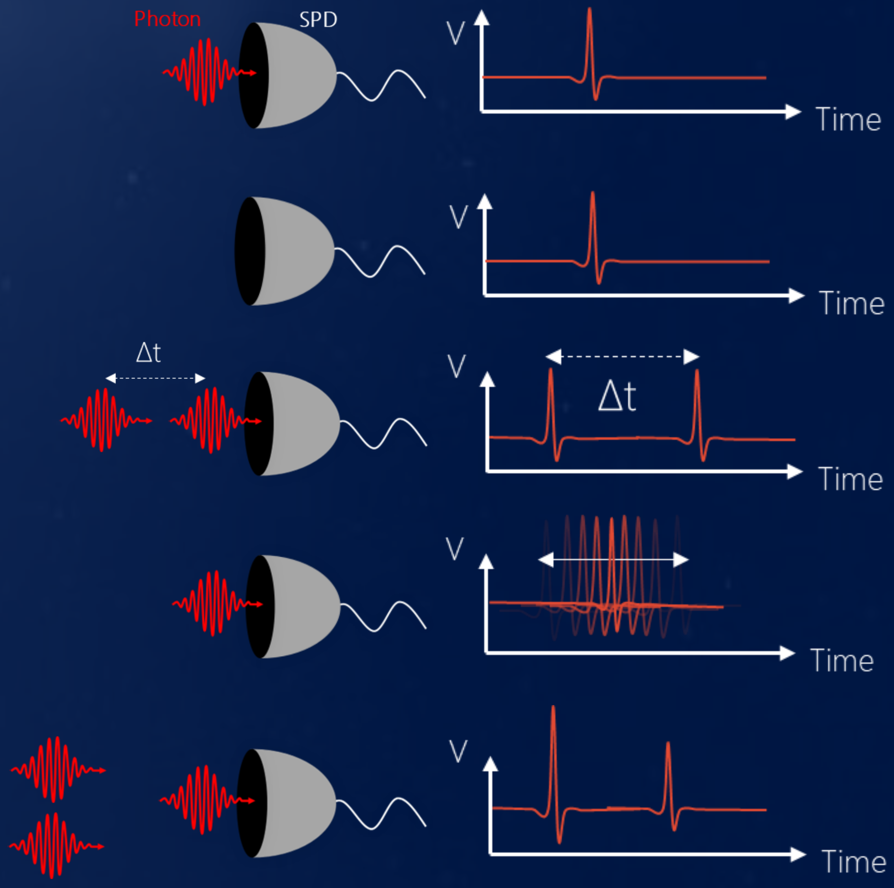




What makes a good single-photon detector ?

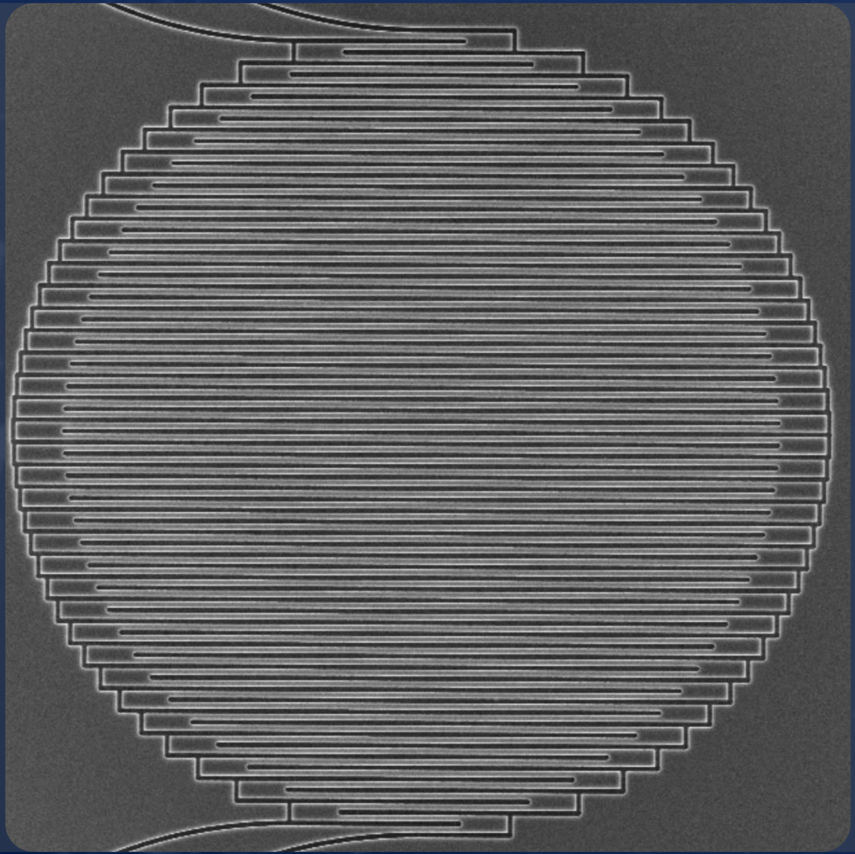
Key metrics

- High system detection efficiency (SDE)
- Low dark-count rate (DCR)
- Low recovery time (RT)
- Good timing precision (jitter)
- Photon-number resolution (PNR)



➢ Bienfang, Joshua, et al. "Single-Photon Sources and Detectors Dictionary." (2023).

Superconducting nanowire single-photon detectors (SNSPDs)



SNSPDs offer the best detection performance and possibilities

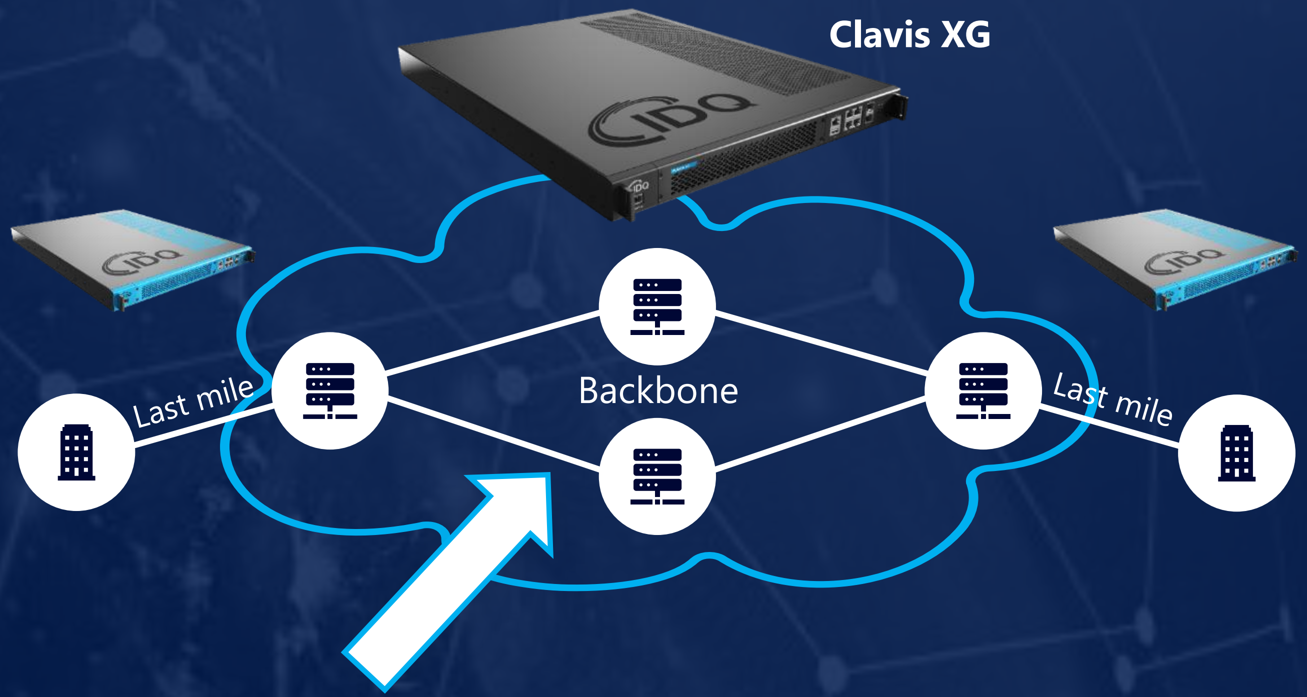
Best combination of

- High broadband detection efficiency (near unity, many λ's)
- Ultra-high time precision (tens of picosecond)
- Ultra-low dark count rate (< 1 cps)
- Ultra-high detection rates (> 1 Gcps)
- Excellent PNR performance

Detection challenges for quantum networks and quantum computing in 2025

Quantum networks today

It starts with QKD networks with trusted nodes



High-speed and/or low-noise detection needs

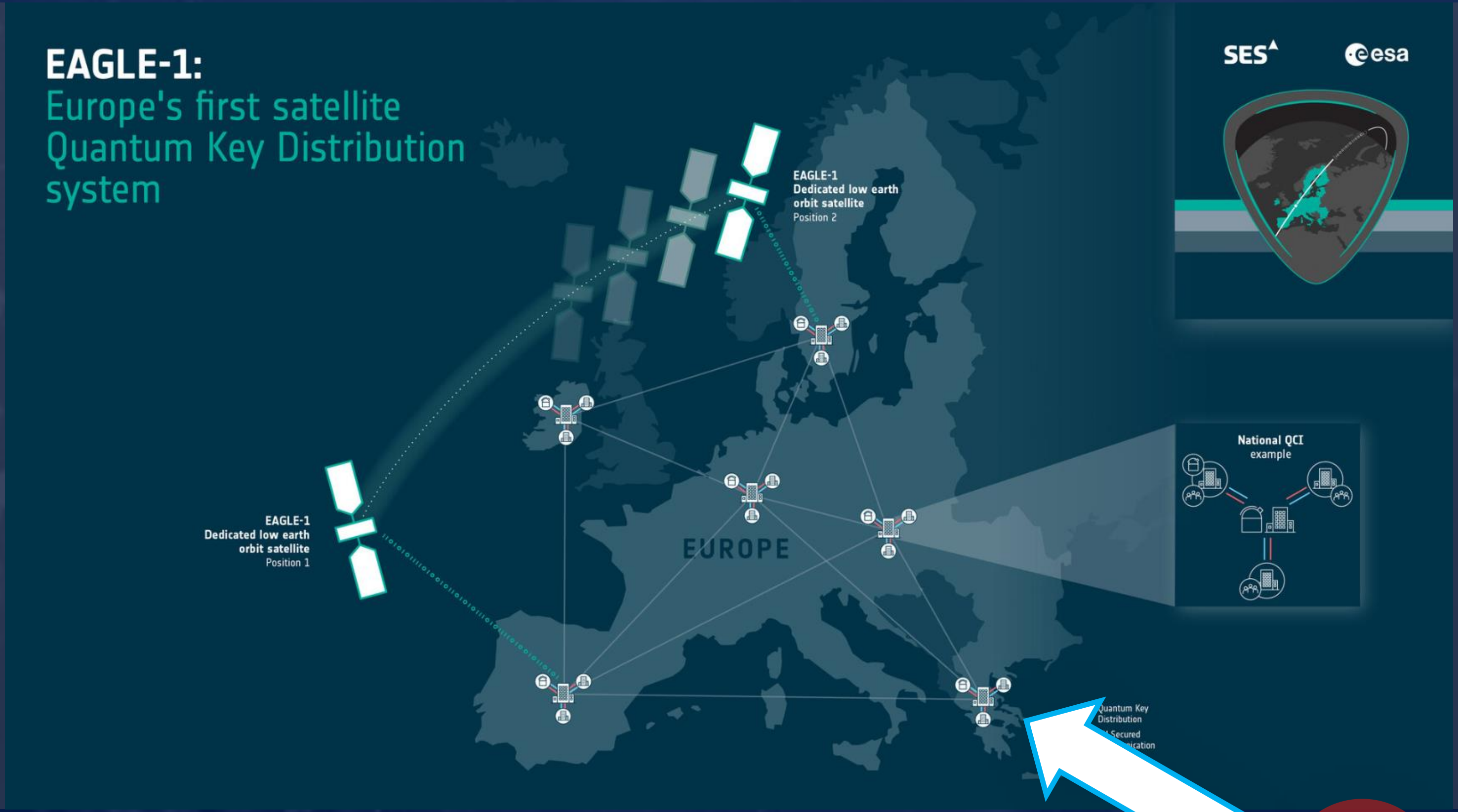
QKD & KMS National Network in South Korea

800 km of optical fiber

48 government organizations

Quantum networks today

Long-distance QKD with satellites



- The first space-based quantum key distribution system to be developed under ESA, the European Commission and 20 companies in Europe.
- Several ground stations across Europe
- To be launched in 2025/2026
- IDQ is a project partner for the QRNG that will be launched in space

Portability, efficiency, time precision

Quantum networks today

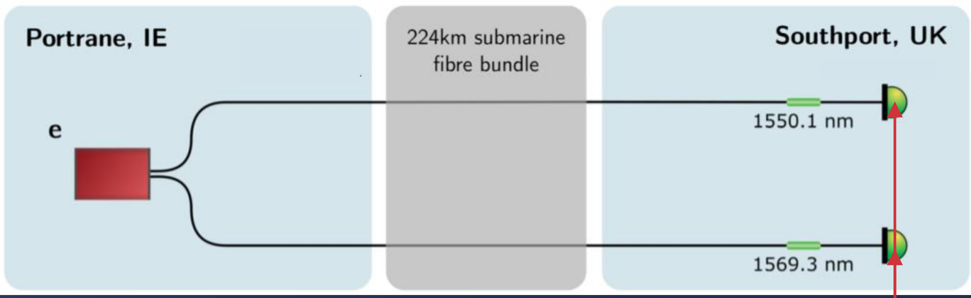
Long-distance using entanglement and low-noise detection

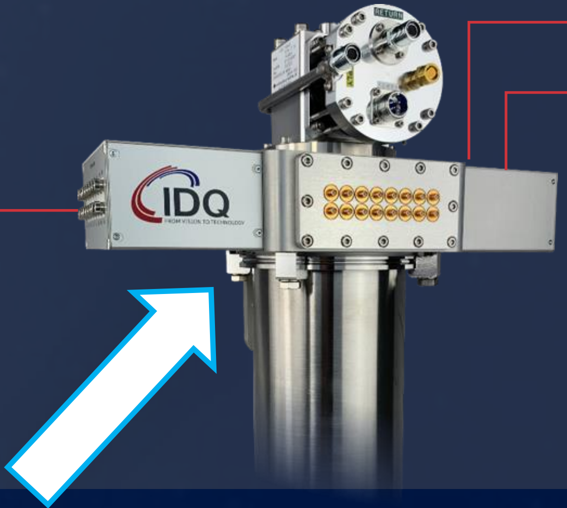
Article

Quantum Communications Feasibility Tests over a UK-Ireland 224 km Undersea Link

Ben Amies-King [1,*,†], Karolina P. Schatz [1,*,†], Haofan Duan [1,†], Ayan Biswas [1], Jack Bailey [2], Adrian Felvinti [2], Jaimes Winward [2], Mike Dixon [2], Mariella Minder [1,3], Rupesh Kumar [1], Sophie Albosh [1] and Marco Lucamarini [1,*]

Entropy **2023**, *25*, 1572. https://doi.org/10.3390/e25121572





High-efficiency and low-noise detection

Quantum networks today

Entanglement-based QKD in metropolitan quantum network

Operational entanglement-based quantum key distribution over 50 km of field-deployed optical fibers

Yoann Pelet, Grégory Sauder, Mathis Cohen, Laurent Labonté, Olivier Alibart, Anthony Martin, and Sébastien Tanzilli

Phys. Rev. Applied **20**, 044006 – Published 3 October 2023

Portability, efficiency, low-noise

High-performance low-noise detection

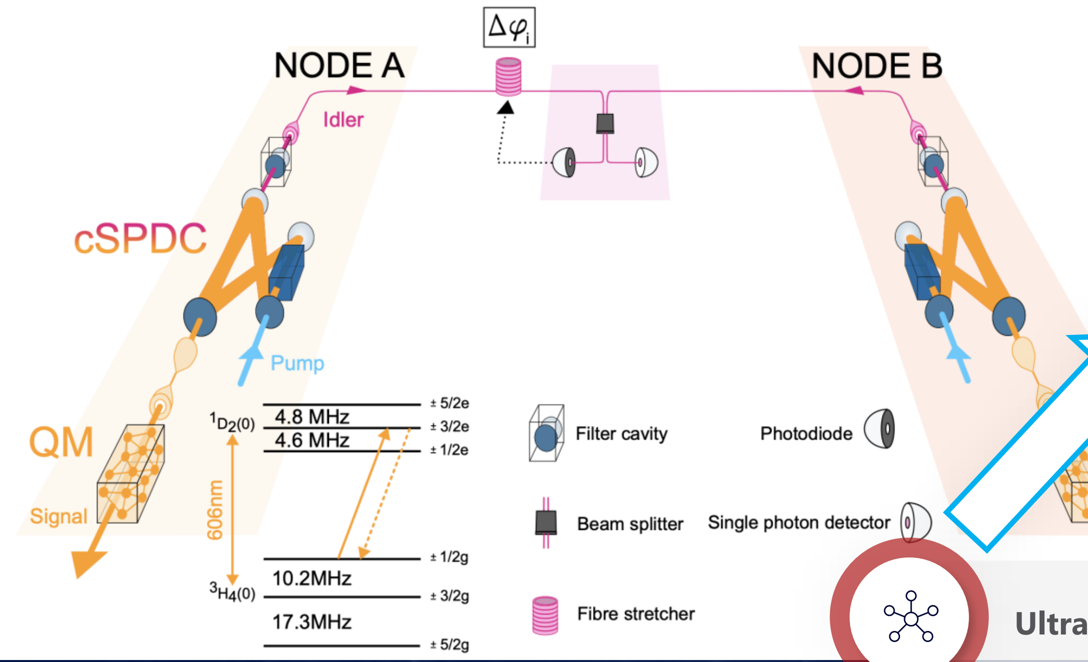
Quantum networks today

Adding entanglement and quantum memories to synchronize quantum information

Telecom-heralded entanglement between multimode solid-state quantum memories

Dario Lago-Rivera, Samuele Grandi, Jelena V. Rakonjac, Alessandro Seri & Hugues de Riedmatten

Nature **594**, 37–40 (2021) | Cite this article

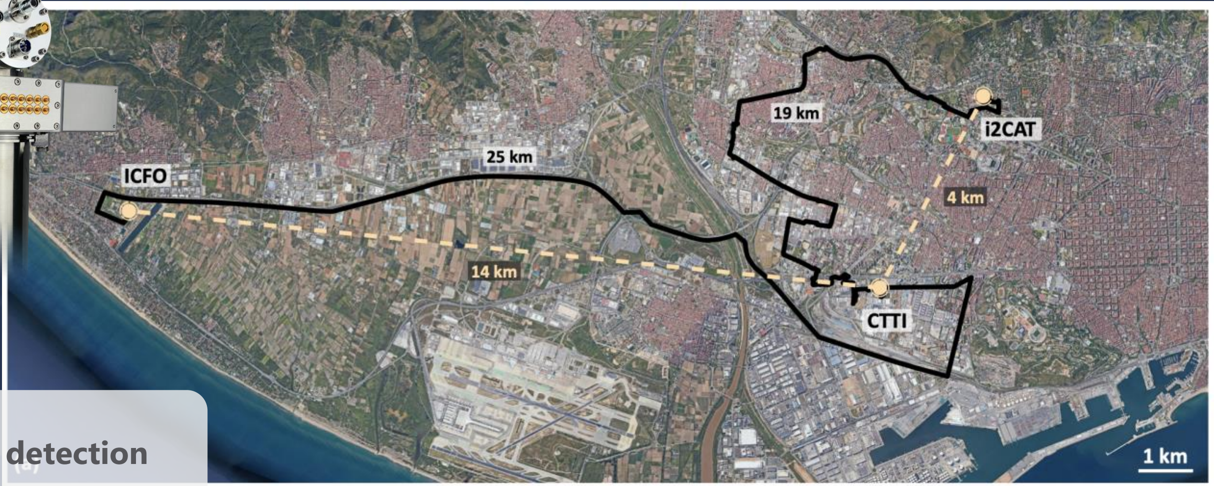


94 Vol. 1, No. 2 / 25 December 2023 / *Optica Quantum* Research Article

OPTICA QUANTUM

Transmission of light–matter entanglement over a metropolitan network

Jelena V. Rakonjac,[1,†] Samuele Grandi,[1,†*] Sören Wengerowsky,[1,†] Dario Lago-Rivera,[1] Félicien Appas,[1] and Hugues de Riedmatten[1,2]

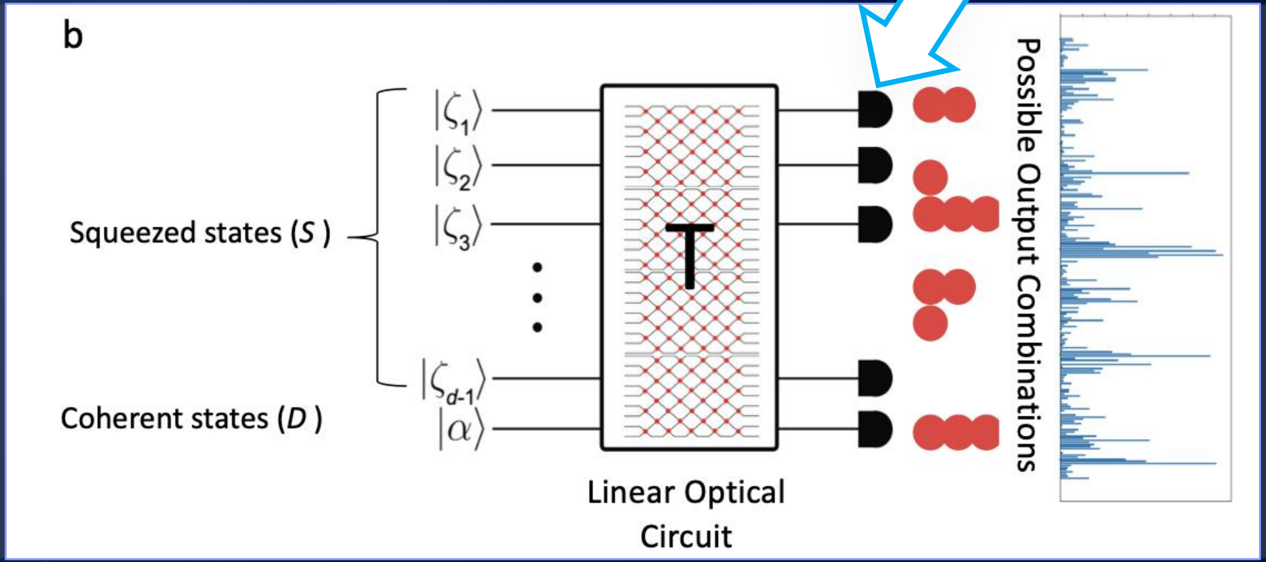


Ultra-low-noise detection

Photonic quantum computing and simulation today

From Boson Sampling machines…

Efficient PNR detection



- Quantum advantage experiments have been performed by several groups (academic and private/commercial), demonstrating the potential of the photonic approach

Images from : I. Walmsley, Optica Quantum 1, 35 (2023)

Perspective Vol. 1, No. 1 / 25 October 2023 / Optica Quantum 35

OPTICA QUANTUM

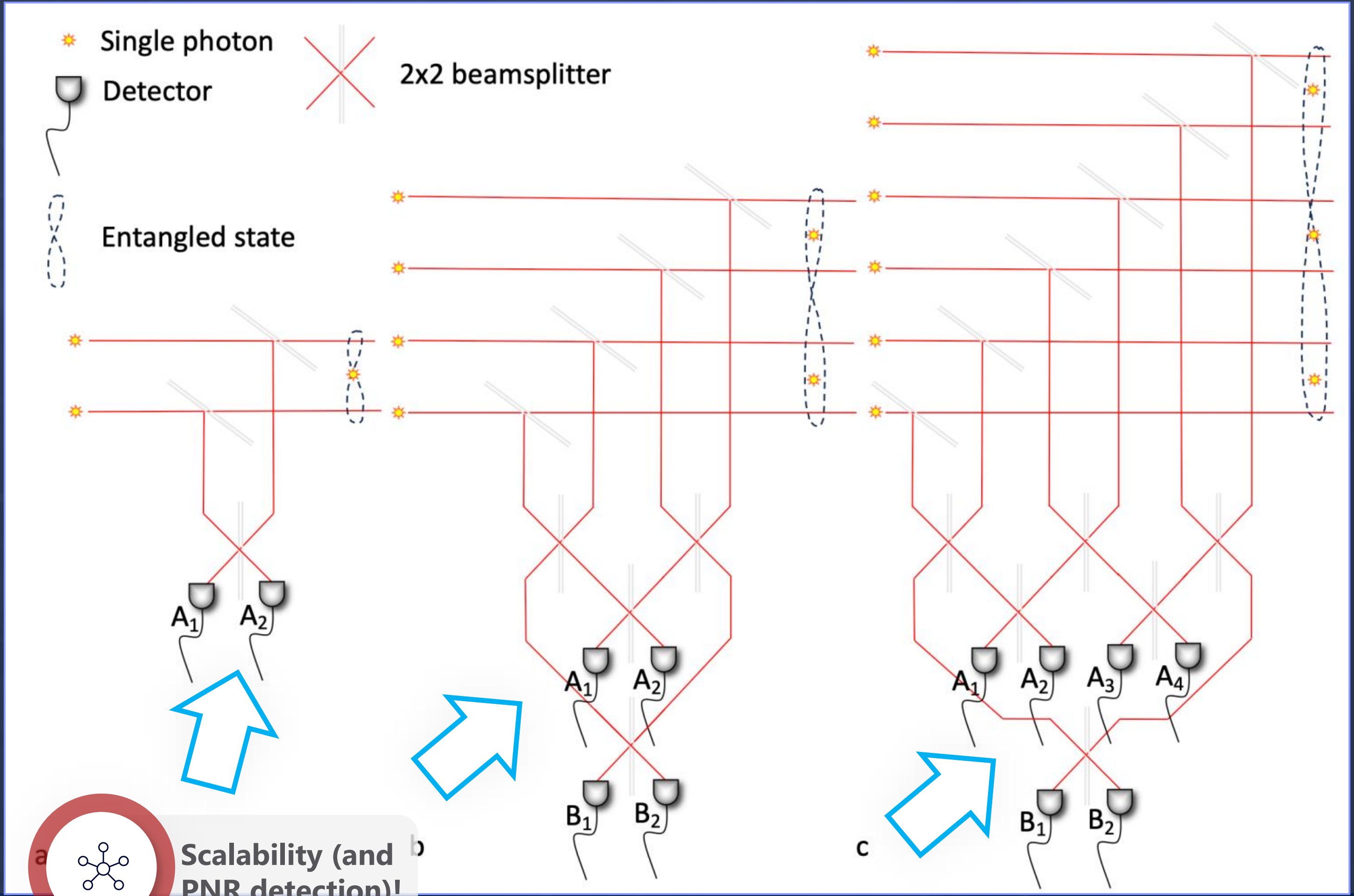
Light in quantum computing and simulation: perspective

IAN WALMSLEY

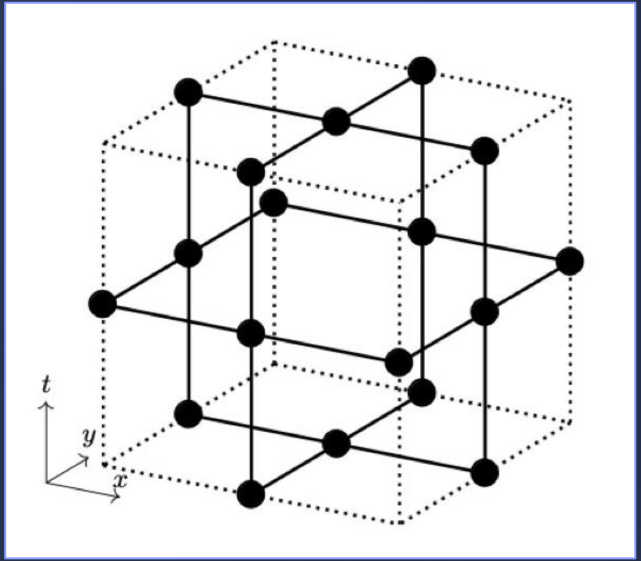
Blackett Laboratory, Department of Physics, Imperial College London, London, SW7 2AZ, UK

Photonic quantum computing and simulation in 2024

... to cluster state generation schemes



Scalability (and PNR detection)!



Images from : I. Walmsley, Optica Quantum 1, 35 (2023)


Perspective

Vol. 1, No. 1 / 25 October 2023 / Optica Quantum 35

OPTICA QUANTUM

Light in quantum computing and simulation: perspective

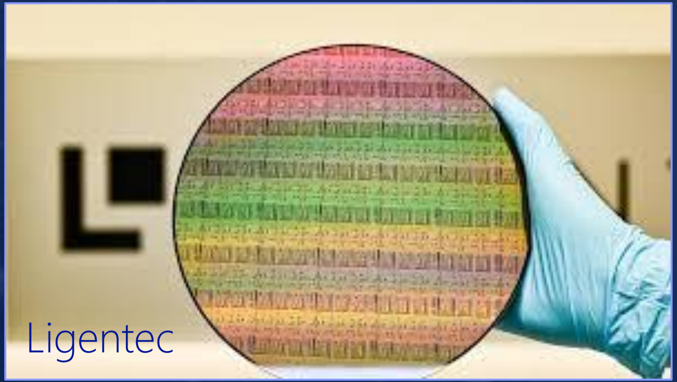
IAN WALMSLEY

Blackett Laboratory, Department of Physics, Imperial College London, London, SW7 2AZ, UK

Photonic quantum computing and simulation

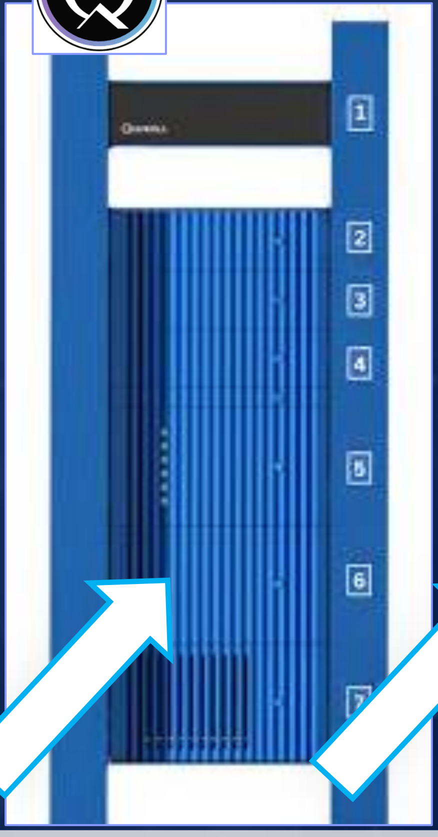
Requires photonic integration, system integration and scalability

Design and fabrication

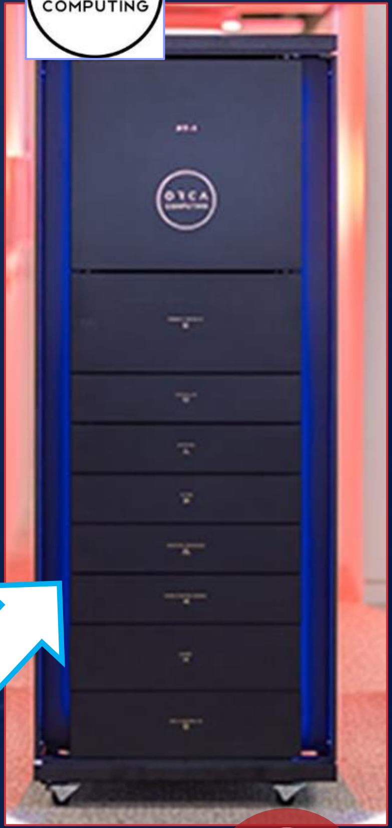


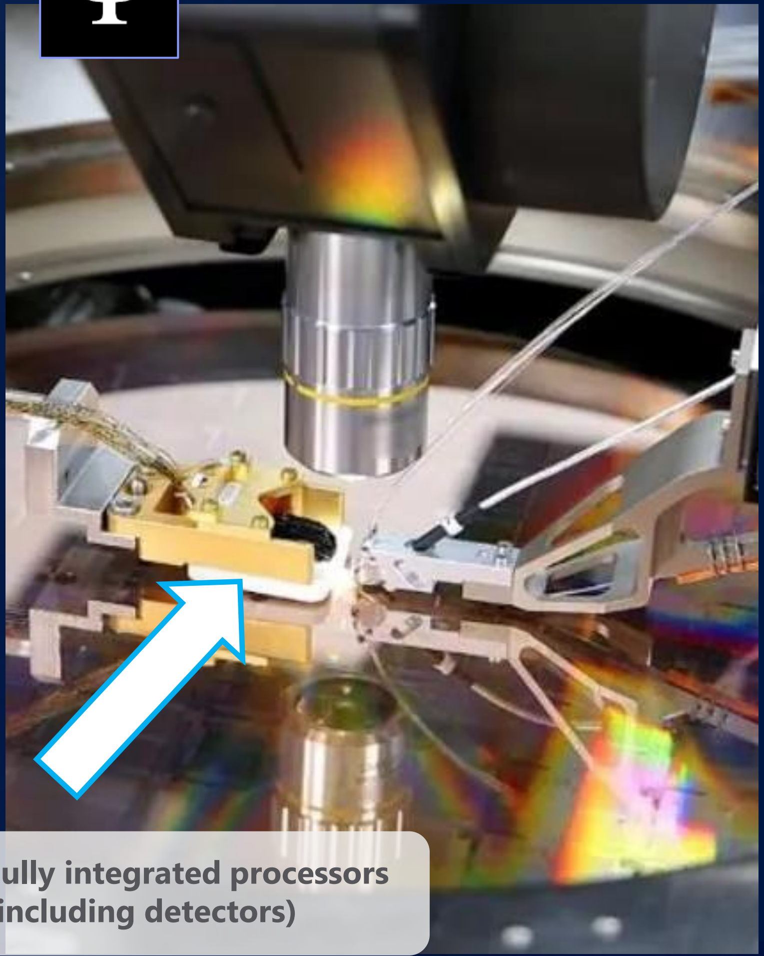
Packaging and programmability

QuiX QUANTUM



ORCA COMPUTING





Detection system in integrated quantum system

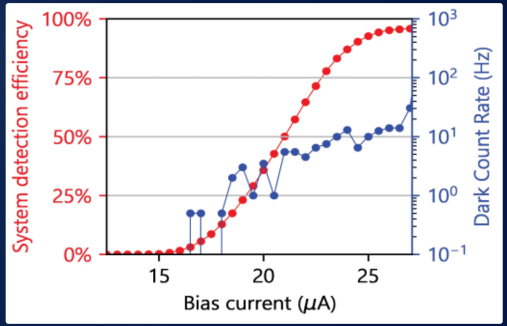
Fully integrated processors (including detectors)

What makes a good single-photon detector ?

Key metrics

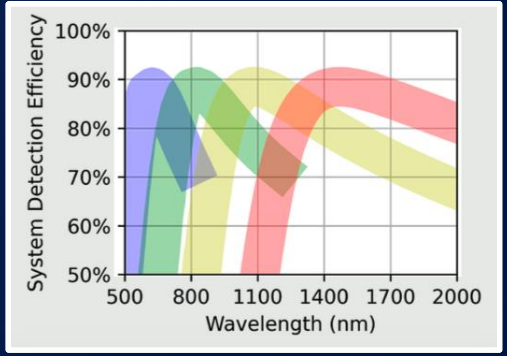
- High system detection efficiency (SDE)
- Low dark-count rate (DCR)
- Good timing precision (jitter)
- Fast detection rates
- Photon-number resolution (PNR)
- Form factor + compatibility + quality + …

Scalability with near-perfect detection efficiency



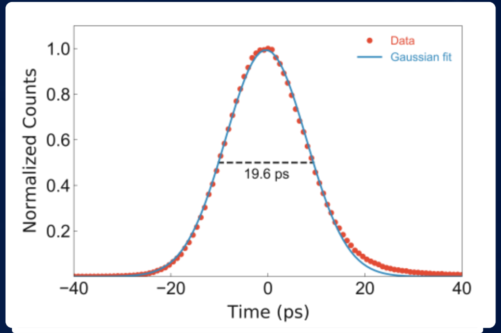
> 90% efficiency
< 1 cps DCR

Quantum science at any wavelength



From < 600 nm to > 2000 nm

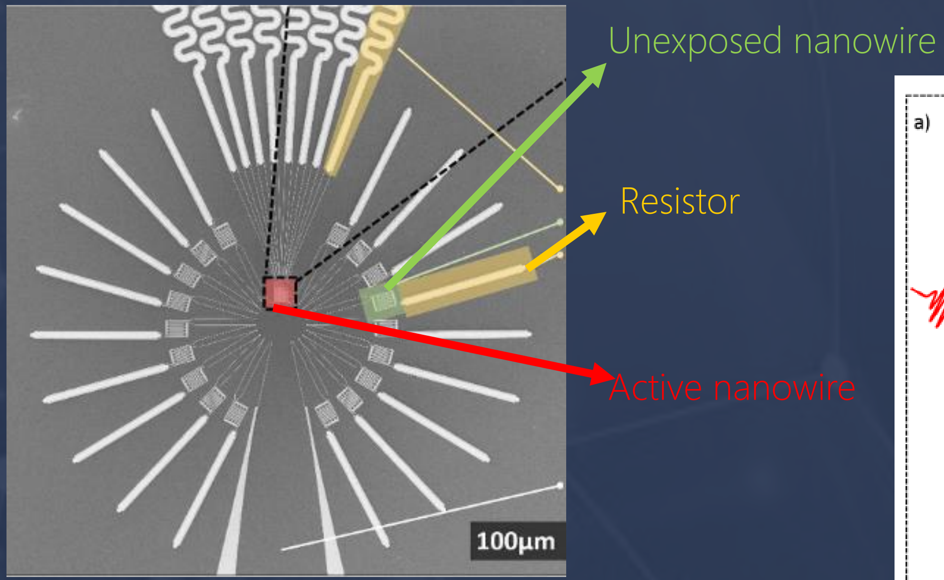
Time precision for any occasion

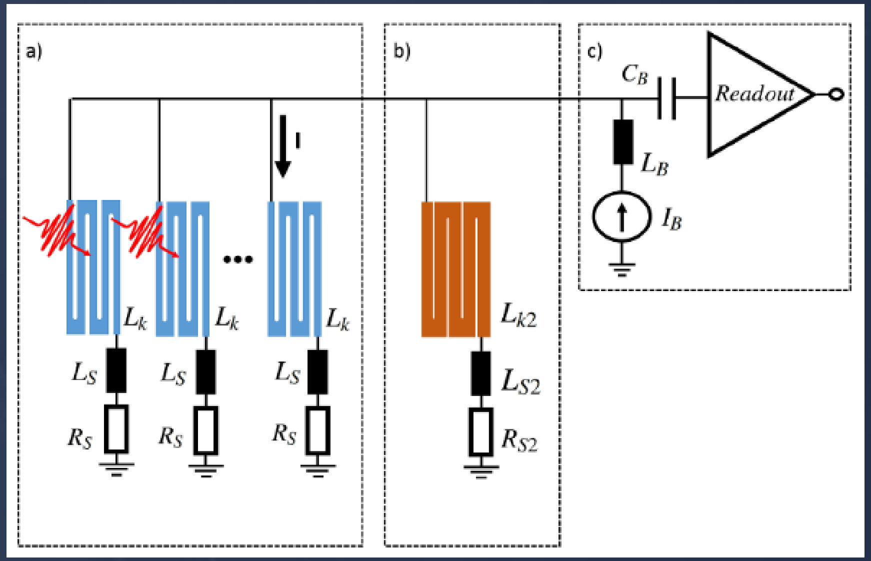


Jitter can be as low as < 20 ps

Parallel SNSPDs (P-SNSPDs)

Unique patented architecture





Additional unexposed nanowire in parallel to minimize current redistribution effect

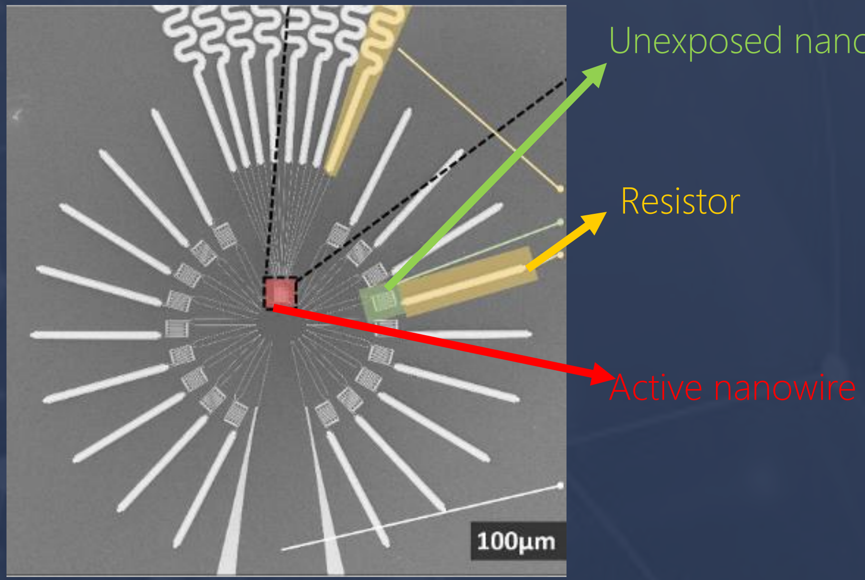
Perrenoud, M., et al. *Superconductor Science and Technology* 34.2 (2021): 024002

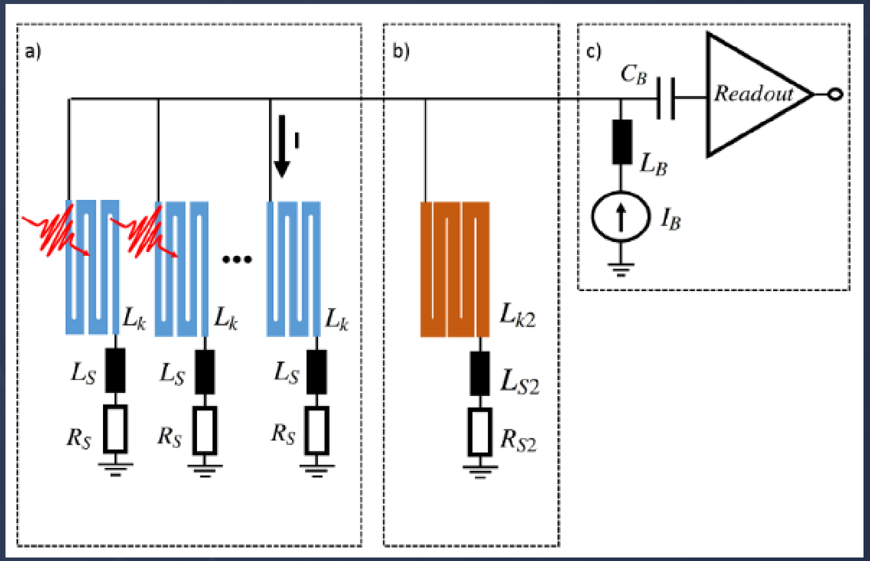
Parallel SNSPDs (P-SNSPDs)

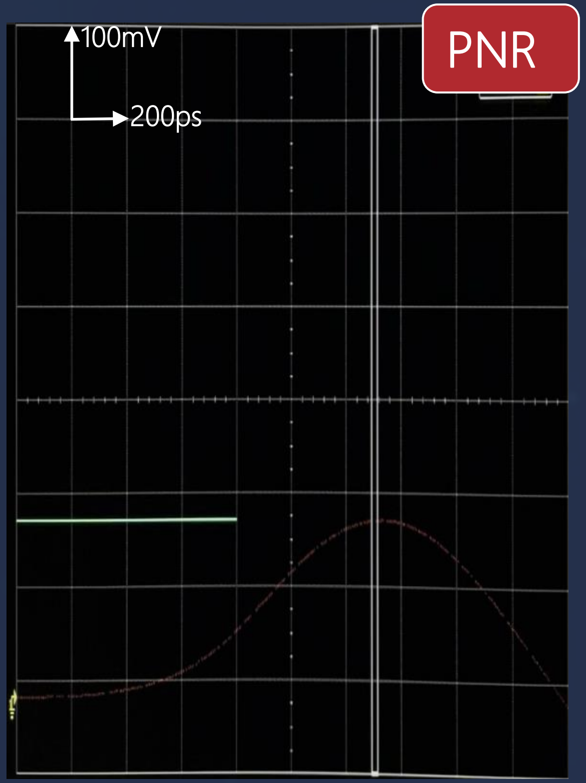
Unique patented architecture

In collaboration with

UNIVERSITÉ DE GENÈVE







Additional unexposed nanowire in parallel to minimize current redistribution effect

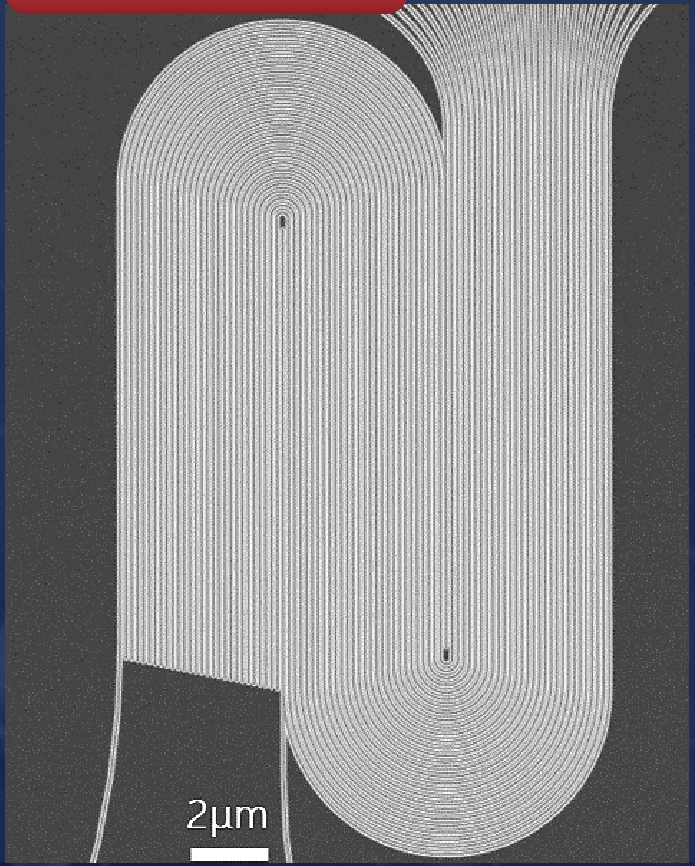
Perrenoud, M., et al. *Superconductor Science and Technology* 34.2 (2021): 024002

Parallel SNSPDs : a new generation

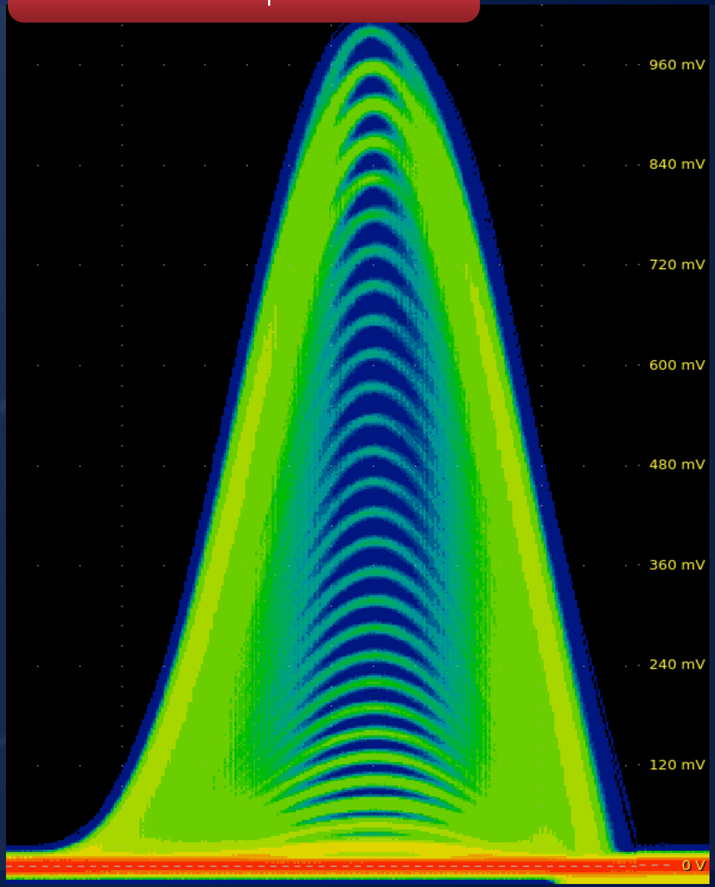
28 interleaved active pixels

In collaboration with UNIVERSITÉ DE GENÈVE

SEM image



Oscilloscope trace

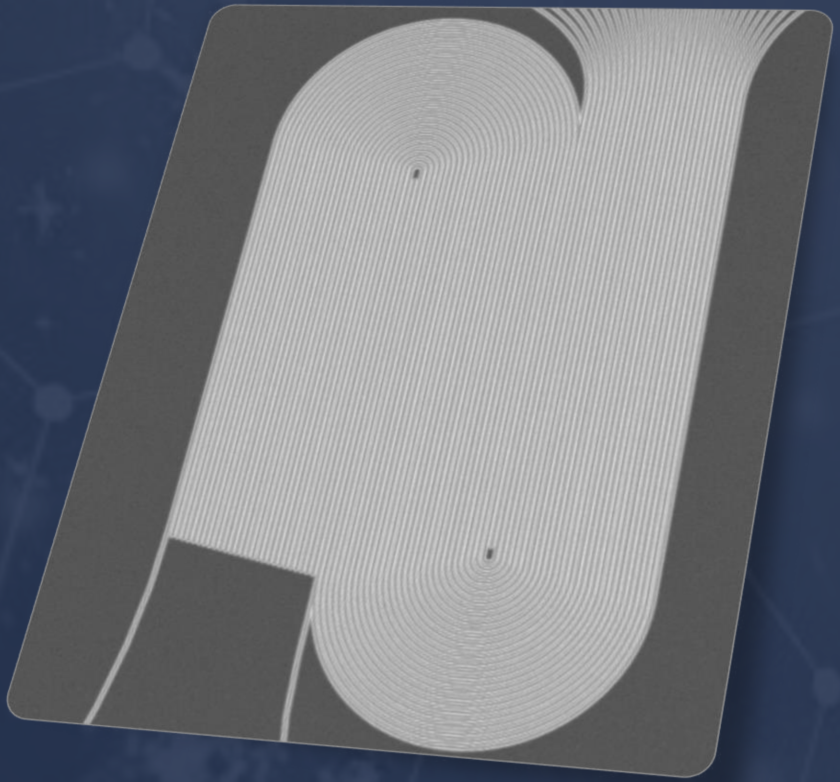


Parallel SNSPDs : a new generation

28 interleaved active pixels

In collaboration with

More pixels is better !



- Faster detectors ✓
- Performances stable at higher count rates ✓
- Improved n-photon efficiencies ✓
- Only 1 coaxial line needed ✓

Stasi, L. et al, ACS Photonics 12, 320-329 (2025) - arXiv:2406.15312 (2024)

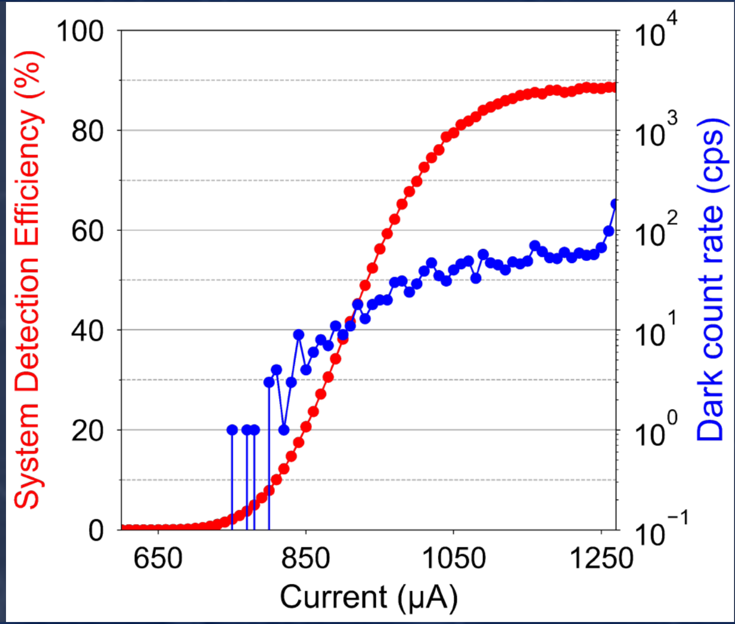
28-pixel P-SNSPD

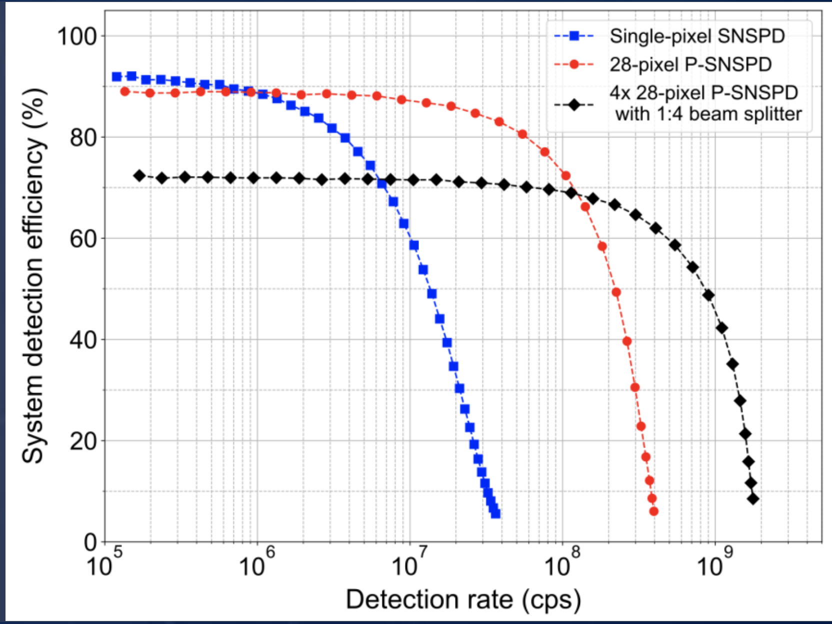
Performances

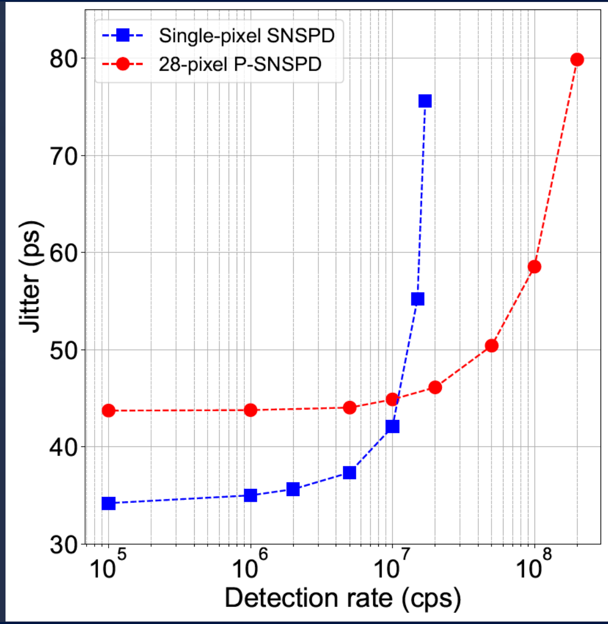
Speed-up the rate of entanglement distribution in quantum networks

Clock distribution

In collaboration with UNIVERSITÉ DE GENÈVE







88% SDE, 1550nm

>200 Mcps @ 50% SDE
> 1 Gcps with 4 devices

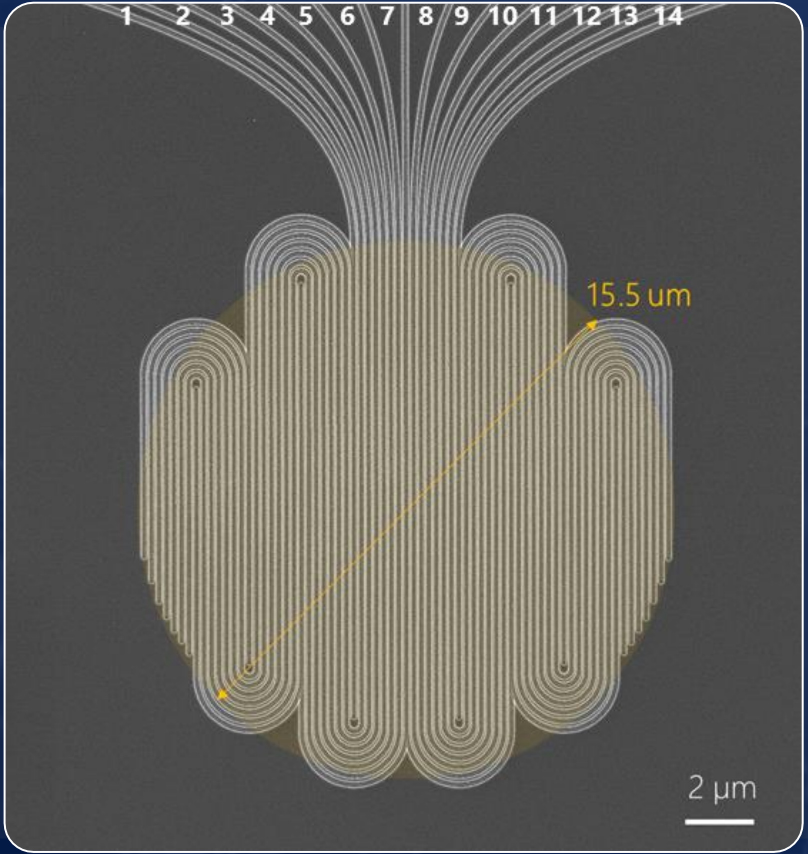
Jitter <60 ps @ 100 Mcps

Stasi, L. et al, ACS Photonics 12, 320-329 (2025) - arXiv:2406.15312 (2024)

MP-SNSPD – 14-pixel implementation

Specifically developed for ultra-fast QKD

In collaboration with UNIVERSITÉ DE GENÈVE

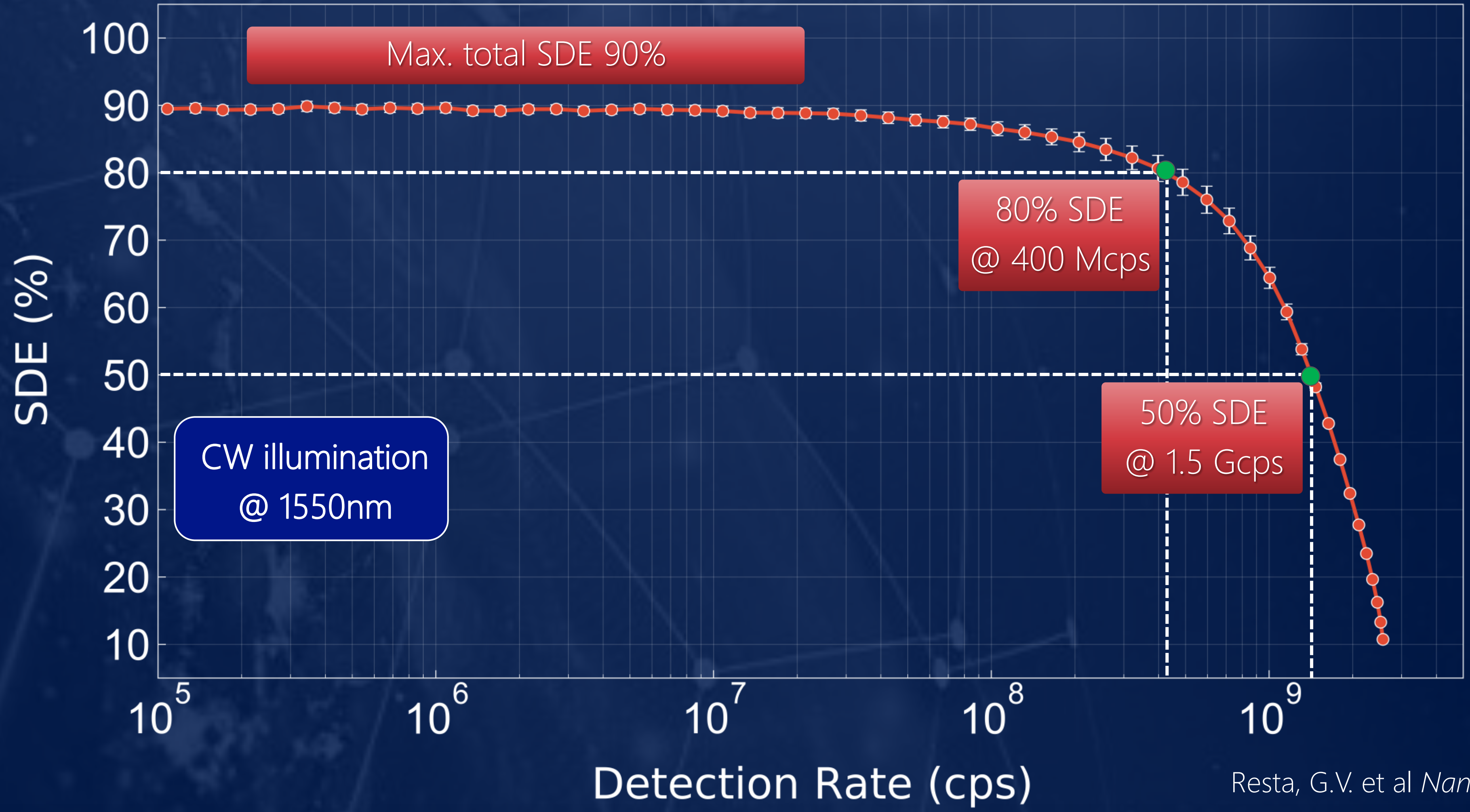


Individual bias and readout →	Highest count-rate and lowest jitter
1 single-mode fiber →	Simple optical set-up
Number of pixels clicking encodes photon number info →	"Dynamic PNR", no limitation on input light

MP-SNSPD performances

Efficiency vs. detection rate with 1550 nm CW light

In collaboration with UNIVERSITÉ DE GENÈVE



Huge Improvement of detection rate through independent operation of the nanowires, with minimal thermal cross-talk

No latching!

Resta, G.V. et al *Nano Letters*, *23* (13), 6018-6026 (2023)

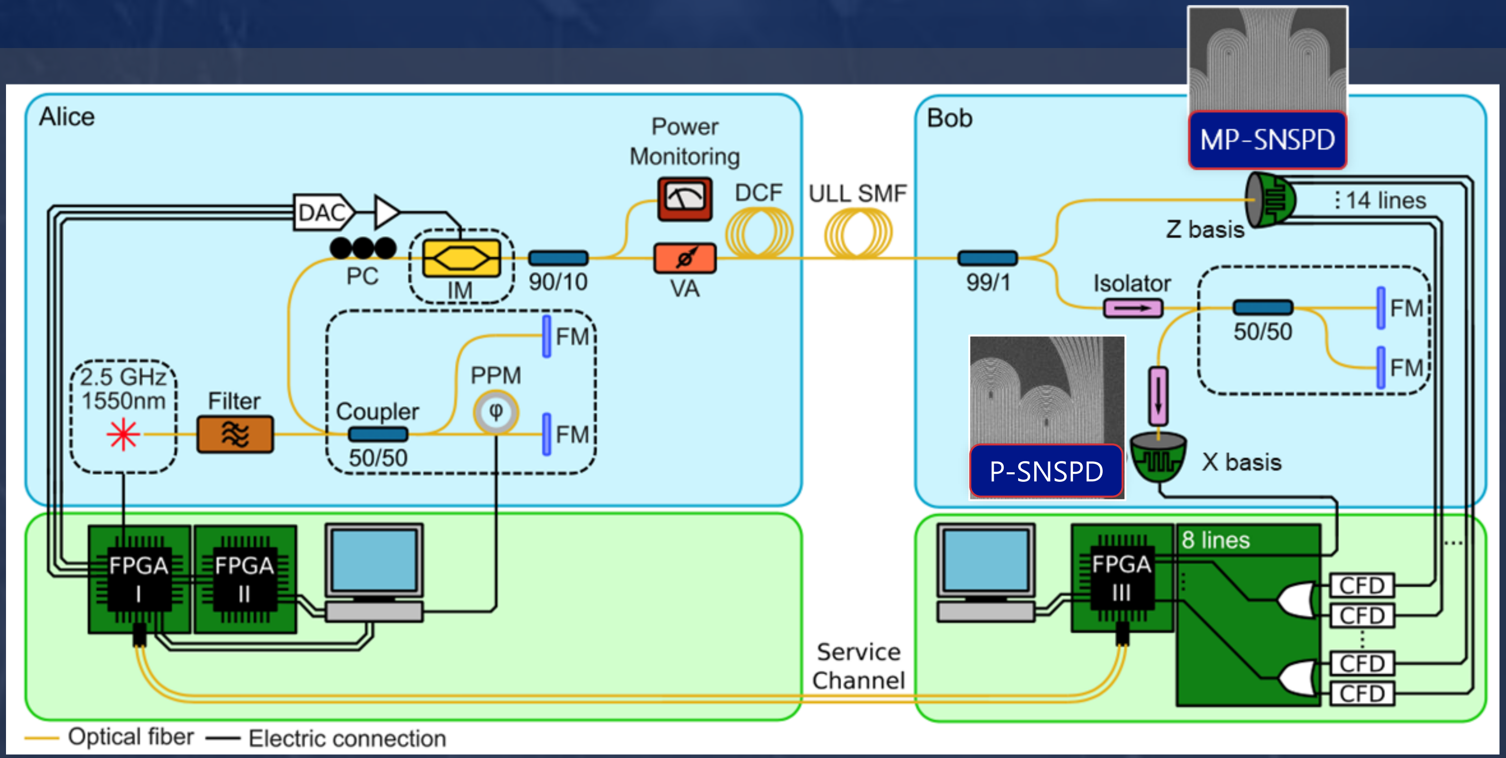
Quantum Key Distribution experiment

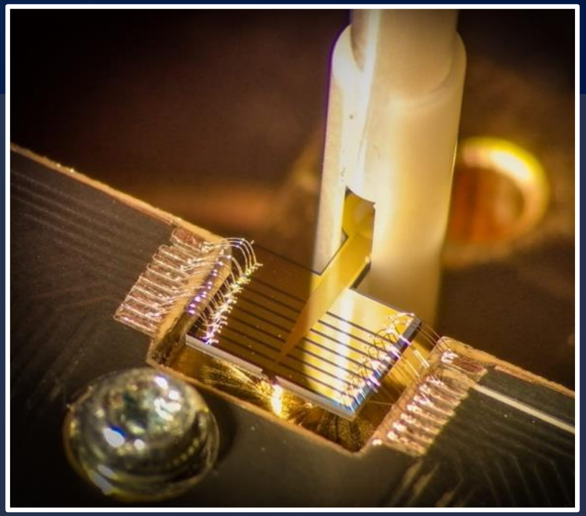
Enable >60 Mbps secret key rates with MP-SNSPDs

IDQ

In collaboration with

UNIVERSITÉ DE GENÈVE





fiber length (km)	att. (dB)	SKR (Mbps)
10.0	1.58	64
102.4	16.34	3.0

Grünenfelder, F. et al. *Nature Photonics*, *17*(5), pp.422-426 (2023).

See also Li, W., *Nature Photonics*, *17*(5), pp.416-421 (2023).

IDQ’s PNR SNSPDs empower ORCA’s quantum processors

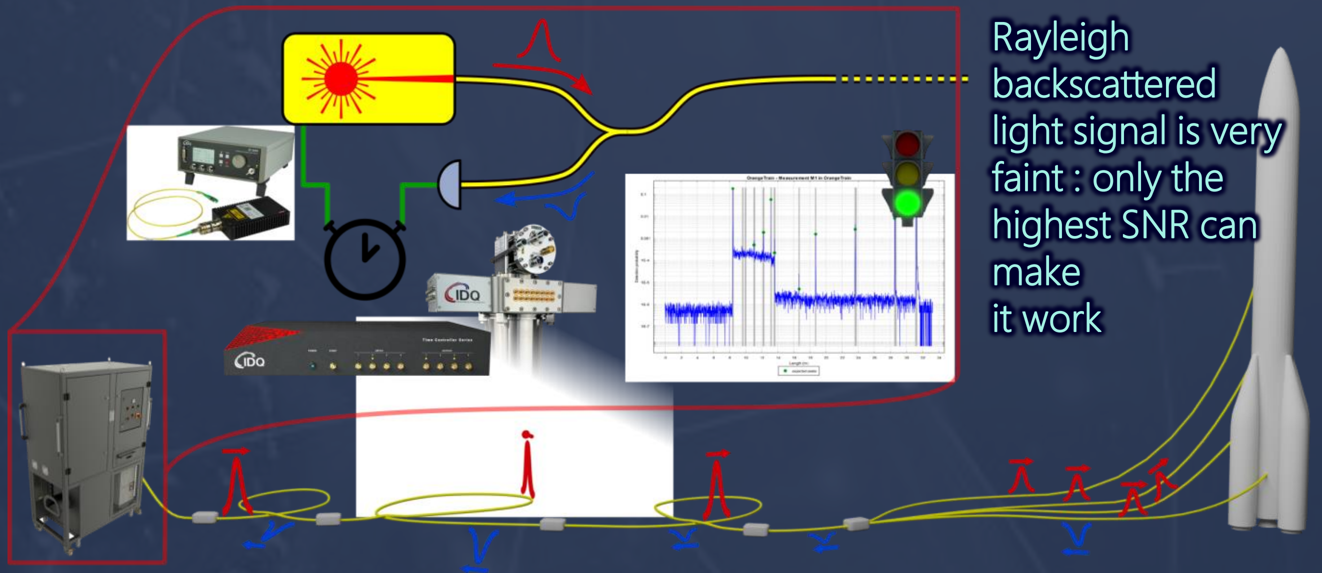
Quantum + AI with near-term usefulness

Near-ideal PNR detectors contribute to

- Reaching/deepening quantum advantage
- Addressing a larger body of computational problems
- Making the processor scalable
- Enabling error-correction and fault-tolerance

Ariane 6 maiden flight - From quantum physics to rocket science

"Extreme" Optical-Time-Domain Reflectometry (OTDR) to test Ariane 6's fibres



Ariane 6 maiden flight - From quantum physics to rocket science

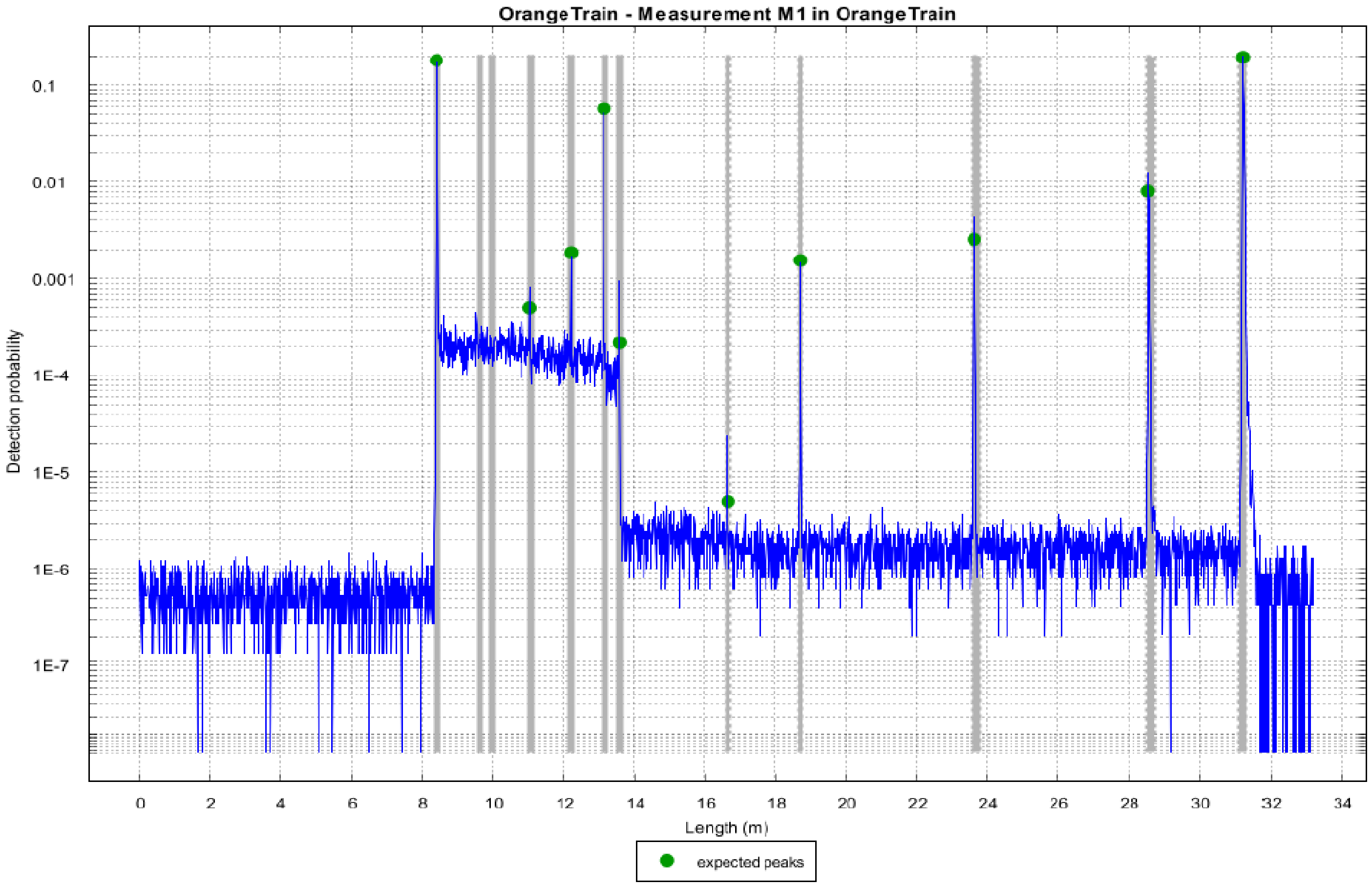
"Extreme" Optical-Time-Domain Reflectometry (OTDR) to test Ariane 6's fibres

Single photon OTDR offers

- Operation with low optical power
- High sensitivity (photon counting)
- High dynamic range (>70 dB)
- High spatial resolution (1.5 cm)
- Virtually no dead zone
- Fast acquisition times (typ. 60 sec)

Required SNSPD system with

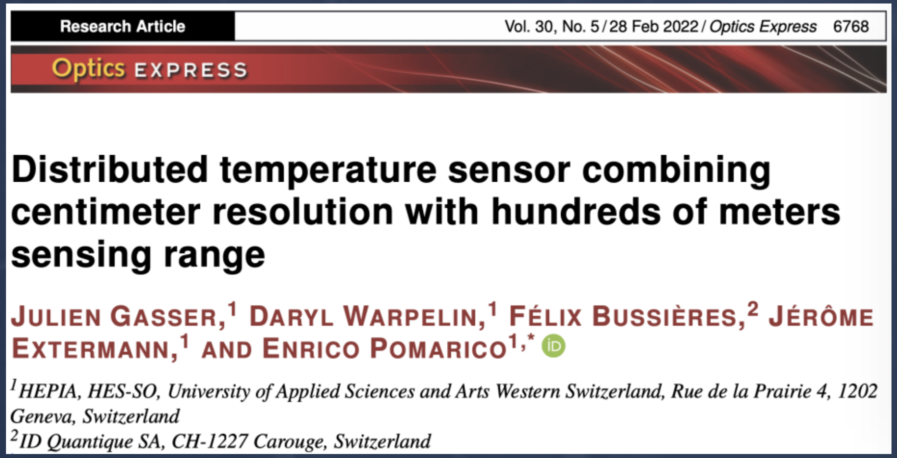
- Polarisation insensitive efficiency (> 70% typical)
- Low DCR (< 100 cps typical)
- Non-latching behavior
- Complete autonomy



ID QUANTIQUE PROPRIETARY

Precise distributed temperature sensing with SNSPDs

From OTDR to Raman-based distributed temperature sensing

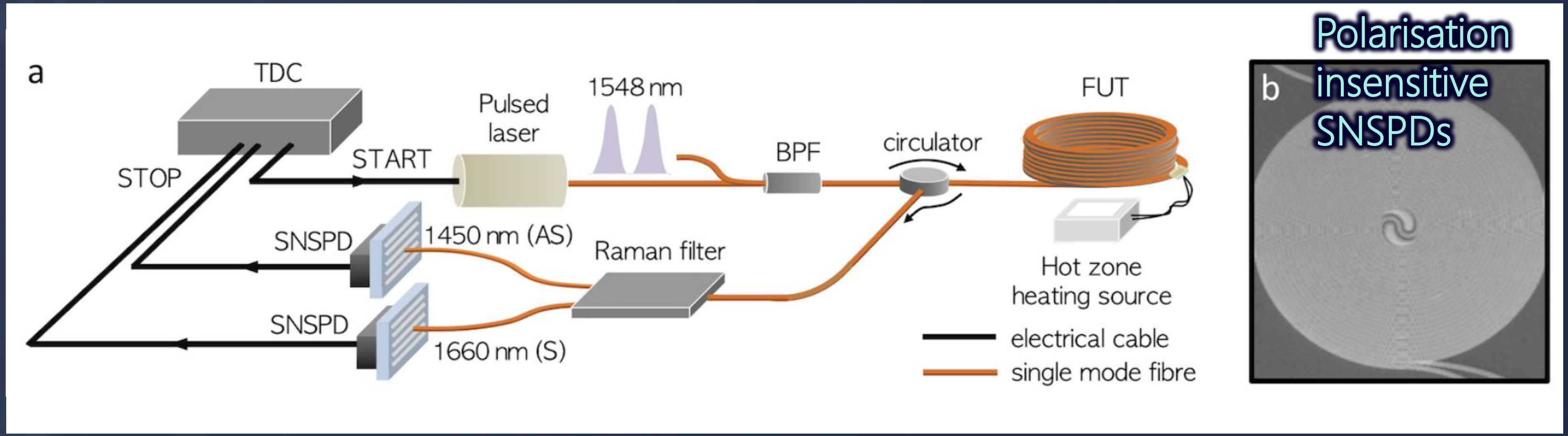

Research Article Vol. 30, No. 5 / 28 Feb 2022 / Optics Express 6768

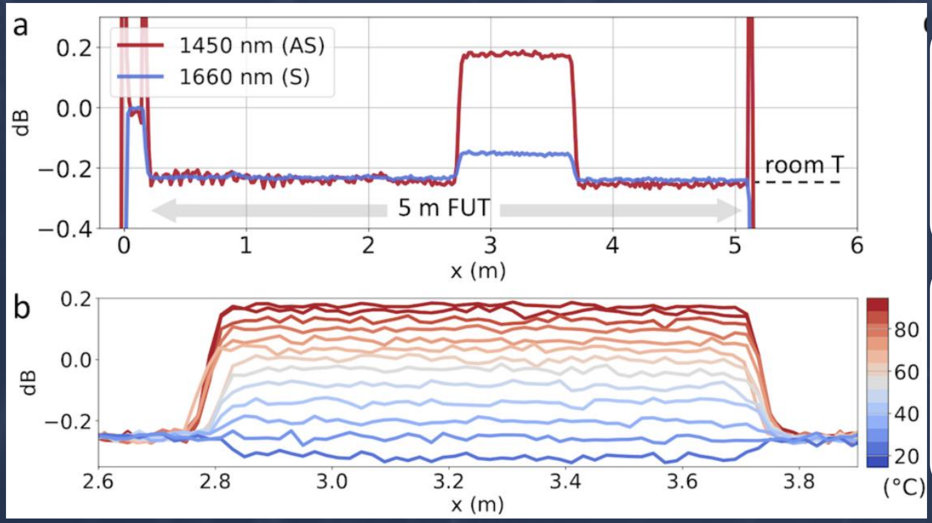
Optics EXPRESS

Distributed temperature sensor combining centimeter resolution with hundreds of meters sensing range

JULIEN GASSER,[1] DARYL WARPELIN,[1] FÉLIX BUSSIÈRES,[2] JÉRÔME EXTERMANN,[1] AND ENRICO POMARICO[1,*]

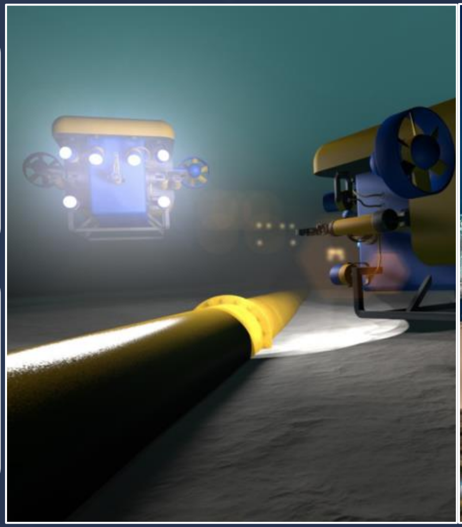
[1] *HEPIA, HES-SO, University of Applied Sciences and Arts Western Switzerland, Rue de la Prairie 4, 1202 Geneva, Switzerland*
[2] *ID Quantique SA, CH-1227 Carouge, Switzerland*





1.5 °C and 3 cm resolution over 5 m with a 1 min integration time

8 °C and 10 cm resolution over 500 m with a 3 min integration time



Cryogenic temperature sensing : one fibre to map a cryostat

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Cryogenic temperature 3D mapping via a distributed temperature sensor with centimeter resolution

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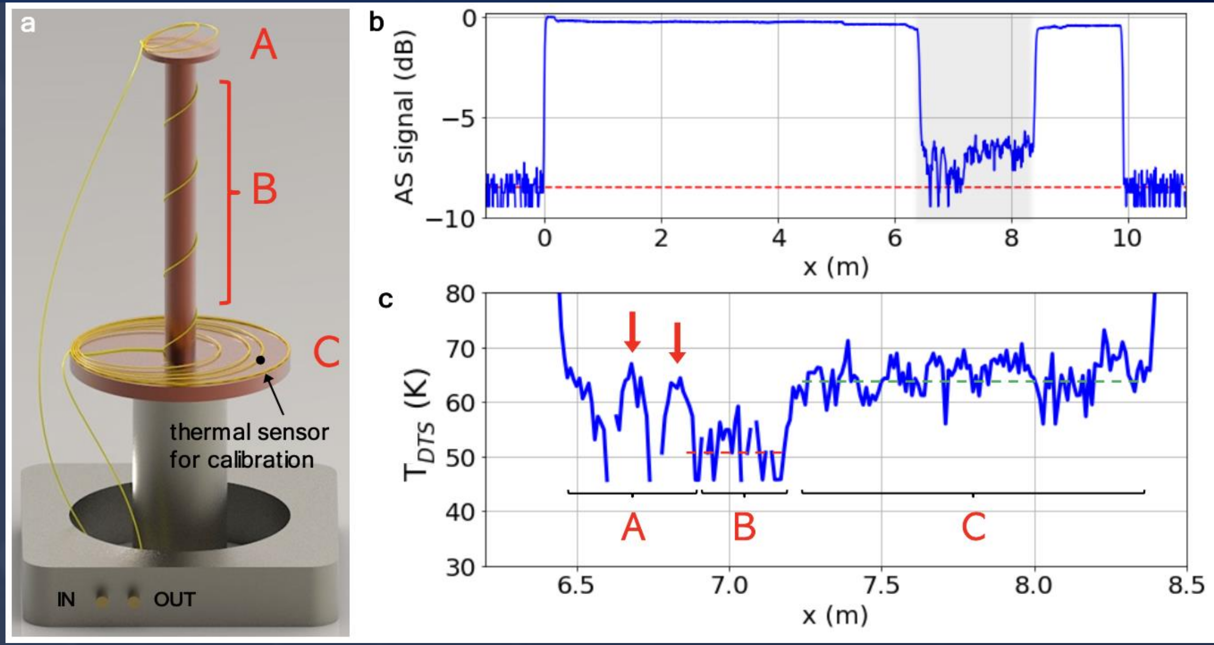

Details of fiber attachment visible!

Works down to ~48 K with 3 cm resolution

2019	RamS OTDR	77	0.3	[14]
2020	RamS OTDR	77	/	[15]
2020	RamS OTDR	76	4	[16]
2023	RamS OTDR	48	0.03	This work

One fiber to map a full cryostat.

Use in cases where heavy use of cryogenic electronics is necessary (Q. computing)

Team members

ID Quantique

Founded in 2001

Team of > 100 people

Geneva, Seoul, Boston, Austria

We develop products for

Quantum-safe security
Quantum technologies

Academic and companies
Startups and industry

In collaboration with

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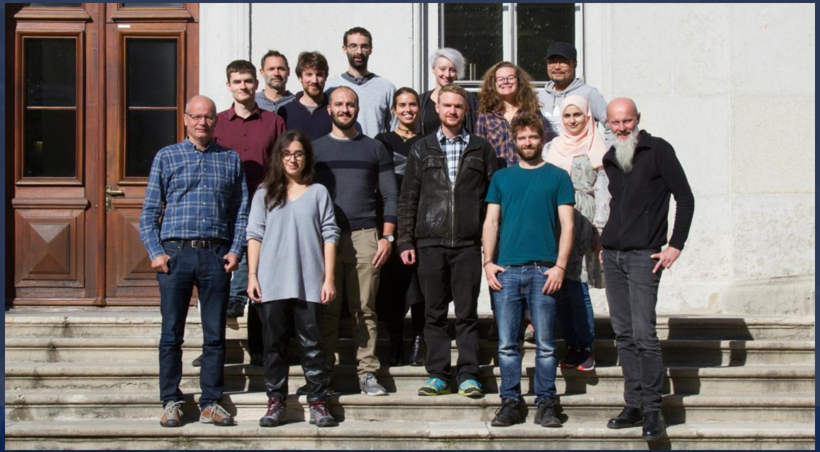

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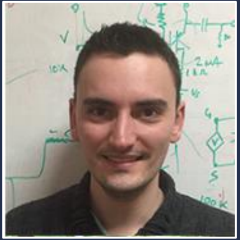

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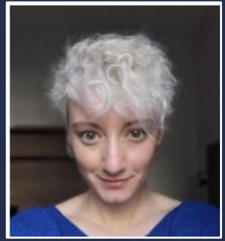

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Geneva Quantum Centre

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