FWO-FWF SQOPE PROJECT

Squeezed Quantum prOcessing with Photonics and Electronics

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Quantum Austria: 3rd Networking Event
March 5 2025, Palais Wertheim Vienna

The SQOPE project

Project: Squeezed Quantum prOcessing with Photonics (SQOPE)

Call: Research project WEAVE FWO-FWF (FWO lead agent)

Duration: 01/09/2022 – 31/08/2026

Goals and aims

- Squeezed light source and receiver on chip
- Applications in quantum communication and computing

SQOPE QUANTUM

Ghent University: Design & fabrication
AIT: quantum communication
Universität Wien: quantum computing

GHENT UNIVERSITY

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

universität wien

Why squeezed light?

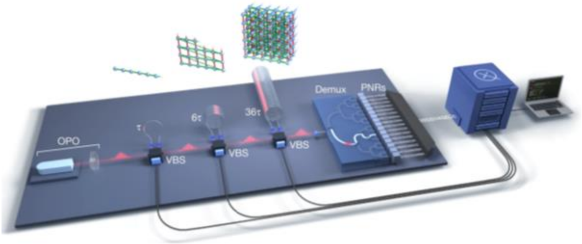
Quantum Technology

Computing

Communication

Sensing

Optical quantum computing



Quantum computational advantage*

CV - QKD

Squeezed light offers enhanced robustness against channel noise and loss, and improved secret key rates***

Gravitational wave detection

Noise

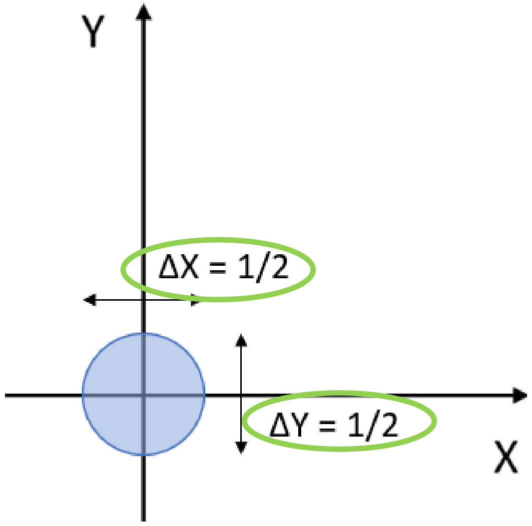
1st detection in 2015**, nobel prize in physics 2017

* L. S. Madsen, et al. "Quantum computational advantage with a programmable photonic processor." *Nature* 606 75-81 (2022)
** B. P. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration), "Observation of Gravitational Waves from a Binary Black Hole Merger", *Phys. Rev. Lett.* 116 (2016)
*** T. Gehring et al., „Implementation of continuous-variable quantum key distribution with composable and one-sided-device-indipendent security against coherent attacks", *Nat Commun.* 6 (2015)

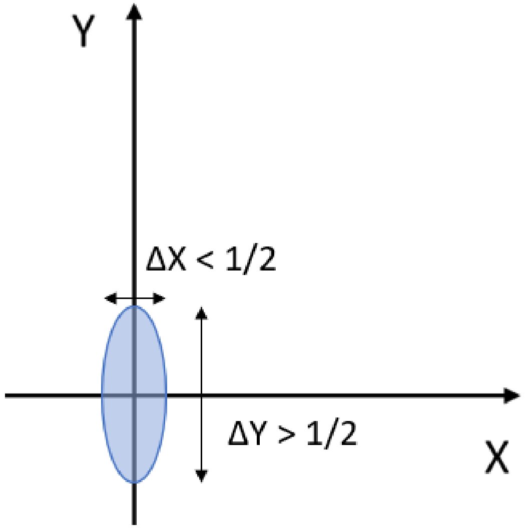
Squeezed light basics

Squeezed light is characterized by having the variance of a quadrature amplitude below the variance of the vacuum (or coherent state). The variance of the conjugated quadrature is larger than the one of the vacuum in order to obey the Heisenberg’s uncertainty relation

Heisenberg‘s uncertainty principle: $\Delta X * \Delta Y \geq 1/4$



Vacuum state |0>

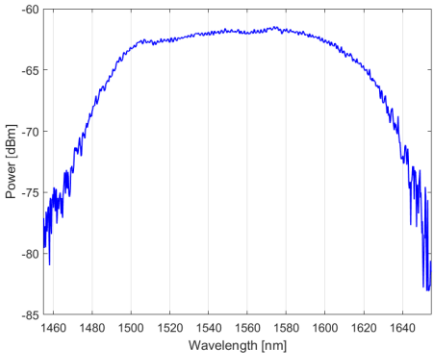


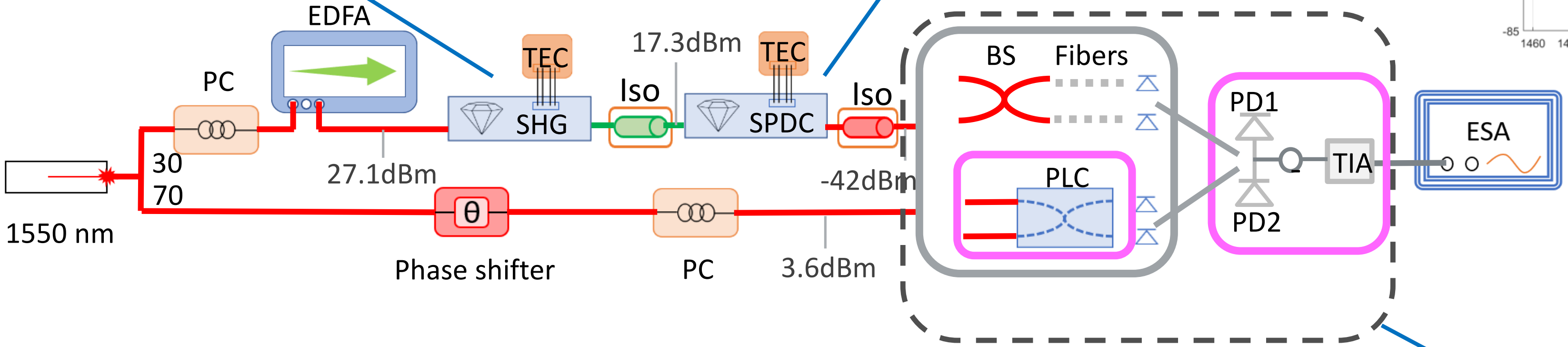
Squeezed vacuum state

Squeezed light set-up

Second harmonic generation for frequency doubling -> 777 nm

Broadband squeezed light with center frequency 1550nm and FWHM of 152nm

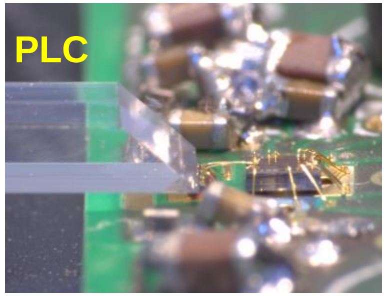


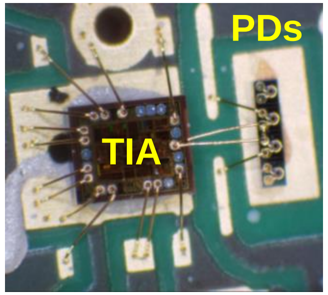


Balanced quantum homodyne receiver

LO phase

$$(\Delta X_\beta)^2 = \eta(e^{2r}\cos^2(\Theta) + e^{-2r}\sin^2(\Theta)) + 1 - \eta$$





D. Milovančev, et al. "Chip-level GHz capable balanced quantum homodyne receivers", *J. Light. Technol.* 40 23 (2022)
E. Zaiser et al., "Detection of broadband squeezed light with a low-noise die-level balanced receiver", arXiv:2407.07588

Squeezed light characterization

$$\eta_{\text{prop}} = \frac{\eta}{\eta_{\text{tot}}} = 79\,\%$$

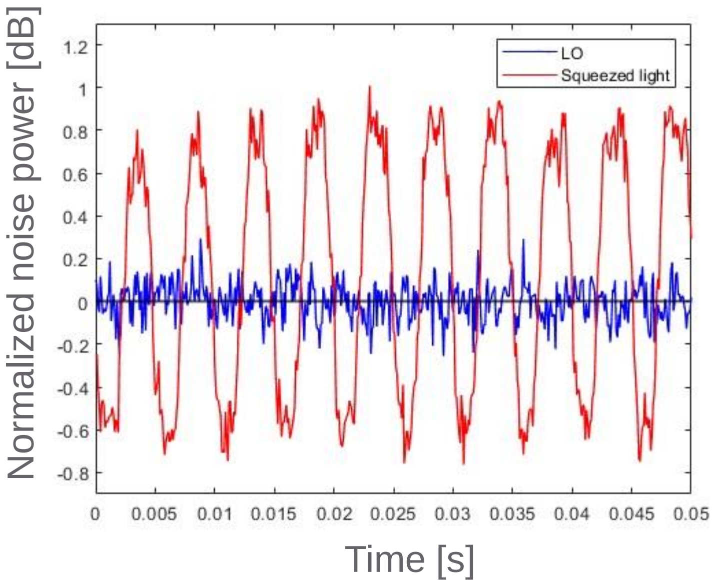
Fit parameters

$$\eta = 30\,\%$$

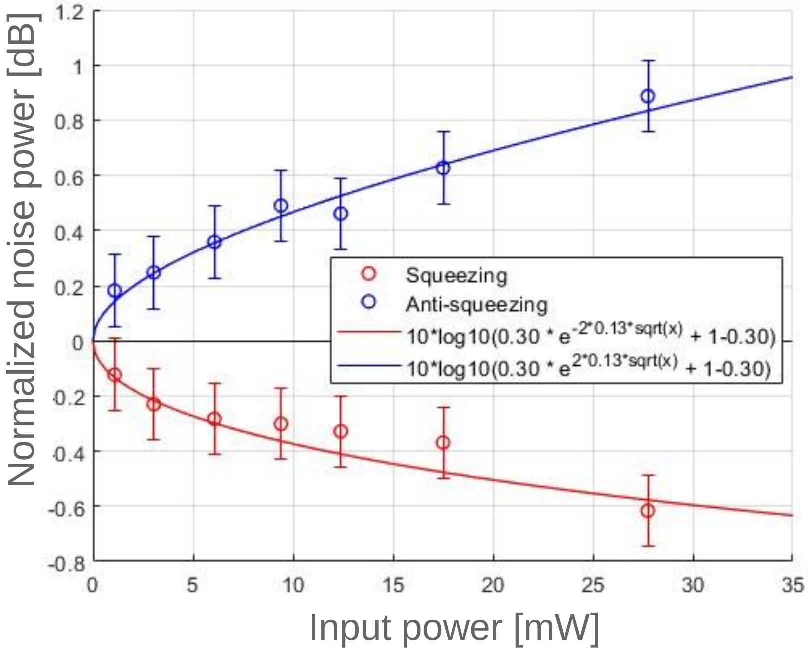
Overall detection efficiency

$$\mu = 0.13\,\text{mW}^{-0.5}$$

Crystal properties (length, interaction strength)



Squeezing at 40MHz measured over 50ms with an input power at SPDC crystal Pin = 14.4dBm (200Hz modulation)



η_{out}=output coupling=86 %,
η_{con}=connection losses=52 %,
η_{det}=detection efficiency=88 %,
η_{el}=electrical noise=96 %

$$\eta_{\text{tot}} = 38\,\%$$

$$r = \mu \cdot \sqrt{P}$$

$$(\Delta X_\beta)^2 = \eta(e^{2r}\cos^2\Theta + e^{-2r}\sin^2\Theta) + 1 - \eta$$

-3.4 dB squeezing at the SPDC crystal

Qu-Test Open Call, second cut-off

QU- TEST

The Call is open to all EU companies in search of support services incorporating cutting-edge technologies in quantum computing, communication, and sensing.

Opening date: October 1, 2024
Deadline: March 31, 2025
Eligibility: companies of all sizes with majority ownership within EU member states, and Iceland, Norway, Israel
Funding: 100% funded, no direct funding to external use case companies
Service offering: Ecosystem Management Platform accessible at https://ecosystem.qu-pilot.eu/technical-marketplace/
Applications steps: 1. check Service offering; 2. fill in Intake form on Qu-Test website; 3. get matched with a Qu-Test Service Provider; 4. fill in application form (3 pages, no budget, submit via Qu-Test Application software)

Take a step into the future of quantum. Apply today!

Funded by European Union | Horizon Europe

Thank you!

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TOMORROW TODAY

Emmily Zaiser

Dinka Milovančev

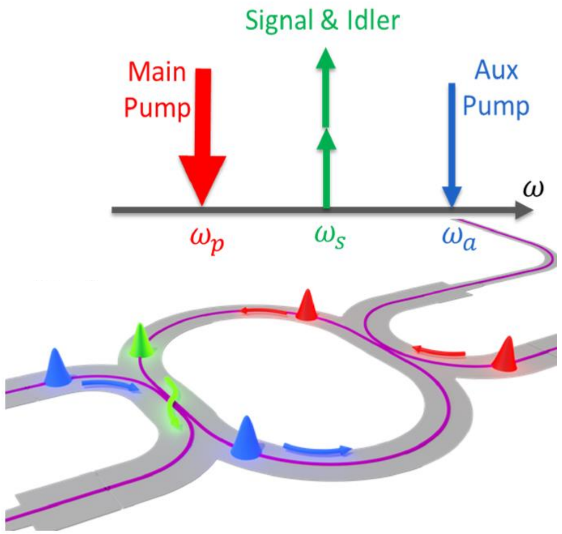
Bernhard Schrenk

Hannes Hübel

Manuela Kos

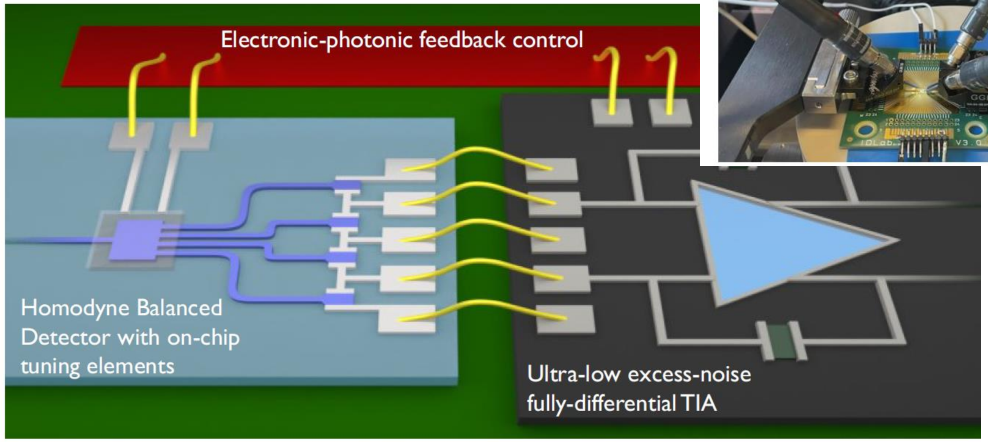
Outlook: towards quantum photonics integrated circuits

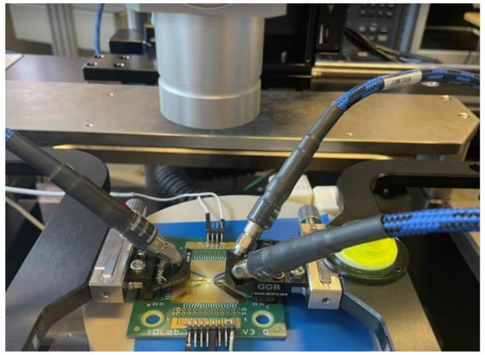
- Dual pumped Four Wave Mixing in a silicon microring resonators with the strong pump at λ > 2.3 µm to avoid detrimental two-photon absorption. Auxiliary pump at 1.2 µm. Squeezed light emitted at 1.55 µm.
- Chips currently characterized in Ghent and will be shipped to Vienna around end of March 2025.



M. Al-Mahmoud and Stephane Clemmen, „Design of Silicon Quantum Squeezer“, Optica Quantum 2.0 (2024)

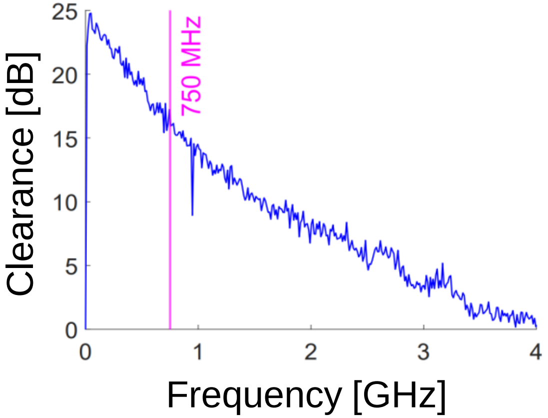
- Co-design and co-integration of a custom transimpedance amplifier (TIA) specifically designed for sensitive analog CV applications (high sensitivity, bandwidth and linearity).
- Receiver under characterization in Ghent





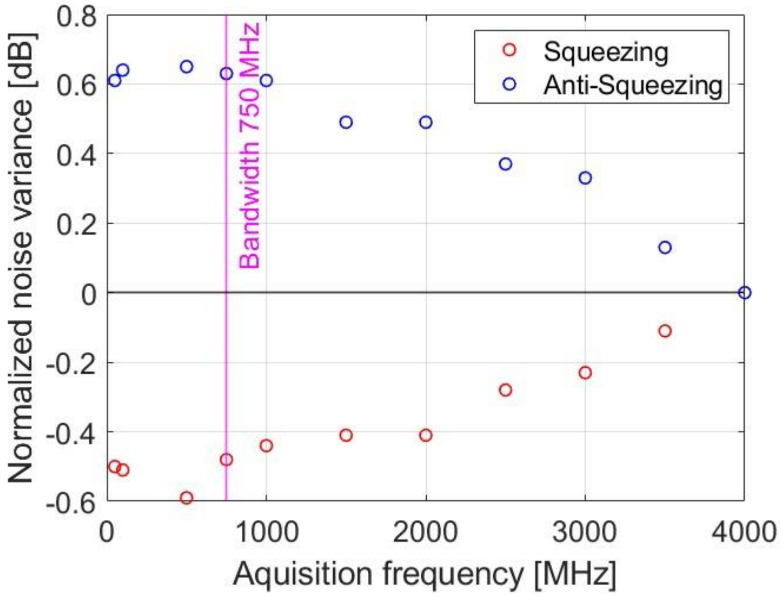
A. Trenti *et al.*, „On-Chip Quantum Communication Devices“, *J. Light. Technol.*, 40, 23, (2022)

Squeezed light measurements at GHz frequencies



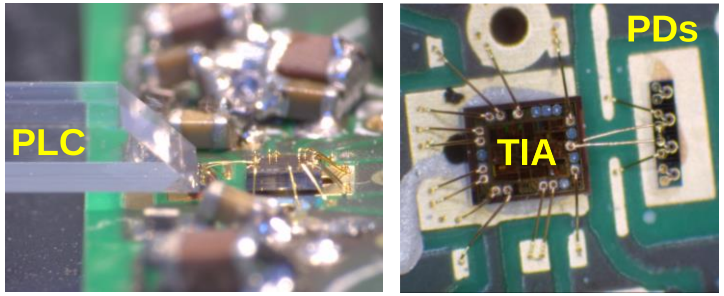
Die-level receivers*

- 750 MHz & 2.8GHz bandwidth
- Low footprint -> reduced parasitics
- High clearance even beyond bandwidth



2 possible couplings:

- 3dB PLC mixer
- Fiber coupling and standard 50/50 BS



- E. Zaiser et al., “Detection of broadband squeezed light with a low-noise die-level balanced receiver”, arXiv:2407.07588
- Contributing talk at IEEE Summer Topical Meeting Series 2024, 15-17 July 2024

* D. Milovančev, et al. "Chip-level GHz capable balanced quantum homodyne receivers“, *J. Light. Technol.* 40 23 (2022)