Next Generation of Spectrometers for Quantum-assisted Astronomy

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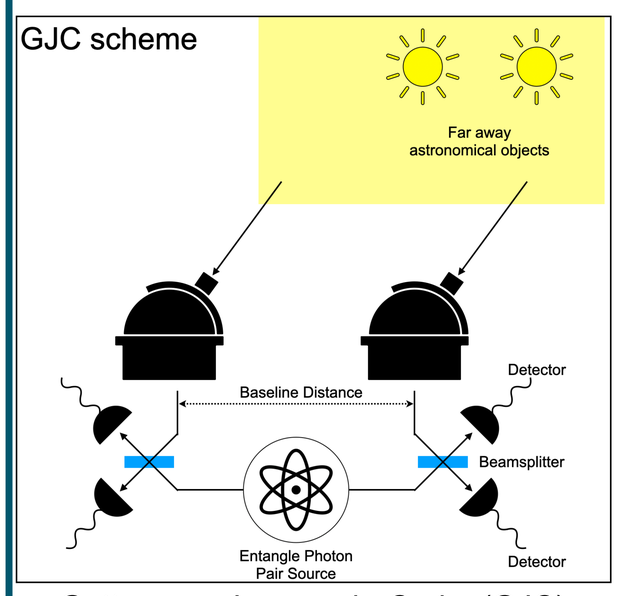
Quantum-assisted Astronomy

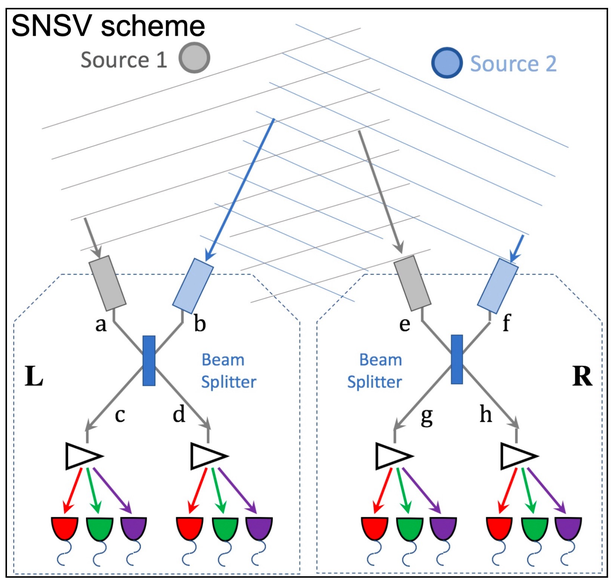


Gottesman-Jennewein-Croke (GJC)

- Seminal work
- Relies on quantum repeaters and entangled photon pairs

Main Challenge:
quantum repeaters

↳ A technology that still requires further development

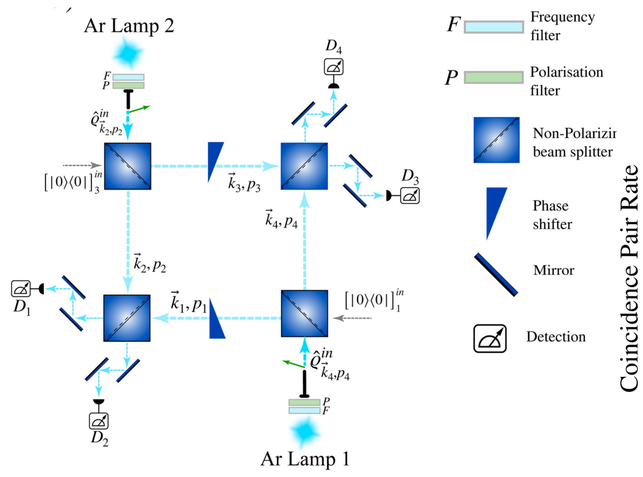


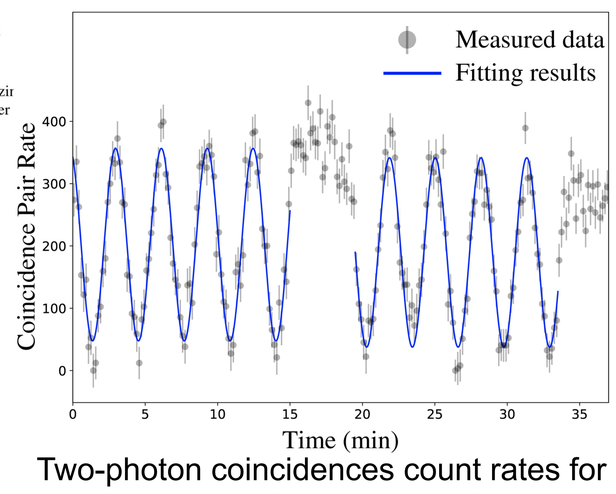
Stankus-Nomerotski-Slosar-Vintskevich (SNSV)

- Simplified requirements for a quantum advantage of astrometrical measurements
- Relies on two effects: Hanbury Brown - Twiss and the Hong-Ou-Mandel.

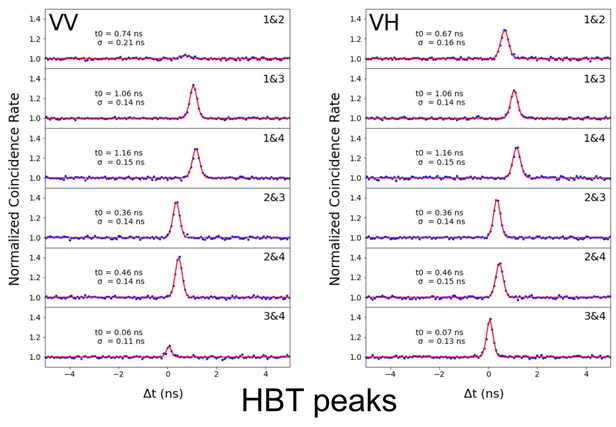
Gottesman, D., Jennewein, T., & Croke, S. 2012, PRL 109, 070503

Lab Demonstration

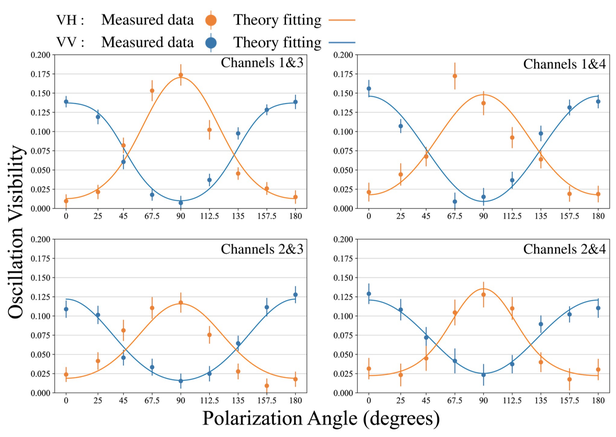




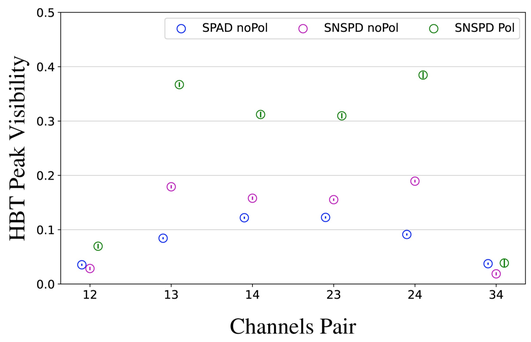
Two-photon coincidences count rates for the oscillations for channels 1&3 in the SNSPD data set with with VV polarization.



HBT peaks



Visibility of two-photon detections as a function of polarization angle



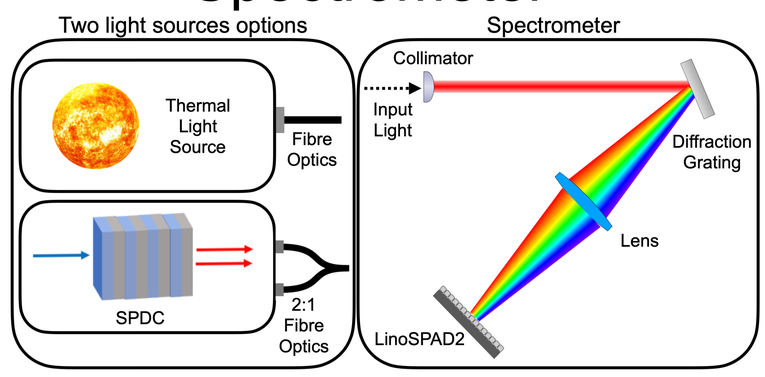
Oscillations observed when expected to happen. ✓

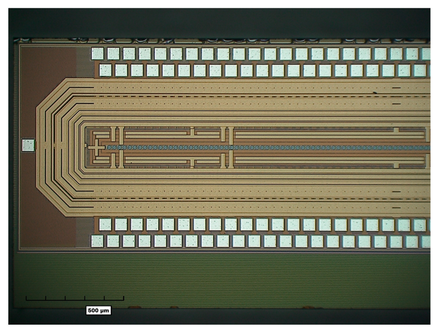
Theory and experiment in agreement. ✓

Different detector technologies tested. ✓

In-lab successful proof-of-principle demonstration. ✓

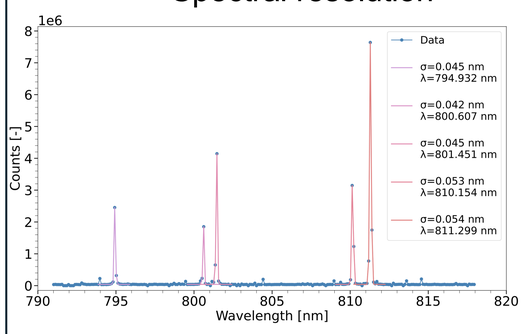
Spectrometer





LinoSPAD2 sensor
512 linear pixels
Data-drive operation

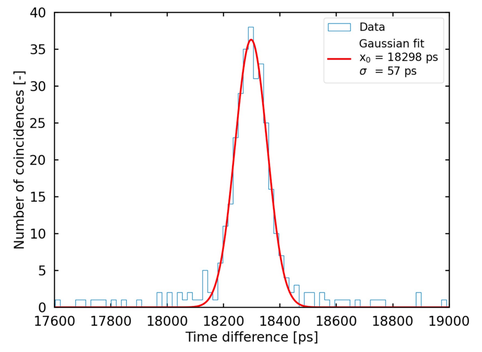
Spectral resolution



Argon lamp

Spectral resolution ≈0.05 nm

Temporal resolution

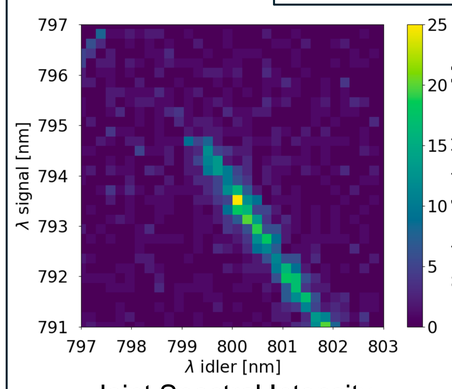


SPDC photons

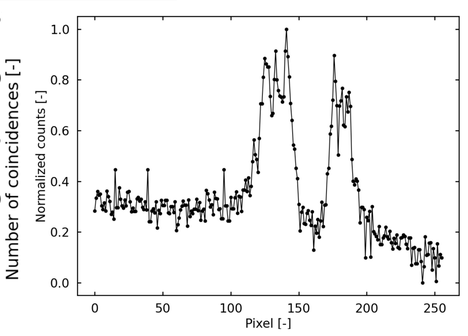
SPDC provides simultaneous photons

Temporal resolution 57 ps for a photon pair ⇒ 40 ps for a single photon

SPDC Characterization



Joint Spectral Intensity



Down-converted photons spectrum
Non-degenerate

Benchmark

Assuming same resolutions (temporal and spectral) apply to a single photon.

$\lambda = 800$ nm and $\Delta\lambda = 0.042$ nm ⇒ $\Delta E = 8.1 \times 10^{-5}$ eV;
$\Delta t = 40$ ps
$\Delta E \Delta t = 3.3 \times 10^{-15}$ eVs ⇒ only a factor of 10 from $\hbar/2$
(Heisenberg Uncertainty Principle)

Two-photon amplitude interferometry for precision astrometry
The Open J. Astrophys. **5** (2022).

Towards Quantum Telescopes: Demonstration of a Two-Photon Interferometer for Quantum-Assisted Astronomy
arXiv:2301.07042

Fast spectrometer near the Heisenberg limit with direct measurement of time and frequency for multiple single photons
arXiv:2304.11999

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