Quantum-memory-assisted Multi-photon Generation for Efficient Quantum Information Processing

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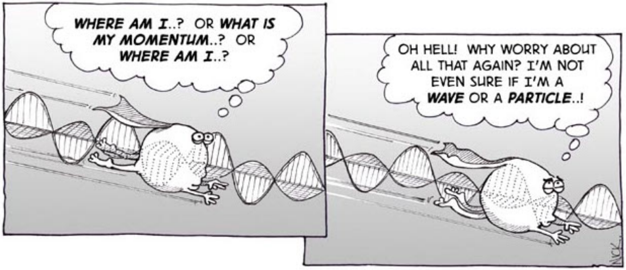
Single Photon Sources



Photon self-identity issues

Cartoon by Nick Kim

Most quantum optics experiments are dependent on having a reliable sources of single photons.

- Photon entanglement and interferometry
- Optical quantum computers
- Quantum cryptography

Single Photon Sources

Solid state single photon sources

Quantum Dots

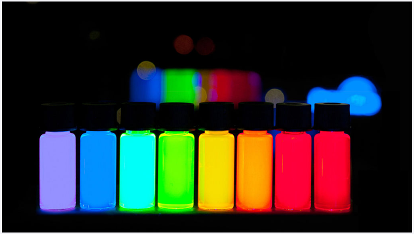
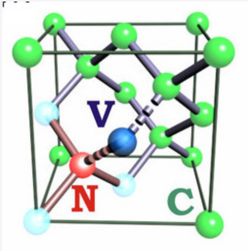


Photo by Wikipedia

Nitrogen-Vacancy Diamonds



Downsides

- Requires cryogenic temperatures
- Source inhomogeneity
- Difficult to achieve high-efficiency photon collection

Single Photon Sources

Spontaneous Parametric Down-conversion

- Uses a χ^2 non-linearity to generate a photon pair from a single high energy pump photon.

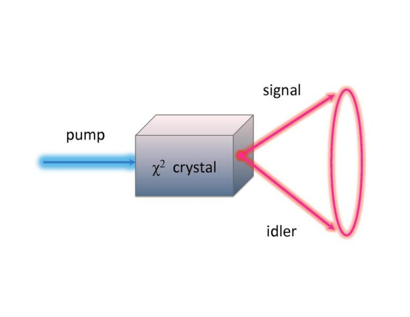


Photo by Wikipedia

Downsides

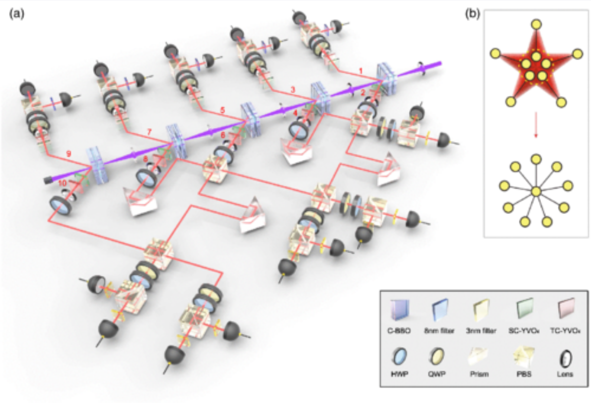
- Non-Deterministic
- Does not scale to multiple coincident photons easily

Multiple Coincident Photon Source

Many quantum information applications require many photons

Example Experiment: 10 Photon Entanglement

- Using 5 SPDC crystals to generate 10 entangled photons
- Coincident rate on the order of an hour



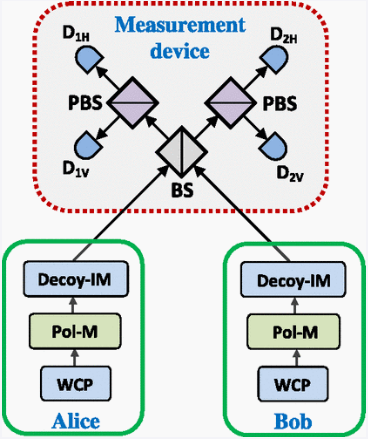
Wang et al. [2016]

Multiple Coincident Photon Source

Synchronization of photons of non-local SPDC sources

Example Experiment: Quantum Key Distribution

- Alice and Bob send qubit-encoded photons to Charlie
- Charlie measure correlation through a Bell-state measurement
- Increased statistics increases security



Lo et al. [2012]

Solution: Use quantum memory to assist SPDC sources

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Quantum-memory-assisted multi-photon generation for efficient quantum information processing

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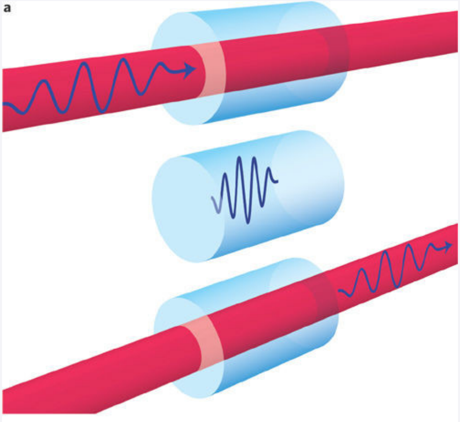
What is a Quantum Memory?

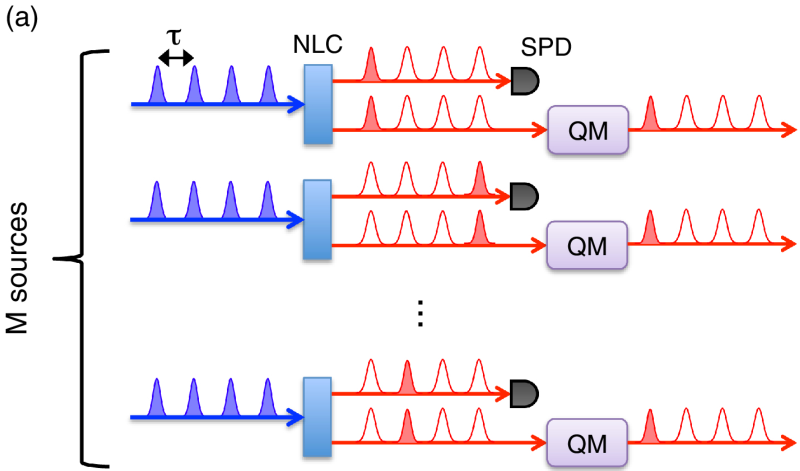
What is a quantum memory?

- A conventional memory stores data (10110101) for a time so that it can be later read
- A quantum memory stores a quantum state $(|10110101\rangle)$ for a time so that it can be later read



Lvovsky et al. [2009]

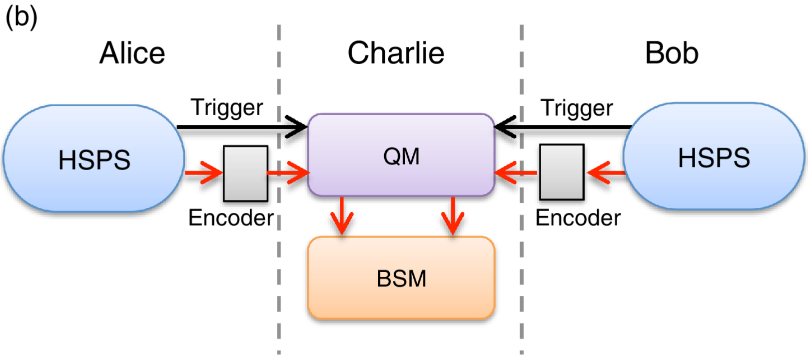
Quantum Memories with a Heralded Single Photon Source



Kaneda et al. [2017]

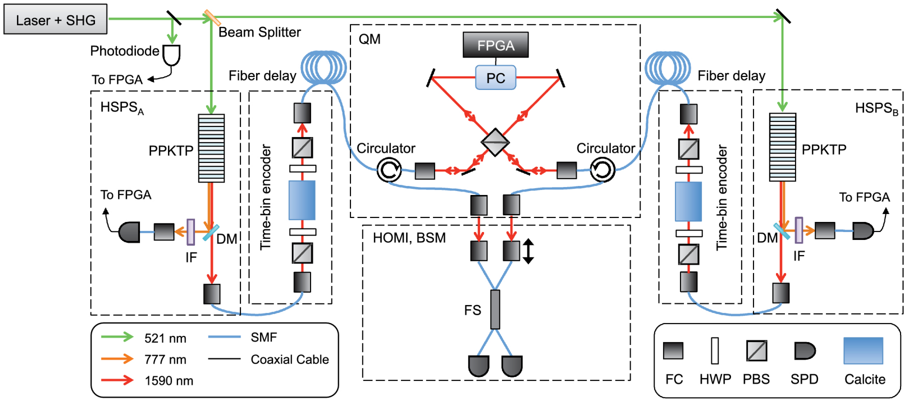
Quantum Memories integrated into Quantum Key Distribution

Proof of concept application



Kaneda et al. [2017]

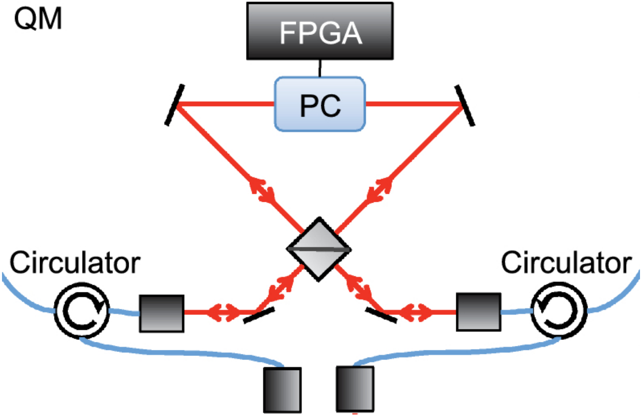
Experimental Schematic



Kaneda et al. [2017]

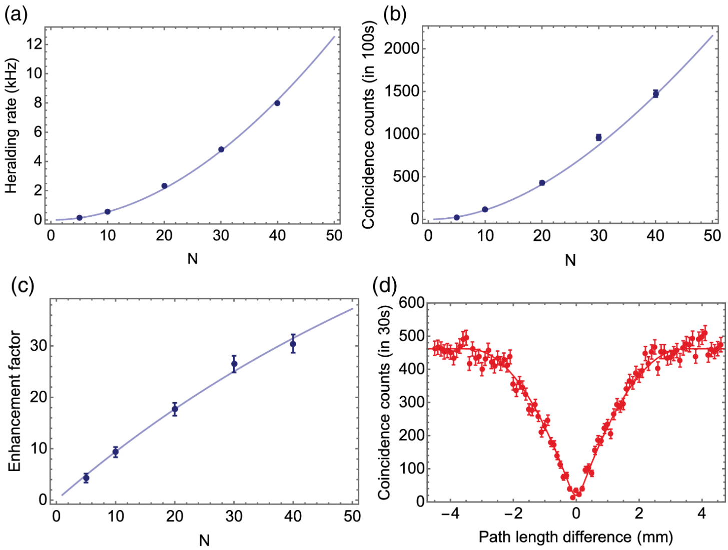
Bulk Optics Quantum Memory Schematic

- Polarized beam splitter allows for storage of photons from two sources
- Rubidium titanyl phosphate crystal pair form Pockels cell (PC) to store and release photons



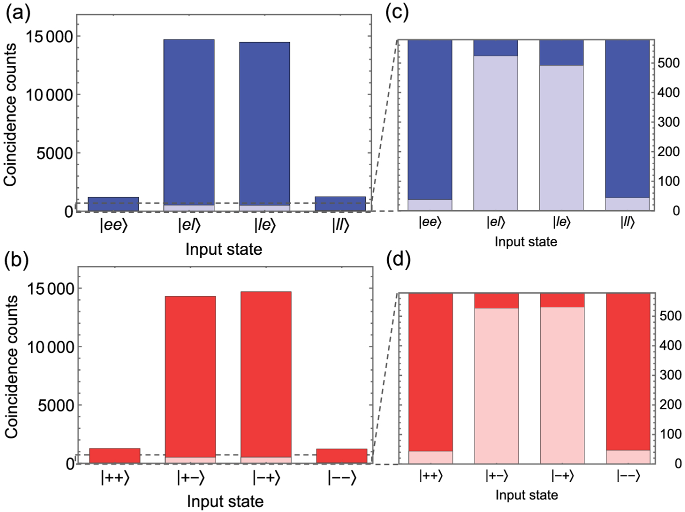
Kaneda et al. [2017]

Coincidence Counts



Kaneda et al. [2017]

Hong-Ou-Mandel Interference as BSM



Kaneda et al. [2017]

Conclusions

- Integration of the quantum memory enhanced coincidence rate by 30
- The current set up could be extended to allow for generation of up to 10 synchronized single photons with a generation rate of $\gtrsim 1\ s^{-1}$.
- Reduction of optical loss could make up to 30 coincident photons every few seconds a possibility.