Single-photon source and quantum memory

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Abstract: We have experimentally demonstrated a new kind of single-photon source and a cyclical quantum memory device for photonic qubits. These initial experiments involved storage loops, active switching, and parametric down-conversion photon pairs.

OCIS codes: (270.0270) Quantum optics

Two of the main requirements in an all-optical approach to quantum computing are a reliable source of single-photons to serve as qubits, and a memory device capable of maintaining the coherence of stored qubits. We have recently performed proof-of-principle experimental demonstrations of a new kind of single-photon source [1], as well as a cyclical quantum memory device for single-photon qubits [2].

As shown in Figure 1, the single-photon source was based on a system in which the detection of one photon of a parametric down-conversion pair caused its twin photon to be electro-optically switched into a storage loop. The twin photon was then known to be circulating in the loop, and could be switched out when needed by the user. The cyclical quantum memory device was also based on photon storage in an optical loop. In this experiment, the qubit values were encoded in the polarization states of single-photons, and the coherence of these photonic qubits was maintained during switching operations by applying controlled pi-phase shifts in a balanced polarizing Sagnac interferometer switch (see Figure 2).

An extension of the cyclical quantum memory for single-photon qubits involves the storage of entangled two-qubit states in two phase-locked devices. We are currently attempting to apply this idea to the storage of heralded two-photon entangled states produced by probabilistic quantum logic operations on multiple down-conversion sources.

It seems likely that an optical approach to quantum computing will rely on a natural clock cycle such as that provided by a master mode-locked laser pulse train. Due to the periodic nature of the optical loops, our photon source and cyclical quantum memory device could be easily synchronized with such a clock cycle, and may be ideally suited for this architecture.

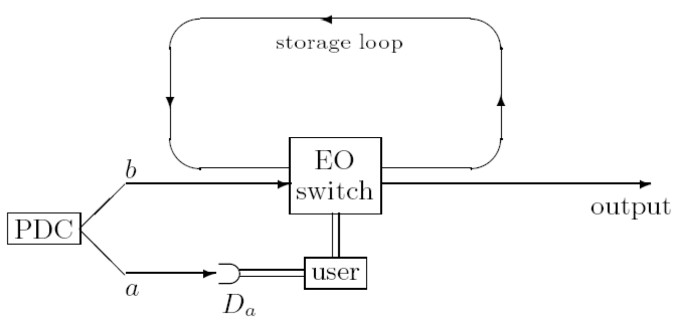

Figure 1. A schematic of the single-photon source. PDC is a parametric down-conversion source, EO is an electro-optic switch, and D_a is a single-photon detector.

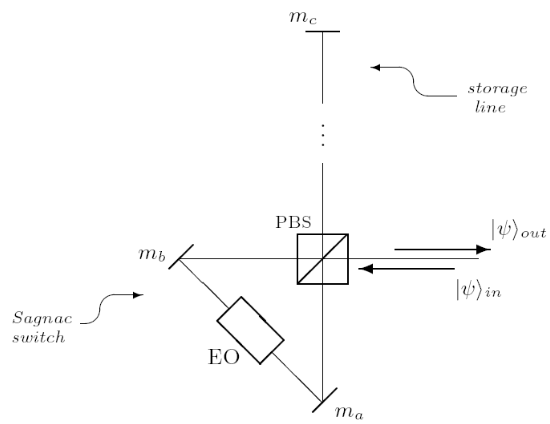

Figure 2. A schematic of the Cyclical Quantum Memory device. The Sagnac interferometer switch is formed by a polarizing beamsplitter (PBS) and mirrors m_a and $m_{b,}$, and the storage line is ended by mirror m_c. EO is a user-controlled electro optic device that is used for polarization rotation and active switching.

[1]. T.B. Pittman, B.C. Jacobs, and J.D. Franson, "Single-photons on pseudodemand from stored parametric down-conversion", Phys. Rev. A 66, 042303 (2002).

[2]. T.B. Pittman and J.D. Franson, "Cyclical quantum memory for photonic qubits", e-print quant-ph/0207041.