

# Quantum buffering for time-multiplexed multi-photon entanglement

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## Abstract

We present a qubit quantum buffer based on a polarization-independent optical delay loop. The buffer stores photonic qubits with greater than 99% average fidelity for up to 200 ns, 88% for 1  $\mu$ s, and efficiency of 93.5% per 13 ns round-trip. We use the buffer to interfere subsequent photons, showing non-classical Hong-Ou-Mandel interference with photons created up to 400 ns apart.

Time is a useful and often employed degree of freedom for optical quantum information processing. Temporal multiplexing of light has enabled near-deterministic single-photon sources [1, 2], large-scale quantum walks [3], and enormous entangled states [4, 5]. Here we demonstrate a polarization-qubit quantum buffer, suitable for the time-multiplexed interference of entangled photons, which shows competitive performance with state-of-the-art quantum memories [6]. This will be useful in quantum communication networks, where photons must be locally synchronized with other photons for example for entanglement swapping. We also show that the buffer directly allows Hong-Ou-Mandel interference between temporally separated photons; the only modification required is in the software that controls the switching sequence.

The polarization-entangled source and quantum buffer are pictured in fig. 1(left). The source is pumped with a Ti:Sapphire laser of 76 MHz repetition rate, giving a chance to produce a photon pair every 13 ns. When a pair is produced, one photon is directly detected, which sends a signal to the buffer to store the partner photon. We measure the buffer's storage efficiency and process fidelity to the identity in the qubit subspace, finding process fidelity above 95% for up to 30 roundtrips. Finally we show in fig. 1(right) Hong-Ou-Mandel interference with visibility  $>50\%$  between photons created up to 400 ns apart.

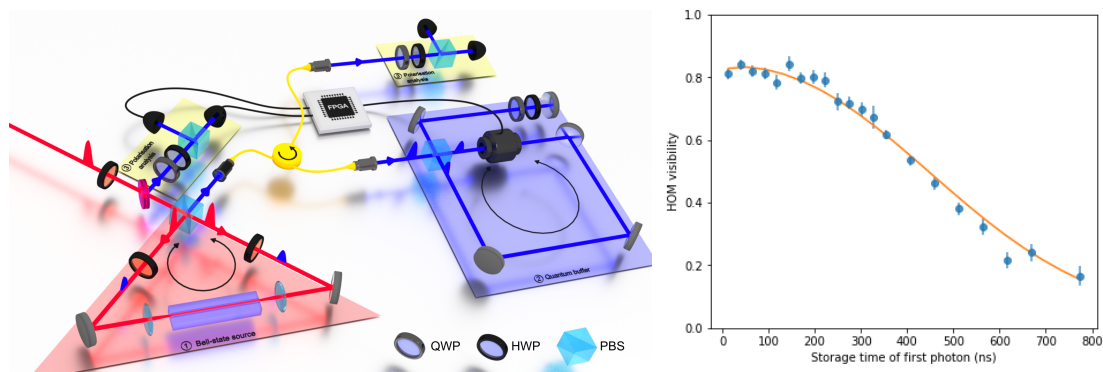


Figure 1: (left) Source of entangled photon pairs (red) and time-multiplexing quantum buffer (blue), which uses a delay loop, retro-reflective arm, and Pockels cell to store, release, and interfere photons. The photon detections from the source tell the buffer when to activate, and depending on the switching pattern, qubit storage or Hong-Ou-Mandel interference can be implemented. The visibility of Hong-Ou-Mandel interference (right) agrees with our model of the asymmetric losses, and is limited by multi-pair emission: at low pump power and short storage times the visibility reaches 94%.

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