Broadband waveguide quantum memory for entangled photons

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The implementation of quantum memory, i.e. a quantum interface between light and matter, is central to advanced applications of quantum information processing and communication [1]. Notably, quantum memories are key ingredients in quantum repeaters [2], which promise extending quantum communication beyond its current distance limit. Towards this end, quantum memories should have many features including the ability to store entangled states.

In this work we report the reversible transfer of photon-photon entanglement into entanglement between a photon and a collective atomic excitation in a rare-earth-ion-doped (RE) crystal [3] (see also [4]). We generate time-bin entangled photon-pairs with the photons of each pair at 795 and 1532 nm wavelength, suitable for low-loss transmission through free space and telecommunication fibres, respectively. The 1532 nm photons travel down an optical fibre while the 795 nm photons are sent into a thulium-doped lithium niobate waveguide cooled to 3 k, are absorbed by the TM ions, and recalled at 7 ns by means of a photon-echo protocol [5] based on an atomic frequency comb (AFC) [6]. The memory acceptance bandwidth has been tailored to 5 GHz, which matches the spectral width of the 795 nm photons.

The entanglement-preserving nature of our storage device is assessed through quantum state tomography before and after storage. Within statistical errors, we find a perfect mapping process. Additionally, we directly verify the non-local nature of the generated and stored quantum states by violating the CHSH bell inequality.

In light of future applications, the broadband and integrated features of our promising quantum storage device facilitate linking with commonly used, efficient sources of photons in bi- and multi-partite entangled states. This study paves the way for new explorations of fundamental and applied studies in quantum physics.

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