Quantum memory and entanglement

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Reversibly mapping entanglement between photons and atoms, which serve as quantum memory, and projecting independent (pure) photonic quantum states after recall from such a memory onto entangled states are key to quantum repeaters and, more generally, quantum networks [1]. In this talk we present the reversible mapping of quantum information encoded into one of two time-bin entangled photons using a photon-echo quantum memory protocol [2] (for closely related work see [3]). Our results show, within experimental uncertainty, that the encoded quantum information, i.e. the property of the stored photon being one member of an entangled pair, can be retrieved without degradation. Furthermore, we will demonstrate two-photon interference and the projection onto an entangled state using attenuated pulses of light (featuring an average of less than one photon per pulse) that have, or have not, been reversibly mapped to separate quantum memories. As the interference visibility is close to the theoretical maximum, regardless of whether none, one, or both pulses have previously been stored, we conclude that our solid-state quantum memories preserve not only encoded quantum information, but the entire photonic wave function during storage. Both investigations take advantage of thulium-doped lithium niobate waveguide quantum memories as storage materials, and employ a photon-echo type quantum memory approach based on atomic frequency combs [4]. Our findings complete previously missing steps towards advanced applications of quantum information processing, and bring us closer to building quantum repeaters, networks, and linear optics quantum computers.

[1] N. Sangouard et al. “Quantum repeaters based on atomic ensembles and linear optics”, Rev. Mod. Phys. 83, 2011, 33.
[2] E. Saglamyurek et al. “Broadband waveguide quantum memory for entangled photons”, Nature 469, 2011, 512.
[3] C. Clausen et al. “Quantum storage of photonic entanglement in a crystal”, Nature 459, 2011, 508.
[4] M. Afzelius et al. “Multimode quantum memory based on atomic frequency combs”, Phys. Rev. A 79, 2009, 052329.