Frequency-multiplexed photon storage and read-out on demand using an atomic frequency comb-based quantum memory

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Optical quantum memories require the ability to reversibly map quantum states between photons and atoms [1]. When employed for quantum repeaters [2], quantum memories are key to enabling long-distance quantum communication. Towards this end, quantum memories require recall on demand with high fidelity and efficiency, long storage times, and the possibility to simultaneously store multiple carriers of quantum information. The combination of a quantum state storage protocol based on an atomic frequency comb (AFC) [3] with rare-earth-ion doped crystals cooled to cryogenic temperatures as storage materials [4] has been shown to meet many of these requirements. In particular, it is well suited for storage of temporally multiplexed photons [5,6]. Yet, despite first proof-of-principle demonstrations [7], recalling quantum information at a desired time (i.e. read-out on demand) with broadband, single-photon-level pulses remains an outstanding challenge.

We will present the first experimental demonstration of frequency-multiplexed storage of attenuated laser pulses followed by read-out on demand in the frequency domain. Our work is based on the AFC protocol and employs a Tm-doped $LiNbO_3$ waveguide [8,9]. We will argue that, in view of a quantum repeater, our approach is equivalent to temporal multiplexing and read-out on demand in the temporal domain. This overcomes one further obstacle to building quantum repeaters using rare-earth-ion doped crystals as memory devices.

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