On-demand storage of photonic qubits at telecom wavelengths

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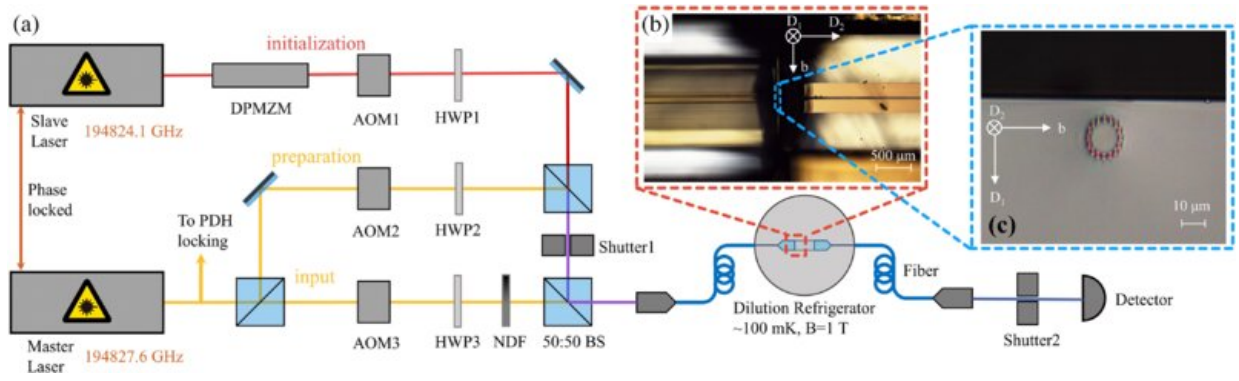

Diagram of the experimental setup. (a) The optical path before cryostat can be divided into three sections: one for spectral initialization, one for AFC preparation, and one for input pulses. All beams are controlled by acousto-optic modulators (AOM) in double-pass configurations. A dual-parallel Mach-Zehnder modulator (DPMZM) is employed for wideband sweeping during the spectral initialization. The input pulse is attenuated to a weak coherent state by neutral density filters (NDF). All beams are combined with two 50:50 beam splitters and collected into a single-mode fiber connecting to the memory. Polarization of the laser of each beam is adjusted with half wave plates (HWP) to optimize the sample absorption. Two mechanical shutters are employed to protect the single-photon detector from a strong laser. (b) A micrograph of the memory device. On the left is a single-channel fiber array. On the right is the $^{167}Er^{3+}$:Y_2SiO_5 crystal with a laser-written waveguide inside (too thin to be visible) and gold electrodes on top of it. (c) The cross section of the laser-written waveguide. Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.129.210501

In a recent study published in *Physical Review Letters*, a research team led by Prof. Guo Guangcan from the University of Science and Technology of China (USTC) of the Chinese Academy of Sciences (CAS) achieved on-demand storage of photonic qubits at telecom wavelengths using a laser-written waveguide fabricated in an erbium-doped crystal.

Quantum memories are crucial devices in quantum networks. In order to construct quantum networks using current optical fiber networks, such devices ought to function at telecom wavelengths. However, due to their fixed read-out time, preexisting quantum memory systems at telecom wavelengths were unable to realize on-demand storage.

In this study, researchers processed a fiber-integrated quantum memory at telecom wavelengths based on a laser-written waveguide fabricated in an erbium-doped yttrium silicate ($^{167}Er^{3+}$:Y_2SiO_5) crystal.

In order to realize on-demand storage and retrieval, the researchers glued and integrated ordinary single-mode fibers at both ends of the waveguide. They used electronic evaporation technology to fabricate on-chip electrodes on both sides of the waveguide. To further increase storage efficiency, they polarized the electron spin of the erbium ion and initialized its nuclear spin state.

Such methods resulted in a fivefold increase (up to 10.9%) in the photon storage efficiency, compared with previously reported results. Additionally, the fidelity of on-demand quantum storage reached 98.3%, reducing the loss in long-distance optical fiber transmission by a significant extent.

This work demonstrates an essential requirement for fiber-based quantum networking applications, and is a leap forward in the construction of large-scale quantum networks based on existing fiber

networks.

More information: Duan-Cheng Liu et al, On-Demand Storage of Photonic Qubits at Telecom Wavelengths, *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.129.210501