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Spectrally Multiplexed Solid-State Memories for Quantum Repeaters

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Quantum communication is currently limited to channel lengths on the order of 100 km. The possibility to overcome this limit hinges on using a quantum repeater that in turn relies on the heralded distribution of entangled photons across subsections of the whole communication channel, on the storage of entanglement (by quantum memories) at the end-nodes of each subsection, and on the swapping of entanglement established in neighbouring sections to the end-points of the total channel. Workable distribution rates can be obtained if multiplexing is used to overcome the low success probabilities of multi-photon operations required in such a repeater. To this end, quantum memory research has focused on photons arriving at different times at the memory (i.e. temporal multiplexing) and recall on demand via a variable storage time. However, quantum repeaters multiplexed with respect to other degrees-of-freedom, such as frequency (spectral multiplexing), can be utilized with memories having fixed storage times, supplemented with on-demand shifting in the degree-of-freedom of importance. In this talk we describe how to build a quantum repeater using qubits encoded into different spectral modes, and present experimental results showing readout on demand from a spectrally multiplexed quantum memory based on atomic frequency combs in a Ti:Tm:$LiNbO_3$ waveguide cooled to 3 K. Our measured fidelity of 0.95 ± 0.03 significantly violates the maximum fidelity of 0.67 achievable using a classical memory, confirming the validity of the spectral multiplexing approach. We anticipate that this will accelerate the development of quantum repeaters, linear optics quantum computing, and advanced quantum optics experiments.

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