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Integrated Multiplexed Photonic Quantum Memories

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Abstract

We present a new approach towards the realization of integrated multiplexed quantum memories, based on laser written waveguides in rare-earth doped crystals. We will report our recent efforts using laser-written waveguides in Pr^{3+}:Y_2SiO_5, including experiments showing the storage and retrieval of non-classical light and of frequency multiplexed single photons.

Photonic quantum memories are important devices for the realization of scalable photonic quantum information architectures, including quantum repeaters and quantum information networks. In recent years, impressive progress has been realized, using atomic and solid-state systems. In order to progress towards the use of quantum memories into complex large scale architectures, it is desirable to find an approach where a large number of memories can be duplicated and where a large number of qubits can be stored in each memory. Multimode quantum memories would greatly help the scaling of quantum networks by decreasing the entanglement distribution time between remote quantum nodes [1]. An interesting advantage of using a solid-state approach for quantum memories is that it lends itself naturally to integrated designs. Rare-earth (RE) doped crystals are promising candidates as integrated photonic quantum memories as they offer excellent coherence properties comparable to those of atomic systems, but provide naturally trapped ions free of the drawbacks deriving from atomic motion. Several approaches have been pursued in that direction [2, 3].

In this talk, I will present a new approach towards the demonstration of solid-state integrated quantum memories, using laser-written waveguides [4]. This technique provides a versatile and cost-effective technique allowing the realization of complex memory enabled photonic networks. We have shown that the laser writing in our Pr^{3+}:Y_2SiO_5 crystal preserves to a large extent the ion coherence. In addition, we also showed that laser written-waveguides can be used to store single heralded photons created by cavity enhanced spontaneous down-conversion with storage time hundred time larger than previous demonstrations in waveguide [5]. Finally, we have demonstrated the quantum storage of a frequency multiplexed heralded single photon containing 15 spectral modes for a duration of 3.5 μs, using the atomic frequency comb scheme [6]. As this scheme is inherently multimode in time, each frequency mode is stored in 9 temporal modes, leading to a total number of modes of 135. Combined with the unique 3D fabrication capability of femtosecond laser writing, these results open prospects for the realization of massively multiplexed integrated quantum memories.

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