Photonic Quantum State Transfer between Disparate Quantum Nodes

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The interconnection of fundamentally different quantum platforms via photons is a key requirement to build future hybrid quantum networks. Such heterogeneous architectures hold promise for more powerful capabilities than their homogeneous counterparts, as they would benefit from the individual strengths of different quantum matter systems.

In this talk, we report on interfacing a cold atomic ensemble of rubidium atoms with a praseodymium ion-doped crystal [1]. The cold atom cloud, besides being an excellent quantum memory (QM) and single photon source [2], also gives access to quantum processing via Rydberg excitation [3]. The crystal offers multiplexed long-lived quantum state storage in a solid-state environment [4]

In our experiment, we demonstrate storage in the solid-state memory of a paired single photon, emitted from the atomic cloud. As both systems exhibit very different optical transitions, we apply cascaded frequency conversion techniques to bridge the wavelength gap between them. Moreover we transfer the quantum information using a single photon at telecom wavelength, favorable for long distance communication in optical fibers. We demonstrate that non-classical correlations are preserved through frequency conversion, storage and retrieval. Finally, we show the transfer of a single-photon time-bin qubit between the two fundamentally different QM systems with a conditional fidelity of 85%, surpassing the classical threshold. These results can also be extended to other types of quantum nodes and open the way to combine quantum nodes with different functionalities.

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