Progress towards a quantum repeater

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Quantum mechanics provides a mechanism for absolutely secure communication between remote parties. For distances greater than 100 kilometers direct quantum communication via optical fiber is not viable, due to fiber losses, and intermediate storage of the quantum information along the transmission channel is necessary. This lead to the concept of the quantum repeater [1]. Optically thick atomic ensembles have emerged as an attractive paradigm for qubit entanglement generation and distribution, offering dramatic practical advantages compared to single-particle qubits [2]. Namely, efficient quantum state transfer between ensemble-based qubits and single photons can be achieved in free space without the need for a high-finesse cavity by utilizing a very weak interaction at a single photon/single atom level.

The first realization of coherent quantum state transfer from a matter qubit to a photonic qubit was achieved using cold rubidium at Georgia Tech in 2004 [3], followed by the first light-matter qubit conversion and entanglement of remote atomic qubits in 2005 [4].

A scheme to achieve long-distance quantum communication at the absorption minimum of optical fibers, employing atomic cascade transitions, has been proposed and its critical elements experimentally verified [5]. In order to boost communication rates, a memory-insensitive multiplexed quantum repeater has been proposed [6].

Further advances relevant to atomic ensemble based quantum networks include: Bell inequality violation between a collective atomic qubit and a photon [7], storage and retrieval of single photons [8], collapses and revivals of quantum memory [9,10], deterministic single photon sources based on quantum measurement, quantum memory, and quantum feedback [11], Hong-Ou-Mandel interference of photon pairs from two independent ensembles [12], robust entanglement of two-isotope matter qubits and frequency light qubits [13].

We will present recent experimental progress and outline future directions.

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