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Investigations of Memory, Entanglement, and Long-Range Interactions Using Ultra-Cold Atoms

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Long-term storage of quantum information has diverse applications in quantum information science. I have employed ultra-cold rubidium atoms confined in one-dimensional optical lattices to demonstrate entanglement between a light field and a long-lived spin wave, to develop light-shift compensated quantum memories, to create entanglement between a telecom-band light field and a light-shift compensated memory qubit of a 0.1 s lifetime, and to store coherent light pulses with 1/e lifetime of 16 s in a magnetically-compensated lattice augmented by dynamic decoupling. Highly excited Rydberg atoms offer a unique platform for study of strongly correlated systems and quantum information, because of their enormous dipole moments and consequent strong, long-range interactions. I will present experimental studies of single collective Rydberg excitations created in a cold atomic gas including first realization of a Rydberg-atom-based single photon source, measurement of entanglement between a Rydberg spin wave and light, investigations of long-range correlations of strongly interacting Rydberg spin waves, and initial observations of coherent many-body Rabi oscillations between the ground level and a Rydberg level using several hundred cold rubidium atoms.