Three-Photon Laser Excitation of the Mesoscopic Ensembles and Single Rb Rydberg Atoms for Quantum Information

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Strong long-range interactions between highly excited Rydberg atoms form the basis for quantum information processing with neutral trapped atoms [1]. Entangled states can be generated using a temporary excitation of ground-state atoms to a strongly interacting Rydberg state. In this talk we will present our related experimental and theoretical results on the three-photon laser excitation of the mesoscopic ensembles and single Rb Rydberg atoms for applications in quantum information.

Three-photon laser excitation of Rydberg states by three different laser beams is of interest as can be arranged in a starlike geometry that simultaneously eliminates the recoil effect and Doppler broadening. Our analytical and numerical calculations for various laser excitation schemes in Rb atoms have shown that, compared to the one- and two-photon laser excitation, this approach provides much narrower linewidth and longer coherence time for both cold atom samples and hot vapors, if the intermediate one-photon resonances of the three-photon transition are detuned by more than respective single-photon Doppler widths [2]. This method can be used to improve fidelity of Rydberg quantum gates and precision of spectroscopic measurements in Rydberg atoms.

Our related experiments were first performed with spatially disordered mesoscopic ensembles of cold Rb atoms in a magneto-optical trap with single-atom resolution provided by a selective field-ionization detector of Rydberg atoms [1,3-6]. We studied the spectra [1,3-5] and dynamics [6] of the three-photon laser excitation 5S-5P-6S-nP with n = 37-120 using three narrowband cw lasers with various detunings and intensities from the intermediate states. In the multi-atom excitation spectra of high Rydberg states we observed the signatures of the dipole blockade effect [5], which is widely used to perform two-qubit quantum gates.

Recently we have switched to the experiments with single Rb atoms in an array of the optical dipole traps. The optical pumping and one-qubit quantum gates with individual addressing have been demonstrated [7,8]. We will present our first experimental results on the three-photon laser excitation of a single Rb atom in an optical dipole trap detected optically by resonant fluorescence of the ground-state atoms [9].

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