Elektromagnetiškai indukuoto praskaidrėjimo ir lokalizacijos efektai sąveikaujančių Rydbergo atomų sistemose

Electromagnetically induced transparency and localization effects in interacting Rydberg atomic systems

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Coherent control of atom and light interactions has many important applications in quantum and nonlinear optics. In particular, electromagnetically induced transparency, a quantum interference effect where the destructive interference between probability amplitudes of the optical transitions occurs, leads to significant changes in material's optical response and a number of peculiar phenomena [1]. Using highly excited Rydberg atoms, having large principal quantum numbers, one can explore a range of previously studied effects in a new regime of nonlinear quantum optics at low light intensities [2]. Because of their extreme polarizability and long-range interactions, systems of Rydberg atoms can be much more efficient compared to the atomic systems in the ground states.

In this work we were interested in the effects of spatially dependent electromagnetically induced transparency (EIT) in the ensemble of cold interacting Rydberg atoms. The spatially dependent EIT patterning has been realized by taking Rydberg atoms in a typical three level ladder scheme and using a special control field combinations being a superposition of two Laguerre–Gaussian modes (Fig. 1). In this setup, where different vortex control field modes are superimposed, the resulting field develops various spatially coherent structures depending on the corresponding orbital angular momentum (OAM) values of the interfering control fields. As a result, the optical response exhibits the formation of different types of bright and dark Ferris wheel structures as can be seen in the absorption (transmission) profiles (Fig. 2). This setup effectively converts phase information of the optical field into intensity profiles and related modified optical response, that, within the specific range of parameters, may be used to produce highly localized distributions [3].

The findings show the possibility of precise spatial patterning of Rydberg atoms in the transverse two-dimensional space enabling the formation of strongly localized optical lattices with the tunable barriers between sites and providing single-site addressability for the arrays of trapped atoms. The proposed setup, based on interference of optical vortex field combinations, may be especially useful for the applications like creation of specific ring traps for quantum gases, phase dependent quantum memories or storage of high-dimensional optical information.

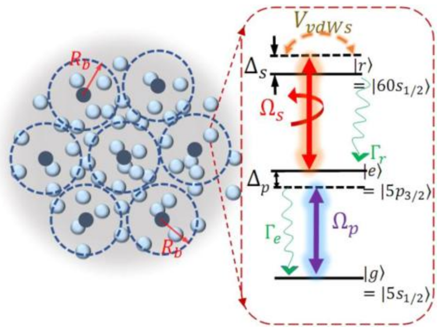

Fig. 1. Schematic representation of a Rydberg atomic ensemble with the ladder energy level configuration coupled by a combined superposition of strong vortex control fields and a weak non-vortex probe field.

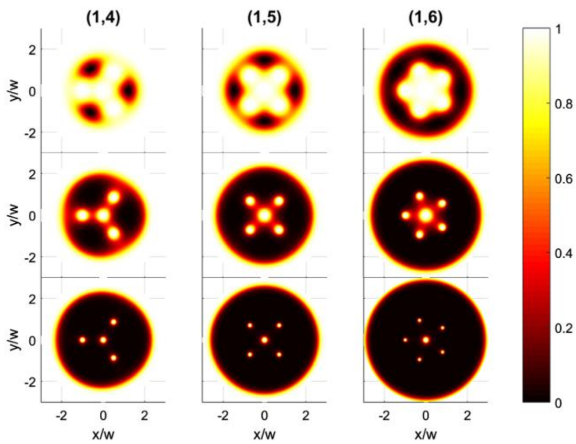

Fig. 2. Normalized absorption distributions for the increasing control field strengths (top to bottom) and different OAM number combinations denoted by the corresponding pairs of numbers above.

Keywords: cold atoms, Rydberg state, optical vortex, induced transparency, absorption pattern

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