Trapping and spectroscopy of Rydberg atoms in modulated optical lattices

Georg Raithel

University of Michigan, Ann Arbor, MI 48109, USA

Here, I will first describe the ponderomotive interaction between Rydberg atoms and optical fields, which results from the A-square term of the atom-field Hamiltonian. Ponderomotive optical lattices of Rydberg atoms and their adiabatic trapping potentials will be discussed. Then, I will explain how modulated lattices can be employed to perform high-precision spectroscopy of Rydberg transitions. The method is Doppler-free and is not limited by spectroscopic selection rules. In the described experiment, cold rubidium atoms are trapped in a 1064-nm optical lattice. Lattice-modulation sub-THz spectroscopy is then performed on several test transitions. In the presented theoretical models, the internal atomic dynamics is treated quantum-mechanically. For the center-of-mass dynamics, both classical or quantum treatments are employed. As an application of the new spectroscopic instrument, I will then talk about an ongoing experiment on spectroscopy of circular Rydberg atoms. Recent high-precision-spectroscopy results on hydrogen and deuterium have given rise to the "proton radius puzzle," a term used for an inconsistency that involves the Rydberg constant and the nuclear charge radius. Here, an independent measurement of the Rydberg constant with circular Rydberg atoms is pursued. Circular Rydberg atoms have long radiative lifetimes and toroidal electron distributions that do not penetrate into the atomic nucleus. Their level energies are therefore not susceptible to perturbations caused by electron wavefunction overlap with the nuclear charge density and quantum-electrodynamics (QED) corrections. A measurement of the Rydberg constant with circular Rydberg atoms will therefore present a valuable contribution to resolve the proton radius puzzle. In the pursued experiment, cold rubidium atoms are trapped in a ponderomotive optical lattice. Doppler-free sub-THz spectroscopy is then performed via two-photon microwave spectroscopy or, alternatively, by the lattice-modulation technique. The measured transition frequencies yield atomic parameters, such as quantum defects and core polarizabilities, and the Rydberg constant. Expected systematic uncertainties and experimental progress will be reviewed.