Quantum Dynamics of Ultracold Rydberg Atoms in Magnetic Quadrupole Fields

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We investigate the dynamics of ultracold electronically excited (Rydberg) atoms exposed to an external magnetic quadrupole field in the regime where both the atomic and electronic motion are quantized. Firstly a general Hamiltonian which describes the quantum dynamics of an atom in an arbitrary linear magnetic field configuration is derived. This makes our approach applicable to a wide range of atoms and magnetic field configurations. The combined problem of the collective and internal motion is solved by performing an adiabatic separation of the electronic and center of mass dynamics. We provide the adiabatic potential energy surfaces for the ultracold center of mass motion and discuss under which conditions trapped center of mass states can be achieved for Rydberg atoms. Energies and wavefunctions of the corresponding combined center of mass - electronic quantum states are studied in detail. By analyzing the properties of these states we demonstrate that the extension of the electronic wavefunction can exceed that of the center of mass motion particularly for the so-called trapped ring states. Therefore the atoms cannot be considered as point-like particles and the electronic Rydberg motion varies significantly over the extension of the center of mass wave function. A discussion of the corresponding electromagnetic transitions is equally provided.

1. I. Lesanovsky and P. Schmelcher, Magnetic Trapping of Rydberg Atoms, Physical Review Letters (August 2005)
2. I. Lesanovsky and P. Schmelcher, Ultracold Quantum Dynamics of Electronically Excited Atoms in a Magnetic Quadrupole Trap, subm. of. publication to Physical Review A