

Trapping and manipulating Rydberg atoms with large electric dipole moments - from quantum optics to antimatter physics

The large static electric dipole moments and electric dipole transition moments associated with Rydberg states of atoms and molecules can allow for strong or ultrastrong interactions with (inhomogeneous) electric fields, electromagnetic fields and other atoms or molecules, which are not easily achievable with ground state samples. In this lecture I will describe experiments with helium and positronium Rydberg atoms in which these giant Rydberg interactions are exploited.

First I will show how the ultrastrong coupling regime of the quantum Rabi model [1], in which the Rabi oscillation frequency approaches a selected microwave transition frequency and which goes beyond the rotating wave approximation, can be studied with helium atoms in Rydberg states with $n=105$ and electric dipole transition moments of 8970 a.u. (22800 debye).

I will then describe experiments in which Förster resonances in collisions of helium Rydberg atoms and ground state ammonia molecules, with electric dipole transition moments of 1300 a.u. (3300 debye) and 0.6 a.u. (1.4 debye), respectively, are controlled and manipulated using electric fields [2,3].

Finally, I will provide an overview of the development of techniques to control and trap Rydberg atoms and molecules using inhomogeneous electric fields [4] and discuss how these methods pertain to next generation microwave quantum optics and cold molecular scattering studies, and tests of fundamental physics with Rydberg positronium atoms [5].

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