Giant Dipole States of Single-Electron and Multi-Electron Systems in Crossed Electric and Magnetic Fields

Peter Schmelcher[1,2],

[1] *Physikalisches Institut, Philosophenweg 12, Universität Heidelberg, 69120 Heidelberg, Germany*
[2] *Theoretische Chemie, Im Neuenheimer Feld 229, Universität Heidelberg, 69120 Heidelberg, Germany*

The origin and physics of giant dipole states for both single-electron and multi-electron systems is reviewed. First an outline of the gauge-independent pseudoseparation of the center of mass motion of moving neutral atomic systems in crossed electric and magnetic fields is provided. As a result a generalized potential picture [1] is derived and discussed in some detail. The double well structure of this potential leads to the existence of weakly bound decentered Rydberg states that possess a huge electric dipole moment: The giant dipole states. The spectral properties of these states is analyzed and linked to the underlying classical dynamics and phase space [2]. An experimental preparation scheme starting from ground state atoms, employing subsequent laser excitation and a sequence of electric field pulses is described. Corresponding simulations yield a well-defined population of low-energy states in the outer potential well [3]. We demonstrate that the crossed field configuration provides a unique way for stabilizing simple matter-antimatter systems [4, 5]. Calculations on positronium predict the existence of long-lived giant dipole states of the e^+/e^- system in which the two particles are separated by several thousand Angstroms. The near zero probability for positron-electron overlap suppresses direct annihilation processes. Transition moments between the ground state in the outer well and the Coulomb states are also extremely small, resulting in lifetimes up to the order of one year.

Multi-electron giant dipole resonances of atoms in crossed electric and magnetic fields [6] are addressed in a next step. Stationary configurations corresponding to a highly symmetric arrangement of the electrons on a decentered circle are derived, and a normal-mode and stability analysis are performed. A classification of the various modes, which are dominated by the magnetic field or the Coulomb interactions, is provided. Based on the MCTDH approach, we carry out a six-dimensional wave-packet dynamical study for the two-electron resonances, yielding in particular lifetimes of more than 0.1μs for strong electric fields [7, 8].

References

[1] O. Dippel, P. Schmelcher and L.S. Cederbaum, Phys. Rev. A **49**, 4415 (1994).

[2] P. Schmelcher and L.S. Cederbaum, Phys. Rev. A **47**, 2634 (1993); Chem. Phys. Lett. **208**, 548 (1993)

[3] V. Averbukh, N. Moiseyev, P. Schmelcher and L.S. Cederbaum, Phys. Rev. A **59**, 3695 (1999)

[4] J. Ackermann, J. Shertzer and P. Schmelcher, Phys. Rev. Lett. **78**, 199 (1997)

[5] J. Shertzer, J. Ackermann, and P. Schmelcher, Phys. Rev. A **58**, 1129 (1998)

[6] P. Schmelcher, Phys. Rev. A **64**, 063412 (2001)

[7] S. Zöllner, H.D. Meyer and P. Schmelcher, Europhys. Lett. **71**, 373 (2005)

[8] S. Zöllner, H.D. Meyer and P. Schmelcher, Phys. Rev. A **72**, 033416 (2005)