University of Stuttgart
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iRyd

SPP 1929 – Seminar

20. Dezember 2016, 16:30 Uhr

Universität Stuttgart
NWZ II, Raum 2.136
Pfaffenwaldring 57, 70569 Stuttgart

Georg Raithel
(University of Michigan)

Spatial imaging of Rydberg-atom pairs and Rydberg molecules

Cold atomic systems have opened new frontiers at the interface of atomic and molecular physics. These include research on novel types of Rydberg molecules. Here, we study the trajectories of Rydberg-atom pairs under the influence of mutual inter-nuclear forces that are caused by van der Waals and permanent-electric-dipole interactions. Rydberg-atom pairs are first laser-excited at a preferred initial inter-nuclear separation. The atoms are then allowed to move for a variable interaction time. Subsequently, the atom positions are read out using an atom imaging technique that has a spatial resolution of about one micron. We obtain the spatial pair-correlation function of the Rydberg atoms, which yields atom-pair trajectories. In the case of van der Waals interactions, the C_6 coefficient follows directly from the trajectory data [1]. In the study of permanent-electric-dipole interactions, an adiabatic state-switching method, applied immediately after laser-excitation, is employed to initially prepare ensembles of strongly interacting dipolar atoms [2]. The trajectory analysis then yields the C_3 coefficient of the electric-dipole interaction [3]. The anisotropy of the electric-dipole interaction is directly observed in images of the correlation function of Rydberg-atom pairs. Results are compared with a theoretical model [4]. I will also present related results on adiabatic potentials and adiabatic states of Rydberg-Rydberg molecules in Rb and Cs. These molecules are formed via electrostatic multipole interactions. The leading interaction term in neutral Rydberg-Rydberg molecules is between two dipoles, with a scaling ~ bond length^(-3), while for ionic Rydberg-Rydberg molecules it is between a dipole and a monopole, which has a scaling ~bond length^(-2).

[1] "Measurement of van-der-Waals interaction by atom trajectory imaging," N. Thaicharoen, A. Schwarzkopf, G. Raithel, Phys. Rev. **A 92** , 040701(R) (2015).
[2] "Dipolar Rydberg-atom gas prepared by adiabatic passage through an avoided crossing," L. Wang, H. Zhang, L. Zhang, C. Li, Y. Yang, J. Zhao, G. Raithel and S. Jia, New J. Phys. **17**, 063011 (2015).
[3] "Atom-pair kinetics with strong electric-dipole interactions," N. Thaicharoen, L. F. Gonçalves, G Raithel, Phys. Rev. Lett. **116**, 213002 (2016).
[4] "Motion of Rydberg atoms with strong permanent-electric-dipole interactions," L. F. Gonçalves, N, Thaicharoen, G, Raithel, J. Phys. B **49**, 154005 (2016).