A 19: Ultracold Rydberg gases (jointly with Q)

Zeit: Donnerstag 8:30–10:00 Raum: 2G

A 19.1 Do 8:30 2G

Rydberg excitation of a Bose-Einstein condensate — •Ulrich Raitzsch, Rolf Heidemann, Vera Bendkowsky, Björn Butscher, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We present our latest results on Rydberg excitation of a Bose-Einstein condensate [1]. Crossing the critical temperature T_c, a signature of the phase transition to Bose condensation is observed in the fraction of excited Rydberg atoms. The main features in the experimental data were reproduced by a simulation using a superatom model. A superatom is formed by N ground state atoms in a sphere with the blockade radius $r_b \propto \sqrt[6]{C_6/\hbar\Omega}$ due to the van der Waals interaction [2].
The Rydberg excitation is proven to be coherent despite strong interactions with a rotary echo technique known from nuclear magnetic resonance physics [3]. The rotary echo experiment was done for various densities of ground state atoms and excitation times, giving insight into the dephasing caused by the van der Waals interaction.

References

[1]R. Heidemann, *et al.*, arXiv:0710.5622 (2007)

[2]R. Heidemann, *et al.*, Phys. Rev. Lett. **99**(16), 163601(2007)

[3]U. Raitzsch, *et al.*, arXiv:0706.3869 (2007)

A 19.2 Do 8:45 2G

Universal Scaling in a Strongly Interacting Rydberg gas — •Hendrik Weimer[1], Hans Peter Büchler[1], Rolf Heidemann[2], Ulrich Raitzsch[2], Vera Bendkowsky[2], Björn Butscher[2], Robert Löw[2], and Tilman Pfau[2] — [1]Institut für Theoretische Physik III, Universität Stuttgart — [2]5. Physikalisches Institut, Universität Stuttgart

We analyze the van der Waals blockade and the quantum evolution of an atomic gas resonantly driven by a laser into a strongly interacting Rydberg state. Such a system has recently been studied experimentally by Heidemann et al. [1]. The main mechanism behind the van der Waals blockade is that once a Rydberg atom is excited, the van der Waals interaction shifts the surrounding atoms out of resonance with the driving laser and therefore suppresses the excitation of additional Rydberg atoms. The combination of the van der Waals interaction with the Rabi frequency of the resonant laser gives rise to a single dimensionless parameter. We show that the experimental data exhibits a data collapse with a universal scaling function in this single dimensionless parameter. A numerical analysis of the effective theory provides excellent agreement for the scaling function with the experiment, and is evidence for universality in a strongly interacting Rydberg gas undergoing coherent quantum evolution.

[1] R. Heidemann et. al. Phys. Rev. Lett. **99**, 163601 (2007).

A 19.3 Do 9:00 2G

Many-particle mechanical effects of an interacting Rydberg gas — •Thomas Amthor, Markus Reetz-Lamour, Christian Giese, and Matthias Weidemüller — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

Gases of ultracold Rydberg atoms have been found to spontaneously ionize and form plasmas [1]. Recent experiments showed that the initial ionization is mainly due to collisions induced by long-range forces between the cold Rydberg atoms. The acceleration and subsequent Penning ionization of Rydberg atoms has been investigated under different conditions, the underlying interactions being either of dipole-dipole [2] or van der Waals type [3]. For attractive interaction potentials, atoms excited to Rydberg states on the red-detuned wing of the resonance are observed to ionize first, as more atom pairs are prepared at short distances and experience strong attractive forces. Here we discuss the ionization dynamics of gases initially prepared in states with purely repulsive interaction. This requires a more detailed model including many-particle aspects and mechanisms for state redistribution to overcome the repulsive forces. A Monte Carlo model for the description of such a system is presented and agrees well with experimental observations [4].

[1] M. P. Robinson et al., Phys. Rev. Lett. 85, 4466 (2000)
[2] W. Li et al., Phys. Rev. Lett. 94, 173001 (2005)
[3] T. Amthor et al., Phys. Rev. Lett. 98, 023004 (2007)
[4] T. Amthor et al., Phys. Rev. A 76, 054702 (2007)

A 19.4 Do 9:15 2G

Prospects for resonant energy transfer in structured ultracold Rydberg gases — •Christian Giese, Christoph Sebastian Hofmann, Wendelin Sprenger, Janne Denskat, Thomas Amthor, Markus Reetz-Lamour, and Matthias Weidemüller — Physikalisches Intitut, Universität Freiburg, Hermann-Herderstr. 3, 79104 Freiburg

Dynamics in cold Rydberg gases are entirely determined by long-range dipole-dipole and van der Waals interactions due to the negligible translational energy. A unique feature of the system is the tunability of these interactions in both strength and character. In this manner, two Rydberg pair states can be made energetically degenerate. This leads to energy and population transfer known as resonant energy transfer (RET) which plays an important role in the process of photosynthesis. In recent work , we have compared Monte Carlo simulations of this process to density dependent population measurements[1]. Coherent energy transfer occurs, but the signature is washed out by many-body diffusion and disorder. To overcome this, we plan to use beamshaping techniques for structuring the atomic cloud. Recently, the theoretical and experimental prospects of coherent exciton transport in linear chains in the presence of excitation traps were discussed[2]. We propose an experimental way of using cold, structured Rydberg gases as a model system for investigating the coherent and incoherent properties of this process when introducing different degrees of disorder.

[1] S. Westermann et al., Eur. J. Phys. D 40, 37 (2006)
[2] O. Mülken et al., Phys. Rev. Lett. 99, 090601 (2007)

A 19.5 Do 9:30 2G

High-resolution spectroscopy of an ultracold Rydberg gas — •Christoph S. Hofmann, Thomas Amthor, Christian Giese, Wendelin Sprenger, Markus Reetz-Lamour, and Matthias Weidemueller — Physics Institute, Albert-Ludwig University Freiburg, 79104 Freiburg, Germany

The exaggerated properties of Rydberg atoms provide a fertile ground for investigating atomic interaction phenomena. Due to the long-range character of the interaction between highly excited atoms, the dynamics of an ultracold gas of Rydberg atoms are entirely determined by van-der-Waals and dipole-dipole interactions. Rydberg excitation-spectra reveal valuable information over a wide range of characteristic phenomena occurring in ultracold Rydberg samples, which are the scope of this talk. For instance, effects like suppression of excitation due to Rydberg-Rydberg interaction [1] can be traced back by analysing these spectra. Spectral features such as line shapes and broadening provide information on interaction potentials. Furthermore highly resolved spectra also permit the observation of long-range molecular resonances [2]. High-resolution spectroscopy requires sophisticated experimental techniques like careful electric and magnetic stray field control, frequency stabilized excitation and probe lasers with narrow line widths as well as sensitive ion detection schemes. An overview about these techniques is given in this talk.

[1] D. Tong et al.,Phys. Rev. Lett. 93, 063001 (2004); K. Singer et al., Phys. Rev. Lett. 93, 163001 (2004)
[2] S. M. Farooqi et al., Phys. Rev. Lett. 91, 183002 (2003)

A 19.6 Do 9:45 2G

Rydberg excitations in an Ion Trap — •Igor Lesanovsky[1], Markus Müller[1], Lin-Mei Liang[1,2], and Peter Zoller[1] — [1]Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria — [2]Department of Physcis, National University of Defense Technology, Changsha 410073, China

We investigate Rydberg excitations of ions which are trapped in a linear Paul trap. In such trap the ions are confined by an electric quadrupole field and a ponderomotive potential due to an oscillating quadrupole. We employ a two-body approach in order to model the Rydberg ions and derive the Hamiltonian governing Rydberg excitations in a linear ion crystal. We show how a strong state-dependent dipole-dipole interaction among the ions can be achieved by coupling

Rydberg states of different parity using a microwave field. This system offers the possibility to study Rydberg excitation dynamics of a mesoscopic ensemble in a structured environment and permits the experimental realization of strongly interacting spin models.