A 17: Rydberg atoms

Time: Tuesday 14:30–16:15 Location: N 3

A 17.1 Tue 14:30 N 3

Trilobite Rydberg molecules in Rubidium — •Kathrin S. Kleinbach[1], Florian Meinert[1], Felix Engel[1], Woojin Kwon[1], Sebastian Hofferberth[1], Robert Löw[1], Tilman Pfau[1], and Georg Raithel[2] — [1]5. Physikalisches Institut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart,Germany — [2]Department of Physics, University of Michigan, Ann Arbor, Michigan 48109, USA

Rydberg atoms exhibit extreme properties due to their large size and high polarizability. Moreover, in the ultracold regime, the interaction of the Rydberg electron with a neutral ground-state atom gives rise to long-range bound molecular states. A class of such homonuclear dimers, so called "trilobite molecules", have been shown to possess huge electronic dipole moments exceeding hundreds of Debye, which arise from interaction-induced admixing of high angular momentum Rydberg states. However, direct photo-association of such states is hindered by the required angular momentum transfer.

Here, we devise a novel method for two-color photo-association of Rb^{87} trilobite Rydberg molecules with large permanent dipole moment employing remote spin flips. More specifically, strong mixing of singlet and triplet scattering channels mediated by the ground-state hyperfine interaction couples the s-wave molecular state 50S↓+5S↑ and the trilobite state 47Trilobite↑+5S↓. This mixing allows for direct laser excitation of trilobite molecules, which we demonstrate via photo-association spectroscopy. Also, the the dipole moment is measured and the data is compared to predictions from calculated potential energy curves.

A 17.2 Tue 14:45 N 3

Rydberg molecule-induced remote spin-flips — •Carsten Lippe[1], Thomas Niederprüm[1], Oliver Thomas[1,2], Tanita Eichert[1], and Herwig Ott[1] — [1]Department of Physics and research center OPTIMAS, University of Kaiserslautern — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz

We have performed high resolution photoassociation spectroscopy of ^{87}Rb Rydberg molecules in the vicinity of the $25P$ state. These exotic states originate from the scattering interaction between a ground state atom located within the electronic wave function of a second atom in a highly excited Rydberg state and the Rydberg electron.
We have investigated two different types of molecular states: Butterfly Rydberg molecules originate from a shape resonance in the p-wave scattering channel and are thus much more deeply bound than the second type, ultra-long range molecules. For the former, we measured bond lengths in the range of 100 a_0 to 350 a_0 and permanent electric dipole moments of around 500 Debye.
For the latter, we find potentials containing contributions of both hyperfine states of the ground state perturber atom due to the hyperfine interaction. Depending on the relative strength of the scattering interaction compared to the hyperfine splitting we identify two distinct regimes where entanglement and spin-flips occur, respectively. Remote spin-flips in the perturber atom can be induced by excitation of Rydberg molecules when the hyperfine interaction dominates the scattering interaction, leading to a possible implementation of long-range spin-dependent interactions for ultracold atoms.

A 17.3 Tue 15:00 N 3

Strong light-matter coupling in Rydberg excitons — •Peter Grünwald[1], Julian Heckötter[2], Marc Assmann[2], Dietmar Fröhlich[2], Manfred Bayer[2], Heinrich Stolz[1], and Stefan Scheel[1] — [1]Institut für Physik, Universität Rostock, Rostock, Germany — [2]Experimentelle Physik 2, TU Dortmund, Dortmund, Germany

Rydberg systems show strong light-matter coupling due to the long life times and large dipole moments of states with high principal quantum number n. In Rydberg excitons [1], the single-exciton light-matter coupling is weak. However, due to collective excitation, strong coupling occurs even for low laser intensities ($\sim \mu W/mm^2$). Additionally, the high-n exciton states display little pure dephasing [2], making them interesting for quantum-optical research. We will discuss the optical properties of Rydberg excitons, and their implications for the Rydberg exciton fluorescence. In particular, nonclassical effects and their detection will be addressed. Because of the limited detection efficiency, homodyne correlation measurements [3] are required.

[1] T. Kazimierczuk *et al.*, Nature **514**, 343 (2014).
[2] P. Grünwald *et al.*, Phys. Rev. Lett. **117**, 133003 (2016).
[3] W. Vogel, Phys. Rev. A **51**, 4160 (1995).

A 17.4 Tue 15:15 N 3

Ionization spectra of highly Stark shifted Rubidium Rydberg states — •Jens Grimmel, Markus Stecker, Manuel Kaiser, Lara Torralbo-Kampo, Andreas Günther, and József Fortágh — Center for Quantum Science, Physikalisches Institut, Universität Tübingen, Germany

Rydberg atoms are extremely sensitive to electric fields and consequently have a rich Stark spectrum. At sufficiently high electric fields these states start to ionize due to tunneling through the potential barrier as well as direct coupling to the continuum. This region is of particular interest for tailoring the ionization process to certain needs, for example in order to create cold ions and electrons for microscopy applications.

In our previous work, we calculated Stark maps including the transition strength from low lying states to Stark shifted Rydberg states [1]. By adding a complex absorbing potential (CAP), we are now able to accurately predict the ionization spectra of Rydberg states beyond the classical ionization threshold. The CAP is adjusted to the external electric field, which allows us to calculate a whole range of the spectrum with only one free parameter. The results from these calculations are compared to experimental data of Stark maps for Rubidium Rydberg atoms with principal quantum numbers up to 70.

[1] J. Grimmel, M. Mack, F. Karlewski, F. Jessen, M. Reinschmidt, N. Sándor and J. Fortágh, N. J. Phys. 17, 053005 (2015).

A 17.5 Tue 15:30 N 3

High resolution ion microscopy of cold atoms — •Raphael Nold, Markus Stecker, Andreas Günther, and József Fortágh — Center for Quantum Science, Physikalisches Institut, Universität Tübingen, Germany

We report on an ion-optical system serving as a microscope for ultracold ground state and Rydberg atoms. The system is designed to achieve a magnification of up to 1000 and a spatial resolution in the 100nm range, thereby surpassing many standard imaging techniques for cold atoms. This allows the observation of trapped quantum gases with single atom sensitivity and high temporal and spatial resolution.

We present the ion optics setup and the corresponding simulations, which show the theoretical limits of the system in terms of magnification and resolution. We also show the experimental implementation in an ultra-cold atom setup. Using spatially patterned 480nm laser light, atoms are ionized out of a magneto-optical trap in order to characterize the imaging quality. Furthermore, we present excitation and detection of Rydberg atoms with this system.

A 17.6 Tue 15:45 N 3

Magnetoexcitons in cuprous oxide — •Frank Schweiner, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, 70550 Stuttgart, Germany

Excitons are often regarded as the hydrogen analog of the solid state due to their hydrogen-like spectrum. In particular, excitons in cuprous oxide (Cu_2O) have recently attracted lots of attention due to the observation of giant Rydberg excitons [1].

However, the spectra of magnetoexcitons cannot be understood from a simple hydrogen-like model. We present the theory of magnetoexcitons in Cu_2O and show that it is indispensable to account for the complex valence band structure and the cubic symmetry of the solid in a quantitative theory. We especially discuss the dependence of the spectra on the direction of the external magnetic field and present a comparison of theoretical and experimental results [2].

Due to the band structure, fundamental differences between magnetoexcitons and the external fields hydrogen atom regarding the symmetry and the line statistics can be observed. While in atomic physics only GOE statistics can be observed, we show that magnetoexcitons break all antiunitary symmetries and thus show GUE statistics [3,4].

[1] T. Kazimierczuk et al, Nature 514, 343, 2014
[2] F. Schweiner et al, arXiv:1609.04275, 2016
[3] M. Aßmann et al, Nature Mater. 15, 741, 2016
[4] F. Schweiner et al, arXiv:1609.04278, 2016

A 17.7 Tue 16:00 N 3

Towards a shotnoise limited optogalvanic vapor cell — •Johannes Schmidt[1,2], Ralf Albrecht[1], Patrick Schalberger[2], Holger Baur[2], Robert Löw[1], Harald Kübler[1], Norbert Frühauf[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut, IQST, University of Stuttgart — [2]Institute for Large Area Microelectronics, IQST, University of Stuttgart

We show how we want to integrate a shotnoise limited ion current detection into an optogalvanic vapor cell. Such a device can be used as a sensitive detector for electric and magnetic fields as well as highly excited atoms and molecules. We excite Alkali Rydberg atoms in an electrically contacted vapor cell [1,2]. These atoms are ionized due to collisions with the background gas. A voltage directs these charges towards the electrodes on the inside of the cell, where they are detected with an amplification circuit based on thin film technology [3]. Requirements for such a circuit are among others, that it is low noise, provides a stable amplification under changing environmental conditions and is chemically inert against the content of the cell. Different implementation schemes are proposed, compared and first results will be presented.

[1] D. Barredo, et al., *Phys. Rev. Lett.* **110**, 123002 (2013)
[2] R. Daschner, et al., *Opt. Lett.* **37**, 2271 (2012)
[3] P. Schalberger, et al., *JSID* **19**, 496-502 (2011)