Q 7: Ultracold plasmas and Rydberg systems I (with A)

Time: Monday 10:30–12:00 Location: DO24 1.101

Q 7.1 Mon 10:30 DO24 1.101

Full counting statistics of laser excited Rydberg aggregates in a one-dimensional geometry — •Hanna Schempp[1], Georg Günter[1], Martin Robert-de-Saint-Vincent[1], Christoph S. Hofmann[1], David Breyel[2], Andreas Komnik[2], David Schönleber[3], Martin Gärttner[3], Jörg Evers[3], Shannon Whitlock[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [3]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We experimentally study the full counting statistics of few-body Rydberg aggregates excited from a quasi-one-dimensional atomic gas [1]. We measure asymmetric excitation spectra and increased second and third order statistical moments of the Rydberg number distribution, from which we determine the average aggregate size. Estimating rates for different excitation processes we conclude that the aggregates grow sequentially around an initial grain. Direct comparison with numerical simulations confirms this conclusion and reveals the presence of liquid-like spatial correlations. Our findings demonstrate the importance of dephasing in strongly correlated Rydberg gases and introduce a way to study spatial correlations in interacting many-body quantum systems without imaging.

[1] H. Schempp et al., accepted for Phys.Rev.Lett., arXiv:1308.0264 (2013)

Q 7.2 Mon 10:45 DO24 1.101

Beyond the Rydberg van-der-Waals Interaction in Thermal Caesium Vapour. — •Alban Urvoy[1], Fabian Ripka[1], David Peter[2], Tilman Pfau[1], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany — [2]Institut für Theoretische Physik III, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany

Rydberg atoms are promising candidates for the realisation of quantum devices, making use of their long-range atom-atom interaction. The presence of van der Waals-type interaction among Rydberg states has recently been demonstrated in thermal rubidium vapour using a pulsed amplifier [1]. We expanded this work to higher atom number density (typ. 10^{12} to 10^{14} cm^{-3}) in caesium vapour and observed two types of atomic response by varying the laser detuning. The border between these two regimes is phase-transition-like. One type of excitation dynamics is consistent with a two-body excitation process, while the other is of many-body nature. We deduce this interpretation from the scaling behaviour of the transition point with Rabi frequency, atom number density and principal quantum number. At such high densities and large excitation bandwidths ($\approx$ 500 MHz), we find that the crossings of the potential of the pair-state of interest with those of neighbouring pair-states become relevant. These modify the pair-state potentials, and allows for direct pair-state excitation at detunings beyond the excitation bandwidth.

[1] T. Baluktsian, B. Huber, et al., PRL **110**, 123001 (2013)

Q 7.3 Mon 11:00 DO24 1.101

Excitation dynamics in dissipative many-body Rydberg systems — •David W. Schönleber[1,2], Martin Gärttner[1], and Jörg Evers[1] — [1]Max-Planck-Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg — [2]Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden

Inevitably present in many current experiments with ultracold Rydberg atoms, dissipative effects such as dephasing and decay modify the dynamics of the examined system. To study the effects of these processes on the excitation dynamics, we employ wave function Monte Carlo technique [1]. Starting from the exact many-body Hamiltonian, wave function Monte Carlo technique allows for a treatment of incoherent effects which is equivalent to master equation treatment. Comparing dissipative with quasi-coherent dynamics, we find qualitatively different excitation dynamics arising in off-resonant excitation. In addition, we test the scope of established models such as the rate equation by means of wave function Monte Carlo calculations.

[1] K. Mølmer et al, J. Opt. Soc. Am. B 10, 524-538 (1993)

Q 7.4 Mon 11:15 DO24 1.101

Millisecond Dynamics of Mesoscopic Rydberg Samples — •Thomas Niederprüm, Tobias Weber, Torsten Manthey, Oliver Thomas, and Herwig Ott — Research Center Optimas, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

A long standing but not yet fully achieved goal in the field of ultracold atoms consists in establishing longe-range interactions between the atoms. Several proposals have demonstrated that dressing ultracold atoms with highly excited Rydberg states is a promising scheme to tailor such interactions. The timescale for such experiments would be in the millisecond range, where thermal motion, heating, decay, ionization and decoherence phenomena are present. While the short time behavior of cold Rydberg gases, the so called frozen Rydberg gas, has been vastly studied in the past only little work has been done to understand the long time behavior of Rydberg excitations in cold atomic gases. This talk will show how we use the arising ion signal as a continuous probe for the Rydberg population in atomic samples. Furthermore the observed ion signal can reveal temporal correlations in the excited sample. Recent experiments on the excitation dynamics of Rydberg samples of intermediate size are presented and evidence for strongly correlated behaviour of Rydberg excitations will be shown.

Q 7.5 Mon 11:30 DO24 1.101

Optical quantum information processing using Rydberg atoms — •David Paredes Barato, Hannes Busche, Simon Ball, David Szwer, Matthew Jones, and Charles Adams — Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, South Road, Durham DH1 3LE, UK

Implementing nontrivial, controllable gates between single photons is a challenge due to the weak nonlinearities present in most materials. When there are strong nonlinearities, such as cross-Kerr nonlinearities, they distort the wavepackets of the photons [1].

Advances in quantum optics with Rydberg atoms have shown that their strong dipole-dipole interactions can be mapped into nonlinearities at the single-photon level [2-4]. The non-local character of these optical nonlinearities at short scales could allow one to circumvent the difficulties in applying other (local) methods to QIP.

Here we present a hybrid optical quantum gate scheme [5] using electromagnetically induced transparency (EIT), dipole blockade and microwave control [4]. This scheme makes use of the spatial properties of the dipole blockade phenomenon to realize a photonic, controlled-z phase gate with fidelities exceding 90%. Current work on the experimental implementation and future developments will be presented.

[1] J.H. Shapiro, Phys Rev. A 73, 062305 (2006).
[2] Y.O. Dudin and A. Kuzmich, Science 18, 887 (2012).
[3] T. Peyronel et al., Nature 488, 57 (2012).
[4] D. Maxwell et al., Phys. Rev. Lett. 110, 103001 (2013).
[5] D. Paredes-Barato and C. S. Adams, Phys. Rev. Lett. *to appear.*

Q 7.6 Mon 11:45 DO24 1.101

Single-Photon Switch Based on Rydberg Blockade — •Simon Baur, Daniel Tiarks, Gerhard Rempe, and Stephan Dürr — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching

All-optical switching is a technique in which a gate light pulse changes the transmission of a target light pulse without the detour via electronic signal processing. We take this to the quantum regime, where the incoming gate light pulse contains only one photon on average [1]. The gate pulse is stored as a Rydberg excitation in an ultracold atomic gas using electromagnetically induced transparency. Rydberg blockade suppresses the transmission of the subsequent target pulse. Finally, the stored gate photon can be retrieved. A retrieved photon heralds successful storage. The corresponding postselected subensemble shows an extinction by a factor of 10. The single-photon switch offers many interesting perspectives ranging from quantum communication to quantum information processing.

[1] S. Baur et al., arXiv:1307.3509