A 20: Ultra-cold plasmas and Rydberg systems III (with Q)

Time: Tuesday 14:00–16:00 Location: BEBEL E44/46

A 20.1 Tue 14:00 BEBEL E44/46

Many-body physics with Strontium Rydberg lattices — •Laura Gil[1], Rick Mukherjee[1], Elizabeth Bridge[2], Matthew Jones[2], and Thomas Pohl[1] — [1]Max-Planck-Institute for the Physics of Complex Systems, Dresden — [2]Joint Quantum Centre, Durham-Newcastle, UK

We theoretically explore the utility of off-resonant Rydberg state dressing for the creation of tunable long-range interactions between atoms in optical lattices. As an application, here we theoretically demonstrate a viable approach to generate squeezed many-body states in Strontium optical lattice clocks, and discuss prospects for realizing extended Bose-Hubbard models with non-linear tunnelling terms.

A 20.2 Tue 14:15 BEBEL E44/46

Parallel execution of quantum gates in a long linear ion chain via Rydberg mode shaping — •Weibin Li[1], Alexander W. Glaetzle[2], Rejish Nath[2], and Igor Lesanovsky[1] — [1]School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, United Kingdom — [2]Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck, Austria

We present a mechanism that permits the parallel execution of multiple quantum gate operations within a single long linear ion chain. Our approach is based on large coherent forces that occur when ions are electronically excited to long-lived Rydberg states. The presence of Rydberg ions drastically affects the vibrational mode structure of the ion crystal, giving rise to modes that are spatially localized on isolated subcrystals which can be individually and independently manipulated. We theoretically discuss this Rydberg mode shaping in an experimentally realistic setup and illustrate its power by analyzing the fidelity of two conditional phase flip gates executed in parallel. The ability to dynamically shape vibrational modes on the single-ion level might find applications in quantum simulators and quantum computation architectures.

A 20.3 Tue 14:30 BEBEL E44/46

Full counting statistics of a dissipative Rydberg gas — Nicola Malossi[1,2], Maria Valado[1,2], Stefano Scotto[2], Paul Huillery[3], Pierre Pillet[3], Donatella Ciampini[1,2,4], Ennio Arimondo[1,2,4], and •Oliver Morsch[1,2] — [1]INO-CNR, Via G. Moruzzi 1, 56124 Pisa, Italy — [2]Dipartimento di Fisica 'E. Fermi', Universita di Pisa, Largo Pontecorvo 3, 56127 Pisa, Italy — [3]Laboratoire Aime Cotton, CNRS, Univ Paris-Sud 11, ENS-Cachan, Campus d'Orsay Bat. 505, 91405 Orsay, France — [4]CNISM UdR Dipartimento di Fisica, Largo Pontecorvo 3, 56127 Pisa, Italy

Ultra-cold gases excited to strongly interacting Rydberg states are a promising system for quantum simulations of many-body systems [1, 2]. For off-resonant excitation of such systems in the dissipative regime, highly correlated many-body states exhibiting intermittency and multi-modal counting distributions are expected to be created [3-5]. Here we report on the realization of a such a dissipative gas of Rydberg atoms and measure its full counting statistics for both resonant and off-resonant excitation. We find strongly bimodal counting distributions in the off-resonant regime that are compatible with intermittency due to the coexistence of dynamical phases. Moreover, we measure the phase diagram of the system and find good agreement with recent theoretical predictions [3, 5].

[1] F. Verstraete et al., Nat. Phys. 5, 633 (2009). [2] H. Weimer et al., Nat. Phys. 6, 382 (2010). [3] C. Ates et al., Phys. Rev. A 85, 043620 (2012). [4] T.E. Lee et al., Phys. Rev. A 84, 031402(R) (2011). [5] T.E. Lee et al., Phys. Rev. Lett. 108, 023602 (2012).

A 20.4 Tue 14:45 BEBEL E44/46

Investigation of d-state Rydberg molecules — •Alexander Krupp[1], Anita Gaj[1], Jonathan Balewski[1], Philipp Ilzhöfer[1], Markus Kurz[2], Sebastian Hofferberth[1], Robert Löw[1], Tilman Pfau[1], and Peter Schmelcher[2] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany

Rydberg electrons can trap ground state atoms giving rise to the creation of large Rydberg molecules with internuclear distances of several thousands of Bohr radii. Spectroscopic studies already proved the existence of these exotic molecules for Rubidium Rydberg s-states[1].

Recently we studied m_j-dependent d-states where the molecular potential shows a different angular dependency. We prove the existence of these molecules for two different m_j states for principal quantum numbers n from 40-50. By changing the polarization and detuning of our excitation laser we are able to selectively excite specific rovibrational states and thereby generate a specific alignment of these d-state molecules. A full theory, using the Born-Oppenheimer approximation and taking s- and p-wave scattering into account, reproduces our spectroscopy data very well.

[1] V. Bendkowsky et al., *Nature* **458**, 0028–0836 (2009)

A 20.5 Tue 15:00 BEBEL E44/46

Ultra-long-range Rydberg molecules in crossed fields — •Markus Kurz[1] and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany — [2]Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Germany

We investigate the impact of crossed external electric and magnetic fields on ultra-long-range Rydberg molecules [1] in the ultracold regime. The theoretical framework of the considered problem is based on the Fermi pseudopotential approximation, where in the electron perturber interaction p-wave contributions are included. This work concludes a number of previous studies where ultra-long-range Rydberg molecules had been exposed to electric and magnetic fields separated [2,3]. The rich topology of the Born-Oppenheimer potential surfaces for several field strengths is studied. Furthermore, we analyze the rovibrational dynamics for different electronically excited states. Finally, we present the electric and magnetic polarizability of field dressed high-ℓ molecular states for various field strengths.

[1] C. H. Greene, A. S. Dickinson, and H. R. Sadeghpour, Phys. Rev. Lett. 85, 2458 (2000).

[2] I. Lesanovsky, H. R. Sadeghpour, and P. Schmelcher, J. Phys. B 39, L69 (2006).

[3] M. Kurz, P. Schmelcher, Phys. Rev. A 88, 022501 (2013)

A 20.6 Tue 15:15 BEBEL E44/46

Patterned Rydberg excitation and ionisation with in-vacuo optical aberration correction — •Rick van Bijnen[1,2], Cornee Ravensbergen[1], Servaas Kokkelmans[1], and Edgar Vredenbregt[1] — [1]Eindhoven University of Technology, P. O. Box 513, 5600 MB Eindhoven, The Netherlands — [2]Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany

We demonstrate the ability to excite atoms at well-defined, programmable locations in a magneto-optical trap, either to the continuum (ionisation), or to a highly excited Rydberg state. To this end, excitation laser light is shaped into arbitrary intensity patterns with a spatial light modulator, such as regular arrays of spots that are spaced several microns apart. Requiring diffraction limited performance, these optical patterns are sensitive to aberrations of the phase of the light field, which occur while traversing the optical beamline. These aberrations are characterised and corrected with the spatial light modulator, without observing the actual light field in the vacuum chamber.

A 20.7 Tue 15:30 BEBEL E44/46

Quantum simulation of correlated solid phases with Rydberg dressed atoms — •Tommaso Macri[1], Fabio Cinti[2], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]National Institute for Theoretical Physics, Stellenbosch, South Africa

The realization and control of long-range interactions in atomic systems at low temperatures opens up a whole new realm of many-body physics that has become a central focus of research. Rydberg gases are suited to achieve this goal, as the van der Waals forces between them are many orders of magnitude larger than for ground state atoms. When the electronic ground state is off-resonantly coupled to a highly excited state with strong binary interactions, the two body interaction is modified into a soft core potential. Importantly, despite the repulsion between the admixed Rydberg states, the dressing of the ground state does not lead to atomic trap-loss, both in free space and in optical lattices. At the many body level these non-local interactions provide an optimal playground for the engineering of exotic many body phases. The ability to control and tune interactions and particle numbers in such systems allows the creation of superfluids, crystalline states as well as the long sought supersolid phase. At high densities the ground state breaks translational invariance and global gauge symmetry creating coherent density waves. For low particle densities, the system is shown to feature a solid phase in which zero-point vacancies emerge spontaneously and give rise to superfluid flow of particles through the crystal, providing the first example of defect-induced supersolidity.

A 20.8 Tue 15:45 BEBEL E44/46

Physics beyond rate equation modeling and the breakdown of universality in Ryberg EIT — •Martin Gärttner and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

For the description of laser driven interacting Rydberg gases and associated nonlinear optical effects, rate equation models have been used extensively recently. We discuss why these models are capable of reproducing collective effects and how they predict a universal relation between Rydberg density and optical susceptibility. By comparing with exact numerical solutions of the many-body master equation, we find regimes in which the rate equation models and the universal relations break down. Most remarkably, for strong coherent driving, an enhancement of Rydberg excitation is found, which cannot be reproduced by rate equation models and thus is a truly coherent effect.