A 11: Ultra-cold plasmas and Rydberg systems (joint session A/Q)

Time: Tuesday 16:30–18:30 Location: P

A 11.1 Tue 16:30 P

Ultrafast Electron Cooling in an Ultracold Microplasma — •Mario Grossmann, Tobias Kroker, Julian Fiedler, Jette Heyer, Markus Drescher, Klaus Sengstock, Philipp Wessels-Staarmann, and Juliette Simonet — The Hamburg Centre for Ultrafast Imaging (CUI), Luruper Chaussee 149, 22761 Hamburg

We utilize the strong light-field of a focused femtosecond laser pulse to instantaneously and locally ionize a controlled number of atoms within a ^{87}Rb Bose-Einstein condensate.
The large atomic densities above 10^{20} m^{-3} combined with low ion temperatures below 40 mK give rise to an initially strongly coupled plasma with up to a few thousand electrons and ions.
Our experimental setup allows us to tune the density, volume and number of ionized atoms as well as the excess energy after ionization which sets the neutrality of the ultracold plasma.
By directly measuring the kinetic energy of the emerging electrons from a highly charged plasma we observe a cooling of the electronic component from 5250 K to 10 K in less then 500 ns.
The finite particle number permits us to perform exact numerical calculations of the plasma dynamics with long-range Coulomb interactions in excellent agreement with our experimental data. These simulations reveal the picosecond dynamics of each particle as well as the ultrafast energy transfer between the electronic and ionic components of the plasma, bridging the natural time-scales of ultracold neutral plasma and ionized nanoclusters.

A 11.2 Tue 16:30 P

Quantum sensing protocol for motionally chiral Rydberg atoms — Stefan Yoshi Buhmann[1], Steffen Giesen[2], Mira Diekmann[2], Robert Berger[2], •Stefan Aull[3], Markus Debatin[3], Peter Zahariev[3,4], and Kilian Singer[3] — [1]Theoretische Physik III, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Fachbereich Chemie, Philipps-Universität Marburg, Hans-Meerwein-Str 4, Marburg 35032, Germany — [3]Experimentalphysik I, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [4]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72, Tzarigradsko Chaussee, 1784 Sofia, Bulgaria

A quantum sensing protocol is proposed for demonstrating the motion-induced chirality of circularly polarised Rydberg atoms. To this end, a cloud of Rydberg atoms is dressed by a bichromatic light field. This allows to exploit the long-lived ground states for implementing a Ramsey interferometer in conjunction with a spin echo pulse sequence for refocussing achiral interactions. Optimal parameters for the dressing lasers are identified. Combining a circularly polarised dipole transition in the Rydberg atom with atomic centre-of-mass motion, the system becomes chiral. The resulting discriminatory chiral energy shifts induced by a chiral mirror are estimated using a macroscopic quantum electrodynamics approach.

A 11.3 Tue 16:30 P

Reconstructing three-dimensional density distributions from absorption images — Henrik Zahn[1], •Maximilian Klaus Müllenbach[2], Titus Franz[2], Clément Hainaut[2], Gerhard Zürn[2], and Matthias Weidemüller[2] — [1]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

We present a novel method to reconstruct a three-dimensional density distribution from its two-dimensional projection in a suitably chosen direction as long as the distribution has an a-priori known continuous symmetry. Our method extends the well-known Abel transform for distributions with axial or spherical symmetry to distributions with more general continuous symmetries. A-priori knowledge of the present symmetries allows us to solve the inversion problem by finding the density distribution's values along its isolines. We apply our method to two distinct settings, the first one being such that Abel inversion can be applied, i.e. rotational symmetry about an axis perpendicular to the integration direction. In the second setting we apply our method to study excitation dynamics of Rydberg atoms, featuring a complex symmetry determined by the cigar-like shape of the ground state density distribution and the axially symmetric excitation laser, angled at 45° with respect to the ground state symmetry axis.

A 11.4 Tue 16:30 P

Towards an optogalvanic flux sensor for nitric oxide based on Rydberg excitations — Patrick Kaspar[1,5], Fabian Munkes[1,5], •Yannick Schellander[3], Lars Baumgärtner[2], Lea Ebel[1], Denis Djekic[2], Patrick Schalberger[3], Holger Baur[3], Jens Anders[2,5], Edward Grant[4], Norbert Frühauf[3], Robert Löw[1,5], Tilman Pfau[1,5], and Harald Kübler[1,5] — [1]5 Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [2]Institut für Intelligente Sensorik und Theoretische Elektrotechnik, Universität Stuttgart, Pfaffenwaldring 47, 70569 Stuttgart — [3]Institut für Großflächige Mikroelektronik, Universität Stuttgart, Allmandring 3b, 70569 Stuttgart — [4]Department of Chemistry & Department of Astronomy, The University of British Columbia, 2036 Main Mall, Vancouver, BC Canada V6T 1Z1 Vancouver, Canada — [5]Center for Integrated Quantum Science and Technology, Universität Stuttgart

We demonstrate the applicability of a new kind of gas sensor based on Rydberg excitations. From a gas mixture the molecule in question is excited to a Rydberg state. By succeeding collisions with all other gas components this molecule becomes ionized and the emerging electrons can be measured as a current. In a proof of concept experiment a detection limit of 10 ppm in a background of He was demonstrated [1,2]. We show first results of the continous wave sensor prototype and first signals of Doppler-free laser spectroscopy on nitric oxide.

[1] J. Schmidt, et. al., *Appl. Phys. Lett.* **113**, 011113 (2018)
[2] J. Schmidt, et. al., SPIE **10674** (2018)

A 11.5 Tue 16:30 P

Two-dimensional spectroscopy of Rydberg gases — •Kaustav Mukherjee[1], Himangshu Prabal Goswami[2,4], Shannon Whitlock[3], Sebastian Wüster[1], and Alexander Eisfeld[4] — [1]Indian Institute of Science Education and Research, Bhopal, India — [2]Gauhati University, Guwahati, India — [3]University of Strasbourg and CNRS, Strasbourg, France — [4]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Two-dimensional (2D) spectroscopy uses multiple electromagnetic pulses to infer the properties of a complex system. A paradigmatic class of target systems is molecular aggregates, for which one can obtain information on the eigenstates, various types of static and dynamic disorder, and relaxation processes. However, two-dimensional spectra can be difficult to interpret without precise knowledge of how the signal components relate to microscopic Hamiltonian parameters and system-bath interactions. Here we show that two-dimensional spectroscopy can be mapped in the microwave domain to highly controllable Rydberg quantum simulators. By porting 2D spectroscopy to Rydberg atoms, we firstly open the possibility of its experimental quantum simulation, in a case where parameters and interactions are very well known. Secondly, the technique may provide additional handles for experimental access to coherences between system states and the ability to discriminate different types of decoherence mechanisms in Rydberg gases. We investigate the requirements for a specific implementation utilizing multiple phase-coherent microwave pulses and a phase cycling technique to isolate signal components.