A 28: Ultracold Plasmas, Rydberg Systems and Molecules (with Q)

Time: Thursday 11:00–13:15 Location: P 104

Group Report A 28.1 Thu 11:00 P 104

Coherent excitation of a single trapped Rydberg ion — •Fabian Pokorny[1], Gerard Higgins[1,2], Chi Zhang[1], Quentin Bodart[1], and Markus Hennrich[1] — [1]Department of Physics, Stockholm University, 10691 Stockholm, Sweden — [2]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria

Trapped Rydberg ions are a novel approach for quantum information processing [1]. By combining the high degree of control of trapped ion systems with the long-range dipolar interactions of Rydberg ions [2], fast entanglement gates may be realised in large ion crystals [3].

Quantum information processing in such a system links qubit rotations in the ions' ground states with entanglement operations via the Rydberg interaction. This combination of quantum operations requires that the Rydberg excitation can be controlled coherently.

In the experiments presented here a strontium ion confined in a linear Paul trap was excited to the Rydberg state via a two-photon excitation with 243nm and 307nm light [4]. We observed EIT in this system and mapped the population to the Rydberg state and back via STIRAP. This is the first observed coherently manipulated Rydberg excitation of an ion.

[1] M. Müller, et al., New J. Phys. **10**, 093009 (2008)
[2] D. Jaksch, et al., Phys. Rev. Lett. **85**, 2208 (2000)
[3] F. Schmidt-Kaler, et al, New J. Phys. **13**, 075014, (2011)
[4] G. Higgins, et al, arXiv:1611.02184v1, (2016)

A 28.2 Thu 11:30 P 104

Multicritical behavior in dissipative Ising models — •Vincent Overbeck[1], Mohammad Maghrebi[2], Alexey Gorshkov[2], and Hendrik Weimer[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Joint Quantum Institute and Joint Center for Quantum Information and Computer Science, NIST/University of Maryland, College Park, Maryland 20742, USA

Physical phenomena of dissipative quantum many-body systems can be quite different from those of their equilibrium counterparts. We analyze a Z_2- preserving dissipative Ising model using a variational principle [1,2]. In the steady state phase diagram, we find in addition to a continuous transition, a first order transition between an ordered and an unordered phase and a tricritical point. We extend our analysis by a Ginzburg-Landau approach, verifying in detail the validity of our product state ansatz. We show that fluctuations due to spatial inhomogeneities are produced in the same way as in equilibrium, allowing us to determine an upper critical dimension, above which fluctuations in the multicritical regime vanish and the critical exponents of our product state theory become correct. Finally, we will present a renormalization group analysis of our functional, investigating how a one loop correction influences the position of the tricritical point.

[1] H. Weimer, Variational Principle for Steady States of Dissipative Quantum Many-Body Systems, Phys. Rev. Lett. 114, 040402 (2015).
[2] H. Weimer, Variational analysis of driven-dissipative Rydberg gases, Phys. Rev. A 91, 063401 (2015).

A 28.3 Thu 11:45 P 104

Critical properties of a one-dimensional adsorbing state model — •Maryam Roghani and Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

We study a quantum version of a one-dimensional adsorbing state model [1]. We find evidence for a steady state phase transition between a phase with algebraic correlations (active) and a phase with exponential decay (inactive). Remarkly, this transition appears to be present despite the system being in a mixed state. In the active phase, we also look into the quantum mutual information of the steady state, comparing to scaling predictions from conformal field theory.

[1]. M. Marcuzzi, M. Buchhold, S. Diehl, and I. Lesanovsky, Phys. Rev. Lett. 116, 245701 (2016)

A 28.4 Thu 12:00 P 104

Structure Formation in a Correlated Rydberg Gas — •Andre Salzinger[1], Elena Kozlikin[2], Martin Pauly[2], Alexander Schuckert[3], Robert Lilow[2], Matthias Bartelmann[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Heidelberg — [2]Institut für Theoretische Astrophysik, Heidelberg — [3]Institut für Theoretische Physik, Heidelberg

Cosmic structure formation can be described by a classical path integral formalism. We apply such a theoretical framework to predict structure formation in an initially correlated ensemble of Rydberg atoms. The free Hamiltonian motion of particles and their initial correlation function are contained in a generating functional. We model the non-classical excitation process including blockade and anti-blockade effects to emulate realistic initial conditions. Interactions between the particles are introduced via an operator acting perturbatively on the free generating functional which is evolved in time. Collective properties, such as density correlations can be extracted by applying appropriate operators.

We will discuss different experimental implementations with the aim of directly or indirectly observing the impact of initial correlations on structure formation.

A 28.5 Thu 12:15 P 104

Many-body dynamics of driven-dissipative Rydberg cavity polaritons — •Tim Pistorius and Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

The usage of photons as long-range information carriers has greatly increased the interest in systems with nonlinear optical properties in recent years. The nonlinearity is easily achievable in Rydberg mediums through the strong van der Waals interaction which makes them one of the best candidates for such a system. Here, we propose a way to analyze the steady state solutions of a Rydberg medium in a cavity through the combination of the variational principle for open quantum systems [1] and the P-distribution of the density matrix. To get a better understanding of the many-body-dynamics a transformation into the polariton picture is performed and investigated.

[1] H. Weimer, Variational Principle for Steady States of Dissipative Quantum Many-Body Systems, Phys. Rev. Lett.114, 040402 (2015).

A 28.6 Thu 12:30 P 104

Pulsed Rydberg four-wave mixing in a microcell — •Fabian Ripka, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart

Photonic quantum devices based on atomic vapors at room temperature combine the advantages of atomic vapors being intrinsically reproducable as well as semiconductor-based concepts being scalable and integrable. One key device in the field of quantum information are on-demand single-photon sources. A promising candidate for realization relies on the combination of two effects in atomic ensembles, namely four-wave mixing (FWM) and the Rydberg blockade effect.

Coherent dynamics to Rydberg states [1] and sufficient Rydberg interaction strengths [2] have already been demonstrated in thermal vapors. Also in a pulsed FWM scheme coherent phenomena could be observed [3,4]. Additionally, time-resolved probing of collective Rydberg excitation has been performed [5], revealing a lifetime long enough for effective Rydberg-Rydberg interactions.

We report on the latest results of Rydberg four-wave mixing in a volume size comparable to the Rydberg interaction range. This scheme promises to enable the creation of non-classical light states.

[1] Huber et al., PRL 107, 243001 (2011)
[2] Baluktsian et al., PRL 110, 123001 (2013)
[3] Huber et al., PRA 90, 053806 (2014)
[4] Chen et al., Appl. Phys. B, 122:18 (2016)
[5] Ripka et al., Phys. Rev. A, 053429 (2016)

A 28.7 Thu 12:45 P 104

Creating $^{23}Na^{40}K$ ground state molecules with detuned STIRAP — •Frauke Seesselberg[1], Xin-Yu Luo[1], Nikolaus Buchheim[1], Zhenkai Lu[1], Immanuel Bloch[1,2], and Christoph Gohle[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Molecules in their absolute vibrational and rotational ground state promise exciting new possibilities for quantum simulation due to their large inducible dipole moments. It is however challenging to obtain molecules, which are sufficiently cold and dense enough for this pur-

pose.

Starting from a near quantum degenerate Bose-Fermi mixture of sodium and potassium we employ stimulated Raman adiabatic passage (STIRAP). STIRAP is a two-photon process, with which we transfer weakly bound heteronuclear NaK Feshbach molecules via an intermediate, excited molecular state in the d/D potential manifold to the molecular ground state. To reduce excessive scattering from near resonant levels in the excited state, we go one-photon detuned with respect to this intermediate molecular level. We experimentally investigate the efficiency of the STIRAP process at various one-photon detunings and compare them with a theoretical model.

A 28.8 Thu 13:00 P 104

Precision two-color spectroscopy of ^{40}Ca for the determination of the s-wave scattering length — •Veit Dahlke[1], Evgenij Pachomow[1], Eberhard Tiemann[2], Fritz Riehle[1], and Uwe Sterr[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

By two-color photoassociation of ^{40}Ca four weakly bound vibrational levels in the Ca_2 $X^1\Sigma_g^+$ ground state potential were measured, using highly spin-forbidden transitions to intermediate states of the coupled system $^3\Pi_u$ and $^3\Sigma_u^+$ near the $^3P_1+^1S_0$ asymptote. We have interrogated cold ensembles of about 10^5 calcium atoms trapped in a crossed optical dipole trap at temperatures of approximately 1 μK. The unperturbed binding energies have been measured with kHz accuracy benefiting from few Hertz linewidth offset-locked tunable lasers and detailed lineshape analysis.

From the observed binding energies, including the least bound state, the long range dispersion coefficients C_6, C_8, C_{10} and a precise value for the s-wave scattering length were derived. The precise description of the asymptotic potential was also used to determine scattering lengths for all stable isotopes of calcium.