Q 3: Quantum gases: Interaction effects I

Time: Monday 11:00–12:30 Location: E 001

Group Report Q 3.1 Mon 11:00 E 001

Rydberg gases at room temperature - coherent dynamics and interaction — •Bernhard Huber, Andreas Kölle, Thomas Baluktsian, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

Rydberg atoms are of great interest due to their prospects in quantum information. Coherent control of the strong Rydberg-Rydberg interaction allows for the realization of quantum operations and devices which have been demonstrated in ultracold experiments. We present our progress on the coherent control and investigation of Rydberg atoms at room temperature. We show that we are able to drive Rabi oscillations on the nanosecond timescale to a Rydberg state by using a pulsed laser excitation and are therefore faster than the coherence time limitation given by the Doppler width [1]. By systematically investigating the dephasing of these oscillations for different atomic densities and Rydberg states we find evidence for van-der Waals interaction in thermal vapor [2]. The strength of the interaction exceeds the energy scale of thermal motion (i.e. the Doppler broadening) and therefore enables strong quantum correlations.

Furthermore we present our latest results on the combination of the pulsed Rydberg excitation with a four-wave-mixing scheme and our progress towards the creation of non-classical light.

[1] Huber et al., PRL **107**, 243001 (2011)
[2] Baluktsian et al., arXiv:1212.0690

Q 3.2 Mon 11:30 E 001

Ground states of dipolar Bose-Einstein condensates in triple-well potentials — •Damir Zajec and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Dipolar Bose-Einstein condensates in triple-well potentials are model systems for larger periodic systems with important contributions of non-local dipole-dipole interactions. We perform grid calculations to determine the ground states of such systems by means of the Gross-Pitaevskii equation. The split-operator method is used to apply a general time evolution operator to an initial state, where time evolution is mainly described by a series of Fourier transforms. Since this numerical scheme is very demanding, the parallel computing architecture CUDA was used to implement the code. We study repulsive and attractive configurations with linear and triangular arrangements and present phase diagrams to illustrate the occurrence of different phases.

Q 3.3 Mon 11:45 E 001

Interband transport in a many-body Wannier-Stark setup — •Carlos Alberto Parra-Murillo[1], Javier Madroñ ero[2], and Sandro Wimberger[1] — [1]Institut für Theoretische Physik and Center for Quantum Dynamics, Universität Heidelberg, 69120 Heidelberg, Germany — [2]Physik Department, Technische Universität München, 85747 Garching, Germany

The transport properties of flat optical lattices loaded with ultracold atoms have been amply studied in recent years in theory as well as in experiment, especially under single band approximation. The coupling to higher Bloch bands can be introduced by a Stark force, which can be considered as a control parameter. This allows the realization of resonant tunneling between energy levels in different potential wells. We study a Wannier-Stark system based on a two-band Bose-Hubbard model. The spectral characteristics of this system in the regime of strong interparticle interaction offer the possibility of a dynamical preparation of specific upper band states and also the study of quench dynamics across the spectrum [1]. Dynamical correlations between the bands imply interesting perspectives for the state-of-the-art experiments with ultracold bosons.

[1] Parra-Murillo C. A., Madronero J., Wimberger S., arXiv:1207.4699 [cond-mat.quant-gas] (2012)

Q 3.4 Mon 12:00 E 001

Variational investigation of dipolar BEC in multi-well potentials — •Rüdiger Eichler, Jörg Main und Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

The dipolar interaction of the atoms in Bose-Einstein condensates leads to a variety of interesting effects such as self-organization and formation of patterns. Multi-well potentials are well suited settings for the examination of these effects and the mechanisms behind. The dynamics of dipolar Bose-Einstein condensates in multi-well potentials can be described in the mean-field limit by an extended time-dependent Gross-Pitaevskii equation (GPE). We solve this GPE by a time-dependent variational principle where we use coupled Gaussian wave packets. With this method we do not only obtain the ground state of the condensate but the excited states as well. These play a crucial role e.g. in the creation of different phases. We show that this is connected to crossings of the involved states. Furthermore, dynamics in multi-well potentials will be shown which now can be interpreted by means of the presence of different states.

Q 3.5 Mon 12:15 E 001

Bifurcations and exceptional points in dipolar Bose-Einstein condensates — •Robin Gutöhrlein, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Deutschland

Bose-Einstein condensates are described in a mean-field approach by the nonlinear Gross-Pitaevskii equation and exhibit phenomena of non-linear dynamics. The eigenstates can undergo bifurcations in such a way that two or more eigenvalues and the corresponding wave functions coalesce at critical values of external parameters, e.g. the scattering length. At the critical point the coalescing states show the properties of an exceptional point. We present a method to uncover all states participating in a pitchfork bifurcation, and investigate in detail the signatures of exceptional points related to bifurcations in dipolar condensates. For the perturbation by two parameters, viz. the scattering length and a parameter breaking the symmetry of the trap, two cases leading to different characteristic eigenvalue and eigenvector patterns under cyclic variation of the parameters need to be distinguished. The observed structures resemble those obtained by G. Demange and E.-M. Graefe [J. Phys. A, 45:025303, 2012] using perturbation theory for non-Hermitian operators in a linear model. Furthermore, the splitting of the exceptional point under symmetry breaking in either two or three branching singularities is examined. Characteristic features are observed when multiple exceptional points are simultaneously encircled.