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Abstracts of the awarded posters

Posters awarded by the committee for the prize of the Europhysics Letters journal

Photoluminescence of exciton polariton condensates at high densities

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Exciton-polariton condensates need to be continuously pumped due to their short lifetime of the order of picoseconds. This open-dissipative nature of the system is particularly important in the high density regime, bringing new physics beyond traditional atomic BEC systems: the gain and loss of the condensate can no longer be ignored. At high density, it has been a controversial issue of whether exciton-polariton BECs would undergo a crossover to photon lasing based on electron-hole plasma, or an electron-hole BCS-like phase [1–3].

In this work we discuss the property of the high density exciton-polariton BECs via two-time correlation function of an open system [4] taking into account of reservoir pumping and cavity, exciton loss. We consider a model where the lower polaritons are pumped into the condensate and decay with the finite lifetime.

We also consider effects of a time dependent pump, which more closely simulates the experimental situation where a pulsed excitation is used.

References

[1] P. Eastham and P. Littlewood, Phys. Rev. B 64, 235101 (2001).
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[3] T. Byrnes et al., Phys. Rev. Lett. 105, 186402 (2010).
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Engineering Dirac points with ultracold fermions in a tunable optical lattice

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We report on the creation of Dirac points with adjustable properties in a tunable honeycomb optical lattice. Using momentum-resolved interband transitions, we observe a minimum band gap inside the

Brillouin zone at the position of the Dirac points. We exploit the unique tunability of our lattice potential to adjust the effective mass of the Dirac fermions by breaking the inversion symmetry of the lattice. Changing the lattice anisotropy allows us to move the position of the Dirac points inside the Brillouin zone. When increasing the anisotropy beyond a critical limit, the two Dirac points merge and annihilate each other. We map out this topological transition and find excellent agreement with ab initio calculations. Our results not only pave the way for using cold atoms to model materials where the topology of the band structure plays a crucial role, but also provide the possibility to explore many-body phases resulting from the interplay of complex lattice geometries with interactions

Sisyphus cooling of polyatomic molecules

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Interest in ultracold polar molecules has experienced tremendous growth in recent years, with potential applications reaching beyond those of ultracold atoms due to additional internal degrees of freedom and long-range dipole-dipole interactions. Developing methods to prepare the required ensembles of ultracold molecules has been a formidable challenge. To this end, we have now achieved first results with opto-electrical cooling [1], a general Sisyphus-type cooling scheme for polar molecules. Molecules are cooled by more than a factor of 4 with an increase in phase space density by a factor of 7. The scheme proceeds in an electric trap, and requires only a single infrared laser with additional RF and microwave fields. The cooling cycle depends on generic properties of polar molecules and can thus be extended to a wide range of molecule species. Ongoing improvements in our trap design will allow cooling to sub-mK temperatures and beyond, opening wide-ranging opportunities for fundamental studies with polyatomic molecules at ultracold temperatures.

Reference

[1] M. Zeppenfeld et. al., Opto-Electrical Cooling of Polar Molecules, Phys. Rev. A 80, 041401 (2009).

Posters awarded by the committee for the prize of the AMO section of the French Physical Society

Negative absolute temperature for motional degrees of freedom

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Absolute temperature is one of the central concepts in statistical mechanics and is usually described as being strictly non-negative. However, in systems with an upper energy bound, also negative temperature states can be realized. In these states, the occupation probability of each basis state increases with

energy. So far, they have been demonstrated only for localized degrees of freedom such as the spin of nuclei or atoms [1, 2]. By using a Feshbach resonance in bosonic ^{39}K, we implemented the attractive Bose-Hubbard model in a three-dimensional optical lattice. Following a recent proposal [3, 4], we were able to create a negative temperature state for motional degrees of freedom, strikingly resulting in a condensate at the upper band edge of the lowest band. This attractively interacting bosonic superfluid is thermodynamically stable, i.e. stable against mean-field collapse for arbitrary atom numbers. We additionally investigated the characteristic timescale for the emergence of coherence in the ensemble, and found an intriguing symmetry between the negative temperature and positive temperature state.

References

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Imaging the build-up of a quantum interference pattern of massive molecules

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New experiments allow us for the first time to visualize the gradual emergence of a deterministic far-field matter-wave diffraction pattern from stochastically arriving single molecules. A slow molecular beam is created via laser evaporation of the molecules from a glass window. The molecules traverse an ultra-thin nanomachined grating at which they are diffracted and quantum delocalized to more than 100 μm before they are captured on a quartz plate at the interface between the vacuum chamber and a self-built fluorescence microscope. Fluorescence imaging provides us with single molecule sensitivity and we can determine the position of each molecule with an accuracy of 10 nm. This new setup is a textbook demonstration but it also enables quantitative explorations of the van der Waals forces between molecules and material gratings. An extrapolation of our present experiments to even thinner gratings is expected to also enlarge the range of nanoparticles that are accessible to advanced quantum experiments.

Reference

[1] Juffmann et al., "Real-time single-molecule imaging of quantum interference", Nature Nanotechnology 7, 297–300 (2012).

Coupling color centers in diamond to fiber-based Fabry-Pérot microcavities

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Optical fibers with machined and coated end facets can serve as high reflectivity mirrors to build low loss optical resonators with free space access [1, 2]. These microcavities feature a very small mode volume on the order of a few tens of cubic wavelengths and a very large Finesse of up to 105, corresponding to quality factors of several millions. Thus, the Purcell factor being proportional to the ratio of quality factor and mode volume can be as high as 104, which can dramatically increase the emission rate of an emitter inside the cavity. We use the microcavities to couple solid state based emitters such as color centers in diamond to the cavity. First results from spectra of ensembles of nitrogen-vacancy centers coupled to the cavity show a strongly increased emission efficiency into the cavity mode. The emission behavior can be modeled with a modified Purcell factor accounting for the dephasing.

References

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Inelastic confinement-induced resonances in low-dimensional quantum systems

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Ultracold atomic systems of reduced dimensionality show intriguing phenomena like fermionization of bosons in the Tonks-Girardeau gas or confinement-induced resonances (CIRs) which allow fora manipulation of the interaction strength by varying the trap geometry. Here, a theoretical model is presented describing inelastic confinement-induced resonances which appear in addition to the regular (elastic) ones and were observed in the recent loss experiment of Haller et al. in terms of particle losses [1]. These resonances originate from possible molecule formation due to the coupling of center-of-mass and relative motion. The model is verified by ab initio calculations and predicts the resonance positions in 1D as well as in 2D confinement in agreement with the experiment. This resolves the contradiction of the experimental observations to previous theoretical predictions.

Reference

[1] E. Haller et al., Phys. Rev. Lett. 104, 153203 (2010).

Controlling chemical reactions of a single particle

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The full control over all quantum mechanical degrees of freedom in binary collisions allows for the identification of fundamental interaction processes and for steering chemical reactions. Focussing on the best-controlled experimental conditions, such as using state-selected single particles and low temperatures, is crucial for the investigation of chemical processes at the most elementary level. The hybrid system of trapped atoms and ions offers key advantages in this undertaking: ion traps have a large potential well depth in order to trap the reaction products, while the absence of a Coulomb-barrier allows the particles to collide at short internuclear distance. Here, we report on the experimental tuning of the exchange reaction rates of a single trapped ion with ultracold neutral atoms by exerting control over both their quantum states. We observe the influence of the hyperfine state on chemical reaction rates and branching ratios and monitor the kinematics of the reaction products. These investigations advance chemistry with single trapped particles towards achieving quantum-limited control of chemical reactions and pave the way to the study of the coherence properties of a single trapped ion in an ultracold buffer gas.

Flux lattices and topological flat bands in dipolar spin systems

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Topological flat bands provide a fascinating route to the realization of fractional topological insulators and anomalous quantum hall states. Here, we provide the first microscopic description of a physical system, which naturally realizes such bands. In particular, we consider a generic two-dimensional lattice system of tilted, interacting dipoles and demonstrate that such a system harbors single-particle bands with non-trivial topology as well as a quenched kinetic energy relative to the interaction scale. Moreover, we demonstrate that such systems naturally enable uniform arbitrary p/N (for all $N \in Z$) flux per plaquette, allowing for the realization of a high-field fractional quantum Hall regime where the flux quanta per lattice cell is large. We propose an experimental realization with polar molecules in optical lattices.