A 40: Ultracold Atoms and Molecules (with Q)

Time: Friday 11:00–13:00 Location: B/SR

A 40.1 Fri 11:00 B/SR

Quadrupole-quadrupole interactions in ultracold atom systems — •Martin Lahrz[1], Mikhail Lemeshko[2], Klaus Sengstock[1], Christoph Becker[1], and Ludwig Mathey[1] — [1]University of Hamburg, Hamburg, Germany — [2]Harvard University, Cambridge, Massachusetts, USA

We investigate quadrupole-quadrupole interactions of ultracold atom systems. These interactions have a long-range and anisotropic character, which goes beyond the properties of contact potentials. In this talk, we will report briefly about our proposal [1] to detect quadrupolar interactions in ultracold Fermi gases by measuring the induced mean-field shift. We consider a quasi-2D system of quadrupoles aligned by an external magnetic field and tilted with respect to the system geometry. This results in a characteristic angular dependence constituting the "smoking gun" feature of this interaction. The magnitude of the shift is of the order of tens of Hertz for $\mathrm{Yb}(^3P_2)$ and similarly for $\mathrm{Sr}(^3P_2)$ making this experimentally conceivable with current technologies. Further, we discuss many-body effects that can be created with quadrupole-quadrupole interactions.

[1] M. Lahrz, M. Lemeshko, K. Sengstock, C. Becker, and L. Mathey, Phys. Rev. A **89**, 043616 (2014).

A 40.2 Fri 11:15 B/SR

Detecting Floquet resonances with directed transport of ultracold atoms — •Christopher Grossert[1], Martin Leder[1], Sergey Denisov[2], Peter Hänggi[2], and Martin Weitz[1] — [1]Institut für Angewandte Physik,Universität Bonn, Germany — [2]Institut für Physik, Universität Augsburg, Germany

The breaking of spatiotemporal symmetry can lead to directed motion in periodically driven systems without any gradients or net forces. To break the relevant symmetries, a biharmonic driving is sufficient in the classical case as well as in the quantum case. For a dissipative system, this so called rocking ratchet system has been studied in previous work. In this talk, we investigate directed transport of ultracold rubidium atoms in a optical realization of a quantum rocking ratchet. By changing parameters of the underlying periodic modulations we resolve transport resonances in the mean momentum of an atomic Bose-Einstein condensate [1]. These resonances are attributed to the avoided crossings between Floquet eigenstates which are widely separated on the energy scale. We observe a bifurcation of a single-peak resonance into a doublet by increasing the amplitude of the drive. Our results prove the feasibility of the fine experimental control over coherent quantum transport in ac-driven optical lattices.

References: [1] Grossert et al., arXiv:1407.0605 (2014)

A 40.3 Fri 11:30 B/SR

Dicke super-radiance as non-destructive probe for superfluidity in optical lattices — •Nicolai ten Brinke and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, D-47057 Duisburg, Germany

We study Dicke super-radiance as collective and coherent absorption and emission of photons from an ensemble of ultra-cold atoms in an optical lattice. Since this process depends on the coherence properties of the atoms (e.g., super-fluidity), it can be used as a probe for their quantum state. This detection method is less invasive than time-of-flight experiments or direct (projective) measurements of the atom number (or parity) per lattice site, which both destroy properties of the quantum state such as phase coherence.

With our method, we are able to distinguish a partially excited (e.g., thermal) gas of atoms from a fully condensed (super-fluid) state. Regarding a phase transition from the Mott state to the super-fluid phase, it is possible to discriminate an adiabatic passage from a sudden transition. In this talk, we also discuss options for an experimental realization.

A 40.4 Fri 11:45 B/SR

Role of excitation spectrum during a quantum phase transition: Semiclassical approach — •Manuel Gessner[1], Victor Manuel Bastidas[2], Tobias Brandes[2], and Andreas Buchleitner[1,3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [3]Freiburg Institute for Advanced Studies, Albert-Ludwig-Universität, Albertstr. 19, 79104 Freiburg

We develop a semiclassical method to reproduce spectral features of a family of spin chain models with variable range in a transverse magnetic field, which interpolates between the Lipkin-Meshkov-Glick and the Ising model. The semiclassical spectrum is exact in the limit of very strong or vanishing external magnetic fields. Each of the semiclassical energy landscapes shows a bifurcation when the external magnetic field drops below a threshold value. This reflects the quantum phase transition from the symmetric paramagnetic phase to the symmetry-breaking (anti-)ferromagnetic phase in the entire excitation spectrum - and not just in the ground state.

A 40.5 Fri 12:00 B/SR

Improved ground-state scattering length of ^{40}Ca by two-colour photoassociation — •Veit P. Dahlke[1], Evgenij Pachomow[1], Eberhard Tiemann[2], Fritz Riehle[1], and Uwe Sterr[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig — [2]Institut für Quantenoptik, Leibniz-Universität Hannover, Welfengarten 1, 30167 Hannover

We have measured the second to last weakly bound ground state vibrational level $J = 0$ in the $^1S_0 + {}^1S_0$ potential of $^{40}\mathrm{Ca}_2$. We used two-colour photoassociation with the intermediate level $v' = -1$, $\Omega' = 1$, $J' = 1$ in the $^1S_0 + {}^3P_1$ potential on a cold ensemble of about 10^5 calcium atoms trapped in a crossed dipole trap at a temperature of approximately 1 μK. The photoassociation light is applied via two offset locked precisely tunable lasers. The vibrational level is located 1387.439(9) MHz below the asymptote and corresponds to the $v = 39$, $J = 0$ state.

With the exact determination of this level it becomes possible to derive a more accurate description of the ground state potential which will result in a more precise value for the ground state scattering length. By detecting more bound levels it will be possible to further improve on the accuracy and also enable us to predict the tunability of the scattering length by low-loss optical Feshbach resonances in the case of ^{40}Ca.

A 40.6 Fri 12:15 B/SR

Photoassociation spectroscopy of an ultra cold 23Na-40K mixture: En route to many-body physics with polar molecules — •Zhenkai Lu[1], Nikolaus Buchheim[1], Frauke Seesselberg[1], Tobias Schneider[1], Immanuel Bloch[1,2], and Christoph Gohle[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Ultra cold quantum gases with long-range dipolar interaction promise exciting new possibilities for quantum simulation of strongly interacting many-body systems. One way of realizing this is to create an ultra cold sample of ground state polar molecules.

A crucial step is the stimulated Raman adiabatic passage (STIRAP), a two-photon process involving a resonant intermediate state. We identified promising candidates for this intermediate level in the molecular potentials of the sodium D-line asymptote. We observe a series of deeply bound vibrational levels, resolving fine and hyperfine structure, by photoassociation spectroscopy on a nearly degenerate mixture of ^{23}Na and ^{40}K. By applying external fields, we observe Zeeman and Stark sub structure.

A 40.7 Fri 12:30 B/SR

Quantum Logic Spectroscopy of Molecular Ions — •Fabian Wolf[1], Jan C. Heip[1], Yong Wan[1], Florian Gebert[1], and Piet O. Schmidt[1,2] — [1]QUEST Institut, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

The rapid development in laser cooling and coherent state manipulation over the past decades has enabled exquisite control over the internal and external degrees of freedom of various species of atomic ions. The same techniques cannot be easily applied to molecular ions because of their rich internal level structure. On the other hand, ultracold molecular ions lend themselves for a number of novel applications, ranging from cold chemistry to tests of fundamental theories.

We propose to prepare a translationally cold molecular ion in a specific ro-vibrational state by employing the quantum logic technique [1] in which a laser-cooled atomic ion is simultaneously trapped with a single molecular ion. The cooling of the external degrees of freedom of the molecular ion is achieved via sympathetic cooling by the sideband-cooled atomic ion, while the preparation of its internal state is achieved via a quantum-non-demolition measurement (QNDM).

By analyzing the signal obtained from QNDM we can extract spectroscopic information about the $X^1\Sigma^+ \rightarrow A^1\Sigma^+$ transition.

References

[1] Schmidt et al., Science 309, 749 (2005)

A 40.8 Fri 12:45 B/SR

Towards ultracold LiK ground-state molecules — •Markus Debatin, Sambit B. Pal, Mark Lam, and Kai Dieckmann — Center for Quantum Technologies, National University of Singapore Block S15, 3 Science Drive 2,Singapore 117543

Ultracold heteronuclear molecules have seen increasing interest in the scientific community over the last few years [1]. Due to their large electric dipole moment of 3.6 Debye LiK ground-state molecules are particularly suited to investigate the physics of strongly-interacting dipolar quantum gases.

In our experiment [2] we perform spectroscopy on ultracold ^{6}Li^{40}K Feshbach molecules with the aim to create ground-state molecules. Starting with samples of about $3 \cdot 10^4$ ultracold Feshbach molecules we currently investigate transitions mainly to levels close to the asymptote of the $B^1\Pi$ electronic potential. For these levels a good coupling efficiency to the ground state of the $X^1\Sigma^+$ potential is predicted. This will be investigated in the next steps in order to develope a scheme to transfer the Feshbach molecules to the absolute ground state via a simulated Raman adiabatic passage (STIRAP). In the talk our spectroscopy results as well as an update on the current experimental status will be presented.

[1] M. A. Baranov et al. Chem. Rev. 112, 5012-5061, 2012

[2] A.-C. Voigt et al. Phys. Rev. Lett. 102, 020405, 2009