Q 6: Ultracold atoms, ions and BEC I (with A)

Time: Monday 10:30–12:30 Location: BEBEL E34

Q 6.1 Mon 10:30 BEBEL E34

Optical Trapping of a Barium Ion — •Thomas Huber, Alexander Lambrecht, Julian Schmidt, Michael Zugenmaier, Leon Karpa, and Tobias Schaetz — Albert-Ludwigs Universität, Freiburg, Deutschland

Trapping ions in optical dipole traps [1] or optical lattices [2] overcomes fundamental limitations for ultracold chemistry experiments set by intrinsic RF driven micromotion [3]. In our former experiments, the lifetime of optically trapped Mg+ ions was limited by recoil heating. We now report the optical trapping of a Ba+ ion in a FORT where the scattering events are substantially suppressed.
We will discuss lifetimes, their limitations, such as the decay into metastable D levels, as well as results on investigating those via efficient repumping schemes. We report about a conceptually new method to compensate electric stray fields necessary to allow high transfer efficiencies between the RF trap (required for initialization) and the FORT. We propose new methods to characterize the dipole force and the related secular frequencies of an ion trapped by the optical dipole trap and the DC potentials.
The progress of a new experiment, mitigating limitations of the current setup will be reported in which the optically trapped ion interacts with atoms from a Magneto Optical Trap.

[1]Nature Photonics 4, 772-775 (2010)
[2]Phys. Rev. Lett. 109, 233004 (2012)
[3]Phys. Rev. Lett. 109, 253201 (2012)

Q 6.2 Mon 10:45 BEBEL E34

Generalised Dicke non-equilibrium dynamics in trapped ions — •Sam Genway[1], Weibin Li[1], Cenap Ates[1], Benjamin Lanyon[2,3], and Igor Lesanovsky[1] — [1]School of Physics and Astronomy, University of Nottingham, United Kingdom — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [3]Institut für Experimentalphysik, Universität Innsbruck, Austria

We explore trapped ions as a setting to investigate non-equilibrium phases in a generalised Dicke Model of dissipative spins coupled to phonon modes. We find a rich dynamical phase diagram as a function of the spin-phonon coupling and dissipation strength, which includes superradiant-like regimes, dynamical phase-coexistence and phonon-lasing behaviour. A particular advantage of the trapped-ion set-up is that these dynamical phases, and the transitions between them, can be probed in situ via fluorescence measurements. We introduce a minimal model that captures the main physical insights and consider an experimental realisation with Ca^+ ions trapped in a linear Paul trap with a dressing scheme to create effective two-level systems with a tunable dissipation rate [1].

[1] S. Genway, W. Li, C. Ates, B. P. Lanyon and I. Lesanovsky. arXiv:1308.1424 (To appear in Phys. Rev. Lett.)

Q 6.3 Mon 11:00 BEBEL E34

Rapid production of a quantum gas of lithium using narrow-line cooling — •Ahmed Omran[1,2], Martin Boll[1,2], Timon Hilker[1,2], Thomas Reimann[1,2], Alexander Keesling[1,2], Konrad Viebahn[1,2], Immanuel Bloch[1,2], and Christian Gross[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str.1, 85748 Garching — [2]Ludwig-Maximilians-Universität München, Fakultät für Physik, Schellingstraße 4, 80799 München

We present an all-optical method for cooling fermionic lithium atoms to degeneracy with a cycle time of 10s. Standard laser cooling of the atomic cloud is followed by a second stage of laser cooling along the narrow $2S_{1/2} \rightarrow 3P_{3/2}$ transition at 323 nm, which yields a lower Doppler temperature [1]. To that end, we built a laser system for producing UV light using two nonlinear frequency conversions, which gives significantly more power than commercial solutions [2].

An optical dipole trap operating near a "magic wavelength", where the UV transition exhibits no light shift, directly captures the atoms from the UV MOT to evaporatively cool them to degeneracy using a Feshbach resonance. This efficient production of fermionic quantum gases is an important step towards our planned study of fermionic many body systems in optical superlattices.

[1] P. M. Duarte et al, Phys. Rev. A 84, 061406(R) [2011]
[2] A. C. Wilson, Appl. Phys. B 105, 741-748 [2011]

Q 6.4 Mon 11:15 BEBEL E34

All-optical cooling scheme for a quantum degenerate ^{6}Li-^{133}Cs mixture — •Alda Arias, Rico Pires, Juris Ulmanis, Stephan Häfner, Carmen Renner, Marc Repp, Eva Kuhnle, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg

We have recently measured Feshbach resonances (FRs) in an ultracold ^{6}Li-^{133}Cs mixture with a phase-space density of a factor of 100 below quantum degeneracy [1]. In this talk we will present an all-optical scheme to bring both gases together to quantum degeneracy. After ^{6}Li is loaded and evaporated in a tightly focused crossed-dipole trap (CDT), ^{133}Cs will be loaded into a spatially separated large volume reservoir trap. Subsequently, both traps are spatially overlapped and the CDT serves as a dimple trap [2] for Cs. The difference in trapping potentials, that both species experience due to their different polarizabilities, is compensated by a tune out wavelength trap. With a frequency between the D_1 and D_2 lines of Cs, it only confines the ^{6}Li atoms, while exerting no additional force on Cs. This independent control of the trapping potential of both species, together with the tunability of the interspecies scattering length by means of FRs will allow us to evaporate to double quantum degeneracy, which is an excellent starting point for future experiments on few- and many-body physics.

[1] M. Repp et al., Phys. Rev. A 87, 010701(R) (2013)
[2] T. Weber et al., Science 299, 232 (2003).

Q 6.5 Mon 11:30 BEBEL E34

Sympathetic cooling of ions in higher-order rf traps using laser-cooled atoms in a MOT — •Pascal Weckesser, Bastian Höltkemeier, Henry Lopez, Julian Glässel, and Matthias Weidemüller — Physikalisches Institut, Im Neuenheimerfeld 226, 69120 Heidelberg, Germany

Molecular ions are usually caught in a linear Paul trap and cooled sympathetically by He buffer gas. In order to reach lower temperatures for a wide range of molecular ions we investigate replacing He with laser-cooled atoms. Recent theories indicate that cooling in ion traps homogeneously filled with ultracold atoms is limited by the atom-ion mass ratio.

We derive that a localized cloud of ultracold atoms in higher order radio frequency traps overcomes the mentioned mass ratio limitation. A proper description of this local criterion and its features will be introduced.

Q 6.6 Mon 11:45 BEBEL E34

Emulating Solid-State Physics with a Hybrid System of Ultracold Ions and Atoms — •Ulf Bissbort[1,2,3], Daniel Cocks[3], Antonio Negretti[4], Zbigniew Idziaszek[5], Tommaso Calarco[6], Ferdinand Schmidt-Kaler[7], Walter Hofstetter[3], and René Gerritsma[7] — [1]MIT, Cambridge, USA — [2]SUTD, Singapore — [3]Johann Wolfgang Goethe-Universität, Frankfurt/Main, Germany — [4]Zentrum für Optische Quantentechnologien, Hamburg, Germany — [5]Faculty of Physics, University of Warsaw, Poland — [6]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany — [7]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany

We propose and theoretically investigate a hybrid system composed of a crystal of trapped ions coupled to a cloud of ultracold fermions. The ions form a periodic lattice and induce a band structure in the atoms. This system combines the advantages of high *delity operations and detection offered by trapped ion systems with ultracold atomic systems. It also features close analogies to natural solid-state systems, as the atomic degrees of freedom couple to phonons of the ion lattice, thereby emulating a solid-state system. Starting from the microscopic many-body Hamiltonian, we derive the low energy Hamiltonian, including the atomic band structure, and give an expression for the atom-phonon coupling. We discuss possible experimental implementations such as a Peierls-like transition into a period-doubled dimerized state.

Q 6.7 Mon 12:00 BEBEL E34

Dysprosium atoms in an optical dipole trap — •Holger Kadau, Thomas Maier, Matthias Schmitt, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Strongly dipolar quantum gases enable the observation of many-body phenomena with anisotropic, long-range interaction. Rotonic features, 2D stable solitons and the supersolid state are some of the exotic many-body phenomena predicted for dipolar quantum gases. The element with the strongest magnetic dipole moment is Dysprosium. It is a rare-earth element with a complex energy level structure and several possible cooling transitions. We have prepared samples of dysprosium atoms at $\sim 10\,\mu$K in a magneto-optical trap by laser cooling on a narrow transition at 626 nm. We load several million atoms into an optical dipole trap and transport them to a glass cell with high optical access.

The next goals are evaporative cooling in a crossed optical dipole trap to quantum degeneracy and implementing a high resolution imaging system with the possibility to create nearly arbitrary time-averaged potentials.

Q 6.8 Mon 12:15 BEBEL E34

Analogue of Cosmological Particle Creation in an Ion Trap
— •Christian Fey[1], Tobias Schaetz[2], and Ralf Schützhold[1] — [1]Universität Duisburg-Essen, Duisburg, Deutschland — [2]Albert-Ludwigs-Universität, Freiburg, Deutschland

We study linear vibrations of ions confined by a trap with a time-dependent potential strength. This system behaves similarly to quantum fields in an expanding or contracting universe, where changes in the metric/curvature produce entangled particles of opposite momenta. For the ions we interpret the strength of the trapping potential as "curvature" and describe the creation of squeezed and entangled phonon-states.