# Q 63: Ultra-cold atoms, ions and BEC IV

Time: Friday 10:30–12:30 Location: V57.03

**Invited Talk** Q 63.1 Fri 10:30 V57.03

**Quantum reflection and matter-wave optics with helium atoms and molecules** — •Wieland Schöllkopf — Fritz-Haber-Institut, Berlin

*Quantum reflection* allows atoms or molecules to be reflected from a solid without colliding with the actual surface. For sufficiently small incident kinetic energy the particle can scatter back at the attractive Casimir-van der Waals potential way in front of the surface. This effect is incompatible with classical physics, but readily explained by quantum mechanics. We have observed non-destructive scattering of $He_2$ (binding energy $10^{-7}$ eV) from a solid reflection grating. Helium dimers are quantum reflected tens of nm above the surface where the surface-induced forces are too weak to dissociate the fragile bond [1].

In another experiment we applied quantum reflection from a grating to observe *emerging beam resonances* in an atom-optical diffraction experiment for the first time [2]. This effect, also known as *Rayleigh-Wood anomalies*, had first been observed in 1902 by R.W. Wood in white-light grating diffraction. Rayleigh found that the anomalies occur when the wavelength and grating period are such that one of the diffraction beams just emerges from the grating surface, causing abrupt intensity variations in the other diffraction beams. Later, the effect was also observed with electrons diffracted from crystal surfaces. Our observation completes the analogy between photon optics and matter-wave optics and might provide a sensitive probe of atom-surface interactions.

[1] B.S. Zhao, G. Meijer, and W. Schöllkopf, Science **331**, 892 (2011).
[2] B.S. Zhao, G. Meijer, and W. Schöllkopf, PRL **104**, 240404 (2010).

Q 63.2 Fri 11:00 V57.03

**Interactions of Cold Atoms with Graphene and Carbon Nanotubes** — Benjamin Jetter[1], Johannes Märkle[1], Philipp Schneeweiss[1], Michael Gierling[1], Robin Scott[2], Andrew Martin[3], Bartek Kaczmarek[4], Andreas Günther[1], József Fortágh[1], Mark Fromhold[4], and •Thomas Judd[1] — [1]University of Tübingen, Tübingen, Germany — [2]University of Trento, Trento, Italy — [3]University of Melbourne, Melbourne, Australia — [4]University of Nottingham, Nottingham, UK

A unique perspective on carbon nanostructures may be gained by combining such devices with cold atom clouds since these constitute the slowest and softest possible probe. Here, we investigate elastic and inelastic scattering of cold atoms on graphene and carbon nanotubes. We show that atomic quantum reflection probabilities from a graphene monolayer can be over 90% and that such experiments can distinguish between theoretical descriptions of graphene. We show that atoms that do not reflect noticeably increase the electrical resistance of graphene, opening the door to a new form of hybrid electronics and real-time monitoring of cold atoms. We also analyse recent data for cold atom scattering on a single carbon nanotube. Quantum reflection is shown to be negligible for thermal clouds, allowing one to extract van der Waals coefficients using classical theories. However, if a BEC is used, the scattering becomes highly non-trivial and effects such as inter-atomic interactions and quantum pressure become important. The van der Waals forces due to the nanotube are shown to be exceptionally small; this suggests a single nanotube can be an effective photon trap.

Q 63.3 Fri 11:15 V57.03

**Superconducting Atom Chips for Ultracold Atoms** — •Simon Bernon, Helge Hattermann, Florian Jessen, Daniel Cano, Daniel Bothner, Martin Knufinke, Matthias Kemmler, Reinhold Kleiner, Dieter Koelle, and Jozsef Fortagh — Physikalisches Institut, Eberhard-Karls-Universität Tübingen, CQ Center for Collective Quantum Phenomena and their Applications, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

Hybrid quantum systems, which combine ultra-cold atoms with solid-state devices, have attracted considerable attention in the last years. Promising applications have been proposed in the areas of precision sensing and quantum information processing for which the long coherence time of atomic ensembles completes very well the fast logical operations performed by solid-state devices.

We report on experiments on ultracold atoms in a superconducting microtrap based on Niobium microstructures at 4.2K. Our data show that we achieved a full control of the magnetic fields of the trap, even in the vicinity of the superconductor where the trap positions and frequencies are modified by the Meissner effect. We also proved that electromagnetic noise near the superconductor is below the Johnson noise limit of normal conductor. This suggests long coherence time of atomic spin states even in the close proximity of superconductors. As a further step, we implemented a superconducting atom chip made of Niobium thin film wires on a Sapphire substrate. There, we achieved Bose-Einstein condensation showing the compatibility and interfacing of cold atoms and integrated superconducting chip.

Q 63.4 Fri 11:30 V57.03

**Light-assisted ion-neutral reactive processes in the cold regime: radiative molecule formation vs. charge exchange** — Felix H. J. Hall[1], Mireille Aymar[2], Nadia Bouloufa[2], •Olivier Dulieu[2], and Stefan Willistch[1] — [1]Department of Chemistry, University of Basel, Klingelbergstrasse 80, 4056 Basel, Switzerland — [2]Laboratoire Aimé Cotton, CNRS, Université Paris-Sud, Orsay, France

We present a combined experimental and theoretical study of cold reactive collisions between lasercooled $Ca^+$ ions and Rb atoms in an ion-atom hybrid trap. We observe rich chemical dynamics which are interpreted in terms of non-adiabatic and radiative charge exchange as well as radiative molecule formation using high-level electronic structure calculations. We study the role of light-assisted processes and show that the efficiency of the dominant chemical pathways is considerably enhanced in excited reaction channels. Our results illustrate the importance of radiative and non-radiative processes for the cold chemistry occurring in ion-atom hybrid traps.

Q 63.5 Fri 11:45 V57.03

**Laser cooling of dense gases by collisional redistribution of radiation** — •Anne Sass[1], Ulrich Vogl[2], and Martin Weitz[1] — [1]Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn — [2]Joint Quantum Institute, University of Maryland in College Park, USA

We study laser cooling of atomic gases by collisional redistribution of fluorescence, a technique applicable to ultradense atomic ensembles of alkali atoms and a few hundred bar of buffer gas pressure. The cooled gas has a density of more than ten orders of magnitude above the typical values in Doppler cooling experiments of dilute atomic gases.

In frequent collisions with noble gas atoms in the dense gas system, the energy levels of the alkali atoms are shifted, and absorption of far red detuned incident radiation becomes feasible. The subsequent spontaneous decay occurs close to the unperturbed resonance frequency, leading to a redistribution of the fluorescence. The emitted photons have a higher energy than the incident ones, and the dense atomic ensemble is cooled. We here describe recent experiments on the redistribution laser cooling of atomic gases carried out using an industrial high power diode laser, with which cooling of a rubidium argon gas mixture from an initial temperature of 390°C down to room temperature is observed. With radiation from a Ti:sapphire laser, cooling to -120°C has been measured.

For the future, we expect that redistribution laser cooling might also be applied to molecular gas samples, where cooling can start directly from room temperature.

Q 63.6 Fri 12:00 V57.03

**Dynamical arrest of ultracold lattice fermions.** — •Bernd Schmidt[1], M. Reza Bakhtiari[1], Irakli Titvinidze[1,2], Ulrich Schneider[3], Michiel Snoek[4], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe-Universität Frankfurt, Frankfurt/Main, Germany — [2]Institut für Theoretische Physik, Universität Hamburg, Hamburg, Germany — [3]Ludwig-Maximilians-Universität, München, Germany — [4]Institute for Theoretical Physics, Universiteit van Amsterdam, Amsterdam, The Netherlands

When a parameter of a system is changed non-adiabatically, it might happen that under certain conditions the system freezes in a metastable state and will not be able to reach equilibrium again. This kind of phenomenon is often called dynamical arrest and is a well known effect in other fields of physics, for example, the gelation of colloidal systems in soft-matter physics. We investigate a very similar effect in a cloud of fermionic atoms during the ramp-up of an optical lattice. We use Dynamical Mean Field Theory to calculate the equilibrium radius of the cloud and compare it to experimental results. This comparison reveals that the system gets indeed trapped into a meta-stable state. Although the theoretical equilibrium behaviour of the system shows an anomalous expansion of the cloud as in the experiment, the experimental size of the cloud is significantly affected by dynamical arrest. Using a combination of numerical simulations and experimental data we are able to determine the critical lattice depth of dynamical arrest. Our results are of major relevance for the interpretation of past and future experiments with attractive fermions in optical lattices.

Q 63.7 Fri 12:15 V57.03

**Efimov trimers and universal N-body states** — •Alessandro Zenesini[1], B. Huang[1,2], M. Berninger[1], S. Besler[1], H.-C Naegerl[1], F. Ferlaino[1], and R. Grimm[1,2] — [1]Institut fuer Experimentalphysik, Universitaet Innsbruck, 6020 Innsbruck, Austria — [2]Institut fuer Quantenoptik und Quanteninformation, OEsterreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

An atomic system becomes "universal" when the scattering length is tuned to large values and the low-energy physics is independent on the details of interaction potential. Efimov trimers and tetramers are two of the most striking examples of universal systems observed in experiment on ultracold atoms [1]. Open questions are whether universality is preserved when different Feshbach resonances are employed for interaction tuning or when another body is added to the system. Our latest results show not only that universality survives across Feshbach resonances but also that hints of a five-body bound state can be observed, in agreement with theoretical predictions of universal N-body states [2].

[1] "Forty years of Efimov physics: How a bizarre prediction turned into a hot topic" F. Ferlaino and R. Grimm, Physics 3, 9 (2010)
[2] "General Theoretical Description of N-Body Recombination" N. P. Mehta et al, PRL 103, 153201 (2009)