A 6: Ultracold Atoms, Ions and Molecules II (with Q)

Time: Monday 14:30–16:30 Location: e001

A 6.1 Mon 14:30 e001

Non-Equilibrium Thermodynamics of Harmonically Trapped Bosons — •Thomas Fogarty[1,4], Miguel Angel Garcia-March[2], Steve Campbell[3], Thomas Busch[4], and Mauro Paternostro[3] — [1]Theoretische Physik, Universitat des Saarlandes, Saarbrucken, Germany — [2]ICFO Institut de Ciencies Fotoniques, Spain — [3]CTAMOP, School of Mathematics and Physics, Queen's University Belfast, United Kingdom — [4]Quantum Systems Unit, Okinawa Institute of Science and Technology Graduate University, Okinawa, Japan

Trapped ensembles of bosonic atoms represent an ideal candidate to simulate some of the most interesting aspects in the phenomenology of out-of-equilibrium quantum systems. In this talk I will focus on harmonically trapped bosons and use the framework of non-equilibrium thermodynamics to the study the role quantum features play in setting the dynamic and static properties of the systems when the Hamiltonian parameters are suddenly quenched. Through a combination of analytical and numerical approaches I explore the non-trivial dynamics that arise from the interplay between the quenched trap frequency and an induced quench of the inter-particle interactions. Interesting quantum phenomena such as Anderson's Orthogonality catastrophe will be explored in this framework. I will further show some qualitative evidence for the relationship between the creation of entanglement and the (irreversible) work performed on the system. This highlights interesting connections between the degree of inter-particle entanglement and their non-equilibrium thermodynamics.

A 6.2 Mon 14:45 e001

Probing reflectionless potentials via atomic dynamics — •Martin Lahrz and Ludwig Mathey — University of Hamburg, Hamburg, Germany

We explore how reflectionless potentials can be probed via atomic dynamics. If a quantum mechanical wave package passes through a potential, ordinarily, a finite fraction of it gets reflected. However, in special cases, e.g. for specific Pöschl-Teller potentials, the reflection is zero and the full object is transmitted. We investigate the influence of the reflectionless potential on the outgoing wave function and compare it with the propagation of the free particle. This scenario might be realized in an ultra-cold atom system where the potential is represented by an optical trap.

A 6.3 Mon 15:00 e001

Two-dimensional Quantum Walks of Neutral Atoms in Spin-dependent Optical Lattices — •Geol Moon, Stefan Brakhane, Volker Schilling, Carsten Robens, Wolfgang Alt, Dieter Meschede, and Andrea Alberti — IAP institute - Wegelerstr. 8 - D-53115 Bonn

We report on the experimental realization of a two-dimensional spin-dependent optical lattice, which we will use to implement discrete-time quantum walks of Cs atoms in a two-dimensional geometry. We demonstrate high-resolution images of single atoms, which we detect through an objective lens with very high numerical aperture (NA∼0.92), which we designed and installed inside the home-built ultra-low-birefringence dodecagonal vacuum glass cell [1]. Our system provides an ideal platform to study the topological features of 2D quantum walk as the simulator of topological phases [2], which can be realized by suitable choice of the coin operation. We expect to observe exotic matter wave flow at the boundary between different topological domains. Furthermore, controlling the phase accumulated when atoms move from site to site on the 2D lattice permits to realize artificial gauge fields and to study the effect of magnetic fields on the 2D quantum walk [3].

[1] S. Brakhane, et al., *Ultra-low birefringence dodecagonal vacuum glass cell*, Submitted to Rev. Sci. Instrum. (2015)
[2] T. Kitagawa, et al., *Exploring topological phases with quantum walks*, Phys. Rev. A **82**, 033429 (2010)
[3] P. Arnault and F. Debbasch, *Quantum Walks and discrete Gauge Theories*, arXiv:1508.00038 (2015)

A 6.4 Mon 15:15 e001

Quantum Walks with Neutral Atoms: A look into the motion of a quantum particle — Carsten Robens, Stefan Brakhane, Wolfgang Alt, Dieter Meschede, and •Andrea Alberti — Institut für Angewandte Physik, Universität Bonn – Wegelerstr. 8, 53115 Bonn

I will present quantum walk experiments performed with neutral atoms in spin-dependent optical lattices. A cesium atom with two long-lived internal states behaves like a pseudo spin-1/2 particle. Depending on its spin state, the atom moves at regular time steps either one site to the left or to the right, delocalizing over multiple quantum paths. In the limit of vanishing lattice constant, its quantum behavior is described by the one-dimensional Dirac equation. We have recently developed a new spin-dependent transport system, which allows us to spin-selectively shift only one spin species at a time by an arbitrary number of lattice sites. The new atom transport system allows us to carry out interaction-free measurements of the atom's position, which we used to exclude (i.e., falsify) any explanation of quantum transport based on classical, well-defined trajectories [1]. To put it into perspective, our experiment represents the most massive test of quantum superposition states that has been hitherto performed based on the stringent, objective criteria provided by the Leggett-Garg inequality.

[1] C. Robens et al. *Ideal Negative Measurements in Quantum Walks Disprove Theories Based on Classical Trajectories*, Phys. Rev. X **5**, 011003 (2015).

A 6.5 Mon 15:30 e001

Half-life times of topological modes of a Bose-Einstein condensate in a gravito optical surface trap — •Zelimir Marojevic, Ertan Göklü, and Claus Lämmerzahl — ZARM, Am Fallturm, 28359 Bremen

We have numerically estimated the half-life times of six topological modes in an axially symmetric gravito optical surface trap $V(\rho, z) = \nu^2\rho^2 + \beta z$. The topological modes are solutions to the stationary Gross–Pitaevskii equation, which correspond to min-max saddle points of the functional, and these solutions are dynamically unstable. Due to the non linear nature of the problem the time evolution of a small perturbation is very complicated and shows different phases.

A 6.6 Mon 15:45 e001

News from the Garching ^{23}Na^{40}K mixture experiment — •Frauke Seeßelberg[1], Nikolaus Buchheim[1], Zhenkai Lu[1], Roman Bause[1], Tobias Schneider[1], Immanuel Bloch[1,2], and Christoph Gohle[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Ultracold quantum gases with long-range dipolar interactions promise exciting new possibilities for quantum simulation of strongly interacting many-body systems. Our experimental apparatus is capable of creating ultracold sodium and potassium mixtures aiming towards ultracold groundstate ^{23}Na^{40}K molecules.
To obtain molecules in their absolute vibrational, rotational and hyperfine ground state, stimulated Raman adiabatic passage (STIRAP) has to be implemented. This is a two photon process capable of transferring weakly bound Feshbach molecules via an intermediate, excited molecular state to the molecular ground state with high efficiency.
With our apparatus we are also capable of analyzing the properties of a small number of potassium atoms immersed into a degenerate Bose gas of sodium atoms. Under these conditions signatures of the Bose polaron can be observed.

A 6.7 Mon 16:00 e001

Inelastic collisions of strongly confined triplet Rb_2 molecules — •Markus Deiss[1], Björn Drews[1], Krzysztof Jachymski[2,3], Zbigniew Idziaszek[2], and Johannes Hecker Denschlag[1] — [1]Institut für Quantenmaterie, Universität Ulm, 89069 Ulm, Germany — [2]Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland — [3]Institut für Theoretische Physik III, Universität Stuttgart, 70550 Stuttgart, Germany

We present experimental studies of inelastic collisions of metastable ultracold triplet molecules in the vibrational ground state. The measurements are performed with nonpolar Rb_2 dimers which are trapped in an array of quasi-1D potentials and prepared in precisely-defined quantum states. Using a simple model we can understand the molecular decay dynamics and extract reaction rate coefficients. We will show results both for nonrotating molecules that are prepared in the energetically absolutely lowest triplet hyperfine level and molecules with two quanta of rotational angular momentum. These results are compared to those obtained for vibrationally highly excited Feshbach molecules.

A 6.8 Mon 16:15 e001

Non-destructive rotational state detection for molecular ions
— •Fabian Wolf[1], Yong Wan[1], Jan C. Heip[1], Florian Gebert[1], Chunyan Shi[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Leibniz Universität Hannover, Germany

High precision spectroscopy of molecular ions is a promising tool for the investigation of fundamental physics, e.g. the search for variation of fundamental constants, an electron electric dipole moment or parity violation in chiral molecules. However, the practictal implementation has remained illusive due to the lack of efficient state preparation and detection schemes. Here, we present the first demonstration of a non-destructive rotational state detection for a single molecular ion trapped in a linear Paul trap [1]. For this purpose, we implement a quantum logic operation between the molecular $^{24}MgH^{+}$ ion and a co-trapped atomic $^{25}Mg^{+}$ logic ion.

The experimental sequence consists of sympathetic ground state cooling with the logic ion [2] and a state dependent optical dipole force that transfers the molecule's internal state to the shared state of motion. Afterwards, the motional state is mapped onto the atomic qubit state, that can be detected efficiently by state dependent fluorescence. We use this technique to perform a variant of quantum logic spectroscopy on a molecular transition.

[1] Wolf et al. arXiv:1507.07511 (2015)
[2] Wan et al. Phys. Rev. A **91**, 043425 (2015)