A 45: Ultracold Atoms II (joint session Q/A)

Time: Friday 10:30–12:30 Location: K 1.022

A 45.1 Fri 10:30 K 1.022

Quantum optimal control for fast atom transport in an optical lattice — •Manolo Rivera[1], Thorsten Groh[1], Natalie Thau[1], Carsten Robens[1], Wolfgang Alt[1], Dieter Meschede[1], Antonio Negretti[2], Tommaso Calarco[3], Simone Montagero[3], and Andrea Alberti[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany — [3]Institut für komplexe Quantensysteme, Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany

We realize fast atom transport in a polarization-synthesized state-dependent optical lattice reaching transport times down to the harmonic oscillator period of around $20\mu s$ over one lattice site ($\approx 0.5\mu m$). Atom transport at such durations reaches the quantum speed limit that we have obtained from numerical simulations of the Schrödinger equation. The transport operations are computed using optimal control theory and reach high fidelities, meaning that the atoms prepared in the ground state remain there after the transport. This is experimentally confirmed by measuring the excitation spectrum of the transported atoms by means of microwave sideband spectroscopy. The current experiment is based on an open-loop approach where the transport operations are theoretically computed. A closed-loop approach using the optimization algorithm directly in the experimental sequence allows us to further improve the fidelity of the optimal control transport operations.

A 45.2 Fri 10:45 K 1.022

Tuning the Scattering Length by Periodic Modulation — •Christoph Dauer, Axel Pelster, and Sebastian Eggert — Physics Department and Research Center OPTIMAS, Technical University of Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

We consider the scattering problem of two ultracold particles with a small time-periodic modulation of the attractive potential, which can be achieved by using a Feshbach resonance. The steady state is described by the Floquet formalism, which leads to a recurrence formula for an effective scattering length a_{eff}. For frequencies corresponding to the bound-state of the potential without driving, we observe strong resonances, which allow the tuning to very large positive and negative values of a_{eff} with relatively small imaginary parts.

A 45.3 Fri 11:00 K 1.022

A two-species five-beam magneto-optical trap for highly magnetic Er and Dy atoms — •Arno Trautmann[1], Philipp Ilzhöfer[1,2], Gianmaria Durastante[1,2], Alexander Patscheider[1,2], Manfred Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Austria — [2]Institut für Experimentalphysik und Zentrum für Quantenoptik, Universität Innsbruck, Austria

We report on the first realization of a two-species magneto-optical trap (MOT) for erbium and dysprosium. The MOT operates on an intercombination line for the respective species. Owing to the narrow-line character of such a cooling transition and the action of gravity, we demonstrate a novel trap geometry employing only five beams in orthogonal configuration. We observe that the mixture is cooled and trapped very efficiently, with up to 5×10^8 Er atoms and 10^9 Dy atoms at temperatures of about $10\,\mu$K. Our results offer an ideal starting condition for the creation of a dipolar quantum mixture of highly magnetic atoms.

A 45.4 Fri 11:15 K 1.022

Few bosons in a double well — •Frank Schäfer[1], Miguel Bastarrachea[1], Axel U. J. Lode[2,3], Laurent de Forges de Parny[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany — [2]Wolfgang Pauli Institute c/o Faculty of Mathematics, University of Vienna, Oskar-Morgenstern Platz 1, 1090 Vienna, Austria — [3]Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

We investigate the spectral and dynamical properties of interacting bosons in a double well. A combination of exact diagonalization with a multi-configurational time-dependent Hartree approach allows us to analyse the time evolution of two- and three- particle states for variable initial conditions, and furthermore subject to (a-)diabatic switching of the tunnelling barrier. We discuss first results for the particles initially prepared at the ground state or at the saddle-point energy, and contrast single- vs. many-particle aspects of the dynamics.

A 45.5 Fri 11:30 K 1.022

Diffusion of Ultracold Atoms Coupled to tailored Bath — •Daniel Adam, Tobias Lausch, Daniel Mayer, Felix Schmidt, Quentin Bouton, and Artur Widera — TU Kaiserslautern, Department of Physics, Kaiserslautern, Germany

Diffusion is an essential phenomenon in nature, occurring in various systems from biological cells to traffic models. Ultracold atoms are ideal model systems to go beyond the mere observation of single particle diffusion, and to engineer the surrounding baths by external fields.

Here, we consider the diffusion of single neutral atoms trapped in a periodic potential and coupled to a near-resonant light field forming the bath. This bath defines both fluctuations as well as the diffusion coefficient via the laser cooling properties of the optical molasses. The diffusion coefficient significantly determines the dynamics of a diffusing tracer, thus its knowledge is of central importance to understand the fundamental diffusion. I will present a method to measure the diffusion coefficient directly with single Cs-atoms confined in a harmonic potential. This method is similar to the method of tethered particle motion known for the observation of DNA dynamics.

Precise knowledge of the diffusion coefficient as a function of external experimental parameters opens the route for quantitative measurements of diffusion in complex potential landscapes or non-equilibrium situations.

A 45.6 Fri 11:45 K 1.022

Revealing Quantum Statistics with a Pair of Distant Atoms — Christian Roos[1], •Andrea Alberti[2], Dieter Meschede[2], Philipp Hauke[3], and Hartmut Häffner[4] — [1]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Austria — [2]Institut für Angewandte Physik der Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany — [3]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 21a, 6020 Innsbruck, Austria — [4]Department of Physics, University of California, Berkeley, California 94720, USA

Quantum statistics have a profound impact on the properties of systems composed of identical particles. At the most elementary level, Bose and Fermi quantum statistics differ in the exchange phase, either 0 or π, which the wave function acquires when two identical particles are exchanged. I will report on a scheme to directly probe the exchange phase with a pair of massive particles by physically exchanging their positions [1]. I present two protocols realizing this scheme where the particles always remain spatially well separated, thus ensuring that the exchange contribution to their interaction energy is negligible and that the detected signal can only be attributed to the exchange symmetry of the wave function. Finally, I discuss possible implementations using a pair of atoms confined in polarization-synthesized optical lattices or trapped ions forming a one-dimensional quantum rotor.

[1] C. F. Roos, A. Alberti, D. Meschede, P. Hauke, and H. Häffner, Phys. Rev. Lett. **119**, 160401 (2017).

A 45.7 Fri 12:00 K 1.022

Signatures of indistinguishability in bosonic many-body dynamics — •Tobias Brünner[1], Gabriel Dufour[1,2], Alberto Rodriguez[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität-Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany — [2]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität-Freiburg, Albertstraße 19, D-79104 Freiburg, Germany

Many-body interference occurs as a fundamental process during the evolution of a quantum system consisting of two or more indistinguishable particles. The (measurable) consequences of this interference, as a function of the particles' mutual indistinguishability, was studied for non-interacting photons transmitted through beam-splitter arrays. However, the role of many-body interference in the dynamics of interacting particles, e.g. cold atoms in optical lattices, had so far remained unclear. We identify a quantifier of the particles' mutual indistinguishability attuned to time-continuously evolving systems of (interacting) particles, which predicts the dynamical behaviour of observables influenced by genuine few-body interference. Our measure allows a systematic exploration of the role of many-body interference in the non-, weakly, and strongly interacting regimes.

A 45.8 Fri 12:15 K 1.022

Survival probability of coherent states in regular regimes
— •Miguel A. Bastarrachea-Magnani[1], Sergio A. Lerma-Hernández[2], Jorge Chávez-Carlos[3], Lea F. Santos[4], and Jorge G. Hirsch[3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany — [2]Facultad de Física, Universidad Veracruzana, Xalapa, México — [3]Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, México — [4]Department of Physics, Yeshiva University, New York, USA

We study the behavior of coherent states under unitary quantum dynamics in systems with one and two degrees of freedom. To this end, we employ the Dicke Hamiltonian, a paradigmatic model of quantum optics. Within the regular regime of the spectrum, the distribution of the coherent states in the eigenstate basis consists of quasi-harmonic sub-sequences of energies with gaussian weights. This allows to derive analytical expressions for the survival probability of the coherent states. The analytical expressions describe the time evolution in agreement with numerical results up to the decay of the survival probability oscillations. We explore how this decay rate is related to the anharmonicity of the spectrum, and, for the chaotic regime of the Dicke model, to interference terms due to the contributions of different subsequences of eigenstates to the coherent states. Moreover, we correlate the dynamics of the coherent states with the classical limit of the model, to elucidate how these interference terms are related to the onset of chaos in the spectrum. Since most bounded Hamiltonians have a regular regime at low energies, the approach has broad applicability.