Q 26: Ultra-cold atoms (joint session A/Q)

Time: Wednesday 10:30–12:30 Location: S HS 1 Physik

Q 26.1 Wed 10:30 S HS 1 Physik

Developing an experimental toolbox for the quantum simulation of high energy physics — •Alexander Mil, Apoorva Hedge, Fabian Olivares, Markus K. Oberthaler, and Fred Jendrzejewski — Kirchhoff Institut für Physik, Universität Heidelberg

Within the Standard Model of Particle Physics, the interaction between fundamental particles is described by gauge theories. These theories have an enormous predictive power, but in many regimes, especially out of equilibrium, their theoretical treatment is exceedingly difficult. Consequently, high-energy physics contains many unsolved problems, for instance Schwinger pair production [1]. Our aim is to build an analog quantum simulator for simple lattice gauge theories with ultracold atomic gases.

We follow the proposal by Kasper et al. [2] and Zache et al. [3] to engineer a model system for quantum electrodynamics (QED) in one dimension using atomic mixtures. In this approach, we use an optical lattice structure with alternatingly populated sites of sodium and lithium. The fermionic matter field in the QED Hamiltonian is described by the lithium atoms whereas the bosonic gauge field is described by the sodium atoms. The gauge coupling is engineered by interspecies spin changing collision between sodium and lithium. In this talk, I will present our progress towards the realization of such simple lattice gauge theories.

[1] Kasper et al. Phys.Let. B 760, 742 (2016) [2] Kasper et al. NJP 19, 023030 (2017). [3] Zache et al. Quantum Sci. Technol. 3, 034010 (2018).

Q 26.2 Wed 10:45 S HS 1 Physik

Effect of Fermi seas on the Efimov spectrum of three ultracold fermionic atoms — •Ali Sanayei[1], Pascal Naidon[2], and Ludwig Mathey[1,3] — [1]Center for Optical Quantum Technologies, Institute for Laser Physics, University of Hamburg, Germany — [2]RIKEN Nishina Centre, RIKEN, Japan — [3]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

We consider two same-species ultracold fermionic atoms in different hyperfine splitting states in a lower band that are subject to an inert Fermi sea and interact attractively in the short range. We include an additional third fermionic atom in an otherwise empty band that interacts attractively in the short range with other two atoms. For three species with the same mass and also for some higher mass imbalances, we show that for either two- or three-resonantly interacting pairs the Fermi sea deforms the Efimov spectrum of the trimer states systematically. We also demonstrates that the Fermi sea modifies the Efimov universal scaling factor.

Q 26.3 Wed 11:00 S HS 1 Physik

Observation of many-body localization in a one-dimensional system with single-particle mobility edge — •Thomas Kohlert[1,2], Sebastian Scherg[1,2], Xiao Li[3], Henrik Lüschen[1,2], Sankar Das Sarma[3], Immanuel Bloch[1,2], and Monika Aidelsburger[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstr. 4, 80799 Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [3]Condensed Matter Theory Center and Joint Quantum Institute, University of Maryland, College Park, Maryland 20742-4111, USA

In this work we experimentally study many-body localization (MBL) in a one-dimensional bichromatic quasiperiodic potential with a single-particle mobility edge (SPME) using ultracold atoms. We measure the time evolution of the density imbalance between even and odd lattice sites from an initial charge density wave, and analyze the corresponding relaxation exponents. We find clear signatures of MBL in this system when the corresponding noninteracting model is deep in the localized phase. We also critically compare and contrast our results with those from a tight-binding Aubry-André model, which does not exhibit an SPME.

Q 26.4 Wed 11:15 S HS 1 Physik

Bound states in a one-dimensional three-body system. — •Lucas Happ[1], Maxim A Efremov[1], and Wolfgang P Schleich[1,2] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm — [2]Hagler Institute for Advanced Study, Institute for Quantum Science and Engineering (IQSE), and Texas A&M AgriLife Research, Texas A&M University, College Station, TX 77843-4242, USA.

We study a three-body system confined to one space dimension, consisting of two identical, non-interacting, heavy particles and a light particle with arbitrary mass ratio interacting with the two heavy particles. In this talk we focus on contact heavy-light interactions, and therefore apply the integral equations of Skorniakov and Ter-Martirosian, in order to obtain the three-body energy spectrum together with the corresponding wave functions. Both spectrum and wave functions are compared to the ones obtained within the Born-Oppenheimer approximation.

Q 26.5 Wed 11:30 S HS 1 Physik

Ultracold and Ultrafast: Coherent manipulation of matter-waves on femtosecond timescales — •Tobias Kroker[1,2], Bernhard Ruff[1,2], Juliette Simonet[1,2], Klaus Sengstock[1,2], Philipp Wessels[1,2], and Markus Drescher[1,2] — [1]Zentrum für Optische Quantentechnologien (ZOQ), Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging (CUI), Luruper Chaussee 149, 22761 Hamburg

Ultrashort laser pulses, even far detuned from atomic resonances, can significantly modify coherent matter-waves, as the high laser intensities produce considerable AC Stark shifts.
We show that phases up to several π can be imprinted within femtoseconds, resulting in accelerations of the atomic cloud up to 10^9 m/s^2. The interplay between the phase gradient and atomic interactions can lead to a stable matter wave. Numerical simulations of the 3D Gross-Pitaevskii equation are in good agreement with our experimental data. Such high laser intensities can even give rise to a coherent superposition between ground and excited states during the femtosecond pulse. Ultracold atoms allow revealing this transient effect, which is not accessible using standard spectroscopy techniques, since they can be trapped in such shallow average light shifts. Accurate measurement of the trapping frequencies indeed demonstrate the transient population of the excited states.

Q 26.6 Wed 11:45 S HS 1 Physik

Light-Induced Coherence in an Atom-Cavity System — •Christoph Georges and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg

We demonstrate a light-induced formation of coherence in a cold atomic gas system that utilizes the suppression of a competing density wave (DW) order. The condensed atoms are placed in an optical cavity and pumped by an external optical standing wave, which induces a long-range interaction mediated by photon scattering and a resulting DW order above a critical pump strength. We show that the light-induced temporal modulation of the pump wave can suppress this DW order and restore coherence. This establishes a foundational principle of dynamical control of competing orders analogous to a hypothesized mechanism for light-induced superconductivity in high-Tc cuprates.

Q 26.7 Wed 12:00 S HS 1 Physik

Dynamical topological transitions in the massive Schwinger model with a θ-term — •Torsten V. Zache[1], Niklas Mueller[2], Jan T. Schneider[1], Fred Jendrzejewski[3], Jürgen Berges[1], and Philipp Hauke[1,3] — [1]Heidelberg University, Institut für Theoretische Physik — [2]Physics Department, Brookhaven National Laboratory — [3]Heidelberg University, Kirchhoff-Institut für Physik

Aiming at a better understanding of anomalous and topological effects in gauge theories out-of-equilibrium, we study the real-time dynamics of the massive Schwinger model with a θ-term. We identify dynamical quantum phase transitions between different topological sectors that appear after sufficiently strong quenches of the θ-parameter. Moreover, we establish a general dynamical topological order parameter, which can be accessed through fermion two-point correlators and, importantly, which can be applied for interacting theories. Enabled by this result, we show that the topological transitions persist beyond the weak-coupling regime. This phenomenon constitutes an ideal target for quantum computing as it can be observed with table-top experiments based on existing cold-atom, superconducting-qubit, and trapped-ion technology. Our work, thus, presents a significant step towards quantum simulating topological and anomalous real-time phenomena relevant to nuclear and high-energy physics.

Q 26.8 Wed 12:15 S HS 1 Physik

The parity anomaly of 2+1 dimensional strong-field QED — •Robert Ott[1], Torsten V. Zache[1], Niklas Mueller[2], and Jürgen Berges[1] — [1]Universität Heidelberg, Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg, Germany — [2]Physics Department, Brookhaven National Laboratory, Building 510A, Upton, New York 11973, USA

Quantum Electrodynamics (QED) in one and two spatial dimensions has recently attracted interest in the context of quantum simulations of gauge theories. Currently there is much effort in extending present ideas to higher dimensions and in identifying relevant phenomena accessible with state-of-the art technology.

To this end, we investigate the non-equilibrium dynamics of massive 2+1 dimensional QED for strong electric fields focussing on the broken parity symmetry. In this regime, symmetry violation induces anomalous charge currents which lead to a non-linear electric field rotation. This scenario is analyzed using classical-statistical lattice simulations, which we compare to analytical predictions.