SYAD 1: SAMOP Dissertation-Prize

Time: Tuesday 11:00–13:00 Location: e415

Invited Talk SYAD 1.1 Tue 11:00 e415
Artificial gauge fields and topology with ultracold atoms in optical lattices — •Monika Aidelsburger — Ludwig-Maximilians-University Munich — Max-Planck-Institute of Quantum Optics, Garching

Many intriguing condensed matter phenomena such as the integer and fractional quantum Hall effect arise due to the non-trivial topological properties of the underlying system. Synthetic materials that consist of ultracold neutral atoms confined in crystal-like structures using laser beams have the potential to simulate and address the complex questions that arise in this context. In this talk I report on the experimental realization of extremely strong artificial magnetic fields based on laser-assisted tunneling which give rise to topological energy bands. Their properties are characterized by topological invariants - the Chern numbers - which are at the origin of the integer quantum Hall effect. In particular we were able to realize the Hofstadter model for an effective flux 1/4 and determined the Chern number of the lowest energy band through a direct measurement of bulk topological currents. These experimental results pave the way for future studies of interacting topological systems with ultracold atoms in optical lattices.

Invited Talk SYAD 1.2 Tue 11:30 e415
Many-body physics with impurities in ultracold quantum gases — •Fabian Grusdt — Department of Physics and research center OPTIMAS, University of Kaiserslautern, Germany — Graduate School Materials Science in Mainz, Kaiserslautern, Germany — Department of Physics, Harvard University, Cambridge, MA 02138, USA

The properties of a many-body system can differ vastly from those of its individual constituents, for example the quantum numbers which are integer quantized without interactions can become fractionalized. In this talk I consider mobile impurity atoms interacting with the elementary excitations of different many-body systems. On the one hand they can serve as a coherent probe of the elementary excitations. In this context I will present a measurement scheme for fractional topological invariants of quantum Hall systems, which also has possible applications for building a robust topological quantum computer. On the other hand, the impurity can induce strong interactions between elementary excitations and create a correlated many-body system on its own. This happens, for example, for an impurity atom immersed in a Bose-Einstein condensate, where a new quasiparticle - the polaron - is formed. I developed a theoretical approach which provides an efficient description of polarons valid at arbitrary coupling strength and thus solves a long-standing problem of polaron physics.

Invited Talk SYAD 1.3 Tue 12:00 e415
How to determine the handedness of single molecules — •Martin Pitzer — Institut für Kernphysik, Goethe-Universität Frankfurt — Experimentalphysik IV, Universität Kassel

Chiral molecules, i.e. molecules that occur like our hands in two mirror image structures, play an important role in biological processes. A variety of techniques is routinely performed for the distinction and separation of the two so-called enantiomers. These techniques, however, probe macroscopic sample properties, and the direct determination of the molecules' microscopic configuration has so far only been possible by using anomalous X-ray diffraction of crystallized samples.

We demonstrated that a COLTRIMS (Cold Target Recoil Ion Momentum Spectroscopy) setup in combination with a femtosecond laser allows to unambiguously determine the absolute configuration of individual molecules in the gas phase. Our approach relies on the concept of Coulomb Explosion Imaging: After multiple ionization of the molecule, the positively charged atomic cores repel each other and their momentum vectors retain information on the handedness of the molecule. For racemic samples (i.e. 1:1 mixtures of enantiomers) of the chiral prototype CHBrClF and of several isotopically chiral analogues, a clear distinction of enantiomers could be shown. In a second step, we compared the ionization by femtosecond laser pulses to the interaction of the molecules with synchrotron radiation and additionally investigated the photoelectron properties. These results highlight the challenges and chances on the way to application in chemical analysis and to a deeper understanding of molecular chirality.

Invited Talk SYAD 1.4 Tue 12:30 e415
Quantum systems under gravitational time dilation — •Magdalena Zych — ARC Centre for Engineered Quantum Systems (EQuS), University of Queensland, Australia

Despite continuous development, modern physics still rests on two separate frameworks, quantum mechanics and general relativity. The notion of time is considered to be central for understanding the regime where the two theories jointly apply. This talk will introduce an operational approach to proper time in quantum theory by considering composed quantum systems – quantum "clocks" – in general spacetime background. The approach describes new quantum effects arising from time dilation in interference experiments with "clocks" (e.g. atoms, molecules) that follow in superposition paths with different proper times. For macroscopic systems these effects lead to an effective decoherence, showing that time dilation might be relevant for the quantum-to-classical transition. The approach further leads to a quantum formulation of the Einstein Equivalence Principle and shows that testing its validity requires conceptually different experiments than in the classical case. Finally, the approach naturally extends to scenarios in which quantum "clocks" are embedded in a non-classical space time, e.g. resulting from a spatial superposition of a large mass. Quantum theory and general relativity provide an unambiguous description of such scenarios and no inconsistencies arise – in contrast to a common assumption that such a description is not possible even in principle.