SYAD 1: SAMOP Dissertation-Prize

Time: Tuesday 10:30–12:30 Location: RW HS

Invited Talk SYAD 1.1 Tue 10:30 RW HS

Integrated photonic quantum walks in complex lattice structures — •Markus Graefe — Institute of Applied Physics, Friedrich-Schiller-Universität Jena, Germany

The dynamics of quantum objects on certain trajectories – so called quantum walks (QWs) – are a fundamental concept, which quantum computing and -simulation are based on. Notably, billions of years before scientists discovered the potential of QWs for quantum technology, the blind watchmaker of evolution harnessed this mechanism for the most essential biochemical process found in nature: the highly-efficient energy transport in light-harvesting molecules during photosynthesis is enabled by QWs, whereas its complexity is still not fully unraveled.

Since photons offer the unique combination of large coherence and insensitivity to environmental influences they are ideally suited as quantum walkers. In addition, laser-written waveguide structures embedded in a small monolithic glass chip, benefit from high robustness, ultra-stability, and miniaturization. Both taken together offer a versatile platform to investigate QWs in almost arbitrary 3D networks.

On the one hand, such systems can be utilized to resolve fundamental questions of quantum physics, including the generation and application of highly-entangled states. On the other hand, interdisciplinary topics like the influence of decoherence on energy transport can be studied in detail. This way, it is clearly demonstrated that decoherence does not inevitably hinder quantum transport, but rather significantly enhances it. Thus, this platform contributes to elucidate the highly-efficient energy transport during photosynthesis.

Invited Talk SYAD 1.2 Tue 11:00 RW HS

Testing the Quantumness of Atom Trajectories — •Carsten Robens — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn — Massachusetts Institute of Technology, Center for Ultracold Atoms, Research Laboratory of Electronics, and Department of Physics, 77 Mass Ave, Cambridge, MA 02139

I will present experiments using individual atoms in optical lattices to test the quantumness of atom trajectories both in a single- and two-particle atom interferometer. These results rely on so-called polarization-synthesized optical lattices—a novel implementation of state-dependent transport—which achieves an unprecedented control over the position of individual atoms with angstrom precision.

At the single-particle level, I conducted a rigorous test of the superposition principle using the Leggett-Garg inequality. Despite the indisputable success of quantum mechanics in describing the microscopic world, it is still an unresolved question how to explain the wave function reduction, which has led to the development of several theories. In 1985 Leggett and Garg derived an inequality that provides an objective criterion to discern quantum- from macro-realistic theories. Our experiment demonstrates for the first time that the trajectories of a single atom are truly nonclassical and our findings constrain macro-realistic theories. Our delocalized Cesium atoms are the most macroscopic objects that have been used to experimentally test the Leggett-Garg inequality using noninvasive measurements.

At the two-particle level, I demonstrate Hong-Ou-Mandel interference between two indistinguishable Cesium atoms. This experiment embodies the fundamental building block of a boson sampling machine, a specialized type of quantum computer, which holds promise to demonstrate a speedup of quantum over classical devices in the near future.

Invited Talk SYAD 1.3 Tue 11:30 RW HS

Engineering and probing topological bands with ultracold atoms — •Nick Fläschner — Institut für Laserphysik, Universität Hamburg

Topological matter such as quantum Hall systems or Chern insulators and their fascinating properties have become a major research focus of modern physics. Key for the description and understanding of topological matter are topological indices like Chern numbers and geometrical properties such as the distribution of Berry curvature. In this talk, I will present experiments demonstrating the capability of ultracold atoms for engineering and characterizing topological systems. By circularly shaking a hexagonal optical lattice, we realize a Haldane-like Floquet Hamiltonian featuring topologically non-trivial bands. After an adiabatic preparation of the Floquet ground state, we demonstrate a novel momentum-resolved state tomography and achieve the first measurement of Berry curvature in a lattice system. Furthermore, we use the exquisite control of our system to realize various quenches in the topological phase diagram and observe the dynamical evolution of the highly-excited system. Surprisingly, we observe topological features in the time-dependent wave function which allow directly measuring the Chern number of the ground state. Our measurements not only allow mapping out the topological phase diagram but also establish a novel approach on characterizing topological systems, which might also be fruitful for studying interacting topological phases.

Invited Talk SYAD 1.4 Tue 12:00 RW HS

Statistical signatures of many-particle interference — •Mattia Walschaers — Albert-Ludwigs Universität Freiburg, Freiburg, Germany — KU Leuven, Leuven, Belgium — Laboratoire Kastler Brossel, Sorbonne Université, ENS-PSL, Collège de France, CNRS, Paris, France

The complexity of a quantum system drastically increases with its number of particles, which gives rise to many conceptual, analytical and computational challenges. A well-known source of such hardship is the interaction between particles. Nevertheless, even in absence of such interactions, the particles' indistinguishability as such can already lead to dynamical interference effects which go well beyond mere quantum statistics. Recently, these many-particle interference effects became the centrepiece of the debate on boson sampling, connecting them to a quantum advantage in computation. As a core message, it was explicitly stressed that such interference patterns are computationally intractable. As a consequence, we are confronted with apparent difficulties upon certification of many-particle interferometers. From a complex systems perspective, the lack of deterministic features in a physical system is a common problem which can often be overcome via statistical treatment. In this presentation, we present statistical signatures of different types of many-particle interference by studying correlation functions combined with techniques from random matrix theory. These signatures are an experimentally feasible tool to differentiate between sampling outcomes that result from genuine bosonic interference and alternative distributions.