Book of abstracts

QUANTUM SIMULATION

Clément Sayrin (LKB and Collège de France, Paris)

Hybrid Rydberg platform for the observation of long-lived spin-exchange interactions

Circular Rydberg atoms, i.e., Rydberg atoms with maximum angular momentum, ideally combine long coherence times and strong interactions. Their lifetimes, hundred times longer than their low-momentum counterparts, make them ideal for quantum simulation of the dynamics of interacting quantum systems. However, local manipulation and detection of individual atoms in an array through direct optical excitation is possible with low-momentum Rydberg levels only. In this talk, I will present our hybrid platform that couples an array of data qubits, encoded in circular Rydberg states, to an auxiliary array of ancilla atoms. We excite the latter to a laser-accessible Rydberg level, that resonantly interacts with a circular Rydberg level, enabling quantum non-demolition detection and optical control of the circular Rydberg atoms. Recently, we have used this platform to record resonant spin-exchange interactions between two circular Rydberg atoms over unprecedented timescales, with the observation of spin oscillations over more than 60µs and 40 oscillations periods. This in particular allowed us to observe the coupling between spin and motional degrees of freedom for the laser-trapped Rydberg atoms through a collapse and revival of the spin oscillations.

*Philipp PREISS (*MPQ Max-Planck-Institut für Quantenoptik)

Quantum Gas Microscopy of Ground-State Phases in the Fermi–Hubbard Model

The Hubbard model is one of the iconic models of strongly correlated electron systems. Although it represents a major simplification of the physics of real-world materials, it is believed to capture the essential physics of strong-correlation phenomena such as d-wave superconductivity and the pseudogap. Even the most advanced numerical methods cannot fully solve the model, but state-of-the-art calculations indicate that its ground-state phase diagram is governed by a close competition between phases with different types of order. The balance between these phases can be strongly affected by small terms beyond the standard Hubbard description.

In this talk, I will report on our recent progress in realizing tunable optical-lattice systems for extended Hubbard models that incorporate such terms. Our quantum gas microscope for ultracold lithium provides fully spin- and charge-resolved readout, tunable lattice geometries, and entropy redistribution. At low temperatures, we observe saturated antiferromagnetic correlations at half filling, which disappear upon doping and give way to signatures of spin-stripe order. By adding a tunable diagonal tunnel coupling to the square lattice, we break particle-hole symmetry and observe doping-dependent magnetism as well as polaron and dopant-pair correlations. At the entropy densities explored here, these signatures can be viewed as precursors of stripe formation and superconductivity.

QUANTUM SENSING

Sophie Djordjevic (LNE, Trappes)

A primary quantum current standard based on the Josephson and the quantum Hall effects

Since the last revision of the International System of Units (SI) in 2019, the new definition of the ampere based on the elementary charge and the frequency accounts for the quantum microscopic nature of the electrical current. Nevertheless, controlling a flow rate of electrons in a circuit with a relative uncertainty of 10^{-8}, relevant since the revision, is very challenging. Here, we present a realization of the ampere based on a quantum current generator, which combines two quantum electrical standards, a quantum Hall resistance standard (QHRS) and a programmable Josephson voltage standard (PJVS), and a highly accurate superconducting dc transformer used in metrology, the cryogenic current comparator (CCC). After presenting the state of the art of these quantum standards, we will focus on the circuit implementation which allows the generation of a current theoretically equal to $n_J e f_J$, with n_J and f_J the number of Josephson junctions and the operating frequency of the PJVS respectively. We will show that this primary quantum standard of electrical current is able to generate currents over a wide range of levels, from the mA down to nA with uncertainties as low as few parts in 10^9 at the µA level. Finally, our work opens the way to a single and versatile experiment for the realization of the electrical units (A, Ω, V).

QUANTUM MATTER

Karyn Le Hur (CPhT, Paris)

Insight on topological phases

Topological phases of matter refer e.g. to insulators, such as in the quantum Hall effect, with additional transport flow at the edge, through the bulk-edge correspondence. Topological superconductors then present Majorana fermions at the edge. I review the progress in the field, through our own progress, addressing the geometrical foundations and topological invariants with new insight on the quantum matter, leading also to new protocols through the light-matter interaction. We are also questioning where interaction effects lead us, in the sense of new phases of matter. I will go through applications in quantum materials, cold atoms and quantum circuits.

EMERGENT DIRECTIONS

Julien Basset (LPS, Paris)

Photoelectric detection of single microwave photons in a granular aluminum high-impedance quantum circuit

I will present a novel type of single microwave photon detector based on photoassisted quasiparticle tunneling events that poison a superconducting island. The method relies on continuously monitoring the island's charge parity using microwave readout of the parity. We achieve 10% detection efficiency with sub 50 ns time resolution and short dead time (~ 1 μs), for microwave photons at 10 GHz. The detector consists of three junctions connected to a superconducting island, which together carry out photoelectric conversion and charge readout. The enhanced light–matter coupling, crucial to photoelectric conversion, is provided by a granular aluminum-based high-impedance microwave cavity. The time resolved detection of itinerant microwave photon opens up perspectives in quantum sensing, microwave quantum optics, readout of superconducting qubits and mesoscopic physics.