FRI 9: Fundamental Quantum Tests

Time: Friday 10:45–11:30 Location: ZHG101

FRI 9.1 Fri 10:45 ZHG101

Optically Hyperpolarized Materials for Levitated Optomechanics - Testing the Nuclear Einstein de-Haas and Barnett Effect — •Marit O. E. Steiner, Julen S. Pedernales, and Martin B. Plenio — Institute of Theoretical Physics, Ulm University, Germany

Levitated solids with controllable spins offer a new platform for exploring spin-mechanical interactions in the solid state. Nuclear spin hyperpolarization enables investigation of the weak couplings between nuclear spins and rotational degrees of freedom, which have so far eluded experimental observation.

I will explore the potential of levitating solids embedded with optically controllable electron spins, which can hyperpolarize their nuclear spin environment. Pentacene-doped naphthalene serves as a leading example. Leveraging photo-excited triplet states in pentacene, this system achieves nuclear spin hyperpolarization in naphthalene with demonstrated polarization rates up to 80%, significantly enhancing spin-dependent forces and sensitivity to spin-rotational couplings.

I then investigate the use of hyperpolarized naphthalene to probe the nuclear Einstein-de Haas and Barnett effect. These theoretically predicted effects have not yet been observed in solids due to weak spin-mechanical coupling. By combining polarized hydrogen nuclear spins with controllable particle rotation, we propose a protocol to enable their first detection in the solid state.

FRI 9.2 Fri 11:00 ZHG101

99 years old and going stronger than ever: the molecular hydrogen ion — Stephan Schiller[1], •Soroosh Alighanbari[1], Magnus Schenkel[1], Vladimir Korobov[2], and Jean-Philippe Karr[3] — [1]Heinrich-Heine-Universität Düsseldorf — [2]Joint Institute for Nuclear Research, Dubna — [3]LKB, Sorbonne Université; Université d' Evry-Val d' Essonne

At the end of 1926, the same year that Schrödinger presented his wave equation, it was applied for the first time to a molecule, the molecular hydrogen ion (MHI) by Burrau. Even famous physicists (Pauli, Teller, Herzberg, Dehmelt, Lamb) worked on the topic at some time. Nevertheless, for the first 70 years, it did not appear that this family of three-body systems would become of much relevance to fundamental physics - it was too difficult to handle, experimentally and computationally. However, thanks to the efforts of a few reserach teams, today the precision physics of the MHI is entering center stage. MHIs are beginning to contribute to the determination of fundamental constants, tests of quantum physics, and the search for new interparticle forces. Furthermore, the perspective of comparing vibrational transitions in H_2^+ and its antimatter counterpart could lead to novel and ultra-accurate tests of CPT invariance.

MHIs are today studied with some of the most advanced techniques, such as sympathetic laser cooling, rotational laser cooling, quantum logic spectroscopy, Penning-Malmberg traps, frequency-comb-based optical metrology, cw-optical parametric oscillators. A bright future of high-accuracy results still lies ahead.

FRI 9.3 Fri 11:15 ZHG101

Multi-Path and Multi-Particle Tests of Complex versus Hyper-Complex Quantum Theory — Ece Ipek Saruhan, Joachim von Zanthier, and •Marc-Oliver Pleinert — Quantum Optics and Quantum Information Group, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany

The axioms of quantum mechanics provide limited information regarding the structure of the Hilbert space, such as the underlying number system. The latter is generally regarded as complex, but generalizations of complex numbers, so-called hyper-complex numbers, cannot be ruled out in theory. Therefore, specialized experiments to test for hyper-complex quantum mechanics are needed. To date, experimental tests are limited to single-particle interference exploiting a closed phase relation in a three-path interferometer called the Peres test. The latter distinguishes complex quantum mechanics from quaternionic quantum mechanics. Here, we propose a general matrix formalism putting the Peres test on a solid mathematical ground. On this basis, we introduce multi-path and multi-particle interference tests, which provide a direct probe for any dimension of the number system of quantum mechanics.

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