A 31: Atomic Systems in External Fields II

Time: Thursday 14:30–16:30 Location: HS 1015

A 31.1 Thu 14:30 HS 1015

Search for new physics with spin-based magnetometry — •Wei Ji[1,2], Kai Wei[3], Jia Liu[4], Changhao Xu[1,2], and Dmitry Budker[1,2,5] — [1]Helmholtz Institut Mainz — [2]Staudingerweg 18 — [3]Beihang University — [4]Peking University — [5]University of California, Berkeley

Spin-based magnetometry has made remarkable progress in recent years, allowing for precise measurements of fundamental physics and the exploration of new physics beyond the standard model. In this talk, I will introduce the alkali-noble gas hybrid spin magnetometry and its applications in searching for exotic spin-dependent interactions and axion dark matter. I will also briefly introduce a new type of magnetometry that is being developed based on levitated ferromagnetic particles.

A 31.2 Thu 14:45 HS 1015

Measuring nuclear spin qubits by qudit-based spectroscopy using the V2 color center in Silicon Carbide — •Pierre Kuna[1], Erik Hesselmeier[1], Istvan Takacs[2], Viktor vady[2,4], Wolfgang Knolle[3], Nguyen Tien Son[4], Misagh Ghezellou[4], Jawad Ul-Hassan[4], Durga Dasari[1], Florian Kaiser[5], Vadim Vorobyov[1], and Jörg Wrachtrup[1] — [1]3rd Institute of Physics, University of Stuttgart, Stuttgart, Germany — [2]Eötvös Loránd , Egyetem tér 1University-3, H-1053 Budapest, Hungary — [3]Department of Sensoric Surfaces and Functional Inter- faces, Leibniz-Institute of Surface Engineering (IOM), Leipzig, Ger- many — [4]Department of Physics, Chemistry and Biology, Linköping University, Linköping, Sweden — [5]Materials Research and Technology (MRT) Department, LIST, 4422 Belvaux, Luxembourg

Nuclear spins with hyperfine coupling to single electron spins are highly valuable quantum bits. In this work [1] we probe and characterise the particularly rich nuclear spin environment around single silicon vacancy color-centers (V2) in 4H-SiC. By using the electron spin-3/2 qudit as a 4 level sensor, we identify several sets of 29Si and 13C nuclear spins through their hyperfine interaction. We extract the major components of their hyperfine coupling via optical detected nuclear resonance, and assign them to shells in the crystal via the DFT simulations. We utilise the ground state level anti-crossing of the electron spin for dynamic nuclear polarization and achieve a nuclear spin polarization of up to 98(6)% and demonstrate coherent control of single nuclear spins. [1] Preprint Arxiv: 2310.15557

A 31.3 Thu 15:00 HS 1015

A Gravitational Analogon of the Metrological Triangle — •Sebastian Ulbricht[1,2] and Claus Lämmerzahl[3] — [1]Physikalisch-Technische Bundesanstalt PTB, Braunschweig, Germany — [2]Technische Universität Braunschweig, Braunschweig, Germany — [3]Center of Applied Space Technology and Microgravity ZARM, University of Bremen, Bremen, Germany

Before the 2019 revision of SI, the quantum metrological triangle provided a tremendously precise measurement scheme for the electron charge e and the Planck constant h based on the Josephson effect, the quantum Hall effect, and the counting of single electrons. Now, after the SI-redefinition, this triangle is used to realize electric standards and offers substantial options for consistency checks, testing our understanding of the electromagnetic interaction of quantum particles. In this talk, we consider a gravitational analogue of the quantum metrological triangle, giving rise to analoga of the Josephson effect and the quantum Hall effect for neutral quantum particles in a gravitational field. This parallels between electromagnetic and gravitational interaction can be drawn, since the weak field limit of General Relativity resembles the mathematical structure of electrodynamics. The gravitational metrological triangle provides a testing field for our understanding of quantum systems in gravity. We in particular discuss its feasibility for quantum tests of the Weak Equivalence Principle and tests of the universality of quantum mechanics.

A 31.4 Thu 15:15 HS 1015

Resonant photon scattering by highly-charged ions exposed to external fields — •Jan Richter — PTB, Braunschweig, Germany — Leibniz Universität, Hannover, Germany

The elastic photon scattering process is a fundamental aspect of atom-light interactions and has been the subject of numerous experimental and theoretical studies. In this talk, we want to revisit the theory of resonant elastic scattering of photons on ions. Hereby, special attention is paid to the influence of external electric and magnetic fields on the scattering process such as the Hanle effect. The impact of this effect is discussed in the framework of different experimental scenarios.

A 31.5 Thu 15:30 HS 1015

Geometric post-Newtonian description of massive spin-half particles in curved spacetime — •Ashkan Alibabaei[1,2], Philip Schwartz[1], and Domenico Giulini[1,3] — [1]Institute for Theoretical Physics, Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany — [3]Center of Applied Space Technology and Microgravity, University of Bremen, Am Fallturm 1, 28359 Bremen, Germany

The equivalence principle requires matter to universally couple to gravity, encoded in spacetime geometry. For quantum fields, this leads to the framework of quantum field theory in curved spacetime. This framework, however, is quite far detached from the practical description of low-energy quantum systems in terms of Galilei-symmetric Schrödinger equations plus special- and general relativistic corrections. We aim to close this gap by considering the one-particle sector of the respective quantum field theory described effectively by a classical field, for this purpose we apply a systematic low energy approximation scheme. In my talk, I will describe a Hydrogen-like atom coupled to gravity and external electromagnetic field in a twofold expansion scheme, first implementing a weak-gravity approximation, and second a slow velocity post-Newtonian expansion. This yields to a systematic and complete generation of general-relativistic correction terms for spin-half quantum systems. We find new terms that were overlooked in the literature and extend the level of approximation.

A 31.6 Thu 15:45 HS 1015

Wave Packet Propagation and the Quantum to Classical Transition — •John S. Briggs — Physikalisches Inst. Universitaet Freiburg, Germany

The free propagation of wave packets is the oldest problem of continuum quantum mechanics. A brief historical review of the theory is given. In contradistinction to text book treatments, the spreading of a wave packet in time is proposed as the paradigm of the quantum to classical transition. Using the Gaussian wave packets as example, the trajectories of normals to the wave fronts (identical to Bohm trajectories) emerge as the dominant feature. Along such trajectories the momentum space wave function is invariant. The trajectories become straight-line line classical trajectories asymptotically.

The complete analogy to the propagation of Hermite-Gauss wave packets in classical optics is demonstrated. In particular the Gouy phase of optics is shown to be a dynamic phase involving the instantaneous harmonic oscillator eigenfunction. Transition to a frame moving along the trajectory gives a simple form where the Gouy phase appears as the proper time in this frame. As example, in the moving frame the propagation of two interfering Gaussian slits is shown to be simply the propagation of two quantum coherent states.

Finally the quantum to classical transition for macroscopic objects is examined . It is argued that the assignment of a wave function to the universe, as in quantum cosmology, is not a valid concept.

A 31.7 Thu 16:00 HS 1015

Vortex electron scattering by atomic targets — •Sophia Strnat[1,2], Lalita Sharma[3], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Institut für Mathematische Physik, Technische Universität, Braunschweig — [3]Indian Institute of Technology, Roorkee

Since the first twisted electrons have been produced, special attention has been paid to these vortex matter waves. Such electrons, characterized by an additional intrinsic angular momentum beyond spin, find applications in transmission electron microscopy (TEM). Notably, their use has been proposed and experimentally demonstrated for determining the chirality of crystals [1]. In electron energy loss spectra, vortex electron beams have the capability to discern the occupation of atomic sublevels, providing a general insight into electronic con-

figurations and offering a powerful tool for probing local properties of nanomaterials and biomolecules [2]. Despite these advancements, a comprehensive and fully relativistic depiction of the inelastic scattering of vortex electrons by atoms remains absent. Our contribution closes this gap by describing the scattering process with quantities such as total excitation rates, alignment and orientation parameters of atomic states for a diverse range of scenarios. Furthermore, we will emphasize the study of scattering on a bare atom versus an atom confined within a potential.

[1] A. Asenjo-Garcia, F.J. Garcia de Abajo, Phys. Rev. Lett. **113** (2014) 066102
[2] R. Juchtmans, J. Verbeeck, Phys. Rev. B **92** (2015) 134108

A 31.8 Thu 16:15 HS 1015

Compton polarimetry of elastic scattering of highly linearly polarized hard x-rays — •Wilko Middents[1,2,3], Günter Weber[1,2], Alexandre Gumberidze[2], Thomas Krings[4], Tobias Over[1,2,3], Philip Pfäfflein[1,2,3], Uwe Spillmann[2], and Thomas Stöhlker[1,2,3] — [1]Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena — [2]GSI GmbH, Planckstraße 1, 64291 Darmstadt — [3]FSU Jena, Leutragraben 1, 07743 Jena — [4]FZ Jülich, Wilhelm-Johnen-Str., 52425 Jülich

Elastic scattering of photons off matter is a fundamental light-matter interaction process. Precise polarization-dependent measurements provide a sensitive test of the underlying theory. For photon energies from several tens of keV up to a few MeV, efficient polarimetry is based on the polarization-sensitive pattern of Compton scattering.

I will report on the technique of Compton polarimetry in the hard x-ray regime via detectors based on a double-sided segmented semiconductor crystal [1]. Furthermore, I will show the results of an experiment on the polarization transfer in elastic scattering of 175 keV x-rays off a gold target and provide an outlook on future possibilities for polarization measurements of elastic scattering.

[1] Vockert, M. et al., (2017), NimB 313-316. https://doi.org/10.1016/j.nimb.