Q 14: Precision Measurements and Metrology

Time: Tuesday 11:00–13:00 Location: a310

Q 14.1 Tue 11:00 a310

Entanglement Enhanced Quantum Interferometer — •Raphael Nold, Joel Schmidt, Tobias Linkewitz, Florian Kaiser, and Jörg Wrachtrup — 3. Physikalisches Institut Universität Stuttgart, Stuttgart, Germany

In metrology, interferometers are widely used for precision measurements. The sensitivity of interferometers with classical light is limited by the shot noise. To overcome this classical standard quantum limit one can make use quantum correlated particles. However, the associated detection schemes are generally very complex and slow. To overcome those issues, we present a nonlinear two-photon interferometer were photons pairs are produced by a PPKTP down converting crystal. By passing through this crystal two times we entangle two paths, which leads to interference in the signal-photon intensity (instead of the ordinary photon pair interference). We present our recent results consisting of an enhancement factor above 1.2 and sampling rates up to 20 kHz (enhancement factor of 8000 to comparable attempts [1]). As an application we make use of the measurement speed advantage to investigate the possibility of an entanglement enhanced quantum microscope for cell analysis and a quantum enhanced microphone for making the quantum effect audible.

[1] Ono, T. et al. Nature Communications 4, 2426 (2013)

Q 14.2 Tue 11:15 a310

Complete theory of Ramsey interferometry with squeezing echos — •Marius Schulte, Victor J. Martínez-Lahuerta, Maja S. Scharnagl, and Klemens Hammerer — Institute for Theoretical Physics and Institute for Gravitational Physics (Albert-Einstein-Institute), Leibniz University Hannover

We consider a large class of Ramsey interferometry protocols which are enhanced by squeezing and un-squeezing operations before and after a phase signal is imprinted on the collective spin of N particles. We report an analytical optimization for any given particle number and strengths of (un-)squeezing, including experimentally relevant decoherence processes. This provides a complete characterization of squeezing echo protocols, recovering a number of known quantum metrological protocols as local sensitivity maxima, thereby proving their optimality. We discover a single new protocol. Its sensitivity enhancement relies on a double inversion of squeezing. In the general class of echo protocols, the newly found over-un-twisting protocol is singled out due to its Heisenberg scaling even at strong collective dephasing. arXiv:1911.11801

Q 14.3 Tue 11:30 a310

Information content of higher-order intensity correlation measurements about the separation of two equally bright thermal light sources — •Manuel Bojer[1], Anton Classen[1,2], and Joachim von Zanthier[1] — [1]Institut für Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen, Germany — [2]Institute for Quantum Science and Engineering Texas A&M University, College Station, TX 77843, USA

Rayleigh's criterion states that two light sources are unresolvable close to each other if their images, blurred by diffraction, overlap significantly. However, via quantum estimation theory it could be shown that even for small distances there should be in principle information about the source separation available. We here explicitly calculate the quantum Fisher information for two thermal light sources of equal intensities in the far field without an imaging system. Additionally we calculate a lower bound on the Fisher information of various measurement schemes including multi-photon measurements and compare them to the quantum Fisher information. We compare the information content of intensity correlation measurements with a certain numerical aperture to the quantum Fisher information of a smaller with a usual $G^{(1)}$ measurement attainable numerical aperture. We show that the intensity correlation measurements scale very favourable over a large interval of separations due to the bigger numerical aperture, such that they look particularly promising in astronomy for enhancing the resolution of two close-by stars.

Q 14.4 Tue 11:45 a310

Characterization of absorption mechanisms in semiconductors by intensity dependent deflection spectroscopy — •Walter Dickmann[1,2], Tom Götze[2], Mark Bieler[2], and Stefanie Kroker[1,2] — [1]Technische Universität Braunschweig — [2]Physikalisch-Technische Bundesanstalt Braunschweig

We report on a method for the characterization of optical absorption in semiconductors at photon energies below the bandgap energy. We use intensity dependent deflection spectroscopy to measure the optical absorption spatially resolved and to separate the occurring absorption mechanisms. To this end, we take advantage of the different intensity scaling of these mechanisms and extract the material parameters by fitting the intensity dependent absorption to an underlying physical model. The model takes into account relevant processes like phonon-assisted absorption, two-photon absorption and the dynamical Franz-Keldysh effect. These processes affect the refractive index and thus lead to a deflection of the probe beam that is measured. Our method enables a simple but sufficient determination of crucial optical loss properties in various semiconductor systems, e.g. substrates for optical components or solar cells.

Q 14.5 Tue 12:00 a310

Lifetime Measurement of the Cesium $5D_{5/2}$ State with Open Data Availability — •Sebastian Pucher[1,2], Philipp Schneeweiss[1,2], Arno Rauschenbeutel[1,2], and Alexandre Dareau[1,3] — [1]Vienna Center for Quantum Science and Technology, TU Wien – Atominstitut, Stadionallee 2, 1020 Vienna, Austria — [2]Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin, Germany — [3]Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Université Paris-Saclay, 91127 Palaiseau cedex, France

We measure the lifetime of the cesium $5D_{5/2}$ state using a time-resolved single-photon-counting method. We excite atoms in a hot vapor cell via an electric quadrupole transition at a wavelength of 685 nm and record the fluorescence of a cascade decay at a wavelength of 852 nm. We extract a lifetime of the $5D_{5/2}$ state of 1356(9) ns. Our value clearly deviates from the previous experimental literature values [1, 2] but is very well in agreement with a recent theoretical prediction [3]. As we also discuss in the talk, we aim to further improve the transparency of studies of this kind by sharing our measurement outcomes and evaluations via an open-access repository.

[1] D. DiBerardino et al., Phys. Rev. A 57, 4204 (1998)
[2] B. Hoeling et al., Opt. Lett. 21, 74 (1996)
[3] M.S. Safronova et al., Phys. Rev. A 94, 012505 (2016)

Q 14.6 Tue 12:15 a310

Towards testing Local Lorentz Symmetry with $^{172}Yb^+$ ions — •Chih-Han Yeh, Robin L. Stampa, André P. Kulosa, Dimitri Kalincev, Henning A. Fürst, Laura S. Dreissen, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Deutschland

We report on an experiment for testing Local Lorentz Invariance (LLI) in the electron-photon sector [1] with $^{172}Yb^+$. Previous experiments did not show an indication of LLI violation to a sensitivity level of $\Delta C_0^{(2)} = 8 \times 10^{-21}$ [2] by comparing two $^{171}Yb^+$ ion clocks for 45 days. With our approach, we expect a sensitivity of 4×10^{-21} within 24 hours using a single ion and 10 s Ramsey dark time without the need of two operational atomic clocks at the level of 10^{-18} and long measurement times. We plan to test LLI via population fluctuations in the F manifold. To be first-order insensitive to magnetic field noise, we mix the Zeeman substates by dynamical decoupling [3]. To excite the highly forbidden F-state and measure its transition frequency, we used rapid adiabatic passage and demonstrated a reduced uncertainty from 700 kHz [4] to about 10Hz. In the future, we will carry out the LLI test in a multi-ion Coulomb crystal with tailored light fields via a spatial light modulator or a holographic phase plate to reach beyond the 10^{-22} sensitivity level.

[1] V.A. Dzuba et al., *Nature Physics* **12**, 465-468 (2016). [2] C. Sanner et al., *Nature* **567**, 204-208 (2019). [3] R. Shaniv et al., *Phys. Rev. Lett.* **120**, 103202 (2018). [4] M. Roberts et al., *Phys. Rev. Lett.* **78**, 1876 (1997).

Q 14.7 Tue 12:30 a310

Searching for a logarithmic nonlinearity in the Schrödinger

equation using free expansion of Bose-Einstein condensates
— •Sascha Vowe[1] and Markus Krutzik[1,2] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Institut Berlin

The time evolution of a quantum mechanical system as described by the Schrödinger Equation (SE) has been shown to yield correct predictions in many, very precise experiments [1]. However, whether the SE can be regarded as a complete description, or rather an linearized approximation of a more general theory, is still an open question.

One of the very first nonlinear additions to the SE which tried to preserve important physical properties such as the separability of non-interacting states was the so called logarithmic SE as proposed by Bialynicki-Birula and Mycielski [2]. We propose novel experiments using the free expansion of Bose-Einstein condensates which, in the light of future long free fall tests on microgravity platforms, are able to put new upper bounds on the strength of this nonlinearity.

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[1] S. Lamoreaux, A Review of the Experimental Tests of Quantum Mechanics. Int. J. Mod. Phys. A 07, 6691 (1992)

[2] I. Bialynicki-Birula and J. Mycielski, Nonlinear Wave Mechanics, Ann. Phys. (N.Y.)100, 62 (1976)

Q 14.8 Tue 12:45 a310

Space-borne quantum test of the weak equivalence principle at the 10^{-17} level
— •Sina Loriani, Sven Abend, Dennis Schlippert, Christian Schubert, Ernst Maria Rasel, and Naceur Gaaloul — Institut für Quantenoptik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover, Welfengarten 1, D- 30167 Hannover, Germany

Matter wave interferometry provides a unique access to the interface of quantum theory and gravity and is well suited for probing various aspects of general relativity, ranging from its postulates as the equivalence principle to its implications such as gravitational waves. In this contribution, we present a dedicated satellite mission for testing the universality of free fall to 10^{-17} as proposed for the ESA Voyage 2050 initiative. The theoretical advances and technological maturity that would allow reaching this performance will be highlighted.

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