Q 62: Precision measurements and metrology IV

Time: Friday 14:00–15:45 Location: DO24 1.101

Group Report Q 62.1 Fri 14:00 DO24 1.101

States, schemes and detection for quantum atom optics — •Ion Stroescu, Wolfgang Muessel, Daniel Linnemann, Helmut Strobel, Jonas Schulz, David B. Hume, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

We present our recent advances in creation and detection of quantum states in atomic systems.

We generate spin squeezed states containing more than 10000 Bose condensed atoms by making use of paralleled nonlinear evolution of two component Bose-Einstein condensates in an optical lattice. The access to the on-site properties allows for precise characterization of technical noise sources, which are found to be the only limitation for the scalability of squeezing with atom number.

Moreover, we report on the first experimental implementation of an SU(1,1) interferometer for an atomic system, which uses active beam splitters realized by spin-changing collisions. We measure the phase-dependent output signal for small average atom numbers inside the interferometer (~ 1 per side mode) and characterize its phase sensitivity, which is predicted to be at the Heisenberg limit.

Harnessing these resources at the ultimate level requires detection with single-atom resolution. We explore the limits of atom number counting via resonant fluorescence detection, reaching single-particle resolution for atom numbers up to 1200. We also develop a hybrid atom trap capable of simultaneous atom counting for multiple spin states, as required for Heisenberg-limited measurements of spin-entangled atoms.

Q 62.2 Fri 14:30 DO24 1.101

Simultaneous dual species matter wave interferometry — •Dennis Schlippert, Henning Albers, Logan Richardson, Christian Meiners, Jonas Hartwig, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

We report on the first realization of a simultaneous dual species matter wave interferometer employing ^{39}K and ^{87}Rb aiming to test Einstein's equivalence principle. Our method is complementary to classical tests. With pulse separation times of up to T=20ms in a Mach-Zehnder geometry, we realize simultaneous absolute measurements of acceleration. We present first results, a stability analysis and the leading order systematic errors. We discuss future use of a dual species dipole trap and large momentum transfer beamsplitters to further increase the stability and accuracy of the apparatus.

Q 62.3 Fri 14:45 DO24 1.101

Multiparticle singlet states and their metrological applications — •Iñigo Urizar-lanz[1], Zoltán Zimboras[1], Iagoba Apellaniz[1], and Géza Tóth[1,2,3] — [1]Theoretical Physics, The University of the Basque Country, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Wigner Research Centre for Physics, Hungarian Academy of Sciences, P.O. Box 49, H-1525 Budapest, Hungary

Singlet states are quantum states of vanishing angular momentum. When composing the angular momenta of two spin-j particles, there appears a unique singlet state, however, for an ensemble of N particles there exists a plethora of different types of singlets. We present a partial classification of them, and then focus on the permutationally invariant (PI) ones. Their basic properties and characterization is presented, and some specific PI singlets are studied for metrological applications. In particular, we calculate the maximal achievable accuracy when measuring the gradient of a magnetic field using these states. Moreover, we single out a measurement set-up that saturates the bound given by the quantum Fisher Information.

Q 62.4 Fri 15:00 DO24 1.101

Coating Thermal Noise Interferometer — •Tobias Westphal and the AEI 10m Prototype team — Albert Einstein Institut Hannover

Coating thermal noise (CTN) is becoming a more and more significant noise source as the sensitivity of interferometry is pushed to its limits. It arises from inherent mechanical loss of thin films in dielectric coatings. Deeper understanding and verification of its theory such as frequency dependence of losses requires direct (off-resonant) observation. The AEI 10 m Prototype facility is probably the best suited environment for this kind of experiment in a frequency range of special importance for earth bound gravitational wave detectors.

In this presentation the CTN- interferometer, being at the transition from construction to commissioning phase, will be presented. The range that is solely limited by CTN is designed to reach from 10 Hz to about 50 kHz, limited by seismic noise at low frequencies and shot noise (photon counting noise) at high frequencies. Therefore the interferometer is suspended in multiple stages. Digitally controlled actuation as well as active damping schemes were successfully demonstrated.

Q 62.5 Fri 15:15 DO24 1.101

Microwave Electrometry with Rydberg Atoms in a Vapor Cell — •Harald Kübler[1,2], Jonathan A. Sedlacek[1], Arne Schwettmann[1], Renate Daschner[2], Haoquan Fan[1], Santosh Kumar[1], Robert Löw[2], Tilman Pfau[2], and James P. Shaffer[1] — [1]Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, 440 W. Brooks St. Norman, Oklahoma 73019, USA — [2]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany

Quantum based standards of length and time as well as measurements of other useful physical quantities, ex. magnetic fields, are important because quantum systems, like atoms, show clear advantages for providing stable and uniform measurements. We demonstrate a new method for measuring microwave electric fields based on quantum interference in a Rubidium atom. Using a bright resonance prepared within an electromagnetically induced transparency window we are able to achieve a sensitivity of $30\mu V cm^{-1}\sqrt{Hz}^{-1}$ and demonstrate detection of microwave electric fields as small as $\sim 8\mu V cm^{-1}$ with a modest setup [1]. This method can be used for vector electrometry with a precision below 1° [2]. We show first results on microwave field imaging with a sub-wavelength resolution.

[1] J.A. Sedlacek, et.al. "Quantum Assisted Electrometry using Bright Atomic Resonances" *Nature Physics* **8**, 819 (2012)

[2] J.A. Sedlacek, et.al. "Atom-Based Vector Microwave Electrometry Using Rubidium Rydberg Atoms in a Vapor Cell" *Phys. Rev. Lett.* **111**, 063001 (2013)

Q 62.6 Fri 15:30 DO24 1.101

Characterization of a high-power fiber amplifier — •Patrick Oppermann[1], Thomas Theeg[2], Hakan Sayinc[2], and Benno Willke[1] — [1]Albert-Einstein-Institut Hannover — [2]Laser Zentrum Hannover e. V.

A detailed beam characterization of continuous-wave single frequency fiber amplifier with an output power of more than 200 W at a wavelength of 1064 nm is presented. The power noise, frequency noise, beam pointing fluctuations and spatial beam quality were measured with a diagnostic instrument called diagnostic breadboard based on an optical ring resonator. The results are compared with the Advanced LIGO Pre-Stabilized Laser system. The laser was automatically characterized over a period of three weeks to investigate the long-term behavior. During this time the laser was running 24 hours a day, without showing any significant problems.