Q 69: Precision Measurements III (joint session Q/A)

Time: Friday 14:30–16:30 Location: HS 1221

Q 69.1 Fri 14:30 HS 1221

Coriolis bias estimation in the transportable Quantum Gravimeter QG-1 — •Pablo Nuñez von Voigt[1], Nina Heine[1], Najwa Al-Zaki[1], Waldemar Herr[2], Christian Schubert[2], Ludger Timmen[3], Jürgen Müller[3], and Ernst M. Rasel[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Hannover, Germany — [2]Deutsches Zentrum für Luft und Raumfahrt, Institut für Satellitengeodäsie und Inertialsensorik, Hannover, Germany — [3]Leibniz Universität Hannover, Institut für Erdmessung, Hannover, Germany

The Quantum Gravimeter QG-1 relies on the interferometric interrogation of magnetically collimated Bose-Einstein condensates (BEC) in a transportable setup. The falling BEC is detected via absorption imaging, allowing a better characterization of uncertainties of the motional degrees of freedom than fluorescence detection. The horizontal velocity component is utilized to estimate the uncertainty in the bias acceleration due to the Coriolis effect. Estimations from a gradiometer measurement are presented together with proposed measures to compensate for the Coriolis effect.

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Q 69.2 Fri 14:45 HS 1221

Inertial sensing deploying painted optical potentials — •Knut Stolzenberg, Sebastian Bode, Christian Struckmann, Alexander Herbst, Daida Thomas, Naceur Gaaloul, Ernst Rasel, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik

Inertial sensors based on atom interferometers can become a viable addition to classical IMUs, e.g., for autonomous driving or aviation in GNSS-denied environments. While they are superior with respect to their accuracy and long-term stability, it remains challenging to simultaneously measure accelerations and rotations in one or more axes in present experiments. In our experiment a 1064 nm crossed optical dipole trap (ODT) is used for creation of quantum-degenerate ensembles. By using acousto-optical deflectors in both ODT beam paths, we add versatile control over the trapping potentials with respect to position and trap depth. This allows for the creation of BECs amounting to a total number of up to 300×10^3 ultracold ^{87}Rb atoms prepared in the magnetically insensitive state $F = 1, m_F = 0$. We report on prospects of implementing guided quantum inertial sensors by light-pulsed atom interferometry in waveguides and by atomtronics in painted potentials.

Q 69.3 Fri 15:00 HS 1221

Enhancing the sensitivity and dynamic range of atom interferometer measurements using an integrated opto-mechanical vibration sensor — •Ashwin Rajagopalan, Ernst M. Rasel, Sven Abend, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik,
Welfengarten 1, 30167 Hannover, Germany

The measurement sensitivity of an atom interferometer (AI) is predominantly impaired by vibrational noise, this is due to its slow measurement rate and relatively small dynamic range. As a first proof of principle, we demonstrated implementing a miniaturized AI compatible opto-mechanical accelerometer to a T = 10 ms AI which resolves measurement ambiguity and measures the local gravitational acceleration with an uncertainty of 4×10^{-6} ms^{-2} after an integration time of 18000 seconds without any vibration isolation. We are now in preparation to implement the next enhanced version of the opto-mechanical accelerometer which is fully integrated with the retro-reflection mirror of the AI, such that the AI and accelerometer share a common inertial reference. This new accelerometer incorporates a Fabry Pérot interferometer with a mirror reflectivity of 99.9 percent for highly sensitive read-out. An efficient vibrational signal read-out scheme has been implemented and first correlation with a state of the art commercial accelerometer has been observed even at sub-Hertz frequencies.

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Q 69.4 Fri 15:15 HS 1221

Towards compact and field deployable quantum sensors for inertial navigation — •Ann Sabu[1], Polina Shelingovskaia[1], Yueyang Zou[1], Mouine Abidi[1], Philipp Barbey[1], Ashwin Rajagopalan[1], Christian Schubert[2], Matthias Gersemann[1], Dennis Schlippert[1], Ernst M. Rasel[1], and Sven Abend[1] — [1]Institut für Quantenoptik - Leibniz Universität, Welfgarten 1, 30167 Hannover — [2]Deutsches Zentrum für Luft- und Raumfahrt

Quantum sensors using atom interferometry enable precise measurements of inertial forces with long-term stability. Highly sensitive and compact quantum sensors for field applications still pose a challenge.

In this talk, the progess of three experimental devices will be presented: a robust single-axis accelerometer for dynamic applications; a transportable multi-axis gyroscope; and a six-axis quantum sensor capable of measuring accelerations and rotations compatible for quantum navigation.

Telecom fiber laser systems are used for all the three devices. For the multi-axis gyroscope and the six-axis sensor, we exploit atom chip technology to create Bose-Einstein condensates for its low expansion rates. We also use a combination of twin-lattice and relaunch mechanisms to form multiple loops, providing a framework for both compact and large-area sensors along with large momentum transfer.

We acknowledge financial support by the DFG EXC2123 QuantumFrontiers - 390837967 and by the DLR with funds provided by BMWK under Grant No. DLR 50NA2106 (QGyro+).

Q 69.5 Fri 15:30 HS 1221

Optically guided BEC interferometry with a single wavelength — •Simon Kanthak[1], Rui Li[2], Ekim Hanimeli[3], Mikhail Cheredinov[2], Matthias Gersemann[2], Sven Herrmann[3], Naceur Gaaloul[2], Sven Abend[2], Ernst M. Rasel[2], Markus Krutzik[1], and the QUANTUS team[1,2,3,4,5] — [1]Institut für Physik, HU Berlin — [2]Institut für Quantenoptik, LU Hannover — [3]ZARM, Universität Bremen — [4]Institut für Quantenphysik, Uni Ulm — [5]Institut für Angewandte Physik, TU Darmstadt

Precision sensing with Bose-Einstein condensates (BECs) has been achieved in macroscopic interferometers with underlying large scale enclosed space-time areas. As an alternative approach, trapped atom systems offer the opportunity for BEC sensors in more compact packages. This requires an optical guide, crossed beams and beam splitters usually operated at different wavelengths.

We report on an optically guided BEC interferometer operated with a single wavelength. To this end, atoms are first Bose condensed and delta-kick collimated using the magnetic potentials supplied by an atom chip. A single far-detuned focused beam in a linear retroreflector configuration then provides both the tools to levitate as well as symmetrically split and recombine the matter-wave packets to form a guided Mach-Zehnder type atom interferometer.

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Q 69.6 Fri 15:45 HS 1221

First experiments in the Hannover Very Long Baseline Atom Interferometer facility — •Vishu Gupta[1], Kai Grensemann[1], Dorothee Tell[1], Ali Lezeik[1], Mario Montero[1], Jonas Klussmeyer[1], Klaus Zipfel[1], Christian Schubert[1,2], Ernst Rasel[1], and Dennis Schlippert[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik — [2]Deutsches Zentrum für Luft und Raumfahrt, Institut für Satellitengeodasie und Inertialsensorik

The gravitational acceleration of freely falling atoms can be measured accurately by tracking their movement with vertical lattices of light in a matter-wave interferometer scheme. The Very Long Baseline Atom Interferometry (VLBAI) facility at the Hannover institute of technology allows for highly accurate inertial measurements with applications ranging from fundamental physics to geodesy. The 10 m baseline facility with Bose-Einstein Condensates (BECs) and high performance seismic attenuation system (SAS) raises great potential for absolute gravimeter. In the Hannover VLBAI facility, rubidium BECs will be launched into the 10 m baseline to perform interferometery based on Bragg momentum transfer. Here we present the recent development of the VLBAI facility. To this point the installation of the Hannover VLBAI facility is complete with the Bragg interferomtery laser system, an all-optical source of rubidium BEC and high-performance in-vacuum SAS. We demonstrate the current status of the all optical Rb-BEC source, first steps for passive vibration isolation using an SAS and the necessary methods such as matter-wave lenses and Bragg beam splitters for first inertial measurements.

Q 69.7 Fri 16:00 HS 1221

Probe thermometry with continuous measurements — •Julia Boeyens[1], Björn Annby-Andersson[2], Pharnam Bakhshinezhad[2,3], Géraldine Haack[4], Martí Perarnau-Llobet[4], Stefan Nimmrichter[1], Patrick P. Potts[5], and Mohammad Mehboudi[3,4] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Siegen 57068, Germany — [2]Physics Department and NanoLund, Lund University, Box 118, 22100 Lund, Sweden — [3]Technische Universität Wien, Stadionallee 2, 1020 Vienna, Austria — [4]Département de Physique Appliquée, Université de Genève, 1211 Genève, Switzerland — [5]Department of Physics, University of Basel and Swiss Nanoscience Institute, Klingelbergstrasse 82, 4056 Basel, Switzerland

Accurate thermometry plays a vital role in natural sciences. A well studied approach is to prepare a probe and allow it to interact with a thermal environment of unknown temperature for a fixed time before being measured. However, in some experimentally relevant settings, it is more practical to allow the probe to interact continuously with the environment. We consider a minimal model consisting of a two-level probe coupled to the thermal environment. Monitoring thermal transitions enables real-time estimation of temperature. We discuss adaptive and non-adaptive strategies. In particular, we evaluate the Fisher information for the trajectories of the probe and optimise according to this. Finally, we investigate the performance of the thermometer when the measurements made are subject to noise. This lays the foundation for experimentally realised real-time adaptive thermometry.

Q 69.8 Fri 16:15 HS 1221

Sideband Thermometry on Ion Crystals — •Ivan Vybornyi[1], Laura Dreissen[2,3], Dominik Kiesenhofer[4,5], Helene Hainzer[4,5], Matthias Bock[4,5], Tuomas Ollikainen[4,5], Daniel Vadlejch[2], Christian Roos[4,5], Tanja Mehlstäubler[2,6], and Klemens Hammerer[1] — [1]Institut für theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany — [3]Department of Physics and Astronomy, LaserLab, Vrije Universiteit, De Boeleaan, 1081 HV Amsterdam, The Netherlands — [4]Universität Innsbruck, Institut für Experimentalphysik, Technikerstraße 25, 6020 Innsbruck, Austria — [5]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstraße 21a, 6020 Innsbruck, Austria — [6]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Coulomb crystals of cold trapped ions are a leading platform for quantum computing, simulations and metrology. For these applications, it is essential to be able to determine the crystal's temperature with high accuracy, which is a challenging task for large crystals due to complex many-body correlations. Recently [arXiv:2306.07880v3] we presented an ion crystal thermometry method that deals with this problem. With two experiments (4 ions 1D linear chain and 19 ions 2D crystal) we test the new method and cross-check it via other techniques. The results confirm the new method being accurate and efficient. Current work aims to generalize ion thermometry for non-thermal states of motion.