Q 37: Precision Measurements and Metrology II

Time: Wednesday 14:00–16:00 Location: S SR 111 Maschb.

Q 37.1 Wed 14:00 S SR 111 Maschb.

Carrier Density Fluctuations as a source of noise in gravitational wave detectors — •Florian Feilong Bruns[1], Johannes Dickmann[1], Daniel Heinert[2], Ronny Nawrodt[3], and Stefanie Kroker[1,4] — [1]Physikalisch-Technische Bundesanstalt Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [3]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [4]LENA Laboratory for Emerging Nanometrology, Technische Universität Braunschweig, Am langen Kamp 6 b, 380106 Braunschweig, Germany

The quantification and mitigation of noise is a critical task to push the sensitivity of gravitational wave detectors to the ultimate limit. In this contribution we theoretically investigate the noise induced by carrier density fluctuations in semiconductors. The Debye screening related to this type of fluctuations increases the correlation of the fluctuations and thus increases the noise amplitude at frequencies above 1 kHz. The first results on silicon and gallium arsenide as test mass materials indicate that the noise amplitude of carrier density noise is bigger than the SQL for frequencies larger than 10kHz.

Q 37.2 Wed 14:15 S SR 111 Maschb.

Time averaged optical potentials for fast BEC creation — •H. Albers[1], A. Rajagopalan[1], W. Ertmer[1], D. Schlippert[1], E.M. Rasel[1], and The PRIMUS-Team[2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]ZARM, Universität Bremen

Quantum sensors employing cold atoms are sampling devices. Ultra cold atoms are crucial for improving the accuracy of inertial sensors. Achieving high repetition rates with ultra cold atoms, such as Bose-Einstein condensates, is challenging as evaporative cooling is time consuming. In optical dipole traps forced evaporative cooling is achieved by lowering the optical power in order to reduce the trap depth. This results in a reduction of the trap frequencies and extended the rethermalisation time. To disentangle trap depth and frequency we use a time averaged optical potential. The potential is realized by modulating the horizontal positions of the crossed dipole trap beams to create a effective harmonic potential. After trapping the reduction of both the optical power and the modulation amplitude leads to a quasi pure BEC of a few 10^5 ^{87}Rb atoms within 3 seconds of forced evaporative cooling. In comparison to evaporation without modulation amplitude reduction this is an increase in speed by a factor of 3.
This talk will focus on the implementation of time averaged optical potential in our existing setup and shows the path towards atomic ensembles with ultra cold effective temperatures at a high repetition rate.
The PRIMUS-project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number DLR 50 WM 1641.

Q 37.3 Wed 14:30 S SR 111 Maschb.

Silicon-based mirror coatings for gravitational-wave detection — •Jessica Steinlechner[1,2], Lukas Terkowski[1], Iain Martin[2], Felix Pein[1], Simon Tait[2], Jim Hough[2], Sheila Rowan[2], and Roman Schnabel[1] — [1]Institut für Laserphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institute for Gravitational Research, University of Glasgow, University Avenue, Glasgow G128QQ, UK

Gravitational waves are ripples in space caused by massive, accelerated objects such as merging black holes. They were predicted by Einstein more than 100 years ago and first measured in 2015. When reaching their design sensitivity, current gravitational-wave detectors - as well as all planned, future detectors - will be limited by thermal noise from the highly-reflective mirror coatings. To detect more, weaker gravitational waves from a wider range of astrophysical sources, it is necessary to develop new coating materials. Besides low thermal noise, there are also strong requirements on the optical absorption and optical scattering of the coatings, which have to be available in large sizes. Due to low thermal noise, amorphous silicon seems to be a promising solution for a coating material. However, the optical absorption of commercially available amorphous silicon is currently far higher than the requirement. In this talk we will present our work on silicon-based mirror coatings in order to make future gravitational-wave detectors more sensitive.

Q 37.4 Wed 14:45 S SR 111 Maschb.

Hybrid two-mirror system for low thermal noise and high reflectivity — •Johannes Dickmann[1], Tim Käseberg[1], Jan Meyer[2], Walter Dickmann[2], and Stefanie Kroker[1,2] — [1]Physikalisch-Technische Bundesanstalt Braunschweig, Germany — [2]Technische Universität Braunschweig, Germany

Thermal noise limits the sensitivity of many high-precision optical devices like gravitational wave detectors and laser stabilization cavities. We present the analysis and optimization of a two-mirror system consisting of a meta-mirror and a conventional Bragg-mirror for low noise and high reflectivity. The system allows an optimization of the severe noise contributions (Brownian, thermo-elastic and thermo-refractive). The hybrid two-mirror system is optimized for an integration in frequency stabilization Fabry-Pérot cavities and the Einstein Telescope (ET) future gravitational wave detector. It is shown theoretically, that the mirror noise can be reduced to an Allan deviation of less than 10^{-18} for a tabletop-sized cavity working at 124 K. For ET, the cryogenic expense becomes obsolete.

Q 37.5 Wed 15:00 S SR 111 Maschb.

Characterisation of a high-flux BEC source for gravity measurements on the $10^{-9}\,\mathrm{m\,s^{-2}}$ inaccuracy level — •Nina Heine[1], Jonas Matthias[1], Maral Sahelgozin[1], Waldemar Herr[1], Ludger Timmen[2], Jürgen Müller[2], and Ernst M. Rasel[1] — [1]Institute of Quantum Optics, Hannover, Germany — [2]Institut für Erdmessung, Hannover, Germany

Inertial sensors based on the principle of atom interferometry will benefit in accuracy from employing Bose-Einstein condensates (BECs) as test masses.

Leading order uncertianties occuring in cold atom gravimeters due to wavefront abberations and the Coriolis force are inherently supressed by the almost vanishing expansion rate of a delta-kick collimated BEC. Further the per-shot sensitivity will be increased by a gain in interferometer contrast and the implementation of higher order momentum transfer for Bragg interferometry. Exploiting these advantages in a transportable sensor requires a compact and robust setup allowing for high repetition rates. For the Quantum Gravimeter QG-1 this is realised in a double magneto-optical trap configuration based on an atom chip.

This talk focuses on the characterisation of the BEC source for the transportable Quantum Gravimeter QG-1 and highlights the way towards the so far unexplored $10^{-9}\,\mathrm{m\,s^{-2}}$ inaccuracy regime.

This work is supported by the Deutsche Forschungsgemeinschaft (DFG) as part of project A01 within the SFB 1128 geo-Q.

Q 37.6 Wed 15:15 S SR 111 Maschb.

The PRIMUS-Project; Optical dipole trapping in a drop tower experiment — •Marian Woltmann[1], Christian Vogt[1], Sven Herrmann[1], Claus Lämmerzahl[1], and The PRIMUS-Team[1,2] — [1]University of Bremen, Center of Applied Space Technology and Microgravity (ZARM) — [2]LU Hannover, Institute of Quantum Optics

The application of a matter wave interferometer in a microgravity (μg) environment offers the potential of largely increased interferometer times and thereby highly increased sensitivities in precision measurements. While most such μg experiments apply magnetic trapping on an atom chip, the PRIMUS-Project develops an optical dipole trap for use in weightlessness as an alternative source for matter wave interferometry. Proven its worth on ground, optical dipole traps have never before been operated in μg, although they offer unique advantages like improved symmetry of the trapping potential and the accessibility of Feshbach resonances. Using a 10W trapping laser at a wavelength of 1949nm, we implement a dual species (Rb and K) cold atom experiment for use in the drop tower at the ZARM in Bremen, offering 4.7s of microgravity time in drop mode. Within this talk we will report on the current status and latest results of the experiment. The PRIMUS-Project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) under grant number DLR 50 WM 1642.

Q 37.7 Wed 15:30 S SR 111 Maschb.

MAIUS-2 and -3: Development and test of the scientific payload — •Baptist Piest, Maike Diana Lachmann, Wolfgang Bartosch, Dennis Becker, Waldemar Herr, Wolfgang Ertmer, and Ernst Maria Rasel — Leibniz Universität Hannover

Quantum tests of the Einstein equivalence principle (EEP) promise to outreach the accuracy of classical tests based on macroscopic test masses in the course of the next decade. Additionally, they offer to probe quantum aspects of the EEP which are inherently inaccessible for classical tests. Current limitations of ground-based tests using light-pulse matter-wave interferometry are mainly given by the maximum pulse separation time T and the terrestrial environment. A promising approach to overcome this limitation is to perform the experiments in extended free fall, e.g. on a satellite. In 2017, the sounding rocket experiment MAIUS-1 succeeded in generating the first BECs in space using Rb-87 atoms and demonstrated further key methods needed for an EEP test in space. The missions MAIUS-2 and -3 aim to demonstrate BEC-borne dual-species matter wave interferometry with K-41 and Rb-87. This talk gives an overview of the experimental setup, its capabilities and technical limitations and the ongoing experiments on ground.

The MAIUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number: 50WP1431.

Q 37.8 Wed 15:45 S SR 111 Maschb.

Gravity gradient cancellation in satellite quantum tests of the Equivalence Principle — •Sina Loriani[1], Wolfgang Ertmer[1], Franck Pereira Dos Santos[2], Dennis Schlippert[1], Christian Schubert[1], Peter Wolf[2], Ernst Maria Rasel[1], and Naceur Gaaloul[1] — [1]Leibniz Universität Hannover, Institute of Quantum Optics, Germany — [2]LNE-SYRTE, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, France

Recent tests of the Einstein Equivalence Principle based on the simultaneous operation of two atomic gravimeters have become a promising tool to compare the differential free fall acceleration of a large variety of test masses for diverse violation scenarios. However, the uncertainty in the initial co-location of the two atomic sources couples into the measurement in the presence of gravity gradients and rotations, displaying one major systematic uncertainty.

In this work, we present a combined strategy of gravity gradient compensation and signal demodulation, which allows to reduce the systematic contributions due to the initial co-location below the 10^{-18} level. Operating on a satellite in inertial configuration leads to temporally modulated gravity gradients in the local frame of the satellite, which requires an extension of the technique presented in *[Roura, Phys. Rev. Lett* ***118****, 160401 (2017)]* . We analyse the feasibility of this scheme and find that for moderate requirements, the mission duration dominated by verification measurements of the initial co-location can be reduced drastically. Moreover, it allows to integrate the induced differential acceleration uncertainty below 10^{-18} faster than shot-noise.