Q 49: Precision Measurements and Metrology (Atom Interferometry) (joint session Q/A)

Time: Wednesday 14:00–15:30 Location: K 2.013

Group Report Q 49.1 Wed 14:00 K 2.013

Probing the forces of blackbody radiation and dark energy with matter waves — •Philipp Haslinger[1], Vitkoria Xu[1], Matt Jaffe[1], Osip Schwartz[1], Paul Hamilton[2], Benjamin Elder[3], Justin Khoury[3], Matthias Sonnleitner[5], Monika Ritsch-Marte[4], Helmut Ritsch[5], and Holger Müller[1] — [1]UC Berkeley, USA — [2]UC Los Angeles, USA — [3]UPenn, USA — [4]Med-Uni Innsbruck, AUT — [5]Uni Innsbruck, AUT

In this talk I will give an overview of our recent work using an optical cavity enhanced atom interferometer to sense with gravitational strength for fifths forces and for an on the first-place counterintuitive inertial property of blackbody radiation. Blackbody (thermal) radiation is emitted by objects at finite temperature with an outward energy-momentum flow, which exerts an outward radiation pressure. At room temperature e.g. a Cs atom scatters on average less than one of these photons every 10^8 years. Thus, it is generally assumed that any scattering force exerted on atoms by such radiation is negligible. However, particles also interact coherently with the thermal electromagnetic field and this leads to a surprisingly strong force acting in the opposite direction of the radiation pressure.

If dark energy, which drives the accelerated expansion of the universe, consists of a screened scalar field (e.g. chameleon models) it might be detectable as a "5th force" using atom interferometric methods. By sensing the gravitational acceleration of a 0.19kg in vacuum source mass, we reach a natural bound for cosmological motivated scalar field theories and were able to place tight constraints.

Q 49.2 Wed 14:30 K 2.013

Matter waves optics with a space-borne Bose-Einstein condensate experiment — •Dennis Becker[1], Ernst M. Rasel[1], Wolfgang Ertmer[1], and the QUANTUS Team[1,2,3,4,5,6,7,8] — [1]IQ, Leibniz Universität Hannover — [2]HU Berlin — [3]JGU Mainz — [4]FBH Berlin — [5]U Ulm — [6]ZARM Bremen — [7]DLR — [8]TU Darmstadt

Atom interferometers are reaching an exquisite performance and expected to be sensitive probes of fundamental interactions. Thanks to the clean environment and long observation times possible, space promises to unfold the full potential of such sensors. In this contribution, we report on the first realization of a cold atom experiment in space achieved by the sounding rocket mission MAIUS-1. Within 6 min of micro-g and 81 experiments, the chip-based BEC machine demonstrated a high degree of stability and a good agreement with quantum gases models. These results are a key milestone towards BEC-based space missions aiming for gravimetry, gradiometry, tests of fundamental physics laws or the detection of gravitational waves.

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Q 49.3 Wed 14:45 K 2.013

New developments with the Gravimetric Atom Interferometer GAIN — •Bastian Leykauf[1], Anne Stiekel[1], Vladimir Schkolnik[1], Christian Freier[1], Hartmut Wziontek[2], Axel Rülke[2], Markus Krutzik[1], and Achim Peters[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]Bundesamt für Karthographie und Geodäsie (BKG)

GAIN uses the interference of cold atoms to precisely and accurately measure temporal changes in the gravitational acceleration [1].

In cooperation with the German Federal Agency for Cartography and Geodesy (Bundesamt für Karthographie und Geodäsie, BKG), we conducted a measurement campaign at the geodetic observatory in Wettzell. We will report on the results of this measurement campaign, including the study of active and passive vibration isolation strategies as well as common-mode noise suppression by differential gravity measurements using two atomic samples. We will furthermore discuss systematic effects in the measured gravity value caused by residual magnetic fields [2] and higher order light-shifts.

[1] Freier et al. *Mobile quantum gravity sensor with unprecedented stability*, Journal of Physics: Conference Series **723** (2016)
[2] Hu et al. *Mapping the absolute magnetic field and evaluating the quadratic Zeeman-effect-induced systematic error in an atom interferometer gravimeter*, Physical Review A **96**, 033414 (2017)

Q 49.4 Wed 15:00 K 2.013

Large momentum transfer in a dual lattice configuration — •Matthias Gersemann[1], Sven Abend[1], Christian Schubert[1], Martina Gebbe[2], Ernst M. Rasel[1], and the QUANTUS team[1,2,3,4,5,6] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU zu Berlin — [4]Institut für Quantenphysik, Uni Ulm — [5]Institut für Angewandte Physik, TU Darmstadt — [6]Institut für Physik, JGU Mainz

Bose-Einstein condensates (BEC) in combination with large momentum transfer beam splitters are a key component for future infrasound atomic gravitational wave detectors. For this reason we developed a new method for symmetric scalable large momentum separation using the combination of double Bragg diffraction and Bloch oscillations in a dual-lattice configuration. The basic principle consists of an initial splitting via Double Bragg diffraction and a subsequent acceleration by Bloch oscillations. This sequence enables the transfer of up to $1008\,\hbar k$ in a single beam splitter and $408\,\hbar k$ when implemented in an atom interferometer, limited by technical constraints. Further perspectives and limits are investigated and already show that this technique is also applicable for sensitivity enhancements of devices with smaller scales.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under grant number DLR 50WM1552-1557 (QUANTUS-IV-Fallturm), the Deutsche Forschungsgemeinschaft (DFG) in the scope of the SFB 1128 geo-Q and "Niedersächsisches Vorab" through QUANOMET.

Q 49.5 Wed 15:15 K 2.013

The linear potential and the cubic phase — •Matthias Zimmermann[1], Maxim A. Efremov[1], Albert Roura[1], Wolfgang P. Schleich[1], Arvind Srinivasan[2], Jon P. Davis[3], Frank A. Narducci[4], Sam A. Werner[5], and Ernst M. Rasel[6] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Germany — [2]Naval Air Systems Command, EO Sensors Division, Patuxent River, USA — [3]AMPAC, North Wales, USA — [4]Naval Postgraduate School, Monterey, USA — [5]Physics Laboratory, NIST, Gaithersburg, USA — [6]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany

The quantum mechanical propagator of a massive particle in a linear gravitational potential is well-known to contain a phase φ_g scaling with the third power of propagation time T. This phase has the remarkable feature of being proportional to the ratio m_g^2/m_i, where m_g and m_i denote the gravitational and the inertial mass of the particle, respectively.

We propose an experiment to observe this phase using an atom interferometer [1]. For this purpose, we prepare two different accelerations g_g and g_e for the ground and excited state of the atom. In this way the atom accumulates two different phases $\varphi_g^{(g,e)}$ depending on its internal state and the total interferometer phase scales as T^3.

[1] M. Zimmermann et al., *Appl. Phys. B* **123**:102 (2017)