Q 21: Precision Measurements and Metrology: Interferometry I

Time: Tuesday 11:00–13:00 Location: P 104

Q 21.1 Tue 11:00 P 104

Challenging Einstein with Very Long Baseline Atom Interferometry — •Etienne Wodey, Christian Meiners, Dorothee Tell, Dennis Schlippert, Christian Schubert, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

In the quest for a theory of quantum gravity, most of the theoretical attempts to reconcile two of physics' most successful theories, quantum mechanics (QM) and general relativity (GR), build upon a violation of Einstein's equivalence principle. Considerable experimental effort to detect potential violations of the universality of free fall (UFF) has therefore been delivered, first using classical test masses and more recently with genuine quantum objects.

Very Long Baseline Atom Interferometers (VLBAI) represent a new class of matter-wave sensors that extend the baseline from tens of centimeters to several meters, enabling free fall times on the order of seconds and a corresponding increase in the phase sensitivity which scales with the square of the free fall time. Using ultracold mixtures of rubidium and ytterbium atoms, this should not only enable quantum tests of the UFF challenging the current state of the art with classical test masses but also permit new experiments ranging from gravimetry and gradiometry with unprecedented resolution and stability to new probes of the intimate interplay between GR and QM.

The VLBAI facility is a major research equipment funded by the DFG. We also acknowledge support from the CRCs 1128 "geo-Q" and 1227 "DQ-mat" and the RTG 1729.

Q 21.2 Tue 11:15 P 104

Operating an interferometer in a noisy environment — •Dipankar Nath, Henning Albers, Christian Meiners, Logan L. Richardson, Dennis Schlippert, Christian Schubert, Etienne Wodey, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Inertial sensitive devices such as atom interferometers are prone to seismic noise. Atom interferometers with longer baselines are particularly susceptible to very low frequency noise where vibration isolation platforms are not very efficient. Using a mechanical sensor like a seismometer, one can correct the contribution from residual vibrations [1]. We demonstrate seismic post correction in an atom interferometer with 2T=152 ms by correlating the atom interferferometer (operated using cold ^{87}Rb atoms) with a Guralp CMG-40T seismometer and show a two fold improvement in the short term stability using the post correction scheme. Such a scheme will also be implemented in the Very Long Baseline Atom interferometer (VLBAI) [2]. Seismic post correction will also be used to improve the test of the Universality of Free Fall in a dual species atom interferometer employing ^{87}Rb and ^{39}K as test masses [3,4]. Post correction schemes such as this will also be used in atom interferometry based transportable gravimeters in the future.

[1] L. Le Gouët et al., Appl. Phys. B 92, 133 (2008)
[2] J. Hartwig et al., New J. Phys. 17, 035011 (2015)
[3] D. Schlippert et al., Phys. Rev. Lett. 112, 203002 (2014)
[4] B. Barrett et. al., arXiv 1609.03598v1

Q 21.3 Tue 11:30 P 104

Trade-off of atomic sources for extended-time atom interferometry — •Sina Loriani, Dennis Schlippert, Christian Schubert, Ernst Maria Rasel, and Naceur Gaaloul — Leibniz University of Hanover, Germany

Proposals for atom-interferometry based sensors designed to detect gravitational waves or testing the universality of free fall assume unprecedented sensitivity for long interferometry times [Hogan et al., Phys. Rev. A 94, 033632, (2016)]. These long drift times of several seconds can be achieved by operation in microgravity and by using phase-space-manipulation techniqes like the delta-kick-collimation(DKC), which drastically reduces the expansion rate of atomic samples [Müntinga, et al. Phys. Rev. Lett. **110**, 093602 (2013), T. Kovachy et al., Phys. Rev. Lett. **114**, 143004 (2015)]. We present a set of theoretical models that treat the impact of collisions and mean-field on the performance of the kick and compare the efficiency of the collimation for all possible temperature and density regimes. The theoretical study covers commonly used alkaline and alkaline-earth-like ensembles of atoms (Rb, Sr, Yb, etc.). The figure of merit is the size of the ensemble when being lensed as the atomic lenses are subject to aberrations depending on the spatial extent of the cloud and the potentials being used. The analysis shows a clear advantage when using condensed ensembles.

Q 21.4 Tue 11:45 P 104

Infrasound gravitational wave detection with atoms — •Christian Schubert, Dennis Schlippert, Sven Abend, Naceur Gaaloul, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Atom interferometry offers an interesting perspective for the detection of gravitational waves in a frequency band between eLISA and Advanced LIGO, resulting in an active field of research. Ground based setups with vertical or horizontal baselines were considered, satellite missions investigated, and interferometer topologies developed. We investigate a novel geometry for a ground based device combining several advantages as a horizontal baseline, enabling long baselines, a single axis laser link between the atom interferometers acting as phasemeters, and suppressing errors sources otherwise implying very strict requirements onto the atomic source. It is based on recent developments in symmetric large momentum beam splitters, relaunching techniques for suspending the atoms against gravity, and delta-kick collimation techniques to generate very slowly expanding atomic ensembles. The idea will be presented and the requirements discussed in comparison with previous proposals and the state of the art in atom optics. The work is supported by the CRC 1227 DQ-mat, the CRC 1128 geo-Q, the RTG 1729, the DFG Excellence Cluster QUEST, the QUEST-LFS, and by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under Grant No. 50WM1552-1557.

Q 21.5 Tue 12:00 P 104

First gravity gradient measurements with the gravimetric atom interferometer GAIN — •Bastian Leykauf, Christian Freier, Vladimir Schkolnik, Matthias Hauth, Markus Krutzik, and Achim Peters — Institut für Physik, Humboldt-Universität zu Berlin

The gravimetric atom interferometer GAIN is based on interfering ensembles of laser-cooled ^{87}Rb atoms in a fountain setup, using stimulated Raman transitions. GAIN's rugged design allows for transports to sites of geodetic and geophysical interest while maintaining a high accuracy compatible with the best classical instruments. Its long-term stability of $0.5\,\mathrm{nm/s^2}$ and the effective control over systematic effects, including Raman beam wavefront aberrations, has previously been reported [1,2], demonstrating the unique properties of atomic sensors.

By using the juggling technique, we are able to perform gravity measurements on two atomic clouds simultaneously. Advantages include the suppression of common mode phase noise, enabling differential phase shift extraction without the need for vibration isolation. We will present the results of our first gravity gradient measurements.

[1] Schkolnik et al. *The effect of wavefront aberrations in atom interferometry*, Applied Physics B (2015)
[2] Freier et al. *Mobile quantum gravity sensor with unprecedented stability*, Journal of Physics: Conference Series (2016)

Q 21.6 Tue 12:15 P 104

Transportable Quantum Gravimeter – QG-1 — •Maral Sahelgozin[1], Jonas Matthias[1], Nina Grove[1], Sven Abend[1], Waldemar Herr[1], Jürgen Müller[2], Wolfgang Ertmer[1], and Ernst M. Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Institut für Erdmessung, Leibniz Universität Hannover, Schneiderberg 50, 30167 Hannover

We present the design of our transportable Quantum Gravimeter – QG-1 and report on the progress of the implementation of an ultracold atomic ensemble loaded on our atom chip constituting the source for matter-wave interferometry. The characterization and optimization of our high flux double MOT system will be presented. In our gravimeter the narrow momentum width of the ensemble in combination with higher order Bragg type beamsplitters will be employed to improve the acceleration sensitivity. More crucially the extremely low momentum distribution of an ultracold atomic ensemble will reduce the systematic errors arising from wavefront inhomogeneities during the interrogation time. This is the major limitation to the accuracy of state-of-the-art atomic gravimeters and will be overcome by our absolute quantum gravimeter. By this our compact atom chip based source, miniaturized electronics and simplified telecom fiber based laser system provide a stable and accurate gravimeter for geodetic field applications.

This work is in the scope of the SFB 1128 geo-Q and supported by the Deutsche Forschungsgemeinschaft (DFG).

Q 21.7 Tue 12:30 P 104

Laser-interferometric dilatometry from 100 K to 325 K — •Ines Hamann[1,2], Ruven Spannagel[1,2], Josep Sanjuan[2], Felipe Guzman[1], and Claus Braxmaier[1,2] — [1]University of Bremen, ZARM Center of Applied Space Technology and Microgravity, 28359 Bremen, Germany — [2]DLR German Aerospace Center, Institute of Space Systems, 28359 Bremen, Germany

To enable high precision optical measurements highly dimensionally stable materials are needed. Dimensional stability is an important material property describing the dependency of geometrical dimensions of an optical setup due to temperature fluctuations. Optical setups are often built with components made of glass-ceramics or composite materials which exhibit low coefficients of thermal expansion (CTE). These materials have to be characterized over the full operating temperature range to accurately predict the response of the optical system and the impact on its measurement performance.

Our laser dilatometer setup is designed to characterize these low expansion materials in a temperature range from 100 K to 325 K, using a heterodyne laser interferometer to measure the dimensional changes of a sample due to well-controlled temperature variations. In this talk, we present the current status of our test facility, and recent improvements to decrease the uncertainty budget to levels of 10 ppb/K over the temperature range from 100 K to 325 K.

Q 21.8 Tue 12:45 P 104

JOKARUS: An iodine frequency reference for space-applications on a sounding rocket — •Vladimir Schkolnik[1,2], Klaus Döringshoff[1], Franz Gutsch[1], Markus Krutzik[1], Achim Peters[1,2], and The JOKARUS Team[1,2,3,4,5,6] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]FBH Berlin — [3]ZARM U Bremen — [4]DLR Bremen — [5]JGU Mainz — [6]Menlo Systems GmbH

Stable optical frequency references are a key component in future missions based on quantum sensors testing Einsteins equivalence principle or long baseline interferometers for gravitational wave detection. In this talk, we present JOKARUS: A simple and compact diode laser based frequency reference, stabilized to an optical transition in iodine at 532 nm. Our frequency reference aims to exceed the performance required for space missions such as LISA and GRACE follow on, and will be operated on a sounding rocket flight in Fall 2017 to demonstrate its technological maturity.

The design of our reference system, including diode laser source, gas cell assembly and electronics is presented in detail. JOKARUS is based on the heritage of three successful sounding rocket missions and is adaptable to various wavelengths to reach narrow optical transitions.

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