Q 6: Precision Measurements and Metrology II (with A)

Time: Monday 14:30–16:15 Location: a310

Q 6.1 Mon 14:30 a310

Atom-chip fountain gravimeter — •Sven Abend[1], Martina Gebbe[2], Matthias Gersemann[1], Hauke Müntinga[2], Holger Ahlers[1], Claus Lämmerzahl[2], Wolfgang Ertmer[1], Ernst M. Rasel[1], and QUANTUS Team[1,2,3,4,5,6,7] — [1]Institut für Quantenoptik, LU Hannover — [2]Zarm, U Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laser-Physik, Hamburg — [5]Institut für Quantenphysik, U Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]Institut für Physik, JGU Mainz

We developed a simple but effective method to coherently relaunch atoms by a combination of double Bragg diffraction and Bloch oscillations in a single retro-reflected light field. This method provides a novel tool for atomic quantum sensors extending the free fall time without increasing their complexity. We demonstrate an atom-chip fountain gravimeter utilizing ultracold atoms, where all necessary atom-optics operations are realized by the atom-chip, including condensation, magnetic transfer and delta-kick cooling. The atom-chip itself even acts as a retro-reflector in vacuum for the beam splitter as inertial reference for gravity. This implementation allows for high contrast interferometry over tens of milliseconds in a volume as little as a one centimeter cube, paving the way for measurements with sub-μGal accuracies in miniaturized devices.

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Q 6.2 Mon 14:45 a310

Atom interferometry with Bose-Einstein condensates on sounding rockets — •Dennis Becker, Maike Lachmann, Stephan Seidel, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

The universality of free fall is one of the fundamental postulates of our description of nature. The comparison of the free fall of two ultra-cold clouds of different atomic species via atom interferometry comprises a method to precisely test this assumption. By performing the experiments in a microgravity environment the sensitivity of such an atom interferometric measurement can be increased. In order to fully utilize the potential of these experiments the usage of a Bose-Einstein condensate as the initial state of the atom interferometer is necessary.

As a step towards the transfer of such a system in space an atom optical experiment is currently being prepared as the scientific payload for a sounding rocket mission. This mission is aiming at the first demonstration of a Bose-Einstein condensate in space and using this quantum degenerate matter as a source for atom interferometry. The launch of the rocket is planned for 2016 from ESRANGE. This first mission will be followed by two more that extend the scientific goals to the creation of degenerate mixtures in space and simultaneous atom interferometry with two atomic species. Their success would mark a major advancement towards a precise measurement of the universality of free fall with a space-born atom interferometer.

Q 6.3 Mon 15:00 a310

Advances towards a T^3-interferometer — •Matthias Zimmermann[1], Maxim A. Efremov[1], Wolfgang P. Schleich[1], Sara A. DeSavage[2], Jon P. Davis[2], Frank A. Narducci[2], and Ernst M. Rasel[3] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, 89081 Ulm, Germany — [2]EO Sensors Division, Naval Air Systems Command, Patuxent River, MD 20670, USA — [3]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

We present the theoretical background for and the progress on a novel atom interferometer with a phase shift scaling as T^3 in contrast to conventional atom interferometers with a scaling of T^2 [1]. Here T denotes the travelling time of the atoms in-between two Raman pulses. These pulses prepare a superposition of two magnetic sublevels while an external magnetic field is applied to imprint two different effective accelerations g_1 and g_2 for these two states [2]. A sequence consisting of four Raman pulses is used to close the interferometer and to obtain the T^3-scaling. Due to the position-dependent Zeeman shift the atomic resonance frequency changes throughout the experiment and the laser frequency has to be chirped in order to stay in resonance.

[1] W.P. Schleich, D.M. Greenberger, and E.M. Rasel, *New J. Phys.* **15**, 013007 (2013)

[2] J.P. Davis and F. A. Narducci, *J. Mod. Opt.*, **55**, 3173 (2008)

Q 6.4 Mon 15:15 a310

Quantum Test of the Universality of Free Fall with a Dual Species Atom Interferometer — •Logan Richardson, Henning Albers, Dipankar Nath, Dennis Schlippert, Christian Schubert, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik and
Centre for Quantum Engineering and Space-Time Research - QUEST, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

To understand gravity's role within the standard model, we can test for violations of the universality of free fall with dual-species atom interferometers [1]. To constrain possible violations we require accurate local gravitational acceleration measurements of both test masses. Vibrations can however corrupt these measurements by inducing phase shifts, masking any possible violation signal and fundamentally limiting the sensitivity of the experiment. Correlation of atomic interferometers with a classical sensor can provide a phase shift correction for vibrationally induced noise[2]. We discuss the experimental results of the application of this method into our dual species ^{87}Rb – ^{39}K interferometer, as well as the strategy for the upcoming large scale ^{87}Rb – ^{170}Yb interferometer[3]

[1] D. Schlippert et al., Phys. Rev. Lett. 112, 203002 (2014)

[2] B. Barrett et al., New Journal of Physics, 17, 085010 (2015)

[3] J. Hartwig et al., New J. Phys. 17, 035011 (2015)

Q 6.5 Mon 15:30 a310

Quantum Test of the Universality of Free Fall in small and large scale devices — •Henning Albers, Christian Meiners, Dipankar Nath, 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

The foundation of general relativity is constituted by Einstein's equivalence principle, which is based on three postulates. One of them is the Universality of Free Fall (UFF), which can be tested by observing the free fall motion of a pair of test masses. Those tests have reached high precision with macroscopic objects [1].

The development of atom optics gives access to new types of inertial sensors to test fundamental physics. By comparing the differential acceleration measured by a simultaneous dual species Mach-Zehnder type atom interferometer we perform a quantum test of the UFF employing the two chemical elements, ^{39}K and ^{87}Rb [2]. We show the latest results as well as the improvements of the experiment aiming towards a test at a ppb uncertainty. To reach this level we will increase the stability and accuracy of the apparatus by using a dipole trap. Another step towards higher sensitivity will be the upscaling towards the 10 m Very Long Baseline Atom Interferometer (VLBAI) apparatus working with Rb and Yb[3].

[1] J. Müller et al., Class. Quantum Grav. 29 184006 (2012)

[2] D. Schlippert et al., Phys. Rev. Lett. 112, 203002 (2014)

[3] J. Hartwig et al., New J. Phys. 17, 035011 (2015)

Q 6.6 Mon 15:45 a310

Towards a new generation of high-performance operational quantum sensors — •Jean Lautier-Gaud, Vincent Ménoret, Pierre Vermeulen, Jean-François Schaff, Guillaume Stern, Cédric Majek, Mathieu Guéridon, and Bruno Desruelle — Muquans, SAS, rue François Mitterrand 33400 Talence France

After 30 years of academic research in cold atom sciences, intensive developments are being conducted to improve the compactness and the reliability of experimental set-ups. One of the main objectives is to transfer such high-sensitivity experiments from laboratory-based research to an operational utilization outside of the laboratory. This will allow non-specialists and other areas of research to benefit from the outstanding advantages and the measurement capabilities that cold atoms offer. We will present the long-lasting developments that we have been carrying to provide the first industrial cold-atom absolute gravimeter and the first industrial cold-atom atomic clock. We will present the principles of operation and the main features of our instruments. Their performances in terms of sensitivity, stability, and accuracy, as well as the latest results they achieved will be reviewed. High-performance frequency-stabilized laser systems are one of the key technological elements to manipulate cold atoms, and they set the quality of the measurements. Muquans now turned these into benchtop reliable turnkey solutions dedicated to scientists eager to reach faster their scientific objectives. Such laser systems have been qualified on our own cold atom instruments, and a specific focus on our latest developments in this area in terms of performances will be proposed.

Q 6.7 Mon 16:00 a310

Dark energy search using atom interferometry — •Philipp Haslinger[1], Matt Jaffe[1], Paul Hamilton[2], Justin Khoury[3], and Holger Müller[1] — [1]University of California, Berkeley, CA 94720, USA — [2]University of California, Los Angeles, CA 90095, USA — [3]University of Pennsylvania, Philadelphia, PA 19104, USA

If dark energy, which drives the accelerated expansion of the universe, consists of a light scalar field it might be detectable as a "fifth force" between normal-matter objects. In order to be consistent with cosmological observation and laboratory experiments, some leading theories use a screening mechanism to suppress this interaction. However, atom-interferometry presents a tool to reduce this screening [1] and has allowed us to place tight constraints on a certain class of these theories, the so-called chameleon models [2]. Recent modifications to our cavity-enhanced atom interferometer have improved the sensitivity by a hundredfold and we expect new results soon.

[1] C. Burrage, E. J. Copeland, E. A. Hinds, Probing dark energy with atom interferometry. J. Cosmol. Astropart. Phys. 2015, 042 (2015). [2] P. Hamilton, M. Jaffe, P. Haslinger, Q. Simmons, H. Müller, and J. Khoury, Atom-interferometry constraints on dark energy. Science 349, 849 (2015).