Q 68: Precision measurements and metrology V

Time: Friday 16:30–18:15 Location: DO24 1.101

Group Report Q 68.1 Fri 16:30 DO24 1.101

The GRACE Follow-On Laser Ranging Interferometer — •Alexander Görth — Max Planck Institut für Gravitationsphysik, Leibniz Universität Hannover, Deutschland

In the year 2017 a follow-on mission to the very successful joint German / NASA mission GRACE (Gravity Recovery And Climate Experiment) will be launched. The two GRACE satellites have been mapping the spatial and temporal variations of the Earth's gravitational field by satellite-to-satellite tracking for more than ten years now. While only a microwave ranging instrument has been used for this measurement in GRACE, an additional laser ranging interferometer (LRI) will be implemented into the architecture of the GRACE Follow-On satellites as a technology demonstrator. It is intended to verify the benefits of a laser-based measurement which is expected to eventually become the main science instrument in future geodesy missions. We will present the status of the development of the LRI as well as the latest results of experimental tests on sub-units of the LRI.

Q 68.2 Fri 17:00 DO24 1.101

Towards the Demonstration of a BEC-based Atom Interferomter in Space — •Stephan Tobias Seidel[1], Dennis Becker[1], Maike Lachmann[1], Ernst Maria Rasel[1], and The Quantus-Team[1,2,3,4,5,6,7,8] — [1]Institut für Quantenoptik, LU Hannove — [2]ZARM, Universität — [3]Institut für Physik, HU Berlin — [4]Institut für Laser-Physik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]MUARC, University of Birmingham — [8]FBH, Berlin

A central goal of modern physics is the test of fundamental principles of nature with ever increasing precision. One of these contains of a differential measurement on freely falling ultra-cold clouds of two atomic species and thus using atom interferometry to test the weak equivalence principle in the quantum domain. By performing such an experiment in a weightless environment the precision of the interferometer can be considerably increased.
Here we demonstrate an apparatus for the first realization of a Bose-Einstein-condensate on a sounding rocket and its use as a source for atom interferometry in space. Its planned launch in November 2014 will be an important step towards the goal of placing high-precision atom-interferometric measurement devices in space.

Q 68.3 Fri 17:15 DO24 1.101

High-precision phasemeter for the Deep Phase Modulation Interferometry — •Thomas S. Schwarze — Albert-Einstein-Institut Hannover

We present our results of the development of a dedicated-hardware modulation signal synthesis and phasemeter system for the Deep Modulation Interferometry technique. For this technique, a sinusoidal modulation is applied through a ring piezo-electric actuator to one arm of a Mach-Zehnder interferometer in order to reach large modulation depths in the order of 10 rad. The interferometer phase is extracted by a complex fit to the harmonic amplitudes of the modulation frequency. The presented system prototype uses a Direct Digital Synthesizer and a Digital Signal Processing core, both implemented on a Field Programmable Gate Array. The first allows generation and control of the modulation signal to drive the ring piezo-electric actuator. The latter computes the harmonic amplitudes by performing multiple single-bin discrete Fourier transforms. These amplitudes are subsequently transmitted to a PC via Ethernet to conduct the complex fit computations. The results obtained from a zero measurement with an optical signal revealed a phasemeter precision of 2.3 pm/rtHz below and 0.1 pm/rtHz above 10 Hz.

Q 68.4 Fri 17:30 DO24 1.101

Absolut distance interferometry based on a physical reference — •Günther Prellinger, Karl Meiners-Hagen, and Florian Pollinger — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

We present an absolute distance interferometer based on frequency-sweeping interferometry with an envisioned range of up to 100 m and a targeted measurement uncertainty well below 1E-6. We use in-situ high resolution spectroscopy to establish traceability with low uncertainty. The basic idea of frequency-sweeping multi-wavelength metrology is to vary the optical frequency over a known frequency interval for a fixed unknown distance in a classical interferometer. In our study, we investigated the use of a spectroscopic reference for the frequency measurement. Therefore, we combine the interferometric phase measurement with simultaneous Doppler-free iodine high resolution spectroscopy at 637 nm. This approach provides direct traceability of the distance measurement together with a lowered demand on environmental stability. The experimental results demonstrate that the relative uncertainty of the position (frequency) determination is approximately 3E-9. For the absolute distance measurement itself, a heterodyne interferometer with vibration compensation has been developed and simultaneous spectroscopic and interferometric measurements have been performed. The authors would like to acknowledge financial support by the Deutsche Forschungsgemeinschaft (DFG) under grant PO1560/1-1.

Q 68.5 Fri 17:45 DO24 1.101

Study of photoreceivers for space-based interferometry — •Germán Fernández Barranco — Albert-Einstein-Institut Hannover

The photoreceiver is a basic element in laser interferometry systems presented in space-based missions such as Lisa Pathfinder or GRACE-FO. The special requirements demanded by those systems rule out any commercial solution for the photoreceiver. Therefore, new photoreceiver designs have been developed and characterized in the Max Planck Institute for Gravitational Physics, Hannover, focusing the efforts on the bandwidth and noise performance. Additionally, a high-accuracy measurement system was configured to perform scans of the photodiodes' surface, which allow a real understanding of the spatial response of those devices.

Q 68.6 Fri 18:00 DO24 1.101

Precision measurements of temperature and chemical potential of quantum gases — Ugo Marzolino[1,2,3] and •Daniel Braun[3,4] — [1]Albert-Ludwigs-Universiät Freiburg, D-79104 Freiburg, Deutschland — [2]Univerza v Ljubljani, Jadranska 19, SI-1000 Ljubljana, Slovenija — [3]Laboratoire de Physique Théorique (IRSAMC), Université de Toulouse and CNRS, F-31062 Toulouse, France — [4]Institut für theoretische Physik, Universität Tübingen, 72076 Tübingen, Germany

We investigate the sensitivity with which the temperature and the chemical potential characterizing quantum gases can be measured. We calculate the corresponding quantum Fisher information matrices for both fermionic and bosonic gases. For the latter, particular attention is devoted to the situation close to the Bose-Einstein condensation transition, which we examine not only for the standard scenario in three dimensions, but also for generalized condensation in lower dimensions, where the bosons condense in a subspace of Hilbert space instead of a unique ground state, as well as condensation at fixed volume or fixed pressure. We show that Bose-Einstein condensation can lead to sub-shot-noise sensitivity for the measurement of the chemical potential. We also examine the influence of interactions on the sensitivity in three different models and show that meanfield and contact interactions deteriorate the sensitivity but only slightly for experimentally accessible weak interactions.