Q 62: Precision Measurements: Gravity II

Time: Friday 11:00–13:00 Location: E214

Q 62.1 Fri 11:00 E214

Optical Zerodur Bench Toolkit for the BECCAL Cold Atom Experiment — •Faruk Alexander Sellami[1], Jean Pierre Marburger[1], Esther del Pino Rosendo[1], André Wenzlawski[1], Ortwin Hellmig[2], Klaus Sengstock[2], Tim Kroh[3], Victoria Henderson[3], Patrick Windpassinger[1], and The MAIUS and BECCAL team[1,2,3,4,5,6,7,8,9,10,11] — [1]Institut für Physik, JGU, Mainz — [2]ILP, UHH, Hamburg — [3]Institut für Physik, HU Berlin, Berlin — [4]FBH, Berlin — [5]IQ & IMS, LUH, Hannover — [6]ZARM, Bremen — [7]Institut für Quantenoptik, Universität Ulm, Ulm — [8]DLR-SC, Braunschweig — [9]DLR-SI, Hannover — [10]DLR-QT, Ulm — [11]OHB-SE, Bremen

The NASA-DLR BECCAL experiment will be a facility for the study of BECs of rubidium and potassium atoms in the microgravity environment of the ISS. For the required laser light distribution and intensity control of several light fields to manipulate the atoms we use an optical bench toolkit based on the glass ceramic Zerodur, which has been already successfully operated in sounding rocket experiments. This material has a negligible coefficient of thermal expansion and can withstand the mechanical shocks during rocket launch as well as temperature and pressure fluctuations to guarantee a stable functionality during the multi-year duration aboard the ISS. Multiple tests of several prototypes are presented. Our work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50 WP 1433, 50 WP 1703 and 50 WP 2103.

Q 62.2 Fri 11:15 E214

An optical dipole trap in a drop tower - the PRIMUS-project — •Marian Woltmann[1], Christian Vogt[1], Sven Herrmann[1], Claus Lämmerzahl[1], and PRIMUS Team[1,2] — [1]University of Bremen, Center of Applied Space Technology and Microgravity (ZARM), 28359 Bremen — [2]LU Hannover, Institute of Quantum Optics

The application of matter wave interferometry in a microgravity (μg) environment offers the potential of largely extended interferometer times and thereby highly increased sensitivities in precision measurements, e.g. of the universality of free fall. While most microgravity cold atom experiments use magnetic trapping with an atom chip, the PRIMUS-project develops an optical dipole trap as an alternative source of ultracold atoms in a drop tower experiment. Solely using optical potentials offers unique advantages like improved trap symmetry, trapping of all magnetic sub-levels and the accessibility of Feshbach resonances. We demonstrated Bose-Einstein condensation of Rubidium in a compact setup on ground while now focusing on a fast, efficient preparation in microgravity using time-averaged optical potentials. Within this talk we will give an overview of the experiment and report on the current status and latest results. The PRIMUS-project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action under grant number DLR 50 WM 2042.

Q 62.3 Fri 11:30 E214

Atom interferometry in the transportable Quantum Gravimeter QG-1 — •Nina Heine[1], Pablo Nuñez von Voigt[1], Ludger Timmen[3], Waldemar Herr[2], Christian Schubert[2], Jürgen Müller[3], and Ernst M. Rasel[1] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Hannover, Germany — [2]Deutsches Zentrum für Luft und Raumfahrt, Institut für Satellitengeodäsie und Inertialsensorik, Hannover, Germany — [3]Leibniz Universität Hannover, Institut für Erdmessung, Hannover, Germany

The transportable Quantum Gravimeter QG-1 is based on the principle of atom interferometry with collimated Bose-Einstein condensates to determine the local gravitational acceleration aiming for an unprecedented level of accuracy $<3\,\mathrm{nm/s^2}$. This talk elaborates on the design and implementation of the interferometry setup into the atom chip based experimental system. An introduction to the measurement concept and studies of the interferometer performance will be presented and put into perspective with perfomance estimates for given experimental parameters.

We acknowledge financial funding by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 434617780 - SFB 1464 and under Germany's Excellence Strategy - EXC 2123 QuantumFrontiers, Project-ID 390837967.

Q 62.4 Fri 11:45 E214

The Hannover Torsion Balance - a test platform for novel inertial sensing concepts — •Christoph Gentemann[1,2], Gerald Bergmann[2,1], Carolin Cordes[1,2], Gerhard Heinzel[2,1], Moritz Mehmet[2,1], and Karsten Danzmann[2,1] — [1]Leibniz Universität Hannover — [2]Max Planck Institute for Gravitational Physics

Current satellite geodesy missions such as GRACE Follow-On are limited at low frequencies by the noise of their accelerometers. These sensors measure non-gravitational accelerations with free-floating test masses in a capacitive housing through capacitance changes. To test new and more sensitive accelerometer designs a setup is desirable that simulates the force-free environment of space in the laboratory.

Suitably designed torsion pendulums can provide such a test bed, since their rotational motion can be designed to have a low resonance frequency and therefore behave approximately force-free in one dimension above said frequency.

In this talk I will present the Hannover Torsion Balance (HTB), which aims at providing a high precision test platform to investigate new optical readout techniques for test mass motion such as deep frequency modulation interferometry. The current status, including test mass sensing and control, will be discussed. In our laboratory these two things are currently based on electrostatic readout and feedback, to provide a sensible comparison with the space-based accelerometers.

Future upgrades to laser interferometric readout of the sensitive degree of freedom will also be discussed.

Q 62.5 Fri 12:00 E214

Deep Frequency Modulation Interferometry for test mass readout — •Stefano Gozzo — Albert Einstein Institute Hannover

The new generation of space-based experiments for gravitational wave detection and geodesy comes with a number of technological challenges. The design of future space-based interferometers will have to comply with sub-pm/*Hz sensitivity requirements at low frequencies while providing multi-fringe dynamic range and minimizing the complexity of the optical set up configuration.

The Deep Frequency Modulation Interferometry (DFMI) technique aims at simplifying the standard interferometric readout by replacing it with an exclusively digital phasemeter. An introduction to the DFMI technique will be given in this talk.

While DFMI allows to reduce the amount of optical component, space-based gravity field recovery missions usually require a two interferometer set up. The unequal length arm nature of space-based interferometers makes them sensitive to frequency noise, so that an additional interferometer for frequency stabilization purposes is needed. In order to minimize the complexity of such an optical set up, we developed a Single Element Double Interferometer (SEDI) design. A single piece optical element hosts an unequal armlength interferometer probing the position of a test mass and an internal reference interferometer.

The combination of a SEDI with a DFMI readout is a promising scheme to achieve minimal optical complexity while complying with the initial sensitivity goal, and its performances are currently being tested in the AEI Hannover laboratories.

Q 62.6 Fri 12:15 E214

Experimental Results on Cavity-Laser-Locking for Future Gravimetric Satellites — •Martin Weberpals, Vitali Müller, Malte Misfeldt, and Gerhard Heinzel — Max Planck Institute for Gravitational Physics, Hannover, Germany

The precise measurement of satellite distance variations in a low earth orbit can reveal the structure of Earth's gravity field, which is directly related to the mass distribution underneath the satellites.

The satellite pairs GRACE (2002-2017) and GRACE Follow-On (2018-) provided monthly maps of Earth's gravity field, which are extremely valuable for climate research and the understanding of mass redistribution processes on Earth. Future missions, in which laser interferometry will be the primary means of determining the inter-satellite range, are currently being prepared.

In this presentation, we give a short overview on the heterodyne laser instrument concept and address our experimental activities conducted so far in supporting European instrument development. We show our setup for achieving a classical Pound-Drever-Hall (PDH) lock, based on commercial RedPitaya devices as an initial stage. We also present the status of our work on an extension to the PDH lock, allowing us to read out the free spectral range of a cavity. This measurement can be used to calculate the absolute laser frequency, which is required to convert ranging phase data into biased inter-satellite distance. In the end, we show how these activities contribute to the development of European Instrument Control Electronics potentially to be used in future missions.

Q 62.7 Fri 12:30 E214

High-Power Laser Beam in Higher-Order Hermite-Gaussian Modes — •Benjamin von Behren[1], Joscha Heinze[2], Nina Bode[1], and Benno Willke[1] — [1]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) and Leibniz Universität Hannover, 30167 Hannover, Germany — [2]School of Physics and Astronomy, University of Birmingham, Birmingham B15 2TT, United Kingdom

The sensitivities of current gravitational-wave detectors are limited around signal frequencies of 100Hz by mirror thermal noise. One proposed option to reduce this thermal noise is to operate the detectors in a higher-order spatial laser mode. This operation would require a high-power laser input beam in such a spatial mode. Here, we discuss the generation of the Hermite-Gaussian modes HG3,3, HG4,4 and HG5,5 using one water-cooled spatial light modulator (SLM) at a continuous-wave optical input power of up to 85W. We report unprecedented conversion efficiencies for a single SLM of about 43%, 42% and 41%, respectively, and demonstrate that the SLM operation is robust against the high laser power. This is an important step towards the implementation of higher-order laser modes in future gravitational-wave detectors.

Q 62.8 Fri 12:45 E214

Laser Welding the 100 g Mirrors for the AEI 10 m Prototype Suspensions with Micrometer Precision — •Juliane von Wrangel[1,2], Steffen Böhme[3], Matteo Carlassara[1,2], Gerd Harnisch[3], Firoz Khan[1,2], Philip Koch[1,2], Tobias Koch[3], Johannes Lehmann[1,2], Harald Lück[1,2], Janis Wöhler[1,2], and David S. Wu[1,2] — [1]Leibniz Universität Hannover — [2]Max-Planck-Institut für Gravitationsphysik, Hannover — [3]Fraunhofer-Institut für Angewandte Optik und Feinmechanik, Jena

The 10 m Prototype facility of the Albert-Einstein-Institute Hannover will measure and surpass the Standard Quantum Limit (SQL) by constructing the Sub-SQL Interferometer in a gravitational wave detector (GWD) like configuration. Compared to a full scale GWD, the 100 g test mass mirrors are relatively lightweight to enhance the quantum radiation pressure noise. To isolate these mirrors seismically, they are designed as triple suspensions. The last pendulum stage is quasi-monolithic to suppress suspension thermal noise. This final stage consists of four 20 um thin glass fibers laser welded to each of the mirrors. The welding procedure needs to be done with micrometer precision due to the small dimensions of the layout to ensure the suspended mirrors to be straight within a pitch angle of < 10 mrad.

In cooperation with the Fraunhofer Institute for Applied Optics and Precision Engineering in Jena, a semi-automated fiber welding machine was designed. For this setup, a CO2 laser is used to cleave and weld the glass fibers with the desired precision. In the future, this technique will also be applicable to other mirror suspensions of similar dimensions.