Q 41: Precision measurements and metrology I

Time: Thursday 14:00–16:00 Location: DO24 1.101

Group Report Q 41.1 Thu 14:00 DO24 1.101
Technology development in Hannover for the space-based gravitational wave detector LISA — •Michael Tröbs, Simon Barke, Iouri Bykov, Oliver Gerberding, Jan-Simon Hennig, Katharina Isleif, Maike Lieser, Jens Reiche, Sönke Schuster, Gerhard Heinzel, and Karsten Danzmann — AEI Hannover

The Laser Interferometer Space Antenna (LISA) is a future space-based gravitational wave detector consisting of three satellites. LISA shall act as a Michelson interferometer and measure distance variations between free-floating test masses inside the satellites.

We give a brief overview on programmatics and report on work performed in Hannover on the main optical instrument (the optical bench) comprising the interferometers, the electronic device to read out the phase changes (the phasemeter) and the phase reference between two optical benches on a spacecraft (backlink).

Q 41.2 Thu 14:30 DO24 1.101
Vorschlag für die Messung der Erdbeschleunigung mit Antiwasserstoff — •Sebastian Wolf und Ferdinand Schmidt-Kaler — Johannes Gutenberg-Universität, Mainz, Deutschland

Die Symmetrie von Materie und Antimaterie ist eine der aktuellsten Fragen in der Physik. Experimentell weitgehend ungeklärt ist die gravitative Wechselwirkung von Antimaterie. Bei geladenen Teilchen wird jeglicher Einfluss der Gravitation durch weit stärkere Coulombkräfte überdeckt, andererseits lassen sich ungeladene Antimaterie Teilchen für Fall-Experimente nicht ausreichend kühlen [1]. In der GBAR-Kollaboration [2] arbeiten wir an einem Fall-Experiment mit Antiwasserstoff. Im ersten Schritt werden am ELENA/AD-Ring (CERN) positiv geladene Antiwasserstoffionen ($\bar{\mathrm{H}}^+$) erzeugt, in einer Paulfalle gefangen und mitfühlend mit $^9\mathrm{Be}^+$- Ionen in den Grundzustand der Bewegung gekühlt. Das Laser-induzierte Abtrennen des Positrons startet das Fall-Experiment bei dem die Gravitationsbeschleunigung auf 1 % genau gemessen werden soll [3,4]. Wir berichten über den Stand des experimentellen Aufbaus.

[1] The ALPHA Collaboration, Nat. Comm. **4**, 1785 (2013).
[2] http://gbar.in2p3.fr/
[2] Dufour et al, to be published
[3] Pérez et al, Class.Quantum Grav. **29**, 184008 (2012).

Q 41.3 Thu 14:45 DO24 1.101
Testing the breadboard model of the LISA Phasemeter — •Oliver Gerberding, Simon Barke, Nils Brause, Ioury Bykov, Karsten Danzmann, Gerhard Heinzel, Joachim Kullmann, Jens Reiche, and Thomas Schwarze — Max-Planck Institut für Gravitationsphysik (Albert Einstein Institut) und Institut für Gravitationsphysik der Leibniz Universität Hannover

The planned space-born gravitational wave detector LISA will allow to detect gravitational waves at frequencies between 0.1 mHz and 1 Hz. It uses precision heterodyne laser interferometry as main measurement technology. A breadboard model for the phase readout system of these interferometers (Phasemeter) has been developed in the scope of an ESA technology development project by a collaboration between the Albert-Einstein Institute, the Technical University of Denmark and the Danish industry partner Axcon Aps. The breadboard is designed to demonstrate all functions for operating a complete LISA-like metrology system, to meet all performance requirements for a future mission and to study the effort of bringing the design to space qualification. Here we will present a system overview and the results of a comprehensive testing campaign. This includes phase readout of signals between 2 and 25 MHz with 1 microcycle/sqrt(Hz) performance, clock noise transfer, inter-satellite ranging and communication, laser frequency control and acquisition. In addition we present an optical non-linearity test that we use to validate the performance of the full metrology chain by aiming to demonstrate the for LISA necessary dynamic range of 10 orders of magnitude at low frequencies.

Q 41.4 Thu 15:00 DO24 1.101
Gravimetric atom interferometer (GAIN): towards mobile absolute gravity measurements — •Christian Freier, Matthias Hauth, Vladimir Schkolnik, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

GAIN (Gravimetric Atom Interferometer) is a mobile atom gravimeter, based on interfering ensembles of laser cooled 87Rb atoms in an atomic fountain configuration. It is specifically designed to show the potential of atom interferometry for mobile gravity measurements in the context of geodesy and geophysics.

We report on recent measurements comparing our atom gravimeter with a state-of-the-art falling corner cube gravimeter and with a super-conducting relative gravimeter. The latter was conducted at the geodetic observatory in Wettzell, demonstrating the mobility and robustness of our set-up.

We achieved a sensitivity of 1×10^{-8}g/shot with no observable instrumental drift. The derived absolute value of g agrees with the expected number up to a level of 10^{-8}g. A thorough analysis and/or elimination of systematic effects is currently underway to significantly improve the absolute accuracy in the near future.

Q 41.5 Thu 15:15 DO24 1.101
Simulation and Optimisation of Laser Interferometers — •Christoph Mahrdt, Evgenia Kochkina, Vitali Müller, Sönke Schuster, Benjamin Sheard, Gudrun Wanner, and Gerhard Heinzel — Max-Planck-Institut für Gravitationsphysik, Hannover

In this talk the main work on interferometer design will be presented which is carried out at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) in Hannover for the space missions such as the Laser Interferometer Space Antenna (LISA), LISA Pathfinder and a planned successor to the Gravity Recovery and Climate Experiment (GRACE) called GRACE Follow-On. Simulations for the laser interferometers of the aforementioned projects are used to investigate noise coupling mechanisms such as tilt-to-length coupling and to study the dependence of their coupling coefficients on misalignments of optical components. Furthermore, simulations are performed to optimise the interferometer design by developing imaging optics that mitigate tilt-to-length coupling or minimise the effect of stray light. The main tool for these simulations is IfoCad (www.geo600.uni-hannover.de/ifocad/), a software library that is being developed at the Albert Einstein Institute in Hannover since 2008. IfoCad includes routines for Gaussian beam tracing in 3D optical systems, photodiode signal computation, sophisticated optimisation routines and various beam types such as general astigmatic Gaussian beams or higher-order Gaussian modes. The current development focuses on including polarisation and diffraction effects. In this talk IfoCad will be introduced and results for important applications will be presented.

Q 41.6 Thu 15:30 DO24 1.101
Precision measurements with Gaussian and non-Gaussian states — •Daniel Braun[1,2], Claude Fabre[3], Pu Jian[3], Olivier Pinel[4], and Nicolas Treps[3] — [1]Laboratoire de Physique Théorique, Universit *e Paul Sabatier and CNRS, 31062 Toulouse, France — [2]Institut für theoretische Physik, Universität Tübingen, 72076 Tübingen, Germany — [3]Laboratoire Kastler Brossel, Université Pierre et Marie Curie-Paris 6, ENS, CNRS, 75252 Paris, France — [4]Centre for Quantum Computation and Communication Technology, Department of Quantum Science, The Australian National University, Canberra, ACT 0200, Australia

We calculate the quantum Cramér-Rao bound for the sensitivity with which parameters encoded in general single-mode (possibly mixed) Gaussian states, or non-Gaussian states obtained by photon-addition or -subtraction can be measured. We apply the formula for the Gaussian state to the problems of estimating phase, purity, loss, amplitude, and squeezing and provide the full quantum Fisher information (QFI) matrix for simultaneous measurement of several parameters. Our results unify previously known partial results and constitute a complete solution of the problem. For the photon-subtracted state, we show that the QFI diverges in the limit of no squeezing and almost no photons, which enable in principle arbitrarily precise measurements with essentially no light. However, this divergence is cancelled by the decaying success probability of the preparation scheme. In the limit of large photon numbers N, the non-classicality of the light only leads to a relative correction of order $1/N$.

Q 41.7 Thu 15:45 DO24 1.101
Cryogenic Sapphire Optical Cavities — •Moritz Nagel, Klaus Döringshoff, Sylvia Schikora, Evgeny V. Kovalchuk, and Achim

Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

We present the status of our work on an ultra-stable cryogenically cooled sapphire optical cavity system, with a prospective thermal noise limited frequency stability better than $3 \cdot 10^{-17}$. These cavities will be used in a high-precision experiment, which will test Lorentz invariance within the 10^{-20} regime.