Q 28: Precision Measurements and Metrology (Gravity)

Time: Wednesday 11:00–12:45 Location: f435

Q 28.1 Wed 11:00 f435

Fundamental investigation of micro-optomechanical devices for quantum measurements — •Mariia Matiushechkina[1,2,3,4], Bernd Schulte[1,2,3], Roman Kossak[1,2], and Michèle Heurs[1,2,3,4] — [1]Leibniz Universität Hannover, Institut für Gravitationsphysik — [2]Max Planck Institut für Gravitationsphysik — [3]QuantumFrontiers — [4]PhoenixD

The sensitivity of future generations of gravitational wave detectors (GWDs) is limited by quantum fluctuations. Quantum Radiation Pressure Noise (RPN) will soon limit the low-frequency sensitivity of interferometric GWDs. A proposed technique to reduce quantum RPN is called Coherent Quantum Noise Cancellation (CQNC) where a tailored quantum state of light couples to a mechanical system. A table-top realisation of the experiment helps to improve and investigate different parts of the set-up. It is essential to understand the basic principles of operation of the optomechanical devices to be able to modify and implement them properly in precise quantum measurements. Other noise sources, such as thermal noise, can mask quantum RPN. The realisation of their origin and numerical calculation of their power spectral densities will make it possible to reduce their influence on the optomechanical system. To model the system and to simulate applied forces, changes in temperature and initial conditions we use COMSOL Multiphysics software based on a Finite Element Method (FEM). We present our investigations into topology, mechanical properties, thermal and optical effects in the high-Q Si3N4 membranes for implementation in quantum noise cancellation experiments.

Q 28.2 Wed 11:15 f435

Gravitational Influence on Earth-based Laser Cavity Experiments — •Sebastian Ulbricht[1,2], Johannes Dickmann[1,2], Robert A. Müller[1,2], Stefanie Kroker[1,2], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Germany — [2]Technische Unversität Braunschweig, Germany

Modern laser cavities with highly reflective mirrors are essential to the nowadays most accurate measurement devices, e.g. optical clocks, high resolution spectroscopy lasers and gravitational wave detectors. Due to the increasing demand for precision in these experiments, the stability of laser cavities underwent a tremendous improvement during the last decades. However, they are not operated in an isolated environment, but in the gravitational field of the Earth. Therefore, in this contribution, we consider the influence of Earth's gravity on laser stabilization cavities. We theoretically investigate the dynamics of electromagnetic waves in Rindler spacetime and give an analytical expression for Gaussian beams, propagating in a homogeneous gravitational field. This result is then used to obtain the output signal of a Fabry-Pérot cavity on Earth. According to our results, gravity causes changes in the intensity profile at the cavity output. Possible scenarios to measure this effect are discussed for three existing cavity settings.

Q 28.3 Wed 11:30 f435

A phase reference distribution system for LISA: Building the optical benches of the Three-Backlink Experiment — •Nicole Knust, Lea Bischof, Stefan Ast, Max Rohr, Daniel Penkert, Juliane von Wrangel, Katharina-Sophie Isleif, Oliver Gerberding, Karsten Danzmann, and Gerhard Heinzel — Leibniz Universität Hannover, Institute for Gravitational Physics, Max Planck Institute for Gravitational Physics, Albert Einstein Institute, Callinstr. 38, 30167 Hannover, Germany

LISA is planned to be a space-based observatory for gravitational waves. It will consist of three satellites arranged in a triangle, connected via laser links. To compensate the breathing of the angles between these links, each spacecraft contains two optical benches that can be actuated by so-called moving optical sub-assemblies. For exchanging the phase between both benches a flexible bi-directional link is necessary. The Three-Backlink Experiment is currently build to test different designs for such a phase reference distribution system. Beam tracing simulations using the C++ library IfoCAD were done for optimizing the set-up in terms of mitigation of spurious light. A fiber connection will be compared to a steered free beam and a fiber backlink, which is utilizing additional frequencies for the light exchange. To ensure stability and precise adjustments, the optical components are glued to the base plates. A pair of calibrated quadrant photo diodes is used in combination with a coordinate measurement machine to build the complex set-up. The talk will cover the construction process as well as results of the characterization of one of the benches.

Q 28.4 Wed 11:45 f435

Optical Metrology Terminal for Satellite-to-Satellite Laser Ranging — •Paul Koschmieder[1,2], Oliver Mandel[1,2], Michael Chwalla[1], Thilo Schuldt[2,3], Jasper Krauser[1], Dennis Weise[1], and Claus Braxmaier[2,3] — [1]Airbus Defense and Space GmbH, 88090 Immenstaad, Germany — [2]Universität Bremen, Zentrum für Angewandte Raumfahrttechnologie und Mikrogravitation (ZARM), 28359 Bremen, Germany — [3]Institut für Raumfahrtsysteme, Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), 28359 Bremen, Germany

Interferometric laser ranging is an enabling technology for high-precision satellite-to-satellite tracking within the context of earth observation, gravitational wave detection, or formation flying. Here we report on the design, setup and initial performance verification of a compact monostatic interferometric measurement terminal, set up in quasi-monolithic fashion. The design was driven by parameters such as orbit dynamics, inter-satellite distance and placement of the platform within a satellite deduced from earlier satellite missions and mission studies. A dedicated optical metrology test environment was set up, confirming the potential of the terminal to measure with nanometer accuracy. Furthermore, concepts for an end-to-end test of an inter-satellite optical metrology link are developed. This test will contain thermal and vacuum testing, as well as a simulation of in-orbit satellite dynamics and its effect on the link. This project received financial support from DLR and BMWi under grant number 50EE1407 and 50EE1409.

Q 28.5 Wed 12:00 f435

Development of a micro-integrated, crossed-beam optical dipole trap setup for integrated atomic quantum sensors — •Marc Christ[1,2], Anne Stiekel[1,2], and Markus Krutzik[1,2] — [1]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [2]Institut für Physik, Humboldt-Universität zu Berlin

Although generation, manipulation and detection of ultra-cold atomic matter has been demonstrated in prototypes operating in field and space environments, the transfer of these techniques into further miniaturized systems with less complexity remains an major technological challenge. One approach to reduce the size of a BEC-based sensor is to integrate optical systems within the vacuum system. This demands ultra-stable and ultra-high vacuum (UHV) compatible components and integration technologies with high mechanical and thermal resilience and alignment precision. To address UHV-compatibility, we set up a versatile qualification apparatus, enabling residual gas analysis and measurements of total gas rates down to estimated $5 \cdot 10^{-10}$ mbar l/s. A prototype design of an UHV-compatible, crossed beam optical dipole trap setup for Rubidium operating at 1064 nm, its application within a atom-chip based quantum sensor and our technology qualification efforts are described. In addition, our current work on a micro-integrated demonstrator setup for first tests with cold atoms is presented.
This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant number DLR 50WM1648, 50WM1949 and 50RK1978.

Q 28.6 Wed 12:15 f435

Suitable optomechanical oscillators for an all optical coherent quantum noise cancellation exeriment — •Bernd Schulte[1,2], Daniel Steinmeyer[1,2], Mariia Matiushechkina[1,2,3], Margot Hensler Hennig[1,2], and Michèle Heurs[1,2,3] — [1]Max Planck Institute for Gravitational Physics and Institute for Gravitational Physics, Hannover, Germany — [2]Quantum Frontiers — [3]PhoenixD

Optomechanical detectors have reached the standard quantum limit in position and force sensing where backaction noise, caused by radiation pressure noise, starts to be the limiting factor for sensitivity. One strategy to circumvent measurement backaction, and surpass the standard quantum limit, has been suggested by M. Tsang and C. Caves [1] and is called Coherent Quantum Noise Cancellation (CQNC). This scheme can be viewed as coupling a second oscillator with an effectively negative mass (see J. Junker) to the one subject to quantum radiation pressure noise and thus realizing a quantum non-demolition measurement. After an introduction of the idea and the requirements for CQNC this talk will be focused on the oscillator susceptible to quantum radiation pressure noise. A Michelson interferometer was used for characterisation of the mechanical linewidth and resonance frequency of the oscillator. We discuss the measurement principles intended to determine mechanical and optical properties of our devices (membrane-in-the-middle vs. membrane-at-the-end setup). These setups could also be used to shift the mechanical properties via the optical spring effect to satisfy CQNC requirements. [1] M. Tsang and C. Caves, Phys. Rev. Lett. 105 ,123601, 2010.

Q 28.7 Wed 12:30 f435

Effective negative-mass oscillator for coherent quantum noise cancellation — •Jonas Junker[1,2,3], Daniel Steinmeyer[1,2,3], Dennis Wilken[1,2,3], and Michèle Heurs[1,2,3] — [1]Max Planck Institute for Gravitational Physics, and Institute for Gravitational Physics, Germany — [2]QuantumFrontiers — [3]PhoenixD

In opto-mechanical measurements, like in gravitational wave detectors, quantum radiation pressure noise is one of the fundamental limitations of low-frequency sensitivity. The concept of coherent quantum noise cancellation proposes to add an effective negative-mass oscillator to such a measurement system. Thus, the back-action effect caused by the quantum radiation pressure can ideally be evaded and the standard quantum limit is surpassed. In our all-optical setup, the negative-mass oscillator is implemented by a detuned optical cavity that is coupled via a beam splitter and a down conversion interaction to the light field. It needs to be matched in resonance frequency, damping and coupling strengths to the measurement system. We present the theoretical background of coherent quantum noise cancellation. Additionally, we show for which realistic conditions the negative-mass oscillator can reduce back-action noise introduced by a positive mass micromechanical oscillator (see contribution by Bernd Schulte). We explain the setup of our negative-mass oscillator consisting of a five-mirror cavity where both polarisation modes are coupled by a wave-plate as beam splitter interaction. A nonlinear crystal is placed in the cavity; this is a polarisation non-degenerate two-mode squeezing process. We will present the current status of the experiment and planned next steps.