Q 9: Precision Measurements and Metrology II

Time: Monday 16:30–18:15 Location: Q-H11

Invited Talk Q 9.1 Mon 16:30 Q-H11

Rotation sensors for planet Earth: Introducing ring laser gyroscopes — •Simon Stellmer[1], Oliver Heckl[2], and Ulrich Schreiber[3,4,5] — [1]Rheinische Friedrich-Wilhelms-Universität Bonn, Germany — [2]Universität Wien, Austria — [3]Technische Universität München, Germany — [4]University of Canterbury, Christchurch, New Zealand — [5]Fundamentalstation Wettzell, Bad Kötzting, Germany

The rotation rate of Earth is not as constant as it may seem: in fact, it is perturbed by various effects, ranging from astronomical and atmospheric phenomena all the way to anthropogenic climate change.

Very-long baseline interferometry (VLBI) is a well-established and highly precise method to access the rotation of Earth, but VLBI is not well-suited for continuous monitoring at high temporal resolution. This is where ring laser gyroscopes enter the stage.

In this presentation, we will introduce the working principle of ring lasers and their application in geodetic observations. We will present the latest developments and future concepts that will allow for continuous tracking of sub-daily variations in the Earth rotation rate. Such observations are in high demand in the fields of radioastronomy, geodesy, and geophysics.

Q 9.2 Mon 17:00 Q-H11

Precision and readout algorithms of DFM-interferometry — •Tobias Eckhardt — Universität Hamburg, Hamburg, Germany

We present our work on the readout of compact displacement sensors based on deep-frequency modulation interferometry. We aim to use such sensors for the local readout of test-masses in future gravitational wave detectors. We show the results of a readout noise analysis for such sensors where we derive their limitations by computing the Cramer-Rao lower bound of their phase estimator in the presence of common noise sources. Additionally we discuss a new algorithm to extract the interferometric phase in deep-frequency-modulation interferometry in a fast and non-recursive way. Finally, we present the status of implementing such an algorithm using real-time FPGA processing.

Q 9.3 Mon 17:15 Q-H11

Investigation of Photoelastic Noise in Einstein Telescope — •Jan Meyer[1,2], Stefanie Kroker[1,2,3], Mika Gaedtke[2,4], and Johannes Dickmann[1,2,3] — [1]TU Braunschweig, Institut für Halbleiterphysik, Germany — [2]LENA Laboratory for Emerging Nanometrology, Braunschweig, Germany — [3]Physikalisch-Technische Bundesanstalt, Braunschweig — [4]Leibniz Universität Hannover, Hannover, Germany

Since the first direct detection of gravitational waves in 2015, the research in the field of interferometric gravitational wave detectors underwent a decisive progress. The second generation of the Laser Interferometer Gravitational-Wave Observatory (Advanced LIGO) and Advanced VIRGO utilizes pioneering noise reduction techniques like squeezing of light to reach sensitivities of better than 1E-23. The most critical noise sources limiting this precision are driven by thermal fluctuations in the optical components. To ensure that future gravitational wave detectors can reach their best possible sensitivity, all noise sources have to be investigated. In this contribution, we quantify photoelastic fluctuations in solids as a noise source in Einstein Telescope (ET). The local variations of the stress caused by thermal fluctuations lead to fluctuations of the refractive index due to the photoelastic material property. We present calculations of the photoelastic noise in the beam splitter and the input test mass of the ET. We show that the amplitude of the photoelastic noise in the ET low-frequency detector is about four orders of magnitude below the maximum design sensitivity and five orders of magnitude below that of the ET high-frequency detector.

Q 9.4 Mon 17:30 Q-H11

High-reflective Si metamaterial coating for 1550 nm — •Mariia Matiushechkina[1], Andrey Evlyukhin[2], Boris Chichkov[2], and Michèle Heurs[1] — [1]Institute for Gravitational Physics, Leibniz Universität Hannover, Callinstr. 36, 30167 Hannover, Germany — [2]Institute of Quantum Optics, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Modern quantum experiments require systems with unique mechanical and optical properties that would be able to operate at the quantum regime. One particular possible implementation is a high-reflective at the wavelength 1550 nm substrate that will be kept at cryogenic temperature for the purpose to increase sensitivity in the future gravitational wave detectors. We suggest a design of a system that exposes not only high mechanical properties but also high-reflectivity due to the metamaterial surface on the top. The metasurface is made from periodically arranged silicon nano-spheres placed on a sapphire substrate that coming into the Mie-resonance with the incident light. We theoretically and numerically investigate the functionality of such metasurface and study the influence of structural and dimensional imperfections on the optical properties.

Q 9.5 Mon 17:45 Q-H11

Frequency-Dependent Squeezing from a Squeezer — •Jonas Junker[1,2,3], Nived Johny[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 force measurements, quantum back-action noise fundamentally limits the measurement sensitivity at low frequencies. To reduce or even evade back-action noise, several techniques have been proposed, e.g. the injection of squeezed light. When the squeezed sidebands have a frequency-dependent phase difference the noise can be likewise reduced in a broad frequency band. However, for a full back-action evasion, an inversely input squeezed state [1] serving as an effective negative mass oscillator can be used [2]. This state calls not only for a frequency-dependent squeezing phase but also for a frequency-dependent squeezing factor. In our talk, we present the idea of using a detuned optical-parametric oscillator (OPO) to generate this needed state. We briefly show how we have realized and experimentally controlled our detuned OPO. We reconstruct the output state of this squeezer with quantum tomography for different measurement frequencies. This allows to even visually demonstrate and analyze the frequency-dependent state rotation. Our system seems to be applicable as a non-ideal, but very simple effective-negative mass oscillator applicable in opto-mechanical force measurements limited by back-action noise. [1] Kimble et al. Phys. Rev. D65, 022002 (2001) [2] Wimmer, Steinmeyer, Hammerer, and Heurs, Phys. Rev. A89,053836 (2014)

Q 9.6 Mon 18:00 Q-H11

Suitable optomechanical oscillators for an all optical coherent quantum noise cancellation epxeriment — •Bernd Schulte[1,2], Roman Kossak[1,2], Nived Johny[1,2], Mariia Matiushechkina[1,2,3], 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. We discuss and show 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.