A 51: Precision measurements and metrology VI (with Q)

Time: Friday 14:00–15:45 Location: E 001

A 51.1 Fri 14:00 E 001

A long reference cavity with contribution from thermal noise to frequency instability of below 10^{-16} — •Sebastian Häfner, Stefan Vogt, Stephan Falke, Christian Lisdat, and Uwe Sterr — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

The stability of current optical clocks is limited through the short-term stability of the interrogation laser. Here, we will focus on the reference cavity of the clock laser system, whose mechanical length stability provides the frequency stability of the clock laser. The length stability of well designed and operated cavities is limited by the Brownian motion of the materials, especially of the mirrors. This influence can be reduced by using longer cavities at the cost of a higher sensitivity to vibrations and more difficult thermal control.

Our laser system uses a 47.7 cm long ULE high finesse cavity which is to our knowledge the longest cavity ever used for frequency stabilization of a laser, with expected frequency instability from thermal noise of $\Delta\nu/\nu = 8 \cdot 10^{-17}$. We have designed a new cavity mounting which shows a measured acceleration sensitivity of $\Delta l/l = 4 \cdot 10^{-11}/g$ and a precision temperature control system with expected temperature instability of below 10 μK. To fully benefit from the cavities stability, we are planing to control all fluctuations of the optical path length from the end mirror of the cavity to the experiment. This work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and EU through the Space Optical Clocks (SOC2) project.

A 51.2 Fri 14:15 E 001

Laser ranging for GRACE follow-on — •Daniel Schütze, Gunnar Stede, Vitali Müller, Alexander Görth, Oliver Gerberding, Christoph Mahrdt, Benjamin Sheard, Gerhard Heinzel, and Karsten Danzmann — Max Planck Institute for Gravitational Physics / Albert Einstein Institute Hanover

The joint NASA/DLR mission GRACE (Gravity Recovery and Climate Experiment) successfully collects data about spatial and temporal variations in the gravity field of the earth using satellite-to-satellite tracking via microwave ranging. A GRACE follow-on mission will be launched in 2017. In addition to the conventional microwave ranging system, the GRACE follow-on satellites will also contain a laser ranging instrument to improve the inter-satellite distance measurements. This laser ranging instrument employs heterodyne interferometry with a receiver-transponder principle and phasemeter readout making use of LISA technologies. Essential parts of the laser ranging instrument are a triple mirror assembly to establish an off-axis roundtrip path between the satellites and a steering mirror setup to account for satellite pointing. A laboratory test setup of the GRACE follow-on interferometer is presented with which these key components are tested.

A 51.3 Fri 14:30 E 001

General Astigmatic Gaussian Beam Model — •Evgenia Kochkina, Dennis Schmelzer, Gudrun Wanner, Gerhard Heinzel, and Karsten Danzmann — Albert Einstein Institute, Hannover

Optical simulations for space interferometers require accurate beam models in order to predict all interesting effects. In many cases circular or elliptical (simple astigmatic) Gaussian beams are sufficient. When a beam is transformed (reflected or refracted) at a curved interface the plane of incidence is defined by the beam direction and the local normal vector to the interface at the point of incidence. This definition is purely geometrical and doesn't account for physical beam properties, such as intensity or phase distribution. If we assume that the transformed beam is elliptical, we need one of it's semi-axes to lie in plane of incidence in order to use simple astigmatic beam model. In a general 3D case it's not necessarily true. When both semi-axes of the beam ellipse do not lie in the plane of incidence, beam transformations can be described using the general astigmatic Gaussian beam model. Such beams have been described in the literature. To our knowledge however there is no available software implementation or a complete general astigmatic Gaussian model description. We will report on our investigations of the general astigmatic Gaussian beam model, it's implementation in the software and the experiments to verify the simulation results.

A 51.4 Fri 14:45 E 001

Ultra-stable 39.5 cm long optical cavity with reduced thermal noise — •Sana Amairi and Piet O. Schmidt — QUEST, PTB, Braunschweig , Germany

We are currently setting up an aluminium quantum logic optical clock. $^{27}Al^{+}$ has been chosen as the clock ion since it has a narrow 8 mHz clock transition at 267 nm which exhibits no electric quadruple shift and a low sensitivity to black-body radiation. The $^{27}Al^{+}$ clock ion is be trapped together with a $^{40}Ca^{+}$ ion which is used for sympathetic cooling and internal state detection of the clock ion. The quantum projection noise limited stability $\sigma_y(\tau)$ for Al^{+} is in the order of $1 \times 10^{-16}/\sqrt{\tau}$. This stability can only be achieved with an interrogation laser with a sufficiently small linewidth, thermal noise-limited instability and drift. The dominant thermal noise contribution to relative frequency instability in state-of-the art optical cavities comes from the mirror coatings. It scales with the inverse length of the cavity and the inverse square of the laser beam radius on the mirrors, which also increases with the length. Therefore, we have set up a long (39.5 cm) ultra-stable optical cavity made of a ULE spacer and fused silica mirrors. We have performed finite element simulations to estimate a thermal noise limited instability of 7×10^{-17} for such a cavity [1]. Furthermore, we have performed numerical simulations to find optimum support points together with allowed machining tolerances and required force balancing. Besides theoretical estimates, we present first experiments towards the characterization of the cavity. Ref[1]:ArXiv:submit/0614173

A 51.5 Fri 15:00 E 001

Digital unterstützte heterodyn Interferometrie — •Katharina-Sophie Isleif, Sina Köhlenbeck, Oliver Gerberding, Stefan Gossler, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationspyhsik und Institut für Gravitationsphysik der Universität Hannover, Callinstraße 38, 30167 Hannover, Deutschland

Heterodyne Laserinterferometrie ist eine der wichtigsten Technologien für präzise Längenänderungsmessungen, die bereits bei den Missionen LISA und LISA Pathfinder zur Anwendung kommt. Digital unterstützte heterodyne Interferometrie ist eine Erweiterung hiervon. Hier wird eine digital erzeugte binäre Pseudozufallszahlenfolge auf die Phase des Lichts in einem Interferometerarm mit Hilfe eines EOM's moduliert. Durch anschließende digitale Decodierung mit derselben Pseudozufallszahlenfolge mit unterschiedlichen Verzögerungen können die Laufwege mehrerer Laserstrahlen eines Strahlenganges separiert werden. Dadurch wird es möglich, mehrere Interferometer gemeinsam auszulesen und die Messempfindlichkeit durch Unterdrückung gemeinsamer Rauschquellen signifikant zu verbessern. Momentan wird am Albert Einstein Institut in Hannover an einem bestehenden Aufbau geforscht, der diese Technologie bereits verwendet.

In diesem Vortrag wird der aktuelle Stand des Interferometers vorgestellt. Die bisher erreichte Messempfindlichkeit beträgt $3\text{pm}/\sqrt{\text{Hz}}$ bei 10Hz. Indem der bisher verwendete Laser auf einen frequenzstabileren iodstabilisierten Laser gelockt wird, erwarten wir eine Verbesserung der Sensitivität unterhalb 10Hz.

A 51.6 Fri 15:15 E 001

Coating thermal noise interferometer — •Tobias Westphal and the AEI 10m Prototype team — Max-Planck-Institute for Gravitational Physics (Albert-Einstein-Institut) and Leibniz University Hannover

Coating thermal noise (CTN) is getting a more and more significant noise source for high precision experiments and metrology. It arises from mechanical losses in the dielectric coatings applied to mirrors to achieve high reflectivity. Deeper understanding and verification of its theory requires direct (off-resonant) observation.

The AEI 10 m Prototype facility is probably the best suited environment for this kind of experiment in a frequency range of special importance for earth bound gravitational wave detectors. A pre-isolated platform shows three to four orders of magnitude attenuated seismic noise inside ultra-high vacuum. Up to 10 W highly stabilized (frequency as well as amplitude) laser power at 1064 nm will be available for experiments.

In this talk the CTN- interferometer being at the transition from design to construction phase will be presented. The range solely limited by CTN is designed to reach from 10 Hz to about 50 kHz, limited by seismic noise at low frequencies and shot noise (photon counting noise) at high frequencies.

A 51.7 Fri 15:30 E 001

Control of optical cavities in light-shining-through-a-wall experiments — •Robin Baehre — Max-Planck-Institute for Gravitational Physics (Albert-Einstein-Institute), Callinstr. 38, 30167 Hannover, Germany

Light-shining-through-a-wall (LSW) experiments are a straightforward approach to laboratory searches for weakly interacting sub-eV particles (WISPs), which are considered as a viable candidate for cold dark matter. WISPs, which exhibit coupling to a photon field, can be produced from a laser beam, which is shone on a solid wall. Due to their weak coupling to ordinary matter, WISPs can transverse the wall, which is opaque to photons, and can reconvert into photons afterwards and consequently be detected by a photon detector. LSW experiments often suffer from the fact that WISP fluxes produced in the laboratory are much smaller than those from astronomical sources. However, LSW searches can be considerably improved by fully exploiting the benefits of using coherent laser light to the production and regeneration process. Using optical resonators on the production and regeneration side helps to probe for very small WISP-photon couplings and to explore the parameter space that can be deduced from observations of anomalous white dwarf cooling and transparency of the universe to TeV photons. I will focus my tak on the optical design of ALPS-II with the implementation of production and regeneration resonator and explain how the demanding requirements on spatial and spectral stability can be fulfilled by application of optical precision measurement and control with picometer accuracy.