Q 16: Precision Measurements and Metrology IV (with A)

Time: Tuesday 11:00–13:00 Location: a310

Q 16.1 Tue 11:00 a310

A micromechanical proof-of-principle experiment for measuring the gravitational force of milligram masses — •Jonas Schmöle and Markus Aspelmeyer — Faculty of Physics, University of Vienna

We address a simple question: how small can one make a gravitational source mass and still detect its gravitational coupling to a nearby test mass? We describe an experimental scheme based on micromechanical sensing that should allow to observe gravity between milligram-scale source masses, thereby improving the current smallest source mass values by three orders of magnitude. We also discuss the implications of such measurements both for improved precision measurements of Newton's constant and for a new generation of experiments at the interface between quantum physics and gravity.

Q 16.2 Tue 11:15 a310

Fundamental uncertainty of the speed of light in vacuum — •Daniel Braun[1], Fabienne Schneiter[1], and Uwe R. Fischer[2] — [1]Institute of Theoretical Physics, University Tübingen, 72076 Tübingen, Germany — [2]Seoul National University, Department of Physics and Astronomy, Center for Theoretical Physics, 151-747 Seoul, Korea

The speed c of light in vacuum is a natural constant of crucial importance for the foundations of physics and many applications. Advanced theories predict quantum fluctuations of c or even a time-evolution. Combining arguments from quantum parameter-estimation-theory and classical general relativity, we here establish rigorously the existence of lower bounds on the precision to which c can be determined *in principle*. They result in minimal uncertainties of lengths measured through the propagation of light signals that are comparable to predictions from quantum gravity theory. However, the minimal uncertainties depend on the quantum state of light used for the measurement, challenging thus the idea of quantum fluctuations of geometry that exist independently of a measurement prescription. In particular, our novel, measurement-based approach predicts that fluctuations on the length scale of the Planck length are only accessible through quantum-enhanced measurements that use highly non-classical states of light.

Q 16.3 Tue 11:30 a310

Laser Interferometer Space Antenna Optical Bench Test Bed — •Michael Tröbs[1], Germán Fernandez Barranco[1], Michael Chwalla[2], Ewan Fitzsimons[2], Oliver Gerberding[1], Gerhard Heinzel[1], Christian Killow[3], Maike Lieser[1], Neda Meshksar[1], Vitali Müller[1], Michael Perreur-Lloyd[3], David Robertson[3], Sönke Schuster[1], Thomas Schwarze[1], Henry Ward[1], Max Zwetz[1], and Karsten Danzmann[1] — [1]Albert Einstein Institut — [2]Airbus Defense and Space — [3]University of Glasgow

The Laser Interferometer Space Antenna (LISA) is a future space-based interferometric gravitational-wave detector consisting of three spacecraft in a triangular configuration in Earth-like orbits around the sun. The interferometric measurements of path length changes between satellites will be performed on so-called optical benches in the satellites. Angular misalignments of the interfering beams will couple into the length measurement and represent a significant noise source (tilt-to-length coupling). Imaging systems are foreseen to reduce this tilt-to-length coupling. We report on an optical bench test bed to investigate imaging systems and the test results. The tilt-to-length coupling requirement of 25 um/rad was met with a two-lens imaging system.

Q 16.4 Tue 11:45 a310

The journey to noise reduced and ultra stable interferometers for high-precision metrology — •Katharina-Sophie Isleif, Oliver Gerberding, Moritz Mehmet, Michael Tröbs, Karsten Danzmann, and Gerhard Heinzel — Albert Einstein Institut, Institut für Gravitationsphysik, 30167 Hannover

Laser interferometry achieving pm/$\sqrt{\text{Hz}}$ sensitivities in the mHz-frequency range is the key technology for satellite missions in the area of gravitational wave detection and geodesy, but it requires sophisticated interferometer layouts that suppress classical interferometer noise sources like scattered light, ghost beams, laser frequency noise and misalignments just by design. We present the recipe for a successful low-noise interferometer construction, starting with a digital design of the interferometer using the C++ library IfoCad, followed by an optimisation in which we are looking at the simulated interferometer data. Different optimisation parameters, like the overall interferometer architecture, the usage of wedged components and the correct positions, are discussed on the basis of two examples: A Mach-Zehnder interferometer used for the test mass readout in future geodesy missions via deep frequency modulation interferometry, and the 3-Backlink-Setup, an experiment for the laser interferometer space antenna (LISA). The interferometer construction combines the manufacture of a template, a thermally stable quasi-monolithic assembly of the components and a Coordinate Measuring Machine. We compare the simulation with a setup assembled by hand and an optimally designed interferometer.

Q 16.5 Tue 12:00 a310

Initial measurements using the eLISA Phasemeter optical testbed — •Germán Fernández Barranco, Daniel Penkert, Thomas Schwarze, Oliver Gerberding, and Gerhard Heinzel — Max Planck Institute for Gravitational Physics, Callinstraße 38 30167 Hannover

The planned spaceborne gravitational wave detector eLISA will allow the detection of gravitational waves at frequencies between 0.1 mHz and 1 Hz. It uses high-precision heterodyne laser interferometry as the main measurement technology. A breadboard model for the phase readout system of these interferometers (Phasemeter) was developed in the scope of an ESA technology development project. This project was completed successfully fulfilling all performance requirements in an electrical two-signal test. Here we present the planning and advances in the implementation of an optical testbed for the Phasemeter as well as initial measurements. The testbed is based on an ultra-stable hexagonal optical bench. This bench allows the generation of three unequal heterodyne beatnotes, thus providing the possibility to probe the Phasemeter for non-linearites in an optical three-signal test. The final goal is to show 1 microcycle/sqrt(Hz) performance in the eLISA band (0.1 mHz - 1 Hz) with a dynamic range of 10 orders of magnitude using beatnotes between 2 and 25 MHz. The initial measurements presented here fulfill the 1 microcycle/sqrt(Hz) requirement down to 100 mHz. Once performance over the full bandwidth is achieved, other components of the eLISA metrology chain (clock noise transfer and removal, inter-satellite ranging and communication) can be tested in this setup.

Q 16.6 Tue 12:15 a310

Deep frequency modulation interferometry — •Oliver Gerberding[1,2], Katharina-Sophie Isleif[1], Thomas Schwarze[1], Moritz Mehmet[1], Gerhard Heinzel[1], and Felipe Guzman Cervantes[2] — [1]Albert Einstein Institut, Institut für Gravitationsphysik, Callinstraße 38, 30167 Hannover — [2]Joint Quantum Institute, National Institute of Standards and Technology, Maryland, USA

Laser interferometry with pm/$\sqrt{\text{Hz}}$ precision and multi-fringe dynamic range at low frequencies is a core technology to measure the motion of various objects (test masses) in space and ground based experiments for gravitational wave detection and geodesy. Even though available interferometer schemes are well understood, their construction remains complex, often involving the need to build quasi-monolithic optical benches with dozens of components. Here we present a new scheme that uses strong laser frequency modulations in unequal arm-length interferometers in combination with a fit algorithm originally developed for the readout of strong phase modulations, the so-called deep phase modulation interferometry. This combination is the basis for the development of a more elegant interferometric sensing toolset for future missions that requires much smaller and simpler interferometric sensors while using advanced digital signal processing for the phase recovery. We discuss noise influences, both from classic sources and new, technique-specific couplings and we present first results achieved in simulations and experiments.

Q 16.7 Tue 12:30 a310

Seismische Isolationsplattform für den AEI 10m-Prototypen — •Robin Kirchhoff — AEI 10m Prototype Team

Im Albert-Einstein-Institut in Hannover wird zur Zeit ein Michelson-Interferometer mit 10m Armlänge aufgebaut, an dem neuartige Techniken für die Gravitationswellendetektion entwickelt und getestet werden. Ein elementarer Bestandteil ist die seismische Isolationsplattform AEI-SAS, welche als Grundlage für die Optiken und weitere Komponenten des Interferometers dient. Das Ziel dieser Plattform ist es, die Störungen durch im Boden vorhandene Seismik bestmöglich zu minimieren. Dies wird einerseits durch passive Mechanismen umgesetzt, welche auf dem Prinzip des Pendels basieren, andererseits wird eine aktive Isolation verwendet, bei der die Bewegung der Plattform ausgelesen, das entstandene Signal bearbeitet und die Bewegung über Aktuatoren minimiert wird. Die Umsetzung dieser passiven und aktiven Techniken am AEI 10m-Prototypen ist Thema dieses Vortrages.

Q 16.8 Tue 12:45 a310

Dreifachpendelaufhängung für das AEI 10m-Prototypinterferometer — •Johannes Lehmann — AEI 10m Prototype Team

Im AEI in Hannover wird ein Interferometer mit 10m Armlänge aufgebaut, dessen Empfindlichkeit durch das Standard Quanten Limit begrenzt sein soll. Dafür müssen andere Rauschquellen wie die Seismik reduziert werden. Als Vorisolation werden dazu Seismische Isolationsplattformen verwendet, auf denen die Komponenten des Interferometers aufgebaut werden. Für die Spiegel des Interferometers wird eine weitere Isolation benötigt, die durch ein Dreifachpendel als Aufhängung gewährleistet werden soll. Das Design und der Aufbau dieser Aufhängung wird im Vortrag vorgestellt.