Q 29: Precision Measurements and Metrology III

Time: Wednesday 14:00–16:15 Location: A 310

Q 29.1 We 14:00 A 310

Stabilising the distance of 10 m separated optical tables to 100 pm/sqrt(Hz) — •Katrin Dahl for the 10 m Prototype team — Max-Planck-Institut für Gravitationphysik (Albert-Einstein-Institut) und Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

The AEI 10 m Prototype Interferometer will develop and test new techniques for the third generation of ground based interferometric gravitational-wave detectors. Furthermore, it provides an ultra-low displacement-noise environment which will be used for other experiments, e.g. related to GRACE follow-on or macroscopic quantum mechanics. To create such a quiet environment, seismically isolated optical tables separated by just above 10 m will be suspended in a large scale ultra-high vacuum system. The relative motion between these tables will be measured by a dedicated set of heterodyne Mach-Zehnder interferometers. With this setup the distance between the tables can then be stabilised via feedback to voice-coil actuators. In this talk we will present first measurements performed between two seismically non-isolated tables separated by about 10 m.

Q 29.2 We 14:15 A 310

Design and control aspects of the AEI 10 m Prototype Interferometer — •Christian Gräf for the AEI 10m Prototype Team — Max-Planck-Institut für Gravitationphysik (Albert-Einstein-Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover

The AEI 10 m Prototype Interferometer aims at beating the Standard Quantum Limit (SQL) at frequencies of about 100 Hz. To reach this ambitious goal all free design parameters of the underlying optical layout need to be thoroughly optimized with regard to bringing down classical noise, eventually allowing for operating the inteferometer with an exclusively quantum noise-limited sensitivity at frequencies in the measuring band. Retaining the feasibility of stably controlling the instrument in all relevant degrees of freedom, using digital feedback control, is a vital boundary condition for the experiment design. Due to the high complexity of the optical system, simulations play a key role in this process. This talk summarizes the status of design and control aspects of the prototype interferometer.

Q 29.3 We 14:30 A 310

Digital control and data system for the AEI 10m prototype interferometer — •Michael Born for the 10m Prototype team — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

A 10m prototype interferometer is currently under construction in Hannover, Germany. One primary goal is to reach and surpass the standard quantum limit of interferometry for 100g test masses [1]. The control and data taking for this complex experimental facility will be carried out with a dedicated digital system. All relevant servo loops will be implemented digitally using a realtime control and data system (CDS) that will also be used for next generation gravitational wave detectors. Control algorithms can be implemented via Matlab/Simulink models or C-code from which a realtime capable module is subsequently generated. In the initial configuration about 500 EPICS channels will be recorded or controlled. Among these are channels for the control of the frequency reference cavity, the main interferometer, and the isolated optical tables inside the UHV envelope. Control signals for these tables will be derived from a supension platform interferometer which adapts LISA Pathfinder phasemeter technology. The data from the phasemeter are read from an enhanced parallel port (EPP) via a newly designed microcontroller-based ethernet interface. The digital control and data system as well as the novel interface to the phasemeter will be introduced in detail.

[1] http://10m-prototype.aei.uni-hannover.de

Q 29.4 We 14:45 A 310

Seismic Attenuation for the 10m Prototype — •Alexander Wanner for the AEI 10m Prototype Interferometer team — Max-Planck-Institut für Gravitationphysik (Albert-Einstein-Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

A 10m Prototype Interferometer facility is currently being set up at the AEI in Hannover. The prototype interferometer will be used to test and develop some of the techniques for potential future upgrades of the gravitational-wave detector GEO600. Furthermore, experiments to explore quantum mechanical effects in macroscopic objects will be run in this facility. By now the ultra-high vacuum system is installed and fully operational. The next step is the installation of seismically isolated optical tables.

The basic stage of isolation will be a set of passive attenuation tables, based on the Advanced LIGO HAM-SAS design. Geometric anti-spring filters will provide vertical isolation (70dB above several Hertz). Attenuation in the horizontal direction (60dB above several Hertz) will be provided by inverted pendulum legs. Several sensors will provide signals for a real-time control system to allow further attenuation via feed-back actuators at the tables. This talk gives an overview of the design of the seismic attenuation system and of the most relevant subsystems of these tables for the 10m Prototype Interferometer.

Q 29.5 We 15:00 A 310

The AEI 10m Prototype Interferometer — •Stefan Gossler for the 10m Prototype team — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) und Leibniz Universität Hannover

A 10m Prototype Interferometer is currently being set up at the AEI in Hannover, Germany. Among the main objectives are the demonstration of novel techniques for future generations of GW detectors, as well as building an instrument operating at and beyond the standard quantum limit of interferometry for 100g test masses.

For the pre-isolation of the experimental setup we will install three seismically isolated optical tables inside a large (ca. $100\mathrm{m}^3$) ultra-high vacuum envelope. The differential motion of these tables will be stabilised via a set of Mach-Zehnder interferometers. All relevant optical components will be mounted on top of these isolated tables by means of multiple-cascaded pendulum suspensions. A suspended triangular ring cavity of finesse ca. 7300 will, in conjunction with a molecular iodine reference, serve as a frequency reference for the stabilisation of the 35W Nd:YAG laser. The main instrument is a 10m Michelson interferometer with Fabry-Perot cavities in the arms. The end mirrors will be made of Khalili-style Fabry-Perot cavities to minimise the effective coating thermal noise. The design of the interferometer is done such that the sum of all classical noises lies well below the sum of quantum noise in a frequency band around 100Hz. The layout, status, and progress of the AEI 10m prototype will be given in this talk.

Q 29.6 We 15:15 A 310

Frequency stabilization system for a sub-SQL experiment with the AEI 10 m Prototype — •Fumiko Kawazoe for the 10m Prototype — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), 30167 Hannover, Germany

The AEI 10 m Prototype Interferometer is will provide a test-bed for very sensitive interferometric experiments, such as the sub-SQL interferometer. It will test new techniques to reach and even surpass the Standard Quantum Limit. In order for the sub-SQL interferometer to achieve the required sensitivity all limiting noise sources need to be suppressed sufficiently. Laser frequency noise will be the main focus of this presentation. The AEI Prototype Interferometer will use a laser frequency stabilization system composed of a 12 m high-finesse triangular frequency reference cavity. The mirrors of the cavity are individually suspended from triple pendulum systems. The laser frequency noise will be suppressed to a level of 10^{-16} to $< 10^{-18}\,\mathrm{m}/\sqrt{\mathrm{Hz}}$, from $\sim 20\,\mathrm{Hz}$ to 1 kHz in terms of a reference-cavity length-noise.

Q 29.7 We 15:30 A 310

Towards the SQL: How to avoid thermal noise using detuned cavities — •Tobias Westphal for the AEI 10m Prototype — Albert Einstein Institut & MPI für Gravitationsphysik, Callinstrasse 38, 30167 Hannover

High sensitivity interferometric experiments are strongly pushing towards the fundamental limits of classical interferometry and beyond. However, thermal noise associated with the dielectric coating stacks of the interferometer mirrors imposes a potential show stopper on the way to such a sensitivity.

One possibile avenue towards a reduced coating thermal noise is to replace highly reflective mirrors by detuned cavities. These so called Khalili cavities will be used for the AEI 10m Prototype Interferometer sub-SQL experiment.

In this talk the theoretical framework will be presented along with the plans for the experimental realisation including the optical design and the according control schemes.

Q 29.8 We 15:45 A 310

Simultaneous stabilization and correlated noise in a single-mode pumped non-planar ring oscillator — •Robin H. Bähre, Tobias Meier, Benno Willke, and Karsten Danzmann — Albert-Einstein-Institute, Max-Planck-Institute for Gravitational Physics, and Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

Simultaneous stabilization is an approach to non-planar ring oscillator (NPRO) laser stabilization that achieves significant suppression of laser power noise by elimination of correlated frequency noise.

A key component to the success of this experiment is a stable pump source of the NPRO. We have set up a Ti:sapphire solid-state laser as a pump source at 808 nm to provide the required pump beam quality, frequency stability and output power to achieve the quantum noise limit of the NPRO laser power.

We report simultaneous stabilization of the laser power of such a Ti:sapphire single-mode pumped Nd:YAG NPRO with a continuous-wave output power of 75 mW at 1064 nm. We present the results of a table-top experiment in air and an improved setup on a platform that is suspended as a pendulum in a seismically and acoustically isolating tank.

Q 29.9 We 16:00 A 310

Wideband frequency stabilization of a 200-W injection-locked laser — •Hyunjoo Kim[1], Rick Savage[2], Benno Willke[1], and Karsten Danzmann[1] — [1]Albert-Einstein-Institut, Hannover, Germany — [2]LIGO Hanford Observatory, USA

We present a wideband frequency stabilization servo system for a 200-W injection-locked Nd:YAG laser that uses the Pound-Drever-Hall locking technique with a high-finesse optical cavity to control the frequency of the master laser. The Advanced LIGO laser consists of a non-planar ring oscillator followed by a four-rod, single-pass, 35-W amplifier and a 200-W injection-locked oscillator. A pre-modecleaner filters the laser light, after which sample beam is directed to frequency stabilization control loop. Additional downstream frequency sensor enables further stabilization via nested control loop. The injection-locked oscillator cavity and the pre-modecleaner introduce transfer functions that make realizing the required 500 kHz unity gain frequency more challenging. We describe a scheme for compensation of the induced phase delays by a phase-lead network in the servo electronics and the results of preliminary measurements with the wideband frequency stabilization servo.