Q 45: Precision Measurement and Metrology 2

Time: Thursday 10:30–13:00 Location: HÜL 386

Q 45.1 Thu 10:30 HÜL 386

Interferometrie für den Gravitationswellendetektor LISA — •Gerhard Heinzel — Max-Planck Institut für Gravitationsphysik (Albert-Einstein Institut) Hannover und QUEST, Leibniz Universität Hannover

Die ESA/NASA Mission LISA soll mittels Laserinterferometrie zwischen 3 Satelliten Gravitationswellen im Frequenzbereich zwischen 0.001 Hz und 1 Hz messen. Wichtige Teile der Laserinterferometrie werden zur Zeit im Labor entwickelt. In diesem Vortrag werden die Herausforderungen, Lösungsvorschläge und der Stand der Entwicklung im Labor zusammengefasst.

Q 45.2 Thu 11:00 HÜL 386

Realistic Test of a Transportable 1 Hz-Linewidth Laser — •Stefan Vogt[1], Christian Lisdat[1], Thomas Legero[1], Sebastian Häfner[1], Uwe Sterr[1], Ingo Ernsting[2], Alexander Nevsky[2], and Stephan Schiller[2] — [1]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Experimentalphysik, Heinrich-Heine Universität Düsseldorf, 40225 Düsseldorf, Germany

Optical clocks based on trapped cold atoms are now outperforming the best microwave clocks. So far these clocks have been only available in dedicated laboratories. Operating them in space and on the ground at different locations would enable new studies and applications, like relativistic geodesy and improved fundamental physics tests. We present the setup of a transportable clock laser at 698 nm for a strontium lattice clock that was developed within the ESA/DLR project "Space Optical Clocks". A master-slave diode laser system is stabilized to a rigidly mounted optical reference cavity. For a realistic test, this setup was transported by truck over 400 km from Braunschweig to Düsseldorf, where the cavity-stabilized laser was compared to a stationary Yb-clock laser at 578 nm. The lasers were compared by a Ti:Sapphire frequency comb used as a transfer oscillator. This setup allowed generating a virtual beat between these lasers which showed a combined linewidth below 1 Hz. We will present the setup and discuss the ongoing activities towards a complete transportable optical clock. The work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and the ERA-NET Plus Programme.

Q 45.3 Thu 11:15 HÜL 386

Development of a cryogenic sub-Hz laser system for optical clocks — •Christian Hagemann[1], Thomas Kessler[1], Thomas Legero[1], Uwe Sterr[1], Fritz Riehle[1], Michael J. Martin[2], and Jun Ye[2] — [1]Physikalisch-Technische Bundesanstalt (PTB) and Centre for Quantum Engineering and Space-Time Research (QUEST), Bundesallee 100, 38116 Braunschweig, Germany — [2]JILA, NIST and University of Colorado, 440 UCB, Boulder, CO 80309-0440, USA

Today's best optical clocks are outperforming the best primary Cs frequency standards. The performance of such clocks is limited by the frequency stability of the lasers that are used to interrogate the atomic or ionic quantum transition used as the pendulum of the atomic clock. In such setups an interrogation laser is locked to a high performance cavity for frequency stabilization.

In the Centre of Excellence (QUEST) we have developed a novel single-crystal silicon cavity operated at a temperature of 120 K. We will present the current setup, comprising the cryostat and the laser system. We have observed a fractional instability of a few times 10^{-15} (1 s) limited by the thermal noise floor of the ULE type reference laser. The impact of possible noise sources such as mechanical vibrations, temperature drifts and thermal noise on the frequency stability will be discussed.

Q 45.4 Thu 11:30 HÜL 386

NV color centers for magnetic field sensing at the nanoscale — •Friedemann Reinhard[1], Bernhard Grotz[1], Gopalakrishnan Balasubramanian[1,3], Julia Tisler[1], Eike Oliver Schäfer-Nolte[1,2], Markus Ternes[2], Florian Rempp[1], Klaus Kern[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, 3. Physikalisches Institut — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart — [3]Max-Planck-Institut für biophysikalische Chemie, Göttingen

The NV color center in diamond can be used as a magnetic field sensor with sub-nanometer spatial resolution. This prospect arises from the fact that its spin sublevels are sensitive to magnetic fields, only ~1kHz wide and are accessible to pulsed optical-microwave precision spectroscopy.

I present our work towards such a scanning probe diamond nanomagnetometer, focussing on the study of centers, which have been created few nanometers below the diamond surface. We are using such centers to sense noise from surface spins and charges, testing advanced techniques like dynamic decoupling and double–resonance EPR spectroscopy.

Q 45.5 Thu 11:45 HÜL 386

The frequency reference cavity for the AEI 10m Prototype interferometer — •Fumiko Kawazoe[1], Alessandro Bertolini[1], Michael Born[1], Yanbei Chen[2], Katrin Dahl[1], Stefan Gossler[1], Christian Graef[1], Gerhard Heinzel[1], Stefan Hild[3], Sabina Huttner[3], Gerrit Kuehn[1], Harald Lueck[1], Kasem Mossavi[1], Roman Schnabel[1], Kentaro Somiya[4], Kenneth A. Strain[3], John R Taylor[1], Alexander Wanner[1], Tobias Westphal[1], Benno Willke[1], and Karsten Danzmann[1] — [1]Max-Planck-Institut fuer Gravitationsphysik, QUEST, and Leibniz Universitaet Hannover,30167 Hannover, Germany — [2]California Institute of Technology, Pasadena, CA 91125 — [3]University of Glasgow, Glasgow, G12 8QQ, UK — [4]Waseda Institute for Advanced Study,1-6-1 Nishi Waseda, Shinjuku-ku, Tokyo 169-8050, Japan

The AEI 10m Prototype Interferometer will run an interferometric experiment called the sub-SQL interferometer whose sensitivity is designed to reach and even surpass the Standard Quantum Limit. In order to achieve such a good sensitivity, it is required that the laser frequency noise is suppressed to a level of $10^{-4}\,\mathrm{Hz}/\sqrt{\mathrm{Hz}}$ at 20 Hz dropping to below $10^{-6}\,\mathrm{Hz}/\sqrt{\mathrm{Hz}}$ at 1 kHz. For this purpose we have designed a ~ 20 Hz round-trip optical cavity with each mirror individually suspended from a triple cascaded pendulum systems. By controlling the laser frequency to follow the reference cavity's supporting frequency, we aim to achieve the required level of frequency stability. Here, details of the reference cavity design and the according control loop are presented.

Q 45.6 Thu 12:00 HÜL 386

Frequency Combs for Calibration of High-Precision Astronomical Spectrographs — •Tobias Wilken[1], Tilo Steinmetz[1,2], Rafael Probst[1], Ronald Holzwarth[1,2], Theodor W. Hänsch[1], and Thomas Udem[1] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Menlosystems GmbH, Martinsried

High precision spectrography in astronomy is at present limited by the available calibration sources. Frequency combs have have been proposed to be an optimal calibration source if they fulfill certain requirements with respect to their spectral bandwidth and mode spacing.

We have developed a frequency comb, based on an Yb-fiber laser which is filtered with Fabry-Perot cavities (FPCs) to have a mode spacing of > 10 GHz. After frequency doubling the comb, ~ 6 nm bandwidth at 526 nm are obtained and this comb was tested at the HARPS spectrograph in La Silla, Chile. This is to date the most precise instrument in the world. A calibration uncertainty limited by photon noise has been observed.

Currently we are working on broadening the optical spectrum to cover the bandwidth of the spectrograph. In this context, noise issues and the reamplification of modes which were initially suppressed by the FPCs need to be investigated in more detail. The latest results will be presented in this talk.

Q 45.7 Thu 12:15 HÜL 386

Hochpräzise Frequenzmetrologie über Glasfasernetzwerke — •Katharina Predehl[1,2], Ronald Holzwarth[1], Thomas Udem[1], Theodor W. Hänsch[1], Osama Terra[2], Gesine Grosche[2] und Harald Schnatz[2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

Optische Atomuhren übertreffen herkömmliche Mikrowellenstandards in Stabilität und Genauigkeit inzwischen bei Weitem. Für diese Uhren existiert damit keine absolute Referenz mehr. Eine Charakterisierung wird im direkten Vergleich mit einer anderen optischen Uhr vorgenommen. Die typischen Entfernungen für solche Uhrenvergleiche zwischen

zwei Instituen sind in Europa um die 1000 - 2000 km. Satellitenkommunkation scheidet hier als Übertragungstechnik aus, sie die geforderten Genauigkeiten nicht erreicht. Glasfasernetzwerke haben sich hingegen als wesentlich geeigneter herausgestellt: das Uhrensignal kann in der Faser sehr rauscharm übertragen werden.

PTB und MPQ haben einen 900 km langen Faserlink aufgebaut, um für die Präzisionsspektroskopie am MPQ hochpräzise Frequenzstandards zur Verfügung stellen zu können. Das Signal wird über 9 fernsteuerbare optische Verstärker übertragen und Schwankungen der Faserlänge werden über die gesamte Strecke aktiv kompensiert. Für das 200 THz-Signal erreichen wir eine Übertragungsstabilität von einem Hz pro Sekunde und eine Genauigkeit im Mikrohertz-Bereich (nach 10000 Sekunden). So erhalten wir am MPQ permanente CSF- Korrekturen für unsere rf- Referenzen und auch optische Signale können direkt mit einem Standard an der PTB verglichen werden.

Q 45.8 Thu 12:30 HÜL 386

Status of the development of LISA Pathfinder — •Jens Reiche, Antonio Francisco García Marín, Heather Audley, Gerhard Heinzel, and Karsten Danzmann — Max Planck Institute for Gravitational Physics (Albert Einstein Institute) Hannover and QUEST, Leibniz University Hannover

LISA Pathfinder is a dedicated technology demonstration mission for the joint ESA/ NASA Laser Interferometer Space Antenna (LISA) mission. LISA Pathfinder will presumably be launched in 2013. LISA is a planned gravitational wave observatory in the frequency range of 0.1 mHz to 1 Hz which is a complementary frequency band to the Earth based detectors. The launch of LISA is planned for 2020. LISA Pathfinder's goal is to demonstrate the key technologies of LISA such as spacecraft control with micronewton thrusters, test mass drag-free control, and precision laser interferometry between free-flying test masses. The talk will give an overview of the actual status of LISA Pathfinder and the payload including its subsystems. The hardware is built by a number of different institutes and industries. Challenges including their solutions and the status of the systems, their integration, verification and testing will be presented.

Q 45.9 Thu 12:45 HÜL 386

Transportable cavity-stabilized fibre laser at 1542 nm — •Thomas Legero, Thomas Kessler, Christian Hagemann, Gesine Grosche, and Harald Schnatz — Physikalisch-Technische Bundesanstalt and Centre for Quantum Engineering and Space-Time Research, Bundesallee 100, 38116 Braunschweig, Germany

Cavity-stabilized laser systems with sub-Hz line width are essential for high-resolution spectroscopy and optical frequency standards. In addition, their superior short term stability in the 10^{-15} regime makes them an excellent tool for referencing fs-frequency combs, optical microwave generation [1] or characterization of optical fibre links [2]. For operation along fibre links the system must be rigid and small enough to be transportable by a small van. We present a compact, cavity stabilized laser system based on a commercial fibre laser at a wavelength of 1542 nm. The cavity setup is designed to withstand typical accelerations during transportation. The complete laser system including the cavity and the electronics package fits into a 19-inch racksystem with a base of 60×60 cm^2 and a height of 1.50 m. Its short term stability of a few times 10^{-15} allows a varity of applications where a mobile highly stable refrence frequency is required.

[1] B. Lipphardt *et al.*, IEEE Trans. Instrum. Meas., **58**, 1258, (2009)

[2] O. Terra *et al.*, Appl. Phys. B, **97**, 541, (2009)