Q 14: Precision Measurements and Metrology II

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

Group Report Q 14.1 Tu 14:00 A 310

Dissemination of reference frequencies via optical telecommunication fiber — •Gesine Grosche[1], Osama Terra[1], Katharina Predehl[1,2], Andre Pape[3], Jan Friebe[3], Matthias Riedmann[3], Temmo Wübbena[3], Janis Alnis[2], Ronald Holzwarth[2], Thomas Legero[1], Burghard Lipphardt[1], Thomas Udem[2], Ernst Rasel[3,4], Uwe Sterr[1,4], and Harald Schnatz[1,4] — [1]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig — [2]Max-Planck-Institut für Quantenoptik (MPQ), Garching — [3]Institut für Quantenoptik (IQ), LUH, Hannover — [4]QUEST, Hannover/ Braunschweig

Optical frequency references have achieved an unprecedented accuracy better than 10^{-16}[1]. They are a formidable tool for precision experiments, since frequency is by far the most precisely measurable quantity. Many of these experiments require the comparison of frequencies between different sites. We present the current status of our frequency dissemination work using optical fibers. We achieved a relative accuracy of 10^{-19} for an optical frequency transmission over 146 km [2,3]. With a reference frequency delivered by fiber from PTB, Braunschweig, to IQ, Hannover, we optimised optical clock lasers on-line [4] and performed a remote frequency measurement of the Mg clock transition. Now a German-wide fiber network (IQ, MPQ, PTB...) is being implemented [5], and we explore how to distribute frequencies to many users simultaneously [6]. [1] Chou *et al.* arXiv:0911.4527v1 (2009) [2] Grosche *et al.* Opt. Lett. **34**, 2270 (2009) [3] Terra *et al.* Appl. Phys. B **97**, 541 (2009) [4] Pape *et al.* arXiv 0908.4238 (2009) [5] Predehl *et al.* CLEO (2009) [6] Grosche, DPMA 10 2008 062 139 (2008)

Q 14.2 Tu 14:30 A 310

Opto-mechanische Kopplung in einem Michelson-Sagnac Interferometer — •Henning Kaufer, Kazuhiro Yamamoto, Tobias Westphal, Daniel Friedrich und Roman Schnabel —
Institut für Gravitationsphysik, Leibniz Universität Hannover und
Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut)
Callinstrasse 38
D-30167 Hannover

Opto-mechanische Kopplung - der Austausch von Impuls zwischen Licht einem mechanischen Oszillator - sorgt für einen quantenmechanischen Rauschbeitrag bei einer Positionsmessung, das sogenannte Strahlungsdruckrauschen. Es übertrifft bei geringen Frequenzen das weiße Schrotrauschen, konnte bisher jedoch nicht experimentell nachgewiesen werden. Wir stellen einen neuen Ansatz für den Nachweis von Strahlungsdruckrauschen vor: Eine leichte ($m \approx 100$ ng) Siliziumnitrid-Membran hoher Güte (10^6) wird als Koppler in einem Michelson-Sagnac Interferometer verwendet. Diese Interfermometertopoglogie gestattet es, die Genauigkeit des Experiments durch Power- und Signal-recycling zu verbessern. Erste Ergebnisse und Berechnungen weisen auf eine notwendige Absenkung der Membrantemperatur auf ca 1 K hin, um thermisches Rauschen zu reduzieren und Strahlungsdruckrauschen zu messen. Die Absorption von SiN bei 1064 nm und hohen Lichtleistungen wird in diesem Zusammenhang bedeutend. Derzeit ist die Empfindlichkeit des Experiments durch das Intenstitätsrauschen des Lasers begrenzt.

Q 14.3 Tu 14:45 A 310

Konzepte für diffraktive Optiken mit geringem thermischen Rauschen — •Stefanie Kroker, Frank Brückner, Ernst-Bernhard Kley und Andreas Tünnermann — Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena

Thermisches Rauschen ist ein bedeutender limitierender Faktor sowohl für die Sensitivität von optischen Hochpräzisionsmessungen wie z.B. der Gravitationswellendetektion als auch für die Frequenzstabilität von Einfrequenz-Lasern. Für ein geringes thermisches Rauschen sind optische Komponenten (z.B. Spiegel) mit niedrigen mechanischen Verlusten notwendig. Dielektrische Schichtstapel liefern dabei einen Hauptbeitrag zum Verlust des Systems. Konzepte auf der Basis resonanter Wellenleitergitter können Lösungen für dieses Problem bieten. Hierbei ermöglicht schon eine auf dem Substrat befindliche dünne mikrostrukturierte Schicht eines höherbrechenden Materials hohe Reflektivitäten. Silizium eignet sich auf Grund des geringen mechanischen Verlustes sehr gut als Material für diese Komponenten. Rein monolithische siliziumbasierte Strukturen mit einem Reflektivität nahe 100% wurden realisiert. Die Herstellung ist hierbei allerdings äußerst anspruchsvoll. Alternativ dazu sollen nun diamantbasierte Gitterkonzepte theoretisch untersucht werden. Diamant wird hierbei sowohl als Substratmaterial in Kombination mit Silizium (als höherbrechende Wellenleiterschicht) als auch als niedrigbrechende Zwischenschicht in Betracht gezogen. Unsere Simulationen umfassen neben der Spiegelfunktion auch reflektiv diffraktive Strahlteiler und Resonatorkoppler, die zukünftig transmittive Optiken in den Messaufbauten ersetzen sollen.

Q 14.4 Tu 15:00 A 310

Interferometry based high-precision dilatometry — •Eugen Stoppel[1,3], Martin Gohlke[1,2], Thilo Schuldt[2,3], Dennis Weise[1], Ulrich Johann[1], and Claus Braxmaier[3] — [1]EADS Astrium — [2]Humboldt-Universität zu Berlin — [3]HTWG Konstanz

In the scope of the gravitational wave detector LISA (Laser Interferometer Space Antenna), EADS Astrium in collaboration with the Humboldt-University Berlin and the University of Applied Sciences Konstanz (HTWG) developed a heterodyne interferometer, combined with technique of the so-called differential wavefront sensing for angle measurements. Based on the heterodyne interferometer, an optical dilatometer for high-accuracy and high-resolution measurement of the linear coefficient of thermal expansion (CTE) was realized.

With the first setup a CTE below 0.1×10^{-6} $1/K$ can be measured. In a new design all main parts are made of ultra stable glass ceramic instead of aluminum, in order to bring the noise performance to the theoretical limit of 10^{-9} $1/K$.

In this presentation, the dilatometer and first results of the measurements will be presented.

Q 14.5 Tu 15:15 A 310

Waveguide gratings as highly reflective mirrors without dielectric coatings — •Daniel Friedrich[1], Frank Brückner[2], Michael Britzger[1], Stefanie Kroker[2], Ernst-Bernhard Kley[2], Andreas Tünnermann[2], Karsten Danzmann[1], and Roman Schnabel[1] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) Callinstrasse 38 D-30167 Hannover — [2]Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1 D-07743 Jena

Thermal noise in multilayer optical coatings may not only limit the sensitivity of future gravitational wave detectors in their most sensitive frequency band but is also a major impediment for experiments that aim to reach the standard quantum limit or to cool mechanical systems to their quantum ground state.

This talk will give an overview about the progress of waveguide gratings as highly reflective mirrors without multilayer coatings. The best result so far includes a monolithic mirror with a measured reflectivity of 99.8% for normal incidence.

Q 14.6 Tu 15:30 A 310

Frequency dissemination using a wide-area telecommunication fiber link — •Osama Terra[1], Gesine Grosche[1], Katharina Predehl[2], Ronald Holzwarth[2], and Harald Schnatz[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig,Germany — [2]Max Planck Institute for Quantum optics, Garching, Germany

Optical frequency standards can reach a relative uncertainty below 10^{-16} and an instability of $10^{-15}/(\tau^{1/2}/s)$. For the dissemination of such a stable frequency, an optical fiber link provides a promising technique which avoids degradation of frequency stability and accuracy when used with a system that compensates temperature fluctuations and acoustic perturbations of the optical fiber. We have investigated the performance of a 146 km telecommunication fiber link to transfer such stable frequencies. We have transferred the stability of a clock laser at PTB to a telecommunication laser at $\lambda = 1542nm$ and measured its stability at the remote end of the fiber. The comparison performed at PTB between the local and the remote signal showed a relative uncertainty below 1×10^{-19} and an instability of $\sigma_y(\tau) = 3.3 \times 10^{-15}/(\tau/s)$, limited by the time delay introduced by the link. We are currently establishing a $900km$ fiber link between PTB and MPQ. The transmitted signal has to be amplified several times to maintain the required power level and SNR. Bidirectional EDFAs that amplify the signal typically every $100km$ are used at the moment. We additionally studied the performance of Brillouin amplifiers to bridge larger distances in one step.

Q 14.7 Tu 15:45 A 310

Continuous-wave squeezed states at 1550 nm — •Moritz Mehmet, Tobias Eberle, Sebastian Steinlechner, Henning Vahlbruch, Karsten Danzmann, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstrasse 38, 30167 Hannover

It seems likely that the potential to enhance the sensitivity of quantum noise limited interferometers will make squeezed-light-injection a standard tool in future Gravitational Wave (GW) detector technology. One means to reduce the inherent noise floor of future detectors could be the use of new materials for optical components. For example, silicon constitutes an excellent test mass material with a high mechanical quality making it superior to the currently used fused silica components. This change would entail the replacement of the presently used laser by lasers operating at 1550 nm at which silicon shows very low optical loss. Besides the issue of how lasers at 1550 nm can be turned into reliable laser sources for future GW interferometers, research has to be undertaken on how to engineer the respective squeezed states.

Here, we report on the generation of cw squeezed vacuum states at a wavelength of 1550 nm with a non-classical noise reduction of 6.4 dB. These squeezed vacuum states were injected into the dark port of a Sagnac interferometer. A reduction of the interferometer shot noise by approximately 4.5 dB was observed and the enhancement of the signal-to-noise ratio for a phase modulation signal generated within the interferometer could be demonstrated.

Q 14.8 Tu 16:00 A 310

Remote characterization of ultrastable optical frequencies via a 73 km long telecommunication fiber link — •Andre Pape[1], Jan Friebe[1], Osama Terra[2], Matthias Riedmann[1], Temmo Wübbena[1], André Kulosa[1], Sana Amairi[1], Hrishikesh Kelkar[1], Ernst-Maria Rasel[1], Wolfgang Ertmer[1], Katharina Predehl[2], Thorsten Feldmann[2], Thomas Legero[2], Burghard Lipphardt[2], Gesine Grosche[2], and Harald Schnatz[2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Dissemination and remote comparison of ultrastable optical frequencies is an important research field, since the complexity of optical clocks does not allow for transportation today. We implemented a 73 km long optical telecommunication fiber link between the Physikalisch-Technische Bundesanstalt (PTB, Braunschweig) and the Institute of Quantum Optics (IQ, Hannover). We report on a remote characterization of ultrastable lasers on the 10^{-15} level in fractions of a second.

We additionally used this fiber link to characterize the magnesium optical frequency standard at the IQ against an ultrastable optical frequency, a hydrogen maser and a Cs fountain clock at PTB and report on an improved frequency measurement. The Mg optical frequency standard is based on cold free falling ensembles of neutral Mg atoms interrogated on the narrow ${}^1S_0 \rightarrow {}^3P_1$ intercombination transition using the Ramsey-Bordé interferometer scheme with subsequent detection using a MOT in the metastable ${}^3P_J \rightarrow {}^3D_{J'}$ system.