GR 4: Gravitationswellen II

Zeit: Dienstag 14:00–16:00 Raum: HS 6

GR 4.1 Di 14:00 HS 6

Silicon - A potential test mass material for future GW detectors — •Jessica Steinlechner[1], Gerd Hofmann[2], Alexander Khalaidovski[1], Julius Komma[2], Christoph Krüger[1], Christian Schwarz[2], Sebastian Steinlechner[1], Ronny Nawrodt[2], and Roman Schnabel[1] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany — [2]Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Helmholtzweg 5, 07743 Jena, Germany

Today's gravitational wave (GW) detectors use test mass mirrors made from fused silica and a laser wavelength of 1064 nm. Future GW detectors such as the Einstein Telescope (ET) [1,2] consider cryogenic cooling of the test-masses to reduce their thermal noise. Due to its high mechanical quality factor at low temperatures and a high heat conductivity, silicon is a promising new test-mass material. An important question is whether the optical absorption of silicon is low enough since some of the test masses require the transmission of intense laser radiation. At 1550 nm silicon is expected to show a rather low optical absorption, however, precise absorption coefficients are not known. This talk deals with the absorption characteristics of crystalline silicon at a wavelength of 1550 nm.

[1] M. Punturo et al., Class. Quantum Grav. 27, 194002 (2010).

[2] B. Sathyaprakash et al., Class. Quantum Grav. 29, 124013 (2012).

GR 4.2 Di 14:15 HS 6

Optical properties of silicon — •Julius Komma[1], Gerd Hofmann[1], Christian Schwarz[1], Daniel Heinert[1], Jessica Steinlechner[2], Roman Schnabel[2], Paul Seidel[1], and Ronny Nawrodt[1] — [1]Friedrich-Schiller-Universität Jena, Institut für Festkörperphysik, Helmholtzweg 5, D-07743 Jena, Germany — [2]Institut für Gravitationsphysik, Universität Hannover, Callinstraße 38, D-30167 Hannover, Germany

Silicon is the chosen test mass material due to its mechanical and thermal properties for the proposed European gravitational wave detector "Einstein Telescope". For the design of such a detector optical parameters like refractive index, thermo-optic coefficient and absorption play an important role for the calculation of noise and the design of this interferometer. The temperature dependent change of the refractive index causes thermal noise due to thermal fluctuations. Another process induced by the thermo-optic coefficient is thermal lensing.

This contribution gives an overview about the optical properties of silicon. We present the measurement technique of the thermo-optic coefficient and data from 5 to 300 K. Hence estimations of the thermal noise in silicon were done. Furthermore calculations of thermal lensing effects in silicon are shown, especially for the low temperature region in which the Einstein Telescope will be operated.

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GR 4.3 Di 14:30 HS 6

Mechanical loss of sapphire at low temperatures — •Gerd Hofmann[1], Julius Komma[1], Christian Schwarz[1], Daniel Heinert[1], Paul Seidel[1], Andreas Tünnermann[2], and Ronny Nawrodt[1] — [1]FSU Jena, Institut für Festkörperphysik, Helmholtzweg 5, D-07743 Jena, Germany — [2]FSU Jena, Institut für Angewandte Physik, Albert-Einstein-Strasse 15, D-07745 Jena, Germany

One crucial limit in the sensitivity of current gravitational wave observatories (GWOs) is given by the thermal noise from the test masses which is directly linked to their temperature and mechanical loss. Current detectors are operated at room temperature with fused silica. The reduction of thermal noise is possible by decreasing the temperature and the mechanical loss. So the next generation of GWOs like the Japanese KAGRA will be operated at cryogenic temperatures. However, fused silica shows a high mechanical loss at cryogenics. Thus new materials especially crystaline ones are required. In this sense sapphire is a promising candidate with low losses at low temperatures.

We present measurements from 5 to 300 K on bulk sapphire as well as sapphire fibers. Data analysis reveals that bulk sapphire is limited in its mechanical loss at lowest temperatures due to Akhiezer damping i.e. the interaction of phonons. In contrast, we found that sapphire fibers mainly follow the theoretical predictions of thermoelastic damping. We further discuss the influence of surface treatment and the supporting structure in detail.

This work is supported by the DFG under contract SFB TR7.

GR 4.4 Di 14:45 HS 6

Silicon surfaces and its impact on gravitational wave detectors — •Christian Schwarz[1], Julius Komma[1], Gerd Hofmann[1], Daniel Heinert[1], Stefanie Kroker[2], Andreas Tünnermann[2], Paul Seidel[1], and Ronny Nawrodt[1] — [1]Institut für Festkörperphysik, FSU Jena, Helmholtzweg 5, D-07743 Jena — [2]Institut für Angewandte Physik, FSU Jena, Albert-Einstein-Strasse 15, D-07745 Jena

Gravitational wave detectors are one of the most precise measurement devices ever developed. Surface conditions can limit the noise performance of these devices effecting their mechanical and thermal properties (e.g. by phonon scattering). In order to change the sample surface different preparation techniques like mechanical polishing, dry and wet etching were used. We present detailed temperature dependent measurements on the mechanical loss ϕ and thermal conductivity κ of small flexures. All measurements were carried out in a temperature range from 5 to 300 K revealing mechanical losses as low as 3×10^{-8} at 10 K.

In order to extract the surface loss parameter we compare our measurements to values known from literature. It can be shown that the surface loss parameter of silicon is significantly smaller than for fused silica.

This work was supported by the German science foundation DFG under contract SFB TR7.

GR 4.5 Di 15:00 HS 6

Thermal noise in grating reflectors — •Daniel Heinert[1], Stefanie Kroker[2], Daniel Friedrich[3], Stefan Hild[4], Iain Martin[4], Ronny Nawrodt[1], Paul Seidel[1], Andreas Tünnermann[2], Sergey Vyatchanin[5], and Kazuhiro Yamamoto[3] — [1]Institut für Festkörperphysik, FSU Jena, 07743 Jena — [2]Institut für Angewandte Physik, FSU Jena, 07745 Jena — [3]Institute for Cosmic Ray Research, The University of Tokyo, Kashiwa, Chiba 277-8582, Japan — [4]SUPA, School of Physics and Astronomy, Institute for Gravitational Research, Glasgow University, Glasgow G12 8QQ, United Kingdom — [5]Faculty of Physics, Moscow State University, Moscow 119991, Russia

The interferometric detection of gravitational waves is crucially limited by the thermal noise of the detector's optical components. Past investigations have identified the high reflective coating layers to show a high mechanical loss. Due to the fluctuation-dissipation theorem they form the dominating noise source in a detector.

A promising alternative to the use of Bragg mirrors can be found in grating reflectors. Such gratings can be designed to exhibit high reflectivities at a specific design wavelength. These structures significantly reduce or even avoid the use of lossy coating materials and thus are expected to show a decreased amount of thermal noise.

In our contribution we present the noise analysis of grating reflectors. We further apply our theory to a 3rd generation gravitational wave detector. Finally, the noise benefit for the use of a grating reflector compared to a conventional layer stack is estimated.

This work is supported by the DFG under contract SFB TR 7.

GR 4.6 Di 15:15 HS 6

Anomalous dynamic back-action in interferometers: beyond the scaling law — •Sergey Tarabrin[1,2], Farid Khalili[3], Klemens Hammerer[1,2], Henning Kaufer[1], and Roman Schnabel[1] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstraße 38, 30167 Hannover, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [3]Department of Physics, Moscow State University, Moscow 119992, Russia

We analyze dynamic back-action in the signal-recycled Michelson-Sagnac interferometer with a translucent membrane positioned in its arm, operated off dark port, and reveal its 'anomalous' features as compared to the ones of 'canonical' back-action, obtained within the scope of scaling law. Given the finite reflectivity of the membrane, optical damping as a function of detuning acquires (i) non-zero value on resonance and (ii) several stability/instability regions. In the case of absolutely reflecting membrane, corresponding to a pure Michelson interferometer, off-dark-port regime results in several intersecting regions of positive/negative values of optical spring and damping. For a certain region of parameters, stable sets of both effects in a free-mass interferometer with a single laser drive are possible. Our results can find implementations in both cavity optomechanics, revealing new regimes of cooling of micromechanical oscillators, and in the gravitational-wave detectors, revealing the possibility of stable single-carrier optical spring which can be utilized for the reduction of quantum noise.

GR 4.7 Di 15:30 HS 6

Diffraktive Optiken in 2. Ordnung Littrow für zukünftige Gravitationswellendetektoren. — •Christoph Krüger[1], Alexander Khalaidovski[1], Michael Britzger[1], Stefanie Kroker[2], Ernst-Bernhard Kley[2], Andreas Tünnermann[2], Karsten Danzmann[1] und Roman Schnabel[1] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany — [2]Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Laserinterferometrische Gravitationswellendetektoren setzen hohe Lichtleistungen ein, um eine möglichst hohe Messgenauigkeit zu erreichen. Für die Detektoren der zweiten Generation ist eine zirkulierende Lichtleistung von vielen hundert Kilowatt geplant. Zur Überhöhung der optischen Leistung werden dabei Fabry-Perot Armresonatoren eingesetzt. Die Restabsorption in den transmittiven Optiken führt schon heute zu einer thermischen Verformung, welche ihrerseits eine Veränderung des Strahlprofils bedingt. Da dieser Effekt nur teilweise kompensiert werden kann, wird er zu einem oberen Limit für die nutzbare Leistung in den künftigen Detektorgenerationen führen. Durch den Einsatz diffraktiver Optiken entfallen die Transmission durch Substrate und die damit verbundenen thermischen Effekte. Im Rahmen des SFB TR7 wurden solche dielektrischen Beugungsgitter hergestellt und charakterisiert. Der Vortrag präsentiert die Charakterisierung eines großformatigen optischen Gitters von 20cm x 20cm und damit in einer für GW-Detektoren verwendbaren Dimension.

GR 4.8 Di 15:45 HS 6

Dynamic tuning for a signal recycled interferometer. — •Dmitry Simakov — Institut für Gravitationsphysik, Leibniz Universität Hannover and
Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstraße 38, 30167 Hannover, Germany

In this work we study a particular method of detection of the chirp signal, the so-called dynamic tuning. The exact simulation of the detector response for the arbitrary signal recycling tuning variation and input signal is performed. Using the response, we calculate the shot noise and prove that it stays white for non-stationary regimes of interferometer operation. This allows us to compute the signal-to-noise ratio of the detection with dynamic tuning. The problem of signal deconvolution is also solved.