GRAvitational-waves Science&technology Symposium (GRASS 2019)

Report of Contributions

https://agenda.infn.it/e/GRASS2019

Contribution ID: **2** Type: **not specified**

Faster than Nature: Engineered swift equilibration of small systems.

Friday, 25 October 2019 08:30 (35 minutes)

A fundamental and intrinsic property of any device or natural system is its relaxation time \tau_{\rm relax}, which is the time it takes to return to equilibrium after the sudden change of a control parameter. Reducing \tau_{\rm relax} is frequently necessary, and is often obtained by a complex feedback process. To overcome the limitations of such an approach, alternative methods based on suitable driving protocols have been recently demonstrated, for isolated quantum and classical systems. Their extension to open systems in contact with a thermostat is a stumbling block for applications. Here, we design a family of protocols, named Engineered Swift Equilibration (ESE), that shortcuts time-consuming relaxations. We apply them to a Brownian particle trapped in an optical potential and to the cantilever of an Atomic Force Microscope, which are paramount tools to measure forces of femtoNewtons with microsecond accuracy. We implement the process experimentally, showing that it allows the system to reach equilibrium several order of magnitude of time faster than the natural equilibration rate (from miliseconds to microseconds). We also measure the increase of the dissipated energy needed to get such a time reduction. The method paves the way for applications in micro- and nano-devices, where the reduction of operation time represents as substantial a challenge as miniaturization.

Primary author: Dr MARTÍNEZ, Ignacio A. (Universidad Complutense de Madrid)

Presenter: Dr MARTÍNEZ, Ignacio A. (Universidad Complutense de Madrid)

Session Classification: Thermal noise in and out of thermodynamic equilibrium

Contribution ID: **3** Type: **not specified**

Operating high sensitivity measurement apparata out of equilibrium

Friday, 25 October 2019 09:05 (25 minutes)

In this work we present an approach aimed at operating high sensitivity measurement apparata out of equilibrium with the purpose to enhance their sensitivity. We show, with an experiment, that selective cooling of thermally activated single modes of a mechanical structure, is capable of positively impacting the measurement sensitivity improving significantly the signal-to-noise ratio in the frequency range where the cooling has been applied. In general, our results suggest that, at difference with the standard way to operate high sensitivity measurement apparata, i.e. under equilibrium conditions, the cyclical drive-and-relax to equilibrium operation might provide increased sensitivity in selected frequency ranges.

Primary authors: Dr NERI, Igor; Prof. GAMMAITONI, Luca

Presenter: Dr NERI, Igor

Session Classification: Thermal noise in and out of thermodynamic equilibrium

Contribution ID: **5** Type: **not specified**

A testbed for Tilt-To-Length coupling and Differential-Wavefront-Sensing performance in LISA

Thursday, 24 October 2019 10:20 (25 minutes)

The LISA mission, which has been accepted by ESA as the ESA-L3 Gravitational Wave Mission, aims at measuring gravitational waves in the sub-Hz band using inter-spacecraft interferometry. LISA consists in a constellation of three satellites in triangle formation with 2.5 Gm-long arms following along an Earth-like heliocentric orbit. The ambitious sensitivity of pm/Hz$^{1/2}$ presents many technical challenges; one of the main issues is the coupling of the angular jitter of the spacecraft and test masses to the interferometrically-measured longitudinal displacement (Tilt-To-Length coupling, or TTL), which can be of geometric origin if the tilt causes an optical pathlength change, or it can be non-geometric, e.g., caused by wavefront curvature mismatches between the interfering beams. To readout length and angular signals, LISA implements the Differential-Wavefront-Sensing (DWS) method, that combines the individual phase readouts from the four segments of a Quadrature PhotoDiode (QPD). An ultra stable interferometer testbed representative of the Optical Bench (OB) of a LISA spacecraft has been developed in order to validate critical interferometric techniques for the LISA mission. The testbed features a pair of steering mirrors that
can induce synthetic tilts between the beams to simulate spacecraft or test mass motion. This experiment has been used to demonstrate optical reduction of TTL by using imaging systems to image the point of rotation of the beams into the detector plane. Current work is focusing on developing a new method to readout the DWS signals from the QPDs.

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Presenter: Mr PIZZELLA, Alvise (Albert Einstein Institute Hannover)

Session Classification: Other challenges for future GW detectors

Contribution ID: **6** Type: **not specified**

6dB of squeezing level at GEO 600

Thursday, 24 October 2019 14:40 (25 minutes)

Squeezed light has been employed at GEO 600 for almost 10 years, recently reaching the highest level ever measured on a large scale interferometer. This improvement was achieved after work towards the reduction of optical losses in the squeezed light injection path.
The in-air injection path was rebuilt by cleaning and substituting some optics. Faraday isolators were carefully tuned in order to achieve optimal isolation; the PBS mounts of the in-vacuum Faraday isolator are equipped with quadrant photodiodes for the monitoring of rejected light during the tuning operation.
Finally, while investigating second-order mode-mismatch, a way to correct for astigmatism was found.

Primary authors: BERGAMIN, Fabio (AEI Hannover); Dr LOUGH, James (AEI Hannover)

Presenter: BERGAMIN, Fabio (AEI Hannover)

Session Classification: New strategies for quantum noise reduction

Contribution ID: **7** Type: **not specified**

Small scale suspended interferometer for ponderomotive squeezing as test bench for EPR squeezer integration in Advanced Virgo

Friday, 25 October 2019 12:20 (25 minutes)

In 2015, after many years of R&D efforts of the LIGO-Virgo collaboration for the upgrade to the second generation of ground based gravitational wave detectors, for the first time it has been possible a direct observation of a gravitational wave event (GW). In the following years, many other GW events have been detected by both LIGO and Virgo. Nevertheless, in the very near future the present generation of detectors will face the limit in sensitivity due to the quantum nature of light: the so-called Standard Quantum Limit (SQL). Therefore, any future upgrade aiming at increasing the sensitivity implies quantum noise reduction techniques. LIGO and Virgo already adopt frequency independent squeezers, which reduce the quantum noise in the high frequency range where shot noise is dominant (above 200Hz). In the very near future, the detectors will be also limited by quantum noise in the low frequency range (below 100Hz), where radiation pressure noise is dominant. Therefore, it is crucial to develop table-top experiments aiming at testing broadband quantum noise reduction (10Hz-1kHz): frequency dependent squeezers. We are developing a small-scale interferometer with monolithic suspension of test masses (SIPS) that will be sensitive to the radiation pressure noise in the audio frequency band of GW detectors. In order to be able to produce frequency dependent squeezing (FDS) in the audio frequency band, seismic noise at low frequency must be suppressed. This can be possible by suspending the whole interferometer to a chain of mechanical filters like a superattenuator of Virgo. In the same time, we are developing a table-top experiment for the FDS generation through the Einstein Rosen Podolsky (EPR) principle. These two experiments are growing up in parallel. EPR technique, before the injection in Virgo for the quantum noise reduction, needs to be tested in an optical cavity achieving the radiation pressure noise limit. Therefore, the small-scale interferometer SIPS turns out to be a suitable test bench for the EPR technique before the integration in Virgo. In this talk the status of the art of the SIPS experiment and the design for the integration with the EPR experiment will be presented.

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Presenter: Dr DI PACE, Sibilla (ROMA1)

Session Classification: New strategies for quantum noise reduction

Contribution ID: **8** Type: **not specified**

Dissipation in a Tantala film from 10K to 150K from thermal noise measurements

Thursday, 24 October 2019 15:30 (25 minutes)

We study the dissipation φ of a silicon μ-cantilever coated with 300nm of Tantala. From the thermal noise spectra, a fit of 10 resonances for flexion modes, and 6 resonances for torsion modes can be performed, giving access to φ from 2 kHz to 600 kHz. Dissipation presents a weak maximum around 50 K in temperature, and is a slowly increasing function of frequency (power law f with α~0.06). An extrapolation of this behaviour to lower frequencies (down to 10 Hz) agrees reasonably well with the thermal noise measurements, even if external noise peaks hinder direct exploitation of noise in this frequency range.

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Session Classification: Ultra-low-noise optical coatings

Contribution ID: **9** Type: **not specified**

Frequency dependent squeezing experiment at TAMA

Thursday, 24 October 2019 13:25 (25 minutes)

Gravitational wave (GW) detectors are the most sensitive displacement sensors on earth. So sensitive that they made possible the first GW detection in September 2015. After the first one, many other GW detections followed, and that was possible mainly due to the several upgrades that were implemented. Among the many noises that limit the GW detector sensitivity, one of the most fundamental is the quantum noise. This noise can be understood as the sum of two different contributors: the shot noise coming from the photon counting noise at the photodiode and the radiation pressure noise, due to the momentum exchange between photon and mirrors. The shot noise is currently the main limiting noise in the high frequency region of the GW detectors'sensitivity. It is expected that soon the radiation pressure noise, will be the main limiting source in the low frequency region, having therefore the quantum noise to limit the entire sensitivity band of GW detectors. The impact of the quantum noise on the total GW sensitivity is even more severe in the case of KAGRA.

KAGRA is an underground GW detector operating at cryogenic temperature, currently under commissioning in Japan. Thanks to these two features, the associated noises (namely the seismic noise and the coating thermal noise) are reduced, having the quantum noise to dominate entirely the detection bandwidth. The most promising technique to achieve a broadband reduction of the quantum noise is the injection of a frequency-dependent squeezed vacuum state from the output port of the GW detector, with the squeeze angle rotated by the reflection off a Fabry-Perot filter cavity, known as filter cavity.

A 300m filter cavity prototype is being developed at the National Astronomical Observatory of Japan, using the vacuum system and the seismic isolation system originally built for the TAMA interferometer. The goal of the experiment is to demonstrate frequency-dependent squeezing, with a rotation angle below 100 Hz, in the region where the rotation is needed for Virgo, LIGO, and KAGRA. The experiment is in its final stages: the frequency independent squeezed light source construction is finished and the commissioning is ongoing (6.1dB of squeezing achieved so far starting from about 10Hz), the filter cavity has been completely characterized and the injection of squeezing into the filter cavity has been started.

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Presenter: Dr LEONARDI, Matteo (NAOJ)

Session Classification: New strategies for quantum noise reduction

Contribution ID: **10** Type: **not specified**

EPR experiment for a broadband quantum noise reduction in gravitational wave detectors

Friday, 25 October 2019 11:55 (25 minutes)

Vacuum fluctuations entering the dark port of an interferometric Gravitational Wave (GW) detector are responsible for Quantum Noise (QN).
The high-frequency component of QN is Shot Noise (SHN), while the low-frequency one is Radiation Pressure Noise (RPN).
The sensitivity of the present detectors is only affected by the first, being the RPN covered by techinical noises. SHN reduction, injecting Frequency Independent Squeezing (FIS) from the dark port of the interferometer, has been already demonstrated in GEO, LIGO and, recently, also in Advanced Virgo.
In the near future, when low-frequency technical noises will be reduced and the laser power will be increased, RPN will limit the detector sensitivity, then a braodband QN reduction will be needed. Since RPN noise is related to the vacuum amplitude fluctuations, one needs two different squeezing angles for low and high frequencies. Starting from phase squeezed frequency independent (FI) vacuum, produced by a degenerate Optical Parametric Oscillator (OPO), one can obtain a Frequency Dependent Squeezing (FDS) by the injection of the FI squeezed vacuum in an external Filter Cavity (FC), before injecting it into the interferometer.
The required squeezing angle rotation must occur around the frequency of the interferometer pole (i.e. around 100 Hz). The additional requirement to limit intra-cavity losses to a few percent implies that the FC must be hundreds of meters long.
Injecting Einsten-Podolsky-Rosen (EPR) entangled vacuum fields into the interferometer can be a valid alternative to the use of a FC. It will allow to abtain the frequency dependent rotation angle with a more compact system avoiding, the expensive infrastructure needed for the Filter Cavity, including all the related control systems and the interface optics between the filter cavity and the interferometer.
The method for obtaining the frequency dependent rotation angle using EPR entangled beams and the experiment that we are developing from a FIS source, which is currently operating at the Virgo site, will be described in the present talk.
The first step will be the realization of a table-top demonstrator that will make use of a test cavity instead of a gravitational wave interferometer. The following step will be the design and the realization of an EPR experiment to inject the entangled beams in Advanced Virgo.

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Session Classification: New strategies for quantum noise reduction

Contribution ID: **14** Type: **not specified**

Modeling and simulations of current and prospective coating materials

Thursday, 24 October 2019 14:40 (25 minutes)

The development of thin-film coatings with lower mechanical losses is of critical importance for the performance of future generations of interferometric gravitational-wave detectors. Significant experimental effort has led to improvements during these years and currently the most advanced technology is the one of amorphous coatings. Yet, there is still a lack of fundamental understanding of the involved dissipation mechanisms. Atomic modeling and simulations can play an important role in elucidating the physical processes and guiding the choices of optimal coating materials. In this work we study dissipation in glasses applying the experimental protocol of mechanical spectroscopy to atomistic simulations. First, we validate this approach on current coating materials, for which our results exhibit impressive agreement with the existing experimental data. Then we investigate prospective materials, which are potential candidates as a possible solution for the reduction of mechanical losses.

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Session Classification: Ultra-low-noise optical coatings

Contribution ID: **17** Type: **not specified**

Thermal fluctuations in an out-of-equilibrium state

Friday, 25 October 2019 09:30 (25 minutes)

Thermal noise manifests itself as a tiny variance around the mean value of an observable x of a physical system. Usually too small to be noticed, it becomes important in an increasing number of applications, such as quantum systems operated close to their ground state, MEMS and NEMS, frequency standards, or the next generation of gravitational wave detectors[1]. Its understanding is thus fundamental.
When in equilibrium, the Fluctuation-Dissipation Theorem (FDT) is a cardinal tool that allows us to couple the fluctuations of x, to the temperature of the system in the form of the Equipartition Principle (EP). Unfortunately, this assumption is often not possible. Our goal is thus probing its validity out of this region.
In our experiment we study a system in a Non-Equilibrium Steady State: a silicon micro-cantilever subject to a heat flux due to a laser heating. We measure the thermal noise driven flexion and torsion and quantify the amplitude of fluctuations with an effective temperature T^{eff}, extending the FDT following recent theoretical developments[2]:
\begin{equation}
k_B T^{eff} = k\langle x^2\rangle
\end{equation}
with k_B the Boltzmann constant, k the stiffness, $\langle x^2\rangle$ the mean square of the observable, i.e. the thermal noise. Whilst in general an excess of fluctuations is expected, in our case a deficit is instead observed, as in Geitner[3]. Thermal noise is below the average temperature T^{avg} of the system, both for flexion and torsion modes.

[1] Harry, G. M. et al. (2006). Appl. Opt. 45, 1569
[2] Komori, K. et al. (2018). Phys. Rev. D 97, 102001
[3] Geitner, M. et al. (2017). Phys. Rev. E 95, 032138

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Session Classification: Thermal noise in and out of thermodynamic equilibrium

Contribution ID: **18** Type: **not specified**

A thermoelastic extension of the fluctuation dissipation theorem in nonequilibrium states

Friday, 25 October 2019 10:40 (25 minutes)

We build a continuous fluctuating description of elastic, conductive and dissipative solids subject to heat fluxes, which takes fully into account linear thermoelastic couplings.
Under the assumption of local equilibrium, we derive an extension of the fluctuation-dissipation theorem
and obtain the strain fluctuations in the nonequilibrium steady state.
We outline next steps towards the assessment of thermal noise for Advanced VIRGO,
Advanced LIGO and next generation of gravitational wave interferometers in realistic nonequilibrium conditions.

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Session Classification: Thermal noise in and out of thermodynamic equilibrium

Contribution ID: **19** Type: **not specified**

Multimaterial Coatings for 3rd Generation Gravitational Wave Detectors

Thursday, 24 October 2019 15:05 (25 minutes)

Thermal noise associated with the mechanical loss of highly reflective mirror coatings is a critical limiting factor to the sensitivity of interferometric gravitational-wave detectors. Several alternative coating materials have been shown to have low mechanical loss, but however, due to their high optical absorption, cannot be implemented in upgrades to these detectors.

New multimaterial coatings designs have been proposed to enable the use of these materials to reduce thermal noise without adversely effecting the absorption. At the University of Glasgow, we have been measuring the mechanical loss, both at room temperature and at cryogenic temperatures, and absorption of new silica/tantala/amorphous silicon coatings to provide the first experimental verification of the multi-material design.

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Session Classification: Ultra-low-noise optical coatings

Contribution ID: **20** Type: **not specified**

Electronic hardware and software development for EPR squeezer

Friday, 25 October 2019 12:45 (25 minutes)

Quantum Noise (QN) is a phenomenon which gives high contribution to the overall noise in the advanced interferometric Gravitational–Wave detectors. In the previous interferometer generation, the most relevant QN component was dominating in the high frequency region (300 Hz –10 kHz) of the detection band. This component of noise could be corrected by injection of optimal squeezed state [1]. Virgo Scientific Collaboration has already implemented Frequency–Independent Squeezing (FIS) injection to the readout port of Advanced Virgo and reported improvement of the sensitivity curve of around 3 dB [2]. Currently, the Collaboration focuses on the work on the Frequency–Dependent Squeezing (FDS) injection using filter cavity which will reduce QN either in the high and low–frequency range. At the same time, Virgo Squeezing working group is studying a possible alternative way of producing frequency–dependent squeezed states without the filter cavity. The mechanism of FDS without filter cavity, called EPR squeezing, was proposed theoretically by Ma et al. [3] and subsequently demonstrated feasible by scientific group from ANU and Hamburg [4].
At the moment, development facility for the production of squeezed vacuum at EGO/Virgo site is being adapted for the preliminary experiment on the EPR. The experiment represents a first step toward implementation of the new squeezing generation technique. For the purpose of the project, Perugia group is developing various types of photo-detectors and automation software based on Finite State Machines (FSM).
In the presentation, I overview the current state of work on the facility and I summarize in details the tasks related to the development of electronics and software. In particular, I present the engineering of analogue electronics for cavity locking and squeezed state measurement. In the conclusions, I include the near future steps: FSM scheme, noise hunting and lock automation.

References:

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4. Gniesmer, Jan, Mikhail Korobko, Sebastian Steinlecher, and Roman Schnabel. "Frequency-Dependent Squeezed States for Gravitational-Wave Detection through EPR Entanglement."Quantum Information and Measurement (QIM) V: Quantum Technologies (2019). doi:10.1364/qim.2019.s2b.4.

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Presenter: BAWAJ, Mateusz (PG)

Session Classification: New strategies for quantum noise reduction

Contribution ID: **21** Type: **not specified**

Coupled cavity optomechanics

Thursday, 24 October 2019 13:50 (25 minutes)

Cavity optomechanics can be used to improve the sensitivity of gravitational-wave detectors via optomechanical filtering and ponderomotive squeezing. Here we present a concept for double resonant enhancement of optomechanical interaction in a multi-cavity optomechanical system that exhibits resonance splitting tuned to be equal to the mechanical resonant frequency. In a detuned cavity in the resolved sideband regime this leads to simultaneous resonant enhancement of the carrier and one of the sidebands of the optical field, drastically increasing the optomechanical coupling strength. We present the design for a proof-of-principle table-top experiment based on highly reflective crystalline GaAs/AlGaAs micro-mechanical resonators, provide estimations for required parameter values, discuss the applications and give update on the current status of the experimental project.

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Presenter: DMITRIEV, Artemii (University of Birmingham)

Session Classification: New strategies for quantum noise reduction

Contribution ID: **22** Type: **not specified**

Cooling System of KAGRA

Friday, 25 October 2019 14:10 (25 minutes)

KAGRA is an only gravitational wave telescope using cryogenic mirror system. Although cryogenic sapphire mirror and suspension is the most direct way to reduce thermal noises, a technical issue is to cope with both cooling and vibration isolation. We worked on this issue for 20 years and realized in KAGRA now. For example, special technologies in KAGRA cooling system are followings;

- Ultra-small vibration cryocooler system
- Funneling effect in beam tubes and its reduction by black coating
- Ultra-soft and large thermal-conductive heat-link
- Heat-link vibration isolation system
- Ultra-small out-gas thermal insulator

And recently, we found an issue of mirror frosting by adsorption of residual gas in cryostat by cryogenic pump effect, and studies this phenomena and solution.
In this presentation, cooling system of KAGRA and some of the issues will be reported.

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Session Classification: Advanced cryogenics

Contribution ID: **23** Type: **not specified**

Cryogenic mirror suspension in KAGRA

Friday, 25 October 2019 14:35 (35 minutes)

KAGRA is a 2G interferometric gravitational wave detector constructed in Japan. Its unique features are using underground site and cryogenic sapphire mirrors. In this talk, I will talk on current status and difficulities of cryogenic mirror suspension and our plan to overcome these issues.

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Presenter: Dr USHIBA, Takafumi (ICRR)

Session Classification: Advanced cryogenics

Contribution ID: **24** Type: **not specified**

Room temperature optomechanical squeezing

Thursday, 24 October 2019 14:15 (25 minutes)

The decades of advancement in technologies pertaining to interferometric measurements have made it possible for us to make the first-ever direct observation of gravitational waves(GWs). These GWs emitted from violent events in the distant universe bring us crucial information about the nature of matter and gravity. In order for us to be able to detect GWs from even farther or weaker sources, we must further reduce the quantum noise in our detectors. In order to lower this quantum noise, GW detectors currently use squeezed light. Squeezed light is a special quantum state of light which has lower uncertainty in a certain quadrature, at the expense of higher uncertainty in the orthogonal quadrature.
In this talk, I focus on using radiation-pressure-mediated optomechanical (OM) interaction to generate squeezed light. Creating squeezed states by using optomechanical interaction opens up possibilities for engineering truly wavelength-independent squeezed light sources that may also be more compact and robust than traditionally used non-linear crystals. Additionally, this project inherently involves studying the OM interaction, which is the mechanism for back-action noise in GW detectors.
These observations are the first-ever direct observation of a room temperature oscillator's motion being overwhelmed by vacuum fluctuations. More so, this is also the first time it has been shown in the low-frequency band, which is relevant to GW detectors, but poses its own technical challenges, and hence has not been done before. Being in the back-action dominated regime along with optimized optical properties has also enabled us to observe OM squeezing in this system. That is the first direct observation of quantum noise suppression in a room temperature OM system. It is also the first direct evidence of quantum correlations in an audio frequency band, in a broadband at non-resonant frequencies.

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Presenter: AGGARWAL, Nancy (Northwestern University)

Session Classification: New strategies for quantum noise reduction

Contribution ID: **25** Type: **not specified**

Annealing effects on the mechanical losses of fluorides thin films

Thursday, 24 October 2019 15:55 (25 minutes)

Fluorides like MgF_2 and AlF_3 have the lowest refractive index among the known coating materials; using them in a high-reflection (HR) Bragg mirror instead of SiO_2, one could reduce the total HR coating thickness and hence its coating thermal noise.
A succession of annealing treatments at different temperatures (but with the same duration) were performed on a silica disk coated with MgF_2. The annealing was done in a controlled Argon atmosphere, in order to prevent the oxidation of the coating. After each annealing cycle, the Q-factor and the weight of the sample were measured, in order to extract the coating losses.
We noticed that after each annealing treatment, the Q-factor of the sample increased, but started to decrease above 500℃.
We repeated the succession of annealing treatments with different durations (but at the same temperature) on a different sample, identical to the previous one.
In this case we noticed that the Q-factor of the sample increased after each annealing, until the fourth treatment (that correspond to 124 hours of cumulative annealing times).

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Session Classification: Ultra-low-noise optical coatings

Contribution ID: **26** Type: **not specified**

Dynamical thermal compensation techniques for Advanced Virgo

Thursday, 24 October 2019 09:30 (25 minutes)

An adaptive optics system (named thermal compensation system - TCS) is currently in operation in Advanced Virgo to monitor and compensate wavefront distortions with an accuracy of the order of nanometers ensuring a duty cycle of the interferometer higher than 75%. During preparatory phase for O3, the TCS actuators have been commissioned and tuned. New research and development activities are being carried out in order to optimize the TCS single actuators operation and the combined action of multiple actuators to become operational in view of the next observing run (O4). The sensors dedicated to the measurement of optical aberrations in Advanced Virgo are the Hartmann Wavefront Sensors (HWS). These devices directly measure the change of a wavefront with respect to a reference encoded in an auxiliary probe beam. To fulfill the more stringent requirements, a significant improvement of the HWS sensor performances are mandatory. The most recent developments of the compensation system will be presented.

Primary authors: FAFONE, Viviana (ROMA2); ROCCHI, Alessio (ROMA2); CESARINI, Elisabetta (ROMA2); LUMACA, Diana (R); NARDECCHIA, Ilaria (ROMA2); AIELLO, Lorenzo (ROMA2); LORENZINI, Matteo (GSSI); MINENKOV, Yury (ROMA2); MAGGIORE, Riccardo (Università di Roma Tor Vergata)

Presenter: NARDECCHIA, Ilaria (ROMA2)

Session Classification: Other challenges for future GW detectors

Contribution ID: **27** Type: **not specified**

Prototype Cryogenic Silicon Suspension Activities at Glasgow

Friday, 25 October 2019 15:10 (25 minutes)

In order to increase strain sensitivity in the 10-200 Hz region of current gravitational wave detectors it is necessary to further reduce the thermal noise of the detector. Proposals have been put forward for the next generation (3G) detectors which will operate at cryogenic temperatures. Silicon is a promising material due to its low mechanical loss, high thermal conductivity and zero thermal expansion at low temperatures (18 K and 123 K). This talk will briefly discuss surface treatment methods aimed at increasing the ultimate tensile strength of silicon as well as initial attempts of cooling silicon suspension elements for use in a prototype cryogenic suspension.

Primary authors: EDDOLLS, Graeme (University of Glasgow); Dr CUMMING, Alan V. (University of Glasgow); Dr HAUGHIAN, Karen (University of Glasgow); HOUGH, James (University of Glasgow); ROWAN, Sheila (University of Glasgow); Mr JONES, Russell (University of Glasgow); HAMMOND, Giles (University of Glasgow); Prof. REID, Stuart (SUPA, University of Strathclyde); Dr BIRNEY, Ross (University of Strathclyde)

Presenter: EDDOLLS, Graeme (University of Glasgow)

Session Classification: Advanced cryogenics

Contribution ID: **28** Type: **not specified**

Updates on silica fibers production and characterization for future gravitational waves detectors

Friday, 25 October 2019 15:35 (25 minutes)

The observation of gravitational waves is highly influenced by the detectors sensitivity, that is limited for the low frequencies (10 -100 Hz) by the thermal noise. For this reason, the monolithic suspensions are one of the most important upgrades of the interferometric detectors including Advanced Ligo (aLigo) and Advanced Virgo (AdV). Currently the silica fibers are built to minimize the thermal noise in the band of interest and to fit the load constrains. Nevertheless, the need to have larger reference masses for the future updates of Virgo and also for the future 3G detectors, requires redesigning the fibers, and all the facilities for their production, testing and characterization. The new fibers for Advanced Virgo Plus (AdV+) will be 50% thicker to deal with a working load four times higher, thus the fabrication system requires a more accurate power stabilization of the CO2 laser in order to control the melting process of the silica more precisely and all the testing facilities have to be updated and, in some cases, completely redesigned for the new high requirements. Furthermore, we aim to study the behavior of the pristine fibers under static and dynamic fatigue in order to achieve a consistent model of lifetime prediction for maintenance and security reasons.

Primary author: MONTANI, Matteo (Istituto Nazionale di Fisica Nucleare)

Presenter: MONTANI, Matteo (Istituto Nazionale di Fisica Nucleare)

Session Classification: Advanced cryogenics

Contribution ID: **29** Type: **not specified**

Improving Gravitational-Wave Detectors with Entangled Light

Friday, 25 October 2019 11:30 (25 minutes)

Squeezed light now has a firm place as a key technology for reducing the quantum noise in gravitational-wave detectors. Quantum noise of coherent and squeezed states is characterized by gaussian measurement uncertainties in their amplitude and phase quadratures. While in a coherent state both quadratures have the same (minimal) uncertainty, in squeezed states the uncertainty in one quadrature is reduced at the cost of increased uncertainty in the other, orthogonal quadrature. The phase quadrature uncertainty appears as shot noise in interferometry, while the amplitude noise appears as radiation pressure noise. This leads to the difficulty of having to transition between the two over a narrow frequency band, in order to get a quantum-noise reduction over a broad frequency range.
Conversely, two-mode squeezed states of light, or entangled states of light, have their uncertainty defined as a sum or difference between two separate modes. Only after measurements on these two modes are compared, their mutual correlation and reduced uncertainty is revealed. This allows for novel approaches in quantum-noise reduction in post-processing, such as the EPR squeezing scheme (Ma et al., 2017) or quantum-dense metrology (Steinlechner et al., 2013). I will review these approaches and report on experimental implementations and results in table-top setups.

Primary author: Dr STEINLECHNER, Sebastian (Maastricht University)

Presenter: Dr STEINLECHNER, Sebastian (Maastricht University)

Session Classification: New strategies for quantum noise reduction

Contribution ID: **30** Type: **not specified**

Towards a silicon monolithic suspension

Thursday, 24 October 2019 09:55 (25 minutes)

The thermal noise of the main optics is a fundamental limit for the sensitivity of present and future GW detectors. To reduce it, the next generation of GW interferometers will use larger mirrors and will be cryogenic. To reach this goal, it is essential to identify suitable materials for substrates and suspensions. That means not only materials with good thermal, mechanical and optical properties but also materials that would allow big size substrates and thin, long, strong fibers. Sapphire is a good candidate already used in the KAGRA experiment but it is hard to produce substrates larger than 20cm, it is hard to machine and to polish and it is very expensive. A very promising alternative candidate is silicon.
The present work will discuss the status of the R&D project on silicon fibers produced by three different methods, the results obtained so far and the hints to improve them. Moreover, it will present the status of the system to characterize silicon bulks in cryogenics before the complete installation of the silicon monolithic suspension.

Primary authors: TRAVASSO, Flavio (PG); VOCCA, Helios (PG); TOMARU, Takayuki (National Astronomical Observatory of Japan); USHIBA, Takafumi (ICRR); Prof. SUZUKI, Toshikazu (Institute for Cosmic Ray Research - Tokyo); PILUSO, Antonfranco (PG); AISA, Damiano (PG); Prof. GIBSON, Ursula (Norwegian University of Science and Technology); Prof. BALLATO, John (Clemson University); Prof. HAWKINS, Thomas (Clemson University)

Presenter: TRAVASSO, Flavio (PG)

Session Classification: Other challenges for future GW detectors

Contribution ID: **31** Type: **not specified**

Results of the long-term measurements from the Mátra Gravitational and Geophysical Laboratory

Thursday, 24 October 2019 10:45 (25 minutes)

Mátra Gravitational and Geophysical Laboratory was established in Hungary in 2015 with the aim to measure and analyze the advantages of the subterranean installation of third generation of gravitational-wave detectors. The laboratory is located 88 m below the ground. Seismic, infrasonic and electromagnetic noise have been monitored. The seismic data have been collected for almost two years. Methodological improvements for long term data evaluation were developed, too. The structure of the rock above the laboratory was examined with a muon detector, and a novel theoretical framework of noise damping of rock masses was also introduced. Applying our results for the site selection can improve the signal to nose ratio of the multi-messenger astrophysics era at the low frequency regime.

Primary author: Ms FENYVESI, Edit (Wigner Research Centre for Physics)

Presenter: Ms FENYVESI, Edit (Wigner Research Centre for Physics)

Session Classification: Other challenges for future GW detectors

Contribution ID: **32** Type: **not specified**

Thermal gradients and Energy equipartition - numerical and theoretical

Friday, 25 October 2019 10:15 (25 minutes)

We discuss a one-dimensional model of a vibrating rigid rod, in and out of equilibrium. We study stationary states when the system is subject to temperature gradients, which is the nonequilibrium scenario, as compared to constant temperature for the equilibrium situations. While some thermomechanical properties remain substantially unchanged comparing in and out of equilibrium situations, the energy of competence of the first few modes is substantially augmented, compared to its putative equipartition among the modes. The numerical model is composed of particles in the bulk which interact purely Newtonianly, thus indicating a genuine effect. The theoretical model is only tentative, and based on probabilistic ansatzes.

Primary author: Dr DE GREGORIO, Paolo (Dipartimento di Scienze Matematiche ”Luigi Lagrange” (DISMA), Politecnico di Torino)

Presenter: Dr DE GREGORIO, Paolo (Dipartimento di Scienze Matematiche ”Luigi Lagrange” (DISMA), Politecnico di Torino)

Session Classification: Thermal noise in and out of thermodynamic equilibrium

Contribution ID: **33** Type: **not specified**

Cryogenic challenges for third generation gravitational wave interferometers

Friday, 25 October 2019 16:00 (25 minutes)

The third generation gravitational wave detectors like Einstein Telescope and LIGO Voyager, will adopt cryogenics mirrors and suspension systems as KAGRA interferometer, to reduce thermal noise and improve the sensitivity. The suspension systems or part of them will operate at low or cryogenic temperatures. The problems and challenges of operating the suspension systems and the interferometers at low temperatures and with low contamination will be discussed, presenting possible technical solutions.

Primary author: Prof. POGGIANI, Rosa (Universita' di Pisa)

Presenter: Prof. POGGIANI, Rosa (Universita' di Pisa)

Session Classification: Advanced cryogenics

Contribution ID: **34** Type: **not specified**

6D inertial seismic isolation system

Thursday, 24 October 2019 11:10 (25 minutes)

Increasing sensitivity of GW detectors in the low-frequency band is important for studying the intermediate mass black holes and accumulating signal from the lighter binary systems. Existing gravitational-wave detectors are limited at low frequencies by seismic noise and mode cross-coupling. Seismic isolation at low frequencies is challenging due to a tilt injection, reduced seismometer response and technical noises.
We suggest an inertial seismic isolation system based on interferometric sensing of the reference mass position in all degrees of freedom. Reference mass is suspended from the platform, which is actuated so that position of the platform is constant relative to the reference mass. This closed loop operation impose the reference mass stability to the platform. The platform may be used as an initial seismic isolated platform for suspension of the GW detector's test masses.
Suggested design has advantages of keeping all DoF simultaneously quiet; very low tilting resonance minimise tilt-coupling; low-noise sensors and high-quality fused silica suspension minimise sensing and thermal noise.

Primary authors: PROKHOROV, Leonid (Institute for Gravitational Wave Astronomy, The University of Birmingham); MOW-LOWRY, Conor (University of Birmingham); MARTYNOV, Denis (University of Birmingham); COOPER, Sam (University of Birmingham); Mr UBHI, Amit (Institute for Gravitational Wave Astronomy, The University of Birmingham); DI FRONZO, Chiara; Mr COLLINS, Chris (University of Maryland); Mr HOYLAND , David (Institute for Gravitational Wave Astronomy, The University of Birmingham)

Presenter: PROKHOROV, Leonid (Institute for Gravitational Wave Astronomy, The University of Birmingham)

Session Classification: Other challenges for future GW detectors

Contribution ID: **35** Type: **not specified**

Guidelines for a Suspension system of the 3rd generation detectors for Gravitational Waves

Thursday, 24 October 2019 11:35 (25 minutes)

The direct detection of the first Gravitational Waves signals by using a ground based laser interferometric network, put in evidence the importance of having a filtering system of seismic noise and local disturbances integrated into the experimental apparatus. The third generation detectors will have more stringent requirements, in terms of sensitivity, and the new instrument should be equipped with a suspension system able to better reduce the transmission of seismic noise to the optical components all over the detection bandwidth. In this presentation, I will focus my attention on a few peculiarities to be used as guidelines in the project of a New Generation of Superattenuators (NGSA) to be installed in an Underground Laboratory with the payload at cryogenic temperature and also with the intent to extend the detection bandwidth in the low frequency region (below 3 Hz).

Primary author: Dr FRASCONI, Franco (INFN Sezione Pisa)

Presenter: Dr FRASCONI, Franco (INFN Sezione Pisa)

Session Classification: Other challenges for future GW detectors

Contribution ID: **36** Type: **not specified**

Studies of quantum noise in GW detectors, optomechanical experiments, and axion searches

Thursday, 24 October 2019 12:50 (35 minutes)

Quantum noise limits the performance of gravitational-wave (GW) detectors, optomechanical experiments, and even recently proposed dark matter searches. This talk discusses the effort of the Birmingham group towards studies of the quantum noise in these experiments. In particular, we will show how to employ the couple cavity resonance for high GW frequency detectors, heterodyne squeezing technique for the future GW detectors, control of an unstable filter for increasing of the gain-bandwidth product of the LIGO detectors. We will also present an optomechanical and axion search experiments planned in Birmingham which will be limited by quantum noises in optical cavities.

Primary authors: Dr MARTYNOV, Denis (University of Birmingham); MIAO, Haixing (University of Birmingham)

Presenter: Dr MARTYNOV, Denis (University of Birmingham)

Session Classification: New strategies for quantum noise reduction

Contribution ID: **37** Type: **not specified**

ET Pathfinder

Thursday, 24 October 2019 12:00 (25 minutes)

With the next generation of gravitational wave detectors being planned to operate at cryogenic temperatures we are facing many new challenges. ET Pathfinder will be a test facility for establishing new techniques required in future cryogenic detectors. In this talk we would like to introduce ET Pathfinder and some of the techniques we are planning to implement, with a focus on test-mass materials and coatings.

Primary author: STEINLECHNER, Jessica (Maastricht University)

Presenter: STEINLECHNER, Jessica (Maastricht University)

Session Classification: Other challenges for future GW detectors

Contribution ID: **38** Type: **not specified**

Numerical modelling of low-T oxide film growth

Thursday, 24 October 2019 14:20 (20 minutes)

Oxide films are customarily manufactured using physical vapor deposition (PVD) at or near room temperature. In such conditions, the covalent bonds formed by oxide atoms (or order a few eV's) cannot be broken by thermal agitation; atoms only rearrange during the impacts of deposited particles. This process hampers the formation of crystalline domains and thus facilitates the growth of homogeneous and amorphous, transparent films. These films, in sharp contrast with bulk glasses, have never experienced or even approached any thermal equilibrium state. They present unusual, protocol-dependent, physical properties, which implies that their microstructures also differ from those of usual glasses and are sensitive to the details of the growth process. How can the film microstructure be characterized? How does it depend on the details of the deposition process? How does it determine macroscopic physical properties? These questions are open, yet hold the key to advancing our ability to control the film physical properties, and in particular, the mechanical losses limiting the resolution of gravitational wave detectors.

In this talk, I will summarize a recent study [1] in which we constructed a numerical model of low-T oxide growth, tested it against experimental data, and analyzed the resulting film microstructure. Our aim was to identify the physical origin of large, anisotropic, in-situ stresses (a few hundreds of MPa's) commonly found in the films produced by e-beam vaporization of silica. Realizing that deposition may involve compound particles enabled us to access steady film growth for the first time using numerical simulations. Microstructural analysis then revealed that the observed stress anisotropy is caused by the slight (a few percents, in line with ion-beam analysis data) oxygen-deficiency of the films. I will emphasize that: (i) low-T film growth is amenable to numerical modelling because thermally activated processes are irrelevant, so that only the series of impact events, during which atoms rearrange, need to be simulated; (ii) however, this effort depends on assumptions concerning the nature (stoichiometry, charge) and speed of the particles impacting the films, which remain largely unknown.

[1] S. Gelin, D. Poinot, S. Chatel, P. J. Calba, and A. Lemaitre. Microstructural origin of compressive in situ stresses in electron-gun-evaporated silica thin films. Phys. Rev. Materials, 3(5):055608, (2019).

Primary author: LEMAITRE, Anael

Presenter: LEMAITRE, Anael

Session Classification: Ultra-low-noise optical coatings

Contribution ID: **39** Type: **not specified**

Space-borne GW detectors

Thursday, 24 October 2019 12:25 (25 minutes)

The talk will shortly review the key instrumental aspects of LISA, including the legacy of LISA Pathfinder, and its current status of development. The talk will also briefly touch on other efforts toward space-borne GW detectors

Primary author: Prof. VITALE, Stefano (Department of Physics, University of Trento)

Presenter: Prof. VITALE, Stefano (Department of Physics, University of Trento)

Session Classification: Other challenges for future GW detectors

Contribution ID: **40** Type: **not specified**

Third Generation Gravitational Wave detectors: the challenge of Einstein Telescope in Europe

Thursday, 24 October 2019 08:40 (25 minutes)

The planning and the construction of 3G detectors represent technological challenge for the next two decades, aimed to great scientific expectations. The talk will be focussed on main experimental aspects of Einstein Telescope, the leading 3G project in Europe.

Primary author: MAJORANA, Ettore (ROMA1)

Presenter: MAJORANA, Ettore (ROMA1)

Session Classification: Other challenges for future GW detectors

Contribution ID: **41** Type: **not specified**

Measuring (excess?) thermal noise on a macroscopic oscillator in non-equilibrium conditions

Friday, 25 October 2019 09:55 (20 minutes)

Past measurements performed by our group on a macroscopic mechanical oscillator subject to a thermal gradient/heat flow have found increased mechanical thermal noise levels with respect to what is calculated from the fluctuation-dissipation theorem, even assuming equilibrium at the highest temperature present in the system.
We have recently upgraded the experimental facility with an optical interferometric readout meant to provide a reliable calibration and to allow us to explore a wider range of thermal gradients.
While some of the recent measurements seem to confirm and strengthen past results, others are not consistent with an increased thermal noise, and leave some as yet unanswered mystery about our results. We will report on these findings and on the efforts to explain the somewhat conflicting results.

Primary authors: CIANI, Giacomo (PD); CONTI, Livia (PD); PIZZELLA, Alvise (Albert Einstein Institute Hannover); FONTANA, Alex (LPENSL)

Presenter: CIANI, Giacomo (PD)

Session Classification: Thermal noise in and out of thermodynamic equilibrium

Contribution ID: **42** Type: **not specified**

Australia's take on GW experimental research in the long term

Thursday, 24 October 2019 09:05 (25 minutes)

The funding of the Australian Research Council Centre of Excellence in Gravitational Wave Discovery (OzGrav) has significantly expanded the volume of experimental work that is being conducted in gravitational wave astronomy. Part of this work has focused on the development of the Australian High Frequency Detector (OzGrav HF). This detector aims to access the "matter region" of the gravitational wave spectrum between 1-4 kHZ using detector techniques that can act as a pathfinder for advanced third generation technologies including extreme high circulating power. The OzGrav community is also conducting research into a vast range of areas ranging from low frequency detectors to high power laser sources for third generation detectors. In this talk I will give an overview of the OzGrav experimental effort.

Primary author: OTTAWAY, David (The University of Adelaide)

Presenter: OTTAWAY, David (The University of Adelaide)

Session Classification: Other challenges for future GW detectors