GWADW2021 Gravitational Wave Advanced Detector Workshop

Report of Contributions

Contribution ID: **1** Type: **talk**

Lunar Gravitational-Wave Antenna

Monday, 17 May 2021 09:00 (20 minutes)

Gravitational waves excite quadrupolar vibrations of elastic bodies. Monitoring these vibrations was one of the first concepts proposed for the detection of gravitational waves by Joseph Weber. At laboratory scale, these experiments became known as resonant-bar detectors, which form an important part of the history of GW detection. Due to the dimensions of these bars, the targeted signal frequencies were in the kHz range. It was also Weber who suggested to monitor vibrations of Earth and Moon to search for gravitational waves in the mHz band. His Lunar Surface Gravimeter was deployed on the Moon in 1972 by the Apollo 17 crew. A design error made it impossible to carry out the intended search for GWs, but the idea remains intriguing. We have proposed a new concept, the Lunar Gravitational-Wave Antenna (LGWA), based on Weber's idea. The key component is a next-generation, high-sensitivity seismometer to be deployed on the Moon. LGWA would have a rich GW and multi-messenger science case with galactic binaries and massive black-hole binaries. It would also serve as a high-precision geophysical station shedding light on the interior structure of the Moon, the mechanisms of moonquakes, and the Moon's formation history.

Primary author: HARMS, Jan (GSGC)

Presenter: HARMS, Jan (GSGC)

Session Classification: Recorded talks: Space missions

Track Classification: Next detectors: Space missions

Contribution ID: **2** Type: **talk**

Lightsaber: A simulator of the angular sensing and control system in LIGO

Wednesday, 19 May 2021 00:00 (20 minutes)

The fundamental requirement for the angular sensing and control (ASC) scheme is to suppress the angular mirror motion at low frequencies, to overcome radiation pressure induced angular instabilities, without reintroducing noise in the GW signal. In the process of controlling test masses' angular motion at low frequencies, high-frequency noise is introduced in the observation band originating mainly from the readout noise of sensors. During the 03 run, controls noise dominated the noise budget approximately between 10 Hz and 25 Hz, and it was a significant noise source up to 55 Hz and there is no straightforward solution. We need better tools to analyze the system and for the development of solutions. We present Lightsaber, a new time-domain simulator of the ASC in LIGO. The simulation is a full, nonlinear simulation of the optomechanical system consisting of the high-power cavity laser beam and the last two stages of suspension in LIGO with the control system, focusing on pitch dynamics. Main noise inputs are power fluctuations, read-out noise of sensors, seismic noise from the ISI, and suspension damping noise. There is the conversion between the local and global basis of the angular motion in the linear feedback control, exactly as in the real system. Some of the studies that can be done with this simulation are understanding the role of DC miscentering and laser power fluctuations for angular dynamics and nonlinear angular mirror pitch motion to strain noise coupling.

Primary author: ANDRIĆ, Tomislav (Istituto Nazionale di Fisica Nucleare)

Co-author: HARMS, Jan (GSGC)

Presenter: ANDRIĆ, Tomislav (Istituto Nazionale di Fisica Nucleare)

Session Classification: Controls and machine learning workshop

Track Classification: Workshops: Controls and machine learning workshop

Contribution ID: **3** Type: **poster**

CSIS: a Cryogenic Superconducting Inertial Sensor

Wednesday, 19 May 2021 16:20 (1 minute)

LIGO and Virgo have detected more than 70 signals from black hole and/or neutron star mergers. All measured signals come in-band at around 30 Hz as suspension control noise, fueled by many cross couplings between angular and translational degrees of freedom, is dominant below 30 Hz. It is impossible to know, but exciting to imagine what signals are lurking there once we can access this regime.

Einstein Telescope (ET) will be an underground and cryogenic detector sensitive to GWs down to 2 Hz. New sensor development is underway for ET. We believe the cryogenic environment can be used in combination with superconducting materials to open up pathways to low-loss actuators and sensor mechanics.

The Cryogenic Superconducting Inertial Sensor (CSIS) revolutionizes the (cryogenic) inertial sensor field by obtaining a displacement sensitivity at 0.5 Hz of 3 orders of magnitude better than state-of-art. Not only will it help ET detect GWs from 2 Hz onwards, CSIS will also be deployed on the Moon. The recently published Lunar GW Antenna (LGWA) concept uses an inertial sensor to probe surface motion as a result of the GW excitation of the Moon's normal body modes (fundamental just below 1 mHz and many other modes and their harmonics at higher frequencies). In summary, CSIS will be the world's most sensitive low-frequency inertial sensor and, when deployed in ET and on the Moon, will enable GW science from 1 mHz to 10 Hz.

Primary authors: Dr VAN HEIJNINGEN, Joris (UCLouvain); Dr BADARACCO, Francesca (UCLouvain); Prof. PERALI, Andrea (UCamerino)

Presenter: Dr VAN HEIJNINGEN, Joris (UCLouvain)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **4** Type: **not specified**

Space missions

Monday, 17 May 2021 17:10 (30 minutes)

Q&A session

Presenter: SOMIYA, Kentaro (Tokyo Institute of Technology)

Session Classification: Plenary Day 1

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

General Relativity

Monday, 17 May 2021 16:10 (30 minutes)

Q&A session

Presenter: PORTER, Edward (APC-Paris)

Session Classification: Plenary Day 1

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

Multimessenger Astronomy

Monday, 17 May 2021 16:40 (30 minutes)

Q&A session

Presenter: CHEN, Hsin-Yu

Session Classification: Plenary Day 1

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

Third generation design

Monday, 17 May 2021 17:40 (30 minutes)

Q&A session

Presenter: BALLMER, Stefan (Syracuse University)

Session Classification: Plenary Day 1

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

Third generation infrastructures

Tuesday, 18 May 2021 17:30 (30 minutes)

Q&A session

Presenter: CALLONI, Enrico (NA)

Session Classification: Plenary Day 2

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

R&D facilities and plans

Tuesday, 18 May 2021 17:00 (30 minutes)

Q&A session

Presenter: HILD, Stefan (Maastricht University)

Session Classification: Plenary Day 2

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

Second generation experience

Tuesday, 18 May 2021 16:00 (30 minutes)

Q&A session

Presenter: ARNAUD, NICOLAS (LAL ORSAY CNRS-IN2P3)

Session Classification: Plenary Day 2

Contribution ID: **11** Type: **not specified**

Beyond second generation

Tuesday, 18 May 2021 16:30 (30 minutes)

Q&A session

Presenter: FAFONE, Viviana (ROMA2)

Session Classification: Plenary Day 2

Contribution ID: **12** Type: **talk**

Localization and early warning for BNSs by third generation detector networks

Monday, 17 May 2021 06:30 (15 minutes)

In multi-messenger era, the scientic output of gravitational waves will be maximized when combined with its electromagnetic counterpart data. The efficiency of electromagnetic follow-up for given gravitational wave trigger largely depends on the localization error and the remain time to merger obtained from gravitational wave. Based on the fisher matrix method, we estimated the localization uncertainty and early warning performance of three third generation gravitational wave detector network for 1.4Msun-1.4Msun BNS mergers at fixed distance of 40Mpc, 200Mpc, 400Mpc, 800Mpc, 1600Mpc, and for 1.4Msun-1.4Msun BNS mergers following the delay time distribution. Especially, the difference of localization and early warning ability between a ET-like detector in Australia and a CE-like detector in Australia is discussed.

Primary authors: LI, Yufeng; HENG, ik siong (University of Glasgow); CHAN, Man Leong; MESSENGER, Chris (AEI Hannover); FAN, Xilong

Presenter: LI, Yufeng

Session Classification: Recorded talks: Multimessenger Astronomy

Track Classification: Physics: Multimessenger perspective

Contribution ID: **13** Type: **talk**

Scattering light modelling and subtraction

Monday, 17 May 2021 10:00 (20 minutes)

Advanced Virgo end benches were a significant source of scattered light noise during the third observing run. We describe how that noise could be subtracted using auxiliary channels during the online strain data reconstruction. We model in detail the scattered light noise coupling and demonstrate that further noise subtraction can be achieved. We also show that the fitted model parameters can be used to optically characterized the interferometer and in particular provide a novel way of establishing an absolute calibration of the detector strain data.

Primary authors: WAS, Michal (LAPP/CNRS); GOUATY, Romain (CNRS/IN2P3/LAPP); BONNAND, Romain (LAPP/CNRS)

Presenter: WAS, Michal (LAPP/CNRS)

Session Classification: Recorded talks: Experience From Current Detectors

Track Classification: Advanced detectors: Experience from current detectors

Contribution ID: **14** Type: **talk**

Mitigation of back-scattered light by dual balanced-homodyne readout

Thursday, 20 May 2021 06:20 (15 minutes)

Back-scattered light results in parasitic modulations of the output light of gravitational-wave observatories. It constitutes a major noise source at low audio-band and sub-audio-band frequencies. Whereas gravitational-wave (GW) signals exclusively appear as amplitude modulations of the output light, modulations due to back-scattered light in general also have projections onto the phase quadrature. This contribution proposes to use two-mode squeezed, dual balanced homodyne detection to discriminate between GW signals and parasitic interferences and to subtract the disturbances from the h(t) output. The proof of principle was researched in recent years [1-2].

[1] M. Meinders; R. Schnabel, Sensitivity improvement of a laser interferometer limited by inelastic back-scattering, employing dual readout, Class. Quantum Grav. 32, 195004 (2015).
[2] M. Ast, S. Steinlechner, R. Schnabel, Reduction of Classical Measurement Noise via Quantum-Dense Metrology, Phys. Rev. Lett. 117, 180801 (2016).

Primary authors: SCHNABEL, Roman (Universität Hamburg); Dr STEINLECHNER, Sebastian (Maastricht University & Nikhef); Dr AST, Melanie (Max-Planck-Institut für Gravitationsphysik)

Presenter: SCHNABEL, Roman (Universität Hamburg)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **15** Type: **talk**

Newtonian-noise cancellation

Tuesday, 18 May 2021 06:00 (20 minutes)

Gravitational fluctuations produced by the environment of a GW detector lead to so-called Newtonian noise. It is a weak contribution to instrument noise at low frequencies, but as soon as it starts to limit the sensitivity of a detector, it will be very challenging to mitigate it. A Newtonian-noise cancellation system is under development for the Virgo detector for the upcoming science runs. Most contributions to Newtonian noise will be greatly reduced in underground facilities like KAGRA and the Einstein Telescope, but a noise-cancellation system might still be required, and it would be a much larger experimental effort to build it compared to surface detectors. New strategies must be found to realize such a system at an acceptable cost. In this presentation, we will outline the main expected challenges when moving on with Newtonian-noise cancellation and what studies and R&D we need for next-generation detectors.

Primary author: HARMS, Jan (GSGC)

Presenter: HARMS, Jan (GSGC)

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **16** Type: **talk**

Instrumented baffle for Virgo input mode-cleaner end-mirror

Monday, 17 May 2021 23:15 (15 minutes)

As part of the upgrade program, Virgo has just installed a new baffle equipped with photosensors that surrounds the end-mirror of the input mode-cleaner. This culminates more than two years of work at IFAE-Barcelona for the design and construction of a novel and innovative device to control and monitor stray light inside the experiment, a persistent source of noise in interferometers. It will serve as a demonstrator of the technology for its future implementation in the main arms of the interferometer, surrounding the test masses. The new baffle will provide valuable data for understanding the cavity and calibrating simulations that describe the propagation of light within the interferometer. The instrumented baffle is now entering a long period of commissioning and integration into Virgo's regular operations, in time to become an integral part of the new O4 observation run, currently scheduled for summer 2022. In this talk we describe the technology and we present the first results of its performance within the experiment.

Primary author: MIR, Lluïsa-Maria (IFAE)

Presenter: MIR, Lluïsa-Maria (IFAE)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **17** Type: **talk**

Update on Cryogenic Silicon Suspension Activities at Glasgow

Tuesday, 18 May 2021 07:25 (20 minutes)

With the need to move to 3rd generation cryogenically cooled detectors, work is ongoing at Glasgow to investigate design, bonding and characterisation of silicon suspensions operating at cryogenic temperatures. Here we present an update on these activities, including details of initial cooling experiments conducted on a silicon ribbon suspending a 1kg mass.

Primary author: EDDOLLS, Graeme (University of Glasgow)

Co-authors: Dr CUMMING, Alan (University of Glasgow); HOUGH, James (University of Glasgow); HAUGHIAN, Karen (University of Glasgow); HAMMOND, Giles (University of Glasgow); ROWAN, Sheila (University of Glasgow); Mr JONES, Russell (University of Glasgow); MARTIN, Iain (University of Glasgow)

Presenter: EDDOLLS, Graeme (University of Glasgow)

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **18** Type: **talk**

The Amaldi Research Center ET Cryogenic Lab in Rome.

Monday, 17 May 2021 12:00 (10 minutes)

At Rome University "La Sapienza"we are building a new Lab dedicated to developing real size cryogenic payloads for ET. The Lab is being financed by the Amaldi Research Center and should be completed at the beginning of next year. In the meantime we are preparing a prototype pulse tube cooling station and we have started to design the test cryostat for the ET-LF Payload prototype.

Primary author: RAPAGNANI, Piero (ROMA1)

Presenter: RAPAGNANI, Piero (ROMA1)

Session Classification: Recorded talks: Third Generation R&D Facilities

Track Classification: Next detectors: R&D facilities and plans

Contribution ID: **19** Type: **talk**

Characterization of light scattering point defects in gravitational wave detector coating layers

Wednesday, 19 May 2021 07:00 (15 minutes)

The high reflective mirrors of the gravitational waves detector LIGO & Virgo present in the coating many micrometer size defects that scattered the light in the interferometer. This scattered light induces a loss of the laser power of the order of a few tens of parts per million (ppm) and a phase noise because of the recombination with the main beam after reflection on the tube walls. This phenomenon limits the sensitivity of the detector and impacts the ability to detect astrophysical events. A reduction of the scattered light is thus required in order to improve the optical performances of the coatings for the new mirrors of the Advanced LIGO and Virgo plus upgrade. For this purpose a dedicated research line is in progress at LMA since 2018.

We studied the point defects for each material tantala and silica separately with monolayers deposited onto micropolished fused-silica substrates. We analyzed the impact of different parameters, such as the thickness, as well as the effect of a post-deposition annealing. The samples were measured with a dark-field detection system in order to compare the density and the size distribution of the defects. We pointed out that even if one material has a much larger defect density, both materials share some similarities. Moreover we noticed an outstanding improvement of the coating quality thanks to the post-deposition annealing.

Primary author: SAYAH, Sihem

Co-authors: CAGNOLI, Gianpietro (ILM-UCBL); Mr DEGALLAIX, Jérôme (LMA-IP2I); Mr MICHEL, Christophe (LMA-IP2I); Mr PINARD, Laurent (LMA-IP2I); Mr SASSOLAS, Benoît (LMA-IP2I); Mrs SORDINI, Viola (IP2I)

Presenter: SAYAH, Sihem

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **20** Type: **talk**

Outline of cryogenic payload compliance with Einstein Telescope LF

Tuesday, 18 May 2021 07:40 (20 minutes)

The scientific target of cooling-down test mass payloads of ET without affecting the capability of reaching very high sensitivity in the low frequency range is often assessed as achievable. Indeed, relevant developments have still to be pursued with the perspective of a reasonable technical design. Moreover, the overall design of cryostats and its technical facets are interlaced with several constraints determined by the payload design. The system must be compliant with very low seismic background and seismic attenuation performance. At the same time, low thermal noise performance achievable at low temperature should not be spoiled by mechanical dissipations embedded in the payload as a part of the cooling system.

Primary author: Mr MAJORANA, Ettore (Università di Roma Sapienza)

Presenter: Mr MAJORANA, Ettore (Università di Roma Sapienza)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **21** Type: **poster**

Sensor Placement Optimization for Broadband Newtonian Noise Cancellation in GW Detectors

Thursday, 20 May 2021 16:27 (1 minute)

The sensitivity of second-generation gravitational-wave detectors is limited in the low frequency region by Newtonian noise. Noise cancellation using Wiener filters has been shown to mitigate the effects of seismic Newtonian noise. This involves placing an array of seismometers around the test mass to monitor the ground fluctuations. Optimal positioning of the seismometers around the test mass will result in maximal subtraction of noise. So far the positions of the seismometers around the test mass have been optimized for a single seismic-wave frequency only. But in reality, the Newtonian noise at detector site is substantial over the frequency band $(8 - 20)$ Hz. Our work expands the sensor placement optimization problem to a multi-objective optimization problem, to ensure that the sensor positions are optimal over the entire desired frequency range. Our results show a significant improvement from the single objective optimization case, and is limited only by the seismometer self-noise.

Primary authors: Ms JOSE, Roselyn (Indian Institute of Technology Madras); Dr KALPANA KALAIMANI, Rachel (Indian Institute of Technology Madras)

Presenter: Ms JOSE, Roselyn (Indian Institute of Technology Madras)

Session Classification: Poster session 2

Track Classification: Advanced detectors: Experience from current detectors

Contribution ID: **22** Type: **talk**

Substrate Transferred Crystalline AlGaAs Coatings Status

Wednesday, 19 May 2021 07:40 (5 minutes)

Substrate-transferred crystalline coatings have demonstrated low thermal noise and excellent optical properties in multiple precision optics applications. The primary challenge in implementing these single-crystal gallium arsenide / aluminum gallium arsenide multilayers in terrestrial interferometric gravitational-wave detectors is the necessity to scale the size of the coatings to ≥ 30 cm in diameter on fused silica substrates with ≥ 40 kg mass. This scaling effort is primarily an engineering development project that will require significant financial investment to design and construct dedicated equipment for producing these novel optics. We will present the latest results from laboratory measurements of GaAs-based crystalline coatings, as well as plans for future measurements. We will also discuss possible paths forward for realizing and implementing LIGO-relevant ultralow-los semiconductor supermirrors.

Primary authors: HARRY, Gregory (American University); Prof. PENN, Steve (Hobart and William Smith Colleges); Dr COLE, Garrett (ThorLabs); Prof. GRETARSSON, Andri (Embry Riddle Aeronautical University)

Presenter: HARRY, Gregory (American University)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **23** Type: **talk**

Reduction of vibration transfer via heat links in KAGRA cryogenic mirror suspension system

Wednesday, 19 May 2021 23:20 (20 minutes)

The cryogenic mirror is a direct way to reduce thermal noise. To cool the mirror at cryogenic temperature, the conductive cooling with heat links is necessary, however, they become a new path of vibration transfer simultaneously. We have newly developed a vibration isolation system for heat links and successfully reduced vibration transfer. Details of design and performance tests will be reported.

Primary author: YAMADA, Tomohiro (High Energy Accelerator Research Organization)

Presenter: YAMADA, Tomohiro (High Energy Accelerator Research Organization)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **24** Type: **talk**

A Post-O5 LIGO with Crystalline Coatings

Monday, 17 May 2021 10:40 (20 minutes)

Crystalline mirror coatings of epitaxially-grown GaAs/AlGaAs are a most promising option for LIGO's Post-O5 upgrade. With extremely low optical losses and a coating thermal noise that is more than 5x lower that Advanced LIGO coatings, these crystalline coatings represent the most significant improvement in coatings research in the past 20 years. The change from amorphous to crystalline coatings does present several challenges, including scaling the crystal growth, devising a new locking scheme, and potential noise sources unique to crystalline coatings. But the expected gains in sensitivity, along with improvements in low frequency and quantum noise, provide an encouraging prospect for the Post-O5 era.

Primary author: PENN, Steven (LSC - Hobart and William Smith Colleges)

Presenter: PENN, Steven (LSC - Hobart and William Smith Colleges)

Session Classification: Recorded talks: Beyond Current Detectors

Track Classification: Advanced detectors: Beyond second generation

Contribution ID: **25** Type: **poster**

Mitigation of the electrostatic charge on test mass mirrors in gravitational wave detectors

Thursday, 20 May 2021 16:07 (1 minute)

To successfully integrate cryocooled optics in the complex system of future gravitational wave detectors, it is mandatory that cryogenics is compliant with the operative methods adopted to properly control and possibly mitigate all noise sources. Among others, electrostatic charging on test mass has been shown to be a limiting noise source for gravitational wave interferometers. Within the LIGO collaboration, a mitigation method proposed and successfully applied consists in the exposure of the mirror to some tenth of mbar of N_2 plasma. It is difficult, if not impossible to apply this method, as it is now, when mirrors are at cryogenic temperatures, since a significantly thick condensed gas layer will develop on the mirror surface severely affecting its performance. Here we present the basic background of a novel method to neutralize test masses electrostatic charge, that can be performed in UHV and can be applied to cryogenic mirrors. We propose the use of selected energy electrons (between 10 to 100 eV) which can impinge on the mirror surface. According to their energy, the secondary electron yield (which is the number of electrons emitted per incident ones) could be ≤ 1 or ≥ 1, i.e. removing or adding electrons to the mirror's dielectric surface or part of it. We will highlight the advantages offered by this new method and the further studies required to pass from the idea here proposed to the desired enabling technology.

Primary author: ANGELUCCI, Marco (LNF)

Co-authors: SPALLINO, Luisa (LNF); MAZZITELLI, Giovanni (LNF); MUSENICH, Riccardo (GE); Dr PASQUALETTI, Antonio (European Gravitational Observatory (EGO)); SORRENTINO, Fiodor (GE); CHINCARINI, Andrea (GE); GEMME, Gianluca (GE); CIMINO, Roberto (LNF)

Presenter: ANGELUCCI, Marco (LNF)

Session Classification: Poster session 2

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **26** Type: **talk**

Impact on Vacuum Requirements by Cryogenically Cooled Mirrors for Gravitational Wave Detection

Thursday, 20 May 2021 00:20 (20 minutes)

To reduce thermal noise and improve the sensitivity at low frequency, future gravitational wave detectors will use cryogenic mirrors. Cryogenically cooled mirrors present a number of extraordinary challenges, one being on the cryogenic vacuum system hosting the cold mirrors.
At cryogenic temperature, gases composing the residual vacuum will cryosorb and form a contaminant ice layer on the mirror surface. Such "frost"is known to be a significant bottleneck in operating cryogenic mirrors since, depending on the thickness, it may cause laser absorption and affect mirrors'optical properties. Stringent cryogenic vacuum conditions are, therefore, crucial to properly limit the ice growth. In fact, the adlayer characteristics (thickness and composition) depend on temperature and on the partial pressures of the different residual gas species composing the residual vacuum.
Here we estimate the ice layer growth rate for given conditions. This analysis sets new limits for an acceptable operating pressure to mitigate frost formation allowing long and continuous periods of data taking. Improving vacuum conditions, the ice growth can be certainly reduced, but not definitely avoided. Here we present a survey of potential mitigation methods to actively cure frost formation by thermal or non-thermal ice desorption from mirrors'surface.

Primary author: SPALLINO, Luisa (LNF)

Co-authors: ANGELUCCI, Marco (LNF); Dr PASQUALETTI, Antonio (European Gravitational Observatory (EGO),); BATTES, Katharina (KIT); DAY, Christian; GROHMANN, Steffen (KIT); MAJORANA, Ettore (ROMA1); RICCI, Fulvio (ROMA1); CIMINO, Roberto (LNF)

Presenter: SPALLINO, Luisa (LNF)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **27** Type: **poster**

Testing athermal glass as laser frequency reference for interferometric sensors

Wednesday, 19 May 2021 16:08 (1 minute)

Improving the sensitivity of existing and future ground-based gravitational-wave detectors will enable us to detect more astronomical sources with higher precision. As the gravitational-wave signals are strong and present for a longer time in the low-frequency regime, it would be beneficial to extend the current sensitivities to lower frequencies (< 10Hz). However, seismic noise coupling into the test masses (TMs) of the detectors is acting as a major limitation and this could be tackled with active isolation with improved inertial sensors. Opto-mechanical inertial sensors with laser interferometric displacement readout are one of the major technologies studied for this. Such interferometers often require a highly stable laser frequency reference to suppress laser frequency noise coupling in due to unequal arm-length. We propose a high-finesse etalon made-up of 'athermal glass'as a potential candidate for this purpose. The athermal material can compensate for the effects of various noises on the frequency stability by maintaining a constant optical length of the cavity. In this poster, we discuss results from the primary simulations of athermal cavities and initial experimental results on our laser stabilization experiment that we plan to use to characterize such etalons.

Primary author: C. S., Shreevathsa (Universität Hamburg, Institut für Experimentalphysik)

Co-author: GERBERDING, Oliver (Universität Hamburg, Institut für Experimentalphysik)

Presenter: C. S., Shreevathsa (Universität Hamburg, Institut für Experimentalphysik)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **28** Type: **talk**

Suspension design for Cosmic Explorer

Tuesday, 18 May 2021 06:20 (20 minutes)

Cosmic Explorer requires an unprecedented level of isolation from the ground and from thermal noise. If we want to reach the design sensitivity of $10^{-23}\mathrm{Hz}^{-1/2}$ down to 5Hz, scaling up the LIGO A+ technology might not be enough, and new designs, as well as new technologies, need to be investigated.
One possibility is Cosmic Explorer 2, or CE2, which either uses a $1\mu\mathrm{m}$ laser with fused silica test masses at room temperature, or a $2\mu\mathrm{m}$ laser with silicon test masses at 123K. To achieve low frequency sensitivity, the resonances of the test mass suspensions need to be kept below a few Hertz as well.
During this talk, we will present different design ideas for the CE2 suspensions. These concepts have been developed with CE2 stringent requirements in mind, trying to anticipate the state-of-art technology for silicon materials.

Primary author: BISCANS, Sebastien (MIT LIGO)

Presenter: BISCANS, Sebastien (MIT LIGO)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **29** Type: **talk**

Cryogenics and Vacuum for the Einstein Telescope project

Tuesday, 18 May 2021 07:20 (20 minutes)

We review the current effort for driving the design of the Cryoneic and vacuum system foer the Einstein Telescope Project.

Primary author: RICCI, Fulvio (ROMA1)

Presenter: RICCI, Fulvio (ROMA1)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **30** Type: **talk**

Status of the frequency dependent squeezed vacuum source development at TAMA (invited)

Tuesday, 18 May 2021 23:00 (15 minutes)

The second-generation gravitational wave detectors are starting to be limited by quantum noise in the entire detection bandwidth. With the use of frequency independent squeezing, aLIGO and Advanced Virgo achieved a quantum noise reduction at high frequency while increasing it at low frequency. To avoid this issue, we can inject into the interferometer a squeezed state which rotates as a function of frequency to counterbalance the ponderomotive effect present in GW detectors. This state is called frequency dependent squeezing.

In TAMA, we developed a frequency dependent squeezed vacuum source suitable for the quantum noise reduction in advanced gravitational wave detectors. With a frequency rotation centered around 90Hz, up to 1dB squeezing (below rotation frequency) and 3.4dB squeezing (above rotation frequency) were observed.

After the first measurement of frequency dependent squeezing, several degradation mechanisms have been characterized and tackled. An auto-alignment system based on wavefront sensing has been implemented to preserve filter cavity alignment. A new locking scheme to stabilize filter cavity detuning frequency was also proposed and tested successfully. We have also investigated noise contribution which prevents the squeezing level observation at low frequency. By optimizing the current system, we achieved a higher squeezing level and cleaner spectrum for frequency independent squeezing.

Primary authors: ZHAO, Yuhang (ICRR, The University of Tokyo); ARITOMI, Naoki (JAPAN); CAPOCASA, Eleonora (APC); LEONARDI, Matteo (NAOJ); EISENMANN, Marc; GUO, Yuefan; POLINI, Eleonora (Sapienza); TOMURA, Akihiro; ARAI, Koji; ASO, Yoichi; HUANG, Yao-Chin; LEE, Ray-Kuang; LÜCK, Harald; MIYAKAWA, Osamu; PRAT, Pierre; SHODA, Ayaka (NAOJ); TACCA, Matteo (Laboratoire Astroparticule et Cosmologie - CNRS); VAHLBRUCH, Henning (AEI Hannover); TAKAHASHI, Ryutaro (National Astronomical Observatory of Japan); WU, Chien-Ming; VARDARO, Marco (University of Amsterdam - Nikhef); BARSUGLIA, Matteo (APC-CNRS); FLAMINIO, Raffaele (Laboratoire des Materiaux Avances - CNRS/IN2P3)

Presenter: ZHAO, Yuhang (ICRR, The University of Tokyo)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **31** Type: **talk**

Helium-based cooling concept of the ET-LF interferometer

Tuesday, 18 May 2021 08:20 (20 minutes)

The low-frequency interferometer in the Einstein Telescope (ET-LF) shall be operated at test mass temperatures of 10 K to 20 K. Motivated by the potential of using superfluid helium (He-II) for cooling the test masses, we derive a general cooling concept for the ET-LF cryostats. This concept is based on a helium refrigerator at each ET corner station, providing cooling capacity with He-II for the test masses at 2 K, as well as cooling capacity with normal helium (He-I) for radiation screens at 5 K and thermal shielding at 50 K to 80 K. The heat extraction path of the 2 K system is implemented by means of long capillaries, where the heat transport takes place by steady-state heat conduction in He-II. The integration of He-II-filled capillary suspensions in the payload design may also offer a solution for achieving low temperatures of the test masses. This option will be investigated in terms of thermal dissipation and the propagation of vibrational noise from the helium cooling system into the payload.

Primary authors: BUSCH, Lennard (Karlsruhe Institute of Technology (KIT)); KOROVESHI, Xhesika (KIT); GROHMANN, Steffen (KIT)

Presenters: BUSCH, Lennard (Karlsruhe Institute of Technology (KIT)); KOROVESHI, Xhesika (KIT); GROHMANN, Steffen (KIT)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **32** Type: **poster**

Poster: Mechanical Design of a HoQI Interferometer for the LIGO Big Beamsplitter Suspension

Wednesday, 19 May 2021 16:09 (1 minute)

There is a funded proposal, and ability to retrofit (as in not part of the Ligo A+ baseline) HoQI Interferometers in the big beamsplitter suspension. While the theoretical design and components had been finalized, no mechanical design was made that would fit the set envelope. This poster will display the first iteration towards a mechanical design that could be installed to allow for local damping between the Penultimate Mass (PUM, M2) and the suspension frame (Lower Tablecloth).

Primary author: VAN DONGEN, Jesse (Nikhef)

Co-authors: MOW-LOWRY, Conor (University of Birmingham); COOPER, Sam (University of Birmingham); PROKHOROV, Leonid (Institute for Gravitational Wave Astronomy, The University of Birmingham)

Presenter: VAN DONGEN, Jesse (Nikhef)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **33** Type: **talk**

Closing a loop between ISC and SEI

Wednesday, 19 May 2021 23:45 (10 minutes)

This talk is to explore the complex link relating low frequency seismic performance and control noise contamination of the primary interferometer signals. Past requirements relating these systems were done using bespoke interferometer and controls models, which have not necessarily translated to the implementations actually used and have certainly not translated into auxiliary controls noises that are subdominant to the fundamental noises. What are the ideas, models, and tools needed to better relate the targets of the seismic system and auxiliary controls systems to best describe when these complex noises will become fundamental noises, ultimately to drive subsystem design for the full system.

Primary author: MCCULLER, Lee

Presenter: MCCULLER, Lee

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **34** Type: **poster**

2um laser R&D plans at Cardiff University

Thursday, 20 May 2021 16:09 (1 minute)

The wavelength of 2um is a candidate for the next generation gravitational-wave detectors such as LIGO Voyager and Einstein Telescope. Although the technical leap of the wavelength change impacts almost all the optical components of laser interferometry, only a few investigations have been ongoing. This poster will present the R&D experiments planned in the Gravitational Exploration Institute, Cardiff University.

Primary author: KOKEYAMA, Keiko (Cardiff University)

Presenter: KOKEYAMA, Keiko (Cardiff University)

Session Classification: Poster session 2

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **35** Type: **poster**

Cosmic Explorer: A Next-Generation Gravitational-Wave Observatory

Wednesday, 19 May 2021 16:21 (1 minute)

Cosmic Explorer (CE) is the US concept for a next-generation ground-based gravitational-wave observatory. CE will have the ability to determine the nature of the densest matter in the universe, reveal binary black hole (BH) populations throughout cosmic time, probe the history of the expanding universe, and explore Einstein's relativity with unprecedented precision. Sources that are barely detectable by Advanced LIGO and Advanced Virgo will be resolved with incredible precision. CE will detect millions of systems per year (compared to tens by the current network). The main driver of increased sensitivity is longer detector arms. The CE reference concept is two L-shaped facilities in the US, one with 40km baseline and a second with 20km baseline. CE will also benefit from R&D of improved seismic isolation, higher laser power and quantum noise reduction, improved coatings and suspensions, and better reduction of Newtonian noises. CE could be operational by the 2030s. This poster is based on a "Horizon Study"white paper currently under development.

Primary author: GRUSON, Alexandra (Cal State Fullerton)

Presenter: GRUSON, Alexandra (Cal State Fullerton)

Session Classification: Poster session 1

Track Classification: Next detectors: Third generation design

Contribution ID: **36** Type: **poster**

Compact High Sensitivity Optomechanical Inertial Sensors

Wednesday, 19 May 2021 16:10 (1 minute)

The Laboratory of Space Systems and Optomechanics (LASSO) at Texas A&M University is working to create novel, highly sensitive inertial sensors by combining our fused-silica optomechanical resonators with compact, high-precision interferometers. Our resonators have high mechanical quality factors and low thermal acceleration noise. Q's of 2.45 x 10^5 were previously achieved at mTorr pressures. This corresponds to an estimated thermal acceleration noise floor of 10^-10 m s^-2/√Hz at frequencies greater than 30 mHz. However, gas damping dominates losses at this pressure. We expect mechanical quality factors on the order of 10^6 and thermal acceleration noise levels of 10^-11 m s^-2/√Hz at lower pressures where gas damping is negligible. We are currently creating a vacuum set up to take Q measurements at these lower pressure ranges. These resonators will be incorporated with our compact high sensitivity displacement interferometer design, with the aim to read out test mass oscillations at picometer sensitivities. Current sensitivities at the sub-nm/√Hz level for sub-Hz frequencies are possible. By subtracting individual noise sources from our heterodyne interferometer bench-top prototype, sensitivities at the picometer level were reached for frequencies above 100 mHz. A compact mount that will hold the combined resonator and interferometer sensor system is being designed, and we hope to have a mount prototype to test with our fused-silica resonators by summer.

Primary authors: NELSON, Andrea (Texas A&M Aerospace Engineering); Mr HINES , Adam (Texas A&M Aerospace Engineering); Ms ZHANG, Yanqi (Texas A&M Aerospace Engineering); Dr GUZMAN , Felipe (Texas A&M Aerospace Engineering)

Presenter: NELSON, Andrea (Texas A&M Aerospace Engineering)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **37** Type: **talk**

Temperature Dependent Cryogenic Loss Measurements of Ti-doped GeO2 thin films

Monday, 17 May 2021 23:20 (15 minutes)

A cryogenic mechanical loss measurement setup built at Stanford University can operate from room temperature down to at least 12K. The experimental method described is based on actuation of a Si oscillator and measurement of its quality factor (Q-factor). The film's mechanical loss can be obtained using the Q-factors of coated and uncoated resonators. Experimental results obtained for several Ti-doped GeO2 films deposited on a double paddle oscillator (DPO) with the resonant frequency of c.a. 6 kHz and temperature range 12 –300 K are presented and discussed. Some preliminary results on micro resonators for frequency dependent measurements of the coatings in LIGO sensitive region (100 Hz –300 Hz) are also presented.

Primary author: Dr KHADKA, Sudiksha (Stanford University)

Co-authors: MARKOSYAN, Ashot (Stanford University); Dr DANA, Aykutlu (Stanford University); Dr BASSIRI, Riccardo (Stanford University); Prof. FEJER, Martin (Stanofrd University); Dr YANG, Le (Colorado State University); Prof. MENONI, Carmen (Colorado State University); Dr MARTIN, Iain (University of Glasgow)

Presenter: Dr KHADKA, Sudiksha (Stanford University)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **38** Type: **talk**

Ultralow Absorption Conductive Al:ZnO Films for Charge Dissipation in LIGO Vacuum Mirrors

Wednesday, 19 May 2021 07:50 (5 minutes)

Accumulated charge on vacuum mirrors can cause degradation of the signal-to-noise ratio in opto-mechanical measurements due to electrostatic coupling of the surface charge to the environment. A conductive film with minimal optical absorption and scattering can dissipate the charge without altering the optical performance of high reflectivity mirrors. We present Aluminum doped ZnO coatings exhibiting < 100 TOhm/sq resistivity while maintaining an optical absorption of 0.1 ppm at 1064 nm. Both Atomic Layer Deposition and Magnetron Sputtering films were used studied. Deposition and post-processing parameters were optimized to achieve the desired specifications. The oxygen vacancies were found to play an important role in both optical absorption and electrical conductivity. Oxygen vacancy density can be controlled during deposition as well as post-deposition annealing in vacuum or oxygen-rich atmospheres. Films exhibiting optical absorption close to the free carrier limit were obtained. On high reflectivity Distributed Bragg Reflectors it was found that for c.a. 10 nm thick films there can be further reduction in the absorption through nulling the electric field at the mirror surface. In such a case, optical absorption reduction of three orders of magnitude can be achieved. Dependence of the mirror reflectivity as well as the reduction in optical absorption of conductive films on film thickness and dielectric parameters are discussed.

Primary author: Dr DANA, Aykutlu (Stanford University)

Co-authors: MARKOSYAN, Ashot (Stanford University); BASSIRI, Riccardo (Stanford University); Mr BONILLA, Edgard (Stanford University); Dr LANTZ, Brian (Stanford University); FEJER, Martin (Stanford University)

Presenter: Dr DANA, Aykutlu (Stanford University)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **39** Type: **poster**

Design of Coupled Wave Front Sensor for TOrsion-Bar Antenna

Wednesday, 19 May 2021 16:11 (1 minute)

TOBA (TOrsion-Bar Antenna) is a ground-based gravitational wave detector using a torsion pendulum. The resonant frequency of torsional motion is ~1 mHz, therefore TOBA has good design sensitivity of 10^{-19} /√Hz at 0.1 Hz in low frequencies (0.1 Hz –10 Hz). TOBA can detect intermediate mass black hole binary mergers and so on. A prototype detector Phase-III TOBA with a 35 cm-scale pendulum is under development to demonstrate noise reduction. The target sensitivity is set to 10^{-15} /√Hz at 0.1 Hz. To achieve our target sensitivity, we need to measure the pendulum rotation precisely. We propose a coupled wave front sensor as an angular sensor for Phase-III TOBA. In our method, an auxiliary cavity is used to enhance the first-order TEM modes in the main cavity. We will show the principle and experimental design of a coupled wave front sensor in this workshop.

Primary author: OSHIMA, Yuka (University of Tokyo)

Co-authors: TAKANO, Satoru (University of Tokyo); OOI, Ching Pin (University of Tokyo); MICHIMURA, Yuta (University of Tokyo); ANDO, Masaki (University of Tokyo)

Presenter: OSHIMA, Yuka (University of Tokyo)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **40** Type: **talk**

Enhanced noise suppression for LISA by combining cavity and arm locking control systems

Monday, 17 May 2021 09:30 (10 minutes)

The Laser Interferometer Space Antenna (LISA) mission is a space-based gravitational wave detector, that consists of three spacecrafts in a triangular formation with 2.5-million-kilometer sides. The displacement sensitivity goal is approximately 10 pm/√Hz for each arm-link to detect gravitational waves in the frequency band, 100 μHz to 1 Hz.
The proposed research introduces a novel method for enhanced laser stabilisation in the mission by locking the master laser to two references –the on-board optical cavity and the arms of the inter-spacecraft interferometer. The changes could be implemented via digital controllers to ensure no hardware changes to the LISA baseline are required.
The main technical issue with this dual sensor approach is the undesirable slow laser frequency pulling which couples into the control system with the imperfect knowledge of the Doppler shift of the light in the LISA arm. In order to maintain the cavity well within resonance, requirements on the Doppler shift knowledge are outlined, with techniques to partially realise these requirements using laser frequency measurements.
The results show the technique lowers the residual laser frequency noise in the LISA science band over by 3 orders of magnitude: from 30 Hz√Hz to as low as 4 mHz√Hz, potentially allowing the requirements on Time-Delay-Interferometry (TDI) to be relaxed - possibly to the point where first generation TDI may be sufficient to realise the sensitivity of LISA.

Primary authors: VALLIYAKALAYIL, Jobin (Australian National University); SHADDOCK, Daniel (Australian National University); MCKENZIE, Kirk (Australian National University)

Presenter: VALLIYAKALAYIL, Jobin (Australian National University)

Session Classification: Recorded talks: Space missions

Track Classification: Next detectors: Space missions

Contribution ID: **41** Type: **talk**

Modal decomposition of phase camera images using convolutional neural networks

Wednesday, 19 May 2021 00:20 (20 minutes)

The alignment control systems of gravitational wave interferometers extensively rely on heterodyne imaging techniques to sense various length & misalignment degrees of freedom. This is achieved via demodulating the beat of various radio-frequency sidebands measured on single and quadrant element photo-diodes. Such a technique offers very high bandwidth sensing but is limited to resolutions of only a few pixels. Future gravitational wave detectors that utilize both higher circulating powers and higher levels of squeezing will require alignment systems which can sense and correct for higher order defects. There are currently various high resolution heterodyne imaging techniques, known collectively as phase cameras, which can provide higher resolution images of the sideband fields and allow the sensing of higher order defects. The utilization of phase cameras requires the development of techniques for processing and analyzing the images they produce.

In this presentation we report on recent work in training a convolutional neural network to perform modal decomposition using simulated phase camera images. This is to our knowledge the first machine learning decomposition scheme to utilize complex phase information to perform modal decomposition. The results of this work shows promise for future machine learning integrated alignment control schemes.

Primary author: SCHIWORSKI, Mitchell (OzGrav, University of Adelaide)

Co-authors: BROWN, Daniel (University of Adelaide); OTTAWAY, David (The University of Adelaide)

Presenter: SCHIWORSKI, Mitchell (OzGrav, University of Adelaide)

Session Classification: Controls and machine learning workshop

Track Classification: Workshops: Controls and machine learning workshop

Contribution ID: **42** Type: **poster**

Mechanical parametric feedback-cooling for pendulum-based gravity experiments

Thursday, 20 May 2021 16:13 (1 minute)

Gravitational forces that oscillate at audio-band frequencies are measured with masses suspended as pendulums that have resonance frequencies even lower.
If the pendulum is excited by thermal energy or by seismic motion of the environment, the measurement sensitivity is reduced.
Conventionally, this problem is mitigated by seismic isolation and linear damping, potentially combined with cryogenic cooling.
Here, we propose mechanical parametric cooling of the pendulum motion during the gravitational field measurement.
We report a proof of principle demonstration in the seismic noise dominated regime and achieve a damping factor of the pendulum motion of 5.7.
We find a model system for which mechanical parametric feedback cooling reaches the quantum mechanical regime near the ground state.
More feasible applications we anticipate in gravitational-wave detectors.

Primary author: HARTWIG, Daniel (Universität Hamburg)

Co-authors: PETERMANN, Jan (Universität Hamburg); SCHNABEL, Roman (Universität Hamburg)

Presenter: HARTWIG, Daniel (Universität Hamburg)

Session Classification: Poster session 2

Track Classification: Advanced detectors: Beyond second generation

Contribution ID: **43** Type: **poster**

Development of a nested inverted pendulum for ET

Wednesday, 19 May 2021 16:06 (1 minute)

For ground-based GW detectors, seismic vibration is the dominating source of noise in low frequency region (0.1 to 10 Hz), limiting both sensitivity and duty cycle. Thanks to high performant suspension systems, like the Virgo Superattenuator, the presently operational 2nd generation advanced GW antennas have extended their detection band down to 10 Hz. The plan for future 3rd generation detectors, like the Einstein Telescope (ET) aim to further extend the detection band down to 2-3 Hz. This requires, underground locations, where seismic noise is about 100 time smaller than on surface, together to other technological improvements like cryogenic payloads and reduced thermal noise.Anyway to achieve the attenuation value of 10^-18m/sqrt(Hz) at few Hz, the suspensions of the optical components must be upgraded with respect to the 2nd generation ones, in order to improve seismic attenuation in low frequency and reduce as far as possible the frequency of mechanical resonances below the detection band. In this talk, preliminary studies and performances of a seismic isolation system adopting a nested, double inverted pendulum will be presented. Residual motion of the test mass, calculated by combining the transfer function and seismic noise measured at Sos-Enattos site, will be compared with respect the nominal ET's sensitivity curve for evaluating benefits, limits and technological challenges connected to the development of this system,and define requirements for control strategies.

Primary authors: TROZZO, Lucia (Istituto Nazionale di Fisica Nucleare); Mr RUGGI , Paolo (EGO); Dr DI FIORE, Luciano (INFN)

Presenter: TROZZO, Lucia (Istituto Nazionale di Fisica Nucleare)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **44** Type: **poster**

Interferometric Suspension and Inertial Sensors

Wednesday, 19 May 2021 16:12 (1 minute)

To detect gravitational waves at frequencies below 30Hz the low-frequency sensitivity of the current observatories must be improved and, in the case of LIGO, this is caused by control noise from a mixture of sources. To facilitate this improvement in sensitivity, new seismic and suspension sensors are required. This poster outlines the development of these new sensors that can be applied to both the seismic platforms and suspensions and highlights the potential improvement they can bring to current detectors.

Primary authors: Dr COOPER, Sam (University of Birmingham); Dr PROKHOROV, Leonid (Institute for Gravitational Wave Astronomy, The University of Birmingham); Dr MOW-LOWRY, Conor (University of Birmingham); VAN DONGEN, Jesse (Vrije Universiteit Amsterdam)

Presenter: Dr COOPER, Sam (University of Birmingham)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **45** Type: **poster**

Squeezed light at 2128 nm for future gravitational-wave observatories

Thursday, 20 May 2021 16:10 (1 minute)

All gravitational-wave observatories (GWOs) have been using the laser wavelength of 1064 nm. Ultra-stable laser devices are at the sites of GEO 600, Kagra, LIGO and Virgo. Since 2019, not only GEO 600 but also LIGO and Virgo have been using separate devices for squeezing the uncertainty of the light, so-called squeeze lasers. The sensitivities of future GWOs will strongly gain from reducing the thermal noise of the suspended mirrors, which involves shifting the wavelength into the 2 μm region. Our work aims for reusing the existing high-performance lasers at 1064 nm. Here, we report the realisation of a squeeze laser at 2128 nm that uses ultra-stable pump light at 1064 nm. We achieve the direct observation of 7.2 dB of squeezing, as the first step at MHz sideband frequencies. The squeeze factor achieved is mainly limited by the photodiode's quantum efficiency, which we estimated to 92 %. Reaching larger squeeze factors, also in the required audio and sub-audio sideband, seems feasible provided photo diodes with sufficiently low dark noise will be available. Our result promotes 2128 nm as the new wavelength of GWOs.

Primary author: GURS, Julian (Universität Hamburg)

Co-authors: DARSOW-FROMM, Christian (Universität Hamburg); Prof. SCHNABEL, Roman (Universität Hamburg); STEINLECHNER, Sebastian (Maastricht University & Nikhef)

Presenter: GURS, Julian (Universität Hamburg)

Session Classification: Poster session 2

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **46** Type: **talk**

Development Update for the TorPeDO Experiment - A Newtonian Noise Sensor for 3G Observatories

Tuesday, 18 May 2021 06:25 (15 minutes)

Third generation gravitational-wave observatories extend their detection bands down to several Hertz. Enhancing sensitivity in this frequency regime will uncover higher mass black hole binaries, and provide earlier identification of multi-messenger astronomy events. Reaching astronomically relevant sensitivities, at these frequencies, requires overcoming technical and fundamental noise sources. One noise source is Newtonian noise; created by the gravitational force of local density fluctuations; both seismic and atmospheric. Techniques to measure or subtract atmospheric Newtonian noise are underdeveloped; representing a fundamental limit to the low frequency sensitivity of 3G gravitational-wave detectors. The Torsion Pendulum Dual Oscillator, TorPeDO experiment, is under development as an apparatus sensitive to Newtonian noise. Such a device will facilitate direct detection of Newtonian noise. With such a sensor, cancellation of Newtonian noise is possible; improving the sensitivity of gravitational-wave observatories. The TorPeDO consists of two torsion pendula, suspended perpendicularly, with a rotational frequency of 25 mHz. Optical cavities provide low noise readout of their differential motion. The project targets a sensitivity of 3e-15 m/rtHz at 0.1 Hz. We present results from the TorPeDO controls prototype, assembled at The Australian National University, including the current interferometric performance, and the pathway to reach the experiment's thermal noise limit.

Primary authors: HOLLAND, Nathan (ANU Centre for Gravitational Astrophysics, The Australian National University, Canberra, Australia); Mr FORSYTH, Perry (ANU Centre for Astrophysics, The Australian National University, Canberra. Australia); YAP, Min Jet (Australian National University); CHUA, Shang Yaw Sheon (Laboratoire Kastler Brossel CNRS); MCCLELLAND, David (The Australian National University); SLAGMOLEN, Bram (The Australian National University)

Presenter: HOLLAND, Nathan (ANU Centre for Gravitational Astrophysics, The Australian National University, Canberra, Australia)

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **47** Type: **poster**

Worldwide service for parametric transient localization using open GW data for multi-messanger community

Wednesday, 19 May 2021 16:05 (1 minute)

GW170817 opened a new era of the observation of the Universe through the multi-messenger astronomy. The full exploitation of this new era will pass through the realisation of innovative tools, possibly compliant with the FAIR principles, allowing the efficient exchange of essential information between the different partners in a multi-messenger observation. Present and future gravitational wave (GW) observatories have to provide an immediate and accurate localisation of astronomical transients: each localisation of the GW source, provided through a Multi-Order Coverage (MOC) map, can be tested in parametrised intersection with the sky area visible from an observatory of interest. This kind of information needs to be easily accessible and must be provided in a clear and standardized format. Technical challenges are linked to the fact that in the upcoming era of ET-class observatories, we will face the increasing rate of announced transients as well as growing and heterogeneous user community.
Hereby we present a solution based on a dedicated web service integrated in the environment of Virtual Observatory and we sketch its implementation.

Primary authors: BAWAJ, Mateusz (University of Perugia); GRECO, Giuseppe (INFN Perugia); VOCCA, Helios (University of Perugia); PUNTURO, Michele (INFN Perugia)

Presenter: BAWAJ, Mateusz (University of Perugia)

Session Classification: Poster session 1

Track Classification: Physics: Multimessenger perspective

Contribution ID: **48** Type: **talk**

Optimizing Interferometer Design for Squeezed Light (invited)

Wednesday, 19 May 2021 00:00 (20 minutes)

Squeezed light is critical in gravitational-wave detection for reaching sensitivities below the standard quantum limit. The success of future detectors will rely on achieving far greater squeezing levels, with an ultimate goal of 10 dB of quantum noise reduction. Even as squeezer technology matures, the internal losses of current detectors remain too large to support such high levels of squeezing. The largest source of internal loss, mode-mismatch between the coupled laser cavities, arises from practical—and largely, irreducible—limitations in the fabrication and positioning of optics. We demonstrate that statistical and machine-learning techniques can be used to optimize coupled-cavity interferometer design for maximum squeezing performance. As an example, we optimize the LIGO A+ design by minimizing its sensitivity to common errors in the positions and radii of curvature of the signal recycling cavity optics. In a head-to-head matchup against the nominal A+ design, we find that in 50% of trials, an optimally error-tolerant design achieves a 43% larger shot noise reduction factor for the same level of injected squeezing.

Primary author: RICHARDSON, Jon (Caltech)

Co-authors: Ms PANDEY, Swadha (Indian Institute of Technology, Kanpur); Ms BYTYQI, Edita (Columbia University); Dr EDO, Tega (Caltech); ADHIKARI, Rana (Caltech)

Presenter: RICHARDSON, Jon (Caltech)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **49** Type: **talk**

Wavefront Sensors for 3rd Generation Gravitational Wave Detectors

Wednesday, 19 May 2021 00:40 (20 minutes)

Wavefront sensors are essential devices in gravitational wave detectors since they are an indispensable tool for the control of the interferometer and a valuable help for the optimisation of the detector.
Next-generation gravitational wave detectors will introduce some fundamental changes that will influence the performance of these sensors (e.g. the use of laser with different wavelength) and requires the development of novel, optimised, sensors. At Nikhef we are developing and characterising new InGaAs/InP photodiodes. We are currently focusing on low-noise large-area quadrant photodiodes for LISA. However, this work will also help us to gain experience in designing new sensors and in characterising photodetectors for future earth-based gravitational wave detectors, like for example ET. We will discuss shortly a strategy towards new sensors for longer wavelengths (1.5 and 2 micron): extended InGaAs, quantum dots, etc.
In parallel we are optimising the Nikhef Phase Cameras, wavefront sensors currently in use at Virgo to read phase and mode content of the beam. They can be used to implement feedback to correct the thermal effects that create aberrations in the mirrors. However, we are not yet using Phase Cameras to their full potential. So far only the intensity profile is studied to determine the the Higher-Order-Mode content, and we like to discuss how to utilise the phase information.

Primary author: PASCUCCI, Daniela

Presenter: PASCUCCI, Daniela

Session Classification: Controls and machine learning workshop

Track Classification: Workshops: Controls and machine learning workshop

Contribution ID: **50** Type: **talk**

Seismic and Newtonian noise estimate at Terziet - the Euregio Meuse-Rhine candidate site for Einstein Telescope

Monday, 17 May 2021 12:20 (20 minutes)

The Einstein Telescope observatory aims to improve the low-frequency sensitivity of current detectors by more than three orders of magnitude at 10 Hz. This is a challenge, as Newtonian noise is expected to limit the low-frequency sensitivity. Surface array studies of vertical component seismic noise and single-station measurements at a depth of 250 m were conducted at Terziet, Netherlands. The observed surface wave dispersion and ellipticity was used to identify the modal contribution of surface wave noise and derive a subsurface velocity model up to a depth of 200 m. Cross-correlation analysis between surface and underground noise was used to understand the surface-body wave contribution to the underground noise. The observed underground noise attenuation and theoretical surface-wave attenuation estimates were used to understand the contribution of different surface wave modes to the underground noise. Further, the diurnal variation of seismic noise measured on the surface and underground was used to quantify the contribution of far-away body-wave sources to the underground noise. Using these parameters, elastic wave simulations were performed for both surface and body-wave sources to estimate the Newtonian noise at a depth of 250 m. The stochastic body-wave background was found to dominate our Newtonian noise predictions for the BGN-site and would constitute one of the main technical noise background for frequencies below 10 Hz and hence would also require a cancellation.

Primary author: KOLEY, Soumen (GSSI)

Co-authors: VAN DEN BRAND, Jo (Nikhef - VU); BULTEN, henk (Vrije Universiteit Amsterdam/Nikhef); LINDE, Frank (Nikhef - APPEC); BADER, Maria (PhD student, Nikhef); Dr CAMPMAN, Xander

Presenter: KOLEY, Soumen (GSSI)

Session Classification: Recorded talks: Third Generation Infrastructures

Contribution ID: **51** Type: **talk**

A broadband xylophone configuration with sloshing Sagnac interferometers

Thursday, 20 May 2021 06:00 (15 minutes)

In high frequency band, the quantum sensitivity is ultimately limited by the optical losses in signal recycling cavity (SRC). The sensitivity limit is independent of the arm length and the squeezing level, which constraints our ability to detect signals from binary neutron star mergers. By creating a cavity with two ETMs of the arm cavities, we can form a sloshing-Sagnac interferometer. It reshapes the signal response via a triply-coupled-cavity resonance, which beats the original SRC loss limit for the Michelson interferometer. The sloshing Sagnac also turns out to be a speed-meter, which can suppress the low-frequency radiation pressure noise. By choosing two sets of parameters for the ETMs and sloshing cavity length, a broadband quantum sensitivity can be achieved from several Hz to several kHz, resulting in a xylophone configuration.

Primary authors: ZHANG, Teng (University of Birmingham); Dr MIAO, Haixing (University of Birmingham)

Presenters: ZHANG, Teng (University of Birmingham); Dr MIAO, Haixing (University of Birmingham)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **52** Type: **talk**

Suspension fibers for large masses of Advanced Virgo Plus and beyond

Monday, 17 May 2021 10:40 (20 minutes)

The observation of gravitational waves is highly influenced by the detectors sensitivity, that is limited at 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). The target sensitivity for the new updates of Advanced Virgo Plus (AdV+) passes through larger and heavy reference masses; this choice requires, among other things, a re-design of the silica fibers and a new capability to produce and test them, in order to minimize the thermal noise in the band of interest and to fit the load constraints.
The talk will present the design requirements of the silica fibers for large masses in terms of mechanical stress, thermal noise and resonant frequencies. Upgrades to the fiber manufacturing system and its advantages will be discussed. Moreover measurements of mechanical behavior and the comparison, in terms of thermal noise, with the AdV configuration will be presented.
Finally we will describe a project for the use of the fiber fabrication machine to produce silicon fibers using a silicon core surrounded by a silica cladding: some preliminary results will be shown.

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

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

Session Classification: Recorded talks: Experience From Current Detectors

Track Classification: Advanced detectors: Experience from current detectors

Contribution ID: **53** Type: **poster**

6D inertial seismic isolation

Wednesday, 19 May 2021 16:13 (1 minute)

Tilt coupling is one of the limiting factors for the low-frequency sensitivity of gravitational-wave detectors. Implementing inertial seismic isolation of the suspension platform in all 6 DoF makes it quiet in all degrees of freedom simultaneously and minimises coupling of all DoF to interferometer length. In this poster, we discuss the potential improvement in the sensitivity of GW detectors and present the current status of the 6D project.

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

Co-authors: MOW-LOWRY, Conor (University of Birmingham); MARTYNOV, Denis (University of Birmingham); COOPER, Sam (University of Birmingham); Mr UBHI, Amit (University of Birmingham); DI FRONZO, Chiara; VAN DONGEN, Jesse (Nikhef); Ms MITCHELL, Alexandra

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

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **54** Type: **talk**

Optical Refrigeration for an Optomechanical Amplifier

Tuesday, 18 May 2021 06:40 (20 minutes)

Radiative cooling is a contact-free cooling technique that allows cooling of 100kg scale mirrors to cryogenic temperatures. However, future optomechanical applications require lightweight mirrors, for which radiative cooling is inefficient. In this talk, I will present optical refrigeration as a low-vibration cooling method for a phase-sensitive optomechanical amplifier, proposed to improve the sensitivity of future gravitational wave detectors (*Physical Review A 102.2 (2020): 023507*). With moderate improvements on coolants currently available, optical refrigeration can improve the amplifier gain by a factor of 2-10, relative to what is possible with radiative cooling. I will also show that the technique does not add significant noise to the amplifier.

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Co-authors: DRORI, Yehonathan (epartment of Physics and Astronomy, Amherst College, Amherst, Massachusetts 01002); Prof. ADHIKARI, Rana (LIGO Laboratory, California Institute of Technology, Pasadena, California 91125)

Presenter: DRORI, Yehonathan (epartment of Physics and Astronomy, Amherst College, Amherst, Massachusetts 01002)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **55** Type: **talk**

The Current Status of TOBA

Tuesday, 18 May 2021 06:45 (15 minutes)

Torsion-bar antenna (TOBA) is a ground-based gravity gradiometer proposed for measurement of gravity gradient fluctuations such as gravitational waves and gravity gradient noise. TOBA consists of two perpendicular torsion pendulum, and the low mechanical resonant frequency of torsion pendulums enables us to measure gravity gradient of frequencies around 0.1 Hz. TOBA aims to achieve the sensitivity 10^(-19) / rtHz at 0.1 Hz.
For the final sensitivity goal we are developing a prototype Phase-III TOBA in order to investigate technical issues and establish noise reduction scheme. One of the key topic of Phase-III TOBA is cryogenic suspension system for the reduction of the thermal noise. We will show the current situation of the cryogenic suspension and future upgrade plans for further improvement.

Primary author: TAKANO, Satoru (The University of Tokyo)

Co-authors: OOI, Ching Pin (University of Tokyo); MICHIMURA, Yuta (University of Tokyo); ANDO, Masaki (University of Tokyo)

Presenter: TAKANO, Satoru (The University of Tokyo)

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **56** Type: **talk**

Optical-parametric signal-amplification for a high-frequency gravitational-wave detector

Thursday, 20 May 2021 07:20 (15 minutes)

We propose a new method beyond the standard quantum limit using an optical parametric amplification (OPA) in a signal recycling cavity (SRC) for the next generation gravitational-wave detector. This method has the advantage of improving the detection sensitivity in a high-frequency band. The OPA technique with a nonlinear crystal realizes a stiff optical spring without increasing the circulating laser power and exceeds the standard quantum limit in the high-frequency band. We have succeeded in operating the Michelson interferometer, SRC, and the intracavity OPA in our prototype experiment at Tokyo Institute of Technology. In this talk, we will present the current status of the OPA system.

Primary authors: HARADA, Ken-ichi (Tokyo Institute of Technology); Mr OTABE, Sotatsu (Tokyo Institute of Technology); Mr SUZUKI, Kaido (Tokyo Institute of Technology); SOMIYA, Kentaro (Tokyo Institute of Technology)

Presenter: HARADA, Ken-ichi (Tokyo Institute of Technology)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **57** Type: **poster**

Demonstration of a dual-pass differential Fabry–Perot interferometer for future interferometric space gravitational wave antennas: DECIGO and B-DECIGO

Wednesday, 19 May 2021 16:14 (1 minute)

A dual-pass differential Fabry–Perot interferometer (DPDFPI) is one candidate of the interferometer configurations utilized in future Fabry–Perot type space gravitational wave antennas, such as Deci-hertz Interferometer Gravitational wave Observatory (DECIGO) and B-DECIGO. In this poster, the working principle of the DPDFPI has been investigated and necessity to adjust the absolute length of the cavity for the operation of the DPDFPI has been found. In addition, using the 55 cm-long prototype, the operation of the DPDFPI has been demonstrated for the first time and it has been confirmed that the adjustment of the absolute arm length reduces the cavity detuning as expected. This work provides the proof of concept of the DPDFPI for application to the future Fabry–Perot type space gravitational wave antennas. For more detail, please also see our recent paper: Koji Nagano et al 2021 Class. Quantum Grav. **38** 085018.

Primary author: Dr NAGANO, Koji (Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency)

Co-authors: TAKEDA, Hiroki (Kyoto University); MICHIMURA, Yuta (University of Tokyo); UCHIYAMA, Takashi (Institute for Cosmic Ray Research); ANDO, Masaki (University of Tokyo)

Presenter: Dr NAGANO, Koji (Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency)

Session Classification: Poster session 1

Track Classification: Next detectors: Space missions

Contribution ID: **58** Type: **talk**

The cooling scenario of the KAGRA test mass without condensation on the surface toward to O4

Wednesday, 19 May 2021 23:00 (20 minutes)

Condensation on the surface of the main mirror and the viewport for oplev of the radiation shield is a serious problem at the cryogenic gravitational wave telescopes, KAGRA. In order to find a way to cool the main mirror down to the required temperature (~20 K) while preventing condensation, cryo-group of KAGRA conducted a cooling experiment of the main mirror using the a KAGRA cryostat.
In this experiment, we succeeded in preventing condensation on the main mirror and the viewport.
The key is that the radiation shields and cryo-ducts which surround the main mirror are cooled down at first. During the cooling period of the cryostat, we measured the residual gas components of partial pressure inside the cryostat, which causes surface condensation, and confirmed that residual gas components are adsorbed on the surface of the radiation shield and cryo-ducts according to their surface temperature.
We also confirmed that the condensation can be defrosted by using the heating heater installed on the radiation shield and in the cryo-payload which suspend main sapphire mirror.
In this talk, the results of the cryostat cooling experiments will be reported.

Primary author: Prof. KIMURA, Nobuhiro (ICRR)

Presenter: Prof. KIMURA, Nobuhiro (ICRR)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **59** Type: **talk**

Status of KAGRA mirrors

Monday, 17 May 2021 10:20 (20 minutes)

The Japanese gravitational wave detector KAGRA is unique since it is the only one, so far, which operates its main mirror at cryogenic temperature in order to reduce their thermal noise. To achieve good performances at such temperature, the chosen material for the mirror bulk is sapphire. After the successful finalization of the construction phase of KAGRA, during the commissioning phase, an unforeseen issue arised.
In this talk I will describe the status of KAGRA core optics and share the research performed so far on optical absorption and birefringence.

Primary author: Dr LEONARDI, Matteo (NAOJ)

Presenter: Dr LEONARDI, Matteo (NAOJ)

Session Classification: Recorded talks: Experience From Current Detectors

Track Classification: Advanced detectors: Experience from current detectors

Contribution ID: **60** Type: **talk**

Optical loss study of the cryogenic molecular layer using a folded cavity for future gravitational-wave detectors

Thursday, 20 May 2021 00:00 (20 minutes)

In the future cryogenic gravitational-wave detectors such as the ET and LIGO Voyager, a molecular layer formed on the cryogenic mirror surface can become one of the problems due to its optical loss. We theoretically estimated the optical loss induced by the molecular layer and revealed that the optical absorption induced by the molecular layer. In addition, we developed 10 K folded optical cavity to investigate the optical loss of not only the coatings but also the molecular layer. In this experiment we realized the cryogenic optical cavity with folded configuration for the first time ever, and proposed a cavity enhanced ellipsometry technique to characterize the thin cryogenic molecular layer. We will present the possible impacts of cryogenic molecular layer on future gravitational-wave detectors, and the way to solve this problem.

Primary author: TANIOKA, Satoshi (ICRR, The University of Tokyo.)

Co-author: Prof. ASO, Yoichi (NAOJ)

Presenter: TANIOKA, Satoshi (ICRR, The University of Tokyo.)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **61** Type: **poster**

Sensing seismic platform relative motion using Digital Interferometry

Wednesday, 19 May 2021 16:15 (1 minute)

Gravitational-wave interferometric detectors have many internal seismic platforms to support the various suspended optics. For future detectors, the relative motion of these seismic platforms, via coupling to the auxiliary length controls of the suspended optics, are predicted to be the limiting noise source at low frequencies below 1 Hz. By measuring, then stabilizing the relative motion between the seismic platforms, the effective control feedback to the optics will be reduced and hence the noise coupling will be less, and potentially improve detector noise performance. The measurement of the relative motion with forms of suspension platform interferometry is an ongoing area of interest, research and development. Digitally-enhanced Interferometry is a decade-mature technique for sensing relative motion, by providing time-tagged pseudorandom phase modulation to isolate signals based on time-of-flight delay. The application of digitally-enhanced interferometry for suspension sensing is active area of development within the Newtonian Noise research program at the Australian National University, and offers another potential method for sensing relative platform motion. We present an overview of digitally-enhanced interferometry, recent developments for its application to suspension sensing, and potential prospectives for sensing seismic platform relative motion.

Primary authors: CHUA, Sheon Shang Yaw (ANU Centre for Gravitational Astrophysics); SLAGMOLEN, Bram (The Australian National University)

Presenter: CHUA, Sheon Shang Yaw (ANU Centre for Gravitational Astrophysics)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **62** Type: **talk**

Recent upgrade of KAGRA cryogenic payload

Wednesday, 19 May 2021 23:40 (19 minutes)

Operating gravitational-wave detectors at cryogenic temperature has several technical difficulties. One known difficulty is an initial alignment of the interferometer. We have observed 150 urad of pitch inclination drift of mirrors during cooling, which is larger than range of coil-magnet actuators of cryogenic payload. During bKAGRA Phase 1 operation, the first cryogenic operation of KAGRA, ball-screw-type moving masses were used for initial alignment and successfully aligned the mirrors. However, we found the long-term reliability problem of the moving mass later, commissioning term for O3. So, a new moving mass, which has a different moving mechanism from the old one, was developed and installed the cryogenic payload. In this talk, design and performance of new moving mass will be reported.

Primary author: USHIBA, Takafumi (ICRR)

Co-author: KAGRA COLLABORATION

Presenter: USHIBA, Takafumi (ICRR)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **63** Type: **poster**

Developing and testing compact displacement sensors using Deep-Frequency Modulation Interferometry

Wednesday, 19 May 2021 16:16 (1 minute)

Multi-fringe capable, compact laser interferomters are studied as sensors for displacement sensing of suspended test masses and inertial sensors in future ground-based detectors to improve their low-frequency noise. We are investigating such a sensor, or optical head, design that uses a quasi-monolithic component and deep-frequency modulation interferometry to enable sub-picometer level displacement sensing in a compact format while providing optimal readout noise floor. We discuss how we plan to supress the coupling of ghost beams in our design using advanced signal processing schemes that are enabled by the unique properties of deep-frequency modulation interferometry. We also present our current plans to develop an inertial testbed with active seismic isolation and suspended test masses in vacuum to study the sensors under realisitc conditions.

Primary authors: GERBERDING, Oliver (Universität Hamburg, Institut für Experimentalphysik); Dr ISLEIF, Katharina-Sophie (DESY)

Presenter: GERBERDING, Oliver (Universität Hamburg, Institut für Experimentalphysik)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **64** Type: **poster**

Influence of environmental noise on Virgo detector during O3

Thursday, 20 May 2021 16:22 (1 minute)

Sources of geophysical and anthropogenic noise, such as wind, sea activity, earthquakes, local traffic, etc., can impact gravitational wave interferometers by causing sensitivity drops and lock losses. During the 1-year long O3 observation run, the Virgo Collaboration collected a statistically significant amount of data to study the response of the detector to a variety of environmental conditions. We used this dataset to correlate different environmental parameters to quantities that monitor detector performance, such as its observation range and duty cycle. Where possible, we identified weaknesses in the detector and worked out strategies to implement to improve Virgo robustness against external environmental disturbances for the next observing run O4, planned for summer 2022. The lessons learned could provide useful insights for the design of the next generation of ground-based interferometers.

Primary authors: LONGO, Alessandro (Istituto Nazionale di Fisica Nucleare); GIUNCHI, Carlo (INGV sez. Pisa); PAOLETTI, Federico (PI); DI RENZO, Francesco (P); FIORI, Irene (European Gravitational Observatory); KAMIEL, Janssens (Uni. Antwerpen, Artemis); OLIVIERI, Marco (INGV); TRINGALI, Maria Concetta (EGO-European Gravitational Observatory); ARNAUD, NICOLAS (LAL ORSAY CNRS-IN2P3); Mr RUGGI , Paolo (EGO); DE ROSA, Rosario (NA)

Presenter: DI RENZO, Francesco (P)

Session Classification: Poster session 2

Track Classification: Advanced detectors: Experience from current detectors

Contribution ID: **65** Type: **talk**

Locking of Central Interferometer of Advanced Virgo+

Monday, 17 May 2021 11:00 (20 minutes)

The target sensitivity of Advanced Virgo for O4 is about 90-120 Mpc for the BNS range. To achieve this, several hardware upgrades are under process. One of the most relevant concerns the installation of the Signal Recycling Mirror. I will describe the procedure followed for locking the Dual Recycled Michelson Interferometer along with the tuning of CO_2 central heating, which assists the lock of DRMI by compensating for the (cold) optical aberrations.

Primary author: GIRI, Priyanka (Istituto Nazionale di Fisica Nucleare)

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Presenter: GIRI, Priyanka (Istituto Nazionale di Fisica Nucleare)

Session Classification: Recorded talks: Experience From Current Detectors

Track Classification: Advanced detectors: Experience from current detectors

Contribution ID: **66** Type: **poster**

Towards low suspension thermal noise of cryogenic torsion pendulums with crystalline fibres

Thursday, 20 May 2021 16:23 (1 minute)

Suspension thermal noise is a significant noise source for torsion pendulums. Two ways to reduce it is to utilize cryogenic temperatures and crystalline fibres. We record our progress here in utilising both in tandem to achieve low suspension noise levels, with an eye on achieving high Q for use in TOrsion Bar Antenna (TOBA), a proposed gravitational wave detector aimed at 0.1-10 Hz

Primary author: OOI, Ching Pin (The University of Tokyo)

Co-authors: TAKANO, Satoru (The University of Tokyo); MICHIMURA, Yuta (Department of Physics, University of Tokyo); ANDO, Masaki (University of Tokyo)

Presenter: OOI, Ching Pin (The University of Tokyo)

Session Classification: Poster session 2

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **67** Type: **poster**

Gas cooling of test masses during observation runs

Wednesday, 19 May 2021 16:00 (1 minute)

The event rate of current observatories is partially limited by noise arising from temperature-driven position fluctuations of the test mass mirror surfaces used for probing space time dynamics. Future gravitational-wave observatories address this limitation by using cryogenically cooled test masses;
current approaches for continuously removing heat (resulting from absorbed laser light) rely on black-body radiation or conduction through suspension fibers.

As a complementing approach for extracting heat during observational runs,
we investigate cooling via helium gas impinging on the test mass in the free molecular flow regime.
We establish a relation between cooling power and corresponding displacement noise, based on analytical models, which
we compare to numerical simulations.
The application of our analytical models and numerical simulations is presented with regard to the conceptual designs of the Einstein Telescope and the Neutron Star Extreme Matter Observatory (NEMO).

Primary authors: REINHARDT, Christoph (Deutsches Elektronen Synchrotron (DESY)); FRANKE, Alexander (Institut für Laserphysik und Zentrum für Optische Quantentechnologien der Universität Hamburg); SCHAFFRAN, Jörn (Deutsches Elektronen Synchrotron (DESY)); SCHNABEL, Roman (Institut für Laserphysik und Zentrum für Optische Quantentechnologien der Universität Hamburg); LINDNER, Axel (Deutsches Elektronen Synchrotron (DESY))

Presenter: FRANKE, Alexander (Institut für Laserphysik und Zentrum für Optische Quantentechnologien der Universität Hamburg)

Session Classification: Poster session 1

Track Classification: Next detectors: Third generation design

Contribution ID: **69** Type: **poster**

Stabilization of a parametric signal-amplification system using a digital signal-processing device

Thursday, 20 May 2021 16:26 (1 minute)

A signal-recycling Michaelson interferometer with an optical parametric amplification (OPA) has a large potential for a high-frequency gravitational-wave detection. The OPA using a nonlinear crystal in the signal-recycling cavity amplifies the signal and makes a stiff optical spring. A number of degrees of freedom need to be controlled to stabilize the system. Using a digital signal-processing device, we can realize such a complex control with a single computer. We have installed a commercial digital signal-processing device sBOX2 to control the signal-recycling Michelson interferometer with an intracaviity OPA. In this poster, we explain the status of our digital control system.

Primary authors: SUZUKI, Kaido (Tokyo Institute of Technology); HARADA, Ken-ichi (Tokyo Institute of Technology); Mr OTABE, Sotatsu (Tokyo Institute of Technology); SOMIYA, Kentaro (Tokyo Institute of Technology)

Presenter: SUZUKI, Kaido (Tokyo Institute of Technology)

Session Classification: Poster session 2

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **70** Type: **poster**

Measurements of multi-material coatings using a cryogenic nodal support

Thursday, 20 May 2021 16:24 (1 minute)

Future gravitational wave detectors plan to operate at cryogenic temperatures using crystalline silicon test masses which are transparent at higher wavelengths of light. Here we present measurements of a multi-material coating design that uses layers of ion-plated tantala, silica and amorphous silicon to reduce coating thermal noise and produce low optical absorption at low temperatures. Here we present the first cryogenic mechanical loss measurements (4K –300K) of these coatings carried out on silicon disks using a cryogenic nodal support.

Primary authors: TAIT, Simon (University of Glasgow); MURRAY, Peter (SUPA University of Glasgow); KINLEY-HANLON, Maya (University of Glasgow); MARTIN, Iain (University of Glasgow); Mr MCGHEE, Graeme (University of Glasgow); Mr MACKESSACK, Robbie (University of Glagsow); GRAHAM, Victoria (University of Glasgow); HOUGH, James (University of Glasgow); ROWAN, Sheila (University of Glasgow)

Presenter: TAIT, Simon (University of Glasgow)

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **71** Type: **talk**

Challenges and Opportunities of Ultra-High-Frequency Gravitational Wave Detection

Monday, 17 May 2021 07:10 (15 minutes)

The first direct detection of gravitational waves by the LIGO and VIRGO collaborations has opened up new avenues to explore the Universe. Currently operating and planned gravitational wave detectors mostly focus on the range below 10 kHz, where signatures from known astrophysical sources are expected to be discovered. However, based on what happens with the electromagnetic spectrum, there should be interesting physics to be discovered at every scale of gravitational wave frequencies. In particular, any discovery of gravitational wave signatures at frequencies higher than 10 kHz would correspond either to exotic astrophysical objects (such as primordial black holes or boson stars) or to cosmological events in the early Universe, such as phase transitions, preheating after inflation, oscillons, cosmic defects, etc. Hence, the search for high-frequency gravitational waves is a promising and challenging search for new physics and it provides a unique opportunity to test many theories beyond the Standard Model that could not be tested otherwise. In this talk, I will briefly review the state of the art about high-frequency gravitational wave physics, both from the theoretical point of view - summarising the most promising known sources and their features - and from the experimental point of view - presenting the state of the art in terms of experimental proposals in this frequency range and what are the possible ways forward.

Primary author: MUIA, Francesco (University of Cambridge)

Presenter: MUIA, Francesco (University of Cambridge)

Session Classification: Recorded talks: GW Physics

Track Classification: Physics: Gravitational wave perspective

Contribution ID: **72** Type: **poster**

Beam expander telescopes for the Michelson beam splitters in third generation Gravitational Wave Observatories.

Wednesday, 19 May 2021 16:17 (1 minute)

The Einstein Telescope will have Michelson interferometers with Fabry-Perot cavities in the two arms. They will need the widest possible stored beams to reduce thermal noise, using mirror test masses with diameter at the limit of technical feasibility. Recombining those wide beams into the beam splitter would be challenging in any case. Unlike other detectors, the Einstein Telescope will have a 60o angle between the arms. Because of its larger incidence angle, at any given beam size, it would require beam splitters almost double in size and much heavier than the 90o case. It is proposed here to install beam expander telescopes with angled mirrors inside the Michelson, located between the Fabry-Perot cavities and the beam splitter. In addition to reducing the beam sizes to manageable sizes, the proposed solution allows to bring the recombination angle to 90o. As a result, beam splitters more than 100 times lighter can be used. The proposed geometry also offers a natural way to separate the beam splitters of different detectors into individual, smaller and more stable caverns, to provide needed beam diagnostic points and convenient degrees of freedom for beam alignment into both the Fabry Perot cavities and the beam splitter, as well as to provide a method for maintaining optimal mode matching of the two arms onto the beam splitter without thermal compensation plates. This easily offsets the added complexity of controlling the telescope mirrors

Primary author: DESALVO, Riccardo (Universita' del Sannio)

Presenter: DESALVO, Riccardo (Universita' del Sannio)

Session Classification: Poster session 1

Track Classification: Next detectors: Third generation design

Contribution ID: **73** Type: **poster**

Beam suspensions for cryogenic mirrors

Thursday, 20 May 2021 16:11 (1 minute)

Cryogenic suspensions are subjected to a number of conflicting requirements.
An idea replacing the suspension fibers with massive beams is presented here to suspend the mirrors while attempting to solve these constraints.

Primary author: DESALVO, Riccardo (Universita' del Sannio)

Presenter: DESALVO, Riccardo (Universita' del Sannio)

Session Classification: Poster session 2

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **74** Type: **poster**

Radiative mirror thermal compensation system

Thursday, 20 May 2021 16:12 (1 minute)

The powerful beams stored in the Fabry Perot cavities of gravitational wave detectors deposit heat on the mirror coatings and cause thermal lensing. We present an experiment that studies the feasibility to balance that excess heat by selectively absorbing the black body heat that at ambient temperature naturally radiates from the test masses. It is shown how the coating heating effect can be fully eliminated in a completely passive way. The method can extract a power of the order of the Watt, depending on the beam spot size.

Primary author: DESALVO, Riccardo (Universita' del Sannio)

Presenter: DESALVO, Riccardo (Universita' del Sannio)

Session Classification: Poster session 2

Track Classification: Advanced detectors: Beyond second generation

Contribution ID: **75** Type: **talk**

Properties of amorphous SiC films

Wednesday, 19 May 2021 07:10 (5 minutes)

The observational horizon of interferometric gravitational wave (GW) detectors is limited by thermal noise in the coating at mid-range frequency, where first GW signals have been detected and many others are expected. The main responsible are the intrinsic dissipations, intimately linked to the inelastic behaviour of the amorphous coating materials. This behaviour is generally explained by the presence of a number of metastable atomic configurations of the amorphous matrix which can switch between two different states by thermally activated processes. Any two of these states that are separated by an energy barrier is called a two level system (TLS). In order to reduce the dissipation of amorphous materials two basic ideas can be pursued: a reduction of the total number density of TLS or an optimal distribution of TLS. Depositing amorphous film of materials whose coordination number is superior to three should lead to a low number of TLS.
Among the candidate high coordination number glasses, we investigated amorphous SiC, interesting for advanced applications and still lacking a deep study. Here are presented structural, chemical, optical and mechanical characterizations of a-SiC films, deposited by Ion Beam Sputtering and Magnetron Sputtering techniques. Furthermore, molecular dynamic simulations to evaluate elastic properties in a wide energetic range are shown.

Primary authors: AMATO, Alex; ARCIPRETE, Fabrizio; BAZZAN, Marco (PD); CAGNOLI, Gianpietro (ILM-UCBL); CESARINI, Elisabetta (ROMA2); DE MATTEIS, Fabio (ROMA2); DAO, thu ha; FAVARO, Giulio (Università degli studi di Padova); GRANATA, Massimo (Laboratoire des Matériaux Avancés - CNRS); GUTIERREZ , N. L.; HONRADO BENITEZ C., C.; LARRUQUERT J. I., J. I.; LUMACA, Diana (Università di Roma Tor Vergata e INFN Sezione di Roma Tor Vergata); MAGGIONI, Gianluigi (LNL); PEREIRA , A.; PLACIDI, Ernesto (Istituto Nazionale di Fisica Nucleare); PROSPOSITO, paolo (Industrial Engineering Department University of Rome Tor Vergata); Dr PUOSI, Francesco (INFN Pisa)

Presenter: LUMACA, Diana (Università di Roma Tor Vergata e INFN Sezione di Roma Tor Vergata)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **76** Type: **talk**

Science case and design considerations for a GW detector in the 10 - 300 kHz band

Thursday, 20 May 2021 07:40 (15 minutes)

The levitated-sensor detector aims to look for gravitational waves (GW) in the frequency range from 10 kHz to 300 kHz. Since it is based on a resonant interaction between the GW and the levitated particle, it can have a significantly smaller footprint than the kilometer-scale detectors, inspring the first generation detector to be tabletop! I will explain the latest design modifications that allow a 20-fold improvement in sensitivity over the previous proposal. I will also talk about the estimate of strain from GW sources like BH superradiance and primordial black holes in this frequency range. Finally, I will provide updates on the latest developments on the first-generation detetcor's implementation in the lab.

Primary author: AGGARWAL, Nancy (Northwestern University)

Presenter: AGGARWAL, Nancy (Northwestern University)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **77** Type: **poster**

Mechanical loss studies at Maastricht University

Thursday, 20 May 2021 16:21 (1 minute)

Authors: V. Spagnuolo, S. Gouvalas, I.W. Martin, G. McGhee, P. Murray, S. Tait, C. Clark, S. Hild, and J. Steinlechner

For current gravitational wave interferometers, the limit in sensitivity at their most sensitive frequencies originates from the combination of thermal noise and quantum noise. The main contribution to the thermal noise arises from the Brownian motion of high reflectivity coatings on the test mass optics, composed of multiple doublets of alternating layers of low and high refractive index materials. Coating thermal noise is dominated by the loss angle of titania-doped-tantala, the high refractive index material. Possible replacement materials with lower mechanical loss for current, and future gravitational-wave detectors are currently under investigation. As part of a new coating characterization laboratory at Maastricht University, a gentle nodal suspension system has been built. We will present initial studies of the mechanical loss of different compositions of titanium dioxide doped with a few percent of germanium dioxide as part of a comprehensive study of the effect of composition and heat treatment on loss and absorption of magnetron-sputtered germania-based coatings.

Primary authors: GOUVALAS, S. (Maastricht University); MARTIN, I.W. (SUPA, School of Physics and Astronomy, University of Glasgow); MCGHEE, G. (SUPA, School of Physics and Astronomy, University of Glasgow); MURRAY , P. (SUPA, School of Physics and Astronomy, University of Glasgow); TAIT, S. (SUPA, School of Physics and Astronomy, University of Glasgow); CLARK, C. (Helia Photonics Ltd.); HILD, S. (Maastricht University, Nikhef Institute); STEINLECHNER, J. (Maastricht University, Nikhef Institute)

Presenter: SPAGNUOLO, Viola (Maastricht University, Nikhef Institute)

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **78** Type: **poster**

Overview of possible multimaterial designs for improving current coatings

Thursday, 20 May 2021 16:14 (1 minute)

A factor of two in coating thermal noise reduction is required to achieve the design sensitivity of Advanced LIGO+. For ET-HF and the initial Cosmic Explorer design very similar coating thermal noise levels are assumed. Low optical absorption of the coatings of <1ppm is also required, but challenging to meet.

Multimaterial designs allow for a trade-off between thermal noise and absorption, allowing for one of the parameters to be reduced while slightly increasing the other. In case of a low refractive index contrast between coating materials, a multimaterial design can reduce the total number of layers required to achieve a certain reflectivity, potentially reducing defects during deposition, or issues from heat treatment or stress effects.

On this poster, we will explore the parameter space of possible improvements in coating performance via multimaterial designs - on the example of the Advanced LIGO+ design. A range of currently interesting materials e.g. germania-based coatings, silicon nitride and aSi will be considered.

Primary author: STEINLECHNER, Jessica (Maastricht University)

Co-author: Dr MARTIN, Iain (University of Glasgow)

Presenter: STEINLECHNER, Jessica (Maastricht University)

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **79** Type: **talk**

Meeting the Advanced LIGO+ coating requirements by using multimaterial designs

Monday, 17 May 2021 23:00 (15 minutes)

To realize the design sensitivity of Advanced LIGO+, about a factor of two in coating thermal noise reduction is required. For ET-HF and the initial Cosmic Explorer design very similar coating thermal noise levels are assumed. Another requirement on the highly-reflective mirror coatings is low optical absorption of <1ppm which is challenging to meet.

Multimaterial designs allow for a trade-off between thermal noise and absorption, allowing for one of the parameters to be reduced while slightly increasing the other. In case of a low refractive index contrast between coating materials, a multimaterial design can reduce the total number of layers required to achieve a certain reflectivity, potentially reducing defects during deposition, or issues from heat treatment or stress effects.

This talk will give an overview of possible improvements of coating performance by using multi-material designs - on the example of the Advanced LIGO+ design. A range of currently interesting materials e.g. germania-based coatings, silicon nitride and aSi will be considered.

Primary authors: MARTIN, Iain (University of Glasgow); STEINLECHNER, Jessica (Maastricht University)

Presenter: MARTIN, Iain (University of Glasgow)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **80** Type: **poster**

Studies of coating absorption for future detectors

Thursday, 20 May 2021 16:15 (1 minute)

As improvements to the current gravitational wave detector network are implemented, and as new detectors are added to the network, any new mirror coating designs must overcome the twofold challenge of producing sufficiently lower thermal noise perfomance, as well as maintaining a low level of optical absorption. Here we present an update on our research into characterizing the room temperature optical absorption of different mirror coatings; including a novel design multimaterial coating stack containing $SiO_2/Ta_2O_5/aSi$ films deposited via ion plated deosition, as well as our work measuring $TiO_2 : GeO_2$ coatings of various doping concentrations. Photothermal common path interferometry was used to measure the absorption of coatings in their as deposited state, and through various stages of heat treatment up to 600,$^O C$. The nuances of direct-to-temperature heat treatment versus progressive heat treatment through intermediate steps were also studied for the multimaterial coating design, with some interesting results being obtained, seemingly showing a significant reduction in the performance of Ta_2O_5 layers at 2000,nm in response to the progressive anneal.

Primary authors: MARTIN, Iain (University of Glasgow); STEINLECHNER, Jessica (Maastricht University); Mr MCGHEE, Graeme (University of Glasgow); JOHNSTON, Ross; HOUGH, James (University of Glasgow); ROWAN, Sheila (University of Glasgow); KINLEY-HANLON, Maya (University of Glasgow); Dr CLARK, Caspar (Helia Photonics Ltd); MAVRIDI, Nena (Helia Photonics Ltd); MURRAY, Peter (SUPA University of Glasgow)

Presenters: Mr MCGHEE, Graeme (University of Glasgow); JOHNSTON, Ross

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **81** Type: **talk**

Metrology open issues in GeNS measurements

Wednesday, 19 May 2021 06:45 (15 minutes)

The Gentle Nodal Suspension (GeNS) has become the most common technique for measuring coating mechanical dissipation, showing an unprecedented result repeatability on disk shaped substrates. GeNS gives the possibilities to perform measurement so accurate that it is possible to follow even tiny changes in the sample mechanical behavior. The high level of sensitivity makes some new systematic effect to be relevant, posing metrological issues which are currently unsolved.
Sample curvature changes caused by non symmetrical coatings and post-deposition thermal treatments, and changes of few degrees in sample temperature, produce mode frequency shifts which overlap to the ones given by the coating itself. This overlapping spoils the accuracy of dilution factor measurement and elastic parameters estimation.
Dissipation of silicon and sapphire substrates, commonly used in cryogenics measurements, are dominated for most of the temperature span by thermoelastic damping. Changing in the thermoelastic dissipation is shown to be induced by coating deposition. Since coating loss angle is measured by difference, this effect gives a systematic error in assuming bare substrate not altered by deposition. Lastly both the thermoelastic damping shift, as well as the dishomogeneity of the coating at the sample edge, can give systematics in trying to disentangle different bulk and shear loss angles. A description of these open issues will be given and a path for solutions will be presented.

Primary author: PIERGIOVANNI, Francesco (Istituto Nazionale di Fisica Nucleare)

Presenter: PIERGIOVANNI, Francesco (Istituto Nazionale di Fisica Nucleare)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **82** Type: **poster**

Auxiliary Suspension Modelling for Glasgow Cryogenic Interferometer Facility

Wednesday, 19 May 2021 16:18 (1 minute)

The Glasgow Cryogenic Interferometer Facility will be a double cavity cryogenic interferometer prototype with suspended silicon optics which will allow the testing of future technologies required for 3rd generation detectors. This poster discusses the modelling of one of the room temperature steering suspensions which will be used at this facility.

Primary authors: GRAHAM, Victoria (University of Glasgow); BARR, Bryan (University of Glasgow); Dr BARTON, Mark (University of Glasgow); Dr CUMMING, Alan (University of Glasgow); HAMMOND, Giles (University of Glasgow); HAUGHIAN, Karen (University of Glasgow); HOUGH, James (University of Glasgow); Mr JONES, Russell (University of Glasgow); Dr MARTIN, Iain (University of Glasgow); OELKER, Eric (MIT LIGO Laboratory); ROWAN, Sheila (University of Glasgow); SPENCER, Andrew (University of Glasgow); Dr WEBSTER, Stephen (University of Glasgow)

Presenter: GRAHAM, Victoria (University of Glasgow)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **83** Type: **poster**

Investigation and mitigation of anomalous power absorptions in the Advanced Virgo Plus core optics

Thursday, 20 May 2021 16:16 (1 minute)

Advanced gravitational waves detectors revealed until now a significant number of signals from the mergers of compact objects with amplitudes of the order of 10^(-21)-10^(-22). The necessity to increase the detection volume and the number of candidate sources requires an improvement of the sensitivity of the interferometers (ITF). For this purpose, an increase of laser power in the ITF and high stability are required.
During O3 observing run, small, highly absorbing areas on the surfaces of the main interferometer optics of Advanced Virgo have been observed. These anomalous micron-scale absorbers produce distortions as additional thermo-elastic deformation of the high reflectivity mirrors surfaces and thermal lensing in the optics substrate. With the aim to understand and mitigate their effects in the interferometer, a detailed and quantitative study of their characteristics has been carried out. The information about their position and fraction of absorbed power allows to put the basis for the development of an adaptive actuator, able to correct these aberrations in the Advanced Virgo Plus (AdV+) test masses. Here the analysis of AdV+ input mirrors surfaces, point absorbers identification and characterization, the corresponding thermo-elastic deformation and its compensation are presented.

Primary author: CIFALDI, Maria (Istituto Nazionale di Fisica Nucleare)

Co-authors: ROCCHI, Alessio (ROMA2); GASBARRA, Claudio (Tor Vergata); NARDECCHIA, Ilaria (ROMA2); LORENZINI, Matteo (GSSI); FAFONE, Viviana (ROMA2)

Presenter: CIFALDI, Maria (Istituto Nazionale di Fisica Nucleare)

Session Classification: Poster session 2

Track Classification: Advanced detectors: Experience from current detectors

Contribution ID: **84** Type: **talk**

Performance of Optimized Ternary Coatings at Ambient and Cryo Temperatures

Wednesday, 19 May 2021 07:30 (5 minutes)

The structure of ternary coatings featuring minimum thermal (Brownian) noise under prescribed transmittance and absorbance constraints is investigated and found to consist of a few tapered quasi-Bragg triplets on top of an almost fixed-thickness stack of wuasi Bragg doublets using the highest contrast material pair.
The noise reduction of coatings based on aSi, TiO2::Ta2O5 and SiO2 as well as SiNx, TiO2::Ta2O5 and SiO2 at 290K, 120K and 20K is evaluated by comparison with alternative recipes.

Primary author: Prof. PINTO, Innocenzo M (University of Naples "Federico II", INFN, LVK and Centro Fermi)

Co-author: Prof. PIERRO, Vincenzo (DING, University of Sannio at Benevento)

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Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **85** Type: **poster**

The A+ Low-Loss Faraday Isolators

Thursday, 20 May 2021 16:17 (1 minute)

Advanced gravitational-wave detectors require low-loss Faraday isolators in the squeezer path, in order to maximize the benefits of the squeezed light injection. The University of Florida and Montclair State University have developed and are currently building two designs of low-loss Faraday isolators for the A+ upgrade, one output Faraday isolator (20 mm clear aperture) and two squeezer Faraday isolators (5 mm aperture). Both designs also serve as circulators. The required losses are <1% single pass, while maintaining an isolation ratio higher than 30 dB.

The designs use TGG as the magneto-optical material placed inside a vacuum-compatible magnet, with temperature tunability of the Verdet constant via a thermo-electric Peltier device. A single quartz rotator cut at 45 deg restores the initial polarization. The input polarizer is a wedged KTP prism while a thin film polarizer at the output allows for the injection of s-polarized light from the squeezer or the optical parametric oscillator. The output Faraday isolator design also includes a fused-silica wedge to compensate for the beam's angular displacement from the signal recycling mirror. All optics are super-polished and coated with high-performance IBS dielectric coatings. The Faraday devices assembled so far show 0.45% - 0.63% single pass loss, with better than 30 dB isolation.

This work was supported by National Science Foundation Awards PHY-1806839, PHY-2012021, CIT 75-S434395, and CIT 75-S434499.

Primary authors: Dr MARTIN, Rodica (Montclair State University); NOTTE, John (Montclair State University); REYES, Jonathan (Montclair State University); Dr GOETZ, Ryan (University of Florida); Dr FULDA, Paul (University of Florida); Dr TANNER, David (University of Florida)

Presenter: Dr MARTIN, Rodica (Montclair State University)

Session Classification: Poster session 2

Track Classification: Advanced detectors: Experience from current detectors

Contribution ID: **86** Type: **talk**

Theoretical Effective Emissivity for the LIGO Voyager Test Masses

Tuesday, 18 May 2021 07:00 (20 minutes)

We present our theoretical calculations of the effective emissivity for the LIGO Voyager test masses. Once Si at 123 K is a semi-transparent material, the emissivity depends on the mean thickness and the absorption, both calculation is also shown in this presentation. Finally, we present our recent resuts using internal reflexions for the mean thickness calculations.

Primary authors: REIS, Juliedson (PhD Student); Dr AGUIAR, Odylio (INPE)

Presenter: REIS, Juliedson (PhD Student)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **87** Type: **talk**

Realizing Cosmic Explorer 2 with LIGO A+ or Voyager Technology

Tuesday, 18 May 2021 06:00 (20 minutes)

Cosmic Explorer is a 40 km long third generation gravitational wave detector envisaged to be realized in two stages. The first stage (CE1) will use the room temperature fused silica and 1 μm laser technology of LIGO A+. The second stage (CE2) will either continue to use this technology or will use the cryogenic silicon and 2 μm laser technology of LIGO Voyager. In this talk, we will compare the fundamental noise sources of these two technologies and show that both realizations of CE2 can reach similar strain sensitivities.

Primary author: KUNS, Kevin (MIT)

Presenter: KUNS, Kevin (MIT)

Session Classification: Cryogenics workshop

Track Classification: Next detectors: Third generation design

Contribution ID: **88** Type: **poster**

A new experimental set-up for scattering studies of mirror coatings

Thursday, 20 May 2021 16:18 (1 minute)

Gravitational wave detectors impose extremely stringent requirements for the optical and mechanical properties of their mirrors. Research in new coating material focuses on minimizing mechanical losses which directly relate to the coating thermal noise. At the same time, absorption and scattering losses need to be kept at extremely low levels, since they strongly affect the operation and sensitivity of the detectors.

Here we present a new experimental set-up that is focused on scattering studies of new coatings at 1064 nm. The set-up is designed to measure bi-directional reflectance distribution functions off of coated surfaces, with a special emphasis in distinguishing scattering from different coating defects. We hope this information combined with scattering models will allow the determination of the depth distribution of defects within the coatings. Our relatively novel approach involves the reduction of image speckle which affects scattering images by reducing the spatial coherence of our laser. Finally, the new set-up is designed to study scattering from mirrors under high power and in vacuum, with the goal of testing coatings under similar conditions to the ones found in GW detectors.

This work complements existing metrology efforts within the LVK collaboration.

Primary authors: Prof. KONTOS, Antonios (Bard College); KING, Bobby (Bard College)

Presenter: Prof. KONTOS, Antonios (Bard College)

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **89** Type: **poster**

Higher-order HG modes for thermal noise reduction

Wednesday, 19 May 2021 16:04 (1 minute)

Thermal noise of the test masses is one of the limiting noise sources in Advanced detectors. It is expected to remain a limiting noise source in future detectors, despite radical changes to the design including cryogenic operations, new materials and the use of longer laser wavelengths. We will discuss progress towards verifying higher-order Hermite-Gauss laser modes as possible alternative or complementary technology to reduce thermal noise. These modes can be made more compatible with realistic imperfect mirror surfaces than the previously considered Laguerre-Gauss modes, and while recent studies show that higher-order modes will be subject to stricter tolerances on alignment and mode matching, this downside may be offset by their correspondingly lower alignment and mode mismatch sensing noise floors.

Primary authors: FULDA, Paul (University of Florida); TAO, Liu (University of Florida); Dr GREEN, Anna (University of Florida)

Presenter: FULDA, Paul (University of Florida)

Session Classification: Poster session 1

Track Classification: Next detectors: Third generation design

Contribution ID: **91** Type: **poster**

Implanted Oxygen Ions in Silicon and the Implication for Future Gravitational Wave Mirrors

Thursday, 20 May 2021 16:20 (1 minute)

While gravitational waves are regularly detected in several gravitational wave detectors globally, the research endeavors to improve the sensitivity of these detectors continues. Low mechanical loss and low optical absorption are key requirements of future coatings. Amorphous silicon has very low loss but relatively high absorption at the relevant wavelengths. Crystalline silicon also has low loss, but with lower absorption. Here we explore the use of ion implantation of oxygen ions into a silicon substrate to create a pattern of silica and crystalline silicon layers just below the surface. We present studies of the mechanical loss arising from a silica layer implanted approximately 100nm below the silicon surface.

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Presenter: KINLEY-HANLON, Maya (University of Glasgow)

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **92** Type: **poster**

Space missions - Developing a LISA optical ground-support equipment testing facility

Wednesday, 19 May 2021 16:03 (1 minute)

The Laser Interferometer Space Antenna (LISA) will be the first space-based gravitational wave observatory. LISA is a high precision interferometer in space with an arm length of 2.5 million km. The optical benches are made by bonding silicate glass components to an ultra-low-expansion glass ceramic which does not allow rearrangements of the optical components. Since the development, implementation and testing of the LISA instrument is a major undertaking a need for additional picometer-stable optical configurations might arise to test specific components, methods or noise couplings.
To prepare for the need of such optical ground support equipment in the future, we experimentally study two technologies: The first one simplifies and quickens the construction of picometer-stable interferometers and enables us to even rearrange optical components to other topologies. The second technology tests an approach to provide portable and comparably cheap laser frequency references for 1064nm laser light that are required to achieve LISA-level phase fidelity and can also be used for dilatometer-type experiments, such as temperature behavior tests of critical opto-mechanical components. Here an athermal glass etalon is probed as laser frequency reference for 1064nm light.
Central to this project is the set-up of a test facility with a vacuum system, laser preparation and readout electronics.

Primary author: BECK, Marcel (University of Hamburg)

Presenter: BECK, Marcel (University of Hamburg)

Session Classification: Poster session 1

Track Classification: Next detectors: Space missions

Contribution ID: **93** Type: **poster**

Constraining The Fraction of Compact Dark Matter Using Gravitational Lensing of Gravitational Waves

Wednesday, 19 May 2021 16:07 (1 minute)

Massive halo compact astrophysical objects (MACHOs) are a potential candidate of dark matter, the presence of which in the interstellar medium can cause deflection of gravitational waves (GWs), a phenomenon called gravitational lensing. If we do not find any lensing signature in the LIGO-Virgo data of gravitational waves, we can put an upper cut-off on their abundance in the mass range of 10-10^5 solar mass. In our work, we show how Bayesian analysis can help us determine the lensing signature of GWs and the absence of which will help constrain the upper limit of the MACHOs

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Presenter: BASAK, SOUMMYADIP (ICTS-TIFR, Bangalore, India)

Session Classification: Poster session 1

Track Classification: Physics: Gravitational wave perspective

Contribution ID: **94** Type: **poster**

Deep Frequency Modulation Readout noise limitations and algorithms

Wednesday, 19 May 2021 16:02 (1 minute)

Ground based gravitational wave detectors are limited at low frequencies by seismic noise and other related technical noise sources.
In order to overcome these limitations, we study the use of interferometry based, local displacement sensors as part of the active seismic noise mitigation at the pendulum-suspensions of these detectors.
Our idea is to use so called "Deep-Frequency-modulated"interferometers which allow for a highly compact design of the sensor while providing accuracies of below 10^{-14} m/Sqrt{Hz} over a large dynamic range. In order to assess the achievable precision of these new sensors, we use the Cramer-Rao-lower-bound from statistical analysis and compare it for different types of laser interferometers to calculate a fundamental limit of the readout.
Our results show that the "Deep-Frequency-modulated"scheme performs within a factor of \sqrt{2} of other interferometry based sensors and might even outperform some of them at specific scenarios.
We also find that in principle a fringe-scanning (deep modulation) scheme can be even more sensitive when combined with an optical resonator topology.
The calculated fundamental readout limits show that DFM-Interferometers can reach very high accuracies with a small physical footprint and seem to be a promising candidate for local displacement sensors for current and future gravitational wave detectors.

Primary author: ECKHARDT, Tobias (University of Hamburg)

Presenter: ECKHARDT, Tobias (University of Hamburg)

Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **95** Type: **poster**

Low frequency vertical inertial sensor improvements

Wednesday, 19 May 2021 16:01 (1 minute)

Nowadays, sensors' resolution limits their performance at low frequency which reduces their operating range. Sensors with a good resolution at low frequency are required to improve the performance of gravitational wave detectors in the sub-Hz frequency range. We are currently developing an inertial sensor with a sufficient resolution at low frequency from 10 mHz to 100 Hz. We are focusing on the improvement of different characteristics of the sensor, among others, its compactness and its thermal noise mitigation. The readout consists of a long-range Michelson interferometer fed by a 1550 nm laser and whose signal is measured by InGaS photodetectors. The use of InGaS photodetector in our interferometer will allow better resolution for future sensor projects. The inertial mass is connected to the frame by a fused silica flexure joint to limit internal damping. Then, translational guidance is implemented to allow the use of a flat mirror. The actual sensor developed at the Precision Mechatronics Laboratory has a resolution of 2x10^(-13) m/√Hz at 1 Hz. Our goal is to reach the same resolution with a compact version: 10x10x10 cm^3.

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Co-authors: Dr DING, Binlei (Université Libre de Bruxelles); Dr ZHAO, Guoying (Université Libre de Bruxelles); WATCHI, Jennifer (Université Libre de Bruxelles); Prof. LAMBERT, Pierre (Université Libre de Bruxelles); Prof. DERAEMAEKER, Arnaud (Université Libre de Bruxelles); Prof. COLLETTE, Christophe (University of Liège)

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Session Classification: Poster session 1

Track Classification: Workshops: Low frequency workshop

Contribution ID: **96** Type: **talk**

Optical and mechanical characterization of ion-beam-sputtered MgF2 and AlF3 thin films

Wednesday, 19 May 2021 07:20 (5 minutes)

GW detector highly reflective coatings are obtained by alternate layers of material with different refractive indexes. Brownian thermal noise associated with the coating stack, limits the mid-frequency region of the GW detector designed sensitivity. Thermal noise reduction can be achieved minimizing the overall thickness of the stack, increasing the refractive index contrast . Fluoride' s coatings, largely used in UV application, show the lowest measured values of refractive index, and they can be interesting for future GW detectors as low index material. The first optical and mechanical characterization of ion-beam-sputtered MgF2 and AlF3 thin films has been performed, starting the investigation on the possible utilization of fluorides in future GW detectors. Methods and results will be described, effects of post deposition thermal treatments will be presented.

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

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

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **97** Type: **poster**

Measurement of the thermo-optic effect in IBS SiNx coating

Thursday, 20 May 2021 16:25 (1 minute)

Thermo-optic noise is one of the possible sources of coating thermal noise that affects precision optical measurements, such as gravitational-wave detectors. A lot of effort is dedicated to identify coatings with low Brownian noise, but also coating thermo-optic noise should be considered as a possible limiting noise source for the next generation of GWDs mirrors. SiNx is one of the most promising new materials for new mirror coatings and a first measurement of thermo-optic parameters has been performed. This kind of measurement permits to know a linear combination of thermal expansion (α) and thermo-optic (β) coefficients. In the near future an evaluation of the thermal expansion coefficient will be carried out by measuring the curvature variation of a coated cantilever as a function of temperature.

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

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **98** Type: **poster**

Birefringence measurement of a sapphire mirror for KAGRA

Thursday, 20 May 2021 16:05 (1 minute)

The four sapphire mirrors in KAGRA will be cooled down to 20K to reduce thermal noise. We selected substrates with the lowest thermal absorption for the input mirrors. As for birefringence, we conducted an X-ray analysis to determine the direction of the crystal axis so that the effect of birefringence on to the laser beam is negligible. However, when we operated the interferometer with the sapphire mirrors, we found that the reflected light contains alternative polarization components.
Although we did not examined the non-uniformity of the birefringence before installing the mirrors in KAGRA, we happened to measure the transmitted wavefront error map with rotating the input polarization at each 45 degrees, from which we can estimate the birefringence map.
It is essential to verify the effectiveness of this method. We have been developing a system to measure the birefringence distribution at NAOJ so that we can compare the birefringence map deduced from the transmitted wavefront error map measurement and the directly measured birefringence map using a sample substrate.

In my poster, I will introduce the method to estimate the birefringence map from the transmitted wavefront error maps and explain the experiment to measure the birefringence map.

Primary author: ABE, Homare (Tokyo Institute of Technology)

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Presenter: ABE, Homare (Tokyo Institute of Technology)

Session Classification: Poster session 2

Track Classification: Advanced detectors: Beyond second generation

Contribution ID: **99** Type: **poster**

Fabrication considerations of large-scale scale silicon mirrors for future cryogenic gravitational wave detectors

Thursday, 20 May 2021 16:04 (1 minute)

Cryogenic gravitational wave detectors are planned to be significantly more sensitive than current room temperature detectors. Cryogenic detection relies on materials that have low mechanical loss and Brownian noise at low temperatures, ruling out the use of the fused silica mirrors currently used. Silicon is proposed as a cryogenic mirror substrate due to its excellent mechanical loss and thermal properties. There are three predominant methods of creating silicon substrates: float-zone silicon, Czochralski silicon, and quasi-monocrystalline silicon. Currently, single-crystalline silicon produced with the float-zone method meets both the low optical absorption and low mechanical loss requirements of these detectors, however, it is limited in the diameters that can be produced. The planned ~50cm, 200kg mass gravitational-wave detection mirrors cannot be achieved with this form of silicon creation. Czochralski silicon does not meet the required low absorption, and may also not meet the diameter requirements, although magnetically-stabilised Czochralski silicon shows some promise. We are studying quasi-monocrystalline silicon, which is made via directional solidification and does have the capacity to meet the desired mirror size requirements. Here we present initial measurements of the optical absorption and mechanical loss of this material.

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Presenters: MURRAY, Peter (SUPA University of Glasgow); KINLEY-HANLON, Maya (University of Glasgow)

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **100** Type: **poster**

Squeezing in higher-order Hermite-Gaussian modes

Thursday, 20 May 2021 16:03 (1 minute)

In the design studies of the next-generation gravitational wave detectors, coating Brownian thermal noise is a major noise contribution at frequencies around 100Hz. One proposed method to mitigate this noise source is to use a higher-order laser mode instead of the currently used fundamental Gaussian mode because their more uniform intensity distributions could average better over the mirror surfaces. To maintain the current quantum noise reduction, this would require the efficient generation of continuous squeezed vacuum states in these modes. We aim to demonstrate and compare the direct generation of squeezing in several symmetric Hermite-Gaussian modes and could already measure 7dB of vacuum noise reduction in HG11 as well as 6dB in HG22 in a first test.

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Co-authors: VAHLBRUCH, Henning (AEI Hannover); WILLKE, Benno (Leibniz University Hannover)

Presenter: HEINZE, Joscha (Albert Einstein Institute Hannover)

Session Classification: Poster session 2

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **102** Type: **poster**

Post-Newtonian properties of an EMRI in non-vacuum region using Logarithmic Potential

Wednesday, 19 May 2021 16:19 (1 minute)

There are many astrophysical scenarios where extreme mass ratio inspiral (EMRI) binaries can be surrounded by matter (esp. dark matter) distribution. The mass distribution can affect the dynamical properties (e.g. orbital frequency, orbital velocity, etc.) and the rate of energy radiation from the EMRI. We assume a power law dependency of mass distribution density on the radial distance from the center of mass (instead of a point mass source as used in Schwarzschild spacetime). Using the Newtonian order Poisson equation one obtains a general power law potential (instead of Kepler-Newton (KN) potential which is valid for vacuum regions). In this presentation, I would discuss the expressions for dynamical quantities and the average energy radiation rate from the circular orbit EMRI corrected up to the first post-Newtonian (1PN) order. These quantities can be significantly different in the presence of potential due to matter distribution as compared to that in the Kepler-Newton potential. The effect of mass distribution could be studied further in more realistic 3D orbits (by including eccentricities, precession, etc). Such signatures can be added to the existing templates for the gravitational waveforms which could be vital for the study using upcoming space-based detectors.

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Presenter: GANDEVIKAR, Chinmay (BITS Pilani India)

Session Classification: Poster session 1

Track Classification: Physics: Multimessenger perspective

Contribution ID: **103** Type: **talk**

ET-Pathfinder

Monday, 17 May 2021 12:10 (10 minutes)

With the discovery and direct measurement of gravitational waves from merging binary black holes and binary neutron stars by the Advanced LIGO and Advanced Virgo detectors a new era of gravitational wave astronomy has begun. Since the current detectors are moving closer to reaching their infrastructural limits, the drive for a third-generation gravitational wave detector increases. The Einstein Telescope (ET) is a proposed gravitational wave detector that will expand the cosmic reach of gravitational wave detection and will allow us to see all merging binary black holes in our universe. In order to research and develop the technologies that will be potentially implemented in ET, a new prototype facility, called ETpathfinder, is currently in its final construction in Maastricht. In this talk (on behalf of the ETpathfinder collaboration) we will present the layout of the prototype facility as well as highlight the initial setting of the cryogenically cooled suspended interferometer. In additionally, we will report on recent progress of the individual subsystems of the ETpathfinder project.

Primary author: HENNIG, Jan-Simon

Presenter: HENNIG, Jan-Simon

Session Classification: Recorded talks: Third Generation R&D Facilities

Track Classification: Next detectors: R&D facilities and plans

Contribution ID: **104** Type: **poster**

Characterization of Sputtered Amorphous GaN Film for High-Reflectivity and Low Loss Coatings

Thursday, 20 May 2021 16:02 (1 minute)

The anelastic behavior of amorphous materials is explained by the presence of two level systems, metastable states that are separated by an energy barrier.
Not all the TLS contribute to the mechanical losses. The ones that are active are only those with a relaxation time comparable to the period T of the strain wave propagating in the material. In order to reduce the dissipation in the material a reduction of the total density of TLS is needed. Amorphous films whose constitutive atoms possess a coordination number larger than 3 should be characterized by a low amount of TLS. Indeed, if this atom is linked to at least four atoms not on the same plane, the structure is more rigid and TLS are unlikely, making structural reorganization more difficult.
Sputtered amorphous GaN has been taken into account as a good candidate for high refarctive index material for future gravitational wave mirrors. Preliminary study on deposition parameters and their effects on optical, structural and morphological properties has been conducted. Good level of amourphousness has been reached using low deposition rate and high pressure. But optical absorption at 1064 nm, estimated by ellipsometric measurments, is still high with respect to GW detector requirments.

Primary author: DAO, thu ha

Co-authors: ARCIPRETE, Fabrizio; CESARINI, Elisabetta (ROMA2); DE MATTEIS, Fabio (ROMA2); DIPIETRANTONIO, F.; FAFONE, Viviana (ROMA2); LORENZINI, Matteo (GSSI); LUMACA, Diana (R); MINENKOW, Y.; NARDECCHIA, Ilaria (ROMA2); PLACIDI, Ernesto (Istituto Nazionale di Fisica Nucleare); PROSPOSITO, paolo (Industrial Engineering Department University of Rome Tor Vergata); ROCCHI, Alessio (ROMA2)

Presenter: DAO, thu ha

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **105** Type: **talk**

Seismic studies at Sos Enattos, the Sardinian site for the Einstein Telescope

Monday, 17 May 2021 12:00 (20 minutes)

In this talk I will give an overview of the currently ongoing seismic characterisation of the Sos Enattos area, the proposed first corner site for ET in Sardinia. In 2019 we started an extensive measurement campaign proving the low environmental noise features of the area. Several measurement stations are installed at surface and at the different depths along the former mine tunnels. New borehole seismometers installations are ongoing at the other two corners planned for ET in Sardinia. Thanks to the peculiar geological frame and to the low population density, the local seismic noise is close to the Peterson's NLNM, even at surface. In particular, from the seismic point of view, the site is among the quietest in the world in the 1-10Hz band. This feature, along with the low EM noise and other favourable aspects, makes the site an ideal candidate for the Einstein Telescope.

Primary author: Dr NATICCHIONI, Luca (INFN Roma)

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Presenter: Dr NATICCHIONI, Luca (INFN Roma)

Session Classification: Recorded talks: Third Generation Infrastructures

Track Classification: Next detectors: Third generation infrastructures

Contribution ID: **106** Type: **talk**

Potential Steps to Improve the Low Frequency Performance of Advanced LIGO

Wednesday, 19 May 2021 23:25 (20 minutes)

On April 6 & 7, 2021, the LSC held a workshop focused on the low frequency (<30 Hz) performance of the Advanced LIGO detectors, the sources of the excess noise, and various approaches to improve the noise. In this talk, I will review a few key points which were presented and then discuss the recommendations which were made in the Workshop Report, L2100055.

Primary authors: LANTZ, Brian (Stanford Univ.); Dr FRITSCHEL, Peter (MIT)

Presenter: LANTZ, Brian (Stanford Univ.)

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **107** Type: **talk**

Microstructuring and high-absorption coatings for scattered light reduction

Monday, 17 May 2021 23:30 (20 minutes)

We here discuss our preliminary findings regarding laser microsctructuring and high-absorption coatings as a potential choice for surface treatments in gravitational wave telescopes for scattered light reduction.

Primary author: Mrs FU, Cailing (RWTH Aachen)

Co-author: HOFMANN, Oskar (RWTH Aachen)

Presenter: Mrs FU, Cailing (RWTH Aachen)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **108** Type: **talk**

Einstein Telescope - update

Monday, 17 May 2021 08:00 (20 minutes)

The Einstein Telescope design and R&D activities are gaining momentum and a project organisational structure is being developed and put in place. This presentation gives a brief update on the status, highlights current and future activities and opportunities for participation.

Primary author: LUECK, Harald (AEI Hannover (MPI f. gravitational Physics / Inst. f. Grav.physics Leibniz Uni Hannover))

Presenter: LUECK, Harald (AEI Hannover (MPI f. gravitational Physics / Inst. f. Grav.physics Leibniz Uni Hannover))

Session Classification: Recorded talks: Third Generation Design

Track Classification: Next detectors: Third generation design

Contribution ID: **109** Type: **talk**

Scattered light study in Advanced Virgo Plus

Tuesday, 18 May 2021 00:30 (15 minutes)

Perspective of the work done during the reviews in the context of scattered light in Advanced Virgo Plus. In particular, study of ghost beams on different detector systems (frequency dependent squeezing, detection) with consequent mitigation actions performed and planned. Status of the tools available for the study of stray light in gravitational wave detectors and future research prospects to limit this problem.

Primary author: POLINI, Eleonora (LAPP)

Presenter: POLINI, Eleonora (LAPP)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **110** Type: **talk**

Stray-light control in KAGRA

Wednesday, 19 May 2021 06:45 (15 minutes)

In this talk, we will introduce several aspects of stray-light control in the KAGRA interferometer. The stray light to be controlled include ghost beams and scattered light produced at optics and mechanical structures in the interferometer and recombined somehow back into the main beam path. These unwanted lights could become critical noise in the end. Although the stray-light noise can be described in a simple formalism of phase fluctuations imprinted on the stray light until the recombination, the actual behaviors of the resultant noise are not always simple. So, the prediction of the behaviors is quite uncertain. To suppress the noise, optical baffles, dumps, or shields in (or out of) vacuum chambers need to be designed under a good connection with those of mechanical stuff like vibration-isolation systems in the very first place, while the seriousness of this noise is not always shared. One should consider the design concept also from the viewpoint of safety if using a high-power laser source. Thus careful engineering, which might be sometimes overlooked by scientists, would be necessary. Summarizing our activities so far would be useful for the detailed design of future interferometers.

Primary author: AKUTSU, Tomotada (National Astronomical Observatory of Japan)

Presenter: AKUTSU, Tomotada (National Astronomical Observatory of Japan)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **111** Type: **poster**

Feasibility Study of the Einstein Telescope – Geological Exploration

Thursday, 20 May 2021 16:06 (1 minute)

The Einstein Telescope (ET) is an advanced, third generation gravitational wave observatory, currently in the planning stage in Europe. The ET project involves construction of a triangular shape underground facility with 10 kilometres long arms. The border region between the Netherlands, Belgium and Germany is considered as a potential location and will be further investigated in a feasibility study funded by the EU, the Dutch Ministry of Economic Affairs, the State of North Rhine-Westphalia, the Province of Flemish Brabant, the Province of Belgian Limburg, the Province of Dutch Limburg, Flanders and Wallonia.
Stable underground conditions with minimal ambient noise are essential for the interferometers to be hosted in the caverns of the ET corner points. A detailed geological, structural, hydrogeological and geotechnical model is required to ensure the desired performance of the underground infrastructures. The current multi-disciplinary feasibility study (E-TEST) allows to collect the required data to (1) optimise the location and orientation of the ET triangle and corner points, (2) plan the construction of subsurface caverns and tunnels, (3) construct a sophisticated, three-dimensional, cross-border geological model of the study area and (4) establish new surveillance methods. This presentation provides a short overview on the geological exploration targets and methods used in the feasibility study E-TEST.

Primary authors: Mr KRITSKI, Alexander; Dr DUFRESNE, Anja (LIH RWTH Aachen); Mr VINK, Björn (antea Group); Prof. AMANN, Florian (LIH RWTH Aachen); Prof. WELLMANN, Florian (DGRE RWTH Aachen); Prof. LINDE, Frank (Nikhef); Dr HAVENITH, Hans-Balder (Georisk & Enviroment Liège University); Mr ENGL, Jan (RWTH Aachen); Mr FRÜND, Jonathan (RWTH Aachen); Mr ZINSER, Jonathan (LIH RWTH Aachen); Dr WALDVOGEL, Marius (EMR RWTH Aachen); Mr CHUDALLA, Nils (CGRE RWTH Aachen); Prof. KUKLA, Peter (EMR RWTH Aachen); Dr HAMDI, Pooya (LIH RWTH Aachen); Dr SHANI-KADMIEL, Shahar (Faculty of Civil Engineering and Geosciences TU Delft); Dr KOLEY, Soumen (Nikhef); Dr BACK, Stefan (EMR RWTH Aachen)

Presenter: Mr ZINSER, Jonathan (LIH RWTH Aachen)

Session Classification: Poster session 2

Track Classification: Next detectors: Third generation infrastructures

Contribution ID: **112** Type: **talk**

The Sar-Grav Laboratory

Monday, 17 May 2021 12:20 (10 minutes)

The Sar-Grav Laboratory is a seed of the third generation of gravitational wave interferometer: Einstein Telescope. The infrastructure is located beside the Sos Enattos mine in Lula (Nuoro, Sardinia). The region is characterized by a very low seismic and anthropogenic noise therefore, Sar-Grav aims to host underground experiments like low seismic noise experiments, cryogenic payloads, low frequency and cryogenic sensor development. A surface of about 900 square meters on the surface is equipped with an optical laboratory, a control room and it is gearing up with cleaned room, while 250 square meters are under construction underground. Archimedes, a fundamental physics experiment, is the first experiment already under installation in the surface area.

Primary author: Dr D'URSO, Domenico (University of Sassari and INFN-LNS)

Presenter: Dr D'URSO, Domenico (University of Sassari and INFN-LNS)

Session Classification: Recorded talks: Third Generation R&D Facilities

Track Classification: Next detectors: R&D facilities and plans

Contribution ID: **113** Type: **talk**

Demonstration of length control for a filter cavity with coherent control sidebands

Tuesday, 18 May 2021 23:40 (15 minutes)

For broadband quantum noise reduction of gravitational-wave detectors, frequency-dependent squeezed vacuum states realized using a filter cavity is a mature technique and will be implemented in Advanced LIGO and Advanced Virgo from the fourth observing run. To obtain the benefit of frequency-dependent squeezing, length and alignment of the filter cavity with respect to squeezed vacuum states must be controlled accurately. To this purpose, we suggested a new control scheme of the filter cavity using coherent control sidebands which are already used to control squeezing angle. We implemented the new control scheme for length control of a 300 m filter cavity and demonstrated the improvement of the locking accuracy of the filter cavity. In this talk, I report the result of the demonstration of the new control scheme for the filter cavity.

Primary authors: ARITOMI, Naoki (National Astronomical Observatory of Japan); ZHAO, Yuhang (ICRR, The University of Tokyo); CAPOCASA, Eleonora (APC); LEONARDI, Matteo (NAOJ); EISENMANN, Marc (NAOJ); GUO, Yuefan; POLINI, Eleonora (LAPP); TOMURA, Akihiro; ARAI, Koji (Caltech); ASO, Yoichi; HUANG, Yao-Chin; LEE, Ray-Kuang; LÜCK, Harald; MIYAKAWA, Osamu; PRAT, Pierre; SHODA, Ayaka (NAOJ); TACCA, Matteo (Laboratoire Astroparticule et Cosmologie - CNRS); TAKAHASHI, Ryutaro (National Astronomical Observatory of Japan); VAHLBRUCH, Henning (AEI Hannover); VARDARO, Marco (University of Amsterdam - Nikhef); WU, Chien-Ming; BARSUGLIA, Matteo (APC-CNRS); FLAMINIO, Raffaele (Laboratoire des Materiaux Avances - CNRS/IN2P3)

Presenter: ARITOMI, Naoki (National Astronomical Observatory of Japan)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **114** Type: **talk**

Space GW Antennae: DECIGO/B-DECIGO

Monday, 17 May 2021 08:20 (20 minutes)

DECIGO is a future gravitational wave antenna for direct observation of primordial gravitational waves from the early universe. It will be formed by three spacecraft separated by 1,000km from each other. B-DECIGO is its precursor mission with 1/10 scale. It is still very sensitive at 0.1Hz frequency band to observe compact binaries, intermediate-mass BBHs, and GW foregrounds. In this presentation, we will show the concept and current status of DECIGO/B-DECIGO missions.

Primary author: ANDO, Masaki (University of Tokyo)

Presenter: ANDO, Masaki (University of Tokyo)

Session Classification: Recorded talks: Space missions

Track Classification: Next detectors: Space missions

Contribution ID: **115** Type: **talk**

Current progress in developing key technologies for TianQin project

Monday, 17 May 2021 08:40 (20 minutes)

The TianQin project was initiated in 2014. The goal is to launch the space-based gravitational-wave observatory around 2035 and to detect GWs in the frequency range 10-4~1 Hz. TianQin consists of three satellites on nearly identical geocentric orbits with radii of the order 105 km, forming a normal triangle constellation. In order to achieve the scientific goals, the nongravitational disturbance on the test masses must be reduced to the order of 10-15 m/s2/Hz1/2, and the noise of the displacement measurement with laser interferometry must be reduced to the order of 1 pm/Hz1/2. In this talk, we present the current progress of the TianQin project, including updated results of the laser ranging experiment in Zhuhai and the experimental results of TianQin-1 technology demonstration satellite.

Primary author: YEH, Hsien-Chi (Sun Yat-sen University)

Presenter: YEH, Hsien-Chi (Sun Yat-sen University)

Session Classification: Recorded talks: Space missions

Track Classification: Next detectors: Space missions

Contribution ID: **116** Type: **talk**

PhaseTrace – Towards a user friendly scattered light simulation

Tuesday, 18 May 2021 00:00 (15 minutes)

The problem of back-scattered light is a major issue at low frequencies and must be tackled to make ET sensitive down to 2 Hz. Back-scatter arises as DC light, either by well-defined light paths due to the design of the optics, by diffraction of the tails of these light paths or imperfect surfaces of the test masses. Diverted out of the main modes and scattered back by modulated surfaces, it can re-couple and be detected as light- or phase noise. Mitigating this noise requires suppression of the primary scattering and/or the back scatter mostly by well-designed baffle plates. Although, many effects can be calculated analytically, a detailed simulation is necessary to take all effects properly into account, for example, to avoid that the new baffle plates introduce noise themselves. Currently, there is no free simulation tool available based on modern technologies that offers a simple user-interface allowing application by a variety of end users. PhaseTrace is a design study for such an implementation, which focuses on performance and a broad user interface (C++, ROOT, Python, GUI).

Primary authors: BRETZ, Thomas (RWTH Aachen University); MAROZAVA, Hanna

Presenter: BRETZ, Thomas (RWTH Aachen University)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **117** Type: **talk**

Summary of Stray Light Mitigation Strategies at 2G interferometers

Monday, 17 May 2021 23:00 (15 minutes)

In this talk we present a summary of the mitigation strategies followed up in the current LIGO/Virgo experimental setups, together with the related studies carried out to determine the residual noise budget, potentially affecting the GW signals. We conclude with some indications of potential improvements in preparation for 3rd generation experiments.

Primary author: MARTINEZ PEREZ, MARIO (ICREA/IFAE-Barcelona)

Presenter: MARTINEZ PEREZ, MARIO (ICREA/IFAE-Barcelona)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **118** Type: **talk**

Virgo post-O5 plans

Monday, 17 May 2021 10:00 (20 minutes)

During last spring the Virgo Collaboration began an effort to define the scientific program in the decade ~ 2026-2036, which corresponds to the period between the end of the O5 data taking and a possible first Einstein Telescope data taking. This work encompasses two axes, developed in parallel: identifying the major science questions to which Virgo - in the framework of the LVK network - can contribute, and identifying what detector improvements are possible in this timeframe. Three main scenarios are considered: the first is a "minimal"one, in which the technologies used for O5 are slightly improved with a modest investment. The second is a "moderate"scenario, in which some major components of the instrument are changed (e.g. mirrors) or/and considerably improved, with an investment similar to Advanced Virgo and Advanced Virgo+. In the third scenario, the most ambitious one, completely new technologies are introduced, with a much large investment. The purpose of this talk, after recalling the working framework of the "Virgo post-O5 committee", is to present our initial considerations and ideas about science, technology and relations with 3G detectors, and –if possible –stimulate a discussion in the GW Community.

Primary author: BARSUGLIA, Matteo (APC-CNRS)

Co-authors: PALOMBA, Cristiano; MILOTTI, Edoardo; TOURNEFIER, Edwige; GEMME, Gianluca; CARPINELLI, Massimo; PUPPO, Paola; NISSANKE, Samaya; HILD, Stefan; REGIMBAU, Tania; DAL CANTON, Tito; FAFONE, Viviana; CHAIBI, Walid

Presenter: BARSUGLIA, Matteo (APC-CNRS)

Session Classification: Recorded talks: Beyond Current Detectors

Track Classification: Advanced detectors: Beyond second generation

Contribution ID: **119** Type: **poster**

Geophysical imaging and characterization to study the implementation of the Einstein Telescope infrastructure

Thursday, 20 May 2021 16:01 (1 minute)

The Einstein Telescope (ET) is a third generation gravitational wave observatory, currently in the planning stage in Europe. The ET project involves the construction of a triangular shape underground facility with 10 kilometres long arms buried in ca. 250 m depth. At the corner points, large caverns host the required infrastructure. The border region between the Netherlands, Belgium and Germany is considered a potential location and is investigated in a multidisciplinary feasibility study, E-TEST, funded by the EU and various authorities of the involved countries.

E-TEST aims to construct geological, hydrogeological and geotechnical models of the potential ET area. Subsurface data are crucial to develop these models. Several geophysical methods allow to collect these data from various depth ranges in different resolutions. Planned geophysical surveys are (I) ERT / IP measurements and (II) active seismic surveys using a sledge hammer to map the shallow subsurface, (III) active seismic surveys using vibro-seis trucks and (IV) passive seismic surveys using naturally occurring seismicity to image the shallow and deep subsurface. 5 dry boreholes hosting seismometers will be drilled. Geophysical logging of these boreholes will take place prior to installation. The combination of all these geophysical data acts as a solid base for the subsurface models of the E-TEST area. The presentation at GWADW2021 provides an insight on the geophysical surveys conducted in the E-TEST project.

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Presenter: WALDVOGEL, Marius (Geological Institute, RWTH Aachen University)

Session Classification: Poster session 2

Track Classification: Next detectors: Third generation infrastructures

Contribution ID: **120** Type: **talk**

SiN films: characterization workflow and examples from analysis

Monday, 17 May 2021 23:40 (15 minutes)

SiN has emerged as one of the most promising materials for the next-generation optical coatings in the mirrors of GW detectors. Optical absorption is currently one of the most critical parameters affecting the performances of SiN films, as a very low absorption is required for GW applications; optical absorption may arise from a variety of causes, including non-ideal stoichiometry and contaminants, which in turn are determined by the fabrication process of the films. In order to tackle the issue of optical absorption in SiN films, a significant effort has been undertaken within the Virgo Coating R&D Collaboration (VCRED), and multi-technique characterization is ongoing to provide information so that the causes of optical absorption are identified and, where possible, minimized during the fabrication of SiN films at LMA.
This talk will provide an overview of the SiN films produced by LMA and characterized within VCRED; a few examples from the ongoing analysis will be presented, in order to clarify the key parameters that affect the performance of SiN films for GW applications.

Primary author: MAGNOZZI, Michele (Istituto Nazionale di Fisica Nucleare)

Presenter: MAGNOZZI, Michele (Istituto Nazionale di Fisica Nucleare)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **121** Type: **talk**

Post-O5 planning for LIGO

Monday, 17 May 2021 10:00 (20 minutes)

The LSC has formed a working group to study scenarios for upgrading the LIGO detectors in the 2025-2035 timeframe. While the work of this group has not yet started in earnest, I will introduce the subject and make an invitation for people to give input on this topic at this workshop.

Primary author: FRITSCHEL, Peter (M.I.T.)

Presenter: FRITSCHEL, Peter (M.I.T.)

Session Classification: Recorded talks: Beyond Current Detectors

Track Classification: Advanced detectors: Beyond second generation

Contribution ID: **122** Type: **talk**

SAR-GRAV underground laboratory (Sardinia): engineering challenges and key solutions.

Monday, 17 May 2021 13:20 (20 minutes)

The SAR-GRAV underground laboratory is located in SOS-ENATTOS mine area (Lula Mining District, Sardinia) and was designed to host small-to-medium-sized experiments, intended as individual experiments of fundamental physics and geophysics, and prototypes of equipment for larger experiments, such as future gravitational wave detectors. The laboratory, which will host the ARCHIMEDE experiment funded by INFN in the first instance, considered a seed for the design the larger infrastructure dedicated to the Einstein Telescope.
The key components of the laboratory area a surface building which currently hosts the first phase of the Archimede experiment and in the future will host the control room and auxiliary laboratory areas and an underground cavern located at about 200 m below the ground level, which will host the liquid nitrogen cryostat and a white room for laser applications. Two access ramps will connect the lab to the existing Sos-Enattos mine tunnels and a service shaft will connect the laboratory with the surface for ventilation and the passage of the installations.
The talk focuses on the main engineering challenges and key solutions that led to the preparation of the feasibility study to design the underground facility which included first mapping and surveying and geological and geotechnical characterization, etc.) and then technical, economic, safety and environmental aspects to setup the feasibility study for the laboratory.

Primary authors: ROSSINI, Claudio (Sapienza DICEZ); Prof. MARSELLA, Maria (Sapienza University, Rome); MAJORANA, E; CARPINELLI, M; CUCCURU, S; D'URSO, D; OGGIANO, G; CALLONI, E; RICCI, F; RAPAGNANI, P; PUPPO, P; PERCIBALLI, M; NATICCHIONI, L; NAPOLEONI, Q; ROTONDA, T; CELAURO, A; DARANNO, P.J.V.; DI GIULIO , A; ROSSINI, C; ROSSI, C; PALENZUELA BAENA, F., J. A.; PAOLI, A; PAOLI, L; FABOZZI, C; LODDO, G; PUNTURO, M; PUNTURO, G

Presenter: ROSSINI, Claudio (Sapienza DICEZ)

Session Classification: Recorded talks: Third Generation Infrastructures

Track Classification: Next detectors: Third generation infrastructures

Contribution ID: **123** Type: **talk**

Feasibility Project On the construction of the underground infrastructure for the Einstein Telescope (ET) Project -Sardinia

Monday, 17 May 2021 13:00 (20 minutes)

An overall feasibility study is carried out in Sardinia as one of potential site for the construction of the Einstein Telescope (ET), a third-generation gravitational wave underground observatory.
In order to optimize the location of the corner points of the tunnels hosting the interferometer a technical feasibility study is performed, also including cost-benefit analyses.
A 3D modeling of the ground and infrastructures represents the starting point for identifying the optimal location of the infrastructure. The design study is based on simultaneous evaluation of multiple environmental, geological and geotechnical aspects having the goal of minimize anthropogenic noises by reducing the distance from possible sources, optimize the surface facilities location and accessibility, guarantee the required rock coverage and define a proper the groundwater drainage system. In addition, a Geodetic Control Network for accurate positioning and deformation monitoring will be established.
In order to carry out a multi-criteria analysis a geo-database and GIS platform has been developed and will be continuously updated and integrated. The analysis of civil works on the surface and underground is supported by the integration with BIM models.
To enforce the capability of evaluating different geometric configurations a multiple criteria decision-making tool will be implemented to achieve that all the relevant quantitative limiting factors are compliant with scientific requirements.

Primary authors: MARSELLA, Maria (Sapienza University, Rome); PUNTURO, M; NAPOLEONI, Q; ROSSINI, C; ROSSI, F; CELAURO, A; DARANNO, P.J.V.; PALENZUELA BAENA, J; ALVIANI, E; PAOLI, A; PAOLI, L; CALLONI, E; SCHILLACI, G; CITTADINO, D; WAHBEH, Wissam; SCARPA, R; D'URSO, D; OGGIANO, G

Presenter: MARSELLA, Maria (Sapienza University, Rome)

Session Classification: Recorded talks: Third Generation Infrastructures

Track Classification: Next detectors: Third generation infrastructures

Contribution ID: **124** Type: **poster**

Actuation time optimization in the Advanced Virgo mirror thermo-elastic correction

Thursday, 20 May 2021 16:00 (1 minute)

Heating elements surrounding the core optics of Gravitational Wave Interferometer are used to correct the radius of curvature of the high reflectivity surface that can deviate from the nominal value because of manufacturing defects and the non-zero absorption of the laser power in the substrate and in the coatings of the test masses. The typical actuation time of these actuators (usually referred to as ring heaters) requires about 10 hours to reach the steady state; this long transient makes a significant impact on the commissioning time of the interferometer.
In this work a new strategy aiming at the reduction of the actuation time of the ring heaters is exposed together with the experimental results of the tests performed on the TeTis facility in the Virgo laboratory of Rome Tor Vergata.
By applying a time varying voltage on the ring heater, the steady state can be reached in less than an hour.

Primary authors: ROCCHI, Alessio (ROMA2); TARANTO, Claudia (INFN Roma2); LUMACA, Diana (R); CESARINI, Elisabetta (ROMA2); PORCELLI, Enrico (University of Roma Tor Vergata); NARDECCHIA, Ilaria (ROMA2); CIFALDI, Maria (Istituto Nazionale di Fisica Nucleare); LORENZINI, Matteo (GSSI); FAFONE, Viviana (ROMA2); MINENKOV, Yury (ROMA2)

Presenter: PORCELLI, Enrico (University of Roma Tor Vergata)

Session Classification: Poster session 2

Track Classification: Advanced detectors: Experience from current detectors

Contribution ID: **125** Type: **talk**

Light scattering noise in Cosmic Explorer

Wednesday, 19 May 2021 07:15 (15 minutes)

Noise from laser backscattering and spurious beam couplings has been an important limitation in first and second generation detectors. In this talk we discuss the on-going design and experimental work for Cosmic Explorer, focusing on the modeling of light scattered by the mirror surface roughness, point defects and noise due to light scattered and diffracted/clipped by the arm cavity baffles.

Primary authors: VAJENTE, Gabriele (Caltech); SMITH, Joshua (California State University Fullerton)

Presenters: VAJENTE, Gabriele (Caltech); SMITH, Joshua (California State University Fullerton)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **126** Type: **talk**

Stray light in the LISA mission: perturbation of an interferometer readout due to back-scattering from an optics and from the backlink optical fibre

Wednesday, 19 May 2021 06:15 (15 minutes)

LISA is a constellation of three spacecraft exchanging laser beams on a 2.5 Mkm triangle. The GW measurement exploits heterodyne interferometric phase measurements of the distance between distant optical benches, with additional interferometers measuring the test mass to optical bench movement, and the optical phase difference of the two lasers onboard the same spacecraft. Stray light (SL) can affect the operations in various ways, but the most obvious perturbation comes from coherent SL being recoupled into one of the interferometers.

We present activities aiming at
- characterizing the re-coupling of SL scattered from a mirror, back into a Michelson interferometer where a collimated beam hits the mirror under test. Back-scatter (BS) from the mirror is measured down to 10^-13 in power
- providing a simple and approximate, yet analytic method to estimate the fraction of BS recoupled into an interferometer: when a complex optics, such as a telescope, is involved, considering only BS rays in the solid angle corresponding to an overlap with the beam waist provides a reasonably precise value of coupled SL
- measuring Rayleigh BS from the "back-link" optical fibre. The back-link allows to prepare the beating of one laser with the other laser on the same spacecraft. We use a heterodyne Mach-Zehnder interferometer to measure BS power in the ppm-level. We also characterize the fibers' reaction to stress and ionizing radiation. Mitigation strategies are presented.

Primary authors: ROHR, Johann Max (Albert Einstein Institute Hannover (Germany)); AST, Stefan (Albert-Einstein-Institute Hannover); GERBERDING, Oliver (Albert-Einstein-Institute Hannover (*)); REICHE, Jens (Albert-Einstein-Institute Hannover); HEINZEL, Gerhard (AEI Max-Planck Institut); KHODNEVYCH, Vitalii (Laboratoire ARTEMIS); NARDELLO, Marco (Laboratoire ARTEMIS); LINTZ, Michel (Laboratoire ARTEMIS, OCA, CNRS)

Presenters: ROHR, Johann Max (Albert Einstein Institute Hannover (Germany)); LINTZ, Michel (Laboratoire ARTEMIS, OCA, CNRS)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **127** Type: **talk**

Stray light from dust in Virgo

Tuesday, 18 May 2021 00:15 (15 minutes)

Surface roughness of optics and dust contamination are two main sources of stray light in advanced GW detectors: stray light can not only contribute extra noise if it recouples to the main beam when reflected by vibrating surfaces, but can also spoil the control signals of the interferometer.
Given the extremely low roughness of the optics employed, dust contamination is critical as it can easily become the leading contributor to scattered light even in the clean environment of Virgo. Predicting dust contamination on the optics' surface based on environmental measurements with commercial particle counters is however very difficult and prone to big uncertainties. Instead, we monitor dust contamination in Advanced Virgo directly: we use silicon wafers as dust witness samples by placing them on the different optical benches and exposing them to the same local environment and activities as the optics we want to monitor. We use a photographic setup to take pictures of the exposed samples and thereby determine the amount of deposited dust as well as its distribution as function of particle diameter: these values serve as input for inferring the BSDF of the polluted optics and hence the amount of produced stray light. We report about the results obtained for the Quantum Noise Reduction subsystem of Advanced Virgo.

Primary author: D'ANGELO, Beatrice (Istituto Nazionale di Fisica Nucleare)

Co-authors: SORRENTINO, Fiodor (GE); CONTI, Livia (PD); CIANI, Giacomo (PD)

Presenter: D'ANGELO, Beatrice (Istituto Nazionale di Fisica Nucleare)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **128** Type: **talk**

Introducing Balanced Homodyne Detection for the O5-run of LIGO

Wednesday, 19 May 2021 07:30 (15 minutes)

For the O5 run of LIGO, it is planned to make a change to the detection scheme, operating with balanced homodyne detection. This involves the introduction of a local oscillator beam derived from the power recycling cavity, to be re-combined with the signal beam from the interferometer in the detection chamber. The layout of the detection chamber has been re-designed to accommodate dual output mode-cleaners and automated wave-front control. We will present Zemax models of both the interferometer and detection chamber and will discuss the challenges presented with the inclusion of new elements.

Primary authors: WEBSTER, Stephen (University of Glasgow); Dr BARTON, Mark (University of Glasgow); Mr BRIGGS, Joseph (University of Glasgow); Mr JONES, Russell; Dr OELKER, Eric (University of Glasgow); Prof. STRAIN, Ken (University of Glasgow)

Presenter: WEBSTER, Stephen (University of Glasgow)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **129** Type: **talk**

Injection and control of Frequency Dependent Squeezing in Advance Virgo Plus (invited)

Tuesday, 18 May 2021 23:20 (20 minutes)

The injection of phase-squeezed vacuum states, in ground based gravitational wave detectors, already demonstrated its efficiency during the last observative run by reducing quantum noise of about 3 dB, above 100 Hz. At this stage, the consequent increase of quantum noise below this frequency, due to the anti-squeezed amplitude quadrature, did not affect the detector sensitivity, being this covered by technical noises.
In view of the next observative run, these noises will be drastically reduced. One of the challenge to face, in order to fullfill the new sensitivity requirents, is a broad-band quantum noise reduction. The adopted strategy is to use frequency dependent squeezing technique, based on filter cavity.
In this talk, the conceptual design, the adopted control strategy and the status of the installation of this technique for Advanced Virgo Plus will be presented.

Primary authors: Dr SEQUINO, Valeria (Università degli Studi di Napoli "Federico II" and INFN sez. Napoli); Dr VARDARO, Marco (Institute for High-Energy Physics, University of Amsterdam and NikHef)

Presenters: Dr SEQUINO, Valeria (Università degli Studi di Napoli "Federico II" and INFN sez. Napoli); Dr VARDARO, Marco (Institute for High-Energy Physics, University of Amsterdam and NikHef)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **130** Type: **talk**

Listening to the Universe with Next Generation Ground-Based Gravitational-Wave Detectors

Monday, 17 May 2021 09:00 (20 minutes)

Upgrades in instrumentation and technology over the next five to ten years will enable the LIGO and Virgo detectors to explore gravitational-wave sources with higher fidelity and the potential to make phenomenal new discoveries. To realize its full potential gravitational-wave astronomy would require the construction of new facilities that can host increasingly improved instrumentation for a period of ~ 50 years. In this study, we use simple performance metrics to assess the science capabilities of planned and future networks. These metrics all refer to coalescences of binary neutron stars and black holes and include: (i) network detection efficiency and detection rate of cosmological sources and their number densities as a function of redshift, (ii) signal-to-noise ratios and the accuracy with which intrinsic and extrinsic parameters would be measured, and (iii) enabling multimessenger astronomy with gravitational waves by accurate 3D localization and early warning alerts. We will in addition discuss the science enabled by the small population of loud and rare events. While imminent upgrades will provide impressive advances in all these metrics, future observatories of Cosmic Explorer and Einstein Telescope, currently being planned, will realize the full potential of gravitational-wave astronomy over the next two to three decades and observe coalescing compact binaries from epochs before the formation of first stars, should they exist.

Primary authors: BORHANIAN, Ssohrab (Penn State); Prof. SATHYAPRAKASH, B. (Penn State)

Presenter: BORHANIAN, Ssohrab (Penn State)

Session Classification: Recorded talks: Third Generation Design

Track Classification: Next detectors: Third generation design

Contribution ID: **131** Type: **talk**

Binary neutron star mergers

Monday, 17 May 2021 06:00 (30 minutes)

What is the nature of neutron stars? Where are r-process elements formed in the Universe? Multimessenger observations of neutron star mergers might provide us with the key to answer these and other important open questions in theoretical astrophysics. In this talk, I will review our current theoretical understanding of how neutron star mergers proceed and of how the dynamics is imprinted in their multimessenger emissions. I will present recent simulation results and discuss their implications. Finally, I will talk about future challenges and prospective for this field.

Primary author: RADICE, David (The Pennsylvania State University)

Presenter: RADICE, David (The Pennsylvania State University)

Session Classification: Recorded talks: Multimessenger Astronomy

Track Classification: Physics: Multimessenger perspective

Contribution ID: **132** Type: **talk**

White Light Signal Enhancement

Thursday, 20 May 2021 06:40 (15 minutes)

White light signal enhancement using an optomechanical negative dispersion systems show promise to dramatically increase the sensitivity bandwidth of gravitational wave detectors. At the University of Western Australia three promising mechanical resonators are being designed and investigated. Demonstrated properties of a phononic metamaterial device have been shown in simulation to increase detector bandwidth by a factor of ~10. Applied to 4km detector such a technology would allow sensitivity at the frequencies where binary neutron star signals will reveal the nature of dense nuclear matter right before it collapses into a black hole. This presentation is a summary of work at UWA to develop the white light signal enhancement technology.

Primary author: BLAIR, Carl (University of Western Australia)

Presenter: BLAIR, Carl (University of Western Australia)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **134** Type: **talk**

Cryogenics and water migration in ET pathfinder

Tuesday, 18 May 2021 08:00 (20 minutes)

Placeholder

Primary author: BULTEN, Henk (Vrije Universiteit Amsterdam/Nikhef)

Presenter: BULTEN, Henk (Vrije Universiteit Amsterdam/Nikhef)

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **135** Type: **talk**

Sorption-based vibration-free cryogenic cooling for ET and ETPathFinder

Thursday, 20 May 2021 00:40 (20 minutes)

One of the key enabling technologies in the third generation laser-interferometer GW detectors is the cryogenic system required for cooling the main optics to 10 –20K. Accounting for the extreme sensitivity that is targeted, it is of paramount importance that the cryogenic cooling under continuous operation is essentially vibration free. Joule-Thomson cryocoolers using sorption compressors are known to generate an absolute minimum of vibrational noise. Based on the heritage acquired in projects for ESA and E-ELT, the University of Twente has proposed a modular cryochain design comprising of sorption compressors and JT cold stages. In the workshop presentation, the basic operation of the cooler is discussed plus the conceptual design of the cooler chain for ETPF.

Primary author: TER BRAKE, Marcel (University of Twente)

Presenters: TER BRAKE, Marcel (University of Twente); XHAHI, Arvi; HOLLAND, Harry

Session Classification: Cryogenics workshop

Track Classification: Workshops: Cryogenics workshop

Contribution ID: **136** Type: **talk**

NEMO, the concept of a high frequency gravitational wave detector

Monday, 17 May 2021 08:40 (20 minutes)

Abstract:
GW170817 was a golden event for multi-messenger astronomy made possible by gravitational wave detection. This this event allowed us to gleam an insight into short gamma-ray bursts, neutron star mergers, jet formation and topology, r-process nucleosynthesis but information about the merger and post-merger phases of the system are still unbeknown to us. A gravitational wave detector engineered to focus on signal frequencies between 0.9 –3 kHz would allow us to probe the exotic nuclear physics in the cores of neutron stars in a regime not accessible with the current terrestrial experiments. The Australian gravitational wave detector concept, NEMO [1] builds on a 4 km long dual recycled Fabry-Perot Michelson design with additional upgrades in terms of Silicon test masses, cryogenic suspensions, long signal recycling cavities to allow for a strain sensitivity comparable to 3G detectors in the frequency band of 0.9 –3 kHz. In this talk, we also discuss some of the preliminary results pertaining to tunability of the NEMO detector using a variable reflectivity signal recycling mirror [2].
References :
[1] Ackley, K., Adya, V., Agrawal, P., Altin, P., Ashton, G., Bailes, M., . . . Zhu, X. (2020). Neutron Star Extreme Matter Observatory: A kilohertz-band gravitational-wave detector in the global network. *Publications of the Astronomical Society of Australia*, 37, E047. doi:10.1017/pasa.2020.39
[2] Glenn de Vine et al 2002 Class. Quantum Grav. **19** 1561

Primary author: ADYA, Vaishali (Australian National University)

Presenter: ADYA, Vaishali (Australian National University)

Session Classification: Recorded talks: Third Generation Design

Track Classification: Next detectors: Third generation design

Contribution ID: **137** Type: **talk**

Low-Frequency Noise in ET, How can we improve by a factor of a million at 3 Hz?

Wednesday, 19 May 2021 23:00 (20 minutes)

The science goals of ET rely on achieving astrophysically interesting sensitivity below 5Hz. This presents an enormous technical challenge, and it was a major focus of the recent ET Instrument Science Board workshop. The question is broken down into several parts: we looked at the key noise-drivers in current detectors and attempt to identify strategies to mitigate them by design in ET. This summary of the workshop will identify some interesting points and unanswered questions.

Primary authors: DOOLEY, Katherine (Cardiff University); MOW-LOWRY, Conor (University of Birmingham)

Presenters: DOOLEY, Katherine (Cardiff University); MOW-LOWRY, Conor (University of Birmingham)

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **138** Type: **talk**

The Science Case for the Einstein Telescope

Monday, 17 May 2021 06:00 (20 minutes)

I will give a broad overview of the scientific targets of the Einstein Telescope in astrophysics, cosmology, and fundamental physics.

Primary author: MAGGIORE, Michele (Geneva University)

Presenter: MAGGIORE, Michele (Geneva University)

Session Classification: Recorded talks: GW Physics

Track Classification: Physics: Gravitational wave perspective

Contribution ID: **139** Type: **talk**

Cosmic Explorer: Status and Plans

Monday, 17 May 2021 08:20 (20 minutes)

Joshua Smith and the Cosmic Explorer Team

We present an overview of the status of and plans for Cosmic Explorer (CE), the U.S. contribution to the third-generation gravitational-wave detector network. CE will observe gravitational-wave sources across the history of the universe. Sources that are barely detectable by today's instruments will be resolved with incredible precision. Considerations such as the number and location of the detectors and the technology choices are discussed along with a roadmap for funding and construction CE.

Primary author: SMITH, Joshua (California State University Fullerton)

Presenter: SMITH, Joshua (California State University Fullerton)

Session Classification: Recorded talks: Third Generation Design

Track Classification: Next detectors: Third generation design

Contribution ID: **140** Type: **talk**

Ranking the Love for the neutron star equation of state with third-generation detectors

Monday, 17 May 2021 06:55 (15 minutes)

Gravitational wave measurements of the tidal deformability
in neutron-star binary coalescences are golden sources to infer properties of the still unknown equation of state (EoS) of dense matter above
the nuclear saturation density. In this talk I will show how, using a
Bayesian-ranking test we can quantify the ability of current and future gravitational-wave observations to discriminate among families of realistic EoS which differ in particle content and ab-initio microscopic calculations.

Building on the lesson taught from GW170817, I will discuss the improvements on
the EOS constraints from single and stacked detections by interferometers at design sensitivity. Morevoer, I will show that even just a single detection with a third-generation detector such as the Einstein Telescope or Cosmic Explorer will rule out several families of EoS with very strong statistical significance, and can discriminate among models which feature similar properties, hence constraining the properties of nuclear matter to unprecedented levels.

Primary authors: MASELLI, Andrea (Sapienza University of Rome); Dr PACILIO, Costantino (Sapienza University of Rome); Prof. PANI, Paolo (Sapienza University of Rome); Dr FASANO, Margherita (Sapienza University of Rome)

Presenter: MASELLI, Andrea (Sapienza University of Rome)

Session Classification: Recorded talks: GW Physics

Track Classification: Physics: Gravitational wave perspective

Contribution ID: **144** Type: **not specified**

Coating choice for O5: Discussion

Tuesday, 18 May 2021 00:30 (30 minutes)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **145** Type: **talk**

Coating choice for O5: Summay

Wednesday, 19 May 2021 06:00 (15 minutes)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **146** Type: **not specified**

Coating choice for O5: Discussion

Wednesday, 19 May 2021 06:15 (30 minutes)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **149** Type: **talk**

Mariner: LIGO Voyager Prototype at the Caltech 40 m Lab

Monday, 17 May 2021 12:30 (10 minutes)

The LIGO Voyager upgrade is designed to maximize the reach of the existing observatory facilities, with radiatively-cooled silicon optics and coatings that enable high-power cryogenic interferometry. I will discuss the ongoing project to realize this design at the 40 m Lab.

Primary author: Dr WIPF, Christopher (Caltech LIGO)

Presenter: Dr WIPF, Christopher (Caltech LIGO)

Session Classification: Recorded talks: Third Generation R&D Facilities

Track Classification: Next detectors: R&D facilities and plans

Contribution ID: **150** Type: **talk**

Next generation gravitational wave detector research at the ANU

Monday, 17 May 2021 12:40 (10 minutes)

Using the optical coating facility at the ANU we will concentrate towards low-loss optical coatings for large scale optics used in gravitational wave detectors. The work is focused on the near-term needs and long-term requirements, either for 1 um or 2 um optical wavelengths. Also work on 2 um optical squeezing generation and its control is underway. A low-frequency gravitational-force sensor is under construction to investigate seismic and atmospheric Newtonian noise sources, while a cryogenic environment is under construction for measuring broadband thermal noise at cryogenic temperatures in silicon flexures.

Primary author: SLAGMOLEN, Bram (The Australian National University)

Presenter: SLAGMOLEN, Bram (The Australian National University)

Session Classification: Recorded talks: Third Generation R&D Facilities

Track Classification: Next detectors: R&D facilities and plans

Contribution ID: **151** Type: **talk**

Glasgow 10m facility

Monday, 17 May 2021 12:50 (10 minutes)

In this talk we present the plans in Glasgow to upgrade or 10m interferometer into a cryogenic facility. The facility will utilise a single 10m reference cavity based on suspended fused silica optics, and a pair of Leidon cryocoolers for a short cryogenic reference cavity. The facility is aimed to be a fast turnaround system with studies focussing on ice growth on optics, monitoring cryogenic violin mode ringdowns and characterising fundamental noise sources in silicon test masses, monolithic silicon suspensions, and cryogenic coatings.

Primary author: HAMMOND, Giles (University of Glasgow)

Presenter: HAMMOND, Giles (University of Glasgow)

Session Classification: Recorded talks: Third Generation R&D Facilities

Track Classification: Next detectors: R&D facilities and plans

Contribution ID: **152** Type: **talk**

Status of R&D activity on IBS SiNx coatings (Invited)

Tuesday, 18 May 2021 00:00 (15 minutes)

Silicon nitride (SiNx) is a well-known coating material, with a relatively high refractive index and very low mechanical loss. In this talk, we will present the development history of ion-beam sputtered amorphous SiNx coatings for gravitational-wave detectors at the Laboratoire des Matériaux Avancés (LMA-IP2I). As this research and development activity is still ongoing to date, we will present our most recent results and discuss the final steps of our roadmap towards the production of SiNx coatings of extremely low optical (scatter, absorption) and mechanical loss.

Primary author: GRANATA, Massimo (Laboratoire des Matériaux Avancés - CNRS)

Presenter: GRANATA, Massimo (Laboratoire des Matériaux Avancés - CNRS)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **153** Type: **talk**

Status of R&D activity on IBS TiO2:GeO2 coatings (Invited)

Tuesday, 18 May 2021 00:15 (15 minutes)

Brownian noise in the current second generator detectors is limited by the internal mechanical energy dissipation of the high index material composing the dielectric reflector stack. One promising alternative to the currently used titania-doped tantala is a mixture of titania and germania. We report here the status of the research on this new material, estimates of the achievable improvements of Brownian noise, and the future work.

Primary author: VAJENTE, Gabriele (Caltech)

Presenter: VAJENTE, Gabriele (Caltech)

Session Classification: Coating thermal noise Workshop

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **154** Type: **talk**

Virgo Coatings Development in the Post-O5 timeline

Monday, 17 May 2021 10:20 (20 minutes)

The R&D activities on the A+ coatings are close to end. The coating recipe has to be confirmed in about 2 months and then it will be the time to optimize the coating deposition on full scale substrates. The legacy of this R&D period is full of new insights about the origin of thermal noise in coatings, less numerous are the insights on the origin of absorption in amorphous materials, but, anyway, the products of this new understanding are yet to come. R&D on coatings is all but over. New amorphous materials are becoming highly competitive with the crystalline ones, on the other hand growth technology and coating transfer for crystalline coatings are becoming competitive with the advanced status of amorphous coating technology. Time has come to make new planning for the coating R&D, compatibly with the Post-O5 timeline. The talk is focused on the Virgo point of view on how to upgrade the AdV+ coatings and how to prepare the road for ET

Primary author: CAGNOLI, Gianpietro (ILM-UCBL)

Presenter: CAGNOLI, Gianpietro (ILM-UCBL)

Session Classification: Recorded talks: Beyond Current Detectors

Track Classification: Advanced detectors: Beyond second generation

Contribution ID: **155** Type: **talk**

Room Temperature Post O5 Coating Design

Placeholder

Primary author: PENN, Steven (LSC - Hobart and William Smith Colleges)

Presenter: PENN, Steven (LSC - Hobart and William Smith Colleges)

Session Classification: Recorded talks: Beyond Current Detectors

Track Classification: Advanced detectors: Beyond second generation

Contribution ID: **156** Type: **poster**

Lockloss prediction for diagnostics and early intervention

Wednesday, 19 May 2021 16:23 (1 minute)

Ground-based interferometric gravitational wave detectors at LIGO are complex instruments that need to be in light resonance or 'locked' in order to take data and make astronomical observations. The 'lock' is maintained by a series of control loops which can be disturbed by systematic or environmental factors. Multiple detectors need to be simultaneously in lock to triangulate the sky location of a source and reacquiring a lost lock is time consuming. Since LIGO has a network of sensors deployed to monitor the instrument and its environment, it is worthwhile to study LIGO's 'lockloss' events and potentially build a data-driven, predictive model using machine learning to find lockloss witnesses which can aid in diagnostics and early intervention. In this work, we use an unsupervised anomaly detection technique called Isolation Forest to investigate whether data from a subset of length and angular degrees of freedom channels is an outlier prior to lockloss events compared to locked time data. The ultimate goal is to find witnesses to the lockloss events that help LIGO instrument experts to diagnose the causes of lockloss events and potentially mitigate them to improve the detector duty cycle and enable multi-messenger astronomy.

Primary author: GURAV, Rutuja (University of California Riverside)

Presenter: GURAV, Rutuja (University of California Riverside)

Session Classification: Poster session 1

Track Classification: Workshops: Controls and machine learning workshop

Contribution ID: **157** Type: **talk**

Site-selection for next generation surface detectors

Monday, 17 May 2021 12:40 (20 minutes)

Next generation surface-based gravitational wave detectors will have increased arm-length of up to 40 km. Due to the earth's curvature 30 m deep trenches or tunnels are required for a straight laser beam to reach the end-stations. Locations with minimal soil digging and filling could help reduce the construction cost. We use digital elevation data to find such optimal locations, in the USA, Canada and Australia for 20 km and 40 km long detectors. However, several physical and human geographical aspects have to be considered (e.g., geology, occupation of the land, local indigenous custodians and values, remoteness, etc) for the selection of a viable location.

Primary author: SLAGMOLEN, Bram (The Australian National University)

Presenter: SLAGMOLEN, Bram (The Australian National University)

Session Classification: Recorded talks: Third Generation Infrastructures

Track Classification: Next detectors: Third generation infrastructures

Contribution ID: **158** Type: **talk**

KAGRA+, next step for KAGRA

Monday, 17 May 2021 10:40 (20 minutes)

One of the keys of interferometric gravitational wave detector projects is to make improvement plan for future. In KAGRA collaborations, we discuss the plan of KAGRA+, which is the next step. The white paper was released on August 2019, just after the previous GWADW. I explain the history and conclusion of this white paper briefly.

Primary author: YAMAMOTO, Kazuhiro (Faculty of Science, University of Toyama)

Presenter: YAMAMOTO, Kazuhiro (Faculty of Science, University of Toyama)

Session Classification: Recorded talks: Beyond Current Detectors

Track Classification: Advanced detectors: Beyond second generation

Contribution ID: **159** Type: **talk**

Progress towards the LISA orbiting observatory for gravitational waves

Monday, 17 May 2021 08:00 (20 minutes)

William Joseph Weber for the LISA Consortium

LISA, the Laser Interferometer Space Antenna, is in preparation to become the ESA Cosmic Vision L3 mission, an orbiting observatory for gravitational waves in the milliHz band with a target launch in 2035. We present here an overview of the LISA measurement concept and baseline hardware, from the heritage of the single-spacecraft LISA Pathfinder flight test to the unique challenges of the full three-spacecraft LISA observatory.

Primary author: WEBER, William (TIFP)

Presenter: WEBER, William (TIFP)

Session Classification: Recorded talks: Space missions

Track Classification: Next detectors: Space missions

Contribution ID: **160** Type: **talk**

Time-delay interferometry for LISA

Monday, 17 May 2021 09:20 (10 minutes)

Olaf Hartwig for the LISA Consortium

The Laser Interferometer Space Antenna (LISA) is a constellation of 3
spacecraft orbiting the sun. They form an almost equilateral triangle with arm lengths of 2.5 million kilometers. These arms can differ in length by up to 25000km, such that a traditional Michelson-like interferometer configuration does not reduce laser noise effectively. Thus, LISA will rely on a post-processing technique called time-delay interferometry (TDI), which combines data streams from different spacecraft to synthesize virtual equal-arm interferometers. We present here an overview of the TDI technique, with particular emphasis on how to include corrections for the three independent spacecraft clocks in constructing the final TDI observable.

Primary author: HARTWIG, Olaf

Presenter: HARTWIG, Olaf

Session Classification: Recorded talks: Space missions

Track Classification: Next detectors: Space missions

Contribution ID: **161** Type: **talk**

Low-frequency ground deformation observed by the geophysics interferometer (GIF) in the KAGRA tunnel

Tuesday, 18 May 2021 07:05 (15 minutes)

A laser strainmeter measures deformation of the ground by sensing distance between two separated points based on the optical interferometer with reference to wavelength of light. To monitor accurate ground deformations and broadband ground motions, a long-baseline laser strainmeter (geophysics interferometer, GIF) was constructed in the KAGRA tunnel and it has been in operation since then.

Primary authors: Prof. ARAYA, Akito (Earthquake Research Institute, the University of Tokyo); Dr TAKAMORI, Akiteru; MIYO, Koseki

Presenter: Prof. ARAYA, Akito (Earthquake Research Institute, the University of Tokyo)

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **162** Type: **talk**

Requirements computation for the Low Frequency third generation gravitational wave detector

Thursday, 20 May 2021 00:10 (20 minutes)

The third generation GW detectors has to provide an unprecedented sensitivity, this requires a careful study on all the intereferometer defects that could spoil its performance. For this reason in order to face this challenge, one of the starting points is to establish the RMS requirements that will allow reaching the target sensitivity. This work is focused on the requirements referring to Longitudinal and Angular controls. The evaluation of the requirement for the sensing and control of the interferometer will lead to set requirements into other areas of the detector as frequency noise, actuation noise, mirror displacement noise, etc.
Here the status of the modeling of the requirements and the foreseen actions will be presented.

Primary author: CASANUEVA DIAZ, Julia (EGO)

Presenter: CASANUEVA DIAZ, Julia (EGO)

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **163** Type: **talk**

Low frequency workshop discussion

Thursday, 20 May 2021 00:30 (30 minutes)

Session Classification: Low frequency workshop

Track Classification: Workshops: Low frequency workshop

Contribution ID: **164** Type: **talk**

On the nature of the remnants in mergers of compact binaries

Monday, 17 May 2021 06:20 (20 minutes)

Observations of binary black holes mergers from the LIGO-Virgo interferometers provide a window to investigate the highly dynamical regime of gravity as well as the nature of astrophysical black holes. The black hole born from the merger of its progenitors emits gravitational waves with a characteristic spectrum, the so-called ringdown, whose direct detection provide informations about the black hole mass, spin and constraints on violations of the predictions of general relativity. In this talk, I will begin by briefly reviewing black hole perturbation theory that stands at the foundation of our understanding of the black hole ringdown. I will then present the current status of the observations and highlight some of the key results in the emerging field of black hole spectroscopy. Finally, I will conclude by discussing some perspectives from future observations.

Primary author: DEL POZZO, Walter (P)

Presenter: DEL POZZO, Walter (P)

Session Classification: Recorded talks: GW Physics

Track Classification: Physics: Gravitational wave perspective

Contribution ID: **165** Type: **talk**

Stray light control upgrades for LIGO 4th Observation run

Wednesday, 19 May 2021 06:30 (15 minutes)

A number of upgrades are planned to be installed for the LIGO 4th observation run, including a new optical path for the frequency dependent squeezer, 300m filter cavity and low loss Fadaray isolators. Any new components added close to the optical path may cause scattered light to propagate toward parts of the vacuum envelope and other components not isolated or less isolated from the environment (such as ground motion or vibration from surrounding equipment). Additionally to that, the allowed stray light threshold lowers as the LIGO detectors become more sensitive with every next run. Therefore, noise coupling due to scatter starts being observed in the areas, which were not causing issues during earlier observation runs. In this work, we will present a summary of stray light baffles currently being installed at LIGO Hanford and LIGO Livingston Observatories for O4 as well as methods and material used for baffles design and fabrication.

Primary author: ANANYEVA, Alena (Caltech)

Presenter: ANANYEVA, Alena (Caltech)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **166** Type: **talk**

Efforts to Mitigate the Effects of Stray Light in the LISA Telescope

Wednesday, 19 May 2021 06:00 (15 minutes)

The Laser Interferometer Space Antenna (LISA) was selected to be the third large mission of the European Space Agency's Cosmic Vision program. LISA, a space-based gravitational wave observatory, will detect gravitational waves in the frequency band extending from 0.1 mHz to 0.1 Hz by measuring picometer-scale length changes along the 2.5 Gm arms of a triangular constellation of satellites. Optical telescopes onboard each spacecraft will simultaneously transmit light to and receive light from the other two spacecraft. Stray light in the LISA telescopes has the potential to be a limiting noise source if not properly accounted for. The following discussion reviews the current state of stray light modeling and plans for mitigating stray light.

Primary author: AUSTIN, Corey (NASA)

Presenter: AUSTIN, Corey (NASA)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **168** Type: **talk**

Searching for Primordial Black Holes: The Role of 3rd Generation Gravitational Wave Detectors

Monday, 17 May 2021 06:40 (15 minutes)

Primordial black holes form in the early universe and can give rise to mergers at high redshift. This distinctive feature can be exploited by 3G detectors to distinguish primordial binaries from the ones generated by other astrophysical formation channels. By considering a primordial black hole population compatible with current gravitational wave data, we show that 3G detectors such as the Einstein Telescope and Cosmic Explorer could observe up to hundreds of mergers from primordial black hole binaries at redshift larger than 30, where there is no astrophysical contamination.

Primary author: FRANCIOLINI, Gabriele (University of Geneva)

Presenter: FRANCIOLINI, Gabriele (University of Geneva)

Session Classification: Recorded talks: GW Physics

Track Classification: Physics: Gravitational wave perspective

Contribution ID: **169** Type: **talk**

Scattered light discussion

Wednesday, 19 May 2021 07:45 (15 minutes)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **170** Type: **talk**

Scattered light discussion

Tuesday, 18 May 2021 00:45 (15 minutes)

Session Classification: Scattered light workshop

Track Classification: Workshops: Scattered light workshop

Contribution ID: **171** Type: **talk**

Impact of calibration uncertainties on cosmological measurements from gravitational wave sources

Monday, 17 May 2021 06:45 (15 minutes)

Calibration is a key step in gravitational wave (GW) analysis converting the photodetector output in the ground-based interferometers to the strain data from which we extract GW signals. In this talk, we present an ongoing study on how calibration errors and uncertainties can affect astrophysical parameter estimation and cosmological measurements. We simulate different types of compact binary coalesces, and add artificial calibration errors motivated by real detector behaviors. We focus on the results on luminosity distance since it is the most important parameter for constraining the Hubble constant. At the single event level, the systematic errors on luminosity distance are smaller than statistical uncertainties, with relative uncertainties of 3% for events with a signal-to-noise ratio of 50. However, the bias may become more significant when we combine multiple events. Thus, we will also simulate a population of 100 binary neutron stars and perform hierarchical Bayesian inference to understand potential biases on the Hubble constant measurement due to calibration errors and uncertainties.

Primary author: HUANG, Yiwen (MIT)

Presenter: HUANG, Yiwen (MIT)

Session Classification: Recorded talks: Multimessenger Astronomy

Track Classification: Physics: Multimessenger perspective

Contribution ID: **172** Type: **poster**

Molecular Dynamics simulations to study dissipation in amorphous SiNx

Thursday, 20 May 2021 16:28 (1 minute)

In interferometric gravitational wave detectors, thermal noise from the mirrors, originating from mechanical dissipation in the coating films, represents the major limitation to sensitivity. 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 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 framework, within this work we numerically study dissipation in amorphous SiNx, which represents a promising candidate as a possible solution for the reduction of mechanical losses in coating films. Following the approach proposed in previous works [1,2], here we apply the experimental protocol of the mechanical spectroscopy to atomistic simulations.

[1] Puosi, Fidecaro, Capaccioli, Pisignano, D. Leporini, Phys. Rev. Research **1** 033121 (2019)
[2] Puosi, Fidecaro, Capaccioli, Pisignano, D. Leporini, Acta Materialia **201** 1 (2020).

Primary authors: PUOSI, Francesco (INFN Pisa); LEPORINI, Dino (University of Pisa); FIDECARO, Francesco (University of Pisa and INFN); PISIGNANO, Dario (University of Pisa); CAPACCIOLI, Simone (University of Pisa)

Presenter: PUOSI, Francesco (INFN Pisa)

Session Classification: Poster session 2

Track Classification: Workshops: Coating thermal noise workshop

Contribution ID: **173** Type: **not specified**

Quantum noise and optical configurations discussion

Wednesday, 19 May 2021 00:20 (40 minutes)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **174** Type: **talk**

Towards broadband quantum noise reduction in GWIs using an atomic noise eater

Thursday, 20 May 2021 07:00 (15 minutes)

Broadband suppression of both shot noise and backaction noise in the GW interferometer can be achieved by adding an auxiliary table-top setup with a room temperature gas cell in magnetic field as the central element [1,2]. The basic idea is the measurement of motion beyond SQL using an atomic spin as a "negative mass oscillator". The idea has been recently experimentally demonstrated for a nanomechanical oscillator by our group [3,4]. We are currently constructing a table-top setup aiming at the proof-of-principle demonstration of applicability of our approach to GWIs.

1. Overcoming the standard quantum limit in gravitational wave detectors using spin systems with a negative effective mass. F. Ya. Khalili and E. S. Polzik, PRL 121, 031101 (2018).
2. Gravitational wave detection beyond the standard quantum limit using a negative-mass spin system and virtual rigidity. E. Zeuthen, E. S. Polzik, F. Ya. Khalili. PRD, 100, 062004 (2019).
3. Quantum back action evading measurement of motion in a negative mass reference frame. C. B. Møller et al. Nature, 547, 191 (2017).
4. Entanglement between Distant Macroscopic Mechanical and Spin Systems. R. A. Thomas et al. Nature Physics 17, 228–233(2021).

Primary authors: POLZIK, Eugene (Niels Bohr Institute, Copenhagen University); BRASIL, T.B.; NOVIKOV, V.A.; JIA, Jun; YDE, R.; ZEUTHEN, E.; KHALILI, Farit (Russian Quantum Center)

Presenter: POLZIK, Eugene (Niels Bohr Institute, Copenhagen University)

Session Classification: Quantum noise and optical configurations workshop

Track Classification: Workshops: Quantum noise and optical configurations workshop

Contribution ID: **175** Type: **not specified**

Summary of Coating thermal noise Workshop

Friday, 21 May 2021 17:40 (20 minutes)

Primary authors: CESARINI, Elisabetta (ROMA2); CAGNOLI, Gianpietro (ILM-UCBL); REID, Stuart (SUPA, University of Strathclyde)

Presenters: CESARINI, Elisabetta (ROMA2); CAGNOLI, Gianpietro (ILM-UCBL); REID, Stuart (SUPA, University of Strathclyde)

Session Classification: Workshop conclusions

Contribution ID: **176** Type: **not specified**

Summary of Scattered light workshop

Friday, 21 May 2021 16:20 (20 minutes)

Primary authors: ANANYEVA, Alena (Caltech); FREISE, Andreas

Presenters: ANANYEVA, Alena (Caltech); FREISE, Andreas

Session Classification: Workshop conclusions

Contribution ID: **177** Type: **not specified**

Summary of Cryogenics workshop

Friday, 21 May 2021 16:40 (20 minutes)

Primary authors: YAMAMOTO, Kazuhiro (Faculty of Science, University of Toyama); PUPPO, Paola (ROMA1)

Presenters: YAMAMOTO, Kazuhiro (Faculty of Science, University of Toyama); PUPPO, Paola (ROMA1)

Session Classification: Workshop conclusions

Contribution ID: **178** Type: **talk**

Summary of Low frequency workshop

Friday, 21 May 2021 17:00 (20 minutes)

Primary authors: Dr MOW-LOWRY, Conor (Vrije Universiteit Amsterdam and Nikhef); ANDO, Masaki (Department of Physics, Univ. of Tokyo)

Presenters: Dr MOW-LOWRY, Conor (Vrije Universiteit Amsterdam and Nikhef); ANDO, Masaki (Department of Physics, Univ. of Tokyo)

Session Classification: Workshop conclusions

Contribution ID: **179** Type: **talk**

Summary of Quantum noise and optical configurations workshop

Friday, 21 May 2021 16:00 (20 minutes)

Primary authors: DE LAURENTIS, Martina (Istituto Nazionale di Fisica Nucleare); STEINLECHNER, Sebastian (Maastricht University & Nikhef)

Presenters: DE LAURENTIS, Martina (Istituto Nazionale di Fisica Nucleare); STEINLECHNER, Sebastian (Maastricht University & Nikhef)

Session Classification: Workshop conclusions

Contribution ID: **180** Type: **not specified**

Summary of Controls and machine learning workshop

Friday, 21 May 2021 17:20 (20 minutes)

Primary authors: SWINKELS, Bas (Nikhef); VAJENTE, Gabriele (Caltech)

Presenters: SWINKELS, Bas (Nikhef); VAJENTE, Gabriele (Caltech)

Session Classification: Workshop conclusions

Contribution ID: **181** Type: **not specified**

GWADW 2022

Friday, 21 May 2021 18:00 (15 minutes)

Primary authors: SOMIYA, Kentaro (Tokyo Institute of Technology); MIYOKI, Shinji (Institute for Cosmic Ray Research, The University of Tokyo)

Presenters: SOMIYA, Kentaro (Tokyo Institute of Technology); MIYOKI, Shinji (Institute for Cosmic Ray Research, The University of Tokyo)

Session Classification: Workshop conclusions

Contribution ID: **182** Type: **not specified**

GWADW 2021 Conclusions

Friday, 21 May 2021 18:15 (15 minutes)

Primary authors: FIDECARO, Francesco (University of Pisa and INFN); VAJENTE, Gabriele (Caltech); SOMIYA, Kentaro (Tokyo Institute of Technology); BRANCHESI, Marica (GSGC); ADHIKARI, Rana (Caltech); MIYOKI, Shinji (Institute for Cosmic Ray Research, The University of Tokyo)

Presenters: FIDECARO, Francesco (University of Pisa and INFN); VAJENTE, Gabriele (Caltech); SOMIYA, Kentaro (Tokyo Institute of Technology); BRANCHESI, Marica (GSGC); ADHIKARI, Rana (Caltech); MIYOKI, Shinji (Institute for Cosmic Ray Research, The University of Tokyo)

Session Classification: Workshop conclusions

Contribution ID: **183** Type: **talk**

Welcome

Monday, 17 May 2021 16:00 (10 minutes)

Primary author: FIDECARO, Francesco (University of Pisa and INFN)

Presenter: FIDECARO, Francesco (University of Pisa and INFN)

Session Classification: Plenary Day 1