GRAvitational-waves Science&technology Symposium (GRASS 2022)

Report of Contributions

https://agenda.infn.it/e/30681

Contribution ID: **1** Type: **Contributed Talk**

Lunar Laser retroreflectors (LRRs) for GW detection on the Moon

LRRs have recently been proposed by the international collaboration LSGA (Lunar Seismic Gravitational Antenna) led by S. Katsanevas (et al) for the Call for Ideas for ESA's lunar Large Logistics Lander (EL3, 2020) and for ESA's Fast Call # 2 (2022). The basic ideas is to perform an interferometric strainmeter experiments on the surface of the Moon using evolved lunar LRRs systems in place of the mirrors à la Virgo/LIGO, on arms of few to several km length on the surface of the Moon. Such a systems directly inherit from the one under development by INFN (CSN2 Science Committee) and ESA, dubbed MoonLIGHT, equipped with dual gimbal pointing actuators and robotic dust cover. MoonLIGHT is under construction at the SCF_Lab of INFN-LNF, Frascati, and will be launched to the Moon in 2024 with NASA-CLPS flight, under a dedicated NASA-ESA MoU. Essential LSGA instruments include the lunar surface laser and seismometer provided by the Univ. of Paris (P. Lognonné et al).

Primary authors: DELL'AGNELLO, Simone (INFN-Frascati); KATSANEVAS, Stavros; LOGNONNÉ, Philippe (University of Paris); PORCELLI, Luca (Istituto Nazionale di Fisica Nucleare); MUCCINO, Marco (L); DELLE MONACHE, Giovanni Ottavio (Istituto Nazionale di Fisica Nucleare); SALVATORI, Lorenzo (LNF); TIBUZZI, Mattia (LNF)

Presenter: DELL'AGNELLO, Simone (INFN-Frascati)

Session Classification: Other challenges for future GW detectors

Track Classification: Other challenges for future GW detectors

Contribution ID: **2** Type: **Contributed Talk**

The 5n-vector ensemble method

Monday, 6 June 2022 13:05 (20 minutes)

We present a multiple test for the targeted search of continuous gravitational waves from an ensemble of known pulsars, combining multidetector single pulsar statistics defined through the 5n-vector method. In order to maximize the detection probability, we describe a rank truncation method to select the most promising sources within the ensemble, based on the p-values computed for single pulsar analysis. We also present the results obtained considering a set of 220 known pulsars and the O3 LIGO and Virgo datasets. No evidence of a GW signal from the ensemble was found, so we set 95% credible upper limit on ensemble parameters.

Primary author: D'ONOFRIO, Luca (Istituto Nazionale di Fisica Nucleare)

Co-authors: DE ROSA, Rosario (Istituto Nazionale di Fisica Nucleare); PALOMBA, Cristiano (Istituto Nazionale di Fisica Nucleare)

Presenter: D'ONOFRIO, Luca (Istituto Nazionale di Fisica Nucleare)

Session Classification: Data analysis

Track Classification: Data analysis

Contribution ID: **3** Type: **Contributed Talk**

Wavefront Sensing with a Coupled Cavity for Torsion-Bar Antenna

Tuesday, 7 June 2022 17:05 (20 minutes)

Torsion-Bar Antenna (TOBA) 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 $10^{-19}\ /\sqrt{\mathrm{Hz}}$ at 0.1 Hz in low frequencies (0.1 Hz –10 Hz). TOBA can detect intermediate mass black hole binary mergers, Newtonian noise, 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 $10^{-15}\ /\sqrt{\mathrm{Hz}}$ at 0.1 Hz. To achieve our target sensitivity, we need to measure the pendulum rotation precisely. We propose a new scheme of wavefront sensing with a coupled cavity for Phase-III TOBA. In our method, an auxiliary cavity is used to compensate Gouy phase of a main cavity and enhance the first-order TEM modes in the main cavity. The simulation with FINESSE and the experimental demonstration were successfully performed in 2021. In this symposium, we will show the principle of angular signal amplification with a coupled cavity and the results of simulation and demonstration.

Primary author: Ms OSHIMA, Yuka (University of Tokyo)

Co-authors: Mr TAKANO, Satoru (University of Tokyo); Mr OOI, Ching Pin (University of Tokyo); Dr MICHIMURA, Yuta (California Institute of Technology); Prof. ANDO, Masaki (University of Tokyo)

Presenter: Ms OSHIMA, Yuka (University of Tokyo)

Session Classification: Wavefront sensing and control

Track Classification: Wavefront sensing and control

Contribution ID: **4** Type: **Contributed Talk**

Substrate-transferred aluminum gallium arsenide crystalline coatings for future gravitational wave detectors

Monday, 6 June 2022 09:50 (20 minutes)

Substrate-transferred crystalline coatings made from aluminum gallium arsenide (AlGaAs) have lower thermal noise than the ion beam sputtered amorphous oxides currently used in ground based gravitational wave detectors. AlGaAs coatings also exhibit excellent optical properties and both thermal noise and optical performance has been successfully utilized in other precision optics applications. The principal challenge to using AlGaAs coatings in future gravitational wave detectors is the size necessary; both the diameter of the coating and the large mass and thickness of the optics. We present results on 10 cm diameter AlGaAs coatings and propose pathways to develop AlGaAs coatings for upgrades to current detectors with up to 40 kg masses and on future detectors with larger masses. We also discuss schedule and budget plans for this development of AlGaAs.

Primary authors: Prof. GRETARSSON, Andri (Embry-Riddle Aeronautical University); HARRY, Gregory (American University); Dr GARRETT, Cole (Thorlabs); PENN, Steven (LSC - Hobart and William Smith Colleges)

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

Session Classification: Optical coatings

Track Classification: Optical coatings

Contribution ID: **6** Type: **Contributed Talk**

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

Tuesday, 7 June 2022 15:50 (20 minutes)

The LISA mission, which has been accepted by ESA as the ESA-L3 Gravitational Wave Mission, aims at measuring gravitational waves in the sub-Hz band using inter-spacecraft interferometry. LISA consists in a constellation of three satellites in triangle formation with 2.5 Gm-long arms following along an Earth-like heliocentric orbit. The target sensitivity of pm/Hz1/2 presents unprecedented technical challenges; such as minimal detected power levels. One of the main issues is the coupling of the angular jitter of the spacecraft and test masses to the interferometrically measured longitudinal displacement (Tilt-To-Length coupling, or TTL). In order to minimize this, the alignment of the satellite constellation is going to be a crucial factor. For this reason, LISA reads out both length and angular signals, implementing a method known as Differential-Wavefront-Sensing (DWS), that combines the individual phase readouts from the four segments of a Quadrature PhotoDiode (QPD). An ultra stable interferometer testbed representative of the Optical Bench (OB) of a LISA spacecraft has been developed in order to validate critical interferometric techniques for the LISA mission. The testbed features a pair of steering mirrors that can induce synthetic tilts between the beams to simulate spacecraft or test mass motion. This experiment has been used to demonstrate optical reduction of TTL by using imaging systems to image the point of rotation of the beams into the detector plane. Current work is focusing on developing a new method to readout the DWS signals from the QPDs and on achieving a target DWS sensitivity below 1 nrad/sqrt(Hz) in the LISA heterodyne detection band.

Primary authors: PIZZELLA, Alvise (Albert Einstein Institute Hannover); HEINZEL, Gerhard (AEI Max-Planck Institut); DOVALE ALVAREZ, Miguel (Albert Einstein Institute Hannover)

Presenter: PIZZELLA, Alvise (Albert Einstein Institute Hannover)

Session Classification: Wavefront sensing and control

Track Classification: Wavefront sensing and control

Contribution ID: **7** Type: **Poster**

Stray Light Measurements With an Instrumented Baffle in the Advanced Virgo Input Mode Cleaner Cavity

Tuesday, 7 June 2022 10:40 (5 minutes)

In April 2021, a new instrumented baffle was installed surrounding the suspended end mirror of the Virgo's Input Mode Cleaner (IMC) cavity, as part of the phase I upgrade of the Advanced Virgo interferometer. The device is equipped with photo sensors that monitor the stray light inside the cavity. It serves as a demonstrator of the technology for the baffles that will monitor the stray light in the main arms, which will be installed during the phase II upgrade in the near future.
We will give an overview of the status of the instrumented baffle and its integration into the Virgo environment and present results on the measured scattered light distribution inside the cavity using data collected between spring 2021 and spring 2022, with Virgo in commissioning phase. The sensitivity and performance stability of the baffle is discussed and the data is compared to scattered light simulations.
These results will serve to calibrate the simulations and demonstrate the potential of instrumented baffles to detect defects in the mirrors and to improve the understanding of the scattered light inside ground-based gravitational wave experiments like Virgo.

Primary author: KOLSTEIN, Machiel (IFAE)

Presenter: KOLSTEIN, Machiel (IFAE)

Session Classification: Poster session

Track Classification: Stray light

Contribution ID: **9** Type: **Poster**

Beam characterization with the phase cameras in Advanced Virgo

Tuesday, 7 June 2022 10:50 (5 minutes)

Wavefront sensing allows for probing mode mismatch, higher order modes and thermal effects in gravitational-wave interferometers, all of which need to be well controlled as they impact the interferometer's stability and sensitivity. The phase cameras installed at Advanced Virgo (AdV) are capable of generating amplitude and phase images of the laser beam wavefront at any beat frequency of interest. The ability to extract independently carrier and upper and lower sidebands provides a rich dynamical dataset which remains largely untapped. We will show results of beam characterization with the phase camera and initial studies of the phase information at AdV. Understanding the phase information can be crucial to improve higher mode content analysis and possibly in monitoring thermal effects.

Additionally, we will present the plans and design of a table-top experiment being set-up at UCLouvain in order to study the use of the phase camera to generate error signals for automatic mode matching control of a coupled cavity. This know-how could, in the future, be directly applied at AdV where phase cameras are already installed.

Primary author: CABRITA, Ricardo (UCLouvain)

Presenter: CABRITA, Ricardo (UCLouvain)

Session Classification: Poster session

Track Classification: Wavefront sensing and control

Contribution ID: **10** Type: **Contributed Talk**

Optical simulations of stray light on instrumented baffles surrounding Virgo end mirrors during O5

Tuesday, 7 June 2022 11:50 (20 minutes)

As part of the second phase of Advanced Virgo update program, instrumented baffles are being constructed to be installed around the end mirrors in the main FP cavities, in continuation of what has been implemented for the input mode cleaner end mirror during phase I. According to the current design, these baffles will be equipped with more than 200 photosensors, allowing for real-time monitoring of the stray light around the mirrors. We present optical simulations of the light distribution in the detector's main cavities to assess the ability of the sensors to effectively monitor misalignment and defects on the mirrors' surface and to play a role in the pre-alignment of the interferometer. The effect of the backscattered light from the baffles is also computed and projected over the O5 sensitivity curve, to evaluate possible effects of the presence of instrumented baffles on the ultimate sensitivity of the detector.

Primary authors: MACQUET, Adrian (IFAE); Mr ANDRES, Marc (IFAE)

Presenters: MACQUET, Adrian (IFAE); Mr ANDRES, Marc (IFAE)

Session Classification: Stray light

Track Classification: Stray light

Contribution ID: **11** Type: **Contributed Talk**

Tunable coherence for straylight suppression in high precision interferometers

Tuesday, 7 June 2022 11:30 (20 minutes)

As straylight is a dominating limitation for the sensitivity of gravitational wave detectors, we investigate the use of tunable coherence in the form of phase modulation following a pseudo-random-sequence on the interferometer laser to break the coherence of the delayed straylight. Thereby, we aim to reduce its intrusive impact on the measurement by effectively realizing a pseudo white-light interferometer with tunable coherence length.
While this has been proven to work with digital demodulation for multiplexing in digital interferometry, we now study optical demodulation at the signal ports of a Michelson-interferometer with higher modulation speeds to reduce the remaining coherence length.
As a first step, we present results and estimated suppression factors from a numerical simulation in preparation of the experimental studies in a tabletop interferometer.

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Presenter: VOIGT, Daniel (University Hamburg, Institute for Experimental Physics)

Session Classification: Stray light

Track Classification: Stray light

Contribution ID: **12** Type: **Contributed Talk**

The crystallization process in Ta2O5 and TiO2-Ta2O5 amorphous films

Monday, 6 June 2022 10:10 (20 minutes)

In the current development of optical coatings for high precision instruments like GW interferometers thermal Brownian noise currently pose a limiting factor on the performances obtainable. In particular in the VIRGO experiment, in the 50-300 Hz region, thermal brownian noise act as the dominant contribution.
Since the Brownian noise is commonly attributed to the existence of many local energy minima in the atomic configuration a non-dissipative system like a crystal is expected to improve the mechanical response of the system. For this reason it is thought that the controlled formation of nanocrystallites inside the amorphous coatings could reduce the Brownian noise. The crystallite size and density must however be precisely controlled in order to find a trade-off between the improvement of the mechanical properties and the formation of light scattering centers.
In this work we studied the crystallization kinetics of Ta2O5 and Ti:Ta2O5 by analyzing the evolution respect to time and temperature of the XRD spectra of our samples obtained treating them either in situ or via rapid thermal annealing. Due to some uncertainity from literature on the Ta2O5 low temperature crystalline phase the kinetics data are also complemented by Raman measurements and ab initio simulations to tackle the problem.

Primary authors: FAVARO, Giulio (Istituto Nazionale di Fisica Nucleare); LEMAITRE, Anael; Dr SHCHEBLANOV, Nikita; MARTINEZ, valérie (Université Claude Bernard Lyon1); BAZZAN, Marco (Istituto Nazionale di Fisica Nucleare)

Presenter: FAVARO, Giulio (Istituto Nazionale di Fisica Nucleare)

Session Classification: Optical coatings

Track Classification: Optical coatings

Contribution ID: **13** Type: **Contributed Talk**

Stray Light issues and control in Advanced Virgo Plus

Tuesday, 7 June 2022 12:10 (20 minutes)

Scattered light is one of the problems that most limits the performance of current gravitational wave detectors.
Simulating stray light is still computationally complicated. Therefore, in order to estimate the amount of scattered light from the optical elements, we built at LAPP an interferometric scatter-meter with which the BRDF of the desired elements is measured.
In parallel, in Virgo we are working to mitigate the identified scattered light sources. On the one hand, we conducted a complete mitigation campaign of secondary beams, i.e. ghost beams, on all Virgo subsystems. As these unwanted beams propagate, they can produce scattered light that recombines with the interferometer beam. On the other hand, we developed a control loop to actively correct the stray light on the squeezing system. This system can be reproduced and applied in other circumstances.

Primary author: POLINI, Eleonora (LAPP)

Presenter: POLINI, Eleonora (LAPP)

Session Classification: Stray light

Track Classification: Stray light

Contribution ID: **14** Type: **Contributed Talk**

Studies of the electro-optic noise in crystalline coatings and cryogenic coating mechanical losses toward future upgrades of gravitational wave detectors

Monday, 6 June 2022 10:30 (20 minutes)

Next generation gravitational wave detectors will provide further insight into the Universe thanks to their improved sensitivity. Low thermal noise mirror coatings play an important role in realizing such gravitational wave detectors as coating thermal noise is one of the limiting noise sources in the most critical frequency region.

Crystalline coatings, which have demonstrated low thermal noise, are one of the candidates for the mirror coatings. However, crystalline coatings may be susceptible to electro-optic (EO) noise. We have developed an experimental setup and investigated the EO noise in crystalline GaAs/AlGaAs coatings. We have set an upper limit on the EO noise which is well below the strain sensitivity.

Study of coating mechanical losses at cryogenic temperature is indispensable for future gravitational wave detectors such as the Einstein Telescope, and vital to understand the fundamental loss mechanisms of the coating materials. For these purposes, we have developed cryogenic gentle nodal suspension (GeNS). This setup enables us to measure mechanical losses over a wide temperature range between 15 - 300 K.

We will present the current status and future prospects of these coating experiments.

Primary author: TANIOKA, Satoshi

Co-authors: DIDIO, Nicholas (Syracuse University); VANDER-HYDE, Daniel (Syracuse University); CAPOTE, Elenna; PENN, Steven (LSC - Hobart and William Smith Colleges); BALLMER, Stefan (Syracuse University)

Presenter: TANIOKA, Satoshi

Session Classification: Optical coatings

Track Classification: Optical coatings

Contribution ID: **15** Type: **Contributed Talk**

Multimodal Gentle Nodal Suspension Measurements of Zirconia-Titania Coatings

Monday, 6 June 2022 11:35 (20 minutes)

Low thermal noise optical coatings are a key part of the design of current and future gravitational wave detectors. Coating thermal noise limits detector sensitivity in the mid range, about 50-300 Hz, where GW detectors are the most sensitive. Tetrahedral metal dioxides, such as silica (SiO2), have been shown to be the most promising materials for low loss amorphous coatings. We present mechanical loss results of zirconia-titania (ZrO2-TiO2) mixtures measured in a multimodal gentle nodal suspension. We demonstrate that high temperature annealing yields the lowest mechanical loss for these mixtures. We also present a method of multimodal data analysis that employs a digital lock-in amplifier to allow time-domain fitting of each mode ringdown. Zirconia-titania coatings are shown to be a promising high index of refraction material for gravitational wave detector optics.

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Presenter: CAPOTE, Elenna

Session Classification: Optical coatings

Track Classification: Optical coatings

Contribution ID: **16** Type: **Contributed Talk**

Astigmatic mode mismatch sensing for the next gravitational wave detectors.

Tuesday, 7 June 2022 17:45 (20 minutes)

One of the main limits of the Quantum Noise Reduction in Gravitational Wave detectors is the optical losses generated by the mismatch between the vacuum squeezed beam and the resonant cavities of the interferometer. In order to correct those aberrations, we need to be able to measure them. For this reason, different efforts have been made to develop wave-front sensing techniques to measure the mismatch between optical cavities.

However, the current technologies based on spherical Gaussian beams are not enough for the next generation of Gravitational Wave Detectors. In fact, the higher requirement on the optical losses imposes to compensate also the mode-matching generated by astigmatic aberrations, so a new generation of wavefront sensor technique is needed.

Here we will present an upgrade of the Mode Conversion Telescope technique that extends the mismatch measurement from the only symmetric aberrations to a complete characterisation of the mismatch between an astigmatic Gaussian beam and a resonance cavity. This extension uses four additional Quadrants Photodiodes sensors to detect the beat note between the Sidebands of the TEM00 and the second-order Hermite-Gauss mode TEM11 of the carrier. In particular, we will describe the method and present the first experimental results of this technique.

Primary author: GRIMALDI, Andrea (TIFPA-INFN)

Co-author: PERRECA, Antonio (TIFP)

Presenter: GRIMALDI, Andrea (TIFPA-INFN)

Session Classification: Wavefront sensing and control

Track Classification: Wavefront sensing and control

Contribution ID: **17** Type: **Contributed Talk**

Interferometric Measurement of Extremely Low Scattered Light from Optical Components

Tuesday, 7 June 2022 09:50 (20 minutes)

The interferometric detection of tiny ripples in the fabric of spacetime called gravitational waves require extreme noise sensitive operating conditions for detectors such LIGO, Virgo, KAGRA, as well as the future planned LISA and ET. One such instrument noise source is scattered light from optical components, that can induce phase noise in the output signal by recombining with the main interferometric beam. Therefore, this backscattered light needs to be accurately quantified for improved detector strain sensitivity in the lower detection bandwidth. In this work, we present an optical low coherence back-scatterometer using a broadband light source centered at 1060 nm with optical bandwidth of 70 nm to characterize the very tiny amount of light retro-reflected and/or back-scattered from optical components, thanks to the relative intensity noise suppression using balanced optical detection. The use of a low coherence optical source allows to measure and distinguish the retro-reflection and back-scattering from individual optical surfaces; thus, the accurate contributions of different involved components can be enabled. We measured retro-reflectance from uncoated N-BK7 and S-LAH66 windows and back-scattering from a silver polished mirror with reflectance value as low as 10^-11.

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Presenter: KHAN, Imran (Institut Fresnel)

Session Classification: Stray light

Track Classification: Stray light

Contribution ID: **19** Type: **Poster**

Scattered light noise from Virgo viewports: results and possible mitigations

Tuesday, 7 June 2022 10:35 (5 minutes)

In addition to the fundamental noises (quantum noise, thermal noise, and seismic noise) affecting the sensitivity of ground-based gravitational-wave interferometers, the technical noises often limit some frequency bands. A substantial part of the detector commissioning is devoted to the study and the mitigation of technical noises. Scattered light is among these noises. In this presentation, the studies of the scattered light from the main Virgo interferometer viewports, during the commissioning in preparation for the O4 run, and some preliminary results applicable for the O5 configuration will be shown. Possible mitigation suggestions will also be discussed.

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Presenter: Dr TRINGALI, Maria Concetta (EGO - European Gravitational Observatory)

Session Classification: Poster session

Track Classification: Stray light

Contribution ID: **20** Type: **Contributed Talk**

Squeezing Backscatter Evasion

Tuesday, 7 June 2022 10:10 (20 minutes)

A peculiar kind of stray light that can affect the performance of a squeezing-enhanced gravitational-wave interferometer is the light that travels backwards along the squeezed light injection path. After being amplified by the nonlinear process inside the optical parametric oscillator (OPO), the backscattered light eventually reaches the readout photodiode of the interferometer with a random phase, thus adding noise. A control scheme can be implemented to lock the phase of the backscattered light to the pump field of the OPO, in order to obtain a de-amplification of this bright field inside the cavity. The control scheme has been successfully implemented at GEO600, and has proven to have a significant impact on maintaining a high level of squeezing. Due to the fact that there are almost no observable differences between the influence of phase noise and backscatter noise in the squeezing level degradation, the control scheme can be used to decouple the two contributions in the characterisation process of the squeezing injection performance, thus obtaining a more faithful estimation of the actual phase noise that affects the squeezing level.

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Presenter: BERGAMIN, Fabio (AEI Hannover)

Session Classification: Stray light

Track Classification: Stray light

Contribution ID: **21** Type: **Contributed Talk**

Mitigating back-scattered light with dual-homodyne readout

Tuesday, 7 June 2022 09:30 (20 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 frequencies. Modulations due to the back-scattered light appear both in phase and amplitude quadratures of the output light. It is proposed to use dual-homodyne detection to measure both quadratures and to discriminate between GW signal and scattered light for consequent subtraction of the parasitic signal from the h(t) strain data. The use of two-mode squeezed light allows to take advantage of quantum enhancement in the detector without suffering the penalty for dual-homodyne readout. The proof of principle was researched in the recent years [1-2]. We discuss its extension to the case of the frequency-dependent squeezing and application in future detectors.

[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: KOROBKO, Mikhail (University of Hamburg); SCHNABEL, Roman (Universität Hamburg)

Presenter: KOROBKO, Mikhail (University of Hamburg)

Session Classification: Stray light

Track Classification: Stray light

Contribution ID: **22** Type: **Contributed Talk**

An unmodeled search for echoes: probing the post-merger phase of a binary black hole coalescence

Monday, 6 June 2022 15:00 (20 minutes)

The current catalog of gravitational waves (GWs) from binary black hole (BBH) mergers allows to conduct refined tests to probe the validity of the general relativity (GR) theory against alternative predictions. It has been proposed that black holes (BHs) may have exotic characteristics making them different from GR BH, such as exotic compact objects (ECOs): they would produce repeated GW pulses of widely uncertain morphology (echoes) in the post-merger phase whose detection would also help to infer fundamental properties of the matter itself because strictly related with the nature of such ECOs.
I will present a method for searching echoes and inferring their fundamental observables if any, which is agnostic to the properties of these GW pulses. The methodology is implemented on a dedicated version of coherent WaveBurst (cWB), an unmodelled GW transient search algorithm, developed in the LIGO Scientific Collaboration (LSC) and Virgo Collaboration, widely used on LIGO-Virgo-KAGRA data.
We will discuss the results of the search, performed on LIGO-Virgo open data (O1, O2, and O3), and provide upper limits in terms of the detectable energy of echo-like signals, in an attempt to constrain the parameters space of ECOs models.

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Presenter: MIANI, Andrea (Istituto Nazionale di Fisica Nucleare)

Session Classification: Data analysis

Track Classification: Data analysis

Contribution ID: **24** Type: **Poster**

Coping with Point Absorbers in Advanced Virgo

Tuesday, 7 June 2022 10:55 (5 minutes)

The increase of the optical power expected for the new observing run (O4) will lead to an improvement of the interferometer (ITF) sensitivity with a consequently increase of the detection volume and the number of candidate sources. At this condition, the thermal distortions, induced by absorption inside the optics, degrade the ITF performance reducing the quality of the control signals and the duty cycle of the instrument. The correction of optical aberrations through adaptive optical systems is crucial to reach the design performances. In addition, during the previous run (O3), highly absorbing areas on the surfaces of the main 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. In this talk, the analysis of AdV+ input mirrors surfaces, point absorbers identification and characterization, the corresponding thermo-elastic deformation and its compensation are illustrated. An overview of the study and characterization process of the new actuator will be also presented.

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

Session Classification: Poster session

Track Classification: Wavefront sensing and control

Contribution ID: **25** Type: **Contributed Talk**

Implications of the quantum nature of the black hole horizon on the gravitational-wave ringdown

Monday, 6 June 2022 17:40 (20 minutes)

Motivated by capturing putative quantum effects at the horizon scale, we model the black hole horizon as a membrane with fluctuations following a Gaussian profile. By extending the membrane paradigm at the semiclassical level, we show that the quantum nature of the black hole horizon implies partially reflective boundary conditions and a frequency-dependent reflectivity. This generically results into a modified quasi-normal mode spectrum and the existence of echoes in the postmerger signal. On a similar note, we derive the horizon boundary condition for a braneworld black hole that could originate from quantum corrections on the brane. This scenario also leads to a modified gravitational-wave ringdown. We discuss general implications of these findings for scenarios predicting quantum corrections at the horizon scale.

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Presenter: CHAKRABORTY, Sumanta (Indian Association for the Cultivation of Science)

Session Classification: Other challenges for future GW detectors

Track Classification: Other challenges for future GW detectors

Contribution ID: **26** Type: **Poster**

Flexible and Fast Estimation of Binary Merger Population Distributions with Adaptive KDE

Tuesday, 7 June 2022 10:45 (5 minutes)

The LIGO Scientific, Virgo and KAGRA Collaborations recently released the third gravitational-wave transient catalog or GWTC-3, significantly expanding the number of gravitational wave (GW) signals. There are various models proposed to describe the underlying mass distribution of these compact objects using computational extensive Bayesian hierarchical models and use them to predict the formation channels of these compact objects. In this work we are proposing a fast and flexible Kernel density estimator (KDE), to reconstruct the mass distribution of LIGO-Virgo binary mergers from parameter estimation outputs of the observation of gravitational waves from publicly available data from GWTC-2 including O1, O2, and O3a observing runs. Under some conditions (sufficiently high statistics, sufficiently low individual event measurement error relative to width of population features) a simple kernel density estimator reconstruction of the mass distribution from parameter estimation median masses will be sufficiently accurate. We propose this in combination with a fast polynomial fit (to injection results) of the mass-dependent sensitivity as a simple non-parametric method for comparison with established Bayesian hierarchical models. We also propose a method to identify significant features such as peaks in the underlying distribution.

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Presenter: Dr SADIQ, Jam (University of Santiago de Compostela, Spain)

Session Classification: Poster session

Track Classification: Data analysis

Contribution ID: **27** Type: **Contributed Talk**

Atmospheric noise contribution to Newtonian Noise for gravitational wave detectors

Monday, 6 June 2022 18:00 (20 minutes)

Since the first detection of gravitational waves (GW) in 2015 by the LIGO and VI
RGO collaborations, the scientific community has been pushing for improving GW detectors as well as the analysis methods and models for noise control. The new generation of GW detectors, LISA and Einstein Telescope (ET), is expected to be orders of magnitude more sensitive than the previous ones, especially in the low-frequency band. The improved sensibility increasingly exposes the detectors to environmental noise, which must therefore be modeled in a very accurate way. One
of the most problematic noises is the one produced by local fluctuations of the gravitational acceleration—the so-called Newtonian noise (NN)—which cannot be shielded. It is thus of paramount importance to accurately estimate the different kinds of NN and, if possible, to actively subtract their effects from the measured signal.

In this talk, we discuss the contribution to NN by temperature fluctuations generated by atmospheric turbulence. These temperature fluctuations result in density fluctuations, whose spectral properties are determined by the advection by the mean wind and by the deformation by the turbulence.

We will first focus on a homogeneous and isotropic model of turbulence (HIT) in the presence of a uniform constant speed wind. Differently from previous estimates, which, within a so-called frozen-turbulence approximation, only considered the effect of wind advection, we will also take into account the continuous deformation and time-decay of turbulent structures. Our approach reproduces known results in the frozen turbulence limit. However, new and potentially important contributions from the time-decay of turbulent structures do emerge. We will consider next a wall-turbulence (WT) model of atmospheric boundary layer, in which the homogeneous isotropic turbulence hypothesis is relaxed and the variations with height of the turbulence intensity and of the wind speed are taken into account. We have evaluated the noise spectra and their dependence on the depth of the detector and the wind and the turbulence characteristics, for both HIT and WT, in the case of Gaussian time correlations.

We have derived our results with special focus on the ET geometry, but they remain valid for any ground-based GW detector. We find that at small depth and/or for high wind-speed, the NN contribution is above the ET sensitivity curve in the
low-frequency band of the spectrum.

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Session Classification: Other challenges for future GW detectors

Track Classification: Other challenges for future GW detectors

Contribution ID: **28** Type: **Contributed Talk**

GW190521: Search for Echoes due to Stimulated Hawking Radiation from Black Holes

Monday, 6 June 2022 15:20 (20 minutes)

Being arguably the most massive binary black hole merger event observed to date, GW190521 deserves special attention. The exceptionally loud ringdown of this merger makes it an ideal candidate to search for gravitational wave echoes, a proposed smoking gun for the quantum structure of black hole horizons. We perform an unprecedented multi-pronged search for echoes via two well-established and independent pipelines: a template-based search for stimulated emission of Hawking radiation, or Boltzmann echoes, and the model-agnostic coherent WaveBurst (cWB) search. Stimulated Hawking radiation from the merger is expected to lead to post-merger echoes at horizon mode frequency of ~ 50 Hz (for quadrupolar gravitational radiation), repeating at intervals of ~ 1 second, due to partial reflection off Planckian quantum structure of the horizon. A careful analysis using dynamic nested sampling yields a Bayesian evidence of 7 ± 2 (90\% confidence level) for this signal following GW190521, carrying an excess of $10^{+9}_{-7}\%$ in gravitational wave energy, relative to the main event. Similarly, the reconstructed waveform of the first echo in cWB carries an energy excess of $13^{+16}_{-7}\%$. Accounting for the "look-elsewhere" effects, we estimate a p-value for false detection probability of 5.1×10^{-3} (or 2.6σ) using cWB pipeline, although the verdict on the co-localization of the post-merger echo and the main event in the sky is inconclusive. While the current evidence for stimulated Hawking radiation does not reach the gold standard of 5σ, our findings are in line with expectations for stimulated Hawking radiation at current detector sensitivities. The next generation of gravitational wave observatories can thus draw a definitive conclusion on the quantum nature of black hole horizons.

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Session Classification: Data analysis

Track Classification: Data analysis

Contribution ID: **29** Type: **Contributed Talk**

Transient localization web service based on open gravitational-wave data for the multi-messenger community.

Monday, 6 June 2022 16:20 (20 minutes)

The LIGO-Virgo-KAGRA O4 observing run will bring the amount of gravitational wave (GW) detections to an unprecedented level. The full exploitation of this opportunity will be possible if we provide innovative tools for quick data analysis using intuitive grafical user interface. In particular this approach is important in the electromagnetic follow-up decision process, as the time spent on investigating the interest of an alert must be short.
Hereby we present a web service https://www.virgo.pg.infn.it/maps integrated in the environment of the International Virtual Observatory Alliance (IVOA) and we sketch its implementation. The application was developed in accordance with the FAIR principles, allowing the efficient exchange of essential information between the different partners in the multi-messenger observation [1]. It provides an immediate and accurate visualization of the localisation of astronomical transients available in the GW open database [2]: each localisation of the GW source, provided through a Multi-Order Coverage (MOC) map [2-3], can be tested and intersected with the sky area visible from an observatory of interest. User parameters and the output information is accessible from a web browser in a clear and standardized format. Finally we would like to point out the technological advantages of our service, from the point of view of future technical challenges, due to the anticipated exponential increase of transient detections [4-5] as well as to the growth of the heterogeneous multi-messenger community.

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Session Classification: Data analysis

Track Classification: Data analysis

Contribution ID: **30** Type: **Contributed Talk**

Tilt-to-Length noise in interferometric GWO in presence of wavefront aberrations

Tuesday, 7 June 2022 16:10 (20 minutes)

We investigated the tilt-to-length contribution to the measure of the distance of the LISA satellites at the vertexes of the triangular constellation [1]. The aberrations of the beam wavefront have been introduced using Zernike polynomials. This greatly limited the spatial frequency of the considered aberrations and the study of local defects due to the optics traversed by the measuring beam. In this study, we extended the bandwidth of the spectra of the wavefront aberrations using a discrete Fourier decomposition. The numerical and analytical analyses have shown that to keep the tilt-to-length error below 10 pm for an angle jitter of 10 nrad and a point-ahead angle less than 1 μrad (as for the requirements of the LISA mission), the wavefront quality must be better than $\lambda/20$.
[1] C P Sasso et al 2018 Class. Quantum Grav. 35 245002

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Session Classification: Wavefront sensing and control

Track Classification: Wavefront sensing and control

Contribution ID: **32** Type: **Contributed Talk**

Overlapping signal detection using cWB pipeline

Monday, 6 June 2022 16:00 (20 minutes)

While the current sensitivity of the interferometers makes the detection of overlapping signals between two different gravitational waves (GWs) very unlikely, this will be quite common for the next generation of detectors: indeed, the detection rate will be high enough so that the probability to have two or more events at the same time is expected to be very high.
We present the results of the analysis on overlapping signals from the perspective of unmodeled searches using the coherent WaveBurst (cWB) pipeline. This analysis is done injecting two overlapping sets of signals on Gaussian noise considering a three detector network (Livingston, Hanford, Virgo). This is done for three different configurations: binary black hole - binary black hole (BBH-BBH), binary black hole - binary neutron star (BBH-BNS) and binary neutron star - binary neutron star (BNS-BNS), reporting in each case the detection efficiency and evaluating the effect of the post production cuts used in the last Advanced LIGO-Virgo run.

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Session Classification: Data analysis

Track Classification: Data analysis

Contribution ID: **33** Type: **Contributed Talk**

Cryogenic Mechanical Loss Measurements using a Gentle Nodal Support

Monday, 6 June 2022 11:55 (20 minutes)

Mechanical loss and thermal noise from both the test mass substrates and their coatings are important factors in the sensitivity of current gravitational wave detectors The next generation of gravitational wave detector are proposed to operate at low temperatures, requiring a change in test mass material and coatings designed to work at higher wavelengths. Silicon has been proposed as an alternative test mass substrate material, however, it is not straightforward to find types with low optical absorption, low mechanical loss and available in the ~200kg sizes required to be used in a future detector. Amorphous silicon similarly shows potential for reducing thermal noise, but due to its high optical absorption, care has to be taken when considering coatings incorporating silicon. New substrates and coating materials with low mechanical loss (and absorption) are being investigated at the University of Glasgow using a pulse cooled cryogenic gentle nodal support (CryoGeNS).
In recent months research has focussed on three areas:

• The cryogenic mechanical loss of "quasi-monocrystalline"silicon, which has the potential to be used to create large low loss silicon test masses.
• Investigations have been made into the loss of ion implanted layers, where a high-energy ion beam is used to implant oxygen to create silica layers within a silicon substrate, and
• Multimaterial coatings have been studied at low temperatures. These coatings allow the use of amorphous silicon to reduce thermal noise while minimising it's impact on the total absorption of a mirror coating. We have been working to verify the multimaterial concept at low temperature, by integrating aSi layers into the lower component of a highly reflective silica and tantala multilayer coating stack, deposited by ion plating.

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Session Classification: Optical coatings

Track Classification: Optical coatings

Contribution ID: **34** Type: **Contributed Talk**

Optical properties of titania-tantala coatings at cryogenic temperatures

Monday, 6 June 2022 12:15 (20 minutes)

Cooling mirrors to cryogenic temperatures has been proposed as a strategy to improve the sensitivity of gravitational waves detectors (GWD). The effects of low temperatures on the optical response of mirrors have to be evaluated; additionally, important issues - such as the formation of an ice layer on the surface of mirrors - must be carefully studied to assess their impact on the GWD sensitivity. In this talk, an optical characterization of titania-tantala coatings at cryogenic temperatures will be presented, along with data analysis that allow to determine the temperature-dependent variations in the Urbach tail of the coatings. Results allow to better understand the fundamental properties of optical coatings, and have implications for next-generation GWD.

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Session Classification: Optical coatings

Track Classification: Optical coatings

Contribution ID: **35** Type: **Poster**

Optical design of the laser injection line into a small-scale suspended interferometer for Quantum Noise reduction in GW detectors

Tuesday, 7 June 2022 11:00 (5 minutes)

On 14 September 2015, a century after the birth of General Relativity, all the scientific and technological efforts for the experimental detection of gravitational waves (GWs) found a reward. The instruments that allowed the first direct detection are second-generation GW interferometers, such as LIGO and Virgo. At present, after the conclusion of the scientific observing run O3, about 90 GW events have been confirmed. The future challenges concern further technological improvements and the extension of the world-wide network of GW detectors. New techniques and strategies should be implemented for reducing any source of noise that inevitably falls into the measurements. Quantum noise (QN) is one of the major limiting contributions to the instrumental sensitivity of ground-based GW detectors, therefore techniques allowing a broadband QN reduction should be investigated before any possible integration in large-scale GW detectors. Currently, the technique adopted by the LIGO and Virgo collaborations consists of a frequency-independent squeezing (FIS) source coupled with a 300 m long detuned filter cavity, which produces in reflection frequency-dependent squeezing (FDS) to be injected from the dark port of the interferometer. Looking forward, especially in view of the third generation GW detectors such as ET, it is crucial to develop more compact FDS setups, such as the one based on the Einstein Podolsky Rosen (EPR) entanglement and on the ponderomotive squeezing. In particular, EPR-entangled states can be obtained by pumping an Optical Parametric Oscillator (OPO) cavity with a second harmonic detuned beam. A set up for testing EPR squeezed states into a small-scale suspended interferometer called SIPS (Suspended Interferometer for Ponderomotive Squeezing) is under implementation at the EGO R&D squeezing laboratory.
In this talk, a brief status of this experiment and the optical design of the laser injection path into SIPS will be illustrated. Particular attention will be given to describe the triangular input mode cleaner (IMC) cavity, a fundamental optical element ensuring that a Gaussian transverse intensity profile of the laser is sent into SIPS interferometer.

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Session Classification: Poster session

Track Classification: Other challenges for future GW detectors

Contribution ID: **36** Type: **Poster**

Optical and mechanical properties of titania-silica coatings

Tuesday, 7 June 2022 10:30 (5 minutes)

The lower limit in sensitivity of gravitational wave detectors at their most sensitive frequencies arises from the Brownian motion of high reflectivity coatings on the test mass optics. In the aim to find alternative materials for the next upgrade of interferometric detectors, large interest was represented by Titania-doped Silica.
We present here our investigations into the mechanical and optical properties of highly-reflective coating stacks made of pure SiO2 and TiO2 doped SiO2, deposited via ion beam sputtering (IBS). Two different concentrations of TiO2 doping in the high-refractive index layers of our coating stacks were investigated, with mechanical loss and optical absorption being measured through different steps of heat treatment for each, with the level of coating thermal noise being calculated from the former.

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Session Classification: Poster session

Track Classification: Optical coatings

Contribution ID: **37** Type: **Contributed Talk**

Improving future searches for gravitational wave transients on multi-detector data

Monday, 6 June 2022 15:40 (20 minutes)

When it comes to gravitational wave signals, both waveform reconstruction and sky localization benefit from as broad a detector network as possible. And yet, in several instances the contribution of the Virgo detector has not been fully exploited, because the advantages are offset by the overall increase of background noise.
This is especially concerning for multi-messenger events, and it motivates our investigations aimed at enhancing the multi-detector performance of "coherent WaveBurst" (cWB), a pipeline routinely used to detect short gravitational-wave transients with a mimimally-modeled method that exploits the coherence of the signals in the detector network.
In this contribution, I discuss the improvements achieved through the implementation of a decision tree algorithm to upgrade the ranking procedure of gravitational wave bursts (GWBs) in cWB in preparation to the upcoming observing run of the LIGO-Virgo-KAGRA collaboration. In particular, I consider the case of the three-detector LIGO-Virgo network and I discuss the robustness of the results across widely different GWB morphologies.

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Session Classification: Data analysis

Track Classification: Data analysis

Contribution ID: **38** Type: **Contributed Talk**

Mode matching sensing through RF Higher Order Modulation

Tuesday, 7 June 2022 17:25 (20 minutes)

Quantum noise is a fundamental limit in Gravitational Waves (GW) detectors and is made up of shot noise (SN) at high frequencies (above about 100Hz) and radiation pressure noise (RPN) at lower frequencies. To reduce this noise, GW interferometers use a technique called squeezing with which we can improve only one of the contributions, while worsening the other: so far, the choice has been to improve SN, which is limiting the performance at high frequencies.
In the upgrade Advanced Virgo+, we need to reduce RPN as well, therefore the squeezing method needs a frequency dependency. To do this a 300m long cavity, called Filter Cavity (FC), will be used. However, one of the main optical loss term is due to the possible mismatch between the fundamental mode of the laser and the one supported by the cavity. This can be described in terms of higher-order mode (HOM) content of the former in the base defined by the latter. When a cavity is locked on the fundamental mode, these HOMs are reflected and carry important information on the origin of the mismatch. In particular, we are interested in mismatch due to differences in dimension and positions of the waist, which give rise to the Laguerre-Gaussian mode LG10.
We are developing an innovative method to sense this mismatch based on RF Higher Order Mode Modulation. This technique aims at sensing the beat signal between the carrier LG10 mode reflected by the cavity and the LG10 sideband generated by a lensing modulator called electro-optical lens (EOL). The EOL works on a frequency such that one of the two generated sidebands is resonant inside the cavity. In this way the reflected LG10 carrier and sideband can generate a beat signal on a photodiode. I/Q demodulation at the sideband frequency allows for extracting the real and imaginary part of the LG10 mode, which are the waist size and waist position mismatch, respectively.

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Session Classification: Wavefront sensing and control

Track Classification: Wavefront sensing and control

Contribution ID: **39** Type: **Invited Talk**

Light scattered by high performance optical components: Numerical prediction and accurate metrology

Tuesday, 7 June 2022 09:00 (30 minutes)

Light scattering issues specific to high performance optical components have received considerable attention over the last decade for several reasons.

Firstly, the manufacturing processes of interference filters have benefited from technological breakthroughs which today allows the routine manufacture of stacks with several hundreds of thin films on substrates with extreme polishes. Such complexity leads to a high increase of scattering phenomena which originate from all interface roughnesses of the coating.

In addition, the specifications for Space applications have become more severe, especially in the development of hyper-spectral micro-imagers (in the form of arrays or pixels). Crosstalk rates and scattering lobes at large angles of the interference filters have become the key to the performances of these components.

Finally, the success of the detection of gravitational waves has brought the mirror requirements to the forefront, including light scattering.

In this context, the Light Scattering Group of the Institut Fresnel has met several scientific challenges that were not addressed until now. These challenges fall into two main areas:

Extreme instrumentation for low-flux metrology with the development of metrology tools aimed at quantifying the scattering budgets of low-loss optical components while discriminating the effects (surface vs. volume, defects vs. roughness, spectrally, spatially and angularly resolved metrology, etc.)

Modelling and control of light scattering in optical surfaces and coatings with the numerical implementation of electromagnetic models allowing the accurate prediction of fields scattered from stacks of "complex" optical thin films and the use of neural networks for the synthesis of stacks based on a light scattering criterion.

For each of these areas, we will present the issues related to space applications as well as the main theoretical, numerical and instrumental developments carried out by the Light Scattering Group of the Institut Fresnel.

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Session Classification: Stray light

Track Classification: Stray light

Contribution ID: **40** Type: **Invited Talk**

Probing fundamental physics with continuous gravitational waves

Monday, 6 June 2022 12:35 (30 minutes)

In this talk I will review the physical mechanisms that can lead to continuous gravitational wave emission, focusing mainly on the role of neutron stars. I will discuss which physical scenarios can be explored with continuous waves, and review recent searches by the LIGO, Virgo, KAGRA collaboration. I will show, in particular, that the sensitivity of the searches has now reached the point where we are beginning to probe astrophysically significant portions of parameter space, and discuss the role of next generation detectors.

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Presenter: HASKELL, Brynmor (CAMK PAN)

Session Classification: Data analysis

Track Classification: Data analysis

Contribution ID: **41** Type: **Invited Talk**

Crystalline mirrors for GW detectors

Monday, 6 June 2022 17:10 (30 minutes)

KAGRA is the first Gravitational Wave (GW) detector which is located in an underground facility and operates the test masses at cryogenic temperatures. For these two major differences with respect to Advanced LIGO and Advanced Virgo, KAGRA is usually addressed as 2.5G detector and its experience will help to bridge the gap between 2G (aLIGO and AdV) and 3G detectors such as Einstein Telescope, Cosmic Explorer, etc.
One of the biggest differences compared to 2G detectors is the necessity to use crystalline test masses substrates instead of amorphous ones. In this talk, the challenges related to this specific aspect will be reported.

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Session Classification: Other challenges for future GW detectors

Track Classification: Other challenges for future GW detectors

Contribution ID: **42** Type: **Contributed Talk**

Development of a light-scattering measurement facility for the characterization of stray light sources in GW optics

Tuesday, 7 June 2022 12:30 (20 minutes)

Stray light is suspected to be a major culprit for the excess noise measured in present gravitational wave interferometers, and is projected to be even more dangerous for the next generation of instruments which will attempt to further push the sensitivity limits. Stray light originating in different areas of the detectors and through various mechanisms can impact the performance either directly, by contributing phase noise at the readout, or by spoiling the performance of control loops. It is therefore essential on one hand to suppress the sources of stray light, and on the other to reduce the fraction which recouples with the main beam and the noise it produces.

In this perspective we are setting up a facility to measure the scattering properties of high quality optical surfaces to be used in GW detectors, with emphasis on the angular distribution and targeting a wide range of scattering angles. This facility will also be used for the characterization of new optical coatings for GW interferometers containing an engineered distribution of nano-crystals.

In parallel, we are studying the dust contamination on the optics in Various Virgo environments, starting from the Quantum Noise Reduction subsystem, in order to predict and eventually mitigate its contribution to stray light, which preliminary estimations place at or above the level contributed by surface roughness. This work will help understanding light scattering from dust in realistic conditions and set cleanliness requirements and cleaning protocols for the experimental environments of upcoming facilities and GW detectors.

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Session Classification: Stray light

Track Classification: Stray light

Contribution ID: **43** Type: **Invited Talk**

Wavefront sensing and control in Gravitational Wave detectors

Tuesday, 7 June 2022 15:20 (30 minutes)

In the past decades the sensitivities of gravitational wave detectors have been improved leading to the detection of more than 90 events. The detection rate should dramatically increase as the sensitivity of the interferometers improves. The LIGO/Virgo/Kagra Scientific Collaboration will increase the range and the sensitivity of gravitational wave interferometers by applying new techniques suitable for the current and the next generation of gravitational wave detectors. This achievement will be possible only when the device presents low losses. Specifically, the optical losses are worrisome for gravitational wave detectors, as, for example, they limit the benefit of future upgrades like squeezing. However, optical losses are responsible for signal to noise ratio degradation. For a gravitational wave interferometer the dominant optical losses are due to the mode matching into the output mode cleaner, as well as the mode matching between signal recycling cavity and interferometer arm. The current gravitational wave detectors design implemented thermal lens correction actuators in the recycling cavities to properly adjust the shape of the resonant light and additional actuators to improve the mode-matching with the external systems such as the Frequency Dependent squeezer and the output mode-cleaner. Here, an overview of the sensing and the control of the light wave-front, together with possible innovative techniques, will be presented.

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Session Classification: Wavefront sensing and control

Track Classification: Wavefront sensing and control

Contribution ID: **44** Type: **Invited Talk**

Crystalline oxides for mirror coatings

Monday, 6 June 2022 09:20 (30 minutes)

Reflective coatings on mirror bodies are key elements of gravitational wave detectors and are a topic of intense research in the community. Two classes of coatings are currently studied namely a broad range of amorphous compounds and a few crystalline materials. The latter group consists of AlGaAs / GaAs and AlGaP / GaP.

In this presentation, the potential of crystalline oxides coatings is explored. Considering the many crystalline oxide substrates that are commercially available in high quality grade, it is a clear that several of these can be used to build up optically reflective heterostructures.

A first selection is proposed based on a number of criteria that will be reviewed. These include: i) substrate considerations, ii) structural parameters, iii) solid state chemistry, iv) thermodynamics, v) elastic properties, vi) coating methodology and vii) coating tool design

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Session Classification: Optical coatings

Track Classification: Optical coatings