- GWADW 2019 -

Gravitational Wave
Advanced Detector Workshop

From Advanced Interferometers to
Third Generation Observatories

POSTERS

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Contribution ID : **2** Type : **poster**

Low-loss Faraday isolators

A crucial aspect of gravitational-wave detectors that use squeezing is the reduction of optical loss in the squeezed path, necessary to maximize the benefits of squeezed light injection. Faraday isolators in the squeezed light path currently contribute optical losses of about 10%, a figure which must be drastically improved to meet the sensitivity goals of these detectors. These low-loss isolators in fact serve as circulators, three-port devices. The University of Florida and Montclair State University are developing the two Faraday isolator designs required for the A+ squeezer upgrades. One would replace the output Faraday isolator and the other is used in the squeezer. The goal for the designs is ~1% loss in single pass.

Some highlights of the designs are:
- Clear apertures of 20 mm (output Faraday isolator) and 5 mm (squeezer Faraday isolator).
- Use of KTF as a low-loss magneto-optical material.
- Temperature tuning of the Verdet constant of the KTF.
- A vacuum compatible magnet, similar that of the Advanced LIGO input Faraday isolator.
- A custom, zeroth-order half-wave plate, with high quality antireflection coatings.
- Use of prism polarizers, where the optical layout allows and ofthin-film polarizers where it does not..

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

Passive Charge Management of Floating Test Masses in Inertial Sensors

Floating test masses (TM) accumulate charge through cosmic radiation and the triboelectric effect thereby downgrading the measurement precision of high sensitivity instruments. Instruments of interest include accelerometers, drag-free sensors and interferometers. For the TM requiring very low residual charge, 0.1 pC to 10 pC, a control loop consisting of a TM, a charge measurement system and a source of charges is presently utilized. However, the charge measurement system adds to the instrument complexity, is limiting the range of critical design parameters and is in itself a source of disturbance for the measurement. Through ground testing and space flight validation we demonstrate a passive bipolar charge reduction system using UV generated photo-electrons. The system converges to less than 0.1 pC from both positive and negative charges and does not require TM charge measurement. It can be conceptualized as a "free-electrons grounding wire".

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Contribution ID : **4** Type : **poster**

TianGO: A Space Interferometer Between the LISA and LIGO Bands

Space based interferometric gravitational wave detectors are sensitive to lower frequencies than their terrestrial counterparts due to the lack of seismic noise in space and the ability to make the arms longer. Space detectors can be used for multiband astronomy by providing an early warning for electromagnetic telescopes and by performing improved parameter estimation when combined with the terrestrial detector network. TianGO is a space detector with 100 km long arms sensitive to the frequency band from 10 mHz to 100 Hz. TianGO operates as a simple Michelson interferometer with 10 dB of squeezing to reach a strain sensitivity of $10^{-22}/\sqrt{\mathrm{Hz}}$. In addition to the prospect of doing multiband astronomy, TianGO's angular resolution provides a method of using binary black holes as standard candles to measure the Hubble constant and a path towards resolving the tension between the cosmological and local measurements.

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Contribution ID : **5** Type : **poster**

Prospects for Detecting Gravitational Waves at 5 Hz with Ground-Based Detectors

Current LIGO and VIRGO detectors are limited by a set of technical noises, such as controls noise and scattered light noise. In this talk, we will discuss what technology is required to reduce the low-frequency noises of the current detectors. I will also outline the status of the Birmingham experimental effort towards improving the low-frequency sensitivity of the future gravitational-wave detectors.

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Contribution ID : **6** Type : **poster**

Advanced Low Frequency Rotational Accelerometer 'ALFRA' for tilt measurement.

In order to reduce the low frequency seismic noise from GW detectors the seismic motion must be accurately measured at low frequencies, this is achieved through the use of seismometers. At frequencies below 100mHz however, the translational motion of the seismometer couples with the ground rotation 'tilt' causing inaccuracy in the translational measurements. One method to solve this is to independently measure the ground rotation and subtract this measurement from the seismometer. We report on the design, build and results of a tilt meter, known as the Advanced Low Frequency Rotational Accelerometer ALFRA, in development at The University of Western Australia. The ALFRA is a beam balance style tiltmeter with a resonant frequency of approximately 10mHz. The ALFRA is designed to remain stationary above the resonant frequency allowing the angle change between the ALFRA and the ground to be measured. Due to the desired use of the ALFRA a thin flexure of 10um is utilised in a cross flexure design allowing it to be mounted in either a vertical or horizontal position. The ALFRA is designed to have a sensitivity of approximately 10−10rad/$\sqrt{\text{Hz}}$ at 10mHz meeting the rotational measurement requirements of the Advanced LIGO detectors.

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Contribution ID : **7**

Type : **poster**

Towards Direct Spatial Mode Readout for Gravitational Wave Detectors

Understanding Higher Order Modes is of particular interest to the Gravitational Wave detection community. For O1 and O2 era detectors, misalignments, mode mismatching and optical defects excited Higher Order Modes causing low power build up, degraded contrast defect at DARM and control problems. The addition of squeezed light for O3 presents a new set of mode matching problems, as any mismatches directly affect the squeezing limited detection rate. Recent research at GEO600 shows that mode mismatches account for a significant amount of the squeezing loss.

I will present the characterisation of a novel mode analysis tool which directly reads out the modal content of a beam. Such a device could be used during commissioning to obtain a better mode matching, higher order mode suppression and improved squeezing throughout the detector - directly improving the detection rate of squeezing limited sources.

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Contribution ID : **8** Type : **poster**

Cancellation of gravity noise in underground detectors

Terrestrial gravity noise, also known as Newtonian noise (NN), will be a significant low-frequency noise contribution in present and future-wave detectors. Lowering this kind of noise is important since it will allow us to explore the existence of intermediate black holes and improve estimation of source parameters.

Current research focuses on NN from seismic fields. So far, only the cancellation of NN from seismic surface waves (Rayleigh waves) has been studied. However, also seismic body waves can give rise to Newtonian noise in surface detectors, but also (and especially) in underground detectors, where the test mass will be surrounded by rock. Building detectors underground, as planned for the Einstein Telescope, has the purpose to mitigate NN, but this will not be enough for ambitious low-frequency sensitivity targets as set by the Einstein Telescope. Additional mitigation can be achieved with coherent noise cancellation.

In this talk, results will be presented concerning the optimization of seismometer arrays for cancellation of NN from seismic body waves with Wiener filters. Optimal array configurations are shown together with the corresponding cancellation performance. The results make us confident that NN cancellation is a possible technology to help achieving the sensitivity target of the Einstein Telescope.

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Contribution ID : **9** Type : **poster**

Annealing effects on the mechanical losses of fluorides thin films

Fluorides like MgF2 and AlF3 have the lowest refractive index among the known coating materials; using them in a high-reflection (HR) Bragg mirror instead of SiO2, one could reduce the total HR coating thickness and hence its coating thermal noise.

A succession of annealing treatments at different temperature were performed on a silica disk coated with MgF2. The annealing was done in a controlled Argon atmosphere, in order to prevent the oxidation of the coating. After each annealing cycle, the Q-factor and the weight of the sample were measured, in order to extract the coating losses; after each annealing treatment, the Q-factor of the sample increased.

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Contribution ID : **52** Type : **poster**

Status of the frequency dependent squeezing experiment at TAMA

In the current and future generation of gravitational wave detectors, quantum noise will be one of the main limiting noise. Frequency dependent squeezing was proposed to achieve broadband quantum noise reduction. It can be realized by the combination of frequency independent squeezing and detuned Fabry-Perot cavity, usually addressed as filter cavity. A cavity length of 300m was proven to be optimal in terms of round trip loss per meter and detector's sensitivity improvement.

At NAOJ, we are testing the production of frequency dependent squeezing, by using one 300m arm of former TAMA detector as a filter cavity. We have already integrated and locked the cavity and we set up a frequency independent squeezing source in the central area of TAMA. Up to now, we have achieved 3.3dB of squeezing and 16.5dB of anti-squeezing above 100 kHz. We are currently working to improve the frequency independent squeezing performance and preparing the injection of the squeezing into the filter cavity.

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Contribution ID : **54** Type : **poster**

Reducing quantum noise for Advanced Virgo gravitational-wave detector by using dependent-frequency squeezing technique with Einstein-Podolsky-Rosen entanglement

To increase the science reach of gravitational-wave detectors, it is fundamental to reduce major noise sources such as quantum noise, generated by vacuum fluctuations entering the dark port of the interferometer.
It has been recently proposed that a broadband reduction of quantum noise in GW detectors can be achieved using a pair of squeezed EPR-entangled beams to produce frequency-dependent squeezing. A frequency-dependent optimization of the injected squeezed light fields is possible with this technique, without the need of an external filter cavity.

In this poster, we show the plans and R&D ongoing work for the implementation of EPR-entanglement squeezing in Virgo.

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Contribution ID : **55** Type : **poster**

Control of a Filter Cavity with Coherent Control Sidebands

The use of a detuned filter cavity together with a frequency independent squeezed light source is a very mature technique for the production of frequency dependent squeezed state. For stable alignment and length control of a filter cavity, we suggest a new control scheme of a filter cavity with coherent control sidebands which are used to control squeezing angle. Since both of coherent control sidebands and squeezed vacuum are aligned to OPO, squeezed vacuum is automatically aligned to a filter cavity with this scheme. In this poster, we present the principle of this scheme and some noise calculations.

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Contribution ID : **56** Type : **poster**

Optical Levitation of a Mirror

Optical levitation is a new method which can evade suspension thermal noise for optomechanical systems. A mirror is supported just by radiation pressure of laser beams, so suspension thermal noise is not introduced.

Optical levitation is important as a noise reduction technique and it enables us to examine quantum noise and possibly macroscopic quantum phenomena. Now we try to prove the stability of our sandwich configuration experimentally.

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

Multimaterial Coatings for 3rd Generation Gravitational Wave Detectors

Future gravitational wave detectors may operate at cryogenic temperatures using crystalline silicon test-mass mirrors and operate at higher wavelengths. We have begun the first mechanical loss measurements of a three-material based multilayer coating comprising of ion-plated silica, tantala and amorphous silicon. With this design, the low absorbing tantala is used in the outermost coating layers to significantly reduce the incident light power, while amorphous silicon is used only in the lower layers to maintain low optical absorption. Here we report on the first cryogenic measurements of the mechanical loss of these ion-plated multimaterial coatings.

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Contribution ID : **58**

Type : **poster**

Tensile strength testing of single crystalline silicon ribbons

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

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Contribution ID : **60** Type : **poster**

FINESSE simulation of near-unstable cavities with mirror maps

Near-unstable cavities have been proposed as an enabling technology for future gravitational wave detectors, as their compact structure and large beam spot can reduce the thermal noise floor of the interferometer. These cavities operate close to the edge of geometrical stability, and may be driven into instability via small cavity length perturbations or mirror surface distortions. They are at risk of suffering from problems such as high optical scattering loss and Gaussian mode degeneracy. The well-defined Gaussian beams can also be distorted through their interaction with the small imperfections of the mirror surfaces. These issues have an adverse impact on the detector sensitivity and controllability. We will report the latest simulation study of influences of mirror defects to modes in a near-unstable cavity, compared with the tabletop experiment carried out in Birmingham.

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Contribution ID : **61**

Type : **poster**

Cavity control with a surrogate field: model and experiment

Nd:YAG NPRO lasers at 1064 nm wavelength are essentially found in all advanced detectors to generate the interferometric signal that reflects the gravitational wave strain. The SHG field at 532 nm is used, among other purposes, as a surrogate of the 1064 nm field for squeezed light injection. The next immediate upgrades to the advanced detectors call for frequency-dependent squeezing featuring a detuned linear cavity where the 1064 nm field is off-resonance by one cavity linewidth. The precise detuning is controlled by the 532 nm surrogate field of the consequent dichroic optical cavity. The fidelity of the 532 nm surrogate to the 1064 nm field affects the phase stability of the squeezed field, and in turn the overall achievable squeezing level to the detector. Such dichroic cavity control technique is also being applied to the photon-regeneration cavity in resonantly-enhanced light-shining-through-a-wall experiments seeking axion-like-particles where the extremely low 1064 nm photon flux necessitates a surrogate to ensure a resonating cavity. The presented work will cover dedicated coating designs to facilitate dichroic cavity control, a refined model on the fidelity of the surrogation, and experiment results of a test dichroic cavity setup.

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Contribution ID : **62** Type : **poster**

Active seismic isolation for the AEI 10 m prototype interferometer

Seismic motion is the dominating noise source for large scale gravitational wave detectors at low frequencies. In order to extend the measurement band of the detectors to lower frequencies, novel seismic isolation techniques have to be developed, tested and implemented.
This poster presents the active control techniques of the seismic isolation system – AEI-SAS – used for the AEI 10m prototype interferometer. This is a testbed for large-scale gravitational wave detectors with the goal to measure and surpass the standard quantum limit. To achieve sufficient sensitivity, the main interferometer optics are isolated by triple-stage suspensions spread across three AEI-SAS for pre-isolation. The AEI-SAS is a soft mechanical isolation system combining low frequency passive isolation and active isolation. Novel methods to improve well-known active isolation techniques are explained and the inter-table control scheme based on optical sensors is presented. The overall isolation performance is shown and limitations are analyzed.

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

Amorphous and crystalline hybrid mirror coatings

The sensitivity of current gravitational wave detectors, such as Advanced LIGO and Advanced Virgo, is partly limited by thermal noise in the highly reflective coatings of the main test masses. Future detectors require the development of new coatings with low thermal noise, which also meet strict optical requirements and can be applied to significantly larger mirror substrates. Here, we present a crystalline-amorphous hybrid coating design [J. Steinlechner and I. W. Martin, Phys. Rev. D 93, 102001, 2016]. This coating uses a single layer of crystalline silicon, with negligible absorption and thermal noise, to reduce the light field in the highly-reflective amorphous coating layers underneath. This design will enable the use of amorphous silicon in coatings for gravitational wave detectors, reducing the thermal noise by a factor of two compared to current detectors, while meeting optical requirements and being available in the required large diameters. On this poster we present the coating design as well as first measurements in order to produce a prototype coating.

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

Investigation into the source and resulting effects of angular misalignments in fused silica fibres

Ensuring the satisfactory alignment of fused silica fibres is essential to obtain optimal performance of the monolithic suspensions in the aLIGO detectors. Current procedure is to eliminate any fibres that have angular misalignments between the stock to neck region greater than one degree.

Understanding the source of angular misalignments in the fibre production process and the potential effects that can result due to these misalignments is therefore essential.

This poster presents results of an ongoing investigation into how the misalignment of the fibre pulling machine and the CO_2 laser can result in angular misalignments between the stock to neck and neck to thin sections of a fused silica fibre during production. Results that will be presented will include an investigation into how to deliberately insert an angular misalignment during the fibre production process, how to calculate the angles that are present in these fibres and an investigation into the effect angular misalignments have on the maximum breaking load and break locations during destructive strength testing.

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Contribution ID : **65** Type : **poster**

Quantum locking with optical spring for space gravitational wave antenna DECIGO

Space gravitational wave antenna DECIGO is a laser interferometric gravitational wave detector, aiming at the detection of the primordial gravitational waves from the inflation. However, from the observation of Planck, the upper limit of the primordial gravitational wave amplitude was reduced. Thus it became necessary to improve the target sensitivity of the conventional DECIGO. It is quantum noise that limits the sensitivity of DECIGO, and the quantum noise cannot be reduced below the standard quantum limit (SQL) with the conventional detection method. One way to overcome the SQL is to use squeezing of light, but DECIGO cannot use squeezing with an arm cavity because its arm is too long and the refraction loss is too large. Thus we implement short sub-cavities and use the quantum locking. The quantum locking can eliminate the radiation pressure noise in a narrow band and break the SQL. In addition to this, we examine whether it is possible to expand the band, where the sensitivity beats SQL, by implementing an optical spring in the sub-cavities. We optimize the sub-cavity parameters and calculate noise. As a result, its sensitivity beats the SQL in a broader band than the case without the optical spring.

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

Preliminary performance of KAGRA's Type A suspension controls

In order to detect gravitational wave signals starting from few Hz, it is important to reduce as much as possible the free swinging of the test masses and keeping the detector working point.
Despite the low seismic background in underground sites, this is also true for KAGRA, whose seismic isolation system is equipped, similarly to Virgo, with several displacement sensors (LVDT) and three inertial sensors (accelerometers or geophones) and several actuators. A feedback control can be implemented at different stages of the suspension chain: Inverted Pendulum (IP), vertical GAS filters, Bottom Filter (BF). To reduce the horizontal swinging along longitudinal (L) and transversal (T) directions, the control on the Top stage (IP) has to be implemented.
To this purpose and to suppress the re-injection of the seismic noise via LVDT, the sensor blending technique, using also velocity of acceleration signals, is implemented. To reduce the Yaw motion of the pendula chain and the vertical oscillation, the damping controls of the resonance modes on the BF and on the vertical filters (GAS), making use only of the LVDT error signal has to be implemented.
The preliminary performance of this control strategy, applied on the KAGRA's Type A suspensions.

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Contribution ID : **105** Type : **poster**

The input optics of KAGRA

We are developing the input optics of KAGRA. The objective of the input optics is to provide stable laser light to the main interferometer. So far, almost all system for the O3 has been installed. The maximum power of the output power from the input optics to the main interferometer is 20 W. We have a pre-mode cleaner, a frequency stabilization system, an intensity stabilization system, a modulation system with Mach-Zehnder interferometer, and an input mode cleaner. These systems are working stably and the performance investigation is ongoing.

In this poster, we will describe the status of the input optics of KAGRA for the O3.

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Co-author(s) : ON BEHALF OF THE KAGRA COLLABORATION

Contribution ID : **106** Type : **poster**

A Cryogenic Testbed for High-Q Thin Films and Optical Coatings

A limiting source of noise for optomechanical experiments, including next-generation gravitational wave detectors, is coupling to the thermal bath of the mechanical system. We present a recently developed cryogenic testbed for measuring the internal friction of thin disk resonators with rapid sample turnover. The apparatus makes use of an amplitude-locked loop to continuously measure the quality factor and eigenfrequencies of several resonances of the system, permitting precise, non-contact temperature control. The testbed has application to the development of amorphous silicon coatings on silicon substrates for use in next-generation gravitational wave interferometers, and for other thin film development.

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Contribution ID : **108** Type : **poster**

Plan for the global control using strain-meter for KAGRA

This poster describes a plan for global control using strain-meter for KAGRA. Strain-meter is a very asymmetric 1500 m Michelson interferometer whose two end mirrors are mounted on the ground directly to measure a strain of the baseline and currently installed only X arm of KAGRA. This strain-meter is installed for not only monitoring some geophysical phenomena such as the Earth tide, free oscillation of the Earth and strain step before and after an earthquake but also measuring a baseline of KAGRA. In this poster, we propose a global control so that an arm cavity isolated by two pre-isolators on the input and end masses are stabilized by strain-meter signal using a sensor correction technique. This method can correct a feedback signal of pre-isolator so that arm cavity length goes to be the constant length from DC to 1 Hz. Therefore, our global control method would improve a lock acquisition directly whenever earthquake or high microseismic come.

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Contribution ID : **109** Type : **poster**

Considerations on Michelson beam splitters for third generation Gravitational Wave Observatories.

The large test masses of third generation Gravitational Wave detectors and the possible 60 degree angle of the proposed ET triangular configuration impose difficult requirements on the size and quality of the beam splitter.
A method is presented here to allow use of beam splitters of arbitrary size, at the optimal 90 degree angle, while also offering a way to dynamically correct the mode matching of the two interfering light spots.

Primary author(s) : DESALVO, Riccardo (University of Sannio - RicLab)

Contribution ID : **110** Type : **poster**

Practial Limitations on Polarisation Depended Speedmeter Interferometers due to Birefringence

Of the topologies of speedmeter interferometers considered for future gravitational wave detectors, a number rely on polarising optics to separate orthogonally polarised light propagating within the interferometer. A speedmeter interferometer as a third-generation gravitational wave detector would have inherently lower quantum noise, but the technology behind such a detector first needs to be demonstrated.
In this work the limitation of the polarisation Sagnac speedmeter scheme due to birefringence effects is investigated with experimental characterisation of suspended polarising optics and a measurement of the birefringence effect of a resonant cavity.

Primary author(s) : SPENCER, Andrew (University of Glasgow)

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

Laser power stabilization via radiation pressure

This work reports a new scheme for laser power stabilization aimed to be implemented in the future generations of gravitational wave detectors as an alternative for the traditional scheme. In this new scheme the power fluctuations of the laser are transferred to phase fluctuations via radiation pressure in a micro-oscillator. The phase fluctuations are then detected with a Michelson interferometer, which is now the sensor in the power stabilization control loop. Since the transferring process is done with the full beam power, a higher signal to noise ratio due to shot noise in the detection path is achieved in comparison with the traditional scheme. Another advantage from this setup is that no light needs to be wasted in the detection process. In the poster some first results of a proof-of-principle experiment will be shown, and the sensitivity and limitations of this setup will be discussed.

Primary author(s) : TRAD NERY, Marina (AEI, Hannover); WILLKE, Benno (Albert Einstein Institute Hannover)

Contribution ID : **112** Type : **poster**

Status of LIGO Voyager

This poster discusses the status of plans to extend the science reach of the existing LIGO facilities in a next generation cryogenic upgrade, LIGO Voyager. The upgrade will rely on heavier silicon test masses, increased laser power, low thermal noise suspensions and coatings, and the latest techniques in quantum limited interferometry to approach the sensitivity limits of a 4km observatory.

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Contribution ID : **113** Type : **poster**

Bilinear noise subtraction at the GEO600 observatory

We develop a scheme to subtract bilinear noise coupling to GW strain data and demonstrate it at the GEO600 observatory. We target longitudinal feedback signal used to control the signal-recycling cavity (S1) length and investigate modulations caused to it by the angular alignment control signals. We first demodulate strain at one of the calibration-line frequencies and obtain its coupling from low-frequency tilt alignment signal (S2). A coherent bilinear signal is then constructed from the product of S1 with S2 and is subtracted from strain via IIR-filtering. In general, the presence of broad dynamic range and resonances in transfer function lead to inaccurate system identification resulting in sub-optimal time-domain filtering. We tackle this by developing a transfer function fitting routine based on surrogate optimization that searches across parameters such as filter order and pole locations. With minimal human effort we create a stable yet accurate model of the measured response. The resulting bilinear signal subtraction leads to 2 dB reduction around the modulation side-bands and 1 dB reduction across the noise floor(250-500 Hz). Finally, we analyze the readiness of the filter for real-time operation and explore possibilities of an adaptive filtering scheme that can account for the changing system dynamics.

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Contribution ID : **114** Type : **poster**

Cavity mode-mismatch sensing by injection of RF LG01 sidebands

Achieving cavity mode-matching close to the 100 percent level is key factor in the reduction of the overall optical losses that compromise the performance of squeezed-vacuum injection in modern GW interferometers. A reliable and precise sensing technique of the mode-mismatch is essential for the implementation of suitable correction systems. The few alternatives currently available are not well-established, and often bear considerable technical difficulties.
We are developing a technique to recover information about beam waist size and position mismatch by exploiting the injection of RF sidebands in the Laguerre-Gauss 01 mode using a custom electro-optic lensing device. The error signal is obtained by I/Q demodulation of the same single-element PD usually already present in reflection of the cavity for PDH locking. Compared to other mismatch-sensing techniques, our approach is significantly less demanding in terms of hardware and electronics needed.

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Contribution ID : **115** Type : **poster**

Tackling optical aberration: the path towards future detectors

The operation and sensitivity of the gravitational wave detectors can be strongly limited by wave-front aberrations, if not properly tackled. These aberrations are due to intrinsic defects in the optics and to the rise of thermal effects, i.e. optical power absorption in the substrate and coatings of the mirrors that induces both an increase of the optical path length (thermal lensing) and a thermo-elastic deformation along the optical axis. All these imperfections can be compensated for by generating proper optical path length corrections. An adaptive Thermal Compensation System (TCS), has been installed and is operating in Advanced Virgo: it includes wave-front sensing and actuators for correcting both the thermal lensing and the surface deformation of optics. While the TCS strategy and design are well suited for the advanced detectors, there is still room for substantial improvement. The third generation of interferometric detectors will surely need an adaptive control of aberrations; for instance, the high frequency component of Einstein Telescope will also suffer from optical aberrations, with the additional issue of the possible use of the LG33 mode, instead of the TEM00. The ongoing research activity for improvements of the adaptive optical system in view of third generation detectors is presented.

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Contribution ID : **116** Type : **poster**

Thermoelasticity in crystalline materials for coating research

The visibility distance of interferometric gravitational wave detectors is limited by mirror thermal noise at mid-range frequency, where the first coalescence GW signals have been detected and many others are expected in the next future. In particular, for 2G+ and 3G we need to increase the performance of the test mass multilayer reflective coatings, developing new materials and technologies. In order to obtain reliable coating loss angle measurements, a specified protocol for measurements with GeNS suspension and detailed models of the substrate mechanical loss has been developed by the Virgo coating R&D collaboration, inside the metrology research line. One of the main topics is the study of thermoelastic damping in crystalline materials, that are promising candidates for cryogenic test masses and particularly suitable substrates for coating research . The model of thermoelastic loss in silicon and sapphire substrates, based on a semi-analytical calculation starting from the heat diffusion equation, will be reviewed and compared with experimental measurements. Moreover, a study on the changes in the peak of the thermoelastic loss angle after coating deposition, with some preliminary results, and sideas toward a future experimental approach to quantify the effect will be also shown.

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Contribution ID : **117** Type : **poster**

Inhibition of Annealing-Induced Crystalization in Nanolayered Titania-Zirconia Composites

The sensitivity of present interferometric gravitational wave detectors is limited by thermal noise in and light scattering from the mirror optical coatings. Many thousands of optical scatterers were observed in the mirrors of the current generation GW detectors. These scatterers, potentially crystalline, may also produce internal friction and be the source of the thermal coating noise.
We show that alternating layers of Titania and Zirconia on the order of few nm in thickness can be annealed to surprisingly high temperatures without crystalizing. Higher annealing temperature is known to reduce mechanical dissipation and thermal noise, and if the inhibited crystallization also reduces the scattering, better sensitivity for GW detection can be obtained with nano-layered coatings.

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Contribution ID : **118** Type : **poster**

Quantum noise in coupled cavity systems

In this poster we present the preliminary results of our investigations on the implications of having a non-linear element in one of the cavities of a three mirror coupled cavity system[1]. This system is analogous to the cavity formed by the signal recycling mirror with the arm cavity of a dual recycled Fabry Perot Michelson interferometer[2]. Current modelling suggests the presence of a non-linear element influences both the signal and noise transfer functions of the coupled cavity at the its pole frequency. This frequency is determined by the transmission of the coupling mirror between the two cavities.

In case of equal length cavities, the response of the coupled cavity peaks at the coupled cavity pole (also called splitting frequency). In such a system, the signal sidebands are symmetrically distributed around the splitting frequency. The presence of a non-linear element here, enhances the response at this frequency. This could potentially be of interest for interferometers with long signal recycling cavities which are focussed on detecting gravitational waves in the high frequency regime.

[1]Korobko et.al. 'Quantum expander for gravitational-wave observatories', arXiv:1903.05930 [quant-ph]
[2]E McClelland David (1995) An Overview of Recycling in Laser Interferometric Gravitational Wave Detectors. Australian Journal of Physics 48, 953-970.

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

Low-Noise External Cavity Diode Laser at 2 Micron

Proposals for silicon-based next-generation gravitational wave detectors target a laser wavelength of 2 μm [1], where Thulium and Holmium-based fiber amplifiers present possible routes towards high-power operation. We are developing a compact low-power fiber-coupled seed laser design based on a commercial diode laser module in an external cavity geometry [2]. The laser is frequency-tunable by angular control of an intra-resonator grating within a 100 nm window at 2 μm, and additional frequency modulation can be achieved by direct modulation of the diode current at MHz – GHz speeds. We present the laser design and discuss preliminary stability results.

[1] Abbott et al., Class. Quantum Gravity 34, 044001 (2017)
[2] Bennetts et al., Opt. Express 22, 10642-10654 (2014)

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Contribution ID : **120** Type : **poster**

Quantum noise reduction schemes at cryogenic temperatures

On this poster we are presenting the current status and outlook on an experiment aimed at the proof-of-principle demonstration of coherent quantum noise cancellation. This feasibility study will first be conducted at room temperature, then at cryogenic (milli-Kelvin) temperatures. We aim to reduce backaction (radiation pressure) noise by introducing another harmonic oscillator with an effective negative mass, to coherently cancel the noise via destructive interference. This oscillator will consist of a detuned ancilla cavity coupled to the meter cavity with a beam splitter and a two-mode squeezing process, non-degenerate in polarisation. On this poster we present first steps towards the cryogenic stage of this experiment and show the proposed layout as well as initial milestones.

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Contribution ID : **122** Type : **poster**

Direct Measurement of Coating Thermal Noise at 1550nm

On this poster we present the current status and outlook on an experiment aimed at directly measuring coating thermal noise at a wavelength of 1550nm. In collaboration with the Fraunhofer Institute in Jena one goal of this experiment is to measure thermal noise of monolithic silicon mirrors (resonant waveguides). Additionally the experiment can also be used to measure dielectric coatings. The measurement scheme as well as the initial cavity layout follow the MIT experiment in which coating thermal noise was measured at 1064nm [S. Gras et al. 2017, PRD 95.022001]. On this poster we present first steps towards the final experiment and show the proposed layout as well as initial milestones.

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Contribution ID : **139** Type : **poster**

A High-Frequency Gravitational Wave Detector

The gravitational waves emitted from coalescing binary neutron stars systems or neutron star-black holes contain information about the structure of nuclear matter at extreme densities. The late in-spiral is influenced by the neutron star equation of state. Post-merger remnant neutron stars are expected to be produced. These rapidly rotating remnants emit gravitational waves, providing clues to the hot post-merger environment — a likely source for r-process elements. Very high sensitivity in the band between 1-4 kHz is crucial if these gravitational wave signatures are to be detected. This level of sensitivity is not currently achievable with the most sensitive of current generation detectors for mergers that occur on yearly timescales. We present the design concept and science case for such a gravitational-wave detector, optimized to study nuclear physics with merging neutron stars. This interferometer can achieve sensitivity comparable to third generation detectors between 1-4 kHz regime because interferometers in this spectral band are predominantly quantum phase noise limited, lessening the requirements on technical displacement noise sources, thus reducing the costs. The concept focusses on designs that make high levels of circulating arm power and optical squeezing to maximize sensitivity in the high frequency regime.

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Contribution ID : **147** Type : **poster**

Cryogenic operation of GeNS: first results from LMA+Discussion

Future generations of GW detectors will operate at cryogenic temperatures. This opens up a whole new set of scientific challenges as not only new materials have to be tested, but also different measurement techniques. Keeping this in mind, we have adapted the GeNS measurement apparatus, already one of the main tools for the estimation of the internal friction at room temperature, to work inside a closed cycle cryostat in order to have an inexpensive way to probe the mechanical properties of the candidate materials across a vast range of temperatures. We report here some preliminary measurement results on bare and silica coated (the coating was performed at LMA) silicon substrates achieved in the context of a collaboration with Naval Research Labs.

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Contribution ID : **152** Type : **poster**

The Archimedes Experiment

Archimedes is an experiment conceived to shed light on one of the most intriguing topics of the modern physics: the interaction between the gravitational field and the vacuum fluctuations. The experiment will measure the force exerted by the gravitational field on a Casimir cavity, whose vacuum energy is modulated with a superconductive transition, by using a balance as a small force detector. Archimedes is an INFN six-year project that will be installed in the SARGRAV laboratory placed in an old mine located the Sardinia italian region. This site is characterized by a very low seismic noise so it is the ideal environment for null force experiments and for third-generation gravitational waves interferometers like ET.

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