NEWS

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Gravitational waves detectors

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WP-3 Co-Leaders

WP3: Gravitational wave detectors (Research, Training, Transfer of Knowledge)

Lead: UNIPG

Participant: INFN, UNIPI, UNINA, UNIPG, Impex, EGO, CNRS, CALTECH, NAOJ

Objectives

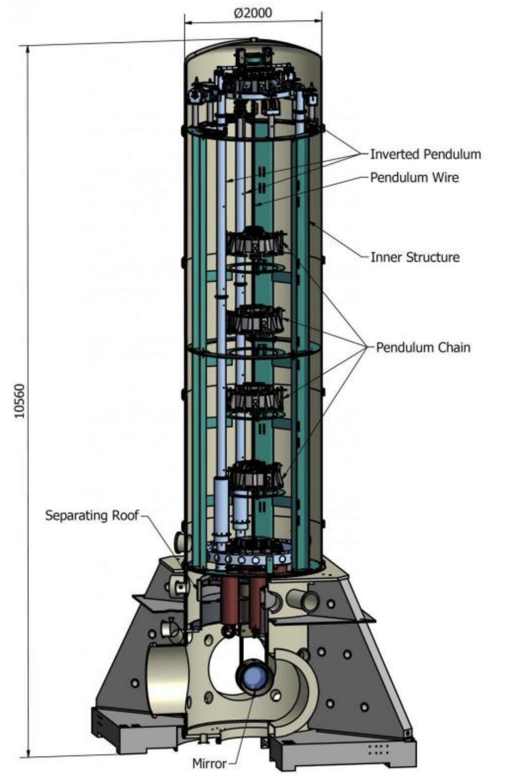
O3.1: Test the frequency dependent squeezing on a fullscale prototype, before using this technique in the Advanced detectors.
O3.2: Develop a subtraction scheme for non stationary gravity gradient noise.
O3.3: Study of silicon and sapphire materials for third generation monolithic suspensions.
O3.4: Study of payload and seismic suspension systems for cryogenic facilities
O3.5: Implementation of advanced control techniques for second and third generation gravitational wave detectors

Motivations

- At the present time gravitational wave physics has started with two detectors in US (Advanced Ligo) and now the one in Europe (Advanced Virgo) is also joining.
- In the near future the Japanese KAGRA detector will start taking data.
- The aim of this WP is to optimize the improvements on R&D to improve the sensitivity of advanced gravitational wave detectors.
- The main noises particularly interesting from the point of view of scientific motivations are Seismic Noise, Newtonian Noise, Thermal Noise and the Quantum noise.

Seismic noise

- Reducing seismic noise is mandatory to extend the bandwidth of detection below 10 Hz. To increase further the detection bandwidth the control approach must be updated. This will be done both by improving the sensors and the control algorithms.
- At low frequencies the signals are generally dominated by tilts. An attempt to realize low frequency tilt-meters to improve the control strategy is in progress. In Advanced Virgo the platform of the inverted pendulum at which the Super Attenuator chain is hanged is controlled using accelerometer sensors.
- An important activity will be the extension of the use of adaptive optimal regulators, based on advanced control techniques



Newtonian Noise

For the Advanced detector generation the main goal is to develop a gravity-noise cancellation system.

- A detailed characterization of the detectors' sites will be carried out to characterize the seismic fields. This is fundamental to design the seismic arrays for noise cancellation. A large number of seismometers will be used, combined with numerical simulations to improve the noise model.

- The seismic arrays will be used also for a first coherent detection of gravity noise in the gravitational-wave (GW) channel. This will lead to the possibility of noise cancellation: seismic arrays in the vicinity of the test masses will provide a coherent estimate of gravity noise, which can be subtracted from the GW channel.

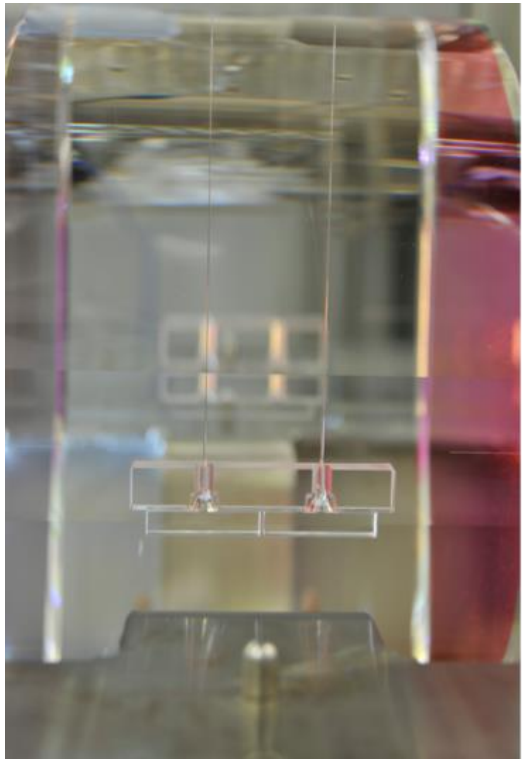
- The non-stationary nature of seismic fields can lead to much greater transient gravity noise. These transients can greatly limit the sensitivity towards low-frequency GW signals such as the merger of two intermediate-mass black holes.

- This experience will be directly relevant to LIGO and Kagra. Scientific exchanges are foreseen.

Thermal Noise

Thermal noise is a fundamental limit for the sensitivity of these kind of detectors. There are several different aspects for limiting this problem studying the materials and the mechanics of the suspensions:

- Suspension fused silica fibers need to be studied better, particularly from the point of view of their sensitivity to the environment and the losses connected to the bonding of the fibers itself and the mirror.
- The minimization of losses generated by the optical coatings of the mirrors, which can be done by doping the coating material is also demanding and still and open question.
- The possibility to study a cryogenic evolution of the present suspension at the EGO site as an upgrade is foreseen. Silicon or sapphire are the foreseen materials in this case. Virgo has already installed a cryogenic line, at 77 K, implementing the cryotraps. New sensors compatible with cryogenic temperatures will be built and installed. The ongoing collaboration with the Kagra (cryogenic) experiment is fundamental.



Quantum noise

Quantum noise is a fundamental limit for the detector sensitivity. Several strategies have been elaborated in order to reduce it, mostly based on the use of squeezed states of light.

- The production of squeezed states is a well demonstrated procedure. The peculiarity of squeezed light needed in gravitational wave experiments is that a good squeezing must be available at the comparatively low frequencies of interest for the sensitivity.

- The effort to increase the squeezing level and to demonstrate the possibility of tuning the squeezing angle in a frequency dependent way is ongoing with the participation of several NEWS researchers and is expected to produce relevant results in the next years.

Interactions

- The activities concerning the implementation of the optical structure for quantum noise reduction will involve mainly CNRS, UNINA and NINS-NAOJ.
- The gravity gradient noise issue will need interaction between INFN, UNINA, EGO and CALTECH.
- Several interactions between the partners of the project are already ongoing for the activity about cryogeny. These will involve INFN, UNIRO, UNINA, UNIPG and Impex as an industrial partner, together with NINS-NAOJ and the KAGRA experiment. Some of these activities overlap with the activity about monolithic fiber suspension, which involve mainly INFN, UNIPG, CALTECH and Impex.
- Advanced control techniques will involve INFN, EGO and CALTECH.