Research Report
ICRR Inter-University Research Program 2019

Research Subject:
Cryogenic Test masses, Isolation, suspension and coatings

Principal Investigator
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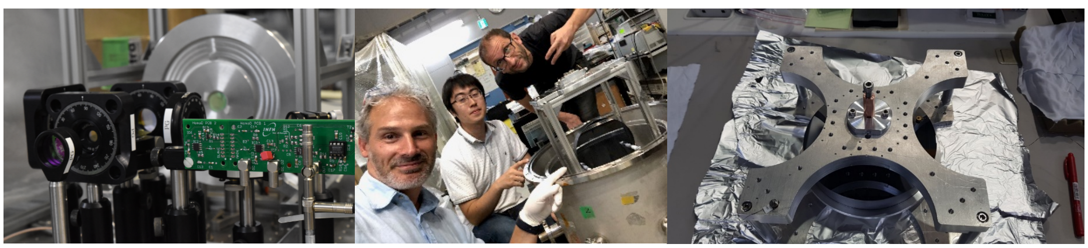
Summary of research results:

Silicon monolithic suspension R&D
This research line was divided into 3 sub-lines: fibers, substrate and control
We characterized silicon fibers produced with three methods, having different doping and different surface quality. Firstly, we measured the thermal conductivity of the fibers at cryogenic temperatures to see if there is a correlation between it and their characteristics. Then we measured the mechanical internal dissipations and then their breaking strength.

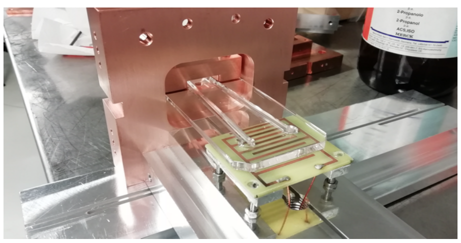


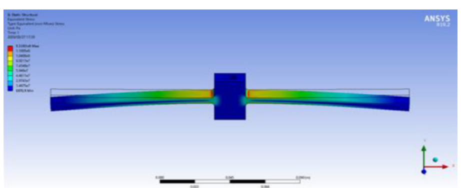
A nodal system was designed and produced in the last fiscal year and tested in a cryostat at ICRR with a silicon substrate. In the last months the barrel of the silicon substrate was polished to reduce the surface losses. Moreover, two lateral flats were machined with a polishing of λ/10 to allow the gluing of the lateral supports, essential step for realizing the monolithic suspension
Furthermore, a homodyne system was developed and tested at ICRR to allow good control of a suspended substrate in a noisy environment such as a cryostat powered by a pulse tube and with three vacuum pumps. The homodyne system is also able to extract the signal to measure the internal losses of the substrate.
All the results and a deeply description of the systems are published in a conference proceeding (DOI: 10.5281/zenodo.3820523).

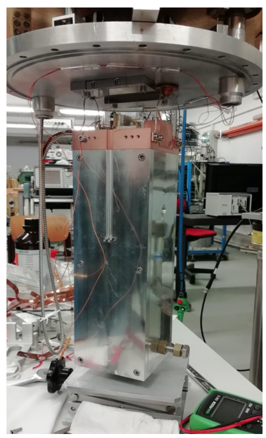
Local control of payloads
The following items have been object of collaboration with KAGRA. 1) low frequency jitter in OpLev system (f<1 Hz) due to air refractive index and general overview of SLED lifetime statistics. 2) Indeed, due to non-clear reasons, ageing is an issue in KAGRA while it isn't in Virgo (3-4years) showing up a lifetime 3 times longer than expected (104 hs). OpLev system adopts BLMS-mini driver using SLD-261-MP2-DBUT-SM-PD-FC/APC and Pilot 4-AC + Superlum SLD-261-MP2-DBUT-SM-PD-FC/APC. 3) Strict collaboration with L. Trozzo (KAGRA staff, SAS) concerning suspension attenuation system performance versus payload control.

Developments on cryogenic payload themes.
The parts of present cryogenic payloads of KAGRA have been developed by testing one-by-one the components of the suspension, considering the mechanical dissipation (leading to

thermal noise estimate) and thermal conductivity. The ICRR Inter-University project aimed to perform the due tests meant to exploit a cryogenic facility in Rome, where the highest values of sapphire quality factor had been measured to: A) measure/check some spare components identical to those finally adopted in KAGRA payloads and B) design improved versions. We partially succeeded, because we properly outlined some clear points. We estimated the cost of new designs to be tested. However, we were not able to finalize an order (due to limited budget in 2019, we plan to purchase the new elements in 2020 in the context of the new project). We modified the apparatus previously used to select Al2O3 suspension rods to test sapphire with three different designs: straight, straight with step and actual (KAGRA), collaborating with T. Yamada.
Quality factors of blades measured adopting a specific design of suspension block in the cryostat in Rome Univ. were generally higher (e.g. 8.9e4 versus 2.0e3 measured in Japan (ICRR/KEK). Suspension concept/design of the apparatus passed to KAGRA
As expected, the measurements showed up limitation to the achievement in high Q design concerning three factors: stress at the clamp, recoil on the stricture, shape of the blade at the level of the clamp.
We finally designed a new concept of double blade and inquired companies in Europe and in Japan about quotations.

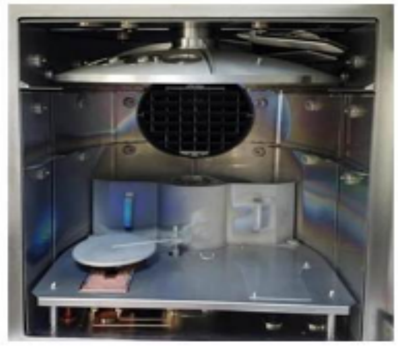






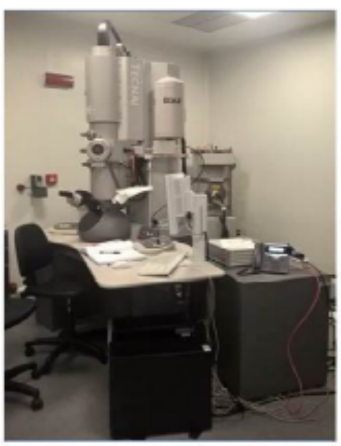
Coating R&D
Coating R&D work has been focused on the following specific topics : 1) downselection of most promising material pairs for (binary) nanolayered-based coatings; 2) deposition of nanolayered composite film prototypes at the USannio facility, and morphological (AFM, SEM, XRD, Raman) analysis of the prototypes, aimed at understanding crystalization dyamics under different annealing conditions; 3) cryogenic characterization of mechanical losses in Silica-Titania nanocomposites (collaboration w. NTHU); 4) Global optimization of binary coatings; 5) investigation of stacked-triplet ternary coatings.
The main results obtained have been summarized in the following documents : 1) LIGO-G1902327; 2) LIGO-G2000454; LIGO-G1902311; 3) LIGO-P1900090, Proc. PIERS-2019, pp. 2437-2442, doi: 10.1109/PIERS-Spring46901.2019.9017449; 4) Opt. Materials 96 109269 (2019); 5) LIGO-G2000218.
The following pictures illustrate the facilities owned by the Sannio and Salerno Labs, and used in our coating R&D work.

iCoRe Optical Film Deposition Lab
at the University of Sannio



- Up to 6 co-deposited materials;
- Dual e-beam (one installed);
- Plasma IAD;
- Fully programmable deposition with GUI;
- Accuracy/repeatability at the Å level;

iCoRe Optical Thin Film Characterization Facilities
at the University of Salerno



Left to right, top to bottom:
FEI Tecnai 20 (TEM);
Zeiss LEO-EVO 50 (EDS-SEM);
Zeiss Sigma Gemini (FE-SEM);
Renishaw Invia (Raman);
JPK Nanowizard 3 (AFM);
Philips 'Xpert-Pro (XRD);

No.