Form 8

Research Result Report
ICRR Inter-University Research Program 2022

Research Subject

Silicon steering stage for monolithic suspension for cryogenic detectors of gravitational waves

Principal Investigator

Flavio Travasso

Participating Researchers

Helios Vocca
Ettore Majorana
Luca Naticchioni
Mateusz Bawaj
Takayuki Tomaru

Summary of Research Result

Given the results obtained from the previous ICRR proposals, for FY2022, our group has requested to continue the research activity initiated in collaboration with ICRR and KAGRA in order to improve the performance of the current cryogenic payload and progress towards a new monolithic suspension design. The main points of the project concerned:

1) *Production of a silicon steering stage*

For this activity, we contacted (thanks to the kind support of Dr. Ushiba) the same Japanese company that in 2020 was able to work a slightly smaller silicon support than what we were proposing now (2.2kg vs 4.6kg). Unfortunately, the company had some concerns about the feasibility of our design. Due to the international COVID situation, we were unable to complete at ICRR all the tests needed to respond to the company in 2022, so we are still discussing this. Furthermore, due to the distances, it has always been very difficult to discuss the respective requests and limitations. For this reason, a face-to-face meeting was decided to be carried out between May and June 2023, the date in which part of the research group should be in Japan.

Since the major economic demand of the project concerned the processing of the silicon support, the project funds for FY2022 are practically untouched. For this reason, a carrying over request was made for FY2023

2) *Measurement of the quality factor of the silicon substrate*

Between FY2021 and FY2022 a nodal system for measuring the quality factor of

massive substrates placed at cryogenic temperatures was developed in Italy and assembled in the ICRR laboratories and in particular it was placed inside the cryostat of KAGRA Group. The first cooling tests, using the smallest silicon substrate (the 2.2kg one), were carried out between 2021 and 2022. In August 2022, the first ring down measurements were carried out at cryogenic temperatures. New measurements are planned for 2023 in order to test the repeatability of the measurements, the reliability of the system and any systematic errors introduced.

3) *Bonding and testing of silicon and sapphire parts*

Bonding tests between silicon and sapphire parts were carried out at ambient temperatures with good results (breaking strength around 10MPa). The next step will be to make measurements around 10K. We are also trying to implement a new method capable of gluing the fiber heads (which are only placed under compressive stress) so that they are firm during normal data-taking operations but which allow easy removal in the event of a suspension accident.

Furthermore, we pursued the activity concerning sapphire component developments. In this context we tested a new shape for the mirror suspension blade, designed through the collaboration between Roma and KEK researchers involved in cryogenic payload R&D, and equivalent, as a single piece, to a pair (double headed). The blade was tested in Rome and at low temperature showed up a quality factor similar to the one of the original blade installed in KAGRA. Through this experiment we learnt that **A)** monolithic bulk should be machined at the blade clamp to increase the Q, as we observed in the past this behavior while the ne new blade, like the KAGRA one has no bulk block be clamped at and **B)** CMP (Chemical Mechanical Polishing) surface treatment does not improve the quality factor. Since, according to the manufacturer (Shinkosha), CMP on sapphire is expensive and constrains the capability of shaping the blade clamp as desired, we further investigated the breaking strength under bending in collaboration with KEK. In this case the measurements were carried out in Japan, at Tokyo Metropolitan Industrial Technology Research Institute. Through these measurements we learnt that **C)** concerning breaking strength CMP performance is undistinguishable from more usual DP (Diamond Polishing), and **D)** that 1GPa can be safely assumed as a reference value for the breaking stress of sapphire under bending. Under such a scenario we go ahead with further sapphire suspension blade developments.

No. G001