

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
-LIGO-
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Minutes of July 28 rd meeting in CNR Tor Vergata, Roma.		
Participants: Alessandro Bertolini, Francesco Cordero, Riccardo DeSalvo, Francesco Fidecaro, Veronica Toccafondo. On the phone: Jean Marie Mackowsky.		

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of the LIGO Project.

California Institute of Technology
LIGO Project – MS 51-33
Pasadena CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – MS 20B-145
Cambridge, MA 01239
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

WWW: <http://www.ligo.caltech.edu>

The meeting was to perform a first test of a new fiber readout for ringdown measurements in slab samples and to discuss on the best strategies to measure the mechanical quality factor in coating samples.

The new fiber readout system consists of fused silica optical fibers bundled on one end, split in two smaller bundles on the other end. Each bundle of fibers is fused together for mechanical stability and polished. Of the smaller bundles the first small bundle is used to inject light and the second to collect and detect it. In the bigger bundle the fibers from the injection and detection bundles are randomly alternated.

If a reflector is placed in contact with the bundle, the injected light is reinjected back on the same fibers and none in the detection fibers. If the reflector is moved progressively away some light, that exits on a 15° cone, is reflected back into the detection fibers. At an optimal distance several percent of the injected light can be collected in the detection fibers. Half way, the amount of light transferred from the injection to the detection fibers is proportional to the distance and can be used to measure its movements with a theoretical resolution of $1A/\sqrt{\text{Hz}}$.

A first rough test was made in comparison with the existing capacitive readout of a sample, and without quantitative measurements, we concluded that a S/N substantially better than the existing one. This despite the total absence of a suitable light injection and detection mechanics and optics and of the coupling to the sample mechanics.

Veronica will analyse some data and give an attempt of semi quantitative evaluation of this rough test.

Particularly useful is the fact that the readout proved to work well with separations from a fraction to more than one millimeter with no need of precision couplings. Mechanically solid couplings though, will be needed for next tests.

This technique may be useful also for a variety of techniques, including, maybe, mirror position readout.

The technique is extremely promising and it was concluded that more development is fully justified.

Also the test was made with DC injection and detection, which was OK on the $\sim\text{KHz}$ resonance, it would require MHz modulation of the light if low frequency measurements were desired.

About measurement of loss factors in coatings.

It is realised that the standard nodal support sample measurement (using rectangular slab samples and supporting them with two wires on the nodes of a mode) is cumbersome and has a reliable sensitivity of the order of the ppm. Better sensitivity can be achieved with more effort but the reproducibility of the measurement is difficult to assure (the nodal positioning is difficult to guarantee).

It is not an easy technique for large number of measurements.

Also a coating, that cannot be thicker than a few microns, over a mm thick slab contributes \sim percent of the mechanically stored energy of the resonance. This dilution, in conjunction with the $\sim 10^{-4}$ measured loss factor in Tantalum Oxyde makes the nodal support measurement marginal. This technique has been proven at Lyon that it can

distinguish between a standard Tantalum Oxide and the enhanced one (1.3 times better), but in case of success (substantially higher coating Q factor) it would have hard time distinguishing between various samples to allow optimization.

Improvements can be made using thinner samples (better coating to substrate ratio), but thin substrates bring in problems of measurement stability (the sample tend to drift away from the nodal support positioning when they are too light).

We discussed on other options.

The standard cantilever sample measurements have problems of clamping and reproducibility.

We concluded that a thin (~100 micron thick) cantilever mached out of a 2-3 mm thick fused silica piece would be fine.

The cantilever would be ground out of the center of a much larger FS slab using the Pisa Ultra Sound milling machine, polished and annealed in oven to cure the surface and restore the FS cantilever Q factor (there are good chances that we will be able to recover $\gg 10^6$ Q factors for such cantilever beam).

Clamping the sample on the thick slab will ensure a much better reproducibility.

Comparison of measurements before and after coating would be much more believable.

Moving to thin cantilevers will reduce the dilution of the coating losses, improving S/N, but it will also move the resonant frequency to lower frequency. Measurements of coating Q factors at ~100Hz, although more difficult, will be even more interesting because they will be exactly in the frequency region of interest of GW interferometers.

After development, this technique should be suitable for fast (same day) Q-factor measurements in Lyon, necessary to explore the different coating compositions.

The nodal support or cantilever resonance measurements are routinely performed at temperatures between liquid helium to a few hundreds Kelvins. JMM indicated that Q factor measurements at room temperature or over a range of few tens of degrees around room temperature would be sufficient for now. In case of a promising coating material, precision measurements may be made in the specialized laboratories in Roma.