

LSC Six-Month Progress Report

LIGO-M000320-00-M

Organization Caltech Experimental Gravitational-Physics Group (CEGG)

Report Date August 15, 2000

Attachment A - LIGO I

Item-task 9 - Not Applicable

Attachment B - Isolation/Suspension/Thermal Noise

Work Relevant to Advanced LIGO, and future upgrades

1. Development of an initial coupled-suspension system and exploratory experiments with it.

In view of the possibility of application of coupled-suspension techniques in Advanced LIGO or future upgrades, effort in this reporting period has been concentrated in this area to improve understanding of some of the phenomena involved.

The first version of a coupled suspension system put into operation has involved double-pendulum test masses in the East-West 40 m arm of the test interferometer vacuum system, with the main interferometer beam between the lower test masses, and the suspension control beam between the upper (intermediate) masses. Each beam is itself operated as an unequal-arm interferometer, with a beamsplitter and short reference arm forming part of the corresponding mass at one end. Corner-cube reflectors are currently used to reduce requirements for orientation controls, and the system is illuminated by a laser stabilized to an atomic line. Feedback forces applied to the masses to lock the two baselines to integral multiples of the laser wavelength are recorded.

Initial tests have showed effective operation over a frequency range extending down to below 1 mHz. Measurements of low-frequency noise have shown unexpectedly large components with periodicity near 24 hours, apparently partially correlated with temperature variations, and a series of experiments aimed at clarifying the nature of this noise, and also of some observed correlations between upper and lower beams, are in progress.

The findings of successive stages in this program have led to improved understanding of experimental problems in this new frequency range, and to several technical improvements in design of the interferometer and suspension system. These include:

(a) A change from a double-loop suspension for the upper masses to a single-loop one, reducing one source of tilt of the test masses;

(b) Introduction of servo-control of primary beam direction over the 40 m baseline, reducing a source of diurnal perturbation;

(c) Introduction of servo-control of the 40 m distance between the test mass chambers, using the stabilized laser wavelength as the reference. This has been achieved by controlling the temperature of a short length of the vacuum beam pipe connecting the chambers, based on the output from the upper 40 m interferometer;

(d) Introduction of servo-control of tilt and horizontal rotation of all four masses. It was found that although the corner reflectors used are 1st-order insensitive to orientation, higher-order effects are significant in practice. These were arising from small dimensional asymmetries together with some coupling of feedback forces to orientation torques through magnetic or other imperfections. Optical-lever monitoring and feedback control of the most critical angular degrees of freedom has been introduced in successive stages, using modified versions of surplus electronic units from the original 40-m prototype. Control of 8 degrees of freedom has been achieved very recently, and this is significantly improving system performance.

Each of these successive steps in the research has given improvements in low-frequency performance, but at present there still remains low-frequency noise which is not completely understood. Further experimental work being prepared includes high-precision monitoring of the laser frequency and other parameters. Overall, it is being found that extending interferometer operation into this previously unexplored frequency region involves a range of disturbing phenomena sufficiently different from those at higher frequencies that fresh investigations and strategies are required. Our continuing program is aimed at as rapid investigation of these as practicable.

2. Work with high-Q paramagnetic crystals

As part of the long-term work relating to magnetic levitation techniques for test-mass suspension, measurements on mechanical Q of paramagnetic crystals gave particularly encouraging results with a repolished crystal. The high Q-values found with relatively small samples indicate that this material may have a near-term application as a replacement for permanent magnets or electrostatic actuators for test-mass control, with control magnetic fields at high frequencies. Further work on this is planned.

3. The overall program of the research continues as outlined in the Proposals under R.W.P. Drever, submitted to NSF in October 1996 and October 1999.

The project is proceeding well, and as planned, and continues to stimulate new ideas and concepts in various areas relating to gravitational wave detection.

Details of some of the recent work is reported in the following publications and reports:

(1) "Measurements of Mechanical Q in Levitated Paramagnetic Crystals", S.J. Augst and R.W.P. Drever, in "Gravitational Waves: Third Edoardo Amaldi Conference", Pasadena, July 1999, Edited by S. Meshkov (AIP, 2000), p. 338-341.

(2) "Progress in Development of some Techniques Relating to Test-Mass Suspension and to the Extension of Operation of Interferometers to Low Frequencies", R.W.P. Drever and S.J. Augst, in "Gravitational Wave Detection II": Proceedings of the 2nd TAMA International Workshop on Gravitational Wave Detection, Tokyo, Japan, October 1999, Edited by S. Kawamura and N. Mio (Universal Academy Press, Tokyo, 2000), p. 75-82.

(3) "Low-Frequency Operation of Interferometers – Potential for LIGO and First Tests with Coupled Suspensions", R.W.P. Drever and S.J. Augst, Aspen 2000 Winter Conference on Gravitational Wave Detection, February 20-26, 2000, Reported on LIGO Website, <http://ligo.caltech.edu/>.

(4) "Low-Frequency Operation of Interferometers - Recent Developments and Experiments with Coupled Suspensions", R.W.P. Drever and S.J. Augst, LIGO Scientific Collaboration Meeting, Hanford Observatory (August 15-17, 2000). Reported on LIGO Website, <http://ligo.caltech.edu/>.