LSC Six-Month Progress

LIGO-M020325-00-M

Organization Caltech Experimental Gravitational-Physics Group (CEGG)
Report Date August 15, 2002

Attachment Participation A - LIGO I

Ligo I

Item task 9 - Not Applicable

Attachment B - Isolation/Suspension/Thermal Noise

Participation

Isolation/Suspension/Thermal Noise

Work Relevant to Advanced LIGO, and future upgrades.

Development of coupled-suspension systems to extend interferometer operation to lower frequencies, and related exploratory experiments and new concepts.

1. Experiments and findings from the first 40-m coupled-suspension system, using single-bounce unequal-arm interferometers for main and suspension beams.

This first system is described in previous reports (and in the publications referred to below). An extensive program of experiments performed with it gave valuable experience of low frequency operation and noise spectra. In summary, an apparent signal with periodicity near 24 hours was observed initially and was eventually found to originate in a diurnal fluctuation in temperature of the laboratory. The coupling took place via small changes in separation between the test mass vacuum enclosures, causing the suspension-point interferometer to apply magnetic feedback forces to the upper masses. Slight unbalances in the magnetization drive magnets led to some rotation of the masses, which with imperfect corner reflectors gave a spurious length signal. The effect was controlled by the introduction of a number of technical improvements into the design of the system. These include locking the distance between the test mass chambers to the stabilized output of the suspension-point interferometer, using a heating element to give fine thermal control of the length of the vacuum tubes. In addition, precise servo control of orientation of both upper and lower masses was added.

At this stage it became practicable to rebuild the system for improved performance, using Fabry-Perot sensing.

2. Design and construction of a 40-m coupled-suspension interferometer with Fabry-Perot cavities in main and suspension beams.

Fused-silica test masses coated for green light were used, initially with a commercial frequency-doubled NdYAG laser as the light source. This laser proved very unreliable and better performance was achieved by building a separate cavity doubler system frequency-locked to a 1 micron NdYAG laser. The frequency of this laser is separately stabilized by a temperature-controlled reference cavity located in a vacuum chamber, whose temperature is itself controlled.

Several new techniques are being developed in this interferometer. The suspensions for the main test masses and the upper masses are single-loop wire suspensions to allow independent orientation control, and a new low-loss wire mounting system has been devised to allow the precise adjustment of the separate suspension wires which is required.

At present the system as a whole is nearly operational, but it is relatively complex and further detailed development and refinement is still in progress.

3. A new interferometer design giving coupled-suspension isolation without a second beam.

An important part of this research program is the introduction of new experimental concepts, and a possible way of achieving some of the properties of a suspension-point interferometer without requiring an additional sensing beam running between the test masses is now being considered. Here the relative positions between each test mass and the mass immediately above it in a multi-pendulum suspension is monitored by a small auxiliary local interferometer. If the directions of the axes of the test masses at the two ends of each arm are locked together precisely, then the distance which a separate suspension-point interferometer would measure can be deduced by combining the outputs of the small local interferometers with the main gravity-wave output. The required directional coupling of the axes of the test masses can be achieved by a suitable wavefront-sensing system. The technique appears to be practical and useful one and further work is in progress.

4. A technique for automatic control of the position of sensing laser beams in relation to the center of gravity of test masses.

Experience with these low-frequency interferometers has shown that tilt errors in test masses can be important. The sensing errors, which can result, are minimized if the laser beams are arranged to pass through the centers of gravity of the test masses. It is suggested that this may be done by looking for modulation of the main interferometer length signal at the frequencies of suitable internal vibration modes of the masses. From the phase and amplitude of this modulation the location of the beams relative to centers of gravity can be determined.

Overall the research is proceeding well and continues to stimulate new interferometer concepts.

Further details of some of the work mentioned above are recorded in the following publications and reports.

Drever, R. W. P., Progress in Development of Some New Techniques for Laser Interferometer Gravitational Wave Detectors, submitted to Proceedings of the TAMA Workshop on Gravitational Wave Detection, November 12-14, 1996, Tokyo, Japan.

Drever, R. W. P., Recycled light improves gravity-wave detection, Physics World, 12 (5), pp. 20-21, May 1999.

Augst, S. J., and Drever, R.W. P., Measurements of Mechanical Q in Levitated Paramagnetic Crystals in Proceedings of the 3rd Amaldi Conference on Gravitational Waves, Caltech, 1999, ed. S. Meshkov, (American Institute of Physics, New York), p. 338-341 (2000)

Drever R.W.P., and Augst, S. J., Progress in Development of some Techniques Relating to Test Mass Suspension and to the Extension of Operation of Interferometers to Low Frequencies, Proceeding of the TAMA Workshop on Gravitational Wave Detection, October 19-22, 1999, Tokyo, Japan, Editors S. Kawamura and N. Mio (University Academy Press, Tokyo) p. 75-82, (2000).

Drever, R.W.P., and Augst, S.J., Low-Frequency Operation of Interferometers Potential for LIGO and First Tests with Coupled Suspensions Proceedings of the Aspen 2000 Winter Conference on Gravitational Waves and their Detection, February 20-23, 2000, Aspen, Colorado http://www.ligo.caltech.edu/%7Everonica/Aspen2000/webpages/scripts/Transparencies.html (2000)

Drever, R.W.P., and Augst, S.J., Extension of Gravity Wave Interferometer Operation to Low Frequencies, and to other fields, Proceedings of the 4th Edoardo Amaldi Conference on Gravitational Waves, July 8-13, 2001, Perth, Western Australia, http://www.gravity.uwa.edu.au/amaldi/papers/index.htm, (2001).

Drever, R.W.P., and Augst, S.J., Extension of Gravity Wave Interferometer Operation to Low Frequencies, Journal of Classical and Quantum Gravity 19, Guest Editor, D. Blair (Institute of Physics Publishing, United Kingdom) p. 2005-2011 (2002)