LIGO-M920004-00-M

# QUARTERLY REPORT
# NSF COOPERATIVE AGREEMENT NO. PHY-9210038
# THE CONSTRUCTION, OPERATION, AND SUPPORTING RESEARCH AND DEVELOPMENT OF A LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY

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## I. INTRODUCTION

This report summarizes the Laser Interferometer Gravitational-Wave Observatory (LIGO) Project activities from July through August 1992. The shortness of the period covered is a result of phasing of the quarterly report to match the funding year as opposed to the previous practice of reporting on calendar year quarters. Future reports will be submitted every three months.

This summary includes work of the Caltech and MIT science groups and the engineering team located at Caltech. The principal areas of activity are:

- LIGO development, including sites, facility design and development of the initial interferometers.
- Prototype laboratory activities aimed at improved understanding of interferometer noise sources or at development of key interferometer techniques.

## II. LIGO DEVELOPMENT

### A. Sites

**Livingston Parish, Louisiana.** The Louisiana legislature authorized funds for land acquisition and road construction. The alignment staking survey was initiated, but suspended when the surveyor discovered a discrepancy between physical property boundary markings and the map furnished with the Louisiana proposal. The reported discrepancy is being investigated by the proposer (Livingston Economic Development Council), and resolution may involve property acquisition from a second landowner.

**Hanford, Washington.** The draft DOE/NSF land use permit and the draft MOU between DOE and NSF to provide LIGO access to Hanford infrastructure and services are presently under review at NSF.

The staking survey has been completed. The subcontract for geotechnical work has been awarded and work at the site will begin upon receipt of permission from DOE to proceed. Award of subcontracts for topographic and environmental surveys are pending.

### B. Industrial Design Subcontracts

A Request for Proposal (RFP) for the design and qualification testing of the LIGO beam tube modules, including an option for fabrication, installation and testing at the two LIGO sites, was released on June 19. A proposal conference was held at Caltech on July 16, and was attended by 75 representatives of 45 companies. Proposals are due on September 11.

Specifications and RFPs for the rest of the LIGO vacuum system and for the LIGO facilities are in preparation.

### C. Beam Tube Investigations

Tests on samples from a new batch of stainless steel were initiated during the last reporting period and continue underway during this period. This batch of steel was manufactured in the factory using a revised annealing procedure which had been previously developed in the LIGO laboratory. The tests are designed to verify that acceptable outgassing rates for hydrogen, water and other constituents can be achieved with steel processed in a factory environment.

Techniques and equipment for rapid measurement of the hydrogen outgassing properties of steel samples are being developed for use as a screening test during the industrial production of the steel for the LIGO beam tubes.

### D. Scattering and Stray Light Analysis for LIGO

The earlier numerical simulation of stray light in the LIGO beam tubes is being repeated to investigate the sensitivity of the results to various parameters. The parameters being investigated are: 1) the distance of the beam from the tube wall, 2) the surface roughness of the tube wall, and 3) the distance to the first baffle in the tube. These results will be used to finalize the baffle specification.

### E. LIGO Interferometer Conceptual Design

A plan to establish the specifications of the critical interferometer optical components and to identify and qualify vendors for the different manufacturing steps was drafted this quarter. Modeling of the effect of wavefront distortions, produced by transmission through and reflection by imperfect optics, on the performance of a LIGO scale interferometer was begun; the results of this analysis will be incorporated into the specifications for the test masses and other large optics to be used in the LIGO. In parallel, contacts with a number of potential suppliers were initiated to determine industrial capabilities.

## III. PROTOTYPE ACTIVITIES

### A. 40-Meter Prototype

**Mark I — Characterization of Interferometer Noise Sources.** Work with the 40-meter prototype was hampered by increased seismic activity in Southern California. On June 28, 1992, a major earthquake struck near Landers, CA, followed about three hours later by a second major earthquake near Big Bear, CA. Although the direct damage to the instrument was less than that incurred in the Sierra Madre earthquake of June 28, 1991, swarms of smaller earthquakes followed for many days after these quakes. Because of potential risks in repairing the instrument and the degraded operating environment due to these aftershocks, repairs to the interferometer were not even attempted during the first week after the earthquake. Interferometer repairs were completed by July 14.

An effort to improve the accuracy of the interferometer calibration was undertaken. An external Michelson interferometer was constructed to directly measure the motion produced by calibration currents applied to the magnetic drive coil on one of the test masses for comparison with the main interferometer signal. The new calibration has an estimated accuracy of ±4%, and differs from the old value by about 15%.

Significant effort has been devoted to final documentation of interferometer parameters in preparation for decommissioning this prototype and constructing the Mark II interferometer in its place. This work included the characterization of violin-mode resonances in the test mass suspension wires.

**Mark II Prototype.** Preparations are nearly complete for installing the present interferometer into a new, larger vacuum envelope, which will provide badly needed space for future evolution of interferometer capability. In addition to a larger vacuum envelope, the new system includes improved vibration isolation stacks, new alignment adjustment features, new pumping system and controls, and substantial upgrades to the laboratory facilities. Stringent vacuum-compatibility standards are being adopted which will allow Mark II to achieve much higher optical power than presently possible.

All designs have been completed, reviewed and released, all procurement and fabrication activities have been initiated, and most parts are on hand. Initiation of the transition of the present interferometer to the new system is planned for September.

**Suspended-Mirror Mode Cleaner.** Procurement of vacuum compatible cabling, which had delayed this task, is expected to be completed by September 1, and final assembly of mechanical components has begun.

## B. Stationary Interferometers

Development continued on the two candidate optical topologies ("asymmetric Michelson" and "external modulation") being prototyped for use in the initial LIGO interferometers. Quantitative testing for agreement between predicted and measured performance for the various control signals needed to operate the interferometer is being pursued in both of the stationary prototypes.

## C. Automatic Alignment of Fabry-Perot Cavities

After the successful completion of the theoretical analysis and an experimental demonstration of the discriminants required for aligning a single cavity in the prior quarter, work has begun on the theoretical analysis and a demonstration experiment for the alignment of a pair of coupled cavities. The coupled cavities are a model for the broad band recycling system to be used in the initial LIGO interferometer. The analytic approach has been laid out, but not yet solved. The original demonstration apparatus is being modified to the coupled cavity configuration.

### D. Vibration Isolation

Testing of the prototype vibration isolation system for the LIGO and the 40 and 5 meter interferometer facilities has continued in this quarter. The prototype stack has been reconstructed using a combination of elastomers: Viton, which has a very low Q, in the bottom two layers, and RTV615, which has a somewhat higher Q but smaller spring constant, in the top two layers. The principal transfer functions have been measured, compared with the previous all-Viton stack; the net result is more than an order of magnitude better isolation in the critical frequency range from 50 to 100 Hz.

### E. Optics Testing and Development

Tests to identify any possible degradation of mirrors exposed to high light power continued. A Fabry-Perot cavity in an all-metal vacuum environment was tested for 100 hours; no sign of degradation in mirror losses or optical spatial mode quality was observed. The circulating power level in this test is the same as will be experienced in the initial LIGO interferometers, but the spot intensity on the mirrors exceeds intensity levels expected in advanced LIGO interferometers because of the short length of these test cavities. This test confirms that current-technology mirrors, if kept clean, will suffice for the inital LIGO. Further testing with cavities that are exposed to Viton and RTV will be done to confirm that these materials can be used for LIGO vibration isolation stacks.

### F. Suspension Development

Measurements of mechanical Q factors for the modes of the suspension wires and test masses have begun in a newly built suspension test apparatus. The goal of these measurements is to develop a method of suspending test masses which gives reliable Q values for suspension and test mass resonances, and eventually to obtain the highest possible Q values for these resonances. Initial tests have begun using the 4-inch-diameter by 3.5-inch-long monolithic test masses fabricated for future use in the 40-meter protoype; these tests will define a testing procedure for mechanical properties of the LIGO test masses and suspensions. A parallel program of analysis is underway to understand resonances and damping in these structures and their influence on thermal noise.

## IV. PERSONNEL CHANGES

Two new staff scientists, Drs. Richard Savage and Andreas Kuhnert, have joined the project. The project has also added a new graduate student, John Carri, at Caltech. Seiji Kawamura (staff scientist) has left LIGO to return to Japan, where he will take up a position with Prof. Kawashima's gravitational wave group. Prof. R.W.P. Drever has separated from the project and will direct an independent research program.

## V. FINANCIAL STATUS

| Financial Status as of 5/1/92 ($M) | | |
|---|---|---|
| Cumulative Funding to date | | 19.1 |
| Cumulative Expenditures to date: | | |
| Site Investigations | 0.2 | |
| In-house | 3.2 | |
| TOTAL | | 3.4 |

## VI. ACTION ITEMS — CALTECH/NSF RESPONSIBILITIES

| | Topic | Status |
|---|---|---|
| 1. | Hanford land use permit | In process |
| 2. | DOE/NSF Memorandum of Understanding | In process |

Pasadena, September 1, 1992

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