# QUARTERLY REPORT
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# CONTINUED PROTOTYPE RESEARCH & DEVELOPMENT AND PLANNING FOR THE CALTECH/MIT LASER GRAVITATIONAL-WAVE DETECTOR (PHYSICS)

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## I. INTRODUCTION

This report summarizes the Laser Interferometer Gravitational-Wave Observatory (LIGO) Project activities from April through June 1991, including work of the Caltech and MIT science groups and the engineering team located at Caltech. Principal foci of research and development activities were:

- Interferometer prototypes
  1) development and testing of technologies needed for full-scale LIGO interferometers
  2) reliability and sensitivity enhancements of prototypes
- LIGO development

## II. PROTOTYPE ACTIVITIES

### A. 40-Meter Prototype

**Characterization of Interferometer Noise Sources.** The systematic characterization of interferometer noise sources has continued, with emphasis below 1 kHz, where the departure from theoretical performance is largest.

Below 50 Hz, the sensitivity is limited by direct coupling of seismic noise, through the isolation stacks and wire suspensions, into test-mass motion. Between 50 and 600 Hz electronic noise generated by the test-mass orientation control servos dominates. A simple model relating jitter in test-mass orientation (coupled by any offset between the mass's center of rotation and the illuminated spot on the mirror) to interferometer displacement noise has been confirmed experimentally. Preliminary measures to reduce this injected noise have resulted in more than order-of-magnitude reductions of interferometer noise over this frequency range.

Experimental work has demonstrated that the noise contribution due to laser frequency and power fluctuations are well below the current noise level. Other tests showed that parasitic interference paths in the input optics do not cause noise in excess of shot noise at frequencies above 200 Hz.

**New 40-Meter Vacuum System Configuration.** Fabrication of the first three new test-mass chambers has been completed at the vacuum chamber subcontractor, Mill Lane Engineering (Lowell, MA). The fourth chamber is expected to be completed by July 1. Leak tests on the first chambers are underway.

**Laser Stabilization.** Assembly of a newly engineered LIGO-compatible laser prestabilization system, tailored to a large-frame Spectra-Physics argon-ion laser, is nearly complete. Stability tests of the output beam will begin in the next few weeks.

### B. Stationary Interferometer

The results of the experiments on a recycled and optically recombined interferometer with Fabry-Perot cavities in the interferometer arms using an external modulation system, summarized in the previous quarterly report, have been submitted for publication.

Work in this quarter has concentrated on analysis and modeling of this system as a candidate LIGO initial interferometer. This analysis has identified several new experiments for the stationary interferometer. To make these experiments more convenient, the stationary interferometer is being moved to a more accessible location. Experiments will start this summer after the move is complete.

### C. Vibration Isolation

Tests on the prototype isolation stack composed of stainless steel rings and "Viton" elastomer radial springs were ended during this quarter. This design proved inadequate due to low frequency internal resonances in the stainless steel rings which compromise the isolation. Since this problem becomes more serious as the suspension is scaled to LIGO dimensions, alternative designs are being explored.

The current effort is to develop a design based on compact intermediate masses that have their internal resonances at much higher frequencies where ground motion is much lower. The design is being carried out with finite element modeling and small scale demonstrations. A full scale stack will be assembled and tested in vacuum once the design has been fully analyzed.

Measurements of the performance of isolation stacks similar to those in the 40-meter prototype were completed. In situ measurements of the isolation provided by the stacks and wire suspensions are underway.

### D. Optics Testing and Development

A new optics laboratory at Caltech has been completed, with over 2000 square feet of space for optical testing and development. Work stations for cleaning, inspecting and routine optical testing of incoming components have been moved to the optics laboratory and are now operational.

Experiments to measure the effects of high power laser beams on optical components and to measure the contamination of supermirrors used in optical cavities have been started.

## III. LIGO DEVELOPMENT

### A. Sites

Technical evaluation of proposals submitted in response to the public solicitation for LIGO sites continues. Estimates of site development costs and draft reports of characteristics relevant to the NSB-approved Site Selection Criteria have been prepared for each proposed site. A proposed implementation plan for the site selection process and a request for supplementary funding to partially cover anticipated costs have been submitted to NSF.

### B. LIGO Interferometer Design

Preliminary design of the LIGO interferometers is underway in four areas: optical topology, test-mass suspension, input optics, and seismic isolation. This work is building on existing prototype designs. The most urgent need is to define the LIGO optical topology, but this effort has been slowed by a manpower shortfall.

### C. LIGO Beam Tube Investigations

Bakeout of a 2 ft. diameter by 120 ft. long beam tube section—30 days at 100°C—was completed. The bakeout test successfully demonstrated a simple, cost-effective heating method for the LIGO beam tubes. Post-bake measurements of outgassing rates indicate that LIGO pressure goals can be met with this type of low temperature bakeout and the pumping strategy described in the construction proposal. Measurements of water vapor outgassing indicate that this gas species does not conform to simple models, and further measurements are underway to understand its behavior.

## IV. OTHER ACTIVITIES

An article, "Recycling for a Cleaner Signal," by F. Raab was published as a "News and Views" article in Nature (Nature **351**, 98, 1991).

R. Vogt attended the Marcel Grossmann Conference in Kyoto, Japan, and gave an invited talk on the LIGO project. M. Zucker and S. Kawamura also attended and gave contributed papers on work with the 40-meter prototype.

## V. CONCERNS

A number of important design tasks for the initial LIGO interferometers continue to be delayed due to lack of personnel. The additional demands of site evaluation have diverted a significant portion of senior staff effort away from the development and design activities. Resource limitations and funding uncertainties have prevented the addition of new staff to cope with this increased burden.

## VI. PERSONNEL CHANGES

Dr. Michael Burka resigned as a research scientist on the LIGO project at MIT effective May 1, 1991. A search is underway to replace him.

Lawrence Chu has joined the LIGO staff as an electrical engineer, and is working primarily to support the urgent needs of the prototype development.

Pasadena, July 2, 1991

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