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 September through December 1992.

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 previously reported discrepancy among various property boundary information has been resolved by the proposer (Livingston Economic Development Council), and will involve acquisition of property not owned by Cavenham, the principal landowner. Affected parties have agreed to cooperate with the proposer in acquiring the needed land. Land acquisition is presently awaiting release of state funds, which was delayed by emergency requirements of Hurricane Andrew. Funds are expected to be released in the next few weeks.

The alignment staking survey, previously suspended because of the boundary discrepancy, was re-initiated and is in process. A Request for Proposal (RFP) for geotechnical and environmental investigations, including wetland permit investigations, has been prepared and will be released soon.

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 negotiation between DOE and NSF.

Geotechnical and environmental investigations have been initiated. A subcontract for topographical surveying has been awarded and work should start soon.

B. Industrial Design Subcontracts

The 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, attracted four proposals. These are presently under evaluation.

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

C. LIGO Beam Tube Investigations

Initial results from tests on samples from a new batch of stainless steel were obtained. This batch of steel was manufactured using a LIGO-developed annealing procedure applied at the factory. The initial results indicate that outgassing rates for hydrogen, water vapor and other gas constituents are acceptable.

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

D. LIGO Scattering and Stray Light Analysis

New results from the numerical stray light modeling indicate: 1) that the noise due to scattering is dominated by back scattering from the baffles and the tube walls, 2) the noise is relatively insensitive to the position of the beam over the clear aperture of the beam tubes, 3) the scattering in the critical region between the first baffle and the mirror has been estimated correctly in the prior numerical models, 4) tube wall roughness is not a critical parameter as long as backscattering dominates. The project is currently considering blackening the baffles to give more margin for the scattering. Samples of blackened aluminum are being tested for their vacuum properties.

E. LIGO Interferometer Conceptual Design

Analytic and computer modeling of the influence of wavefront distortions (produced by transmission through and reflection by imperfect optics) on the contrast and losses in a LIGO scale interferometer continued during this quarter. The results of this analysis are required to establish the specifications for the large diameter optics to be used in the LIGO.

First results of the analysis are that slope errors with spatial periods comparable to the principal mode size dominate in producing cavity loss and interferometer contrast defects. The spatial maps of several LIGO size mirrors have been analyzed and show that it is well within industrial grinding capability to manufacture mirrors with the surface figure adequate for the initial LIGO interferometer. The perturbations due to mirror coating inhomogeneity are presently under analysis.

III. PROTOTYPE ACTIVITIES

A. 40-Meter Interferometer

Mark I — Characterization of Interferometer Noise Sources. The ongoing characterization of the suspended test masses continued. Analysis of experiments on the violin-mode resonances of the test mass suspension wires has shown that 1) the vibrations of these wires are excited thermally, and 2) the damping of these wires is consistent with a constant energy loss per cycle independent of frequency. A model for the thermal noise contributed by the test mass suspension wires has been formulated based on this new knowledge. According to this model, suspension thermal noise may decrease with frequency more rapidly than was originally assumed.

A continuous high-bandwidth record of interferometer and environmental data was taken over 24 hours as a first step in developing hardware and software for analyzing interferometer data for bursts. The recorded data are being analyzed for burst statistics in the various channels and for correlations between channels. Strategies and programs are being developed for later data recording and analysis with the Mark II interferometer.

The 40–meter Mark I interferometer was decommissioned on September 10, to make way for the new Mark II interferometer. Final documentation and characterization of the Mark I was completed.

Mark II Interferometer. Construction of the Mark II prototype interferometer has begun. The Mark I interferometer has been disassembled and extensive upgrades to the laboratory facilities have been completed. Parts for the new, vacuum-compatible vibration-isolation stacks were completed and transfer function measurements of an assembled stack are underway. Assembly of the new vacuum envelope was begun, and the new vacuum pumping/instrumentation/control system was assembled and is being tested.

After the vacuum envelope has been certified, the new vibration isolation stacks will be installed and tested. After that step has been completed, the interferometer will be installed, aligned and debugged.

Suspended-Mirror Mode Cleaner. Construction of all parts has been completed but integration has been delayed as effort and equipment have been dedicated to Mark II construction.

B. Stationary Interferometers

The goal of stationary interferometer research is to investigate two candidate modulation and optical topology schemes that may be used in the initial LIGO interferometer.

Operation of interferometers with the new aspects of the two topologies has been demonstrated. The expected increase in sensitivity to cavity length changes with the addition of the Fabry-Perot cavities and recycling has been observed. The servo signals and systems are being studied, and locking techniques developed. Detailed comparison of predicted and observed performance are being pursued on both systems.

C. Alignment of Fabry-Perot Cavities

Significant progress has been made on the theoretical analysis of methods to align the LIGO interferometers using signals derived from the main optical beams. The current emphasis of the analysis is to develop techniques for the alignment of a pair of coupled cavities. The coupled cavities are a model for the broadband recycling system to be used in the initial LIGO interferometer. The analytic method being developed uses perturbed coupled mode analysis. The method has been successfully developed, and applied to a particular phenomenon observed in the stationary interferometer having to do with the spatial mode structure in the recycling cavity. The model is in quantitative agreement with experiment.

The setup of a pair of coupled cavities for experimental investigation of alignment signals has progressed. A low-frequency modulation system has been assembled, and one of the cavities locked using this system. Results from this experiment will be used to check the theoretical analysis

D. Vibration Isolation

Tests on the vibration isolation stacks to be installed in the Mark II interferometer revealed a problem with cracks in the Viton springs which caused the stack to have a large drift. A systematic investigation showed that the cracking was the result of a baking step used to remove outgassing contaminants. Discussions with the supplier of the base material led to a revised baking schedule. This change was tested and found to eliminate the cracking problems.

E. Optics Testing and Development

Tests to identify any possible degradation of mirrors exposed to elastomers at high light powers continued. This effort is intended to qualify elastomers for use in vibration-isolation stacks for initial LIGO interferometers. Fabry-Perot cavities, in a vacuum chamber containing either Viton or a specially prepared RTV silicone rubber, were exposed to optical intensities of 400 kW/cm^2 for 100 hours with no indication of mirror degradation. This corresponds to much higher intensities than will be experienced by mirrors in initial LIGO interferometers.

F. Suspension Development

Theoretical and experimental studies of suspended test masses continued. A 1.5–kg mass was suspended by two wire loops and measurements of the mechanical Q factors were made for the various modes of the suspension wires. Systematic variations were made in the details of the connections at the tops and bottoms of the wires to develop a design which will minimize the thermal noise contributed by the suspension wires. Consistently high Q factors (> 250,000) can now be obtained for violin-mode resonances of the wires. A theoretical model for thermal noise from the suspension wires indicates that similarly suspended masses could meet the suspension thermal noise goal for the initial LIGO interferometer. Studies of the effects of varying the lengths of the wires or the size of the suspended mass are underway. Measurements have also been made on the vibrational modes of the test masses, and modeling efforts are underway to aid in interpreting these results.

IV. PERSONNEL CHANGES

Dr. Jordan Camp (previously at Los Alamos) has joined the project as a staff scientist. A new graduate student, Brian Lantz, has joined the project at MIT.

V. OTHER ACTIVITIES

A national committee of scientists and engineers and NSF officials conducted a site visit to Caltech and LIGO project review on November 18 through 20.

VI. CONCERNS

Progress on critical LIGO activities, particularly on the specification and procurement for the design contractors for the vacuum equipment and the civil construction, has been severely impeded by outside interference. A small faction of Caltech faculty have attacked the decision to separate Professor Drever from LIGO, propagating a large number of false or misleading charges throughout the Caltech and outside community. Correction of these misperceptions and education of the scientific community about the state of the project has required the LIGO team (and in particular the management team) to divert substantial time away from their technical activities.

The increasing number of review and oversight bodies has severely burdened an already lean LIGO staff. While a well-designed oversight system should be helpful to the project management, the current channels have been put in place piecemeal, often with vague or conflicting charters. As such, the oversight process has more often been a distraction rather than a help.

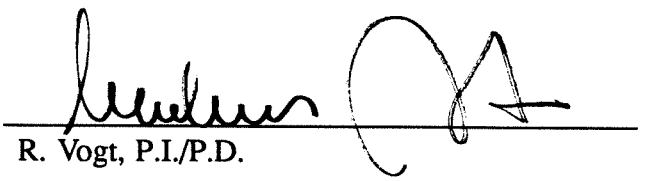
VII. FINANCIAL STATUS

Financial Status as of 9/1/92 ($M)	
Cumulative Funding to date	19.1
Cumulative Expenditures to date:	
Site Investigations	0.3
In-house	4.8
TOTAL	5.1

VIII. ACTION ITEMS — CALTECH/NSF RESPONSIBILITIES

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

Pasadena, December 7, 1992



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