

**LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
-LIGO-**

California Institute of Technology
Massachusetts Institute of Technology

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**LIGO Annual Report for FY03-FY04
Campus based research activities
At the 40 Meter Interferometer Facility**

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of the LIGO Laboratory.*

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July 8, 2004

Project Progress and Status as of summer 2004:

The upgrade of the 40 Meter Laboratory to prototype the Advanced LIGO optical configuration and controls has completed its first phase. The laboratory building, electrical power, control room, vacuum envelope and equipment and controls, electronics racks, optical tables, environmental monitoring, and other utilities are in place. An Initial-LIGO-like data acquisition (DAQS) system, slow control and monitoring (EPICS) system, and Global Diagnostics systems are all in place. Active seismic pre-isolation (the commercial STACIS system) is installed and in operation. The Initial-LIGO-like Pre-Stabilized Laser (PSL) and 13-meter suspended mass input mode cleaner are installed, fully commissioned, and operating regularly, robustly, and according to specifications. Their noise performance is continuously being improved. All seven of the core suspended optics and suspensions are completed and installed in the vacuum chambers. Optical sensing trains and electro-optics are in place on the sensing tables. Key input optics systems (in-vacuum Faraday Isolator and mode-matching telescope) have been designed, constructed, installed, and commissioned in the vacuum chambers. Digital suspension controllers and optical lever systems are completely commissioned. Several innovations in the controls architecture have been successfully prototyped in the 40 Meter Lab, in preparation for installation at the sites; these include a PSL intensity stabilization servo, digital controls for the input mode cleaner auto-alignment system, enhanced digital filtering capabilities for the front-end servos using commodity Linux computers, and the merging of the fiber-optic “reflective memory” networks for the front end servos and for the data acquisition into one network.

A first-generation Length Sensing and Control (LSC) system was installed in summer of 2003, and was used to lock the 3 length degrees of freedom of the core Michelson interferometer with Fabry-Perot arms (the 40 Meter interferometer has Fabry-Perot arms with the same high finesse as Advanced LIGO). A next-generation LSC system, incorporating more flexible controls, double-demodulation of the exit port signals at the difference frequency between two pairs of RF sidebands, and a faster linux-based front-end VME cpu, should be complete by the end of summer 2004. In the course of commissioning this system, we have discovered that the “sidebands on sidebands” introduced by the RF modulation of the light by EOMs in series will cause serious problems with the Advanced LIGO length sensing scheme (problems that were not anticipated due to an oversight in the modeling of the system). To address this problem, we have implemented a small Mach-Zehnder interferometer on the PSL table to apply the RF modulation of the light in parallel rather than in series. This new system is now being commissioned, and its effect on the signals that will be used to control the main interferometer are under study.

We have begun to use the tools and infrastructure now in place to learn how to optimally acquire and maintain lock of the full dual-recycled Fabry-Perot Michelson interferometer. This will require close interplay between experiment and detailed simulations of the dynamics of both the 40 Meter and Advanced LIGO interferometers. We are therefore pursuing development of models and simulations of the 40 Meter and Advanced LIGO dual-recycled interferometers in parallel. The FINESSE modeling tool has been used to optimize the length sensing signals and to develop a plan for lock acquisition. We have begun a collaboration with the VIRGO Orsay group to develop a detailed time-domain model simulation of Advanced LIGO and 40 Meter interferometers using the E2E package, and significant progress is being made.

We will delay until FY05 the implementation of some elements of the interferometer that have not yet been designed in any detail: the output mode cleaner and associated sensing system, and the DC demodulation scheme. We also continue to consider the possibility of implementing multiple pendulum suspensions, at a later stage in the project.

The 40 Meter team continues to work closely with the LIGO Controls group, the LIGO E2E simulation group, the LSC Advanced Interferometer Configurations subgroup, and LIGO Laboratory management.

Graduate students, REU summer students, visiting students and visiting scientists have contributed to all aspects of the project over the last 5 years. In particular, REU students have made major contributions to design of the main interferometer optical plant and the length and alignment control systems, to the configuration and commissioning of the pre-stabilized laser, digital suspension controllers, suspended-mass input mode cleaner, and optical lever alignment sensing systems, and to the simulation of lock acquisition and dynamics of the dual-recycled interferometers with E2E. In the past year, the 40 Meter lab has hosted fruitful long-term visits from scientists from Tokyo, Perth, Canberra, Glasgow, and Orsay. We will continue to involve students and visitors with all aspects of the project and its goals. The laboratory continues to be a popular tour site for local students, journalists, scientific visitors, and dignitaries.