

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

California Institute of Technology
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**Status, accomplishments, and plans
for the LIGO Caltech 40 Meter
Prototype Interferometer Laboratory**

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Status, accomplishments, and plans for the LIGO Caltech 40 Meter Prototype Interferometer Laboratory

Alan Weinstein, Caltech, 2/15/05

The upgrade of the 40 Meter Laboratory prototype of the Advanced LIGO optical configuration and controls has completed its construction phase. In the last six months, we have accomplished the following tasks:

- We have acquired lock and controlled the interferometer in several different configurations, in stages leading to the control of the full Advanced LIGO configuration.
- Using an Initial-LIGO-like Length Sensing and Control (LSC) system, we can control the 3 length degrees of freedom of the core Michelson interferometer with Fabry-Perot arms (FPMI; the 40 Meter interferometer has Fabry-Perot arms with the same high finesse as Advanced LIGO, much higher than in Initial LIGO).
- A next-generation LSC system has been implemented in the last six months. This system incorporates more flexible controls, a small input Mach-Zehnder interferometer to apply two pairs of RF sidebands without applying sideband-on-sidebands, double-demodulation of the exit port signals at the difference frequency between the two pairs of RF sidebands, tools for dither-locking, and faster linux-based front-end VME cpus.
- This system has been used to lock and control the power- and signal-recycled Michelson (dual recycled Michelson, or DRMI), as well as the Initial-LIGO-like power-recycled FPMI (PRFPMI).
- Most recently, we have learned to add the two Fabry Perot arms to the DRMI (the 5-degree-of-freedom DRFPMI), but only when the arm lock is offset with respect to the full resonant state. Moving from this “offset-locked” state to the full Advanced LIGO configuration is difficult because the control signals change dramatically when approaching that state.
- In order to successfully make the transition to the full Advanced LIGO configuration, the entire interferometer must be operating optimally, in order to accomplish this transition, with precisely tuned demodulation phases and servo filters, extremely stable pre-stabilized laser and mode cleaner servo, perfectly aligned mirrors, diagonalized mirror suspensions, and low electronic and seismic noise. Much of the last six months has been devoted to this optimization.
- We have made heavy use of modeling and simulation with the FINESSE, TWIDDLE, and E2E software to guide us in this work; these tools have given us much insight into the far more complex Advanced LIGO optical configuration.
- Finally, we initiated the design of a homodyne (DC) detection experiment, featuring in-vacuum output mode cleaner and low-noise DC photodiode at the asymmetric port.

In the next six months:

- We will continue the optimization of the interferometer and controls, and expect to be locking the full Advanced LIGO DRFPMI optical configuration routinely, rapidly and robustly, with all tuning and lock acquisition transitions fully automated.
- We will be verifying the expected power recycling gain and arm cavity gain, the correct signal cavity tune, and the ponderomotive optical squeezing effect. We will measure the GW response, all the various transfer functions, and the noise spectrum.
- We will study the various noise sources and couplings, but reduction of the noise is only a secondary goal.
- We hope to have the design of the homodyne detection experiment complete in the coming months, and begin the implementation and commissioning of the system.
- At that time, a quantitative understanding of the noise couplings will be important, and modeling will be playing an increasingly important role.