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Status, accomplishments, and plans for the LIGO Caltech 40 Meter Prototype Interferometer Laboratory for FY05

This is an internal working note
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Status, accomplishments, and plans for the LIGO Caltech 40 Meter Prototype Interferometer Laboratory

Alan Weinstein, Caltech, 8/9/05

The upgrade of the 40 Meter Laboratory prototype of the Advanced LIGO optical configuration and controls has completed its construction phase. Active participants presently are Ben Abbott, Rana Adhikari, Dan Busby, Jay Heefner, Osamu Miyakawa, Virginio Sannibale, Mike Smith, Bob Taylor, Monica Varvella, Steve Vass, Rob Ward, and Alan Weinstein, with many important contributions from visitors.

In the last six months, we have accomplished the following tasks:

- We have completed the installation and commissioning of a next-generation Length Sensing and Control (LSC) system, capable of acquiring length control signals from many different RF and DC photodiodes, and employing them in a very flexible way during lock acquisition.

- We have established robust length sensing signals for all degrees of freedom, and have acquired lock and controlled the interferometer in several different configurations, in stages leading to the control of the full Advanced LIGO configuration. We have verified the expected presence of unbalanced RF sidebands in the detuned signal cavity, and have made measurements of the finesse in the arm cavities and the power recycling cavity.

- We are able to routinely lock and control all five length degrees of freedom with a semi-automated procedure, but only when the arm common-mode degree of freedom 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 (dual-recycled Fabry-Perot Michelson, or DRFPMI), the entire interferometer must be operating optimally, with precisely tuned demodulation phases and servo filters, stable pre-stabilized laser and mode cleaner servo, well aligned mirrors, diagonalized mirror suspensions, and low electronic and seismic noise. Much of the last year has been devoted to this optimization. Most of the tuning procedures have now been automated and are exercised regularly.

- 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, and on the broad range of difficulties that we are encountering while attempting to acquire full lock. A combination of analytical and modeling tools have been used to estimate the contributions to the noise in the GW channel from frequency noise and intensity noise, accounting for quantum correlations.

- Work on using E2E to extrapolate the lock acquisition procedure and control plant from the 40m to a 4 km interferometer is proceeding.

- We have begun to build a noise model and diagnostic system for identifying and measuring the various contributions to the noise in the GW channel.

- We have completed the design of a homodyne (DC) readout experiment, featuring in-vacuum output mode cleaner and low-noise DC photodiode at asymmetric port. An in-lab review was held in July 2005. We are now procuring the required equipment.

In the next six to twelve 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.

- Once full lock of the DRFPMI is achieved, we will be verifying the expected power recycling gain and arm cavity gain, 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 will begin the implementation and commissioning of the homodyne readout experiment. When it is operational, we will measure the GW response and the noise spectrum, and identify and measure the various contributions to the noise in the GW channel.

- We will extrapolate our methods and solutions to a 4 km interferometer, using the E2E time-domain simulation software.

- We will develop plans for installing an MIT-built squeezed vacuum source into the asymmetric port of the interferometer, to study the effect on the shot noise.