LSC Six-Month Progress Report

Organization Stanford Advanced Gravitational Wave Interferometry Group
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Attachment D - Advanced Detector Configurations Development Group
For the period February 2002 to August 2002

Advanced Configurations (R. Byer, M. Fejer, S. Rowan, E. Gustafson, R. Beausoleil, A. Bullington, and S. Sinha,)

(a) In the area of improved modeling of distortions in all-reflective design of LIGO interferometers, the following manuscript describing our previous work has been under revision prior to submission.

> S. Traeger, P. Beyersdorf, Patrick Lu, J. Mansell, R. Beausoleil, E. Gustafson, R.L. Byer and M.M. Fejer, "Wavefront distortion produced by thermoelastic deformation of a diffraction grating"

b) Development of the MELODY thermal modeling package has continued with the addition of code to the LASER_FIELD class of computational analyses to provide transverse mode intensity/phase plots of the total electric field anywhere in an arbitrary optical system. In addition, MELODY now enables extraction of highly distorted interferometer eigenmodes for mode-matching simulations, and utility routines have been provided which allow MELODY users to change bases in simulations where the distortions have become so large that the curvature of the wavefront has changed sign relative to that of the corresponding unperturbed basis state at a given position. In order to support early experiments at the Gingin facility in Adelaide, a GINGIN class has been added, and an upgrade has been completed to allow modeling of power-independent optical distortions due to substrate index inhomogeneities.

(MELODY will be an integral part of the modeling effort supporting the sapphire down-select decision process, so the code incorporating the results of the FEMLAB numerical computations of perturbation matrices into MELODY has been automated and streamlined significantly to allow routine changes in test mass parameters without significant user intervention. The 1000x speed advantage of MELODY over FFT and other numerical tools has been maintained during the latest upgrade cycle.)

c) Initial experiments last year by visiting researcher C. Janke showed the expected linear behavior of output power vs. input power for low-loss cavity folding mirrors of a few ppm, and sub-linear behavior for higher loss chrome-coated mirrors of 27 ppm, with roll-off beginning at 1 W incident power. Higher order modal structure was also seen in the sub-linear regime and this was attributed to the cavity losing its lock to the fundamental laser TEM00 mode and locking instead to one of the higher order laser modes. This observation was consistent with the sub-linear behavior and high-order modal structure on the test cavity output, and it clearly established the need for a ring mode-cleaner between the laser and the test cavity in further thermal loading stability tests. It was unclear whether the higher order modal structure was caused by the distortion of the chrome-coated mirror or from higher order modes contained within the astigmatic laser beam. Increasing the circulating power in the cavity while using only low loss optics can help to avoid the sub-linear behavior seen with the chrome-coated mirror. An optical amplifier from Lightwave Electronics was installed in the spring of 2002 to increase the LIGO laser's output to 23W for experiments to demonstrate a 100W and 200W design for advanced LIGO. This 23W beam is ideal for increasing the cavity's circulating power and will be utilized in the coming months for this experiment.

With the installment of the optical amplifier, laser power was sufficient to test for thermal distortion of optical components. Experiments were planned using a ring cavity identical to the pre-mode cleaner installed at the LIGO laboratory. The cavity uses two low loss (~1ppm) mirrors and one chrome-coated higher loss mirror (27ppm). Initial observations showed that a critical power of approximately 1W was the point where the cavity's circulating power would change significantly. The mode matching into the cavity was expected to change such that the TEM00 mode was no longer the dominant mode of the cavity and the circulating power would drop substantially. However, because the output beam from Stanford's LIGO laser is astigmatic, highly efficient mode matching has not yet been achieved.

d) In order for students to gain experience working on the LIGO project, one student (A. Bullington) spent two months during the summer at LIGO Livingston getting on-site exposure to the facility. She worked on a project studying the usefulness of the butterfly mode of the test masses for interferometer alignment. Butterfly mode resonance frequencies and quality factors were determined for the inner and end test masses. The correlation between interferometer alignment and strength of the butterfly mode signal was studied to determine if the butterfly mode could be used to center the laser beam on the test masses. While the butterfly mode signal was minimized when the laser beam was properly centered on the optics, it was not an efficient way to align the Fabry-Perot cavities or the Power Recycled Michelson, much less the entire interferometer.