LSC Progress Report

Organization Hobart and William Smith Colleges LIGO Group (HWSLG)
Report Date May 14, 2004, covering activities since 3 September 2003

Attachment A - LIGO I
Attachment B – Advanced LIGO
Participation Steven Penn - 50% (20% LIGO I, 30% Advanced LIGO)

During the past several months the Hobart and William Smith Colleges LIGO Group has been very busy with Detector Characterization research for LIGO I and with Thermal Noise research for Advanced LIGO. Performing research while teaching five courses and setting up a new research laboratory remains a challenge, but those tasks are becoming more manageable as the laboratory set-up is nearing completion.

Again this summer, I will have two students who will each conduct research for twelve weeks. One of these students, David Niedzwiecki, worked with me last summer on silica thermal noise research. I anticipate a fruitful research program with David this summer. In addition I will have a second student, Benjamin Schechter, who will be working on my detector characterization research exploring bilinear noise.

At the end of June, the LIGO Downselect committee will choose the test mass material for use in LASTI. Our team will be working hard to provide information on our current knowledge of fused silica in order to better inform that decision. We are in the process of formulating an empirical model of loss in fused silica that can explain all high precision data taken by research groups in LIGO and TAMA. We are also working hard to provide measurements on annealed polished optics, in order to demonstrate to what extent a slow annealing process can raise the Q of these samples. The time before the downselect decision does not allow for a complete study of annealing. Fortunately there exists some time between the decision on LASTI optics and the decision date for Advanced LIGO optics. Whatever the committee decides in June, our work will continue for at least a year afterwards in order to inform the decision on the Advanced LIGO test masses.

Detector Characterization

I (Steven Penn) lead the Bilinear Couplings Investigation Team in the Detector Characterization Working Group. Our investigation was dealt a serious setback when Vijay Chickarmane left LIGO for the biotech industry. Vijay was the team's sole investigator at the sites and he had performed some very valuable initial investigations into the coupling of seismic and power mains noise into the gravity wave channel. Remaining in the team are my group and Nelson Christensen's group at Carleton. As Nelson and I both teach at undergraduate colleges, we do not have the ability to do the daily concentrated investigation that Vijay performed. And Nelson's primarly focus in detector characterization is correlations.

My work on the Bilinear Couplings team is concentrated on the development of DMT-based software to explore and monitor bicoherence in LIGO data. The reasons for this focus are that the tools for detecting bicoherence in LIGO must exist before the phenomena can be studied. Moreover, since conceptualizing bicoherence is a common difficulty, it is a great benefit to this investigation to have a tool to properly visualize bicoherence. To that end I have been developing two tools: BicoViewer, a stand-alone, GUI-based application for exploring bicoherence, and BicoMon, a background DMT monitor that can be used to monitor bicoherence in channels known to be sensitive to this noise. Both monitor utilize the BicoDir class to perform the bicoherence calculation.

From September through January I developed BicoMon for use in the S3 run. Initially that development consisted of writing the BicoDir class, a class for performing the direct calculation of the bicoherence for use with both the BicoMon and BicoViewer monitors. This class has been tested to agree with the output of MatLab-based codes that perform these same calculations. I have streamlined the code to use FFTW3, which is faster and utilizes vector-based algorithms if the CPU has a vector unit. This new class also allows a monitor to perform several bicoherence calculations on a given data segment and to perform several measurements on each calculated bicoherence. These measurements include monitoring the bicoherence trends of numerous frequency pairs. One can also monitor the total integrated autobicoherence, which is a measure of the Gaussianity of a given channel. As in its previous version, this class performs either auto- or cross-bicoherence.

During the Fall I also wrote BicoMon. BicoMon reads in user configuration file which specifies the list of bicoherence calculations required and, for each calculation, the desired measurements of the bicoherence. These measurements are then trended to a results file and to the DMTviewer for graphical display.

I discovered late in the preparation for S3 a serious conflict between BicoMon and the DMT. BicoMon allowed for the possibility of multiple requests of the same data channel from a given frame. Multiple requests are not allowed by the DMT, but no exception or error is issued. The arrays are simply not filled. I discovered this bug late in the development cycle. I was forced to write a new class to intervene between BicoMon's data requests and the DMT provided data arrays.

Given the timing of the S3 run and my teaching obligations, I did not finish this code update until late into S3. One project for my summer students will be rerunning the S3 data with the new version of BicoMon.

This Spring I have been finishing up BicoViewer. I demonstrated a version at the Spring LSC Meeting at LLO. The viewer now calls the BicoDir class which is proving to be robust in its ability to calculated bicoherences with a wide range of parameters, even down to mHz frequency resolutions. The challenges that remain for BicoViewer are threefold:

- better display of bicoherence results including plots to trend the bicoherence at given frequency pairs,
- improved output formats including text tabular output and movie output, and
- the ability to spool jobs to BicoMon from BicoViewer.

In theory the bicoherence is completely insensitive to the level of Gaussian noise but produces a strong signal for frequency or phase coupled data. Thus glitch, burst, or chirp signals buried in Gaussian noise should in theory still produce prominent bicoherence signals. Our team has discussed using bicoherence tools in the DMT to search for glitches or chirps. A chirp signal, even when buried in Gaussian noise, produces a strong bicoherence signal. Nelson Christensen and I have been in discussion about how we can follow up on this idea. Our goal is to eventually design an algorithm that can analyze the bicoherence of the gravity wave channel for glitch and chirp detection.

Thermal Noise Research

Mechanical Loss in Fused Silica

Silica research has been a busy field of study over the past 18 months. It was then that Sasha Ageyev and I used annealing techniques to increase the Q of an 8mm diameter, Suprasil 312 fiber to its surface loss limit of 200 million. Since then Phil Willems of Caltech has measured a Q of 120 million on an uncoated, polished initial LIGO test mass. Indeed an overview of data from all our collaborators at Syracuse, MIT, Caltech, and Tokyo, is revealing a loss in fused silica that shows both frequency and surface loss dependence. We are in the process now of developing that model for a forthcoming paper. The implications of this model are that properly annealed optics of fused silica should be able to achieve a mechanical loss below the requirements for Advanced LIGO. Our current work is measuring annealed, polished, silica samples with increasing V/S ratios — eventually reaching LIGO-sized test masses. In parallel we are developing the theoretical loss model for fused silica.

In January 2003 I applied for an NSF Major Reseach Instrumentation (MRI) grant in order to purchase a vacuum, annealing furnace that could anneal large optics. I received that grant in August. The furnace was delivered to the HWS campus in early November. Unfortunately an accident in shipping damaged the furnace by shearing off the rear electrical and water feedthroughs. The damage proved more extensive than initially surmised. Not only did we have to replace the feedthrough ends, but the accident opened a vacuum leak deep in the furnace. This required the furnace to be completely torn apart to fix the leak. I am happy to report that the furnace is working again, but the delay has been significant. While I am grateful to the NSF for awarding me the MRI grant, they reduced the grant amount, knowingly restricting me to purchase a refurbished furnace. The quality of these refurbished units and of the companies who sell them is not high. The money saved in the purchase has been more than wasted in time lost on choosing a refurbished unit.

A research plan for developing annealing techniques for large fused silica optics has been written and is available from the LIGO DCC (LIGO-T030102-00-R).

I have a summer research student whose sole task will be the measuring of *Q*'s of annealed samples. Our goal is to have some small (3″ OD x 0.1″ thick) and medium (3″ OD x 1.0″ thick) samples measured by the end of June, with at least one large (40 m test mass) sample done by the August LSC meeting. The model is slated for completion by the June LSC meeting.

Mechanical Loss in Dielectric Mirror Coatings

The coatings collaboration consists of research groups at Glasgow, Stanford, Caltech, MIT, and HWS. My work on mechanical loss in coatings is temporarily suspended to allow me to devote more time to my research on annealing fused silica. I plan to rejoin that effort in a year when the silica work is planned to be drawing to completion. Coating mechanical loss is likely to provide the leading loss mechanism in Advanced LIGO's central frequency region. Finding methods for reducing that loss has proved to be a difficult problem. I am sure that much work will remain when I return to the problem in a year.

LSC Six-Month Progress Report

Organization Hobart and William Smith Colleges LIGO Group (WHSLG)

Report Date February 15, 2004

Educational Outreach Program

We have initiated a LIGO-related Research Program at Geneva High School. Modeled after the successful program at Gladstone High School, the Geneva High School project will allow gifted high school students the opportunity to engage in LIGO research. This program is being led by Greg Baker, a graduate of Hobart & William Smith Colleges (HWS), who will spend five weeks this summer performing research at LIGO Hanford Observatory (LHO).

Greg's research will focus on using the Bicoherence monitor to explore bilinear noise. In the fall, Greg will then lead the students in performing bilinear noise investigations.

The student research program will also devote significant time to learning about LIGO in general, both its purpose and its function.

This initial year of the project will involve only seniors who have completed AP Physics B. If this first year proves successful, then the long-term plan would include extending the program to younger students as a motivation for students to become involved in physics.