Attachment OPT to the Memorandum of Understanding LIGO-M050315-00 between the Hobart & William Smith Colleges LIGO Group (HWSLG) and the Laser Interferometer Gravitational Wave Observatory (LIGO)

For The Period

August 15, 2007 - August 14, 2008

This Attachment OPT to the Memorandum of Understanding LIGO-M050315-00 defines the role of the Hobart & William Smith Colleges LIGO Group (HWSLG) as a Member of the LIGO Scientific Collaboration (LSC), and a member of the Optics Development Group (LDG). The period of performance for the activities in this Attachment is from August 15, 2007 - August 14, 2008.

1. Collaboration

The Optics Development Group (ODG) is the scientific collaboration for defining and developing instruments in optics for use in advanced subsystems for the initial LIGO interferometers, or in entirely new advanced interferometers.
MOU Attachment OPT defines the roles and responsibilities of groups in this development group.

2. Participation

During the period August 15, 2007 - August 14, 2008, the members of HWSLG will participate in ODG in the following areas:

a. Optics Characterization

The Advanced LIGO design specifies that the test mass optics will be made of fused silica, specifically Heraeus Suprasil 311. The selection of fused silica, rather than sapphire, was based upon the much greater familiarity with using fused silica as an optical substrate and on the realization that the mechanical loss in fused silica was on par with sapphire. Our group had a major role in the experiments that defined that minimal loss for fused silica, and the PI was the lead author of the paper that modeled that loss dependence (Physics Letters A, #352 (2006) p.3-6).

There remain two thermal noise research projects on the Advanced LIGO substrates that are still outstanding. First, additional measurements are required to better define the region of minimal loss. And a series of experiment must be performed to optimize the preparation method for the large test mass optics.

Our model of the mechanical loss includes a term that depends on frequency (actually $f^{0.7}$ and a term that depends on the surface-to-volume ratio (S/V). The Advanced LIGO test masses, with their large volume and low frequency range of interest, benefit from both of these dependencies and should have a loss well below the loss in the applied mirror coating and below the loss arising from the laser. Unfortunately there are no measurements to test the model at these conditions. In March 2005 I ordered a cantilever rod sample from Heraeus with a S/V ratio similar to the Advanced LIGO optics and four resonances below 4 kHz. I specified that the rod sample was to have a flame-polished surface. I also specified the annealing curve so that the sample would cool at only 1°C/hr from the annealing point to the stress point. This slow cool down should minimize any residual stress in the sample.

In February 2006, we took delivery of the sample. Unfortunately the surface of the sample was found to contain several defects. It appears that the surface was not prepared as specified and that leads one to speculate whether the sample was properly annealed. Despite these defects we suspended the sample) but the measured Q's were a disappointing 50 million. The frequency dependence was flat rather than $f^{0.7}$, which suggests some excess loss mechanism that we believe is from the marred surface.

For pictures of the sample see:
`http://web.mac.com/penn/iWeb/Lab/LargeCantileverSample.html`

To review the data see:
http://www.ligo.caltech.edu/docs/G/G060140-00.pdf.

Heraeus agreed to repair the sample. They will manufacture a new thick rod sample, welding it to the large counterweight, and annealing the entire piece. Heraeus produces excellent fused silica, but their manufacturing time scales can be quite lengthy. One year elapsed between ordering and receiving the large cantilever sample. By July 2006 I had convinced them that the sample was defective and in need of repair. In November 2006 we agreed upon the method for remaking the sample and that the work would be performed without any additional cost to me. As they are essentially remaking the sample, I would not be surprised if I did not see it until November 2007. I have been unable to obtain any estimate of a delivery date, but then they never provided a delivery date for the original sample either. After receipt of the sample, the measurements will require a few months. If the loss matches the predicted value, then each resonant Q measurement can take from a few days to a week.

The HWSLG is responsible for performing the experiments to determine the optimal annealing cycle for Advanced LIGO optics. The goal of these experiments is to anneal each optics so that its mechanical loss is on or near the minimum loss surface (as described in Penn et al., (Physics Letters A, #352 (2006) p.3-6) but not to alter the optical characteristics in the process. These experiments will be performed on a set of optics that are logarithmically-spaced in size (V/S) between previously measured small optics and Advanced LIGO optics. Both the mechanical loss and the cooling rate of the annealing process will depend on the size of the optic. The set of optics were ordered from Heraeus in the summer of 2005.

About a year later they arrived at Caltech where they were optically characterized. We received the samples in mid-June 2007.

As described in Attachment SUS, we have been placing the majority of our recent research efforts into understanding and improving the suspension thermal noise for Enhanced LIGO. This work has occupied both of our vacuum bell jars and as such we required a third bell jar for the experiments to optimize the annealing cycle. We purchased a bell jar from Peter Saulson in early June. Last week we received the new vacuum pump, and we finished building the support frame for hoisting the bell. The remaining commissioning steps include bake out, building the sample suspension, and assembling the detector system. With the advent of a new academic year, I estimate that this experiment will be on line by mid to late October. These measurements will require about 1.5 years depending on the number of annealing cycles required to optimize the process. Each annealing cycle can require two weeks or more for large optics. I am planning for this experiment to become the senior honors project of either Paul Stephens or Emily Newman.

b. Other Contributions

Not Applicable

3. Resource Sharing

The LIGO Laboratory will contribute resources including allocation of appropriate scientific and engineering personnel, research facilities, and funding in support of the effort in Item No. 2, as indicated below.

a. Research accommodations for HWSLG group members while on LIGO research assignment at any LIGO Laboratory site.

Not Applicable

b. Access to LIGO data through established LSC channels in support of this work.

Not Applicable

4. Coordination and Reporting

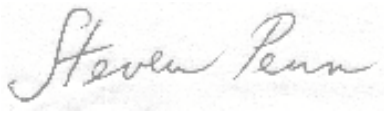
HWSLG will perform research within the structures established by the LIGO Laboratory and the LSC where appropriate. In particular, activities described in Item 2 will be carried out within the Optics Development Working Group of the LSC.
This includes keeping the Group leaders informed of activities and plans, reporting to the group at meetings and telecons, and through technical documents submitted to the LIGO Document Control Center.
In addition, an annual report will be submitted with the update to this Attachment, giving a summary status on research by topic as indicated in Item No. 2, including progress against the milestones if any, significant accomplishments such as new insights/discoveries or publications, issues of concern if any, and an indication of invested time.

This Attachment will be updated at least annually with a plan of activities for the succeeding one-year period. These documents will be due one month before the close of the period of performance under this Attachment.

5. Computer Code

All computer code delivered to the LSC under this Attachment must be developed in consultation with the LSC Data Analysis Software Working Group (DASWG) and archived, documented and reviewed as determined by that group.

Jay Marx
LIGO Laboratory Director



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