LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Technical Note **LIGO-T1700203–v4** 2017/05/15

In-Vacuum Heat Switch

Adele Zawada

California Institute of Technology
LIGO Project, MS 18-34
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project, Room NW22-295
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
Route 10, Mile Marker 2
Richland, WA 99352
Phone (509) 372-8106
Fax (509) 372-8137
E-mail: info@ligo.caltech.edu

LIGO Livingston Observatory
19100 LIGO Lane
Livingston, LA 70754
Phone (225) 686-3100
Fax (225) 686-7189
E-mail: info@ligo.caltech.edu

http://www.ligo.caltech.edu/

1 Introduction

LIGO Voyager is a design concept for a next generation gravitational wave (GW) detector that is currently being developed with the aims of reaching the limits of the current LIGO facilities. One of the major upgrades is switching to silicon mirrors, along with new, optimized coatings and operating the system at a temperature of 123K. Coating research and development is ongoing with the goal to reduce thermal noise in the experiment. This improvement along with other changes will increase the sensitivity of the LIGO Voyager by a factor of two or three compared to Advanced LIGO [1].

In operation mode, Voyager will only use radiative cooling to maintain cryogenic temperatures, but other methods of heat transfer are being considered to accelerate the initial cooldown. Because there are strict requirements on the vacuum levels in LIGO, using an exchange gas for convective cooling is not an option. Developing a heat switch and cooling the mirrors through thermal conduction is a viable solution for an accelerated cooldown. My research for this summer will be focused around studying the efficiency of heat flow across sample interfaces for different switch mechanisms. Additionally, I can use the study of heat flow to characterize the quality and strength of optically contacted samples. Optical contacting is a form of bonding where two super-polished surfaces get so close to each other that they are joined and held together by intermolecular forces. Heat flow is an indicator for the effective contact area, and so it can be used to assess different switch geometries and bond qualities.

2 Objectives

My objective for this summer is to construct a setup that is able to measure the heat flow of different samples, and then use this information to assess switch and bond strengths. The research on thermal conduction and heat flow will be utilized in two main ways. The first is developing a cooling mechanism that has good thermal contact with the mirror's barrel but does not damage its high emissivity coating. Since it is nearly impossible to avoid coupling seismic noise when there is contact with the mirrors, the cooling mechanism must have a way of attaching and detaching. I will compare commercial solutions and possibly design and test a custom switch. The second focus of my summer project involves the characterization of bond strength of optically contacted samples. Thermal conductivity is an indicator of contact area, where the better and stronger the contact, the more heat flow will cross the interface. The strength of the bond is expected to depend on the way the sample is formed, and so we will be creating samples under different heat and pressures and testing their thermal conductivity as a way of assessing relative bond strength. Developing a way to measure the strength of optically bonded samples will be useful for future projects.

3 Approach

In order to study the heat flow across interfaces, I will be testing different samples using a small cryostat that has a work plate at the bottom of the in-vacuum reservoir for liquid nitrogen. See Figure 1. I will construct a measurement rig where one sample is in direct contact with the cold plate while the other is connected to a heating element. With the heater, one can create a temperature gradient, and in the steady state the heat crossing the interface is equal to the heating power deposited by the heater. See Figure 2.

For the first focus of my project, we will be collecting clamping mechanisms from different vendors, or possibly creating our own switches, and attaching them to our silicon samples. Using the general method described above, we will study how the interface thermal conductivity changes depending on contact pressure and surface quality.

For the second focus of my project, we will assemble optically contacted samples for testing. After the initial contacting, we will let the samples rest in order to form a stronger bond with time. During the curing phase we will apply heat and pressure and investigate if they have an effect on the quality of the formed bond. We will then test the samples in the cryostat using the general method described above and evaluate the results.

4 Project Schedule

Week 1: Getting familiar with the lab, configuring the cryostat and designing testing methods for the heat conduction experiments.

Week 2-3: Running thermal conduction and heat flow tests on the silicon samples with different clamping/gripping mechanisms. Possibly design other cooling mechanisms and test them.

Week 4: Analyzing results.

Week 5: Creating optically bonded samples in the clean room, carefully documenting the process and any heat or additional pressure we apply to the samples. Configuring the cryostat for the new experiment.

Week 6-7: Running tests on the new samples, developing a way to characterize bond strength busing information on thermal conduction.

Week 8: Analyzing results.

Week 9-10: Run more tests depending on the results, finalizing and wrapping up both experiments.

References

[1] https://wiki.ligo.org/pub/LSC/LIGOworkshop2016/WebHome/Dawn-II-Report-SecondDraft-v2.pdf

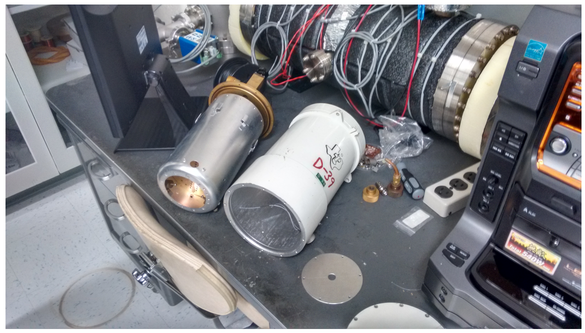

Figure 1: Cryostat with a work plate at the bottom that will be used to measure the heat flow across different sample interfaces.

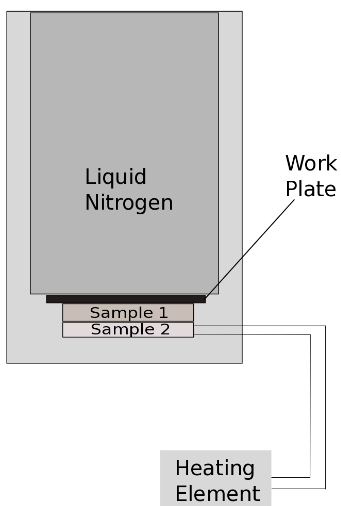

Figure 2: Sample 1 and Sample 2 can correspond to a silicon sample and a heat switch mechanism respectively, or they can correspond to an optically contacted sample.