LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
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SURF PROPOSAL

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Quality Testing Optically Contacted Bonds

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Abstract

This project is aimed at determining the mechanical loss of optically contacted bonds in order to provide a quantitative measure of their quality. The eventual goal is to create an ideal optically contacted bond which minimizes damping and energy loss.

1 Background

Optical contacting uses intermolecular forces like the Van der Waals dispersion force to bond surfaces without glue. Optical contacting works by reducing the space between molecules of different surfaces. In order to reduce the space between molecules, the surfaces must be very flat and polished. Any diversity in the geometry of the plates would decrease the strength of the bond [1]. Once the surfaces are made flat and polished, they can be brought together, and the strength of the intermolecular forces will increase and essentially join the two surfaces into one. Though heat and pressure are known to increase the strength of the bond, little research has gone into characterizing optically contacted bonds [3]. This project will answer the question of what affects an optically contacted bond and how to make the most ideal bond.

2 Motivation

Optical contacting bonding has important implications for space equipment. Equipment in space relies on the presence of strong, light bonds. Adhesives may sometimes outgas and produce contaminants. Optical contacting bonds do not outgas and so could be one solution to the contaminant problem. Optical contacting bonds could also reduce the risk of failing that comes with having adhesives with different chemical and thermal properties. Optical contacting bonding is particularly useful in high sensitivity probes such as LISA and the LIGO Voyager when it is used to bond silicon, which has a small thermal expansion coefficient [1]. The ultimate goal is to use optical contacting in the LIGO Voyager, but before we can do that, we have to test the mechanical loss of the bonds.

3 Approach

This project will focus on testing the mechanical loss or internal friction of the bond, which is known to be dependent on the amount of heat and pressure used when making the bond.

This project builds on previous work done by SURF student Jennifer Hritz last Summer and work I completed over the Fall and Winter terms. Hritz's project focused on using heat to increase the strength of the optically contacted bonds. Over the term, I worked with Hritz to model the heating of the surfaces with a python simulation in order to ultimately determine the temperature between the surfaces, which could not be measured directly. Once we determine the temperature and a measure of the mechanical loss of the bond, we can compare the temperature and mechanical loss to find the ideal conditions for creating a quality bond.

The mechanical loss can be calculated using the following equation:

$\phi(\omega_0) = \frac{E_{dissipated}}{2\pi E_{stored}}$

where $\phi(\omega_0)$ is the mechanical loss at angular resonant frequency ω_0, $E_{dissipated}$ is the energy dissipated with each cycle, and E_{stored} is the total energy stored in the oscillating system [2].

The energies and resonant frequency can be found using finite element analysis [2].

4 Proposed Work

Week $1-2$: Training and familiarization with mechanical loss testing.

Week $3-4$: Preparation of equipment and samples.

Week $5-6$: Testing different optically contact bonds, controlling for heat and pressure.

Week $7-10$: Measuring the success of bonds and further refining methods to improve their mechanical loss.

5 Summary

Through optical contacting, silicon surfaces can be adhered into a single object which, if optimized, could prove useful for the LIGO Voyager.

References

[1] Wright, J. J. Zissa, *D. E. OPTICAL CONTACTING FOR GRAVITY PROBE STAR TRACKER*. 14 (1984).

[2] Douglas, R., *Aspects of hydroxide catalysis bonding of sapphire and silicon for use in future gravitational wave detectors*. (2017).

[3] Zawada, A., *Final Report: In-Vacuum Heat Switch*. 14.