Control and Automation of A Cryostat for Gravitational-Wave Optic Experiment

Edmarck Sosa, Citrus College
Dr. Joshua Smith, Daniel Martinez, Department of Physics, California State University, Fullerton

Background

Gravitational waves are ripples in spacetime that were predicted by Albert Einstein's general theory of relativity in 1916[1]. The Laser Interferometer Gravitational-wave Observatory, LIGO, was conceived by Rainer Weiss in his 1972 paper, "Electromagnetically coupled Broadband Gravitational Antenna"[2].

LIGO is a modified Michelson interferometer that has two 4 kilometers long arms perpendicular to each other. A laser beam is shot out which hits a beam splitter, is split evenly and travels down the two long arms to two fixed optics and reflects causing the beam to interfere at the detector. When there is a shift in arm length caused by a passing gravitational wave, then a light shift is created on the photodiode and this output is recorded for analysis by scientists. In 2015 LIGO detected a gravitational wave caused by the collision of two blackholes 1.3 billion light years away[2]. Since then, LIGO has seen 90 gravitational-wave signals.

Figure 1

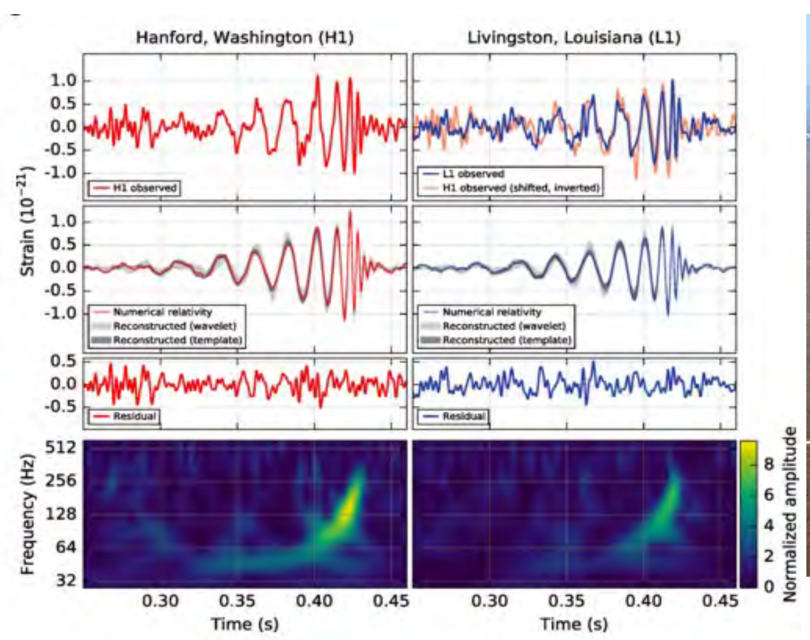


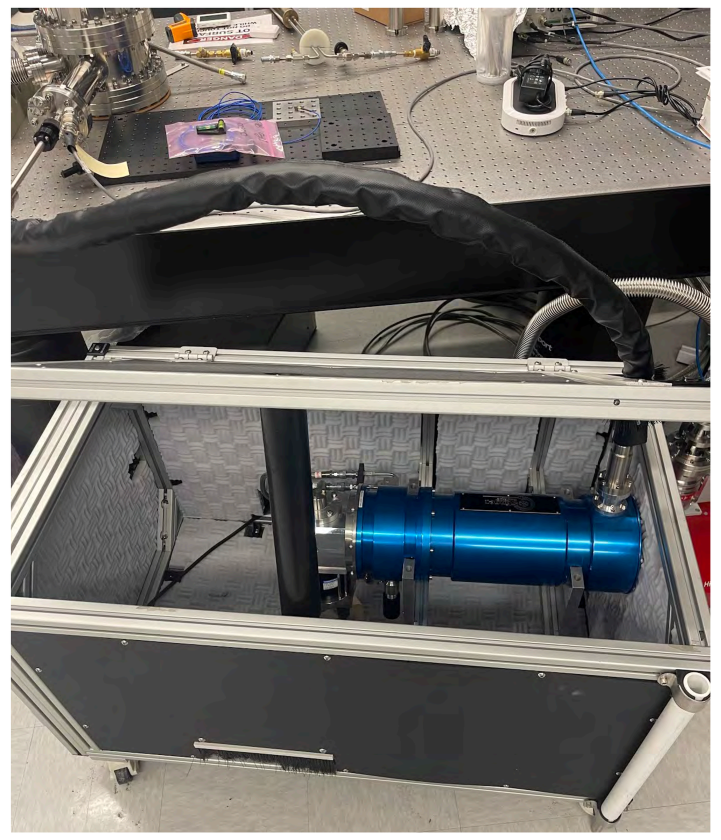
Figure 2

One way to allow LIGO to see gravitational waves from more sources and with more precision is to lower its noise. Currently LIGO uses fused silica mirrors at room temperature. Silicon mirrors at cryogenic temperatures are a promising technology to improve LIGO due to their Brownian **3** noise reduction[3]. At California State University Fullerton, optical materials of the current generation of detectors and materials being considered for future detectors are tested understand how to reduce the noise. This project focuses on an experiment to measure the optical scatter of cryogenic silicon and specifically designing a LabVIEW Virtual Instrument to control the experiment.

Hypothesis

The cryogenics experiment in the CSUF Gravitational-Wave Physics and Astronomy Center (GWPAC) lab was designed to quantify the optical characteristics of crystalline silicon at cryogenic temperatures. We expect the optical scatter to be similar to that at room temperature but with some additional scatter due to the possible formation of a thin layer of ice. To test this hypothesis, we require LabVIEW to create temperature profiles for us to follow as well as collect and record data from the various instruments.

Methods

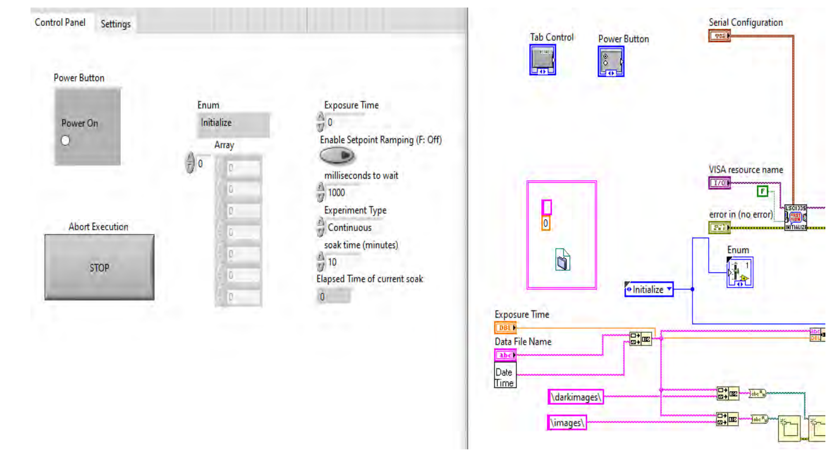


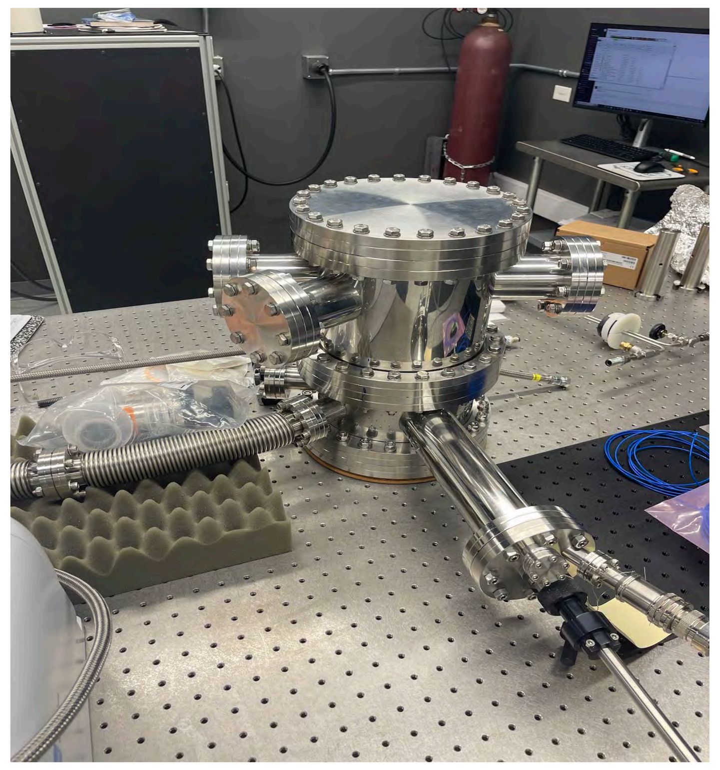
The GWPAC Cryostat is a ColdEdge Stinger, which uses a closed-cycle helium cooling based on the Sumimoto Gifford-McMahon Cryocooler. This cooler is attached to a 10-inch-diameter ultra-high-vacuum chamber in which our silicon samples will be placed. The system should be controllable to operate from room temperature down to below 4 Kelvin. The cryogenic machine is filled with 99.9% helium at 100 PSI. The Joule Thomson Effect allows the system to be cooled at cryogenic temperatures.

Methods Continued

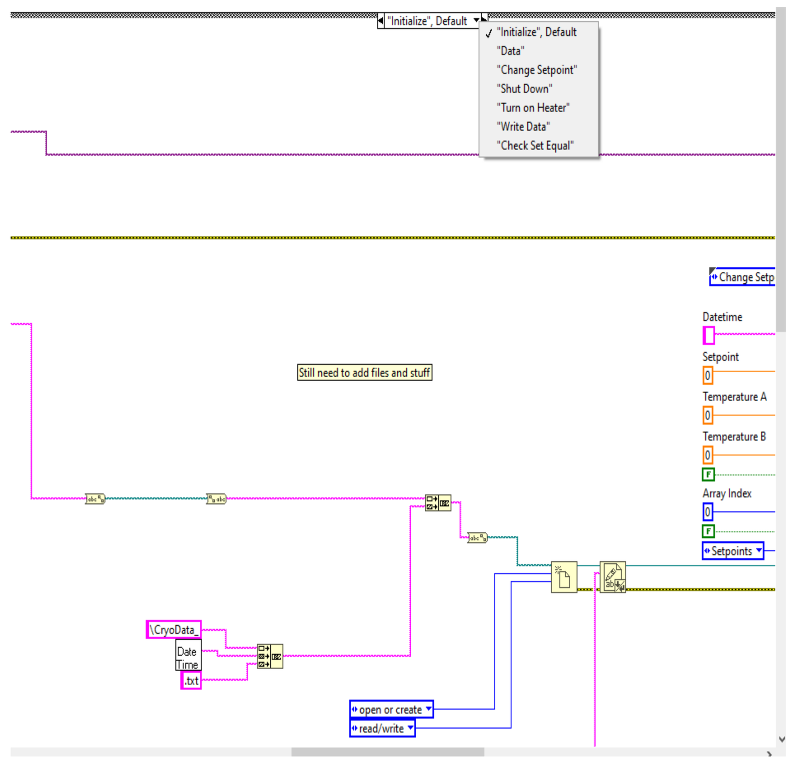
LabVIEW is the industry standard for experimental control.

- Using LabVIEW, we can create a virtual instrument by using a graphical programming language which shows the paths and logic in a diagram.





- Our LabVIEW code must communicate with the Lakeshore temperature controller to keep the chamber at a specific temperature and change temperature for our experiments
- The code must also read and write data throughout the experiment for plotting and later analysis
- The UI (user Interface) was edited to be accessible easier to the user. In addition, there were radio buttons that were added as the program cycled through each profile while recording data.



Results

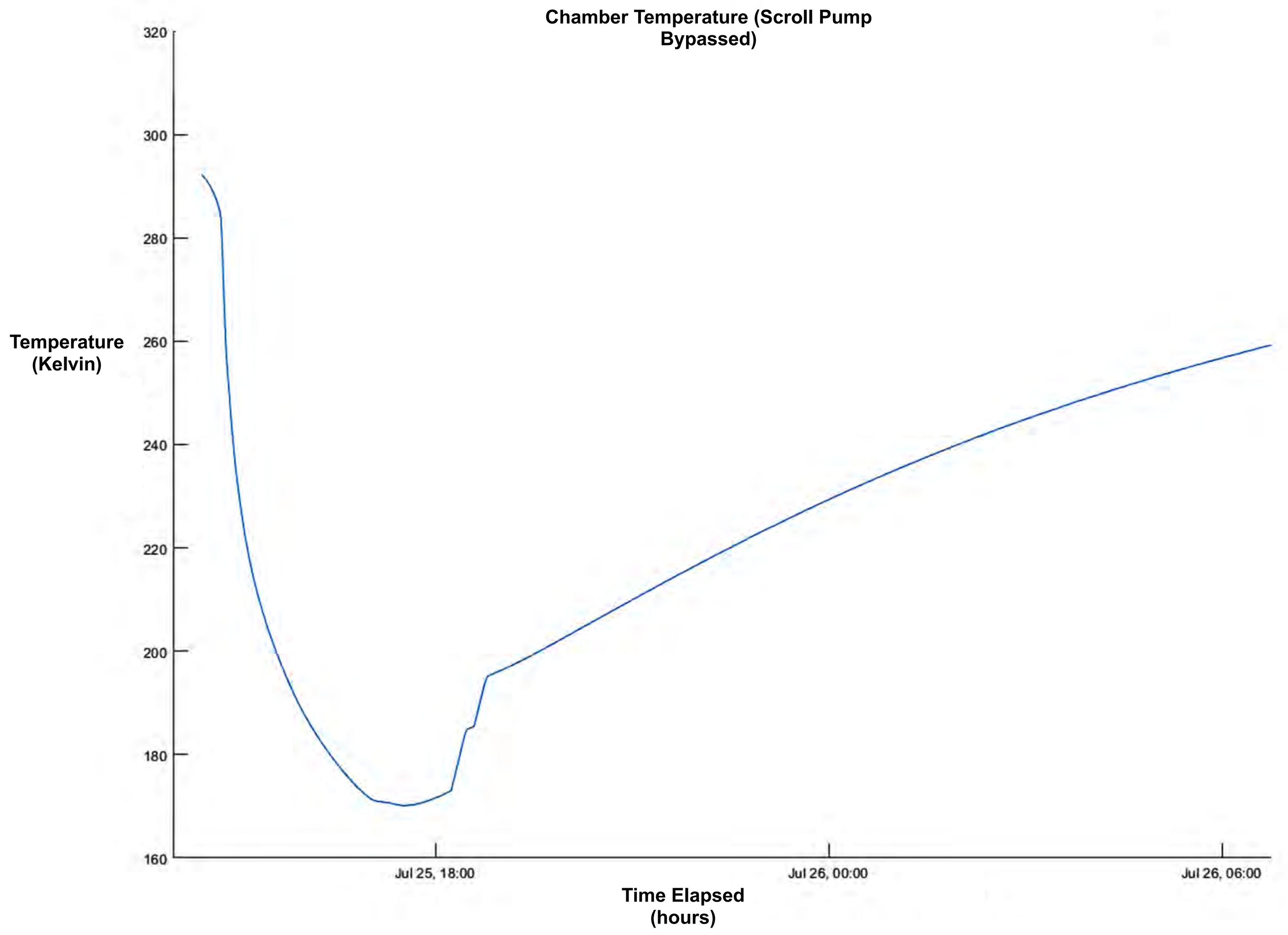


Figure 3: This shows the recorded temperature versus time data of the chamber initially starting at room temperature (293k) and then stabilizing at 123K. From then it grew 10k in partitions of 10 as it stayed there for 5 minutes. After the last partition, the chamber goes back to room temperature.

Conclusion & Discussion

The Cryostat ColdEdge can reach 4 kelvin, but in the graph, it peaked right around 171 Kelvin due to a contaminants in the system. So, we are looking into cleaning the system and removing any contaminants. As for the Figure 3, we see that it does hold and maintain temperature at our provided time constraint.

Regarding LabVIEW, were now able to implement more data acquisition into our data sequence. Now between data and check set point we can implement more sequences such as checking pressure gauge.

Future Work

LabVIEW is currently under the works to be fully automated by itself. As of now, LabVIEW needs constant surveillance in regards its capability through the user interface.

An optical and mechanical setup needs to be placed alongside the chamber to conduct the experiment of silicon monolith at near zero Kelvin.

Additionally, the cryogenic machine requires the installation of the remaining hardware for the experiment including the silicon silica monolith sample, the laser, viewports on the chamber, and camera.

We will continue to add to the LabView program such that it can automate not only the temperature control but also the image acquisition.

Figure 3

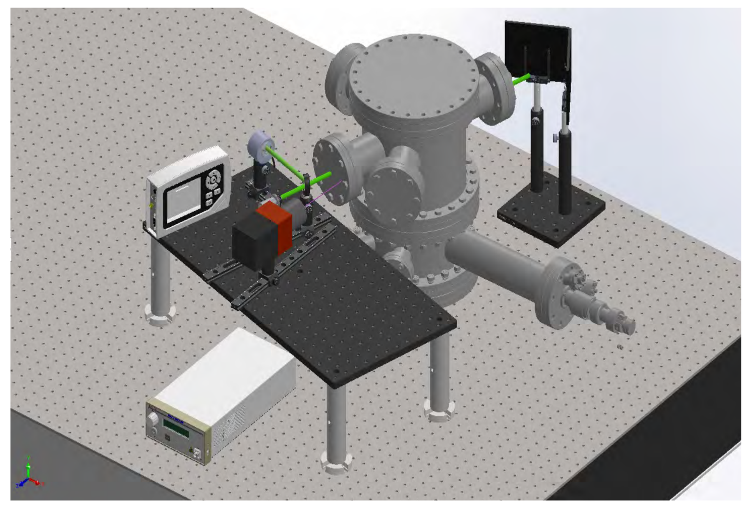
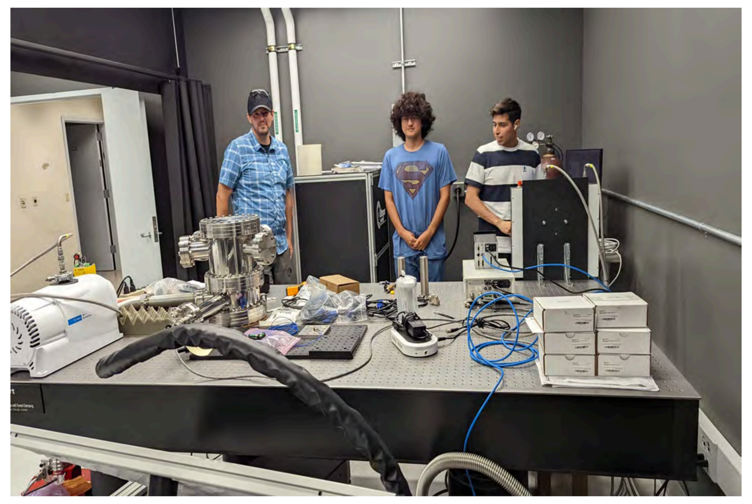


Figure 4



References

[1] "Nobel Prize Awarded to LIGO Founders." *Caltech.*

[2] "What Are Gravitational Waves?" *Caltech.*

[3] Adhikari, Rana, et al. "A Cryogenic Silicon Interferometer for Gravitational-Wave Detection." *ResearchGate.*

[4] Abbott, B. P., and Et Al. "Observation of Gravitational Waves from a Binary Black Hole Merger." *Physical Review Letters*, American Physical Society.

[5] CALTECH/MIT/LIGO Lab "LIGO Hanford." *LIGO Caltech*, 2 May 2008, https://www.ligo.caltech.edu/image/ligo20150731f

Figures:

Figure 1 – This shows the recorded gravitational wave in both Hansford and Livingston Ligo Center[4].

Figure 2 – Ariel shot of the Hanford, Washinton[5] Laser Interferometer Gravitational Wave Observatory

Figure 3 – 3D render model of the chamber created by Kevin Silverio

Figure 4 – Picture of Dr. Joshua Smith, Daniel, and I by Kevin Silverio

Acknowledgements

Project supported by Project RAISE, U.S. Department of Education HSI-STEM award number P031C160152 and Project RAISER U.S. Department of Education HSI-STEM award number P031C2100118.

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Alternate text

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Figure 1 and Figure 2

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Methods: The GWPAC Cryostat is a ColdEdge Stinger, which uses a closed-cycle helium cooling based on the Sumimoto Gifford-McMahon Cryocooler. This cooler is attached to a 10-inch-diameter ultra-high vacuum chamber in which our silicon samples will be placed. The system should be controllable to operate from room temperature down to below 4 Kelvin. The cryogenic machine is filled with 99.9% helium at 100 PSI. The Joule Thomson Effect allows the system to be cooled at cryogenic temperatures.

Image of ColdEdge system.

Methods Continued: LabVIEW is the industry standard for experimental control. • Using LabVIEW, we can create a virtual instrument by using a graphical programming language which shows the paths and logic in a diagram.

Image of device relevant to the experiment along with other relevant visual representations.

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Images labeled figure 3 and figure 4

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