Progress Report 1

Katie Banowetz

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1 Background

The Laser Interferometer Gravitational Wave Observatory, or LIGO, is built from a collaboration of scientists with a common goal: to detect gravitational waves. These waves can be produced when certain cosmic events occur, as predicted by Albert Einstein's theory of general relativity.

In order to detect these waves, both LIGO setups, one in Hanford, WA and one in Livingston, LA, consist of two perpendicular 4 km long arms with a mirror, called a test mass, at the end of each. Laser light splits and moves through vacuum in the beam tubes in both arms, reflects off the test mass, and recombines at the same time. The thought is that even a small gravitational wave will stretch space in the direction of one arm, and compress it in the other arm's direction, therefore making it so that the beams would return to the recombination spot at separate times. [1]

Since the Advanced LIGO set up is created to be extremely sensitive to movements of the test mass as low as $1 \times 10^{-20} \frac{m}{\sqrt{Hz}}$, many signals other than those of gravitational waves can be detected by the system. Some factors that can affect the output of the system include acoustic noise, external magnetic fields, and tilt caused by wind surrounding the observatory.

In order to detect these environmental signals, a Physical Environmental Monitoring (PEM) System setup is used at each interferometer. This system includes microphones, magnetometers, seismometers, and various other sensors. The goal of the PEM system is to understand how the environment affects the signal in the interferometer, so that a clear gravitational wave can one day be detected.

2 The Problem

2.1 Acoustic Coupling

One major environmental issue is with acoustic coupling. This occurs within a LIGO HAM, or horizontal access module, when pressure created by sound shakes the blue cross beams that are external to the chamber. Since these beams support the ISI table, the first stage of the table shakes. The second stage, which is supported from the first stage by wires and springs, becomes a pendulum with a resonant frequency of about 1 Hz. At resonances of the suspension spring and wires, the pendulum isolation is much reduced, which makes the second stage of the ISI, the table top, move more at these resonances. Mirrors placed on the table in order to direct the laser beam then move extra at the frequencies that the table top is vibrating at. The mirrors move enough that the resulting slight misalignments cause the amount of light on the gravitational wave detecting photodiodes to vary. These variances put peaks in the gravitational wave channel at the resonances of the ISI suspension. These peaks that are created are within the frequencies that a gravitational wave could appear, so it is very important to find a way to limit these resonances.

2.2 Magnetometer Calibrations

A very important part of working with environmental monitors is making sure that they are properly maintained. Many of the magnetometers have not been checked on for almost a year now, so part of the work that will be done this summer is to check that their outputs are reading correctly, that they have all the proper equipment, including filter boxes, and that they are leveled. This work contributes to the physical environmental monitoring system because it makes sure that everything is working correctly and allows the measurements to be accurate.

2.3 Noise and Coupling Function Calculation

With the use of many instruments to monitor environmental signals, there has not been a streamlined way to calculate the effect of those on the DARM output. There has been quite a large need for a program that will calculate this for us, instead of continually calculating it by hand. This program should account for ambient background noise from a source, as well as harmonic coupling functions, such as the acoustic coupling discussed above.

Creating this program basically consists of figuring out exactly what it needs to do, picking a platform, and then programming it. The program should be able to take multiple inputs, such as the x,y, and z components of a magnetometer, or just one environmental signal. It should also have the capability to take reference signals as well and compare those in the measurements.

3 Progress and Future Goals

After three weeks of working at LIGO, I have been able to complete a good amount of tasks, but I still have a lot more to do during my time here. Most of my work up to now has been with the program that calculates ambient noise and coupling functions, but I have also completed a few magnetometer calibrations and worked on some attempts to dampen the acoustic coupling in HAM 6.

3.1 Acoustic Coupling

During my first week, I worked with my mentor on testing out possible damping materials by creating clamps to temporarily put on the suspension wires in HAM 6 and testing out their effectiveness. It was noted that when the wires were flicked without the clamps, they produced a peak around 800 Hz that did not appear with the damping clamps. However, future goals would be to have a permanent clamp for this used designed for this frequency, as well as the peaks in the 300 to 400 Hz range and the 900 Hz range

3.2 Magnetometer Calibrations

During my third week, I checked the calibration and leveling of the magnetometer at the corner station vertex. That still leaves four non electronics bay magnetometers that need calibration. Of these, the corner station Input Optics magnetometer does not have a cable connecting it to anything else, the corner station Output Optics magnetometer is within a running clean room, which skews the magnetometer output when calibrating,and the magnetometer in the Y axis end station does not have a filter box connected. The filter box and cable problems are easy fixes, and the goal is to find those and put them in place within the next couple days so that those calibrations can be done. The Output Optics magnetometer, however, can only be done when the clean room isn't on anymore.

My goal for magnetometer calibrations in the next few weeks is to calibrate the one in the X-axis end station as soon as possible, and hopefully finish the two with easy modifications needed in that same time frame. I also plan on working on the Output Optics magnetometer as soon as the clean room is off. Once the magnetometers' calibration is checked and they are leveled, the measurements taken by them will be accurate.

3.3 Noise and Coupling Function Calculation

Much of my work over the past two weeks has been focused on this program. I chose to create the program in Python because it is a versatile, easy to edit language that allows for inputs of text files and has the ability to edit and export text files as well. So far, I have produced a program that takes outputs of a sensor, such as a magnetometer, that has a coupling function, the DARM output, the frequency of the initial harmonic, and what harmonics you would like analyzed. The program works with these to find and output the factor that shows the effect of the acoustic coupling on the DARM output for each harmonic frequency.

In the next month, I hope to have produced a fully functional program that produces both the effects of coupling and ambient background noise from the signal. This program should produce a file with these factors for each frequency so that the effects can be calculated. So far, I have been working on this program one step at a time, and I plan on approaching the rest of the program the same way.

4 Anticipated Challenges

Up to this point, most of the challenges that I have faced have been related to the steep learning curve related to programming to analyze data in Python. I have ended up rewriting my program two different times now because I found much simpler ways to do what I had originally programmed manually. I expect that this learning curve will still be a challenge for the remainder of the summer, but to solve these problems, I have utilized python help webpages and guides to programming. These resources have helped me become very successful in programming this program and I plan on continuing to use these to solve any problems that come up.

Most of my problems with magnetometer calibrations that have come up have been related to the magnetometers on the floor not being ready to be leveled and calibrated, as I mentioned in 3.2. I anticipate that the PEM group and myself will resolve most of these problems quickly by installing the correct equipment, and then I will be able to calibrate and level every magnetometer.

5 Resources

In the first three weeks of this program, the only resources that I have required are Python programming help websites. I anticipate that I will still require these resources for the rest of the programming that I am completing.

References

[1] "LIGO Overview" *LIGO Hanford Observatory* 2010. Web. 06 July 2015