Measuring Scattering off of LIGO Test Masses

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Introduction

The LIGO detectors are modified Michelson interferometers. Because of the sensitivity necessary to detect gravitational waves, minimizing optical losses along each arm of the interferometer is critical to achieving the signal to noise ratio necessary to detect gravitational waves. Therefore, understanding where losses comes from and minimizing each one can help increase the performance of the detector. One source of optical loss that has been identified but has not been completely characterized is light scattering off of the tests masses at the ends of each of the arms of the interferometer. More than 100kW of laser power is reflected off of the test masses at the end of each arm, and a very small, unknown portion of it is scattered and out of the beam. This project will seek to continue work done by a previous SURF student to calibrate cameras situated at the end of the arms which observe the scattering off the test masses. By calibrating the cameras, the amount of light scattered by the test masses can be measured. After this project is completed, additional commissioning tasks will be started and completed as time permits.

Objectives

The previous student obtained a few calibrations for different types of lenses attached to a Nikon DSLR camera, including a Celestron Telescope. Preliminary work was also done to obtain the calibration of the image sensor of the DSLR, but was inconclusive. This project would aim to complete this calibration.

A number of issues were found when attempting to calibrate the image sensor. The main obstacle is that it appears the performance of the sensor depends on the laser beam profile. If this is correct, then this poses significant challenges for the calibration because the profile of the detector's laser beam scattering off of the test mass will have its own unique profile. The first objective of the project will be to determine the response of the image sensor does in fact depend on the beam profile. Ideally, the sensor will respond independently of the beam profile, and the calibration that is developed can be used to measure the amount of light scattered off of the test mass. If not, it will be necessary to emulate light scattering off of the test mass in order to develop a calibration for that type of beam profile.

Approach

First, tests determining whether beam profile affects the calibration will be conducted. The image sensor will be exposed to different beam profiles, and the response to each will be characterized. The initial procedure used will be similar to the procedure used by the previous SURF student in order to confirm their results. The DSLR produces RAW (uncompressed) images which can be analyzed to determine how much light is hitting an individual sensor (which corresponds to a pixel in the image). Each trial will occur with a constant ISO (sensor sensitivity) and aperture. As long as the pixels do not saturate (reach their maximum brightness), summing the value of all of the pixels will give an indication of how much light reaches the sensor. If pixels saturate, then additional light will hit the sensor without being registered in the image. Using a laser of known intensity (power) directed at the camera, the relationship between the sum of the pixel values in the image and the amount of light incident on the image will be developed.

Schedule

A tentative schedule for this project allows for two weeks to collect the data, and another two to three weeks to analyze the resulting data and make any necessary changes to the data collection procedure, along with additional time to write the report. If this project is completed before the end of the summer, additional commissioning projects will be started.

References

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4. B.P. Abbot, *et al*., GW150914: The Advanced LIGO Detectors in the Era of First Discoveries, Physical Review Letters, 116, 131103 (2016).