LIGO Student Fellowship Application: Development and characterization of the first DC readout system on a LIGO interferometer

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Introduction

The Advanced LIGO design calls for replacement of Initial LIGO's heterodyne readout, in which gravitational wave signals are detected by their beat against optical RF sidebands, with a homodyne readout [2] [1], in which the signal beats against the laser carrier. It is currently planned to install the homodyne readout at the end of S5, producing an intermediate configuration called Enhanced LIGO, which also involves increased laser power, an in-vacuum Output Mode Cleaner, and other modifications.

Until the end of S5, I will be in residence at the Caltech LIGO Laboratory where a homodyne readout is being prototyped on the 40 meter interferometer. Following my time at Caltech, I plan to relocate to the LIGO Livingston Observatory for at least one year to work on the development and characterization of this first homodyne readout system on a full-scale LIGO interferometer as a significant component of my PhD thesis work. I am applying for this LIGO Student Fellowship in support of this project.

Description of the project

Commissioning of the homodyne readout will require the effort of many people over several months, including installation of the Output Mode Cleaner and other optics, photodiodes, and installation of a new seismic isolation system. Once the system is built, lock acquisition will be re-established and the performance of the system will be evaluated and tuned. Homodyne detection presents certain advantages and is required by other aspects of the Advanced LIGO design, but also presents several complications; sensitivity to laser amplitude noise is increased, and no output mode cleaner with sufficiently low noise in our band of interest has ever been built. It will be necessary to investigate, debug, and characterize these effects.

At the Caltech 40 meter laboratory I will be involved in the characterization and improvement of the DC readout and Output Mode Cleaner system with the power-recycled, Fabry-Perot Michelson interferometer. This will involve measuring many noise coupling terms, generating a noise budget for the homodyne readout, and reducing 'junk' noise terms such as due to scattering, clipping, and readout electronics. This work will serve as good preparation for similar work at the Observatory in support of Enhanced LIGO.

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Significance

As noted in [3], Enhanced LIGO will ease the transition to Advanced LIGO by "gaining more confidence that there are no unforeseen noise sources or other limiting phenomena that lie between the initial and advanced sensitivities, or learning to deal with any that are discovered; early implementation and debugging of Advanced LIGO hardware on a full-scale interferometer, to reduce commissioning time of Advanced LIGO; gaining experience with higher power operation of a full-scale interferometer and its components, likely also to reduce commissioning time of AdLIGO." Additionally Enhanced LIGO will allow observations at increased sensitivity before the long downtime required for Advanced LIGO construction.

Additionally this project will result in at least one graduate student becoming significantly more familiar with interferometers for gravitational-wave detection.

Why it is desirable to carry out this project at an observatory

The homodyne readout is currently being implemented at the 40 meter laboratory; this project concerns the implementation and characterization of the technology on a full-scale LIGO interferometer, which naturally must be done at one of the sites. Currently Livingston is preferred as Enhanced LIGO commissioning is slated to begin there.

Resources needed

Other than Enhanced LIGO hardware currently under development and standard test equipment, no special resources are required.

Others involved

My primary advisor for this project will be Rana Adhikari; on site at Livingston I will work with the LLO staff.

References

[1] Ben Abbott, Rana Adhikari, Daniel Busby, Jay Heefner, Keita Kawabe, Osamu Miyakawa, Virginio Sannibale, Mike Smith, Monica Varvella, Steve Vass, Rob Ward, and Alan Weinstein. Proposal for a homodyne (DC) detection experiment at the LIGO Caltech 40-meter laboratory. Technical Report LIGO-T050086-00-R, July 2005.

[2] Rana Adhikari, Peter Fritschel, and Sam Waldman. Enhanced LIGO. Technical Report LIGO-T060156-01-I, July 2006.

[3] Peter Fritschel, Rana Adhikari, and Rainer Weiss. Enhancements to the LIGO S5 detectors. Technical Report LIGO-T0050252-00-I, November 2005.