

LONG RANGE MICHELSON READOUT

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INTRODUCTION

The Laser Interferometer Gravitational-wave Observatory (LIGO) at the California Institute of Technology (CalTech) is part of a large-scale physics experiment aimed at detecting and analyzing gravitational waves of astrophysical origin. This holds the promise of testing general relativity in the “strong-field regime, of providing a new probe of exotic objects such as black holes and neutron stars, and of uncovering unanticipated new astrophysics.” [1]

By modifying the present tip-tilt suspension of the 40m prototype at CalTech with a magnetic levitation system, increased stability and sensitivity may be achieved. The magnetic levitation system would involve suspending rod-shaped magnets between metal rings, which is similarly beneficial for improved eddy-current damping. A proposed configuration may use permanent magnets in attraction to balance the suspended weight, “plus a closed loop position control to obtain a stable levitation.” [2] Drever first proposed using stable levitation for the mirror suspensions of long baseline detectors. [3] The primary advantage of this system is the ability to hold the optical piece without direct contact; this avoids noise contributions due to suspension wires.

OBJECTIVES

The objectives of this project are both finite and sweeping. Primarily, a magnetic levitation suspension (as described above) will be modeled using a finite element analysis (FEA) tool from an engineering/schematic standpoint. This design will then be tested with the FEA software, among other stress tests. Ideally, a prototype of the proposed suspension configuration will then be built and experimentally tested. This is in conjunction with the tip-tilt suspension presently being used, which does not utilize magnetic levitation for noise cancellation, as modeled with BOSEMS (schematics available on LIGO 40m Wiki page). Then, an optical Michelson readout with a large dynamic range will be needed, which requires the development of an interferometric readout such as that developed by Zumberge, et al, at the University of California San Diego. [4] Such a readout involves the implementation of an optical fringe resolver to replace the electronic displacement transducer of the typical seismometer or, in this case, interferometer. This allows for a linear, high-resolution displacement detector, absolute displacement measurement reference to the wavelength of light, and less equipment.

APPROACH

Theoretical

First, a model of the new must be designed using a software such as SIMULINK and experimentally tested using FEA tools and other software. Prior to this, calculations will be performed to justify the use of magnetic levitation and show its benefit to the 40m. The simulation and modeling may also be performed using the COMSOL package to simulate magnetic fields and their interactions with surroundings. One of the worries is that the stray field from the suspension will produce eddy current damping in the suspension cage, so this will need to be overcome. The model to be built is a sixteen dipole design; the main advantage is that this can be to make a very low frequency pendulum frequency and thus give a high amount of isolation from seismic noise. A similar schematic would need to be developed for the dynamic readout, which will be used for LIGO data analysis.

Experimental

After the designs have been tested with FEA tools, prototypes will be built and implemented, and tested within the 40m system. This data will then be used to optimize performance, increase noise cancellation, and fine-tune and better utilize the long-range dynamic readout.

PROJECT SCHEDULE

The first two weeks of the summer will be devoted mainly towards calculations and acquiring a sound background knowledge, as outlined in “Approach”, to aid with data analysis and correction later. The next three weeks will then be devoted to designing and optimizing a model of the new magnetic suspension using SIMULINK and testing using a FEA tool and other software, such as MATLAB. Building the suspension and testing it, then tuning the new design in lieu of the knowledge from the first few weeks should take another three to four weeks, in addition to implementing the large-range dynamic optical readout. Finally, this leaves a week or two for final adjustments, paper preparation, and extra data analysis.