Digitizing the Motorized Polarization Controller of LIGO's Arm Length Stabilization System

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Abstract

The first few weeks working to digitize the motorized polarization controller were spent establishing communication between the MPC and the TwinCAT software. Now that this has been established, focus has shifted to writing comprehensive, user-friendly, and robust controls for the system.

1 Motivation

The gravitational wave detector in LIGO Hanford Observatory (LHO) is a specialized Michelson interferometer with 4 km long arms that convert spacetime perturbations into a measurable signal [1]. The difficulty in this measurement is due to the length scale of these perturbations; this requires both that the interferometer mirrors are isolated from disturbances and that the noise encountered is quantifiable and removable. Thus, arm length stabilization (ALS) is essential. The current ALS system, however, faces issues with the drift of the polarization of light along fiber optic cables. This drift is corrected by a motorized polarization controller that currently must be adjusted manually on a regular basis. As aLIGO progresses, it is important to maximize the time spent locked and observing; by streamlining and digitizing the process to correct this polarization drift, we will allow for greater efficiency.

2 Background

2.1 Arm Length Stabilization (ALS) System

In order for the interferometer to be functional, the Fabry-Perot cavities, power recycling cavity, and signal recycling cavity must be kept locked on resonance. For aLIGO, a stabilization system was devised to make locking reliable and repeatable using active feedback control. The arm length stabilization (ALS) system locks each arm cavity individually from the central recycling cavities using lasers mounted behind each end test mass; they are doubled Nd:YAG lasers operating at 532 nm (green) deployed at each end station to distinguish them from the main laser. [2]

Once the auxiliary laser is locked to the fiber transmission, the output of the laser is locked to the arm cavity. Unfortunately, the drift of polarization of the light over these fiber optic cables causes some of that input light to be rejected due to a mismatch of polarization. This drift can be caused by factors such as thermal stress, mechanical stress, and irregularities in the shape of the core. [3] To correct this drift, a polarization controller was installed to manually adjust the polarization across the fiber optic cables; this polarization controller is part of a larger fiber noise cancellation scheme. The polarization of the 532 nm beam is linearized by wave plates before it passes through a Faraday isolator. [4]

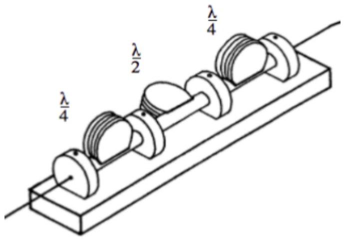

Figure 1: Fiber polarization controller consisting of three sequential Lefèvre loops. The orientation of these loops determines the state-of-polarization. [6]

2.2 Motorized Polarization Controller (MPC)

The motorized polarization controller used at LHO in the ALS system is a dual channel MPC1-02 from FiberControl. It alters the state-of-polarization of single mode optical fibers using stress-induced birefringence. The optical fibers are formed into three Lefèvre loops, each mechanically connected to a paddle for independent motion [5]. The stress produced by these loops causes them to act as three fractional waveplates (or retarders); with these three degrees of freedom, they can transform any arbitrary waveform into any other. The first Lefèvre loop acts as a quarter waveplate ($\frac{\lambda}{4}$) to transform elliptically polarized light into linearly polarized light. The second acts as a half waveplate ($\frac{\lambda}{2}$) to rotate the linear polarization. The final acts as a quarter waveplate ($\frac{\lambda}{4}$) to transform back to elliptically polarized light, if required [3]. These three Lefèvre loops are labeled in Figure 1.

3 Current Status of Project

In order to connect the MPC to existing software, the first goal was to build familiarity with programming industrial control systems using Structured Text and the TwinCAT 2 Programmable Logic Controller (PLC) software used by LHO. Next, the MPC was connected to the EtherCAT system, which is used to run slow controls hardware, using a serial connection. This system is controlled through TwinCAT, run on a rack-mounted PC and accessed remotely. [7] This TwinCAT software sets up a PLC in the IEC-1131 language standard and receives input and sends commands to the EtherCAT bus terminals, which in turn takes input and feeds output to the MPC.

Once the MPC was connected to the PLC software, the next goal was to establish communication and response. While the communication was easily established, the MPC did not initially respond as expected to simple commands. Instead, it echoed back any command that it was sent. After much investigation and trial and error, the proper syntax was discovered such that the MPC would implement any change requested. Currently, the MPC can be remotely adjusted on both channels, told to report on its updated position, centered all channels on 0.00 degrees, and reset remotely using the TwinCAT software.

4 Future Work and Goals

Now that the MPC responds to commands issued from TwinCAT, focus has shifted to developing comprehensive controls. After completing the details of the code, the next goal will be to increase its usability; an interface for the controls will be created using the EPICS OPC server. Subsequently, the interface will be tested; after it is proven robust, it will be updated to the TwinCAT 3 system. Finally, the program will be installed and integrated into the LHO controls.

Another opportunity for the expansion of this program is the automation of finding the ideal settings for the MPC1. Currently, to achieve a polarization that results in less than 5% of the light rejected, the knobs of the MPC1 are adjusted at random until the percent of rejection is minimized. If time allows, a final goal will be to program a way to cycle through each knob until the minimum is reached, without manual adjustment.

References

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