LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Technical Note **LIGO-T1200429-v1-** Date: 2012/09/03

Arm Length Stabilisation - FIBRE Phase-Locked-Loop

Bram Slagmolen and Daniel Sigg

Distribution of this document:

ISC

Draft

California Institute of Technology
LIGO Project, MS 18-34
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project, Room NW17-161
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
Route 10, Mile Marker 2
Richland, WA 99352
Phone (509) 372-8106
Fax (509) 372-8137
E-mail: info@ligo.caltech.edu

LIGO Livingston Observatory
19100 LIGO Lane
Livingston, LA 70754
Phone (225) 686-3100
Fax (225) 686-7189
E-mail: info@ligo.caltech.edu

http://www.ligo.caltech.edu/

1 Introduction

For the Arm Length Stabilisation the auxiliary laser in the end-stations is locked to the PSL frequency via an optical fibre. The 1064 nm light of the light transmitted through the PSL Reference Cavity is injected into an optical fibre, which is then sent to the ALS Fibre Distribution Chassis. Inside this chassis, the light will be frequency shifted via an AOM. After the AOM the fibre is split into three paths, two to the end-stations and one spare for later use.

On the ALS table in the end-stations the fibre output, approximately 300 μW, is combined with the 1046 nm light of the prometheus laser. The resulting beatnote, from an RF photo detector, will be tuned to 40 MHz by adjusting the temperature of the prometheus laser. The beatnote signal will be mixed with a VCO at 39.7 MHz to obtain en error-signal for feedback to the laser PZT and temperature. A 'Common-mode Board Servo' is used to implement the control servo. In this note the configuration of the CMB is described.

For the One Arm Test, a separate reference cavity was set up in the optics lab in the OSB. The transmitted light of the reference cavity was injected into a fibre and sent to the Y-end station. Approximately 300 μW came out of the fibre on the ALS-Y table. The optical power of the local oscillator was adjusted until the input monitor read approx. -25 dB (the monitor reads 20 dB less then the actual RF input).

2 Approach

The fibre to the end-station is directed to the ALS table. The 1064 nm output of the auxiliary laser will be combined with the fibre output. The auxiliary laser temperature will be adjusted to obtain a beatnote at +/- 40 MHz. A Common-mode Board Servo is implemented as a servo to lock the auxiliary laser to the 40 MHz beatnote. Feedback is done to the laser temperature and the PZT.

The local oscillator is half the standard 78.89 MHz signal at 39.4 MHz, and serves as a reference for the VCO. A Phase-Frequency Discriminator between the beatnote and the VCO to obtain the error-signal. When the beatnote is near the 39.4 MHz the error signal has the maximum slope. When the beatnote is further away (?? Hz) the VCO frequency the slope decreases (to an almost flat response).

The output of the Phase-Frequency Discriminator is connected to the Common-mode Board (CMB). The signal path of the PLL CMB is shown in figure 1, with the poles and zeros of the servo shape listed in Table 1. Because the phase discriminator has an inherent 1/f slope there is only a single 1.35/4k Hz stage (acting as a boost) in the signal path which needs to be engaged. The 100kHz complex pole is to prevent the PZT resonance to make the loop unstable. Unfortunately, an additional notch filter was required. This requires that each FIBR-CMB need its custom notch frequency measured, listed in Table 2.

The CMB Fast output ($\pm$10 V) is connected to the PZT on the laser head. This signal is digitised by the slow controls via the CMB Beckhoff interface. In addition this signal is digitised by the front-end. Within the Beckhoff an integrator is employed and controls the

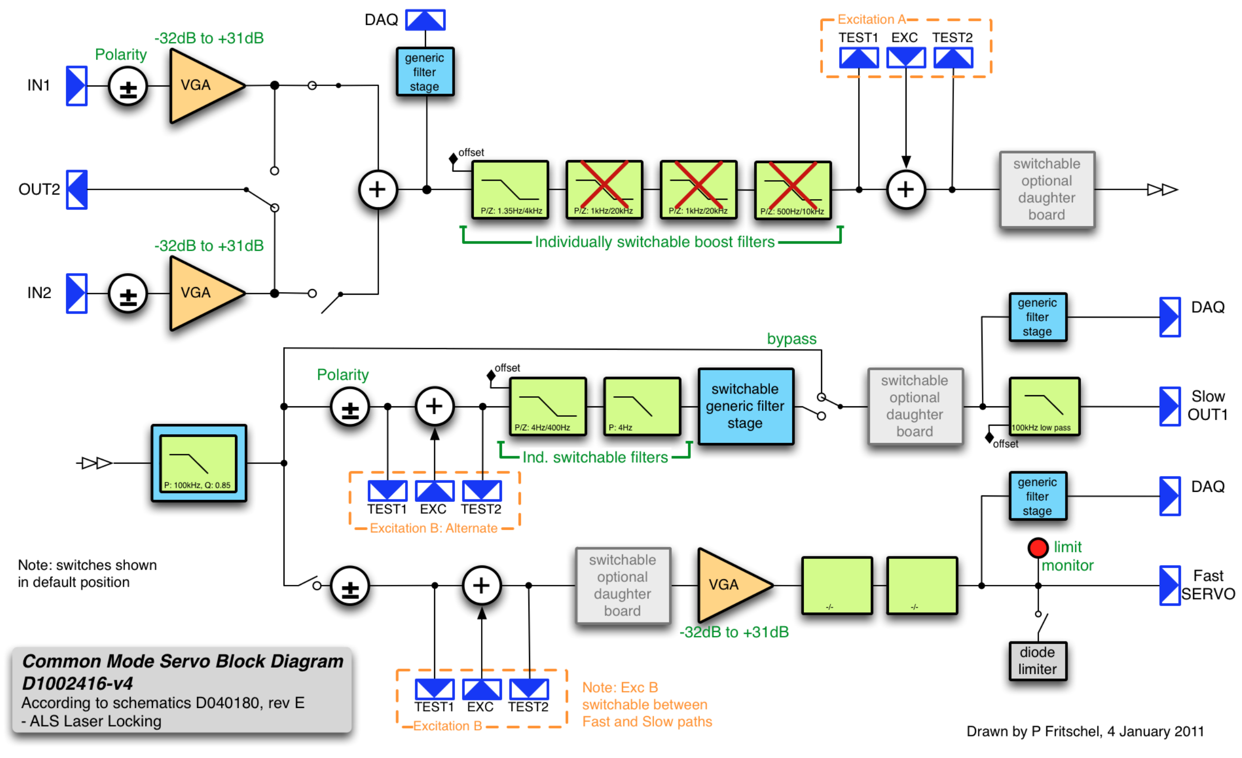

Figure 1: Signal path through the common mode servo board, with the PLL specific filters as listed in Table 1.

laser temperature (connected to the laser controller). The integrator settings are done by providing the unity-gain-frequency.

3 Implementation

Once the servo is engaged it provides a stable operation. Figure 2 shows the openloop transfer function. Due to the large amount of gain in the servo, only the response around the UGF has been measured. The modelled transfer function is based on the poles and zeros in Table 1.

Table 1: ALS Common Mode Servo Poles and Zeros.

Poles/Zeros	Where	Comment
0/-	before/common	phase detector
1.35/4k	board/common	common compensation
100k/Q=0.85	board/common	common filter
0/-	digital/slow	PID in slow controls
notch @282 kHz	before input (board)	currently in a pomona box

Table 2: ALS FIBR-Servo laser PZT resonance.

Laser (serial #)	Notch Frequency	Q
H2:ALS-Y (SN 2011B)	287.55k	191
H1:ALS-X	–	–
L1:ALS-X	–	–
L1:ALS-Y	–	–
H/I2:ALS-X	–	–
H/I2:ALS-Y	–	–

Figures 3 and 4 show the PZT resonance at 287.5 kHz, as well the Pomona box implementation of the notch filter. As of this writing the notch filter is located before the CMB input, due to its impedance and not to load the PZT. At a later stage this will be located within the CMB chassis (e.g. switchable optional daughter board).

Figures 5 and 6 show the MEDM screens controlling the FIBR Servo, the CMB and the laser temperature.

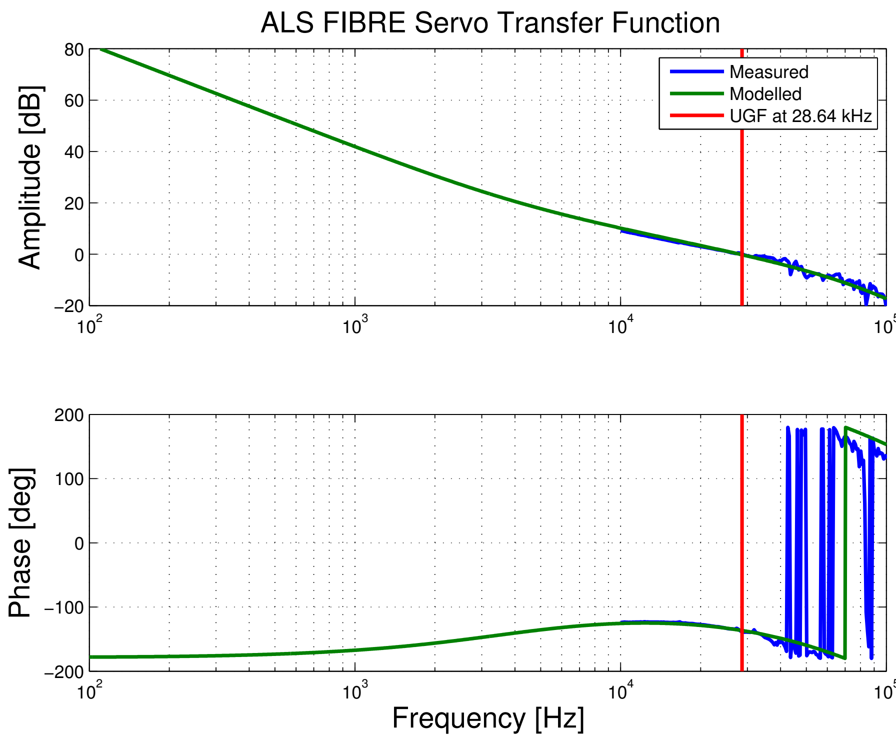

Figure 2: The measured and modelled transfer function of the PLL servo. The measurement is done around the UGF, which is at 28.64 kHz with a phase at -136 degrees (incl. the notch filter)

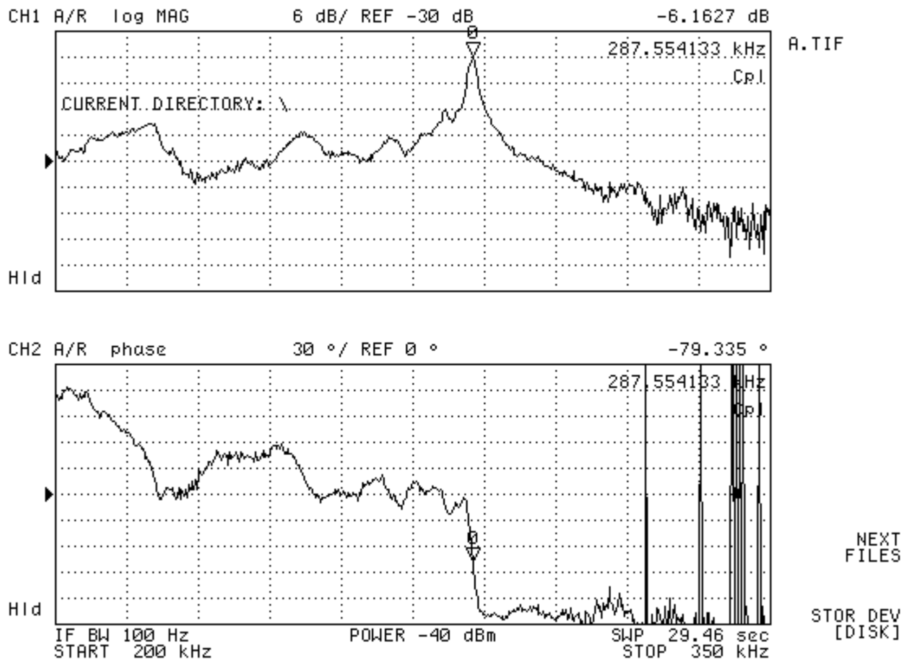

Figure 3: The transfer function of the PLL servo without the notch filter. The UGF during the measurement was approx. 7 kHz (approx. 10 dB less gain).

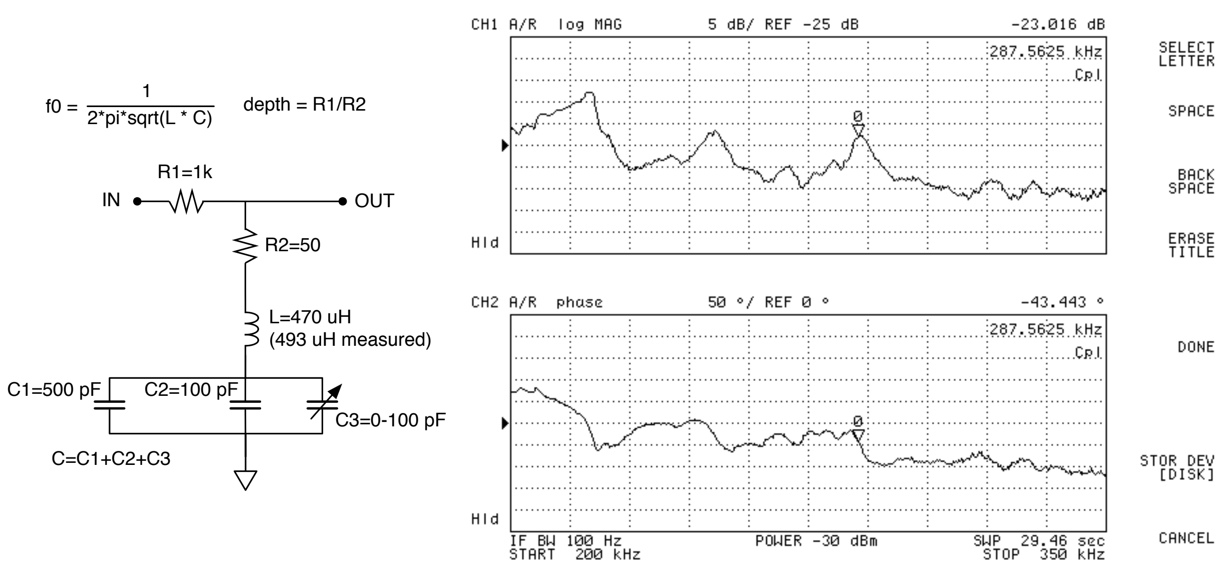

Figure 4: LEFT: Schematic of the notch filter. RIGTH: The transfer function of the PLL servo with the notch filter. The UGF during the measurement was approx. 28 kHz with a servo gain of -6 dB.

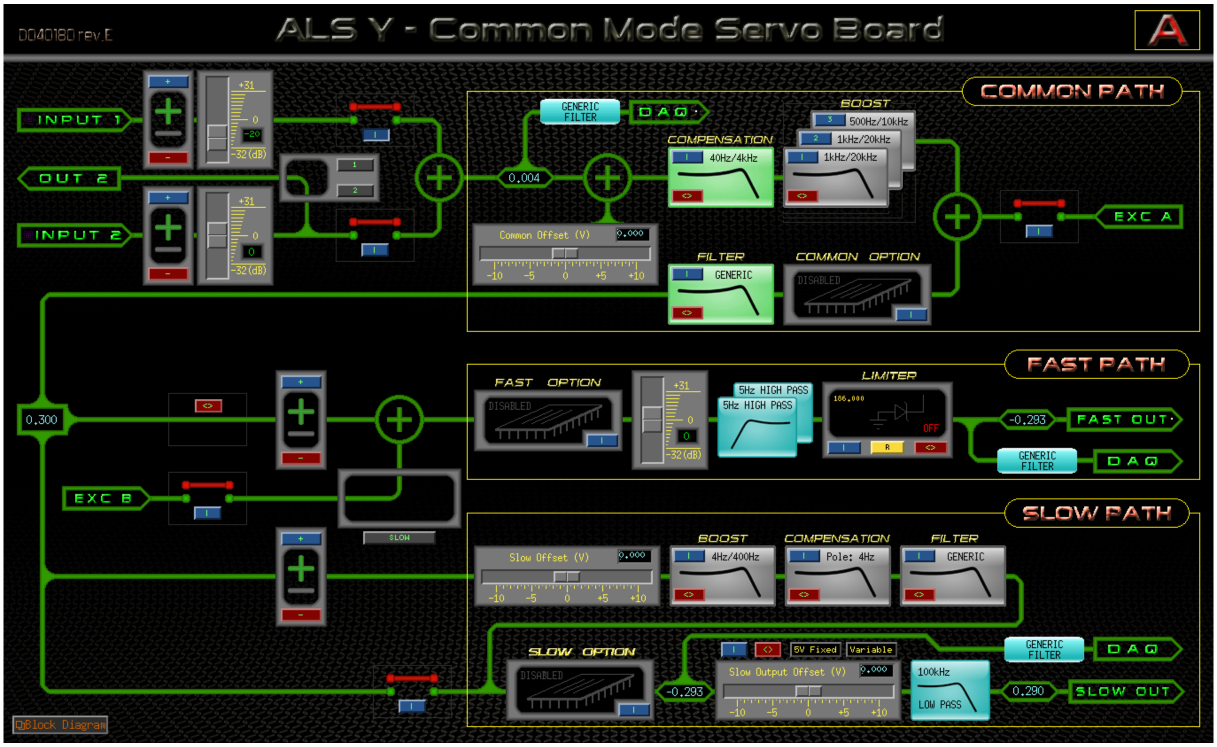

Figure 5: MEDM screen of the CMB-A (ALS FIBR Servo) control interface (loop is open). The 'COMPENSATION" switch engages the 1.35/4k Hz pole zero stage, while the 'FILTER' enables the 100 kHz complex pole. The Notch filter, although inline, is not controlled by this interface.

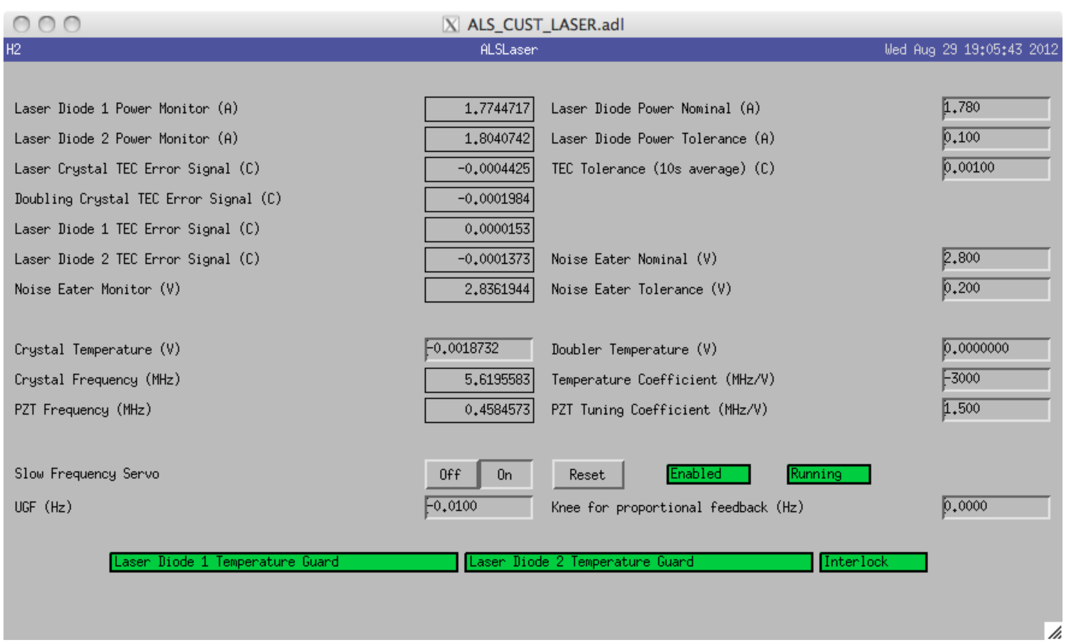

Figure 6: MEDM screen of the laser temperature control interface (slow control of the ALS FIBR Servo), engaged. The servo UGF is set at 10 mHz (bottom in the left column). The minus-sign in front of the value indicates the polarity setting.