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E-LIGO Wavefront Sensor Telescope Upgrade

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Table of Contents

1 Introduction

1.1 Purpose

The purpose of this document is to describe the changes that were made to the Wavefront Sensor Telescope (WFST) on ISCT1 table as part of e-LIGO IO upgrade. Details of new components installed and repositioning of currently installed optics is being presented.

1.2 Scope

As part of e-LIGO IO upgrade, the Faraday Isolator (FI) is located between MMT1 and MMT2. Therefore the reflected beam does not see MMT1 on its path to the ISCT1 table. Hence the Gouy phase and the beam sizes on the WFS also changed. The WFST had to be re-optimized to get back the Gouy phase and the beam sizes. Typical readers of this include people involved in designing alignment control and sensing matrix. After rework on the ISCT1 table, the Gouy phase and beam sizes are same as during S5.

1.3 Definitions

1.4 Acronyms

WFS: Wavefron Sensor

ROC: Radius of curvature

WFST: Wavefront Sensing Telescope

1.4.1 LIGO Documents

1. ISCT1 layout, http://www.ligo-wa.caltech.edu/~cgray/pics/PSL_IO/ISCT1/ISCT1_50.jpg
2. Component list, http://www.ligo-wa.caltech.edu/~cgray/ISCT1.html

1.4.2 Non-LIGO Documents

2 General description

As part of the e-LIGO IO upgrade, FI has to be put between MMT1 and MMT2. The reflected beam from the PRM travels back to the FI and is rejected by the thin film polarizer (TFP) and propagates towards the ISCT1 table. The rejected beam is used to measure the power through refl diode and is used for the WFS3 and WFS4. WFS3 is used to detect the RM degree of freedom by using the non-resonant (NR) sideband while WFS4 is used to detect a linear combination of common ITM and ETM degrees of freedom.

However, as the reflected beam is rejected by the TFP, it never sees MMT1, Due to this, the beam size as it reaches the periscope is out of Rayleigh range and is expending. In initial LIGO, the FI was in between SM1 and MMT1 and therefore would see MMT1 ROC. The beam was 'collimated' as it reaches the ISCT1 table. This situation demanded re-optimizing the ISCT1 table.

Figure 1 shows the FI details in HAM1.

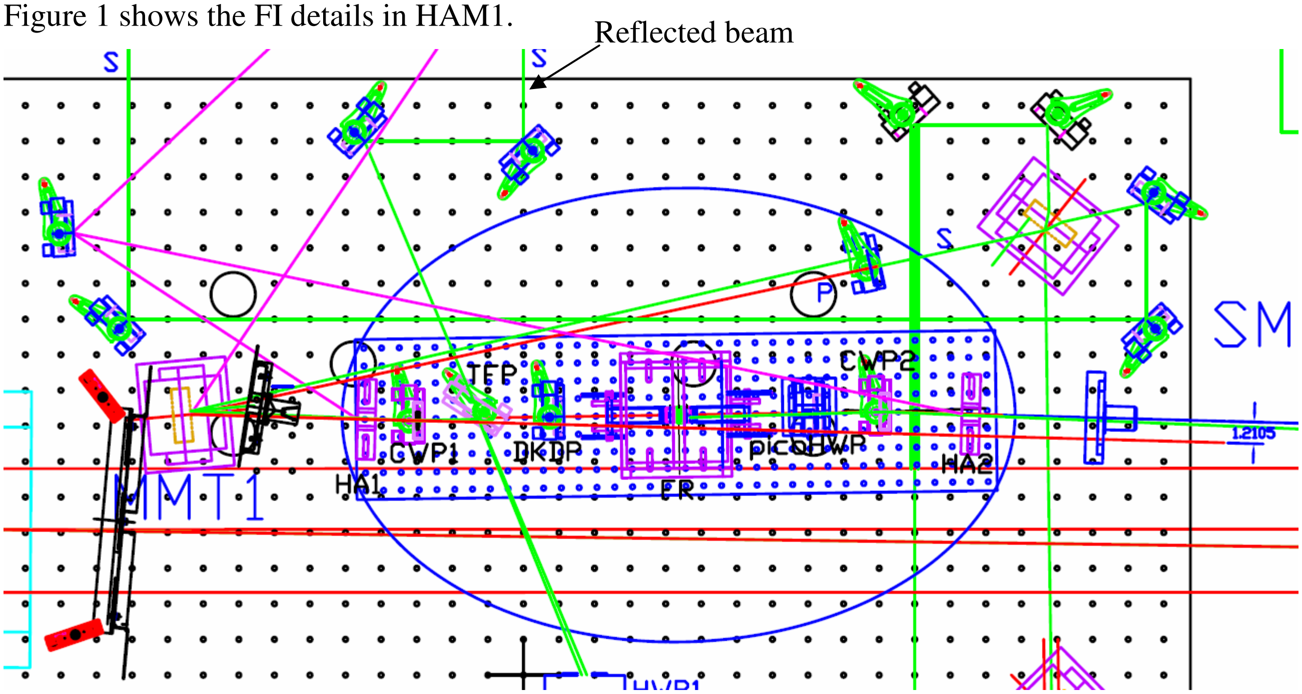

Fig. 1: FI details in HAM1 showing the reflected beam being reflected by the TFP.

3 Changes in the ISCT1 Table Layout

As mentioned earlier, placement of FI between MMT1 and MMT2 changed the reflected beam profile from S5 values. Another change was the increased distance from between Mode Cleaner (MC) and the Steering Mirror (SM) and increased distance between SM and MMT1. The changes on the HAM1 table are as follows:

Table 1: Changes in HAM Tables during S5 Upgrade

Arm	iligo (mm)	eligo (mm)	Beam size (mm) (Ending Optics)
MC waist to SM1	642.6	796.0614	1.637
SM1 to MMT1	686.5	1198.2958	1.68
MMT1 to MMT2	13551.5	14046.4286	5.388
MMT2 to MMT3	14433.1	14421.1	36.89

The beam size propagation is shown in Fig. 2.

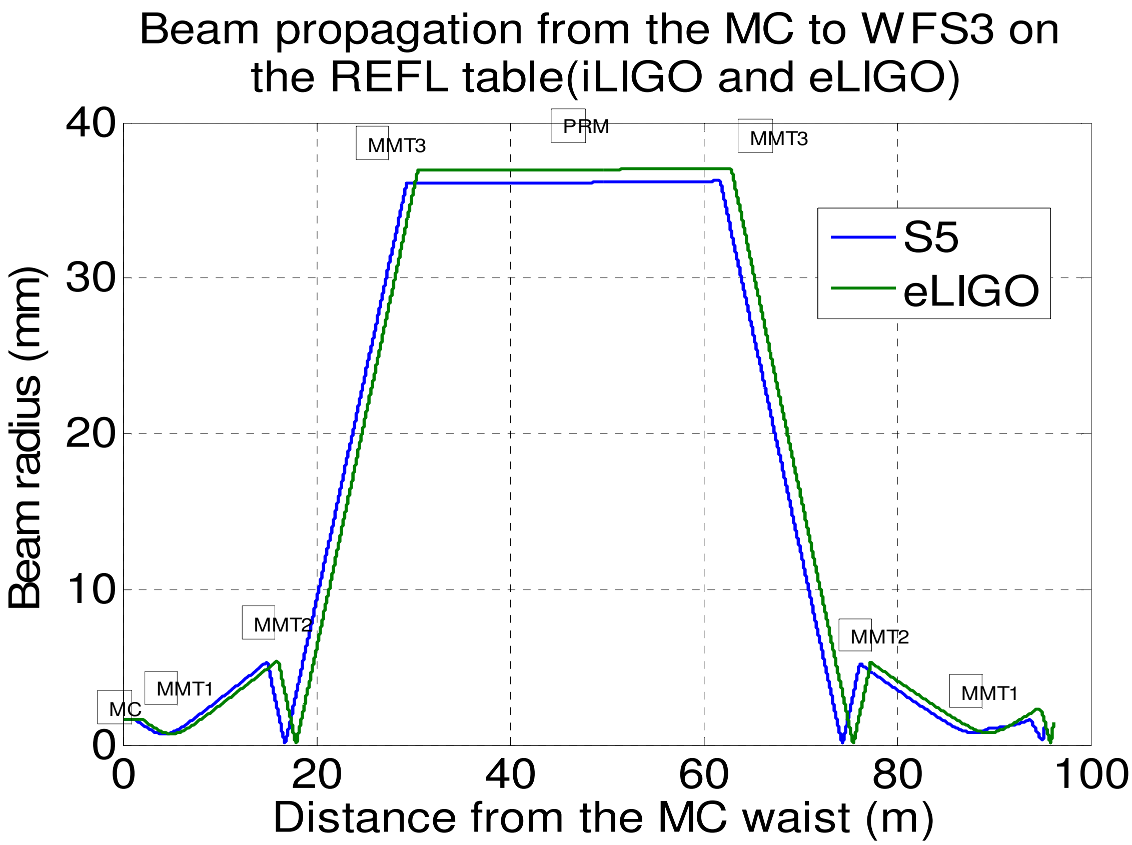

Fig. 2: The beam propagation from MC to the reflected port. A zoomed plot for the ISCT1 table will be discussed later.

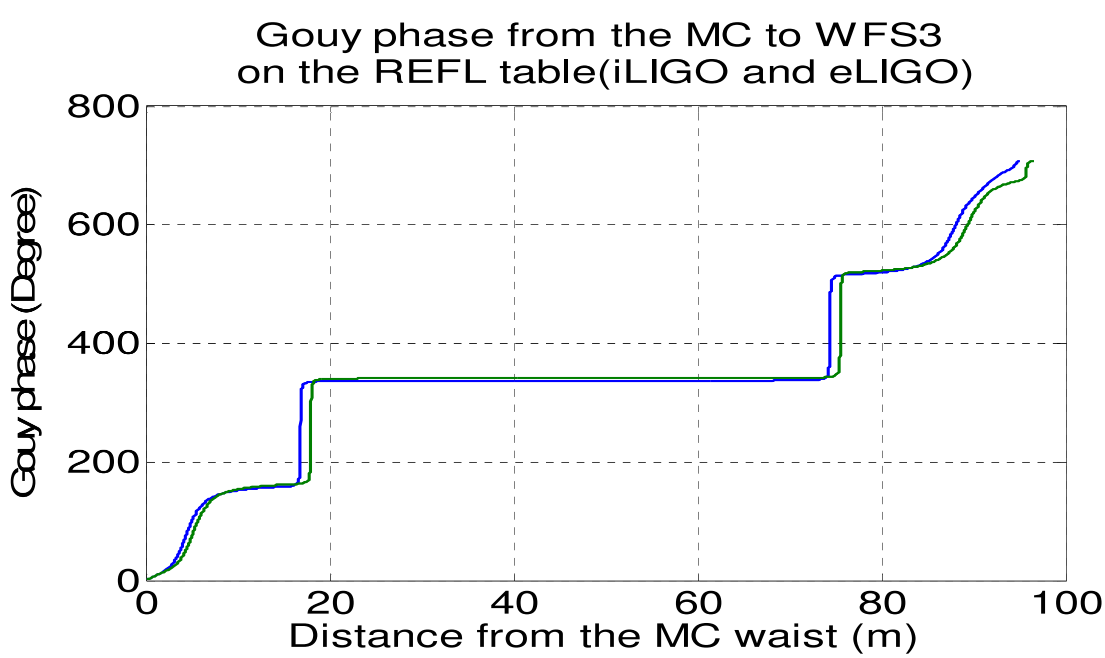

Fig. 3: Gouy phase propagation for the reflected port.

3.1 Changes in the common path for the reflected beam

According to Ref. 1, there is a 1 m nominal focal length lens at (47,29) after the periscope assembly. This lens has been replaced by a lens with focal length = 2.2912 m (for 1064 nm). The lens is standard fused silica CVI lens and the part number is PLCX-50.8-1030.2-UV. The aforementioned 1 m (1.1456 m focal length at 1064 nm) has been moved forward to a new position of (47,13) on the ISCT1 table.

Another consequence of changing the lenses was that the beam size at refl diode and CCD changed. We inserted a lens PLCX-50.8-515.1-UV at (49,26) on the table. The steering mirrors were adjusted to realign the beam on the diode and the CCD.

3.2 WFS3 Layout

For WFS3, during S5, there was a -143 mm focal length lens. This lens has been replaced by a new lens, i.e., a lens with focal length of -76.3 mm (1064 nm). The part number is PLCC-25.4-25.8-UV-1064. Note that this lens was previously on the ISCT1 table and was intended to be used with WFS5. Since there is no WFS5, so we re-used this lens. This lens is now placed at 0.7120 m away from the aforementioned 1 m focal length lens in the common path of the reflected beam.

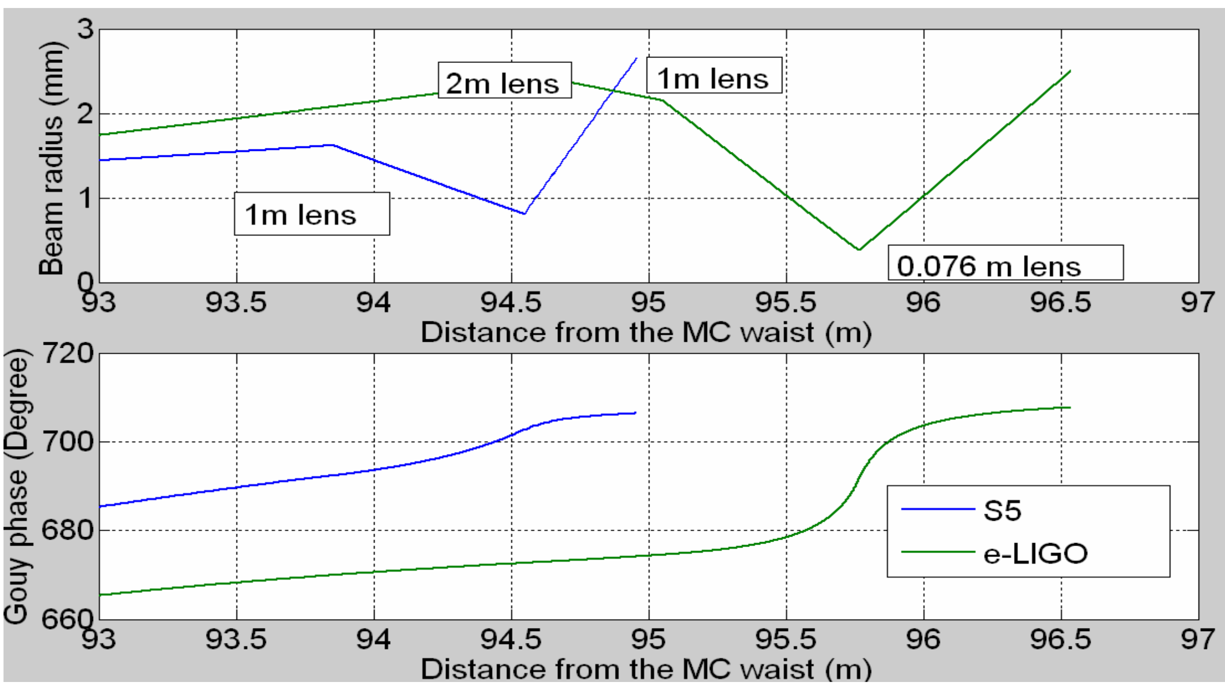

Fig. 4: Beam propagation and Gouy phase for WFS3 showing S5 and e-LIGO values. The beam waist and the Gouy phase have been restored to S5 values by putting additional optical components and by changing the position of WFS3.

The WFS3 position has also been changed. This is now located at a distance of 0.77 from the -76.3 mm focal length. Note that the distance between the lens and the WFS3 can be changed if the beam waist or the Gouy phase needs to be changed.

3.3 WFS4 Layout

For WFS4, the -57.4 mm lens has been replaced by a focal length -43.6 mm. The new distance between the 1 m lens in the common path and the -43.6 mm focal length has been changed to 0.88 m and the distance between the -43.6 mm lens and WFS4 is 0.2699 m.

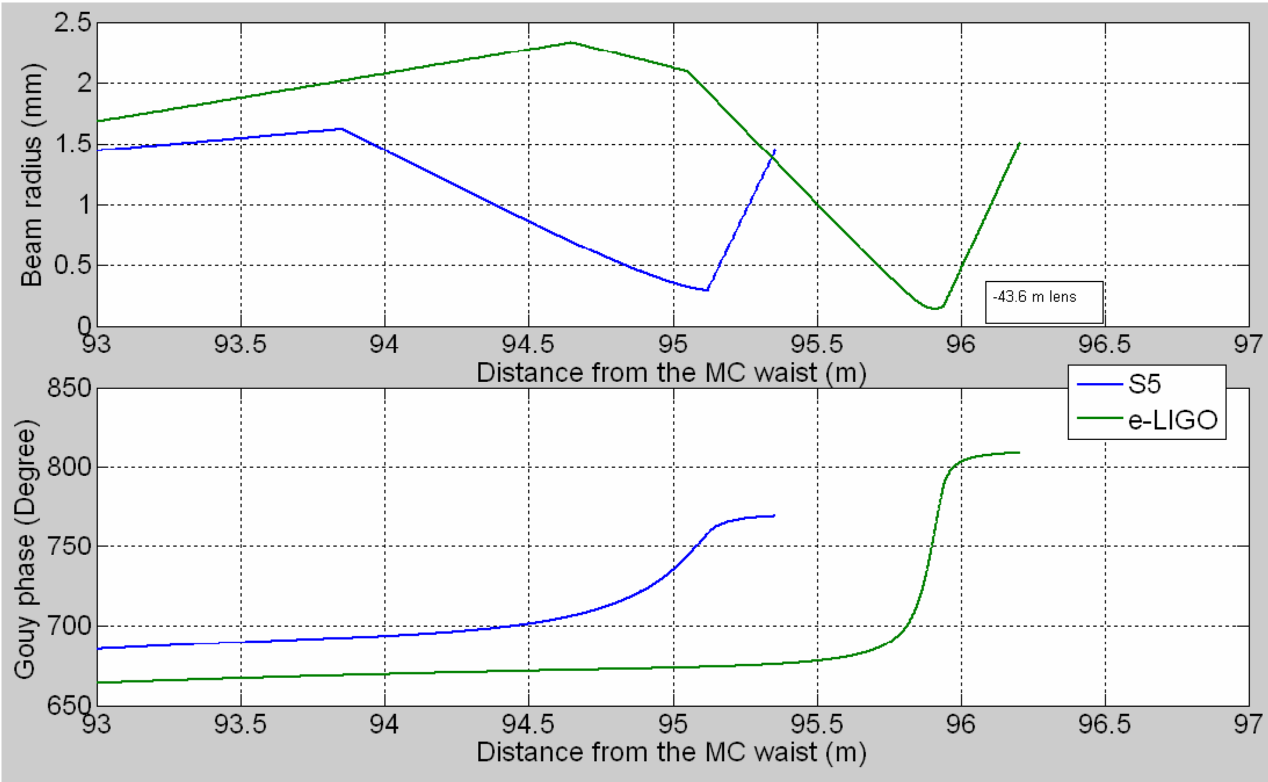

Fig. 5: Beam propagation and Gouy phase for WFS4 showing S5 and e-LIGO values. The beam waist and the Gouy phase have been restored to close to S5 values by putting additional optical components and by changing the position of WFS4.

Note that the beam waist at WFS4 has is close to S5 values however, the Gouy phase is different by 49 degree. However, now the difference of Gouy phase between WFS3 and WFS4 is about 100 degree that is close to the expected 90 degree Gouy phase difference.

Fig. 6 shows the ISCT1 table layout after rework. The added lenses are indicated on the figure.

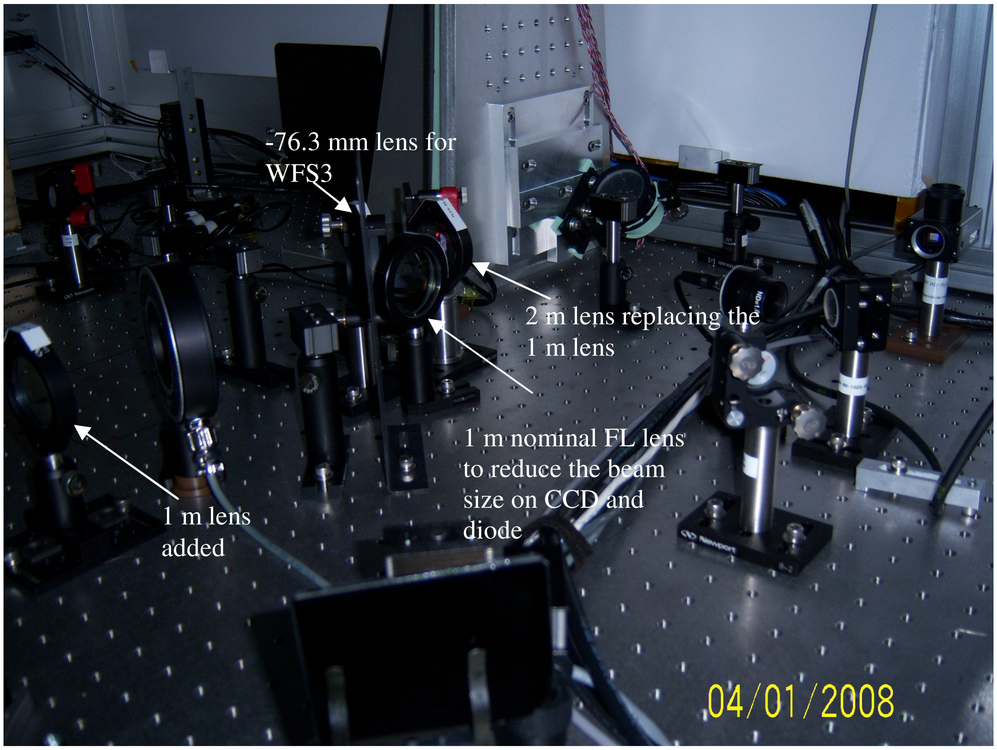

Fig. 6: Picture of ISCT1 Table layout after rework

4 Summary

The above discussion can be summarized as follows.

- E-LIGO IOO update has changed the reflected beam profile. Now the reflected beam does not see MMT1 due to FI being in between MMT1 and MMT2.
- Due to this, the beam sizes and the Gouy phases have been changed.
- ISCT1 table has been reworked to restore beam sizes and Gouy phases on WFS3 nd WFS4.
- The Gouy phase difference can be changed by moving the newly installed lenses.