LASER INTERFEROMETER GRAVATATIONAL WAVE OBSERVATORY
-LIGO-

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LIGO Hanford Observatory

Optical Lever Calibration

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GENERAL

I. PURPOSE AND SCOPE

This procedure was developed as a guideline to calibrate the suspended core optic, optical levers. It was derived from LIGO-T990026 by Mike Zucker. This document uses the formulas and techniques described in the above document and it also explains the use of the fixturing that was built to complete the calibration task. To better understand this process it is recommended that one reads the above-mentioned document.

II. KEYWORDS

Optical Levers, Quadrant Photo Diodes, Optical Lever Transmitter and Receiver, Parallel BK7 Glass Plate, Beam Displacement, MEDM Screens.

III.OVERVIEW

This calibration is used to establish the value of the angular motion seen by the quad photo diode (QPD). This QPD output signal is graphically displayed on a MEDM screen, which has a scale of ± 1 Unit for both X & Y axis. This calibration establishes the angular sensitivity expressed in micro radians per Unit (see below).

IV. HAZARDS

The optical lever laser is a class IIIa laser with an output <5mW @ 670nM wavelength. The typical ¼ second blink reflex will protect your eye from a brief direct exposure to the beam. Direct exposures of 10 seconds or longer could cause eye damage.

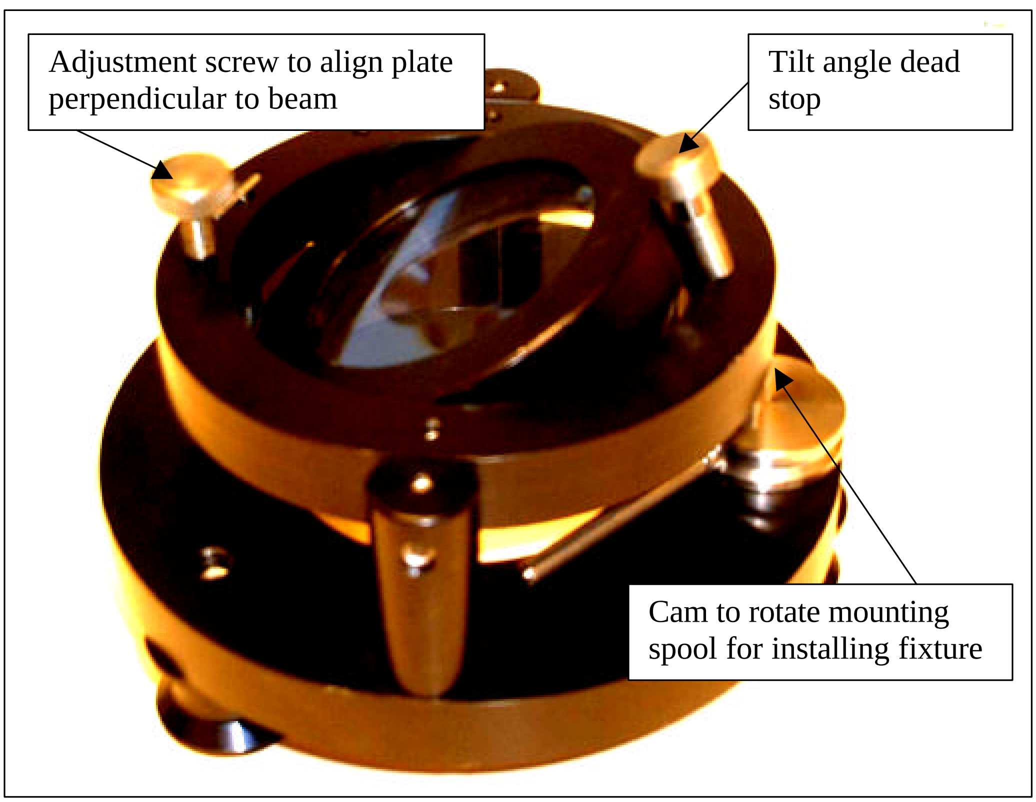
V. REQUIREMENTS

The tilt plate fixture set for 20-degree tilt and containing a 1mm thick plano parallel window.
The fixed 1mm iris and fixture for setting the beam diameter.
An Ophire power meter with the low power head.
A laptop with Exceed and Excel.
A copy of the Excel spreadsheet for crunching the numbers.

VI. CALIBRATION STEPS

1/ Verify that core optic is aligned.
2/ Steer the optical lever receiver steering mirror to null the X and Y signals.
3/ Measure the actual power at the QPD with an Ophire Si power meter for comparison and record (spreadsheet col#2).
4/ Record the SUMo, YAWo and PITCHo values from the MEDM screen (Baseline values).
5/ Place the 1mm diameter iris and mount into the QPD input aperture and center the iris to the beam by rotating and linearly adjusting the translation stage.
6/ Record the SUMo value
7/ Remove the iris.
8/ For 2mm diameter beam (used for 10X expanders) adjust the laser expander on the transmitter to 61% of the Sum value.
9 / For 5mm diameter beam (used for 30X expanders) adjust the laser expander on the transmitter to 89% of the Sum value.

10/ Record (spreadsheet col#4,5,6) the SUMo, YAWo and PITCHo values from the MEDM screen (Baseline values).
11/ Remove bellows from the optical lever receiver box and install the tilt fixture.
12/ Align the fixture for the YAW measurement. Steer the beam, to direct the beam back onto itself using a pinhole target near the viewport. Use the single adjustment screw to align the YAW axis and rotate the fixture for PITCH. You may not be able to bring the PITCH axis completely back to the pinhole due to the receiver box not being mounted perpendicular to the beam and only having a minimal steering effect with the rotation of the fixture. It is more important to correct for the YAW axis at this time.
13/ Record (spreadsheet col#7,8) the SUM1 and YAWoo values from the MEDM screen (Baseline values). These baseline values change from the earlier ones due to the reflection of some of the light ~ 4% per surface from the plate.
14/ Tilt the plate (20 degrees).
15/ Record (spreadsheet col#9) the YAW1 value.
16/ Rotate the fixture 90 degrees for the PITCH axis measurements.
17/ Align the fixture for the PITCH measurement first. Steer the beam, to direct the beam back onto itself using a pinhole target near the viewport. Use the single adjustment screw to align the PITCH axis and rotate the fixture for YAW. You may not be able to bring the YAW axis completely back to the pinhole due to the receiver box not being mounted perpendicular to the beam and only having a minimal steering effect with the rotation of the fixture. It is more important to correct for the PITCH axis at this time.
18/ Record (spreadsheet col#10) the PIToo values from the MEDM screen (Baseline value). These baseline values change from the earlier ones due to the reflection of some of the light, ~ 4% per surface from the plate. For calculating purposes we use the same Sum1 (col#7) recorded earlier.
15/ Tilt the plate (20 degrees).
16/ Record (spreadsheet col#11) the PIT1 value.
17/ Calculate the urads/Unit values for both YAW and PITCH (use the spreadsheet for convenience).



OPTICAL LEVER CALIBRATION FIXTURE

RECORDED VALUES

For Core Optic: ______________ by: ________________________Date: ____________

Fixture Settings:

A. Window Thickness *t* = *1mm*

B. Index of refraction *n* = *1.52 (BK7)*

C. Fixture angle = 20 *degrees*

D. Displacement *d* = .1251*mm*

$$d = \frac{t \sin\left[\theta - \arcsin\left[\frac{\sin(\theta)}{n}\right]\right]}{\sqrt{1 - \frac{(\sin(\theta))^2}{n^2}}}$$

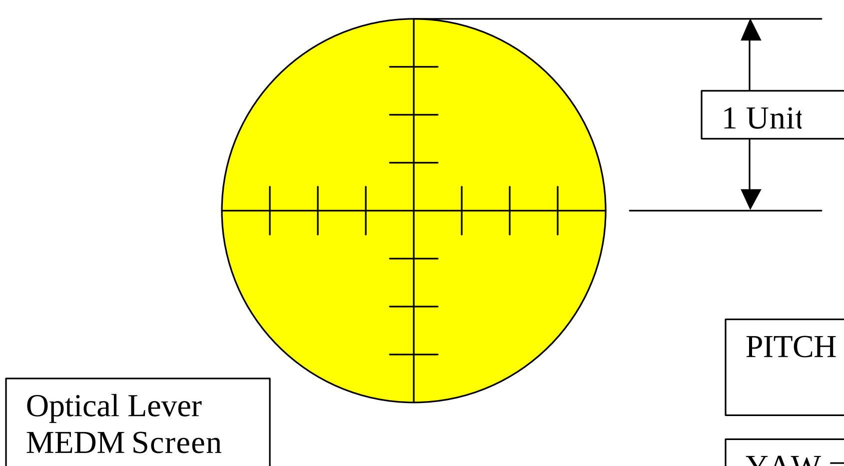
MEASUREMENTS	VALUES FROM EPICS SCREEN
SUMo = Sum 'baseline' before inserting the fixture (null).	
YAWo = YAW' baseline' before inserting the fixture (null).	
PITo = PIT'baseline' before inserting the fixture (null).	
INSTALL FIXTURE- ***Not tilted*** **Align fixture for the YAW measurement first. -** Steer the beam to direct the beam back onto itself using a pinhole target near the viewport. Use the single screw for the alignment axis and rotate the fixture for the other axis.	
SUM1 = Sum after inserting the fixture. (Corrected value for diminished beam power intensity due to the window in the fixture).	
YAWoo = value after inserting the fixture. (Corrected value for diminished beam power intensity due to the window in the fixture).	
Tilt window to the 20 degree stop	
YAW1 = YAW value after tilting plate	
Calculate the Linear Sensitivity in Volts/mm or Counts/mm: $YAWaxis = \frac{YAWoo - YAW1}{d} = Units/mm$	

Note: Use 16,384 Counts = 1 Volt.

MEASUREMENTS (continued)	VALUES FROM EPICS SCREEN
INSTALL FIXTURE- ***Not tilted*** **Align fixture for the PITCH measurement next. -** Steer the beam, to direct the beam back onto itself using a pinhole target near the viewport. Use the single screw for the alignment axis and rotate the fixture for the other axis**.**	
SUM1 = Sum after inserting the fixture. (Corrected value for diminished beam power intensity due to the window in the fixture).	
PIToo= value after inserting the fixture. . (Corrected value for diminished beam power intensity due to the window in the fixture).	
Tilt window to the 20 degree stop	
PIT1 = PITCH value after tilting plate	
Calculate the Linear Sensitivity in V/mm or Counts/mm: $PITCHaxis = \frac{PIToo - PIT1}{d} = Units / mm$	

Note: Use 16,384 Counts = 1 Volt.

Calculate uradians per unit
$Units/mm \times 2L(table1) \times 0.000001 = Units/urad = \frac{1}{Units/urad} = urads/unit$



PITCH =

YAW =

CORE OPTIC	**L = Distance from Core Optic to Receiver QPD in mm**
MMT3-2K	1454.15 mm
RM-2K	4305.30 mm
BS-2K	1677.67 mm
FMx-2K	1235.08 mm
ITMx-2K	33329.88mm
ETMx-2K	6088.38 mm
FMy-2K	2067.56 mm
ITMy-2K	33329.88 mm
ETMy-2K	6088.38 mm
MMT3-4K	1080.77 mm
RM-4K	3260.09 mm
BS-4K	1833.88 mm
ITMx-4K	28399.74 mm
ETMx-4K	6088.38 mm
ITMy-4K	30914.34 mm
ETMy-4K	6088.38 mm