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

Document Type	**LIGO-E000062-C - W**	02/16/00

LOS Installation Procedures for BSC Chambers

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This is an internal working note
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1 PURPOSE AND SCOPE

This document is the standard guideline for properly handling and installing the Large Optic Suspension (LOS) assemblies into the BSC chambers at the LIGO Hanford Observatory. It contains a step by step check list to aid in the installation process (see Appendix 1). This is done to prevent over-looking important installation details, which when omitted, have in the past, proven to damage suspended optics. This procedure picks up at the point where the optic has had its post bake cleaning, inspection, the magnets checked for bond integrity, and is re-hung in its structure. The LOS balance and tilt measurements should have been confirmed and logged. The OSEM open-light voltages recorded and the OSEMs set at 60% of the open light voltage. PAM magnets should be set to length and damping checked and readings recorded. The optics table on which the LOS is destined, should contain the counter weight payload and be level and sitting at the proper elevation.

2 HAZARDS

The LOS assemblies are heavy and awkward to maneuver, and require two persons coordinating their movements carefully, to prevent personnel from becoming injured or damaging property. The LOS assembles have under gone several expensive, time consuming operations, prior to this point of installation, and the optic itself, being a very expensive, long lead time component, requires personnel to be alert and diligent when handling them.

3 CONTAMINATION AND CONTROLS

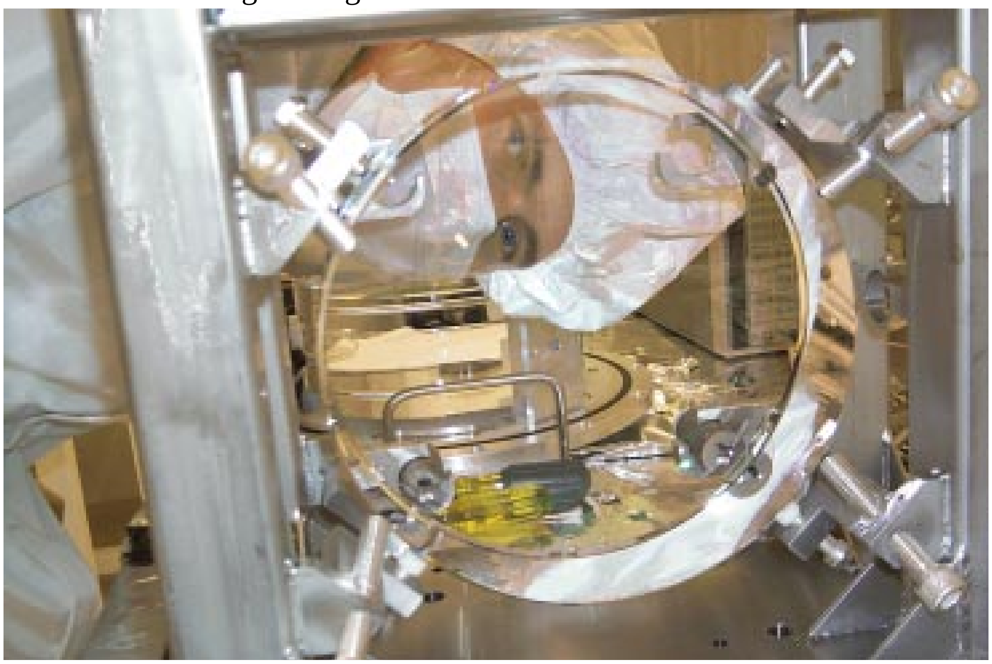
To provide reasonable assurance against the inadvertent introduction of contaminants to the optic, fixturing and/or the vacuum envelope, all personnel assisting with LOS installations, should be familiar with the LIGO Hanford Observatory Contamination Control Plan, LIGO-M990034-A-W and the LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures, LIGO-E960022-05-E. It is important that proper clean room attire is worn in the appropriate areas, while handling the LOS assemblies and their related fixtures.

4 REQUIREMENTS

The minimum gowning requirements for working in close proximity to an LOS assembly in the Optics Labs are: *Bouffant Cap, Frock, Overshoe Covers, Face Mask and UHV Gloves*, all from the approved supply. When doing the actual installation into an open chamber, while working under the soft wall enclosure, the minimum garment requirements are: *Full Hood, Face Mask, Clean Room Coveralls, Clean Room Knee High Boots, and UHV Gloves*, all from the approved supply. If you are going to be entering into the chamber, *Inside Chamber Overshoe Covers* are to be worn over the *Cleanroom Knee High Boots*, donning them at the time you transition to the chamber interior, making sure the *Inside Chamber Overshoe Covers* do not come in contact with surfaces on the exterior of the chamber. The forgoing is just part of the protocols required when working with contamination-sensitive hardware. It is a must that the Contamination Control Plan be followed in it's entirety.

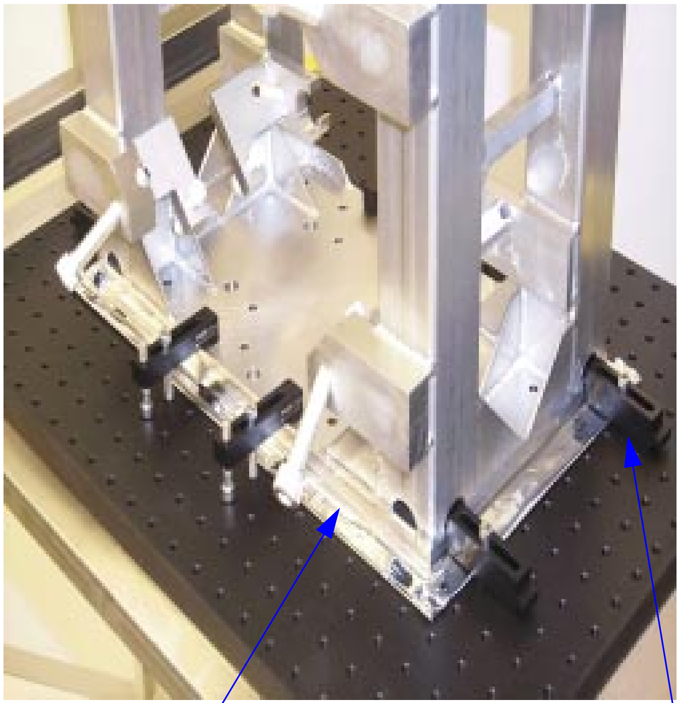
APPENDIX 1 INSTALLATION PROCEDURES

1. Check the alignment between the magnets and the OSEMs. Magnets should still be centered in the OSEM openings.
2. Using a low power HeNe laser for an optic lever transmitter and a quad diode receiver, clamp the optic in its balanced position. Check that the 4 Teflon capped silver plated bottom support screws are *lightly touching* the optic. Next contact the optic with the 8 chamfer stop screws while maintaining the alignment. Next clamp the optic with the 4 top Viton tipped safety stop screws while maintaining the alignment.



3. Position the LOS near the edge of the optics table, in close proximity to the *transport cart*. Place clean UHV foil on the top of the transport cart. Wrap the OSEM "pig tails" in a UHV foil pouch to prevent them from dangling free or wrap them through the structure.
4. One person should man the transport cart to prevent it from moving, pushing it against the optics table.
5. With a second and third person facing each other, keeping hands clear of critical components, grip the LOS structure in a comfortable, balanced position, and upon a "count down", lift the LOS onto the transport cart.

Shows the Stainless Steel LOS *Transport Cart* with its shock absorbing casters. There is an optical bread board fastened to the cart to enable the structure to be clamped down during transport. There are four nylon slings for craning purposes. Use eight "dog clamps" to secure the structure



UHV Aluminum Foil

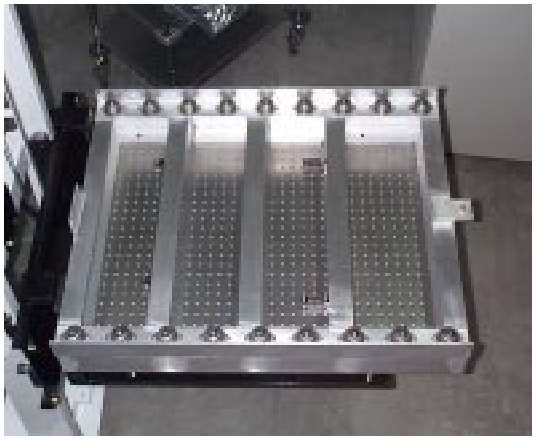
"Dog" Clamps

2 styles from Thor Labs

6. Clean the optic with the CO2 *"snow-gun"* and ion N2 gun to remove dust particles and foreign matter, and wrap the structure with UHV foil before transporting it from the optics lab. Roll the optic to the HAM chamber and into the soft wall enclosure. If craning is required, use the dedicated straps and tag lines.

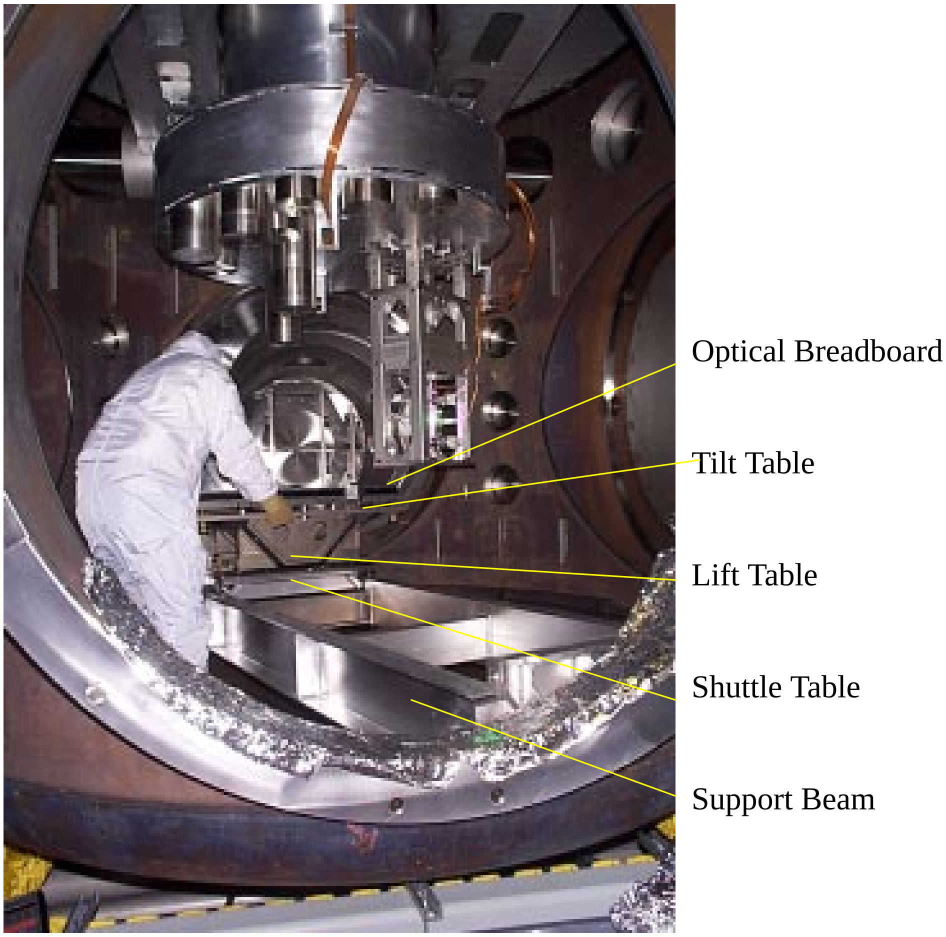
7. Bolt the *optical breadboard and posts* to the forks of the *straddle*.
8. Place the *roller truck* onto the breadboard and "Dog" clamp it down.

Straddle with roller truck installed in place. (this set up is only used to install the lift table into BSC chambers).

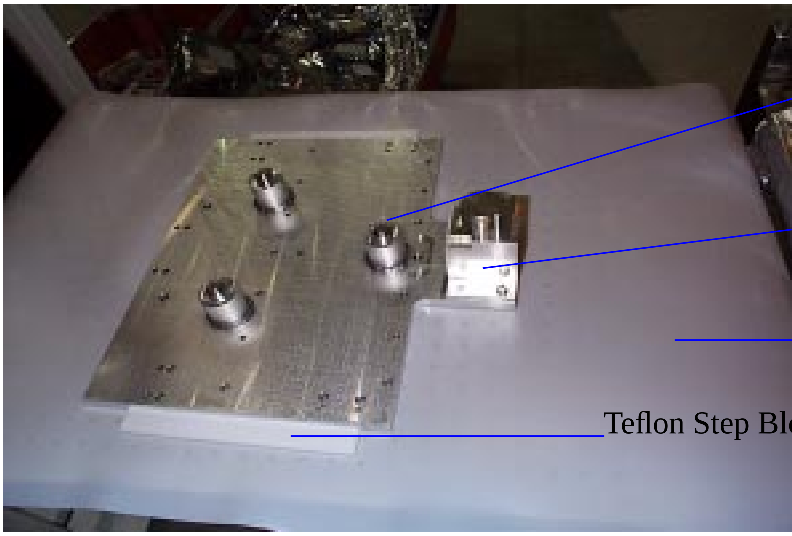


Bread Board and Posts

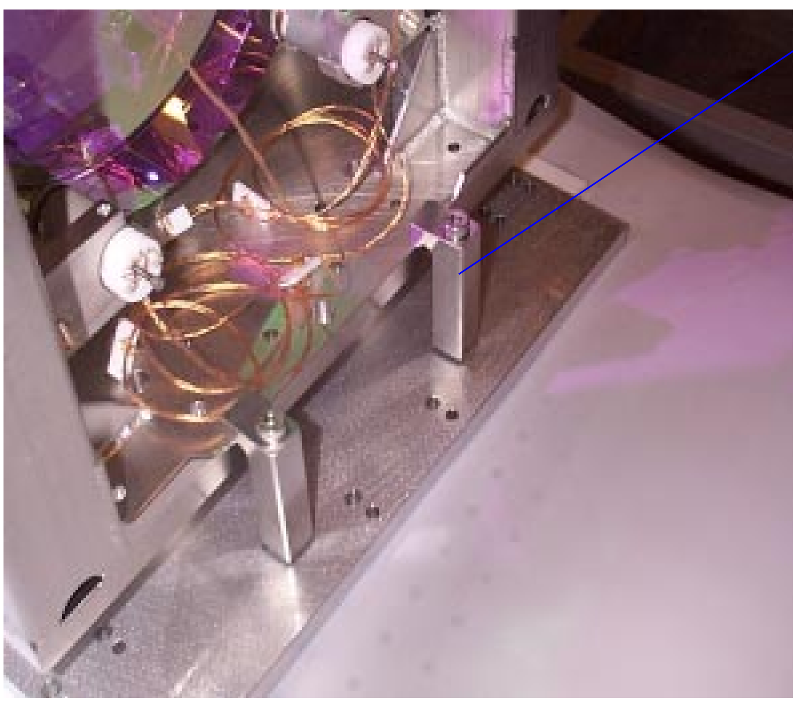
9. Place the *lift table* onto the roller trucks. Use caution as the lift table is heavy and awkward.
10. Bolt the *Tilt Table* onto the *Lift Table*
11. With two people on the inside of the chamber and two on the outside pass the *Support Beam* through the door and place it onto the interior rail of the BSC chamber.
12. Place the *Shuttle Table* onto the Support Beam and lock into place near the door opening using 4 class ‘B’ C-clamps.
13. Wheel the *Straddle* to the chamber door opening.
14. Crank the *Straddle* with the *Lift Table* and *Tilt Table* up to a height that allows the *Straddle* forks to enter into the chamber. The two persons in the chamber must transfer the *Lift Table* down onto the *Shuttle Table*. Use caution as the *Lift Table* is heavy.
15. Pass the *Optical Breadboard* into the chamber and clamp to the *Tilt Table* with the 4 special clamps.



16. Back out and lower the Straddle forks and remove the Roller Truck from the straddle.
17. Position the Straddle and the LOS Transport Cart in close proximity to each other to facilitate easy transferring of the LOS to the Straddle Breadboard 1.
18. Place the *Teflon Sheeting* on the Optical Breadboard
19. Place the *Teflon Step Blocks* onto the Teflon sheet.



20. Place the *Alignment Fixture BSC Adaptor* onto the Teflon Step Blocks.



“Dog” clamps holding the structure to the BSC Adaptor Plate.

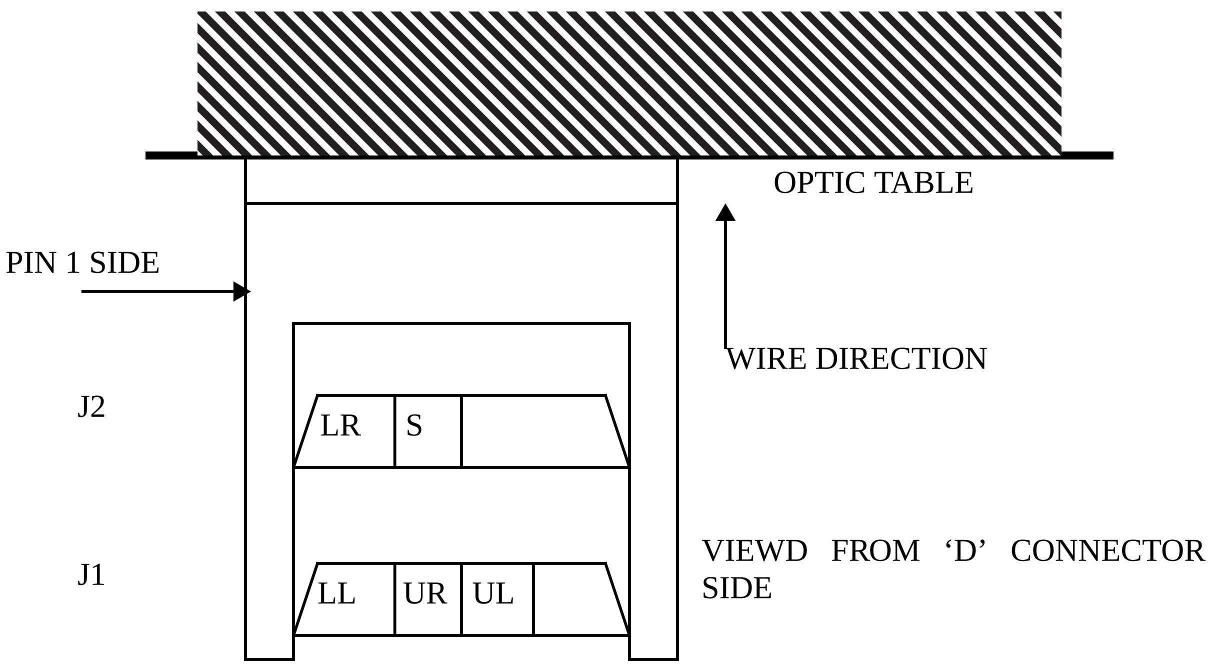
SUS cage with optic locate on the three posts and secured with the ‘dog’ clamps. Prism mount is on the front side (HR side of the optic)

21. One person should secure the transport cart, while a second and third person facing each other, keeping their hands clear of critical areas, grip the LOS structure in a comfortable, balanced position, and upon a "count down", lift the LOS from the transport cart onto the three tapered pins of the Alignment Fixture BSC Adaptor and clamp it into position using the three special "Dog Clamps".
22. Fasten the *LOS* to its *Height Adaptor* with 1/4-20 X 1 1/4 SST cap screws and lock washer and silverplated SST nuts. (18 each).
23. The two people in the chamber will receive the LOS and two people will assist from the outside until transfer is completed.
24. Rotate the Support Beam perpendicular to the opening of the chamber and tighten lock screws.
25. Slide the Shuttle Table, with the Lift Table and Tilt Platform and Optic Table 2 along the Support Beam to the opening of the chamber and secure it using 4 class 'B',C- clamps.
26. Steer the Straddle to the opening of the chamber and raise the Optical Breadboard height up to match the Optical Breadboard height on the Lift Table. Gently push the straddle forward, and butt to two Optical Breadboards together.
27. Gently slide the LOS onto the Optical Breadboard on the Lift Table.

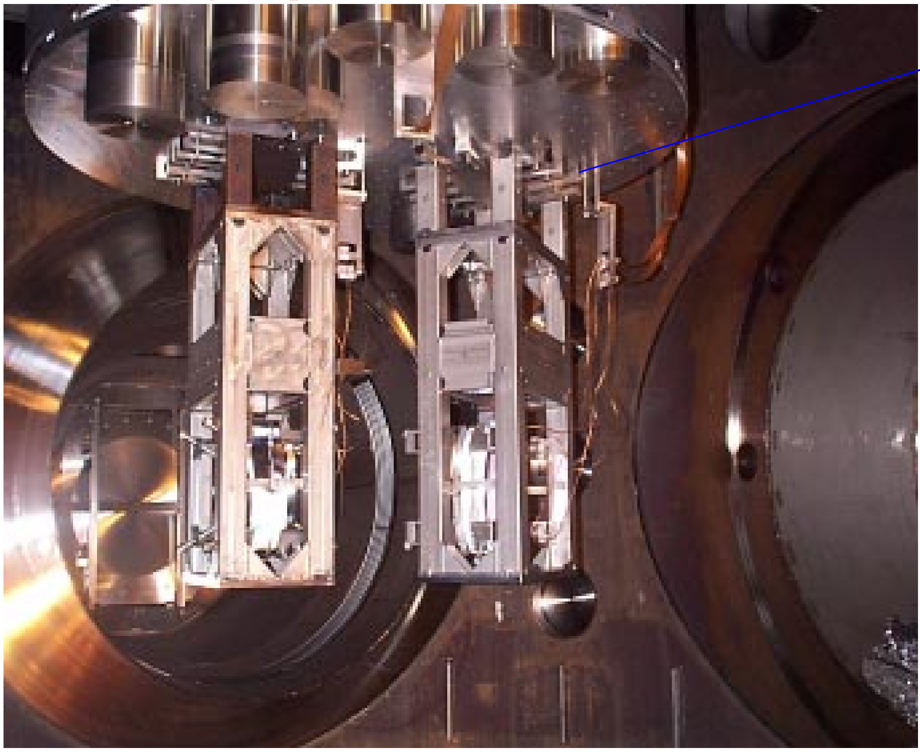
28. .Rotate the Support Beam, slide the Shuttle Table along the Support Beams, slide the LOS around on the Teflon Sheet as needed to orient the LOS. Locate the LOS according to the counter weight location drawing. Counter weights may need to be removed to clear a path. Replace the counter weights once the LOS is to its location and recheck the Optic Table level.

- **.Note: The optics table should always have its counter weights in place and be level during alignment. Check using a Starrett model 98 spirit level (.005" / foot rated accuracy.)**

29. Raise the Lift Table to bring the top of the LOS assembly within 1 mm of the Optic Table.
30. Using the Tilt Platform adjust the top of the LOS assembly to be parallel to the Optic Table.(by EYE).Mount the *Prism* onto its post and have the IAS group check the initial transverse and axial positions.
31. Translate the LOS to the correct location, using the theodolite readings of prism position. Remove the prism and use the laser autocollimator to orient the angle. Recheck the position and angle and make any corrections needed. (use the *Brass Pusher Bars* and screws for fine movements).
32. Connect OSEM cabling and verify signals (see below)
33. Continue to raise the Lift Table and adjust the LOS parallelism to the Optic Table. Using a clean .005 thick "feeler" gage as a "Go" gage and a .010 thick "feeler" gage as a "No Go" gage, check the gap between the LOS and the Optic Table. Fine tune the Tilt Table until the "go" enters the gap and the "no go" does not.
34. Gently back off the four top "clamping" safety stops.
35. Gently and evenly back off the four bottom "Support" safety stops to give 1 mm. clearance.
36. Gently and evenly back off the eight "Chamfer" stops while watching to see that the magnets always remain centered in the OSEM openings. Pay particular attention to the side magnet clearance. Maintain a gap of about.5 mm. between the Viton screw tips and the chamfers on the optic.
37. Activate the SUS controller and verify the damping of the optic.
38. Recheck the orientation using the laser autocollimator with optic suspended.



39. ***Snug chamfer stops.***



40. Remove Brass Pusher Bars
41. Recheck the alignment.
42. When the LOS is properly positioned transversely(<.5mm), axially(<.5mm) and set to the proper angles(<10micro radians), secure to the optic table with the LOS "Dog" clamps.
43. Remove the Alignment Adaptor clamps.
44. Remove the LOS compensation Counter Weights.
45. Lower the Lift Table and remove the Alignment Adaptor.
46. ***Check Table Levelness.***
47. Minimize any local disturbances to the optic by covering all open chamber doors with cloth covers, (drape a cover over the person aligning if necessary). You may even need to cut a window in a cover for the theodolite to reduce air currents. Reduce purge air to a minimal flow. Do not set items on the optics table.
48. Carefully release chamfer stops, maintaining a .5mm gap.
49. Adjust fine alignment using the PAM magnets to complete the Pitch and Yaw coordinates. This is easier to do if can view the autocollimator digital read out directly or by setting up an oscilloscope with remote leads to the autocollimator controller. Allow adequate time for the optic to damp before making the next adjustment. Be patient.

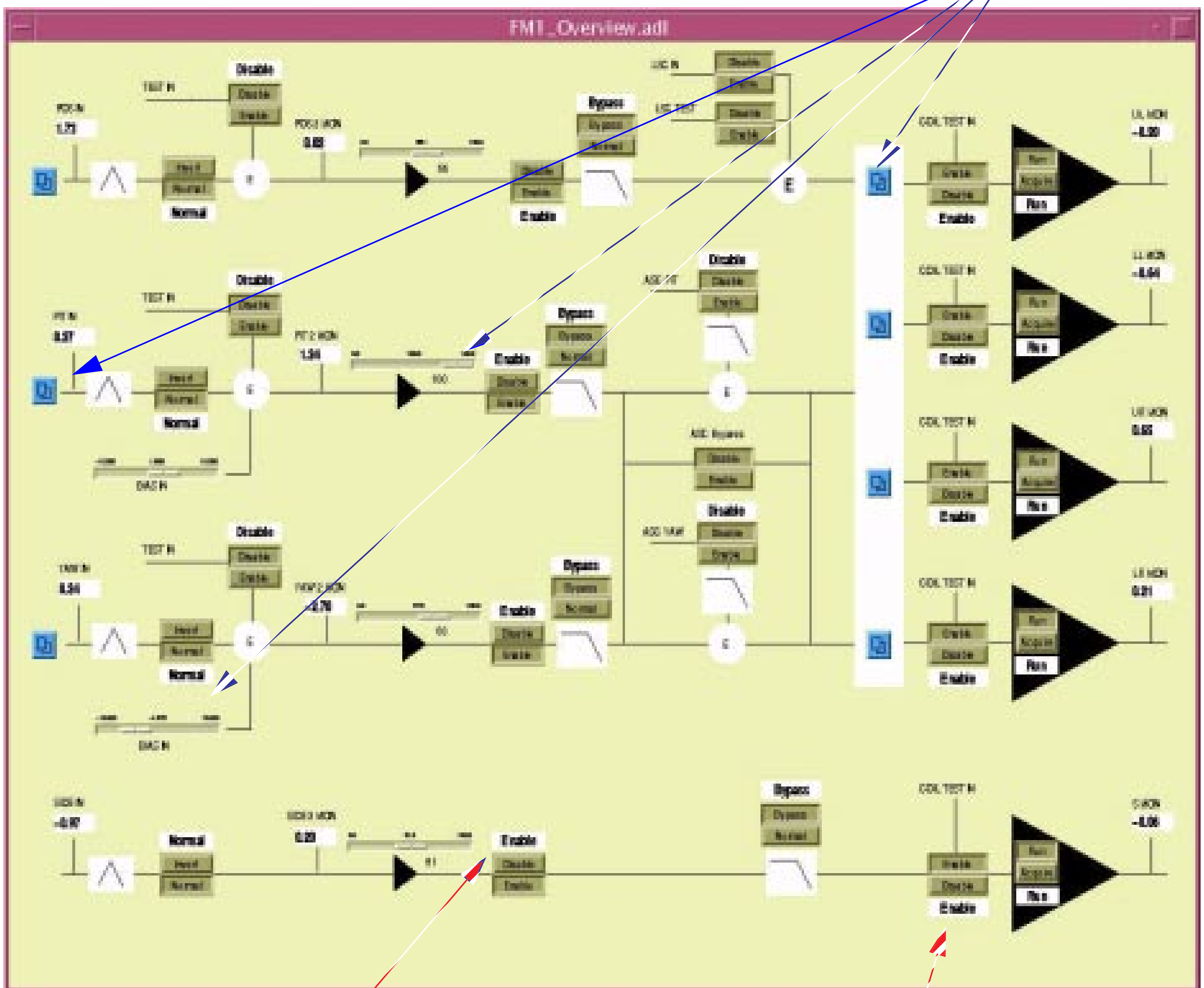
- **Pitch** is adjusted by turning the two PAMs on the upper right and lower right side either *in* or *out* equal amounts using 1/2 turn increments to start. With each adjustment made with the upper and lower right PAMs an equal adjustment may be needed to be made in the opposite direction with the upper left and lower left PAMs.
- **YAW** is adjusted by turning the two upper PAMs either *in* or *out* equal amounts using 1/2 turn increments to start. With each adjustment made with the upper PAMs an equal adjustment may needed to be in the opposite direction with the lower two PAMs.

- As the signals nears “zero”, smaller turns will be necessary. It may then may be easier to very finely adjust just one PAM at a time to deferentially move in both pitch and yaw simultaneously.

50. Set up Optical Lever
51. ***Snug Chamfer Stops***
52. Remove the four bottom Teflon tips for the safety stops and replace them with Viton tips.
53. Remove installation fixturing and all tooling etc.
54. Tie back OSEM pigtails from obstructing optical path with class ‘A’ stainless steel wire.
55. Clean optic with CO2 ‘snow gun’
56. Final Chamber Check.
57. Release Chamfer Stops and exit.

5 TESTING THE DAMPING OPTIC D.O.F.

1. Open up the Optical Lever screen along with the SUS Controller screen
2. Disable all d.o.f. and set the polarity to Normal (4 plcs) with loop and sensor gains to the nominal values (see below) for the optic under test.

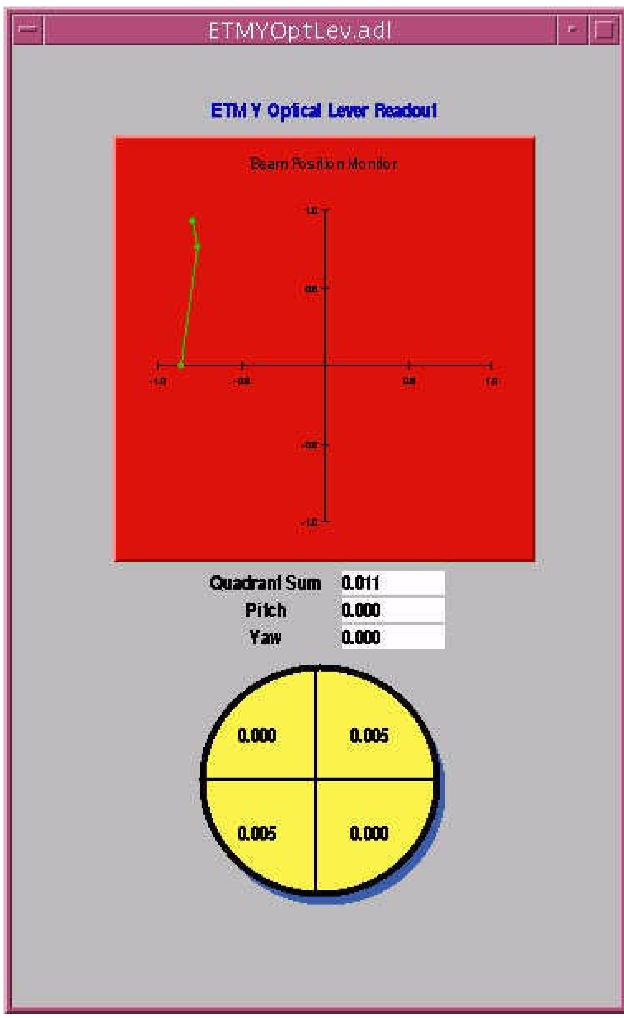


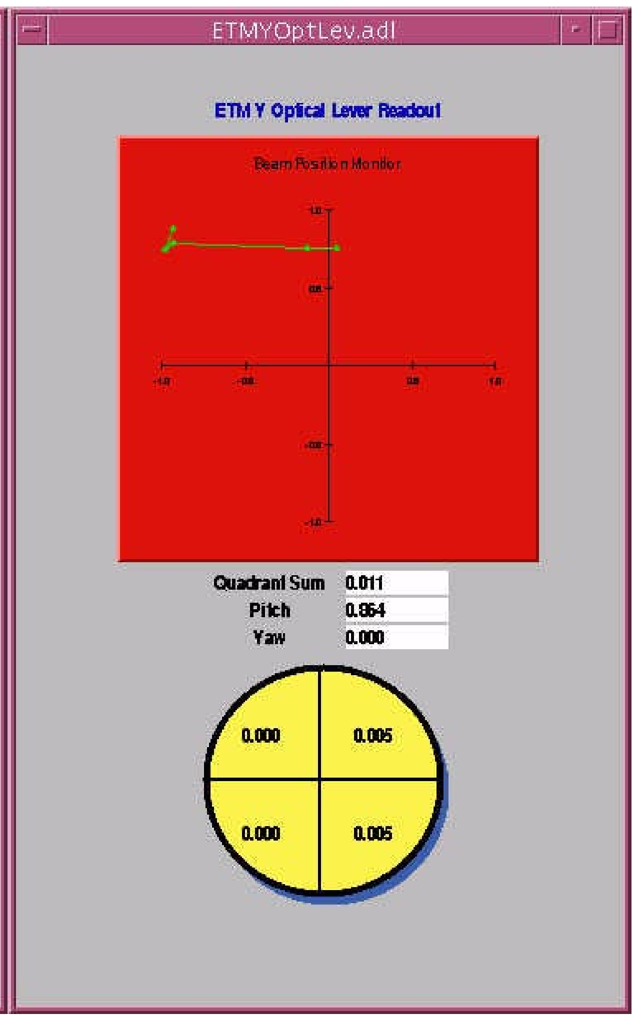
3. From a Function Generator (Stanford Reseach Systems model DS345), input a 2 Hz sine wave with an amplitude of 1Volt into the ‘S-Coil Test In’ LEMO connector on the SUS Controller and tee the signal into channel 1 of an oscilloscope for reference and signal verification.
4. From the’S-Coil Monitor’ LEMO connector on the SUS Controller connect a cable to the channel 2 of the oscilloscope, “click” the ‘S-Coil Test In’ dof to Disable and verify the 2Hz signal. This will verify that the controller sees the coil. You will also see some minor deflection of the optic on the optical lever display.
5. Re-Enable the dof. (2Hz signal will “flatline”)
6. Enable damping. An irregular low amplitude sine wave will form.
7. Invert the polarity briefly, the ampltude will begin to increase. Before it rails (signal clips) revert to the Normal setting. The signal should damp back down in a few cycles. The optical lever display should show the movement.

8. Repeat steps 4 through 7 for LR-Coil Monitor; UR-Coil Monitor; UL-Coil Monitor; and LL-Coil Monitors.
9. Disable all d.o.f.
10. A second damping verification using the “shadow sensors” can be performed by the following:
11. Connecting the oscilloscope channel 2, to the Side Monitor LEMO on the SUS Controller.
12. Enable damping. An irregular low amplitude sine wave will form.
13. Invert the polarity briefly, the ampltude will begin to increase. Before it rails (signal clips) revert to the Normal setting. The signal should damp back down in a few cycles. The optical lever display should show the movement.
14. Connect oscilloscope channel 2, to the Pitch Monitor LEMO on the SUS Controller and repeat steps 11 and 12.
15. Connect oscilloscope channel 2, to the Yaw Monitor LEMO on the SUS Controller and repeat steps 11 and 12.
16. Connect oscilloscope channel 2, to the Pos Monitor LEMO on the SUS Controller and repeat steps 11 and 12.

With all d.o.f. enabled the optic should be damped. Verify optical lever display.

Optical lever displays showing typical Pitch and Yaw changes when monitoring the SUS controller.



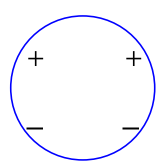


6
IOSEM SENSOR CONSISTENCY CHECK *BY BILL KELLS*

When an LOS is installed we assume that the tower package, including OSEMs and their wiring, has been properly tested to identify and route the OSEM signals. Once installed this is again "checked" by verifying damping for pitch, yaw, position, and side motion. However this verification via damping might be ambiguous, since it is often found that the degrees of freedom are sufficiently coupled to allow induced [anti]damping. Motivated by at least one situation where the as installed OSEM wiring identification was called into doubt due to such ambiguities, this more explicit check of the as installed OSEM response was developed. It is based on comparing a known mirror motion, as established by the LOS' optical lever, with direct individual OSEM shadow sensor photo-diode levels. Therefore this test is restricted to suspended optics with optical lever monitors, i.e. the LOS. However this could be extended to any suspended optic if an auxiliary optical lever monitoring its motion could be set up. As described here the check assumes that the OSEM actuation is correctly wired, and only the shadow sensing readout is tested. A similar procedure might be developed to test the actuation, but would not be so straight forward since control of individual OSEM actutation is not accessible leads to coupled motions. A distinct feature of this check is that it requires no perturbation of the fully operational LOS. For instance it can be performed once the optic is inaccessible, under vacuum.

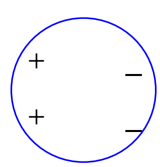
First I describe the generic procedure (subsequently a specific, quantitative example is summarized). Two steps may be distinguished:

STEP 1. The correlation between LOS pitch and yaw bias setting and optical lever pitch and yaw readings are established. One anticipates that variation of LOS pitch bias changes only lever pitch to some good approximation, and similarly for yaw. In general there will be some degree of pitch/ yaw cross coupling. The level of this which can be tolerated for unambiguous OSEM verification will have to be decided on an individual basis. Then for a significant pitch bias shift one expects the 4 OSEM shadow sensor voltage levels to change:



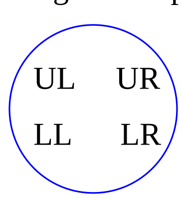
with overall sign ambiguity.

and for a significant yaw bias shift:



with overall sign ambiguity.

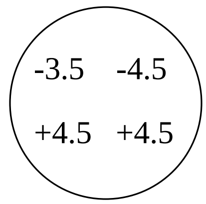
where the convention here is a view looking at the optic from the back:



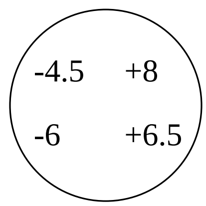
STEP 2. Now the above expected shadow sensor voltage change patterns are determined by measuring the (~DC) analog voltages extracted at the “J3” test point connection on the LOS controller satellite box. If both pitch and yaw expected voltage change patterns are confirmed, then the OSEM sensors must be routed correctly through to the satellite box.

As an example, this procedure was actually applied to the LHO 2K interferometer Y arm ITM. For both pitch and yaw, the bias was changed by +19.0 slider units (nearly full scale, with the not being tested degree of freedom bias set to 0 slider units). The measured J3 voltage changes were:

for pitch:



and for yaw:



where all numbers refer to milli-volts of level change. Note that the typical OSEM sensor voltage at this test point is ~1.6 volts, so that the difference measured here is quite small. However it is unambiguously determined by using a digital oscilloscope with a large number of traces averaged and the scale greatly expanded. The relative signs of the above pitch compared to the yaw data, is not relevant for the basic OSEM routing determination. However it does reveal the relative sense of the pitch vs. yaw slider bias actuation and drive matrices.