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

Procedure	**LIGO-E1200453-V4**	**25/Oct/2012**

Fine Initial Alignment Procedure of the Transmission Monitor Telescope

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1. References

1. "SOP for Arm Length Stabilization Setup in LVEA and VEA", M1100040v6.
2. "TRANSMON ISC Table Layout and Opto-Mechanics", D1000484-V9.

2. Tools Required

- One laser sensor card to be used inside the chamber. The card should be wiped thoroughly clean and the part where the worker holds should be wrapped with aluminum foil. Make sure to double fold the foil edge so no aluminum shedding falls inside the chamber.
- One laser sensor card to be used outside the chamber.
- One green laser pointer for misc. work.
- Assortment of class B Allen keys.
- An iris on a small post and post holder. If a sensor card with a 3 to 4 mm diameter hole is available, it is convenient to mount the card on a post and use it as an iris.
- Half wave plate for green beam that is mounted in the ALS table for the red path work.

3. Check Before Starting

- Rough initial alignment of the TMS to the ETM should have been done by IAS group outside of the chamber under the test end.
- Fine initial alignment of the ETM should have been done by IAS inside the chamber. (Make sure that HEPI didn't move after ETM alignment was done.)
- TMS suspension system should be working, i.e. the TMS should be freely hanging with OSEM damping, and the OSEMs should react to various offsets.
- ISC frontend should be working, i.e. green QPDs on the TMS ISC table should be connected to the ADCs, h2iscey should be monitoring these QPDs and MEDM screen should be available for this.
- All the tools should be available.

4. Man power needed

This is a four-persons' job.

- One person to work inside the chamber.
- One person to work as a support outside of the chamber.
- One person to work on the ALS table.
- One person to work on the CDS workstation.

5. Procedure for green path alignment

1. Transition the VEA to laser hazard as per SOP.
2. Turn the laser on.
3. Remove the ALS table panel behind the green beam periscope.
4. Place an iris at a convenient place between the top periscope mirror and the partial mirror splitting the Hartman and the ISC beam path on the ALS table. Exact

position doesn't matter, but it should be at a comfortable position for the worker to look at both sides.

5. Free and damp the TMS if it's not.
6. Completely remove the First Contact both on ERM and ETM (the weight of the first contact is large enough to tilt ETM in PIT significantly). Ask SUS people for help.
7. Confirm that the ETM and ERM are both free and damped. Ask SUS people for help.
8. Adjust the offset of the green QPDs so the output of all four quadrants become zero when no beam is hitting the QPD.
9. Inject the green beam into the chamber via the West viewport on the South door for EY, or the North viewport on the East door for EX.
10. Adjust the periscope mirror on the ALS table so the beam hits the center of the first steering mirror in the green beam path on the TMS ISC table.
11. Look at the beam position on the viewport. Adjust the table position along the arm until the beam is about 1 inch above the center and centered horizontally.
12. Repeat 10. and 11. until the beam is centered on the first steering mirror and roughly 1 inch above the center and centered horizontally on the viewport.
13. Steer the first steering mirror on the TMS ISC table until the beam hits both of the QPDs.
14. Try to exactly center the beam on two QPDs by slightly adjusting the beam position on the first steering mirror on TMS ISC table and realign. It might not be possible to do this easily, so give up if it takes too much effort. For anything except the first build (i.e. H2 EY), it's worth trying to enable QPD centering servo by copying the servo matrix elements from H2 EY. Note that you might have to flip the sign of YAW loops.
15. At this point, the TMS beam should already be hitting the ETM. Observe how the beam is coming back from the ETM.
16. Move the TMS by adjusting the TMS SUS offset so the beam is roughly retro reflected by the ETM. The forward and the backward propagating beam should meet at the same spot on the secondary mirror.
17. The above step changes the relative alignment of TMS in relation to the ALS table. Repeat steps 10 to 13 until the beam is roughly retro reflected by the ETM while the QPDs are reasonably centered. “Reasonably centered” means that the beam is not on a single quadrant.
18. At this point, look at the iris. Repeat steps 12 to 16 until the retro reflected beam is centered in the iris.
19. Confirm that the beam is still roughly at the position specified in step 11. If not, you need to go back to step 10 and follow all the steps after that again.
20. At this point, the main beam path should be in a good shape. The beam doesn't have to be exactly centered on any of the telescope mirrors, but excessive offsets on the secondary and/or the primary might indicate that something is wrong.
21. Look at the beam position on the top periscope mirror of HWS pick-off path on the TMS ISC table. It's OK if it's somewhat off-centered, but if it looks really bad (e.g. ¼ inches off from the center) you need to adjust the bottom periscope mirror on the TMS ISC table.

22. Adjust the top periscope mirror of the HWS pick-off path ON THE TMS ISC TABLE so the pick-off beam hits the center of the HWS top periscope mirror ON THE ALS TABLE.
23. Look at the HWS pick-off beam position on the viewport. If it's too far off from the center, adjust the top HWS periscope mirror position on the ALS table and repeat.
24. At this point, the HWS pick-off beam path is in a good shape.

6. Procedure for red path alignment

The red beam QPD path will be fine-tuned by using picomotors once the 1064 nm beam from the corner station resonates with the arm, but this path should be aligned at this stage so the beam at least hits both of the red QPDs. Also, the steering mirror to bring the red beam out of the chamber should be adjusted.
Although the red and green beams are not exactly co-axial due to dispersion and the wedges in ETM and ERM, green retro-reflected beam is still usable as an alignment marker because the difference is small enough: The QPD diameter is 3mm, while the position difference between red and green at QPD1 is about 1.3mm vertical and 0.6mm horizontal, see the matlab script in the same DCC number. The reflectivity of the dichroic (M4 in D1000484) and IR mirrors are not zero for 532 nm light, and it is already known from the first installation that the beam is visible.

1. With the green beam retro reflected from the ETM, find the green beam reflected by the dichroic mirror (M4) into the direction of corner station. With the laser safety glasses this might be difficult. Use sensor card and beam viewer. Raise the laser power if necessary. It might help to install a half wave plate at a convenient location on the ALS table to change the polarization.
2. Adjust the dichroic mirror so the beam is centered on M12 splitter and M14 steering mirror at the corner. If you cannot center these at the same time, just spread the error. Do NOT move the position of these mirrors.
3. Adjust M14 and M15 steering mirrors so the two lenses L101 and L102 are reasonably centered. A perfect job is not necessary, but try to better center L102 than L101.
4. Adjust M101 steering mirror on the red QPD sled so the beam is centered on M102.
5. Adjust M102 to center the beam on M104.
6. Adjust M103 to center the beam on the red QPD1.
7. Adjust M104 to center the beam on the red QPD2.
8. Hopefully, this is close enough that the red beam hits at least QPD1 in vacuum, and from that point on you can use picomotors to center the QPDs.
9. Put the beam diverter to the “off” position so the path to the vacuum chamber viewport is not blocked.
10. If you can find the green beam propagating toward the viewport, use that beam to align M12, M10 and M13 so the beam comes out of the chamber.
11. If the above is not the case, you need to depend on the eyesight from outside the chamber. Shut down the green laser. The outside observer should try to see the

reflected image of M12 through M13 and M10. Use a strong flashlight. Placing a white object such as the tip of a screw driver wrapped by a clean Vectra wipe might also help. Adjust M13 and M10 if necessary until the entire rim of M12 is visible from outside.

12. Do the same for the image of M4. This time, adjust M12. At this stage the red path should be reasonably aligned.

Worker Name:

Date:

Green QPD1 values:

Green QPD2 values:

Main green beam position on the viewport:

HWS pick-off beam position on the viewport:

Red beam position on the viewport if visible: