LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
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Pcal End Station Power Sensor Responsivity Ratio Measurements: Procedures and Log

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End Station: ....Ex.... Date: ....2024/01/28....
Sphere Name and Number: ....PS4 WSH....
Measurements Performed By: ....Tony + F. Llamas....

Items to take to the end station for the measurements:

- ✓ Working Standard (in protective case)
- ✓ CDS Laptop including the power chord
- ✓ PD Satellite Box (blue box), D1300368
- ✓ Long (25') DB9 cable
- ✓ DB9/BNC male to DB9 female temperature cable
- ✓ BNC cable
- ✓ A Fluke handheld digital voltmeter
- ✓ Martel calibrated voltage source, banana-to-BNC adapter cable, and charger/AC adapter
- ✓ IR-only laser glasses (for use ONLY if work in the ALS laser enclosure, which could expose the VEA to green laser light, will not be ongoing in parallel)
- ✓ IR viewing cards: high-power (white) and low power (orange)
- ✓ 1.5 mm allen key to remove input aperture cover from Working Standard
- ✓ Handheld IR Viewer

Before (or after) going to the End Station

- Check the calibration of the Keithley Model 2100 voltmeter using the Martel Calibrated Voltage source at following three different voltages (the same one that will be taken to the end station). Note: use negative polarity.

  1. (**-4 V**): with Martel = ...-3.9998.... V on Keithley 2100 DVM
  2. (**-2 V**): with Martel = ...-1.9998.... V on Keithley 2100 DVM
  3. (**0 V**):with Martel = ...-0.0003 mV.... V on Keithley 2100 DVM

PS5
-3.9998V
-1.9999V
-0.002mV

1 Before starting Pcal work in VEA

- ✓ Call the Control Room (ext. 202) to notify them of the laser status change.
- ✓ Transition VEA to **LASER HAZARD** status.

- Plug in the Blue Satelite Box to the WS_PD connector on the PCAL Chassis, using the DB9/BNC male to DB9 female to power the Blue box. Ensure the Power Source switch on the back is in the proper setting. Plug the BNC cable into the FLuke Voltmeter for now. Plug in the integrating sphere while it is sitting in a safe location. Power on the power sensor and take note of the current temperature of the on-board AD590 using the Fluke Voltmeter.
  WS on-board temperature: 297.1 K .... K

9:17

- Make sure that the IFO's ISC LOCK Gaurdian is in a down or idle state, and that it will not try to auto lock. (sitemap / GRD / ISC OVERVIEW)
  DO NOT CHANGE STATE OF GUARDIAN UNLESS APPROVED BY THE ON-SHIFT OPERATOR
- Close the ALS laser shutter via the MEDM screen (sitemap/LSC/Shutters/ISCTX(Y) green beam.) This protects you from the 50 mW ALS green lasers
- Check that SEI ENV is set to Maintenance Mode to Shut Off Sensor correction (The Operator should have done this for Tuesday Maintenance but check anyways.) (sitemap/SEI/ISI SENSOR CONFIG)

1.1 Before starting the measurements

- Record Rx enclosure Digital Thermometer ("Outside" display) = 19.8 .... deg. C
- Record Rx enclosure Digital Thermometer (" Inside" display) = 19.2 .... deg. C
- Turn PCAL Interlock bypass to the ON position.
- Set shutter to local
- Disable all three excitations on the Pcal MEDM screen (sitemap/Cal/PcalX(Y)/Excitation):
  1. H(L)1:CAL-PCALX(Y)_SWEPT_SINE
  2. H(L)1:CAL-PCALX(Y)_OSC_SUM
  3. H(L)1:CAL-INJ_MASTER_SW
- Ensure that the ETM pointing is in the "aligned" state, If you cannot tell from the medm screen call the operator and ask them.
- Remove cover from Rx enclosure and verify that Pcal beam spots are close to their nominal locations (centered on the Rx sensor input aperture). If they are not, adjust their positions using the final steering mirrors inside the output section of the Tx module enclosure.
- Open a GPS Clock window (type `gpsclock &` in a terminal window).

- Open **StripTool** (type `StripTool &` in a terminal window) and display the following four sensor outputs. Always verify that signals are stable before recording time series.

  1. ✓ **H(L)1:CAL-PCALX(Y)_TX_PD_WATTS_OUTMON**
  2. ✓ **H(L)1:CAL-PCALX(Y)_RX_PD_WATTS_OUTMON**
  3. ✓ **H(L)1:CAL-PCALX(Y)_WS_PD_OUTMON**
  4. ✓ **H(L)1:CAL-PCALX(Y)_OFS_PD_OUTMON**

- ✓ Make sure the OFS is not railed, if it is turn the loop off and back on.

[09:27] 2.992 V (temperature ~~OFS~~ WS)

2 Calibration measurements

2.1 Preliminary measurements

2.1.1 Record Optical Follower Servo (OFS) settings

- Offset: 3.85 V
- Gain: 39.60 dB
- OFS PD: -3.833 V

2.1.2 Calibrate the Working standard channel

- ✓ Connect **Martel Calibrated Voltage Source** to INPUT 1 on the ***BNC to DB9*** interface module mounted in the Pcal transmitter pylon. Note: use negative polarity, and adjust Range to 0.000 to allow up to 4V.

- Inject the three following input voltages for 15 seconds each and record the GPS time and the output level displayed on the StripTool for each 15 second interval.

  1. (**-4 V**): GPS Start Time 1422120650; Voltage = -3.99601 V
  2. (**-2 V**): GPS Start Time 1422120700; Voltage = -1.99795 V
  3. (**0 V**): GPS Start Time 1422120760; Voltage = +2.59701e-5 V

2.1.3 Record Working Standard temperature

- Measure the Working Standard on-board temperature using at DVM at the BNC output of the DB9/BNC to DB9 cable. Multiply the voltage by 100 to obtain the temperature in K.

  – GPS time: 1422120855

  – WS on-board temperature: 2.996 K

2.2 Power sensor measurements

- Connect the Pcal Satellite Box PD MON output to INPUT 1 on the ***BNC to DB9*** interface module mounted in the Pcal transmitter pylon.
- Record GPS start and end times and nominal StripTool output levels during the measurements.

2.2.1 Measurement 1:

- Block the OUTER beam with a razor blade beam block in the Tx module.
- Loop cable around something to ensure that the sphere doesn't fall when the cable is stepped on.
- Place the WS in the INNER beam in the Tx module.

WS in the INNER beam in the Tx module.				
GPS times		StripTool outputs		
`Start Time #1`	1422121080	TxPD	0.522841	W
`Duration`	`300 seconds`	WSPD	-1.21275	V
`End Time #1`	1422121380	OFSPD	-3.83283	V

2.2.2 Measurement 2:

- Move the beam block to the INNER beam in the Tx module.
- Move the WS to the OUTER beam in the Tx module.

WS in the OUTER beam in the Tx module.				
GPS times		StripTool outputs		
`Start Time #2`	1422121480	TxPD	0.523083	W
`Duration`	`300 seconds`	WSPD	-1.23813	V
`End Time #2`	1422121780	OFSPD	-3.83281	V

2.2.3 Measurement 3:

- Leave the WS in the OUTER beam in the Tx module with the INNER beam blocked.
- Close the shutter in the Tx module.

WS in the OUTER beam in the Tx module. Shutter CLOSED.				
GPS times		StripTool outputs		
Start Time #3	1422121800	TxPD	7.6431e-5	W
Duration	60 seconds	WSPD	0.003199	V
End Time #3	860	OFSPD	-0.0104	V

2.2.4 Measurement 4:

- ✓ Leave the block in the INNER beam in the Tx module.
- ✓ Leave shutter closed in the TX module.
- ✓ Replace the Rx sensor with the WS in the Rx module.
- ✓ Open the shutter in the Tx module.
- ✓ Check if OFS is railed.

WS in the Rx module. INNER beam blocked in the Tx module.				
GPS times		StripTool outputs		
Start Time #4	1422122150	TxPD	0.53227	W
Duration	300 seconds	WSPD	-1.22708	V
End Time #4	450	OFSPD	-3.8329	V

2.2.5 Measurement 5:

- ✓ Move the block to the OUTER beam in the Tx module.

WS in the Rx module. OUTER beam blocked in the Tx module.				
GPS times		StripTool outputs		
Start Time #5	1422122510	TxPD	0.523091	W
Duration	300 seconds	WSPD	-1.19818	V
End Time #5	810	OFSPD	-3.83281	V

WSPd ?

$100 \times \frac{-1.19818}{-1.22708} = 97.6449\%$

2.2.6 Measurement 6:

- CLOSE the shutter in the Tx module.

WS in the Rx module. Shutter CLOSED in the Tx module.				
GPS times		StripTool outputs		
Start Time #6	1422122865	TxPD	+7.7423e-5	W
Duration	60 seconds	WSPD	0.00319	V
End Time #6	925	OFSPD	-0.0103	V

2.2.7 Measurement 7:

- ✓ REMOVE the beam block from the OUTER beam in the Tx module.

☑ Open shutter

WS sensor in the Rx module, both Inner and Outer beams on it				
GPS times		StripTool outputs		
Start Time #7	1422122980	TxPD	0.52307	W
Duration	300 seconds	WsPD	-2.43032	W
End Time #7	123280	OFSPD	-3.83286	V

2.2.8 Measurement 8:

- ✓ CLOSE the shutter in the Tx module
- ✓ Replace WS sphere with the Rx sphere at the Rx Module.
- ✓ Open the shutter in the Tx module
- ✓ Verify that the Pcal beam spots are centered on the input aperture of the Rx sensor (photograph spot locations on white card).

Both Inner and Outer beams on Rx sensor in the Rx module.				
GPS times		StripTool outputs		
Start Time #8	1422123840	TxPD	0.522846	W
Duration	300 seconds	RxPD	0.518053	W
End Time #8	124140	OFSPD	-3.83267	V

2.2.9 Measurement 9:

- ✓ CLOSE the shutter in the Tx module.

Shutter CLOSED in the Tx module.				
GPS times		StripTool outputs		
Start Time #9	1422124200	TxPD	0.000109387	W
Duration	60 seconds	RxPD	0.000149029	W
End Time #9		OFSPD	-0.0103238	V

2.2.10 Before leaving VEA

1. OPEN the shutter in the Tx module.
2. Set the shutter control to **Remote** on interface module.
3. Replace the enclosure covers on both the Tx & Rx modules
4. Re-enable the three excitations on the Pcal MEDM screen (if applicable)
5. Make sure **ALL** covers are back on before Turning the interlock bypass to **OFF**.
6. Transition VEA back **LASER SAFE** status
7. Call the Control Room (ext. 202) to notify them of the laser status change and that they may unshutter ALS and take the SEI ENV to CALM if they wish to start Locking.

2.2.11 To complete the end station measurement effort

- Analyze the data (see Section 3) and upload results to the GIT.
- Make an aLog entry; append images of the beam spots at the Rx power sensor aperture.

3 Data Retrieval and calculations

3.1 Data Acquisition, Plots and Report

1. Log in to the CDS laptop as yourself to avoid username and permissions issues. If you are already logged in as controls you can use the terminal command su firstname.lastname to log in to the terminal as your self, but you will only be logged into the terminal so you will have to use terminal editors like nano or VIM.
2. Make sure that the Local PCAL Git Repo on CDS machines is up to date with the latest version of the master branch. Navigate to /ligo/gitcommon/Calibration in a terminal and run the git status and git pull commands. If you run into any issues, read the README.md file found on the Remote Git lab Repo found here: https://git.ligo.org/Calibration/pcal .

3. open /ligo/gitcommon/Calibration/pcal/O4/ES/scripts/pcalEndstationPy/config.py
4. edit the Lines 6, 7, and 8 with the values from your procedure. IFO String is just the IFO and arm you did the measurements at. Usually looks like 'LHO_EndY' or something similar. The date code its a D followed by the date written in this format: 'DYYYYMMDD'.
5. edit the Lines 13,14, and 8 with the GPS values from your procedure during the start of the each Martel Voltage injections.
6. edit the Lines 19 -27 with the GPS START times for each measurement written in your procedure, then save the document.
7. Get the date of the latest WS_GS Lab Measurement that was considered to be a good measurement from the pcal/O4/lab/measurements/reviewed_measurements/ directory
8. Run the command:

   ```
   python3 generate\_measurement\_data.py --$WS "PS#" --date "YYYY-MM-DD"
   ```

   Where the WS is the PS# of the Working Standard you took down to the End Station, and the Date is the latest date of the last reviewed WS_GS measurement. Once it is running you you will see times series plots of the Martel Voltage injections, and all the measurements you have made. Make sure that those plots don't have any obvious issues before closing them.
9. then switch directories to the pcalTrends with the the command

   ```
   cd ../pcalTrendsPy/
   ```

10. then run

    ```
    python3 pcalPublishReportsV4.py LHO_EndY t[datecode]
    ```

    where the date code is the date code found in the config.py file you opened in step 3
11. Once this is done you can push this to the master branch on the git repository with a

    ```
    git commit -a -m "Notes about your Es measurement"
    ```

12. Once you have commited your changes run a

    ```
    git push
    ```

    to push the new measurement to the remote git repo.

Add to alog

Add the plots of the time series of the measurements, their ratios and the generated trend plots to an alog, along with a scan of this procedure and the beam alignment photo.