LIGO Laboratory / LIGO Scientific Collaboration

LIGO- E1200508 *LIGO* Jan 23rd, 2014

aLIGO HAM-ISI, Installation Test Report, Phase II

Chamber-Side Testing & Initial Chamber Testing

LHO HAM4-ISI (unit #7)

E1200508-V5

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PHASE II Testing

The phase II of HAM-ISI testing corresponds to the tests performed after the *Assembly Validation*, and before the *Control and Commissioning* of the Units. It is divided in two parts. The present document is divided in two sections: One for each part of the Phase II testing:

Part.1 Chamber-Side testing
Part.2 Initial Chamber Testing

Chamber-Side Testing is a basic sensor check with a spectrum analyzer. Units can be inserted in their chamber of destination once they pass.

Initial Chamber Testing takes place in open chamber, with the optics off, and HEPI locked. The ISI is then connected to the electronic rack with the final in-field cables. Models are installed and running. Tests are performed with Matlab® scripts.

Optics and Suspensions can be installed right after the end of this phase of testing. No test is performed during their installation.

Final Chamber Testing starts once Optics and Suspensions are installed. The lockers and the CPSs usually need to be reset at this point.

Introduction

Chamber-Side Testing

HAM-ISI Unit #7 was intended to populate HAM4 chamber.

Conclusion

Chamber-Side Testing

HAM-ISI Unit #7 was intended to populate HAM4 chamber. No chamber-side testing was performed.

Introduction

Initial Chamber Testing

This part of the Phase II testing takes place in open chamber, with the optics off, and HEPI locked. The ISI is then connected to the electronic rack with the final in-field cables. Models are installed and running. Tests are performed with Matlab® scripts.

Optics and Suspensions can be installed right after the end of this phase of testing. No test is performed during their installation.

Final Chamber Testing starts once Optics and Suspensions are installed. The lockers and the CPSs usually need to be reset at this point.

INITIAL IN CHAMBER TESTING

HAM4-ISI was installed in in its chamber on May 21st 2013. This initial in chamber testing was conducted after Jan 22nd 2014.

Step 1: Cables Inventory

Actuator cables were replaced in chamber to reach the feedthrough. S/N were recorded.

Cable Connects	Cable S/N			
Part Name	Configuration	Corner 1	Corner 2	Corner 3
GS13	Horizontal			
	Vertical			
L4C	Horizontal			
	Vertical			
Actuator	Horizontal			
	Vertical			

Table – Cables inventory

Acceptance Criteria:

Inventory is complete

Test result: **Passed: __X__**
Failed: ___

Step 2: Electronics Inventory

Hardware	LIGO reference	S/N
Coil driver	D0902744	
Anti Image filter	D1100202	
Anti aliasing filter	D1000269	
Interface chassis	D1000067	

Acceptance Criteria:

Inventory is complete

Test result: **Passed: __X__** **Failed: ___**

1. Step 3: Level of Stage 1

The optical table is level within a $^{+}$/.0.1mm tolerance.

Max angle = 0.008” / 86” = 93µrad

Acceptance Criteria

- The maximum angle of the table with the horizontal mustn’t exceed ~100µrad

Test result: **Passed: __X__**
Failed: ___

Step 4: Mass Budget

	00	01	02	03	04	05	06		
	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
w9			1	1	1		1	41.8	19
w1				2	1			16.9	7.7
w2	1	3	2	1			1	37.8	17.1
w3							1	27.2	12.3
w4									
w5	1		1	1			1	34.5	15.6
w6							1	27.2	12.3
w7		1					1	28.3	12.8
w8		1					1	28.3	12.8
Side Masses Total	2	5	4	5	2	0	7	242	109.7

Table – Wall masses distribution

	00	01	02	03	04	05	06		
	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
k1					1		1	35.1	15.92
k2						2		31.2	14.15
k3					1		1	35.1	15.92
k4						2		31.2	14.15
k5					1		1	35.1	15.92
k6						2		31.2	14.15
Keel Masses Total	0	0	0	0	3	6	3	198.9	90.22

Table – Keel masses distribution

50lbs	597lbs	10kg	Total (kg)
4	1	0	361.4

Table – Optic table masses distribution

	Side	Keel	Top	Total
Weigh (kg)	109.7	90.22	361.4	561.3

Table – Mass budget sum up

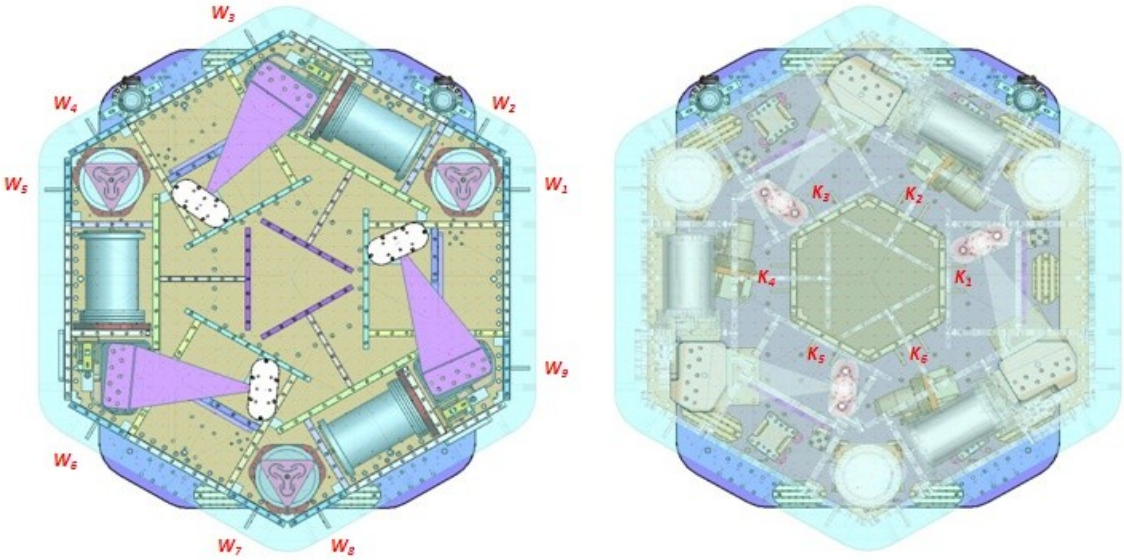


Figure – Wall Masses (W) and Keel masses (K) location. ***South of picture = corner 1***

Issues/difficulties/comments regarding this test:
The mass budget was reported to be 576.22kgs during Assembly Validation. It is now 15kg lighter.

- The ISI was roughly balanced for the Initial In Chamber Testing.

Acceptance Criteria
The Mass budget must be

- 579.1 Kg (cf. E1100427)+/-25Kg (5%)

Test result: **Passed: __X__**
Failed: ___

2. Step 5: Shim Thickness

Issues/difficulties/comments regarding this test:

- The shims for locker D needed to be changed in-chamber, from .123” to .127”.
-

Lockers	Shim thickness (mils)
A	124
B	127
C	125
D	127

Table – Shims Thickness

Test result: **Passed: __X__**
Failed: ___

3. Step 6: Blade Spring Profile

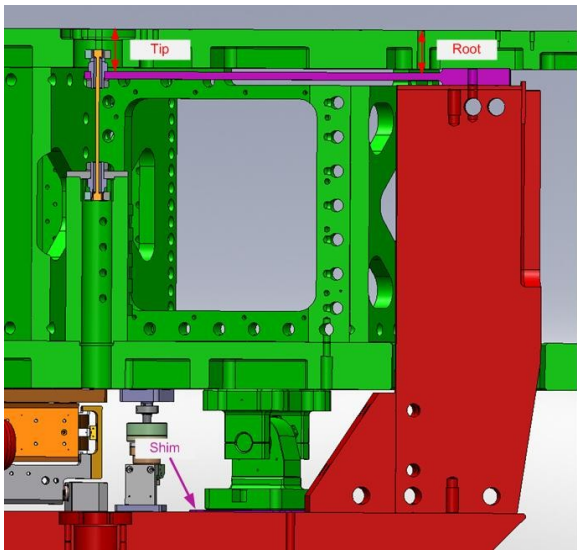


figure – Blade spring profile measurement points

Blade #	Root (Mils)	Tip(Mils)	Flatness (mils)
1	380	375	5
2	393	376	17
3	391	394	3

Table – Blade Spring Profile

Issues/difficulties/comments regarding this test:
Blade #2 is slightly out of the preferred range. The measurement was performed on a locked ISI. The locked position is not optimal, as lockers need to be reset.

Acceptance Criteria:

- Recorded for traceability.
- Flatness preferred within 0.015" inches.

Test result: **Passed: __X___**
Failed: ___

4. Step 7: Lockers Adjustment

The maximum difference recorded on the CPSs between the unlocked and the locked positions is about 1V which roughly corresponds to 3280cts

Issues/difficulties/comments regarding this test:

- The maximum difference recorded on the CPSs between the unlocked and the locked positions is out of the preferred +/-1600cts range.
- Lockers should be set up with CPS Gaps, after this phase of testing.
- Lockers are reset after the installation of suspensions.

Acceptance criteria:
- Recorded for traceability
- Preferred within +/-1600cts

Test result: **Passed: ____**
Failed: __X__

5. Step 8: CPS Gap

H1 readout (count)	1794
H2 readout (count)	2222
H3 readout (count)	-3023
V1 readout (count)	1341
V2 readout (count)	42
V3 readout (count)	-1088

Table – CPS sensor readouts – ISI Unlocked, no drive

Issues/difficulties/comments regarding this test:
- CPS mean readouts are out of the preferred +/-400cts range.
- CPS Gap should not be set up during this phase of testing.
- CPSs are reset after the installation of suspensions.

Acceptance criteria:
- Recorded for traceability
- Preferred within +/-400cts

Test result: **Passed: __X__**
Failed: ___

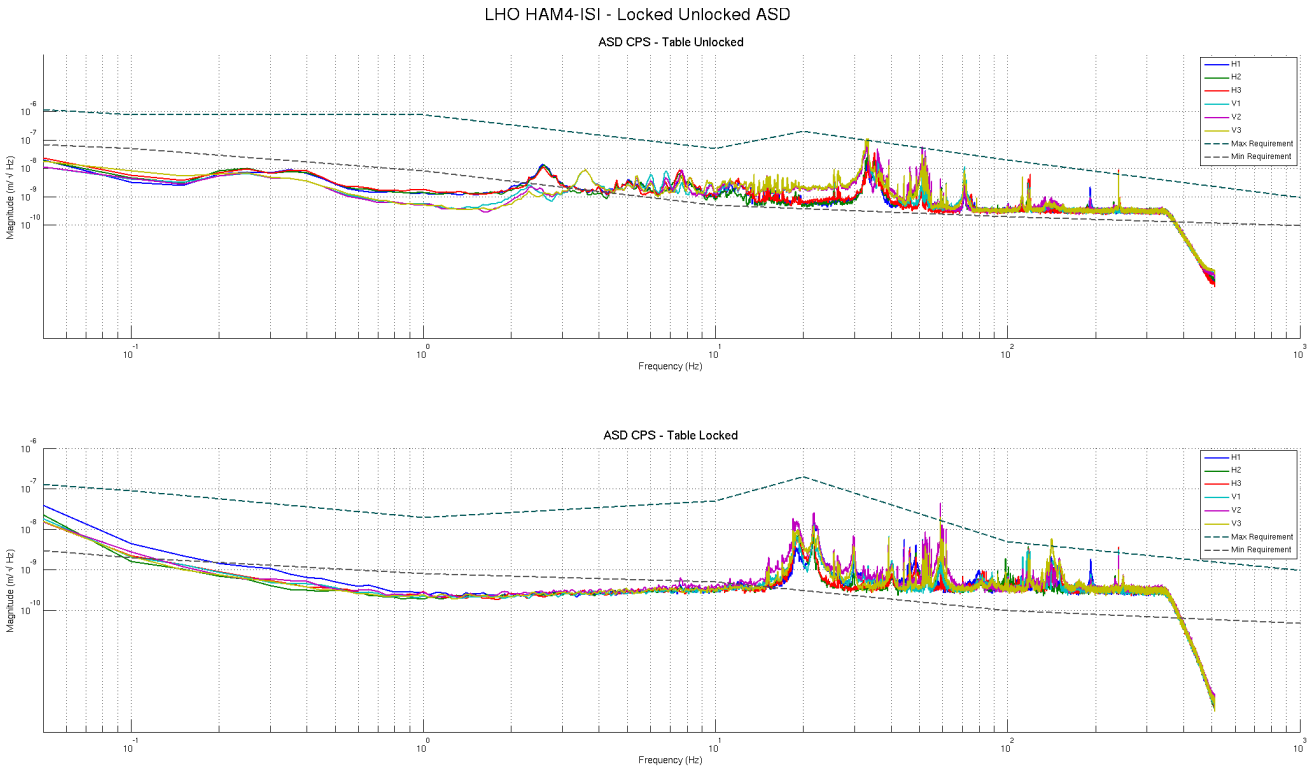
Step 9: CPS and GS13 Spectra - ISI Unlocked

Data files in SVN at:
/seismic/HAM-ISI/H1/HAM4/Data/Spectra/Undamped/
- LHO_ISI_HAM4_ASD_m_CPS_T240_L4C_GS13_Locked_vs_Unlocked_2014_01_23.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Plot_ASD_Unlocked_Locked_HAM_ISI.m
- Plot_ASD_Unlocked_Locked_Group_HAM_ISI.m

Figures in SVN at:
seismic/HAM-ISI/H1/HAM4/Data/Figures/Spectra/Undamped/
- LHO_ISI_HAM4_ASD_m_GS13_Requirements_Locked_vs_Unlocked_2014_01_23.fig
- LHO_ISI_HAM4_ASD_m_CPS_Requirements_Locked_vs_Unlocked_2012_01_23.fig

CPS calibration:
The CPS power spectrums are calibrated by using a sensitivity of 30.2 nm/count.



Measurement length: 1010s - Sample window: 20s - Overlap: 50% - Frequency resolution: 50mHz - Averages: 100 - Measurement start (GPS): 1074586413

Figure - Calibrated CPS power spectrum – ISI Unlocked/Locked

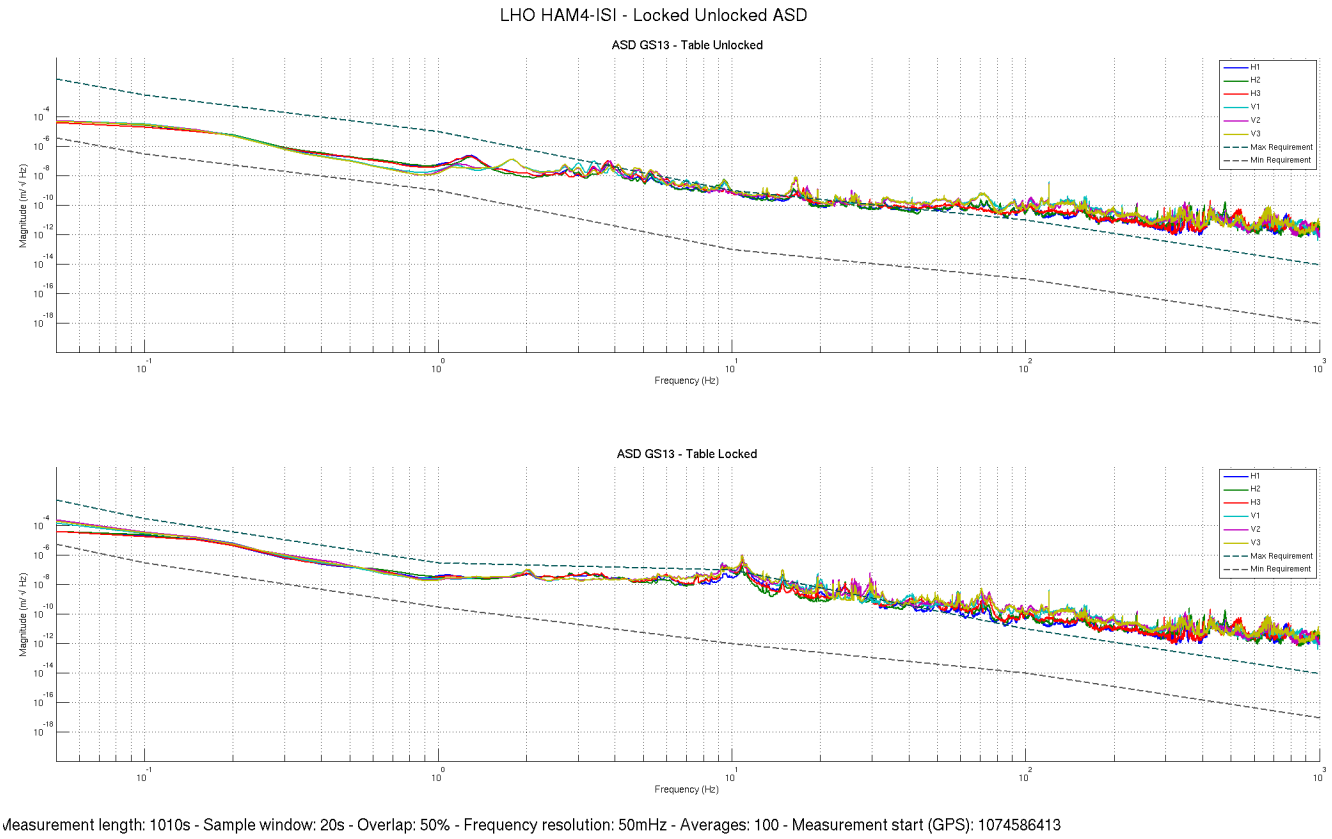


Figure – Power spectrum Calibrated GS13 – ISI Unlocked/Locked

Issues/difficulties/comments regarding this test:

- Locked data was recorded during the weekend, after the optical table payload was removed (421.51kg).

Acceptance criteria:

- No cross talk (peaks at low frequencies + harmonics on measurements)
- Magnitudes of power spectra must be between requirement curves such as in the following figures (dashed lines)

Test result: **Passed: __X__**
Failed: ___

Comment:
GS13 requirement curves need to be updated.

6. Step 10: GS13 ASD - Tabled Tilted

Not performed.

Test result: Waived __X___ Passed: ____Failed: ___

7. Step 11: GS13 pressure readout

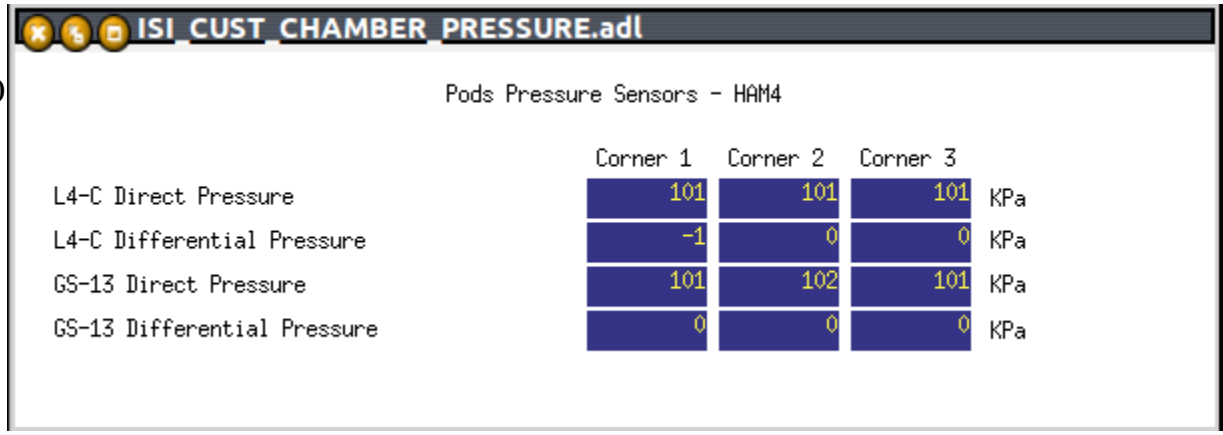


Figure – Pressure Readouts (01/23/2014)

Acceptance criteria:
- The pressure on *GS13_P* channels must be 102KPa +/- 8 KPa (25000 counts +/- 3000 counts)
- *GS13_P* must vary the same way in each corner and *GS13_DIFF* must be constant (channels follow comparable trend)

Test result: **Passed: __X__**
Failed: ___

8. Step 12: Actuators Sign and range of motion (Local drive)

	Negative drive	No Drive	Positive drive
H1 readout (count)	-23313	1793	24345
H2 readout (count)	-23516	2209	23745
H3 readout (count)	-26077	-3049	23196
V1 readout (count)	-17968	1361	21018
V2 readout (count)	-23484	26	26979
V3 readout (count)	-23434	-1084	21278

Table - Range of motion - Local drive

Acceptance criteria:
- Main couplings sensors readout must be at least 16000 counts (~0.02”)
- A positive offset drive on one actuator must give positive sensor readout on the collocated sensor. Signs will also be tested when measuring local-to-local transfer functions.

Test result: **Passed: __X__**
Failed: ___

Step 13: Static Testing (Tests in the local basis)

	Sensors (counts)

	H1	H2	H3	V1	V2	V3
H1	1880	1177	1170	-6	2	-2
H2	1175	1873	1167	-10	-2	-1
H3	1199	1196	1909	-16	-11	15
V1	178	173	-349	1339	-33	-586
V2	-343	184	172	-593	1344	-32
V3	180	-359	185	-40	-602	1425

Table - Main couplings and cross couplings

Issues/difficulties/comments regarding this test:

Acceptance criteria:

- **Vertical**
  For a +1000 count offset drive on vertical actuators
  - Collocated sensors must be 1400 counts +/- 10%

- **Horizontal**
  For a +1000 count offset drive on horizontal actuators
  - Collocated sensors must be 2000 counts +/- 10%
  - Non-collocated horizontal sensors must be 1250 counts +/-10%

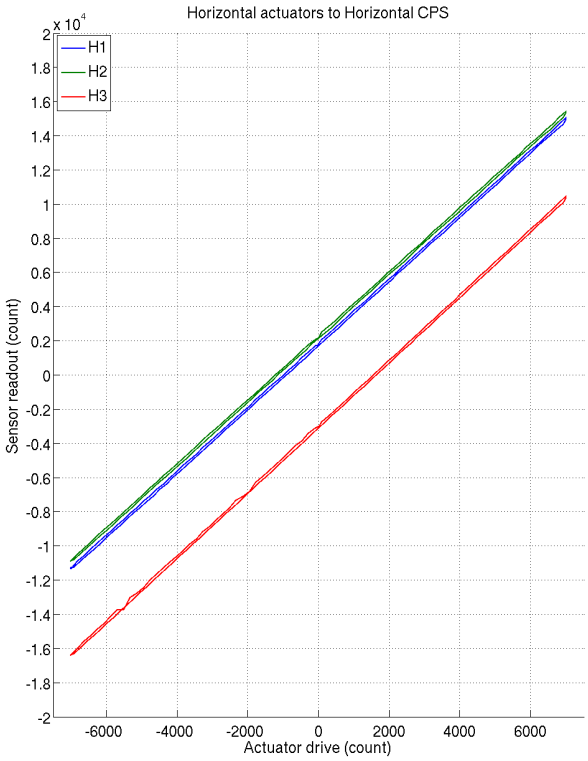
Test result: **Passed: __X__**
Failed: ___

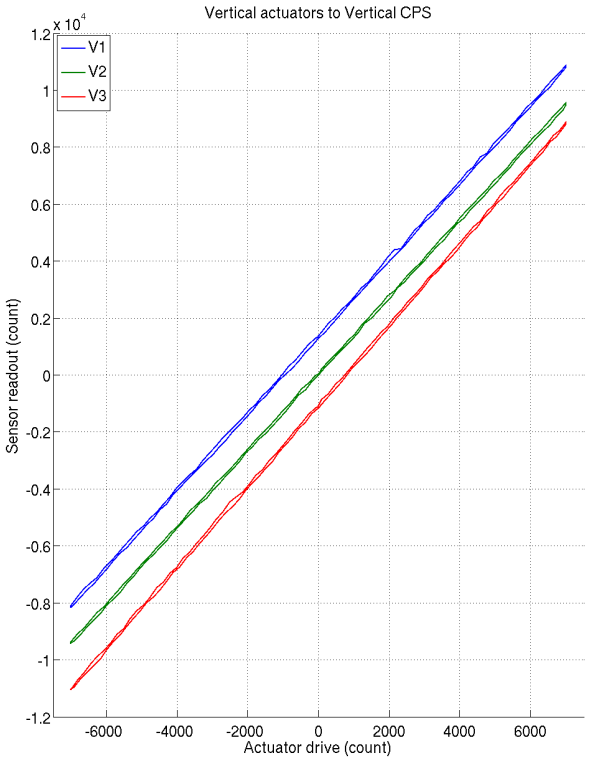
9. *Step 14: Linearity test*

	Slope	Offset	Average slope	Variation from average(%)
H1	1.88	1800	1.89	-.5
H2	1.87	2220		-.7
H3	1.91	-3000		1.3
V1	1.35	1350	1.37	-1.6
V2	1.35	43		-1.7
V3	1.42	-1086		3.3

Table - Slopes and offset of the triplet Actuators - HAM-ISI - Sensors

Figure - Horizontal and vertical actuators x HAM-ISI x sensors





Scripts files for taking data in SVN at:

seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- Linearity_Test_Awgstream_HAM_ISI.m

Data files in SVN at: seismic/HAM-ISI/L1/HAM4/Data/Linearity_Test/

- LHO_ISI_HAM4_Linearity_test_20140123.mat

Figures in SVN at:
seismic/HAM-ISI/H1/HAM4/Data/Figures/Linearity_Test/

- LHO_ISI_HAM4_Linearity_test_20140123.fig

Issues/difficulties/comments regarding this test:
V3 actuator is out of spec.

Acceptance criteria:

- Horizontal and vertical slopes of the triplet actuators x HAM-ISI x sensors = Average slope +/- 1.5%

Test result: **Passed: __X__**

Failed: ___

10. Step 15: Frequency response

All input/output filters are ON. HEPI is locked. The chamber is closed with sheets on.

11. Step 15.1: Local to local measurements

Data files in SVN at:
seismic/HAM-ISI/H1/HAM4/Data/Transfer_Functions/Measurements/Undamped/

- H1_HAM4_ISI_Data_TF_L2L_5Hz_200Hz_20140124-174341.mat
- H1_HAM4_ISI_Data_TF_L2L_10mHz_100mHz_20140124-231906.mat
- H1_HAM4_ISI_Data_TF_L2L_100mHz_500mHz_20140124-223721.mat
- H1_HAM4_ISI_Data_TF_L2L_200Hz_800Hz_20140124-141943.mat
- H1_HAM4_ISI_Data_TF_L2L_500mHz_5Hz_20140125-101949.mat

Data collection script files:
seismic/HAM-ISI/H1/HAM4/Scripts/Data_Collection/

- Run_Exc_Batch_H1_HAM4.m

Scripts files for processing and plotting in SVN at:
seismic/HAM-ISI/H1/HAM4/Scripts/Control_Scripts/Version_2/

- Step_1_TF_Loc_to_Loc_H1_ISI_HAM4.m

Figures in SVN at:
seismic/HAM-ISI/H1/HAM4/Data/Figures/Transfer_Functions/Measurements/Undamped/

- H1_ISI_HAM4_TF_L2L_Raw_from_ACT_to_CPS_2014_01_24 .fig
- H1_ISI_HAM4_TF_L2L_Raw_from_ACT_to_GS13_2014_01_24 .fig

Storage of measured transfer functions in the SVN at:
seismic/HAM-ISI/H1/HAM4/Data/Transfer_Functions/Simulations/Undamped/

- H1_ISI_HAM4_TF_L2L_Raw_2014_01_24.mat

The local to local transfer functions and presented below.

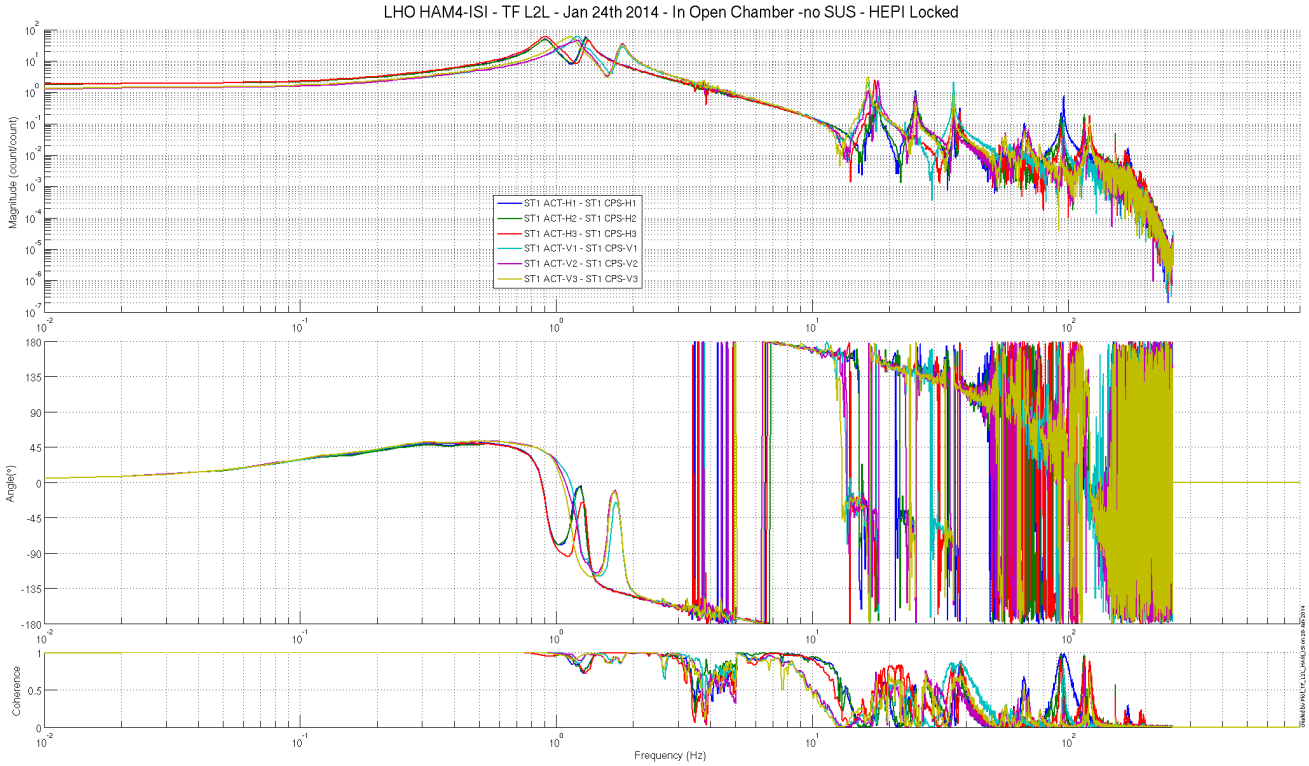


Figure - Local to Local Measurements –Capacitive Position Sensors

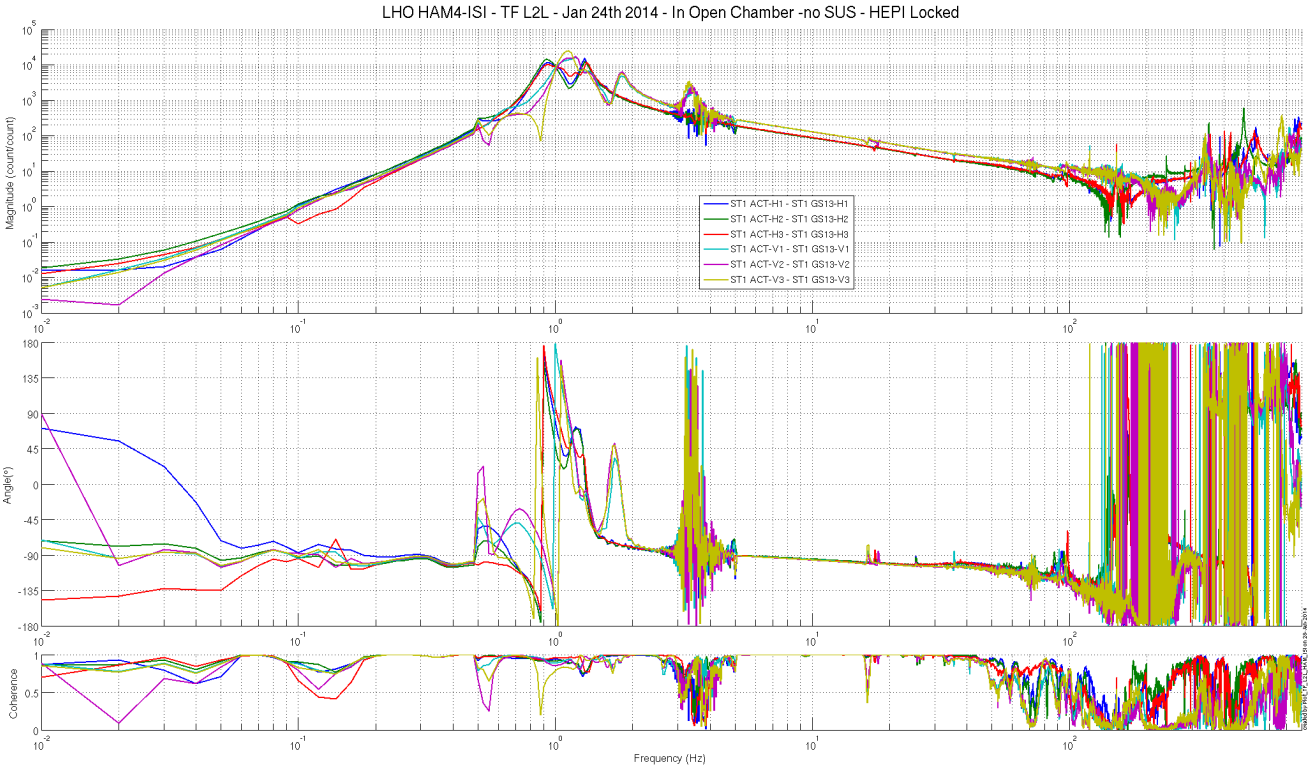


Figure - Local to Local Measurements – Inertial sensors

12.Step 15.2: Local to local measurements V.S. LLO

Data files in SVN at:

LHO:

seismic/HAM-ISI/H1/HAM4/Data/Transfer_Functions/Measurements/Undamped/

- H1_HAM4_ISI_Data_TF_L2L_5Hz_200Hz_20140124-174341.mat
- H1_HAM4_ISI_Data_TF_L2L_10mHz_100mHz_20140124-231906.mat
- H1_HAM4_ISI_Data_TF_L2L_100mHz_500mHz_20140124-223721.mat
- H1_HAM4_ISI_Data_TF_L2L_500mHz_5Hz_20140124-194728.mat
- H1_HAM4_ISI_Data_TF_L2L_200Hz_800Hz_20140124-141943.mat

Scripts files for processing and plotting in SVN at:

seismic/HAM-ISI/H1/HAM4/Scripts/Control_Scripts/Version_2/

- Step_1_TF_Loc_to_Loc_H1_ISI_HAM4.m
- Plot_TF_L2L_HAM_with_LLO.m

Figure – TF L2L – Horizontal CPS

Figure – TF L2L – Vertical CPS

Figure – TF L2L – Horizontal GS13

Figure – TF L2L – Vertical GS13

Acceptance criteria:

- Good concordance with TF measured under the same conditions at LLO.
- Local to local measurements
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC
  - Identical shape in each corner
- Cartesian to Cartesian measurements
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC
  - Identical shape X/Y and RX/RY

Test result: **Passed: __X__**

Failed: ___

Conclusion

Initial In-Chamber testing

The ISI was tested between Tuesday January 22nd and Saturday January 28th 2014. All the tests presented here were performed during that period. Other tasks were also performed then:

- Models were installed
- In-field cables were installed
-

A few major issues were found, as well as a number of normal minor issues.
Minor:

- CPSs and lockers will need to be reset after SUS install, as expected
- Several model errors were uncovered during testing. They have now been resolved. HAM5 had similar issues that have also been corrected.

Major:

- There are problems with the GS13 sections of the transfer functions. In the .5-5hz range the transfer function looks bad. The curves are not smooth up to the first resonance, only on the vertical sensors.
- At ~3 hz there is an additional resonance that may be caused by purge air. Many sensors also show low coherence here.
- The .5-5hz section was repeated with careful tuning in DTT and the issues can not be reproduced. This issue is still being looked into.
- The asci files for the DTT tf's are in the LHO H1 SVN at:
- seismic/HAM-ISI/H1/HAM4/Data/Transfer_Functions/Measurements/Undamped/
  DTT_TF_20140128_GS13
  DTT_TF_20140128_GS13_coh

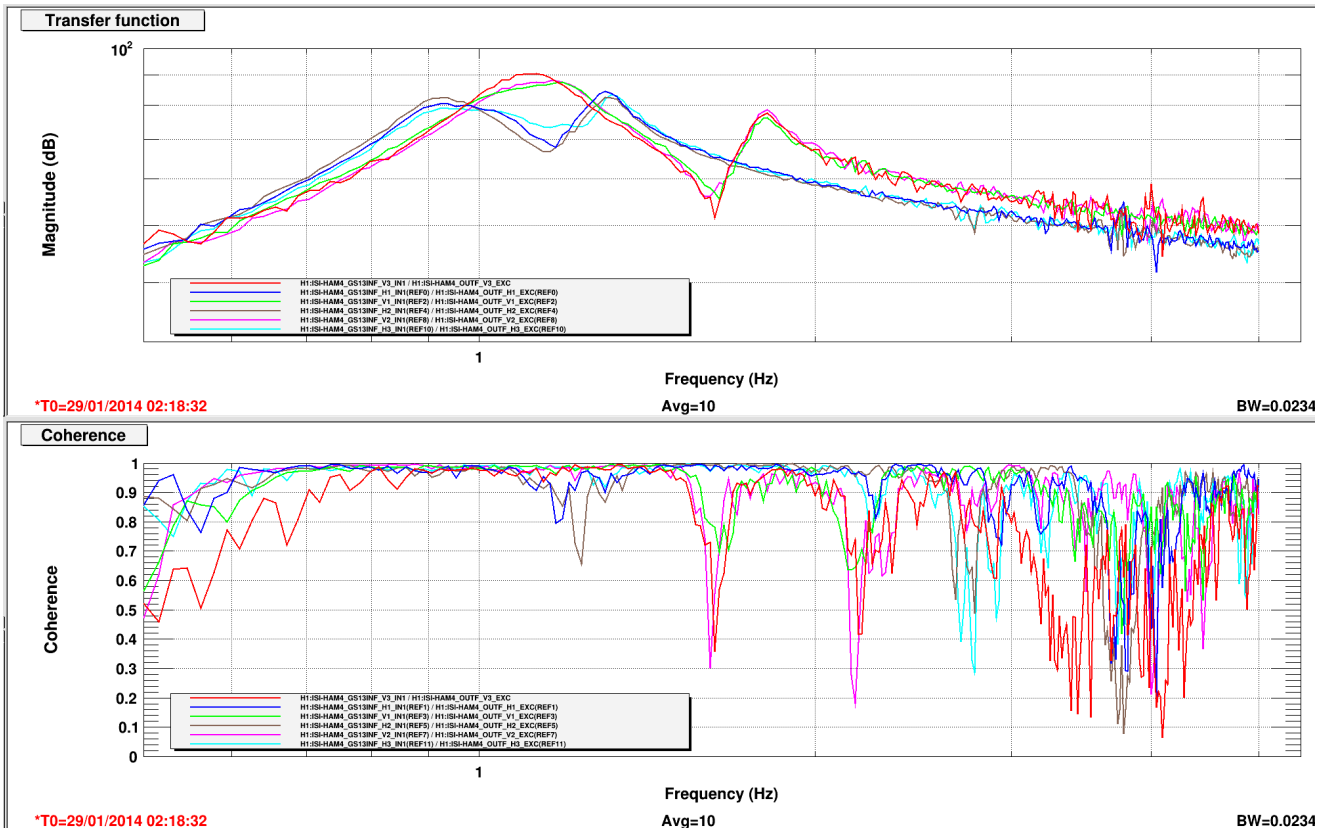


Figure – TF L2L – GS13 in DTT

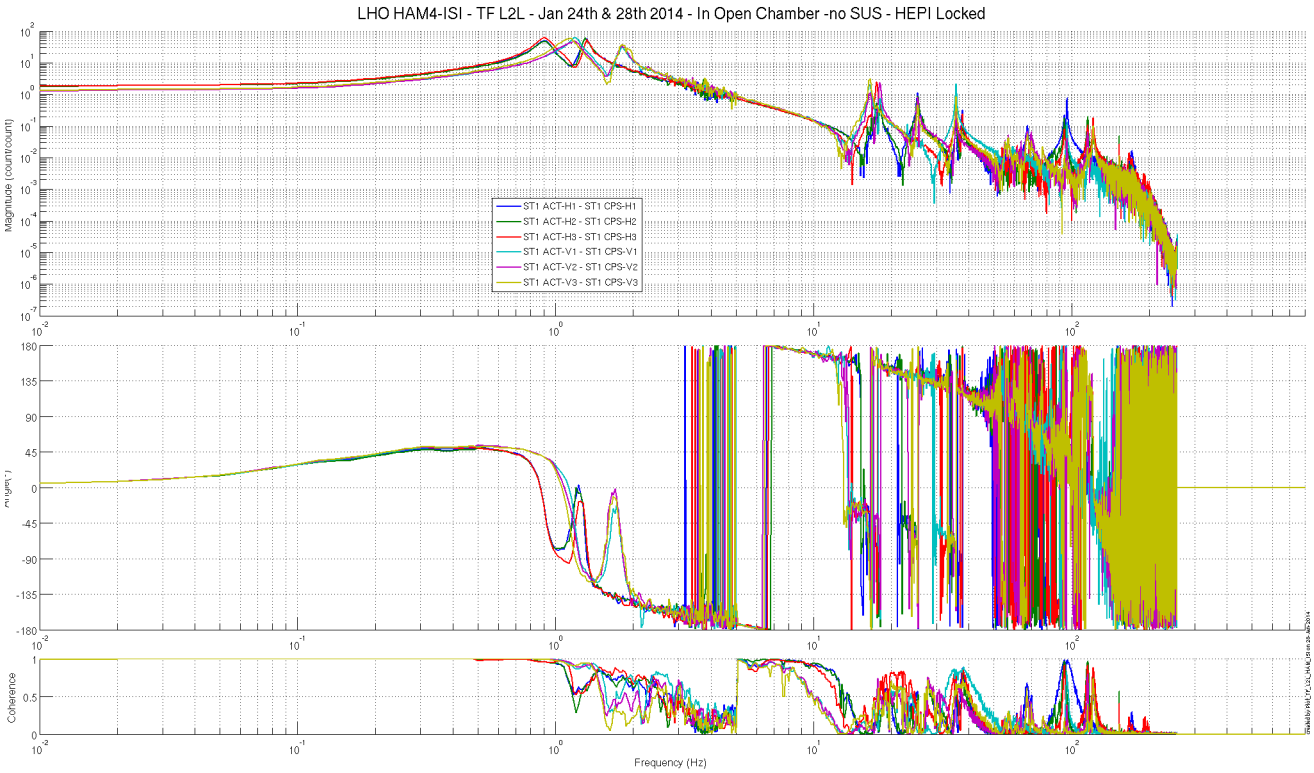


Figure - Local to Local Measurements –Capacitive Position Sensors

Figure - Local to Local Measurements – Inertial sensors