PRMI Locking Procedure

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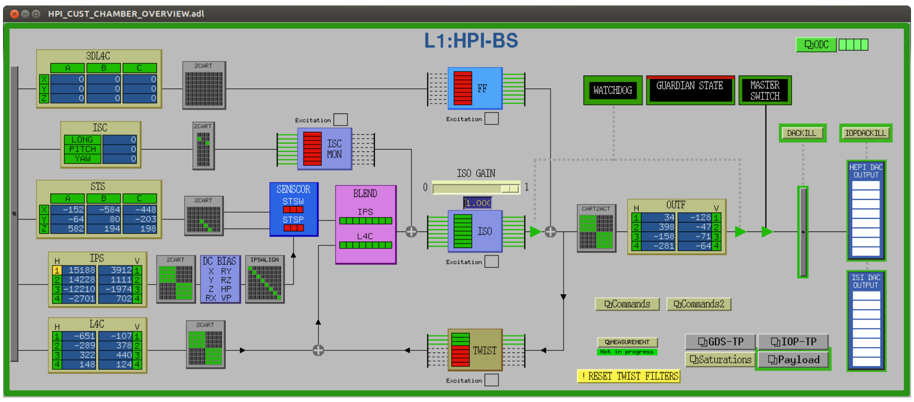
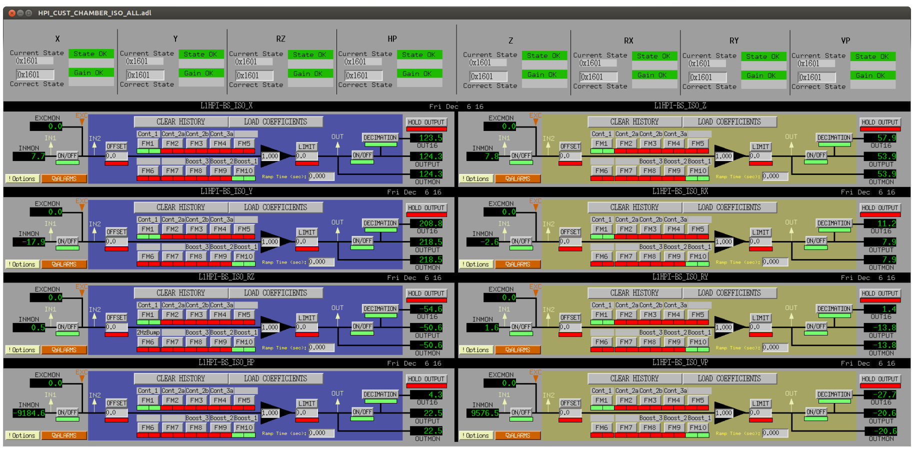
Seismic configuration

Contrary to IMC locking, at Livingston we found that the ambient ground motion was too large to lock the PRMI without the active seismic isolation systems running. The largest effect is excess angular motion, particularly of the HLTS optics (PR3 & SR3), which couple strongly to cavity misalignment.

HEPI:

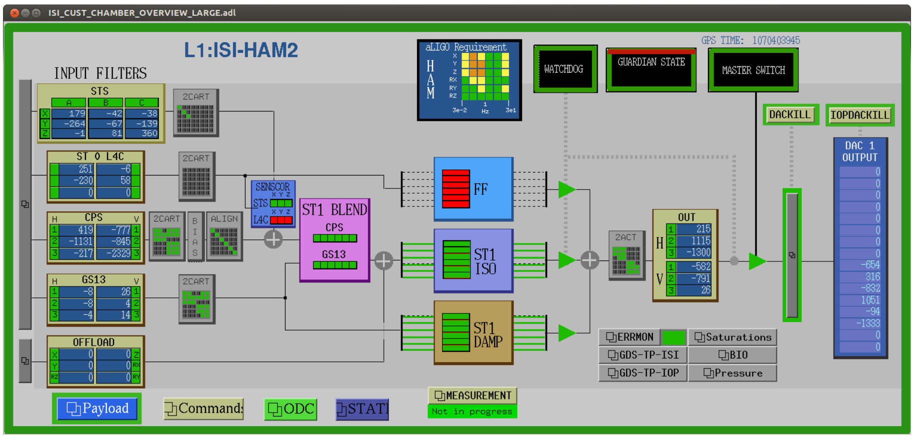
- HAM HEPI systems can either be fastened in place with their hard stops or with position sensor loops (UGF ∼5 Hz)
- BSC HEPI systems should be running position sensor loops (UGF ∼5 Hz)

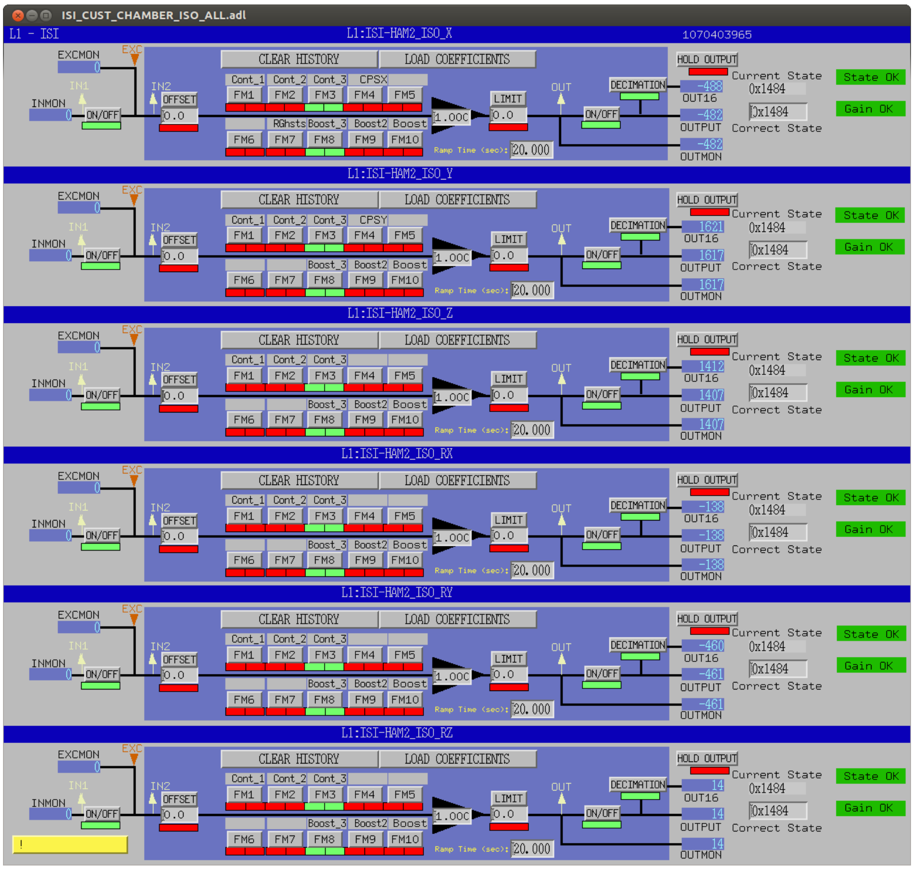




ISI:

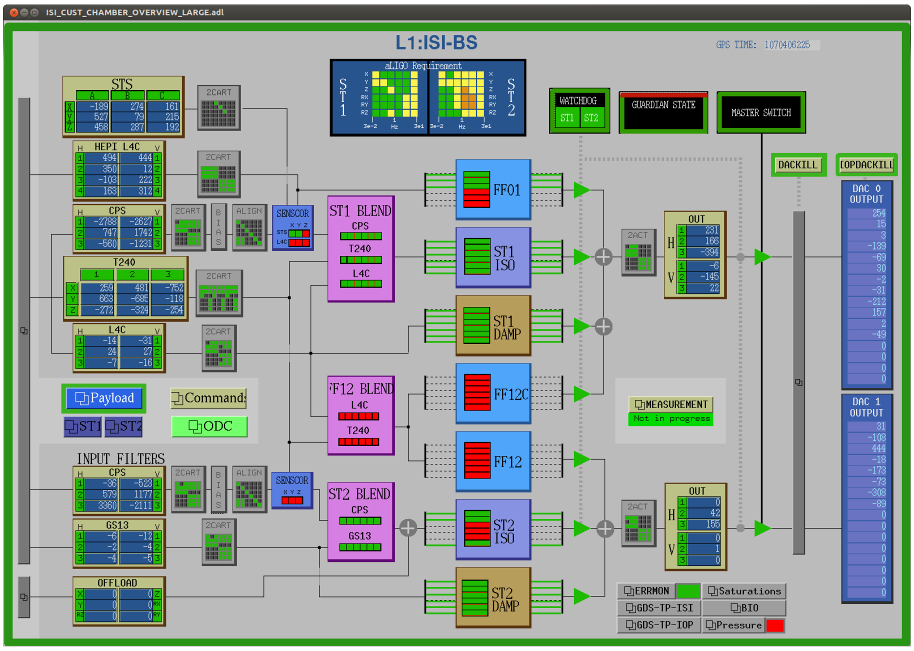
- HAM ISIs run feedback loops with ∼30 Hz UGFs (*level 3*) and the ISI inertial sensors blended into the error point around 250 mHz in translation and around 400 mHz in rotation. Isolation at the microseism is achieved via feed-forward to the ISI error point, using an STS-2 seismometer on the LVEA slab located next to HAM2 (this is called STSA in the front ends and drawings).





- Stage 1 of the BSC ISIs run feedback loops with ∼40 Hz UGFs in translation and ∼30 Hz UGFs in rotation (*both are level 3*), except for RZ which only uses a *level 1* controller with ∼10 Hz UGF. The stage 1 inertial sensors blended into the error point around 45 mHz in translation, providing isolation at the microseism, and around 250 mHz in rotation. Some sensor correction is also used, from STSB on the LVEA slab, to provide extra isolation around the main core optic suspension resonances, ∼0.5 Hz. A feed-forward path from the HEPI L4Cs provides some isolation around 10 Hz, where the BSC's suffer from some amplification of ground motion due to structural resonances.

- Stage 2 of the BSC ISIs run feedback only in the translational DOFs, with ∼10 Hz UGFs (*level 1*) and the inertial sensors blended in around 250 mHz. This isolation is only effective above ∼1 Hz and is **not** required for lock acquisition.

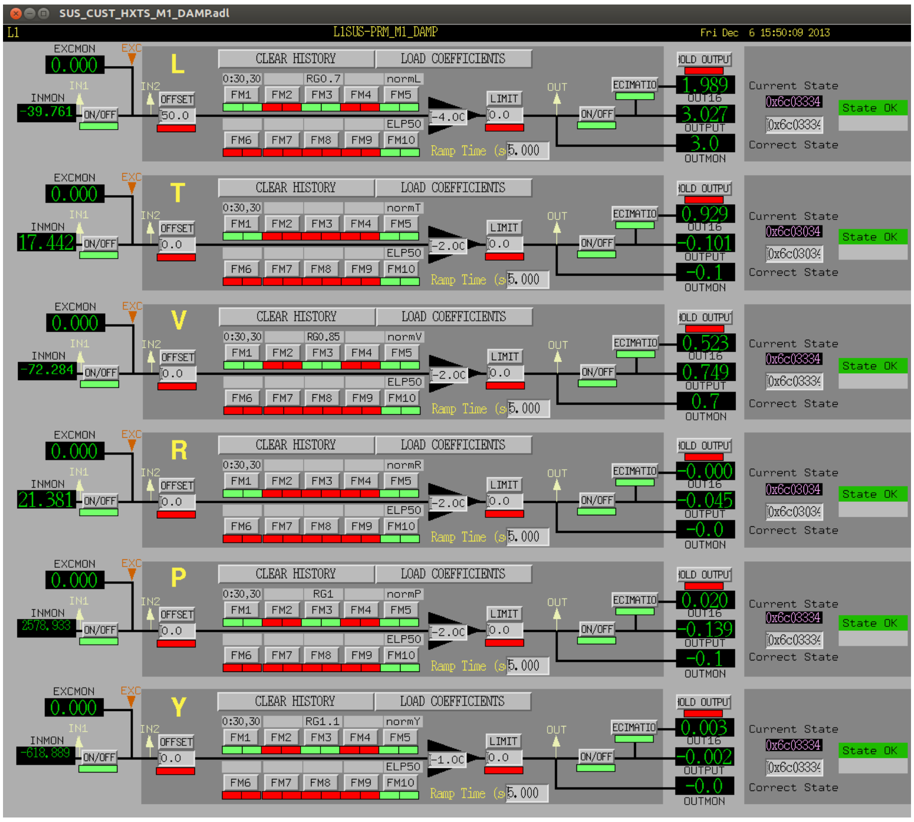

ISI_CUST_CHAMBER_OVERVIEW_LARGE.adl
L1:ISI-BS
aLIGO Requirement
WATCHDOG
GUARDIAN STATE
MASTER SWITCH
STS
HEPI L4C
CPS
T240
L4C
DACKILL
DAC 0 OUTPUT
DAC 1 OUTPUT
ST1 BLEND
FF01
ST1 ISO
ST1 DAMP
FF12 BLEND
FF12C
FF12
ST2 BLEND
ST2 ISO
ST2 DAMP
Payload
Command
ST1
ST2
ODC
INPUT FILTERS
GS13
OFFLOAD
MEASUREMENT
Not in progress
ERRMON
Saturations
GDS-TP-ISI
BIO
GDS-TP-IOP
Pressure


ISI_CUST_CHAMBER_ST1_ISO_ALL.adl
L1ISI-BS_ST1_ISO_X
L1ISI-BS_ST1_ISO_Y
L1ISI-BS_ST1_ISO_Z
L1ISI-BS_ST1_ISO_RX
L1ISI-BS_ST1_ISO_RY
L1ISI-BS_ST1_ISO_RZ
EXCMON
INMON
CLEAR HISTORY
LOAD COEFFICIENTS
OFFSET
LIMIT
DECIMATION
HOLD OUTPUT
OUT16
OUTPUT
OUTMON
Current State
Correct State
State OK
Gain OK
Options
ALARMS

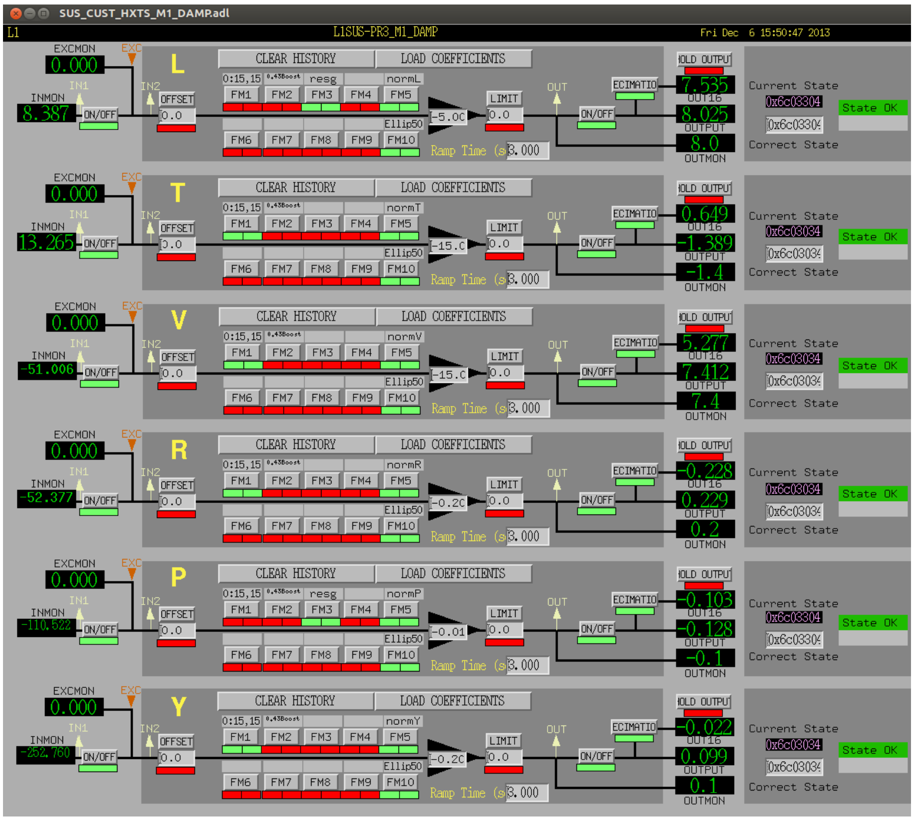
Suspension configuration

Damping:

- HAM triple suspensions use velocity damping with resonant gain for the length and pitch DOFs (*FM1, FM3, FM5, and FM10 engaged*), and plain velocity damping for the other DOFs, all with 50 Hz elliptical cutoffs (*FM1, FM5, and FM10* engaged). For a HSTS the damping gains in L,T,V,R,P,Y are [-4, -2, -2, -2, -2, -1].

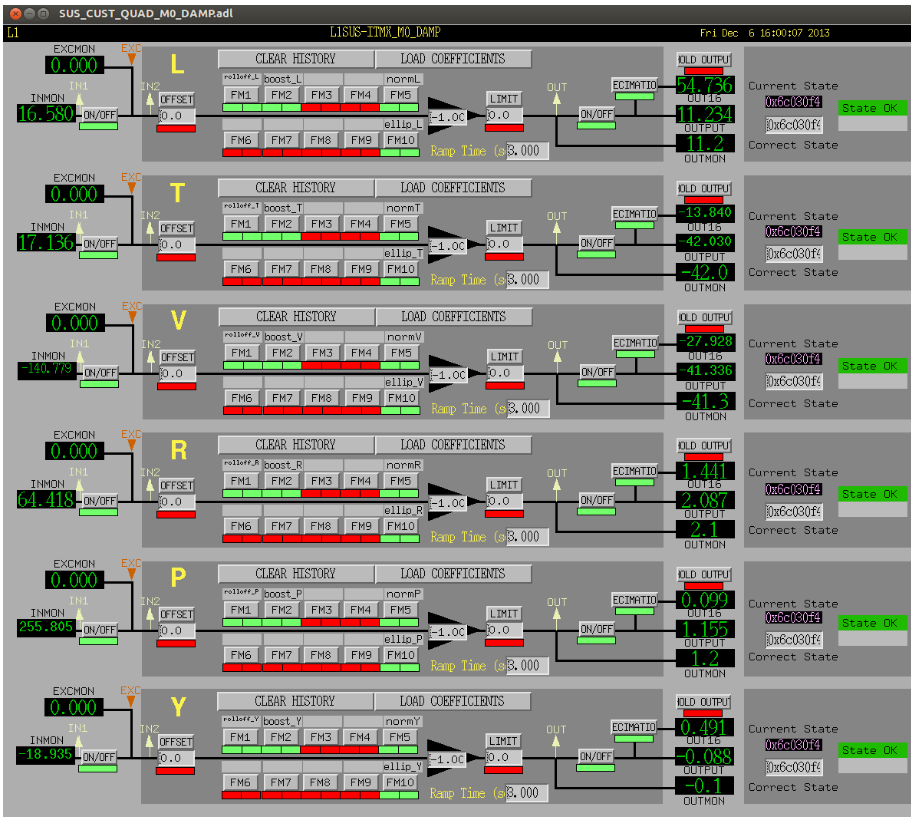


For a HLTS the damping gains in L,T,V,R,P,Y are [-5,-15,-15,-0.2,-0.01,-0.2].



- The BS suspension damping loops use velocity damping with resonant gain in the length, transverse, and pitch DOFs (*FM5, FM6, FM8, FM9 engaged*), with plain velocity damping for the other DOFs, all with 50 Hz elliptical cutoffs (*FM5, FM6, FM9* engaged). The damping gains in L,T,V,R,P,Y are [-18,-0.5,-2,-0.5,-5,-0.6]. An optical lever servo is also used, feeding to the M2 stage actuators.

- The ITMs have resonant gain damping on all DOFs (*FM1, FM2, FM5, FM10* engaged), all damping gains are set to -1.



BIO switches:

- All HSTS and BS stages are in state 2 (ACQ ON, LP OFF). The ITMs and PR3 are not used for length actuation, and can be in low noise mode.

BS suspension tuning

Balancing is done with the BS optical lever servo engaged.

- Balance the BS M2 coils by adjusting their gains while driving the M2 stage at high frequency (above the suspension resonances) in the pringle/butterfly degree of freedom and minimizing the peaks in pitch and yaw as measured by the optical lever. The coil gains are normalized to give a sum of the magnitudes equal to 4.
- Measure the transfer functions from the M2 L2P and P2P filters in the DRIVEALIGN matrix to the optical lever response (above 5 Hz the suspension model may be more accurate than the measurement).
- Fit the transfer functions, P2P and L2P, using the vectfit MATLAB routine. Be aware that this fit can produce RHP zeros.
- Make the synthetic data for the frequency response of the ratio of the filters L2P/P2P and fit it again with vecfit.
- Invert the filter from the previous step and install the inverted filter into the L2P filter of the DRIVEALIGN matrix.
- Repeat the above steps for yaw.

Initial alignment

- Align the input beam (adjusting IM3 or IM4) by centering the beam on the PR2 baffle.

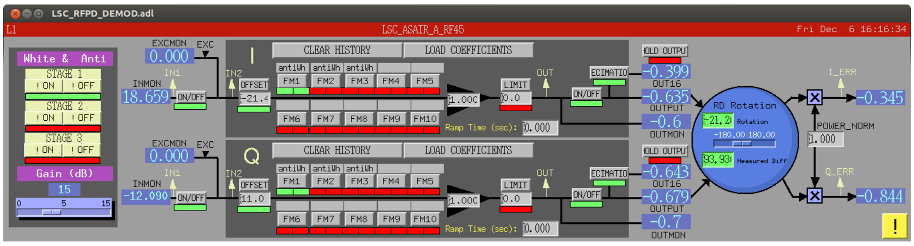
- Align PR2/PR3. With the PRM misaligned find the leakage beam on the REFL port camera by moving PR2 and/or PR3. The PR2/PR3 alignment is degenerate in this configuration. The cavity alignment relative to the input beam is ∼10x more sensitive to PR3's angle than to PR2's.

- Align the simple Michelson. With the PRM misaligned use the camera at the AS port (try using REFL if AS not available?) camera to overlap the beams returning from the ITMs.

- Align the PRM. Maximize the flashes on the AS camera or dips/spikes in the REFL/POP detectors.

Simple Michelson locking

- The AS (REFL if AS not available?) port I/Q phases are first adjusted with the free swinging Michelson. At LLO the AS45_AIR phase is -21.2°. The AS45_AIR photodetector also has 15 dB of analog gain.



- The filters are:
  - f starting at 1 Hz with roll off at 50 Hz, 0.1:0.6 Hz boost (*FM4* in L1:LSC-MICH)
  - bandstop for the BS bounce mode around 17 Hz (*FM6* in L1:LSC-MICH)
  - bandstop for the BS roll mode around 25 Hz (*FM7* in L1:LSC-MICH)
  - f^2 starting at 1 Hz with roll off above 50 Hz (*FM6* in L1:SUS-BS_M2_LOCK_L)

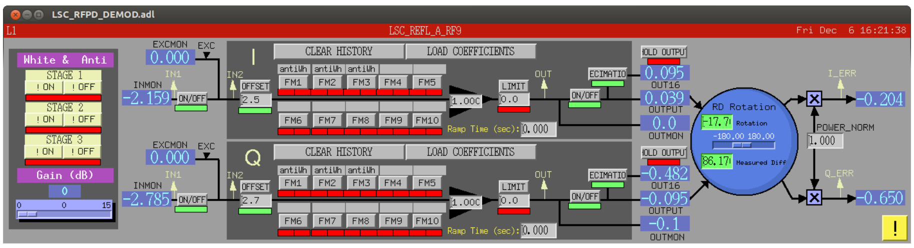
- two boosts are triggered, *FM2* and *FM8*

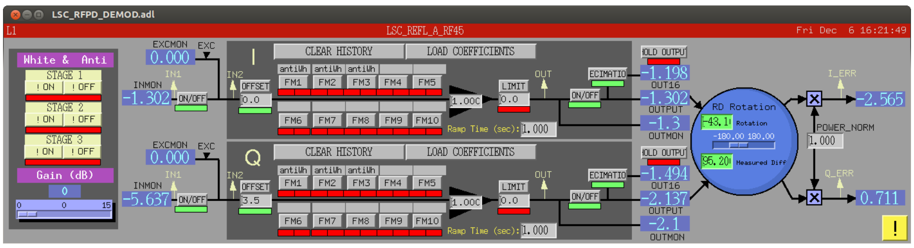
- the servo ugf is ∼10 Hz with a MICH gain of +/- 600 (dark/bright)

PRX/Y locking

- The REFL port phases can be initially set/checked with free swinging PRX(Y)

- No analog gain is used for the REFL photodetectors





- Once PRX(Y) is locked **on sideband** the phase is set by minimizing the response to PRM drive in the Q-quadrature.
- The phase difference between PRX and PRY is determined by the Schnupp assymetry and should be 22° for RF45 and 4.5° for RF9. For the PRMI locking REFL RF phases are set up as an average between PRX and PRY configurations.
- Other checks can be made in PRX(Y) configuration:
  - the BS optical lever loop shapes
  - the BS suspension transfer function
  - the PRM suspension transfer function
  - the PRM M2/M3 crossover transfer function

PRMI locking

- The servo gains in PRMI configuration can be obtained from the PRX(Y) servo gain and Optickle modeling. At LLO the PRX cavity is locked with a servo gain of +/-10000 (sideband/carrier) to give a UGF of ~100 Hz. To get the same UGF in the PRMI configuration the PRCL servo gain is set to 1/500 of the PRX gain (+/-20 in sideband/carrier). The simple Michelson is locked on AS 45Q with a MICH servo gain of +/- 600 (dark/bright) and a UGF of ~8 Hz. To get the same MICH UGF in PRMI the scaling is ~1/20 so the MICH gain is 30.
- The actuation used in the PRMI configuration is: MICH to BS M2, PRCL to PRM M3/M2 and PR2 M3 (PR2 is only needed during the lock acquision transient).
- During the lock transient the PRM M3/M2 crossover is set to 0.4 Hz to avoid a strong suspension transient. The PRCL and MICH filter outputs are triggered when the PRC build up is ~3. Once lock is acquired, integrators are triggered for the PRCL and MICH loops with a delay of 0.5 sec. The PRM M2 gain is icreased by a factor of 10 and an integrator is enabled in this bank as well.

Scripts

Some temporary setup and locking scripts were generated, and can be made available upon request, but is expected to be replaced by an ISC Guardian in the future.