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Executive Summary of the One Arm Test

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Executive Summary of the One Arm Test

This summary indicates that the test was quite successful, a welcome result. I accept the recommendations of the summary.

David Shoemaker, Project Leader

The One Arm Test was the first integration phase of the Advanced LIGO project. It took place at LIGO Hanford Observatory using the Y-arm cavity of H2, starting on June 21, 2012, and ending during the week of September 10, 2012. The applicable integration planning document can be found as T1100080.

The One Arm Test was a great success. Establishing the basic functionality between different subsystems was straight forward with only small problems—a significant and refreshing improvement compared to the first steps of initial LIGO commissioning. As an example, finding the initial beam and getting the arm cavity locked only took days, compared to the 3 months for locking the initial LIGO mode cleaner.

The goals of the One Arm Test were met as follows:

Initial alignment: Sustained flashes of optical resonances in the arm cavity
Achieved.

Cavity locking/ISC: Green laser locked to cavity for 10 minutes or more
Achieved.

TransMon/ALS: Active beam pointing error on the TransMon table below 1 urad rms in angle and below 100 um rms in transverse motion
Achieved.

Calibration: ETM displacement calibration at the 20% level
Achieved.

TCS: Ring heater wavefront distortion, as measured by the Hartmann sensor, in agreement with the model at the 10 nm rms level.
Achieved.

Optical levers: Optical lever long-term drift below 1 urad
We observed diurnal motion that was about twice as larger. However, it was not clear, if this was due to the test mass motion or the optical lever. Since there is no indication that this is limiting us, we consider this closed.

Controls/SUS: Decoupling of length-to-angle at the level of 0.05 rad/m or less, for frequencies below 0.5 Hz
This was only really worked on for the TOP stage of ETMY with a precision of about 0.1 rad/m—close enough. The other stages showed larger cross-coupling, but there was no tuning attempted. This can be worked on in the coming months using just the optical lever.

SEI: Relative motion at the suspension point between the two SEI platforms below 250 nm rms (without global feedback)
Achieved. However, this required a more sophisticated controls network than level 1. Lower frequency blend filters were required to reduce the motion between 0.1Hz to 1Hz, and particularly at the lowest resonance of the quad suspension at 0.45 Hz. Lowering the blend filters leads to an amplification of the motion below 0.1Hz. It is unlikely that this will become a problem down the road, since the corner ALS system should have ample feedback gain at these low frequencies.

Cavity alignment fluctuations/SEI/SUS: Relative alignment fluctuations between the ITM and ETM below 100 nrad rms for frequencies above 0.1 Hz (without global feedback)
This will have to be assessed offline. The RF wavefront sensors were commissioned successfully, but the analysis is still left to be done. Overall, alignment fluctuations and drifts were no problems in locking the arm cavity.

Cavity length control/SEI/SUS/ALS: Relative longitudinal motion between ITM and ETM below 10 nm rms for frequencies below 0.5 Hz

ALS: Ability to control frequency offset between 1064 nm and 532 nm resonances at the 10 Hz level

ALS: Relative stability of the 1064 nm and 532 nm resonances at the 10 Hz level for frequencies below 0.5 Hz
The arm length is compared to the laser frequency. Since this reference is contaminated by fiber phase noise and reference cavity thermal fluctuations, we have no way to assess this requirement. This strongly argues to start the corner ALS integration phase as soon as feasible. An accelerated HIFO-Y will validate the common mode ALS locking scheme with an additional frequency stability provided by the input mode cleaner. A full validation of the ALS scheme probably has to wait for the X-arm, since this will be the first time we have a look at the true arm cavity motion. The suspension model for hierarchical control that is necessary for a full validation of the ALS scheme is being worked on using the data obtained from the one arm test.

Controls/ISC: Fully automated cavity locking sequence; long term cavity locking
Long term cavity locking has been achieved. Due to the shortening of the overall one arm test duration automation is still only rudimentary. For some systems like the PLL this can be corrected during the next few weeks, whereas others, like the cavity locking, will have to wait for the HIFO integration phase.

Summarizing, the basic functionality of the HEPI, SEI and SUS for BSC systems has been validated. The end station ALS system has also performed as designed. Systems auxiliary to the one arm test such as TCS and optical levers have demonstrated their functionality as well. As expected, we have not learned anything significant about the low noise behavior of these systems.

Going forward we have the following recommendations:

1. We recommend eliminating the ALS wavefront sensors from the design. Short term drifts are not large enough to require auto-alignment during locking.

2. We recommend keeping the PZT steering mirrors however. Aligning both the cavity and the input steering manually is tedious and time consuming. Additionally, in case we completely lose the input pointing by an accident, which happened once during the one arm test, automatically

scanning the input pointing greatly reduces the recovery time from days to an hour. This has the potential to affect the interferometer duty cycle.

3. Additional hardware is required to support automation. This includes measuring the beat note frequency of the PLL loop, and additional DC photodetectors to remove ambiguities in the automation process.

4. We need improvements in the usability of individual subsystems. This would include writing a user's manual as well as developing operations procedure and screens.