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Executive Summary of the LHO HIFO-Y Test

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Executive Summary of the LHO HIFO-Y Test

The HIFO-Y test was the third integration phase at the LIGO Hanford Observatory. It started on June 10th, 2013 and ended July 26th, 2013. The applicable integration planning document can be found as [T1300174](#).

The LHO HIFO-Y was an overall success demonstrating the arm length stabilization system on a single arm cavity. It is a continuation of the one arm test, see [E1300627](#). The one arm test included only green laser light injected from the end, whereas HIFO-Y added the green transmission path as well as the (infra-)red laser light from input mode cleaner. This makes it possible to resonant both colors and investigate their relative stability. We achieved an rms stability of better than 4 Hz which compares favorably with the HIFO-Y goal of <10 Hz.

The goals of the HIFO-Y test were met as follows:

SHG: Long term stability of the emitted green light at the 5% level
Achieved.

Cavity locking/ISC: Fully automated cavity locking using the improved hardware in the end
Achieved.

Controls/ALS: Locking the PSL laser frequency to the arm cavity and achieve 10 Hz relative stability over 10 minutes
Achieved. We used both the transmission mid power point and the PDH signal in reflection to evaluate the red locking behavior.

TransMon/ISC: Calibration of IR QPDs for the cavity alignment at 10% level
Achieved.

TransMon/ISC: Use red Trans QPD to characterize the red cavity power and show resolution of 1% of full cavity power
Achieved.

ALS: Ability to control frequency offset between 1064 nm and 532 nm resonances at the 10 Hz level
Surpassed. It was necessary to make functional changes in the servo topology which will require additional hardware. To achieve the 4 Hz stability we were require to use a very low bandwidth common mode loop. A higher bandwidth loop is highly desirable due to its improved robustness. This will require a acoustic mitigation effort which is detailed in the recommendation section.

ALS: Relative stability of the 1064 nm and 532 nm resonances at the 10 Hz level for frequencies below 0.5 Hz
Surpassed.

Cavity alignment fluctuations/SEI/SUS: Characterize the effect of pointing fluctuations onto the locking offset and demonstrate less than 10 Hz rms over 10 minutes
Achieved.

Cavity length fluctuations/SEI/SUS: Agreement between modeled and measured length fluctuations, around the lowest quad suspension modes, to better than a factor of 2
The transfer functions now agree within a factor of 2. But, the understanding the cavity length spectrum is still a work in progress.

Controls/ISC: Fully automated ALS locking sequence; long term robustness

Due to time constraints only partial automation of the new system was achieved. In particular, no initial alignment scripts have been developed. A locking sequence has been worked out for the length degrees-of-freedom. Automatic initial alignment will have to be interleaved with the ALS auto locking flow. Alignment was done by hand during the HIFO-Y test. The length locking has been tested, and additional synchronization hardware between TwinCAT and real-time system was installed. No fundamental problems have been identified to achieve full automation.

Optical levers: Optical lever long term drift below 1 μ rad

Achieved, see T1300563.

The HIFO-Y test is also closing out all but one of the remaining issues discovered in the one arm test. In detail:

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 not important to achieve the HIFO-Y goals. The length to angle coupling was not a problem, since we are using feedback to the HEPI actuators for the one arm length drift. Also, all test masses involved in this test will be moved and replaced in the future, so this effort is better invested in the final configuration. This can be worked on in the coming months using just the optical lever.

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)

Achieved.

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 above three goals were rolled in the HIFO-Y test and have been achieved.

Controls/ISC: Fully automated cavity locking sequence; long term cavity locking

The remaining item of automation has been completed.

All but one recommendations from the one arm test have been successfully implemented and tested. In detail:

Green wavefront sensors: Eliminated from design.

Input steering: Servo with PZTs was maintained in the design.

Additional hardware is required to support automation: Beat note measurement and additional photodetectors have been implemented and integrated in software.

We need improvements in the usability of individual subsystems: Not enough progress has been achieved. See recommendations in this report.

Finally, the IMC auto-alignment system was not fully implemented and tested during the dedicated IMC test phase due to electronics problems. This task has now been completed.

Summarizing, the basic functionality of the ALS system controlling a single arm cavity has been validated. All required subsystems, HEPI, SEI, SUS, PSL, IO, ISC and AOS, have performed at the necessary level. Some changes in the ALS setup were required to achieve the stated goals. These changes are listed in the recommendations section below. We closed out the remaining tasks from both the one arm test and the input mode cleaner test.

Going forward we have the following recommendations:

1. We require a change in the servo topology in the locking of the two VCOs controlling the common and differential degrees-of-freedom. We intended to directly phase lock the green beat note to the PSL frequency using the VCO as a reference frequency. We found that we had to phase lock the VCO to the beat note, and use its frequency output as the error signal to lock the PSL frequency. This requires a new PLL servo board.
2. We recommend to implement a second frequency difference divider for the common and differential VCOs to reduce its rms frequency noise level by an order of magnitude. As it stands the frequency noise of the VCOs would limit the relative red/green stability to about 15 Hz rms.
3. We recommend to implement an additional oscillator source to drive the fiber AOM at a fixed frequency. This was required to improve the robustness of the ALS system. Using the PSL VCO proved to negatively affect the green laser locking in the end station.
4. We recommend to implement ECR E1300403 among all interferometers. This will allow for coordination between the main ALS slow controls and the real-time system.
5. To further reduce the red/green relative frequency noise we recommend to invest in some acoustic mitigation, but as a backup rely on the factor of 2 improvements we will get, when installation activity ceases. We do recommend to install the acoustic panels in ISCT1 and to work on damping individual mirror mounts. We recommend looking at the feasibility to bring out the green beams and the red beam from the laser through the same viewport and down the same periscope, preferably using the same top periscope mirror.
6. We need improvements in the usability of individual subsystems. In particular, top-level non-expert controls are mostly missing in the subsystems. Too much commissioning time was wasted chasing down inappropriate settings, or trying to figure out basic functionality.
7. We recommend to improve the locking speed of both the mode cleaner and the PSL reference cavity. With the feedback coming from the common mode servo the likelihood has greatly increased that they will lose lock during lock attempts and lock losses. Currently, they are limiting the rate of relocking.
8. Access to control room resources is critical to effectively commission an interferometer. Currently, this typically requires a physical presence in the control room, even if the activity itself could easily be performed remotely. We recommend that remote access to the control room machines is established through a VPN type access and is available to commissioners during the next dedicated integration phase.