Arm Length Stabilization at the 40m prototype

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Abstract

A test for the Arm Length Stabilization (ALS) is underway at the caltech 40m prototype interferometer (IFO). The experimental setup has been completed for a single arm and we have started examining the performance of the ALS scheme. The scheme employs a frequency-doubled auxiliary laser to sense the arm cavity motion prior to full lock acquisition. It enables us to hold the arm length at a desired value to ease the complexity of the successive lock acquisition steps. A successful lock of the ALS has been demonstrated for the single arm, resulting in a residual displacement of 200 pm in rms.

1. Background

The lock acquisition of the advanced IFOs will be more difficult because:

- Complexity of the response from the IFOs [1]
- Weak actuators for the test masses
- A failure of lock excites the motion of the test masses

solution **a smooth and deterministic lock acquisition technique**

- Deterministic lock acquisition

* Cease a probabilistic lock (i.e. wait until the arms locked)
* Once an initial condition is fulfilled, it brings the IFO to the full lock state in a well-defined protocol
* To achieve the initial condition the arm lengths should be controlled at the beginning without locking the central part (e.g. MICH, PRC, SRC)

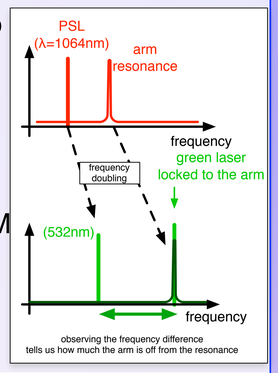
Requires a technique to pre-stabilize the arm length

2. Arm Length Stabilization

- How to stabilize the arm cavities ?

* Lock the frequency-doubled aux. lasers to the arms. ⇨ freq. change of the aux. laser represents the arm motion
* Measure the frequency difference between the frequency-doubled PSL and the aux. laser at the vertex
* Feedback the frequency difference to ETM

(Dichroic ITM and ETM give moderately low finesse of 100)

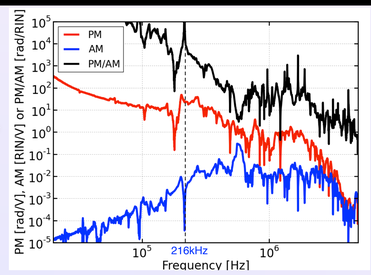


The experimental setup is shown below

3. Technologies

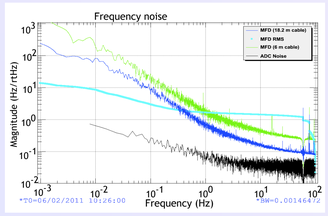
- PDH locking for the aux. green laser

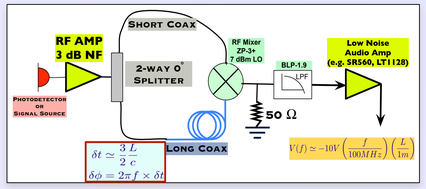
* Frequency doubling by PPKTP crystal
* 216 kHz modulation using the laser PZT where PM/AM ratio is maximized
* A digital slow temperature servo ⇨ offset allows us to select the freq. offset between the PSL and the aux. laser



-Mixer-based Frequency Discriminator (MFD)

* Low noise 10Hz/√Hz @ 0.1Hz currently limited by noise of the preamp.
* Two MFDs are used
  2m delay line for coarse control (+/-30MHz range),
  42 m delay line for fine control (+/- 1MHz range)

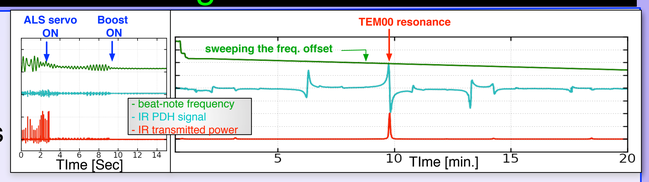




4. Results : single arm test

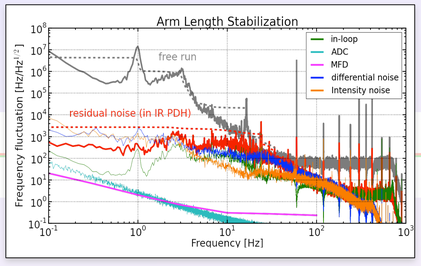
- ALS is engaged

* To find a resonance the cavity length was swept by changing the freq. offset



- Noise performance

* Observed rms in IR PDH signal is **2 kHz** or **200 pm**, which is within the linewidth of the cavity (~1nm)
* mostly dominated by intensity noise from the transmitted light of the arm cavity



5. aLIGO vs. 40m prototype

- Length is different by 100 times

* In aLIGO the frequency noise will be lesser by the same factor of 100. But it needs 100 times smaller sensing noise for the beat-note frequency detection.

- Control scheme

*The 40m will mainly demonstrate control of each arm individually. aLIGO ALS will instead control Common and Differential degrees of freedom.
So we will also try Common and Differential control using a digital signal matrix, which is not as fast as that of aLIGO.

6. Summary and Plans

- summary

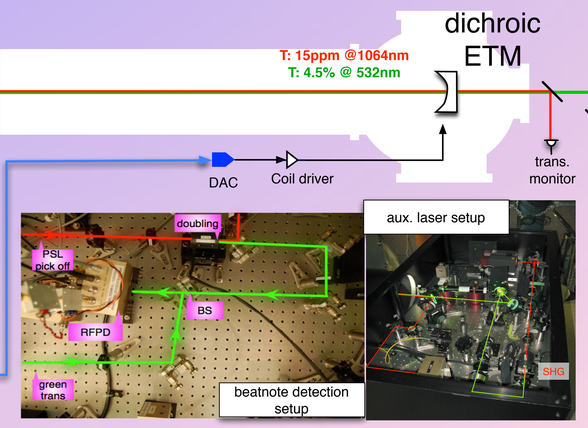
* Dichroic ITM and ETM have been installed
* Started single-arm test
* Achieved the rms of 200 pm which is less than the linewidth of the arm cavity
* Resultant noise is limited by intensity noise

- Plans

* Intensity Stabilization for the aux. laser (soon)
* Handing off the servo from the green to the IR (March)
* ALS for the other arm (April -)
* Full lock trials (July-)
* Study of the full lock acquisition (Aug -)

References

[1] *Length Sensing and Control of a Prototype Advanced Interferometric Gravitational Wave Detector*, R.Ward, Thesis
[2] *Vertex Green Locking for Arm Length Stabilization*, A.Brooks, et al., LIGO-T0900526
[3] *Arm Length Stabilization (ALS): A plan for testing at the 40m*, A.Brooks et al., LIGO-G1000293
[4] *Advanced LIGO Arm Length Stabilization System Design*, M.Evans, et al., LIGO-T0900144



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