Correlating Temperature Variation with Phase Noise on LOT

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LISA

LISA (Laser Interferometer Space Antenna) is a space project designed to detect gravitational waves.

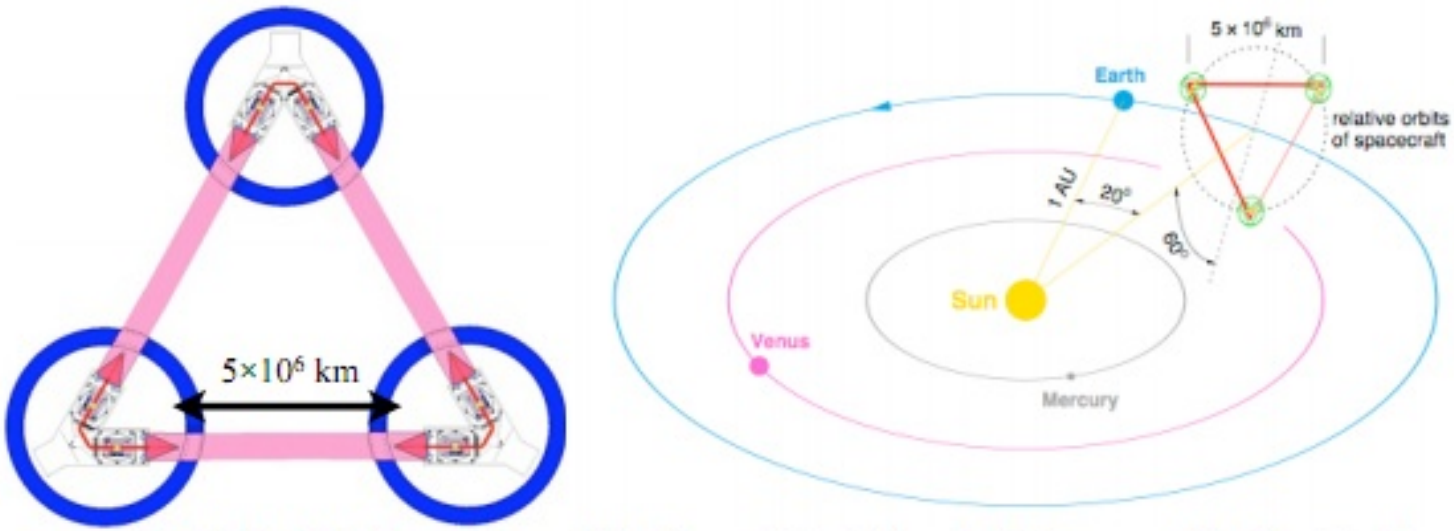


Fig. 1. The 3 LISA satellites with their laser links (left) and orbiting around the Sun (right)

LISA has two main technical difficulties:

- the free falling masses must be isolated from all forces other than gravity, and the spacecraft must precisely follow these test masses
- outstanding precision of phase shift measurements.

Motivation

LISA's capability to measure very small displacements relies on a number of algorithms and stabilization techniques, very low noise, and extremely high performance instruments.

Simulation software can simulate Doppler effects, propogation delays, reconstruction algorithms, etc., and many of the stabilization techniques (such as TDI and arm-locking) have been tested theoretically and by numerical simulation.

LISA On Table (LOT) is an optical simulator for LISA. This hardware development is desirable in order to characterize detection devices, validate numerical models, and study the influence of the hardware on the detection algorithm.

Experimental Set-up

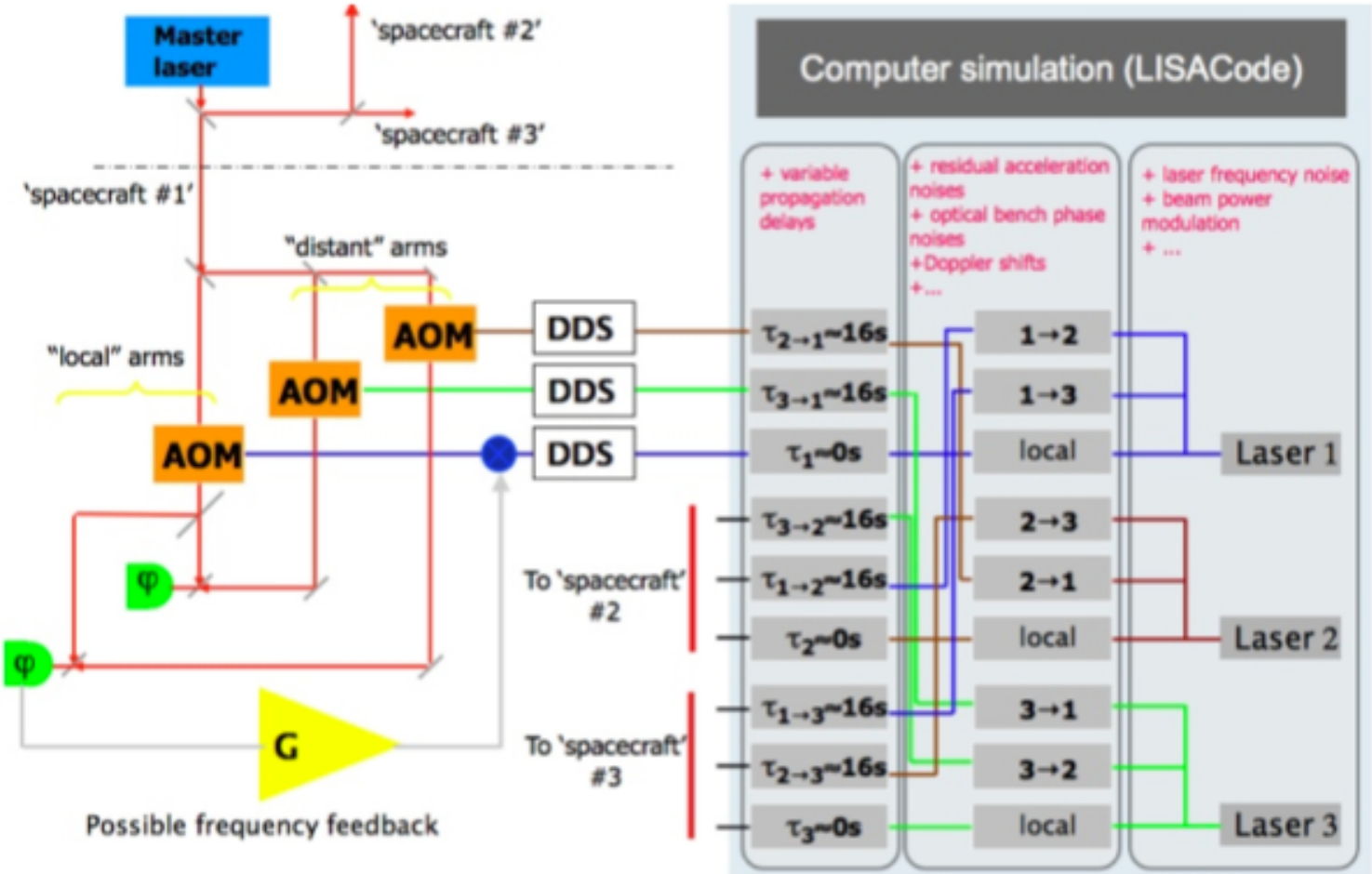
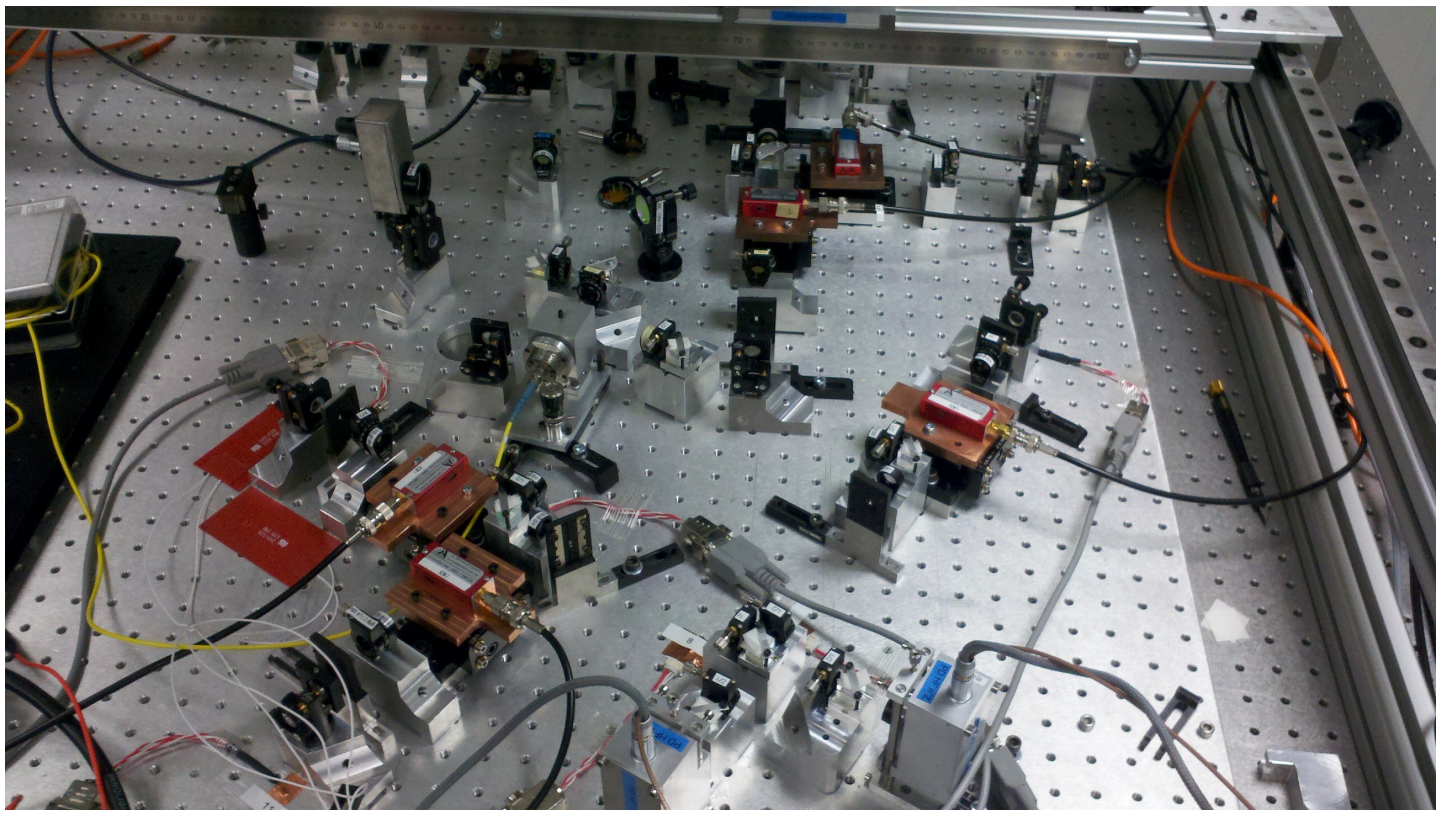


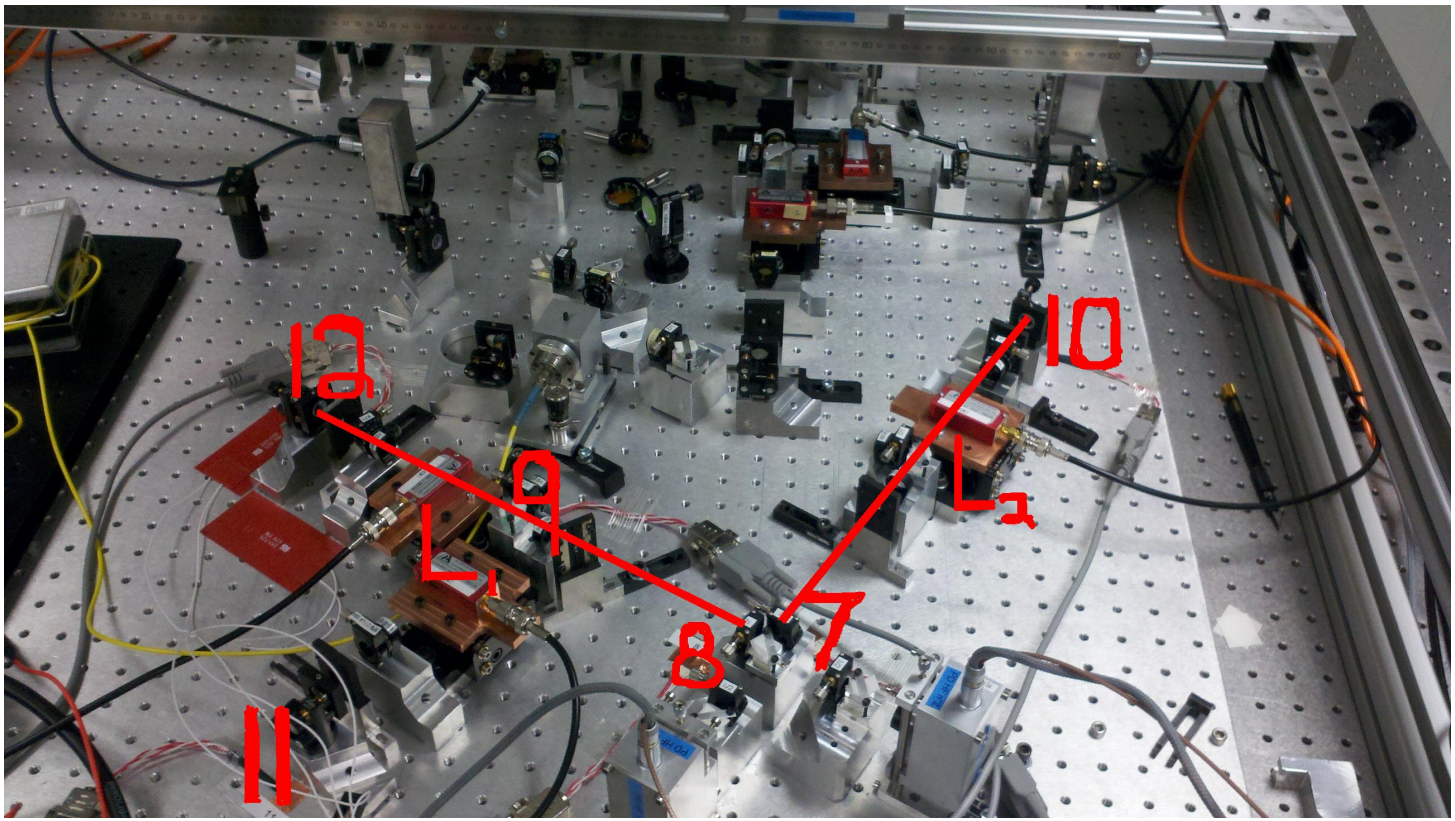
Fig 2. Principle scheme of the LISA On Table experiment

Actual Optomechanical Set-up



- AOMs are in cat's eye configuration, allowing frequency change with over 20MHz range with small angular deviation
- Configuration allows two distant beams to follow the same optical path on perpendicular polarizations

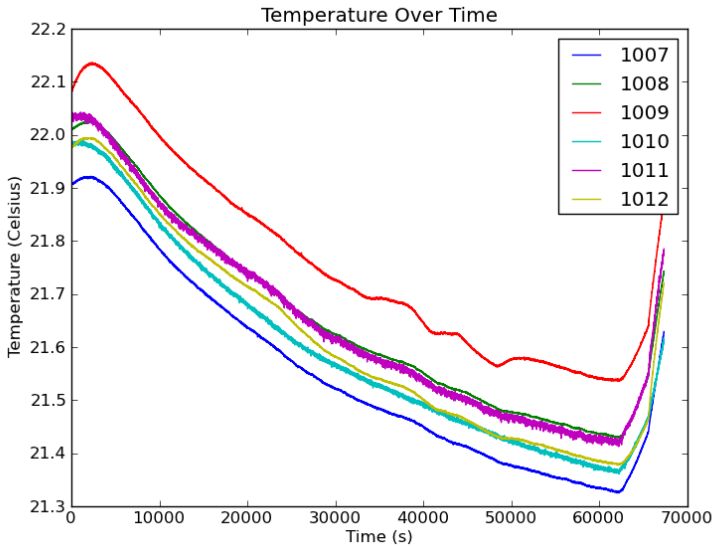
Expectations

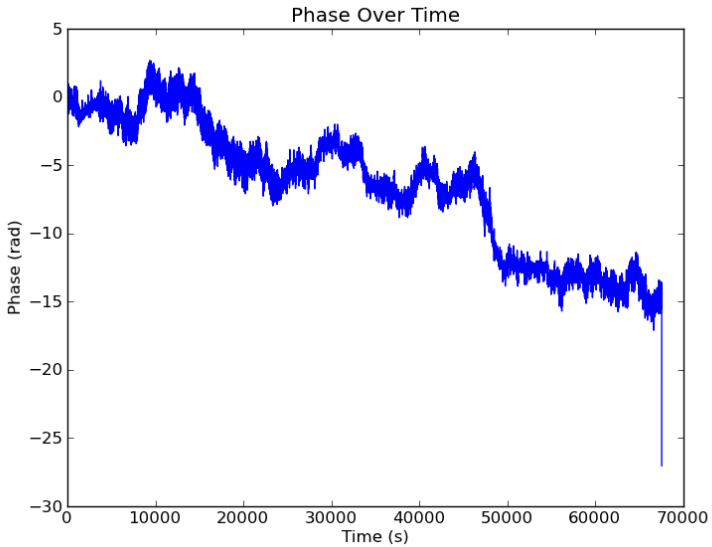


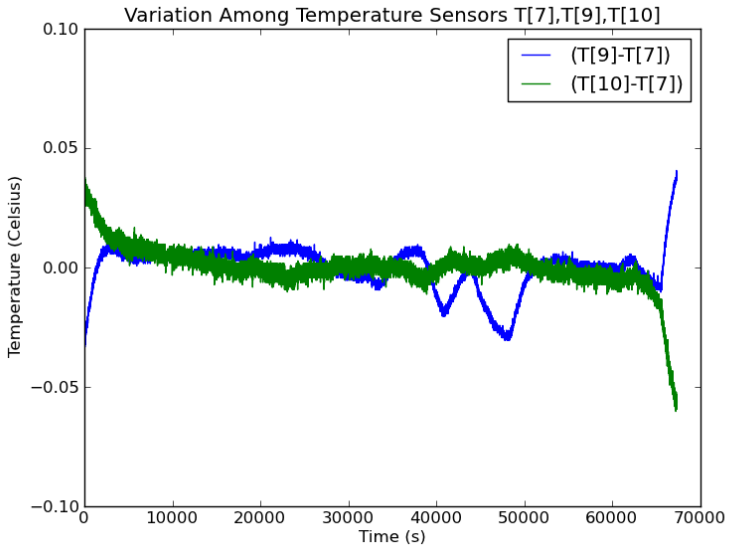
$$\delta L_1 \propto \left\{ \begin{array}{l} T_9 \\ T_{11} \\ T_{12} \end{array} \right. - \left\{ \begin{array}{l} T_7 \\ T_8 \end{array} \right. \quad \text{and} \quad \delta L_2 \propto T_{10} - \left\{ \begin{array}{l} T_7 \\ T_8 \end{array} \right. .$$

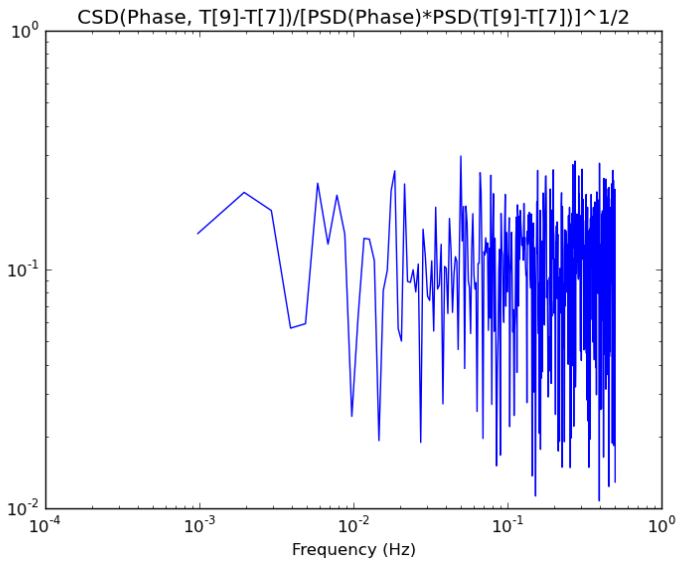
$$\delta\varphi \propto \delta L_1 - \delta L_2$$

First Attempt



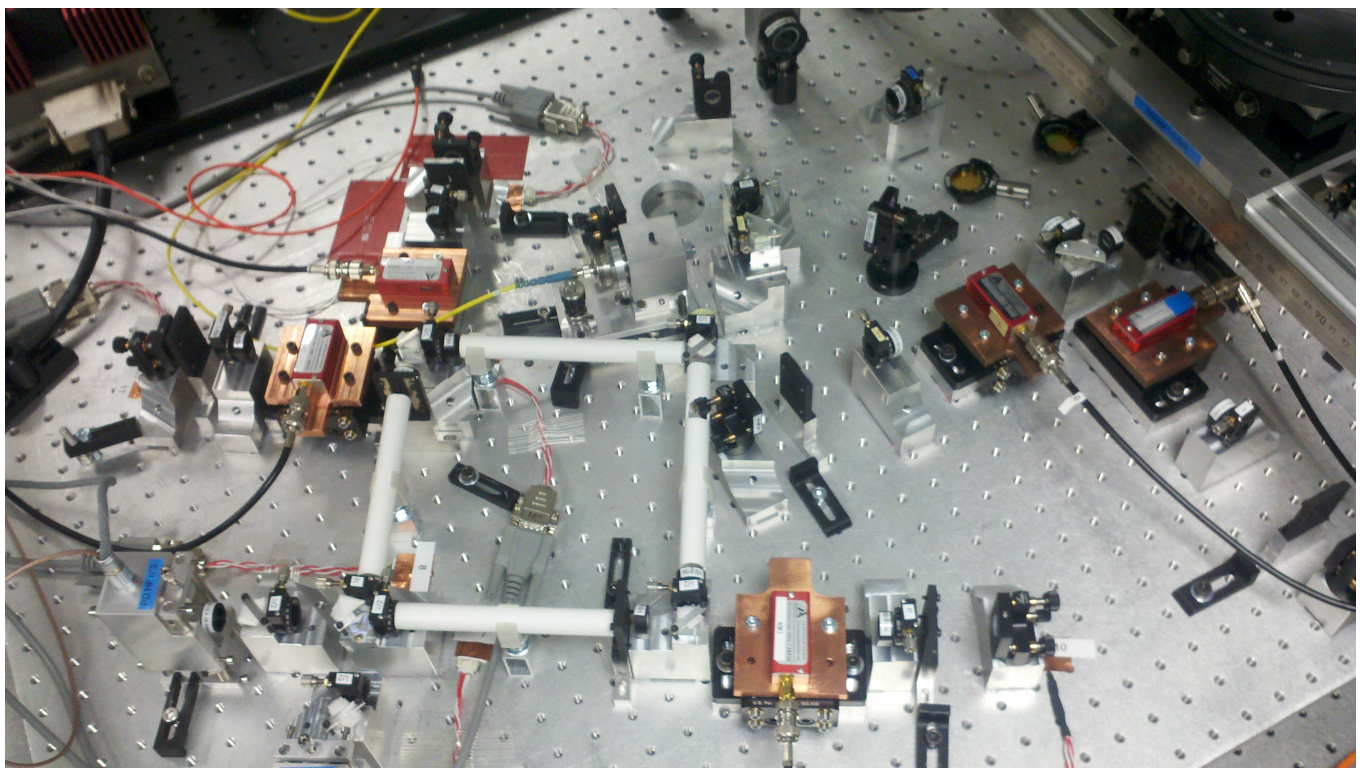




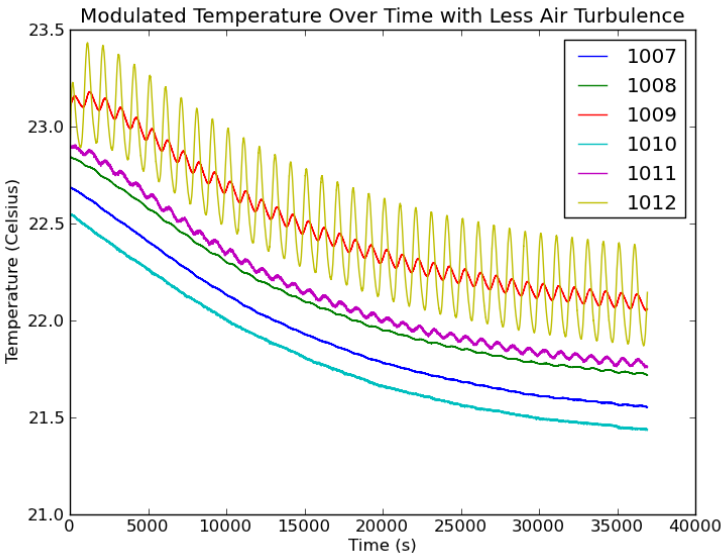

CSD(Phase, T[9]-T[7])/[PSD(Phase)*PSD(T[9]-T[7])]^1/2
10^{0}
10^{-1}
10^{-2}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
Frequency (Hz)

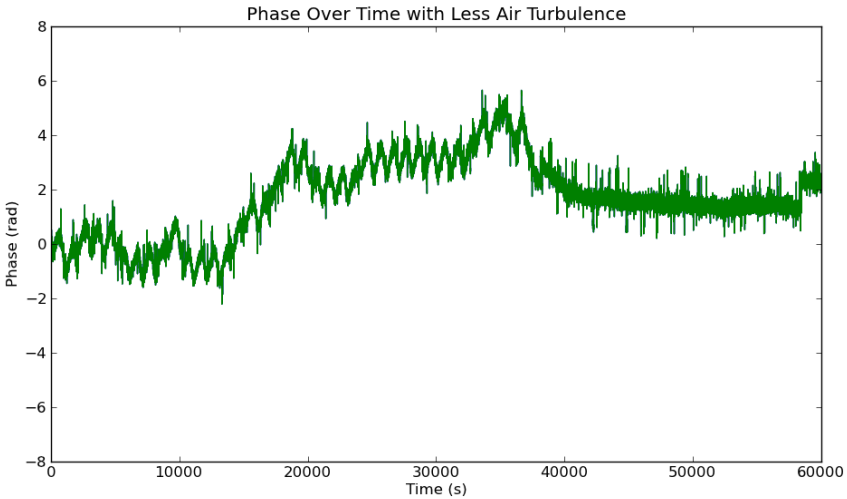
Lessen Air Turbulence and Modulate Temperature

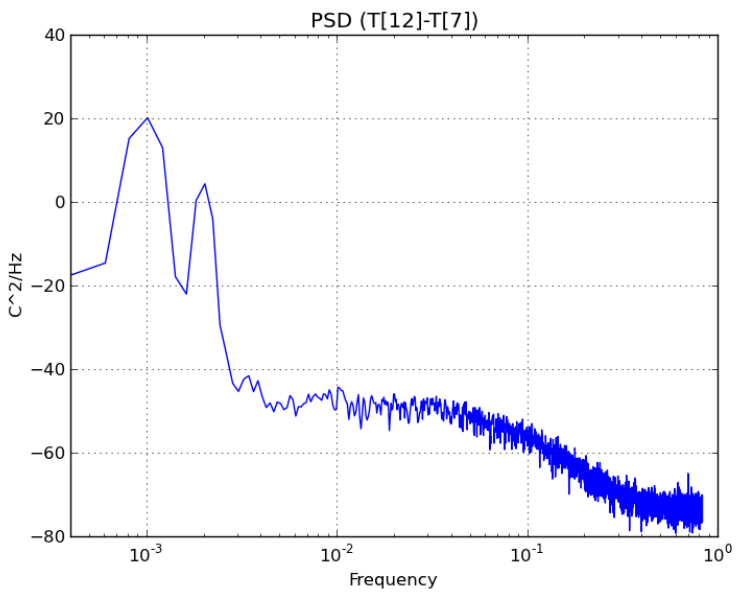
- Air turbulence is a large source of noise which may mask the temperature noise.
- It will be easier to find correlation if we can modulate the temperature and look for predetermined frequency of phase.

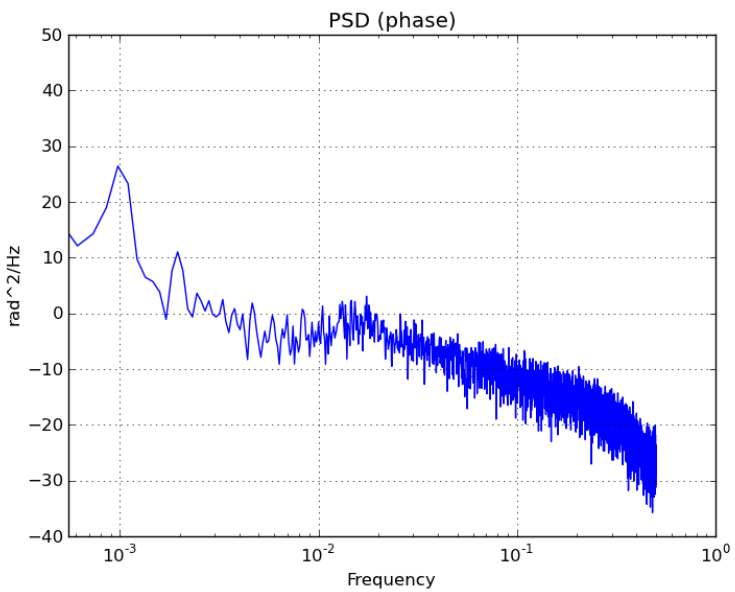


Results

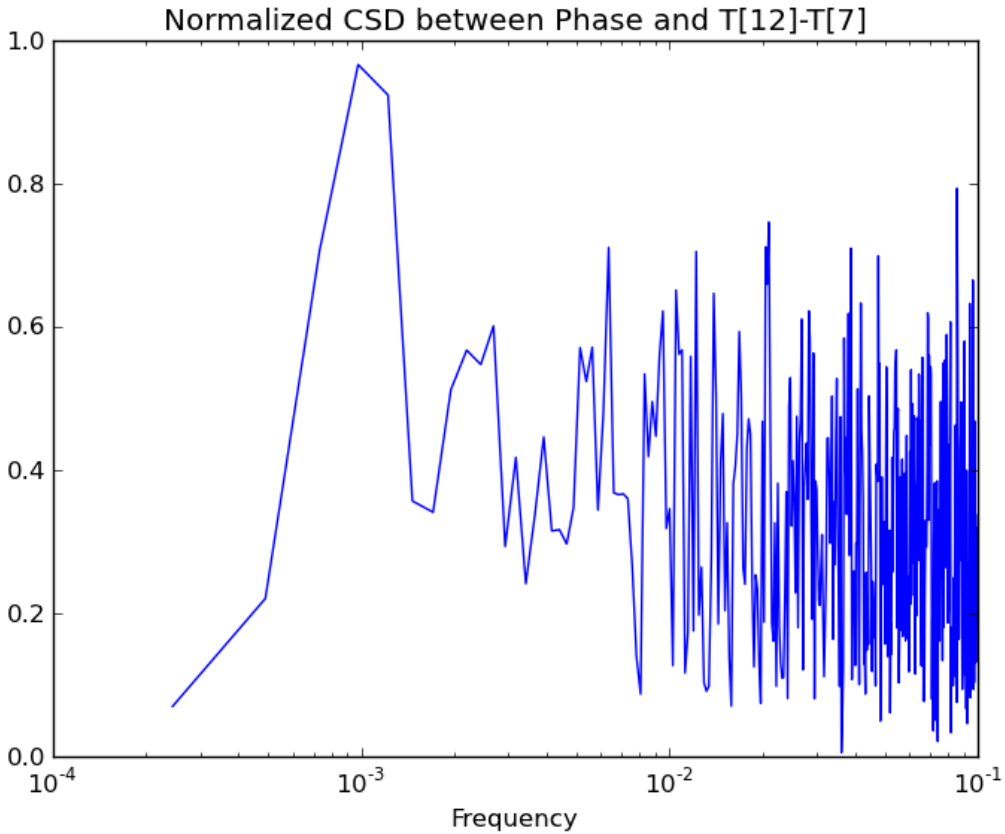

Modulated Temperature Over Time with Less Air Turbulence
Temperature (Celsius)
Time (s)
1007
1008
1009
1010
1011
1012


Phase Over Time with Less Air Turbulence
Phase (rad)
Time (s)


PSD (T[12]-T[7])
C^2/Hz
Frequency


PSD (phase)
rad^2/Hz
Frequency

Results



We have almost perfect correlation at the expected frequency.

Conclusion

This information is very valuable to the experiment. In particular, this creates a greater incentive to mount LOT on an invar plate as opposed to the current aluminum plate.

Future goals:

- Determine correlation relation - allowing us to know the required minimal temperature variation needed to achieve a threshold of phase noise.
- If invar cannot be purchased, find a way to account for the temperature variation in phase data.

Resources

1. Hubert Halloin et al., "Overview of the LISA Mission and R&D Developments at the APC", *SF2A 2009*.
2. Hubert Halloin et al., "LISA on Table: An Optical Simulator for LISA", *ICSO 2010*.
3. "Laser Interferometer Space Antenna", *http://en.wikipedia.org/wiki/Laser_Interferometer_Space_Antenna"*.