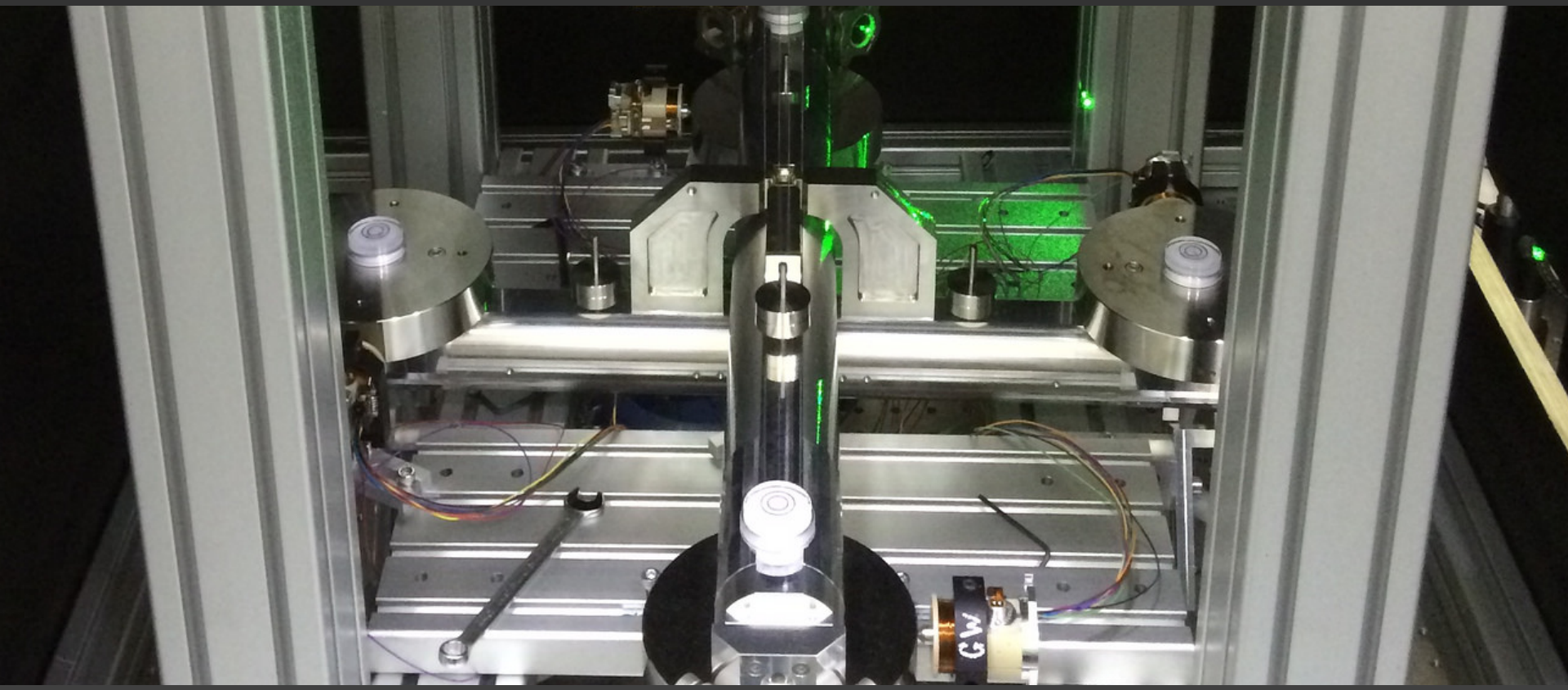
Australian National University



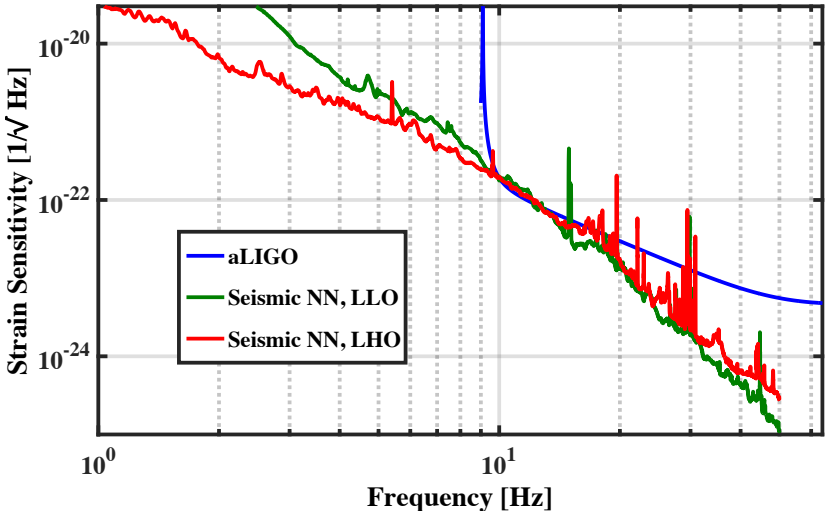
TorPeDO - An Oscillator for Newtonian Noise Sensing and Other Applications

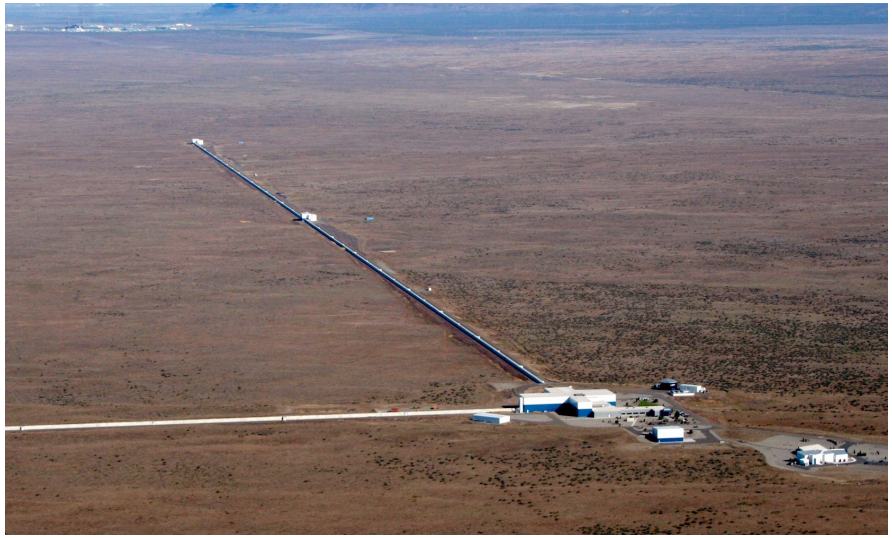
David McManus , Perry Forsyth, Jenne Driggers,
Robert Ward, Bram Slagmolen, Daniel Shaddock, David McClelland

LIGO-G1601503

Newtonian Noise at LIGO

- Newtonian noise at LIGO is caused by local gravity fluctuations coupling into the test masses
- In the near future LIGO may be limited by seismic Newtonian noise in the vicinity of 10Hz
- The **TorPeDO** and the **LHO NN Array** are two different Newtonian noise investigations

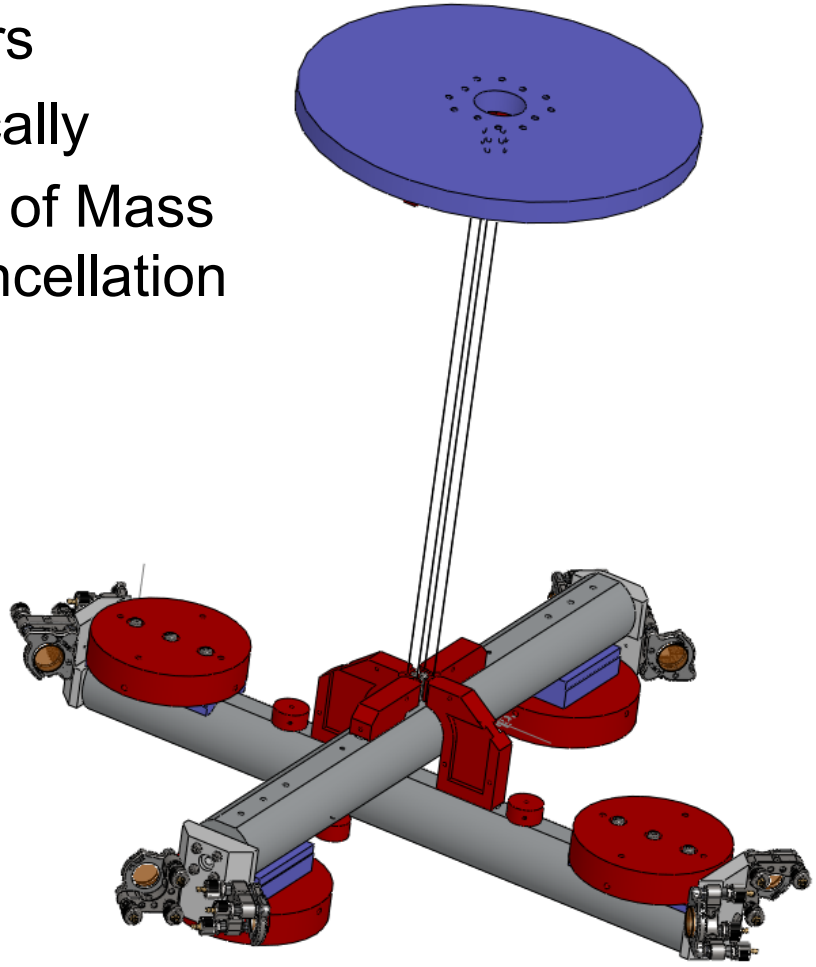




TorPeDO: Torsion Pendulum Dual Oscillator

Based on the TOBA (M.Ando, et al. 2010)

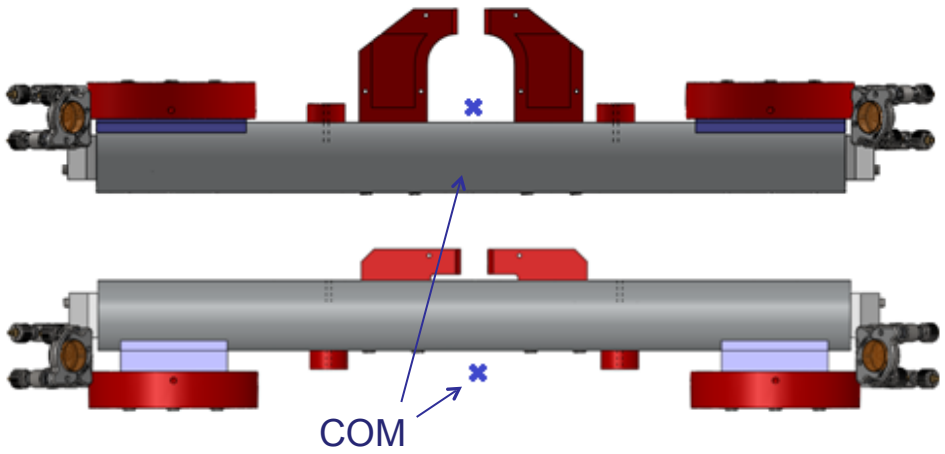
- Changes in gravitational force cause a differential rotation between the bars
- Differential angle is measured optically
- Resonant frequencies and Centres of Mass are matched for common mode cancellation

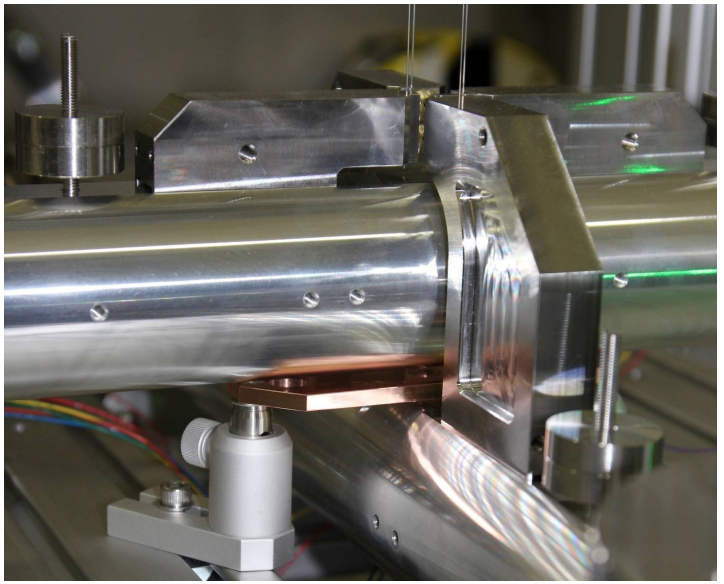


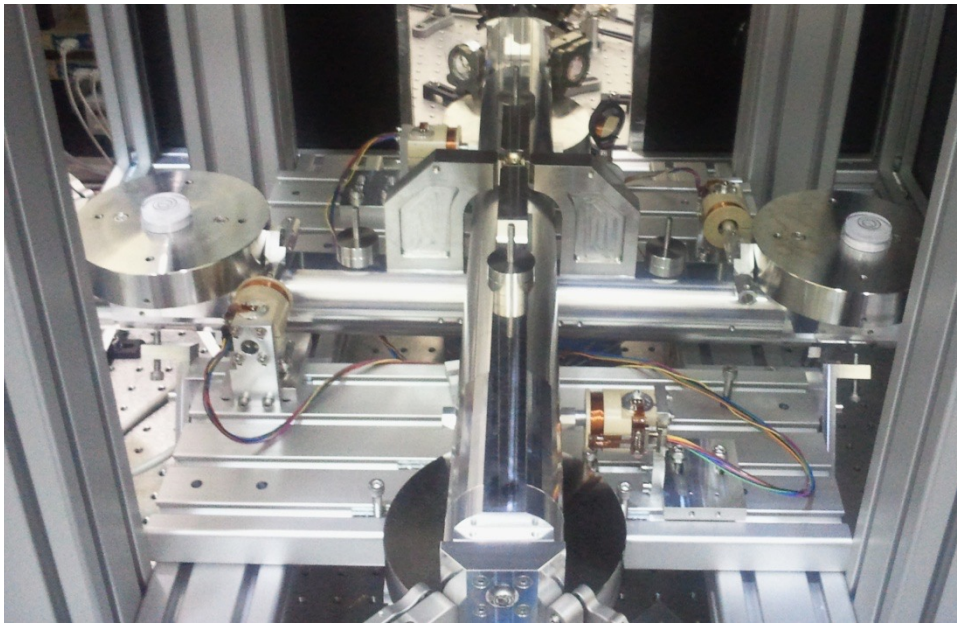
Future experiments?

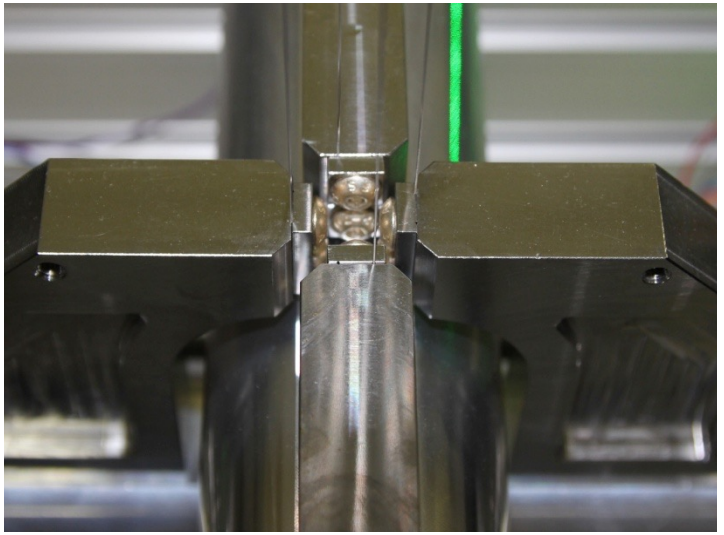
- Measuring Newtonian noise
- Early earthquake detection
- Measuring Quantum Radiation Pressure Noise
- Testing semi-classical gravity
- Measurements of big G
- Thermal noise tests

Stage 1: Controls Prototype

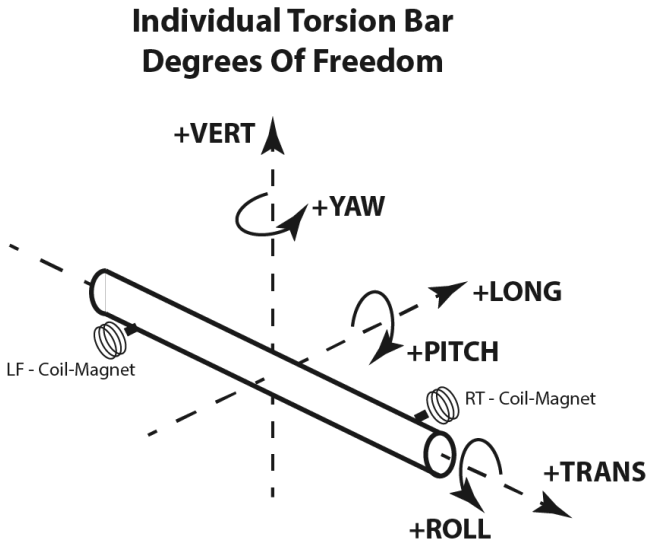


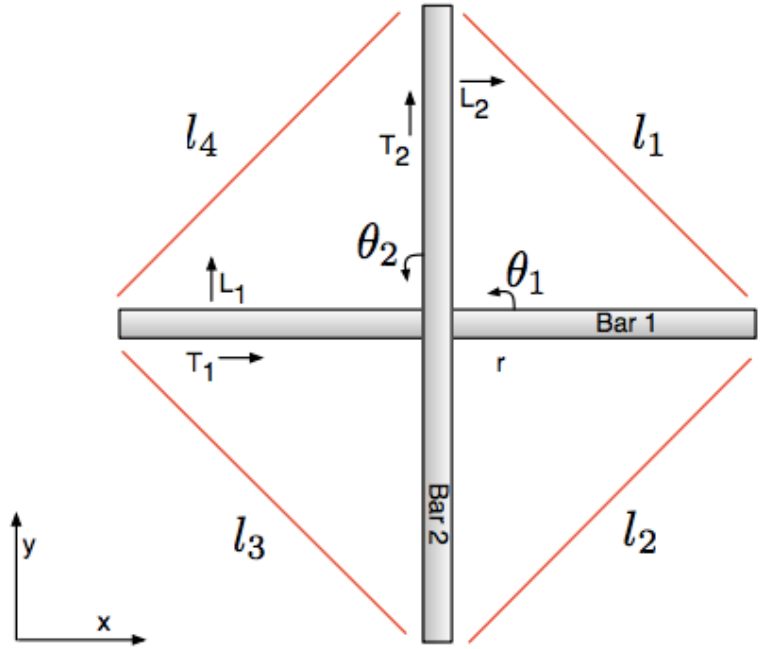


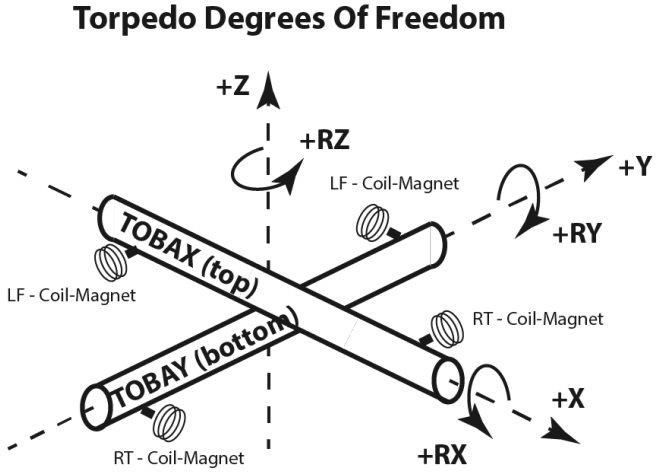




Degrees of freedom







$$\delta l_1 = 2r\theta_- + \frac{1}{\sqrt{2}}Y_- + \frac{1}{\sqrt{2}}X_-$$

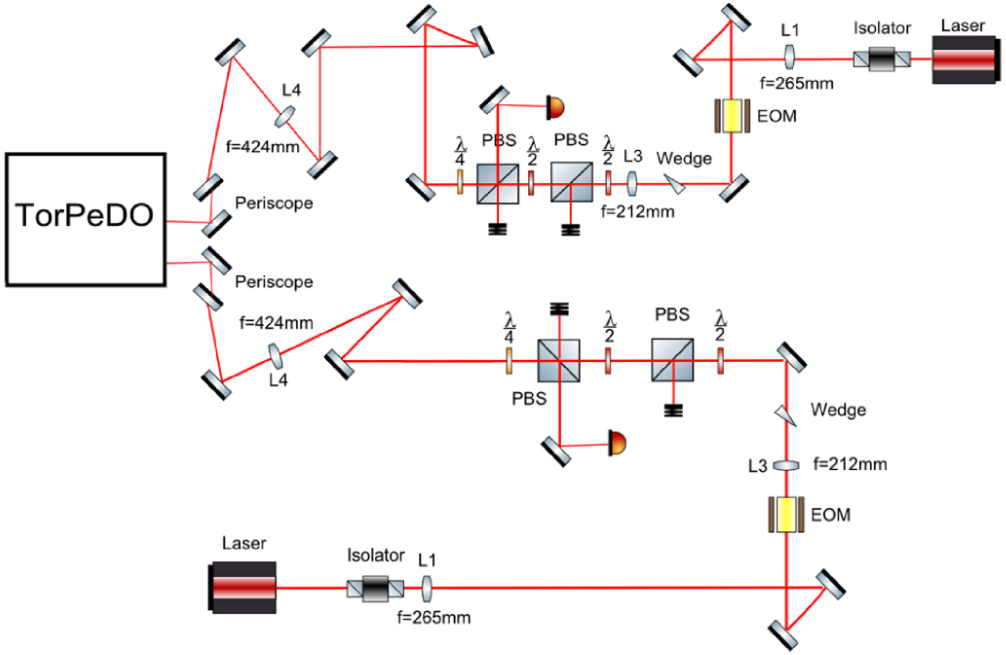
$$\delta l_2 = -2r\theta_- - \frac{1}{\sqrt{2}}Y_- + \frac{1}{\sqrt{2}}X_-$$

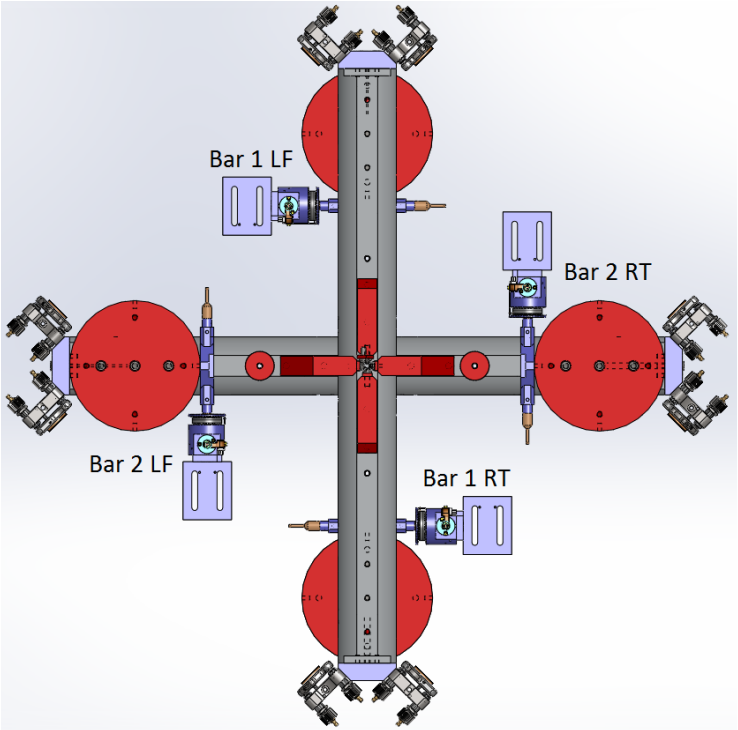
$$\delta l_3 = 2r\theta_- - \frac{1}{\sqrt{2}}Y_- - \frac{1}{\sqrt{2}}X_-$$

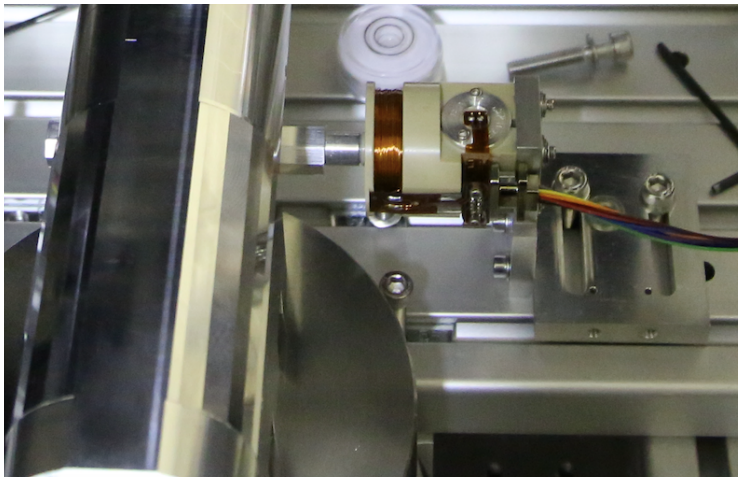
$$\delta l_4 = -2r\theta_- + \frac{1}{\sqrt{2}}Y_- - \frac{1}{\sqrt{2}}X_-$$

Actuation & Control

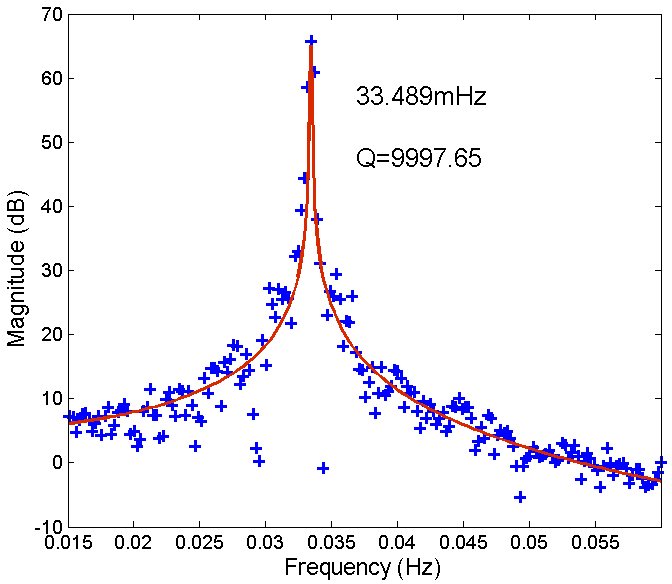
- Four BOSEMS mounted to rigid frame
- Magnets/Flags mounted to bars
- Cavity mirrors at ends of each bar.
- Four cavities total



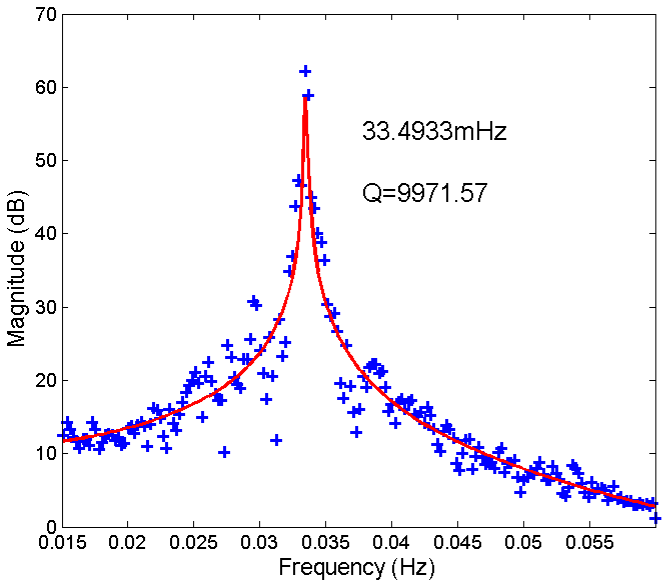




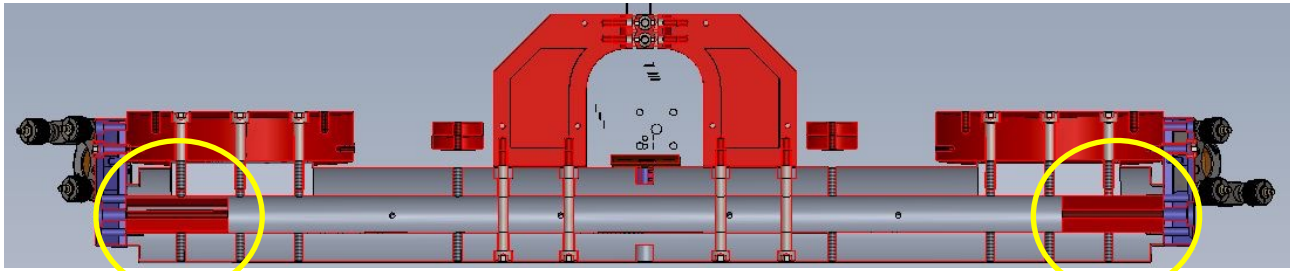
Tuned Torsion Mode Measurement



Bar 1

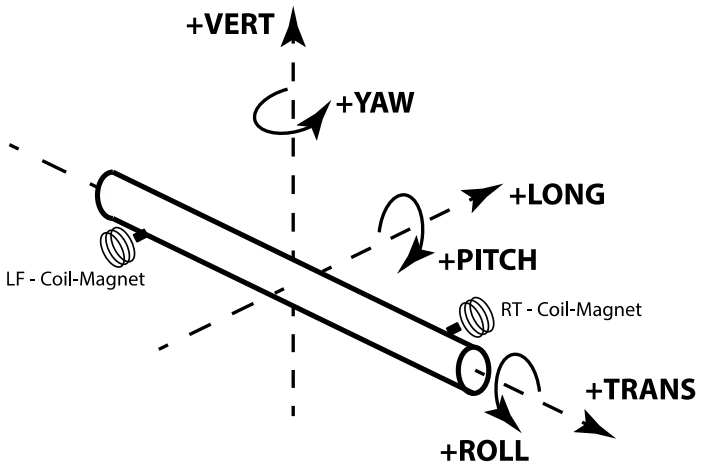


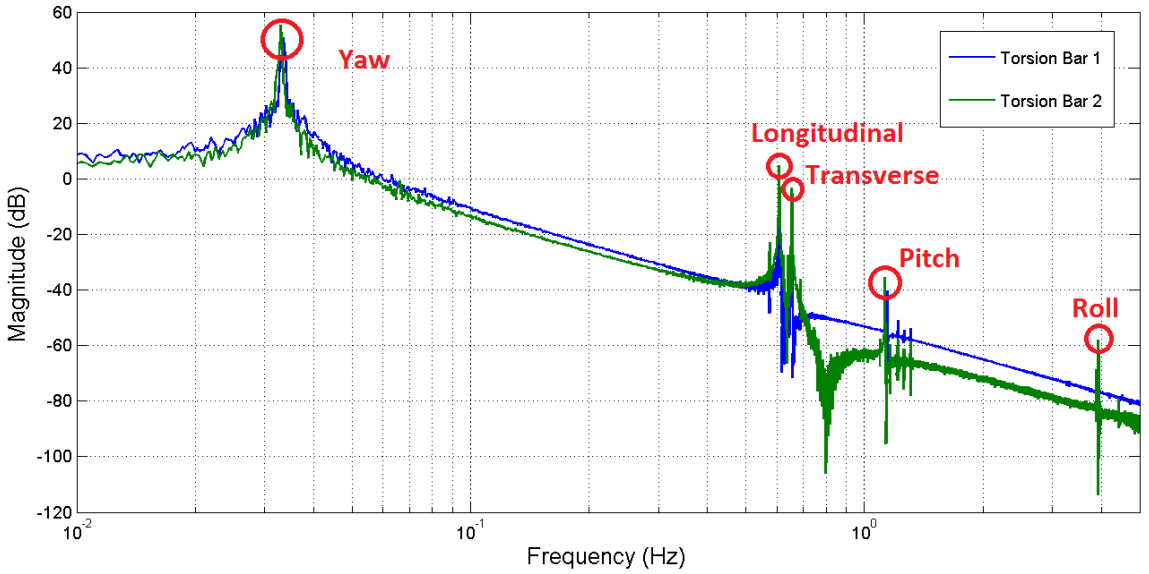
Bar 2



Modes Summary

Mode	Bar 1	Bar 2	Δf	Δf/f
Yaw	33.4933 mHz	33.489 mHz	4.3 μHz	0.0001284
Longitudinal	0.6072 Hz	0.6077 Hz	0.53 mHz	0.0008725
Transverse	0.65465 Hz	0.653 Hz	1.6 mHz	0.0024
Pitch	1.16286 Hz	1.14326 Hz	0.0196 Hz	0.0170
Roll	4.334 Hz	3.853 Hz	0.481 Hz	0.117



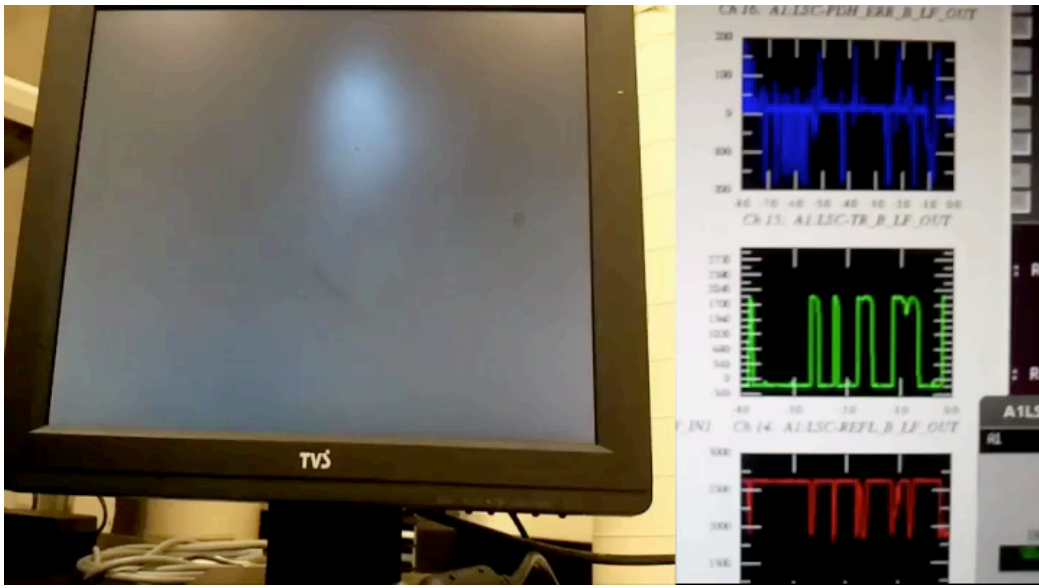


Cavity Locking

Laser is locked to cavity a high frequency, cavity is locked to laser at low frequency.

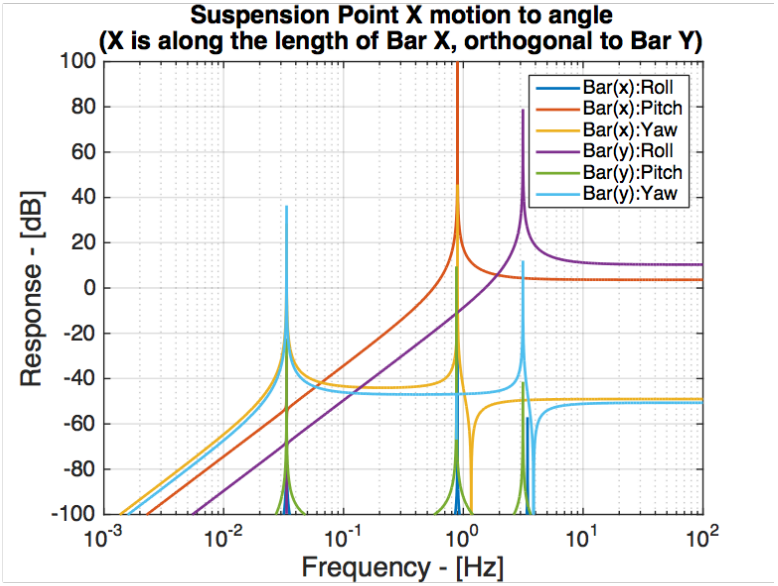
- Bar 1 uses ‘pendulum mode’ feedback
- Bar 2 uses ‘torsion mode’ feedback
- Drift makes it hard to keep both cavities locked simultaneously
- Third cavity has been aligned

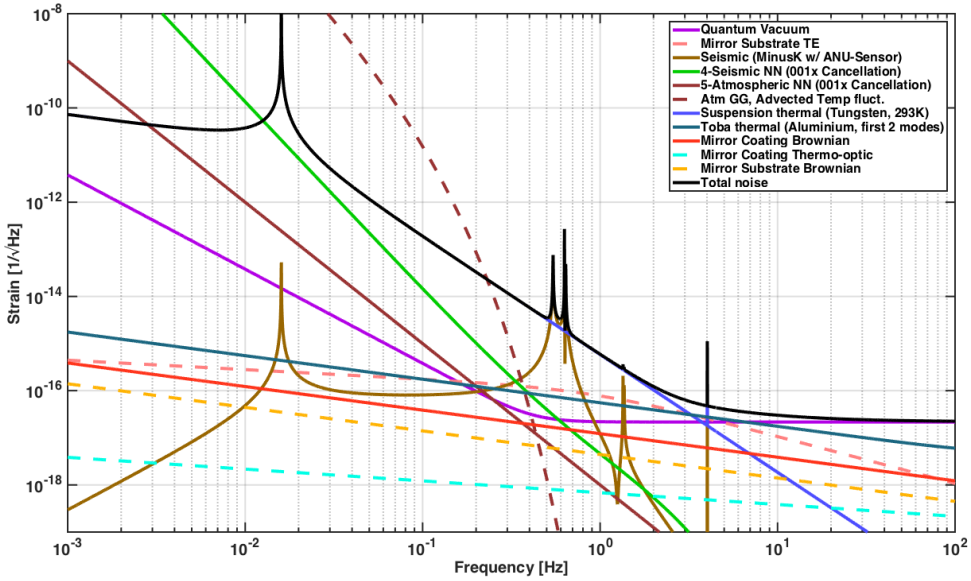
Video



Cross Coupling & Sensitivity

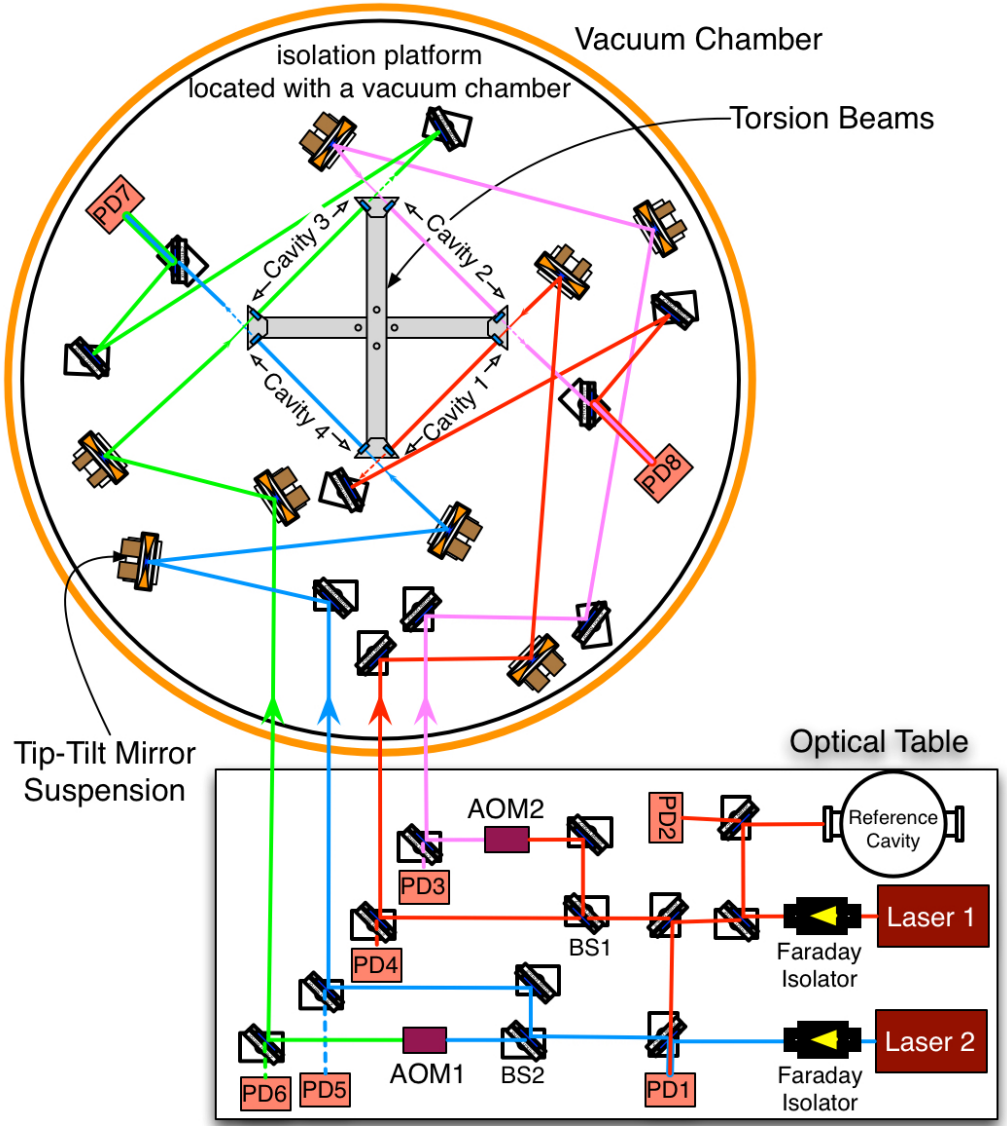
- Mismatch between centre of mass and wire attachment point leads to cross-coupling.
- The larger this offset is, the more seismic isolation is required





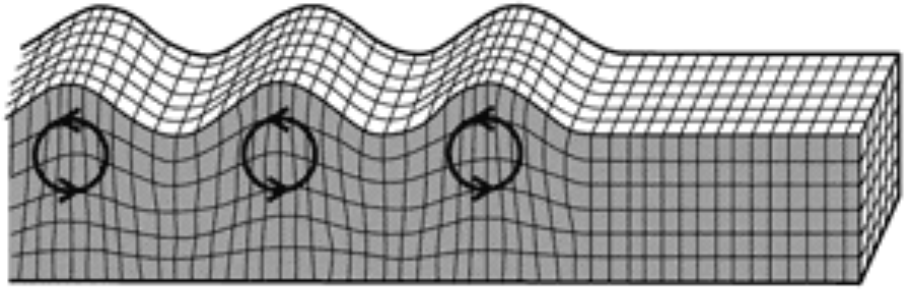
Future Plans

- Move the experiment inside vacuum, and make improvements to the suspension
- Obtain optical read-out with 4 cavities
- Create future models with improvements from the prototype



Sensor Arrays

- An array of Seismometers allows us to characterise the seismic field - the source of seismic NN



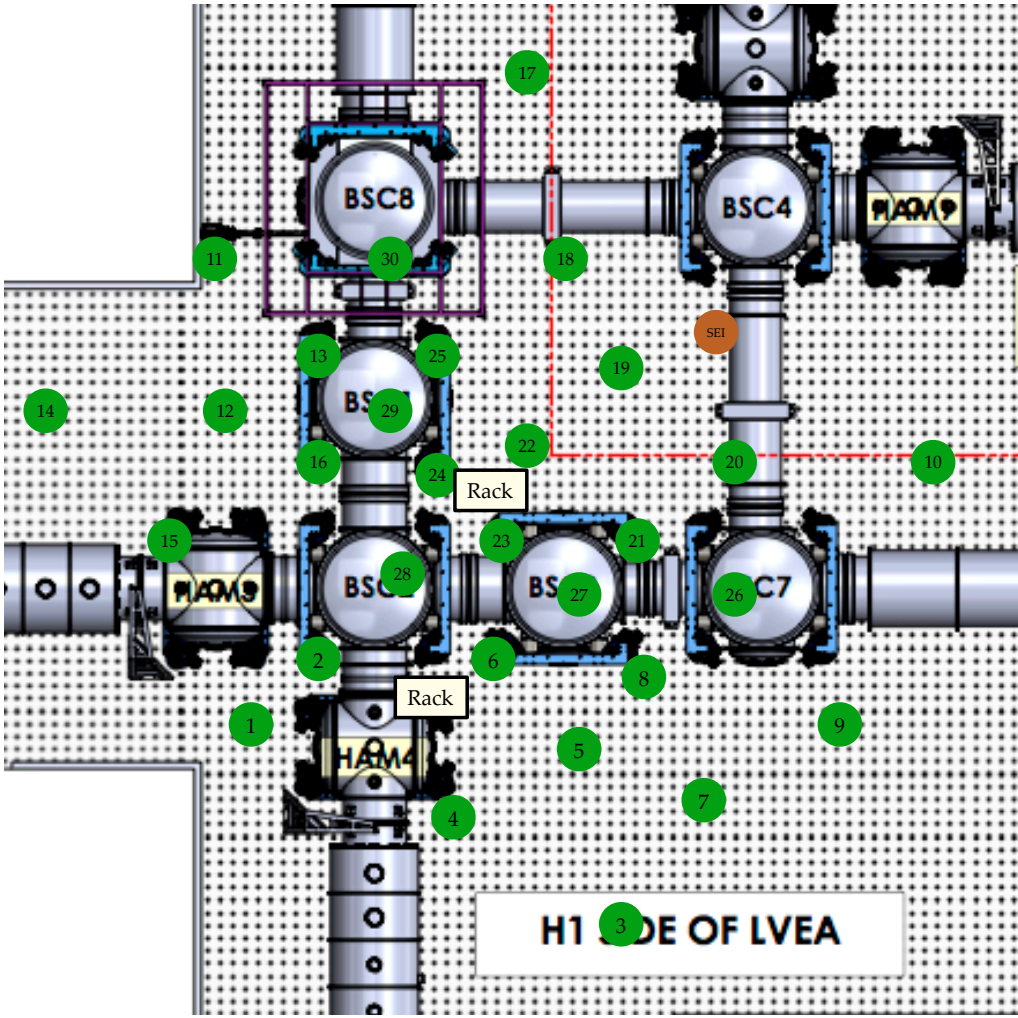
- Accurate modelling of this field gives us an estimate of the Newtonian noise influence on the test masses

- Feed Forward cancellation using Wiener Filters allows for cancellation of a coherent Newtonian noise estimate from our measurements

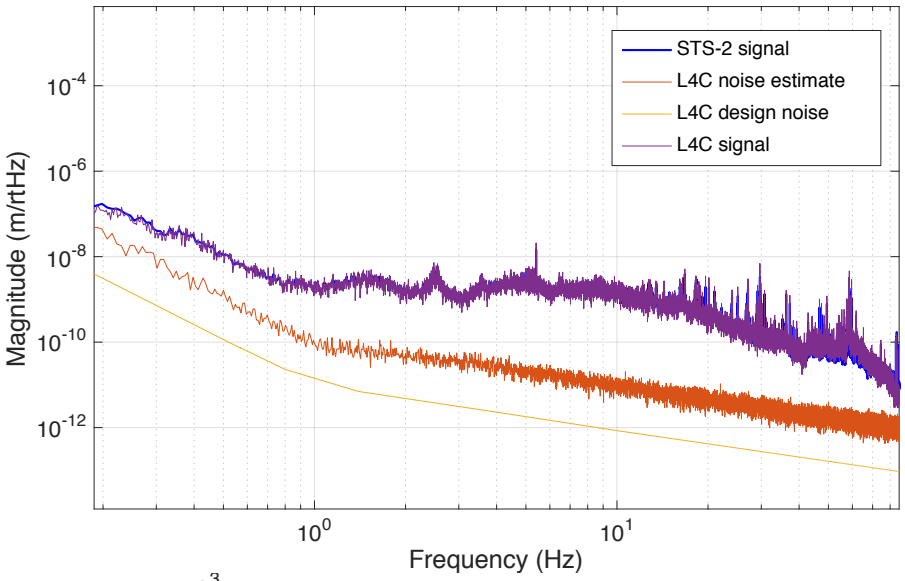
L4C Test Array at LHO

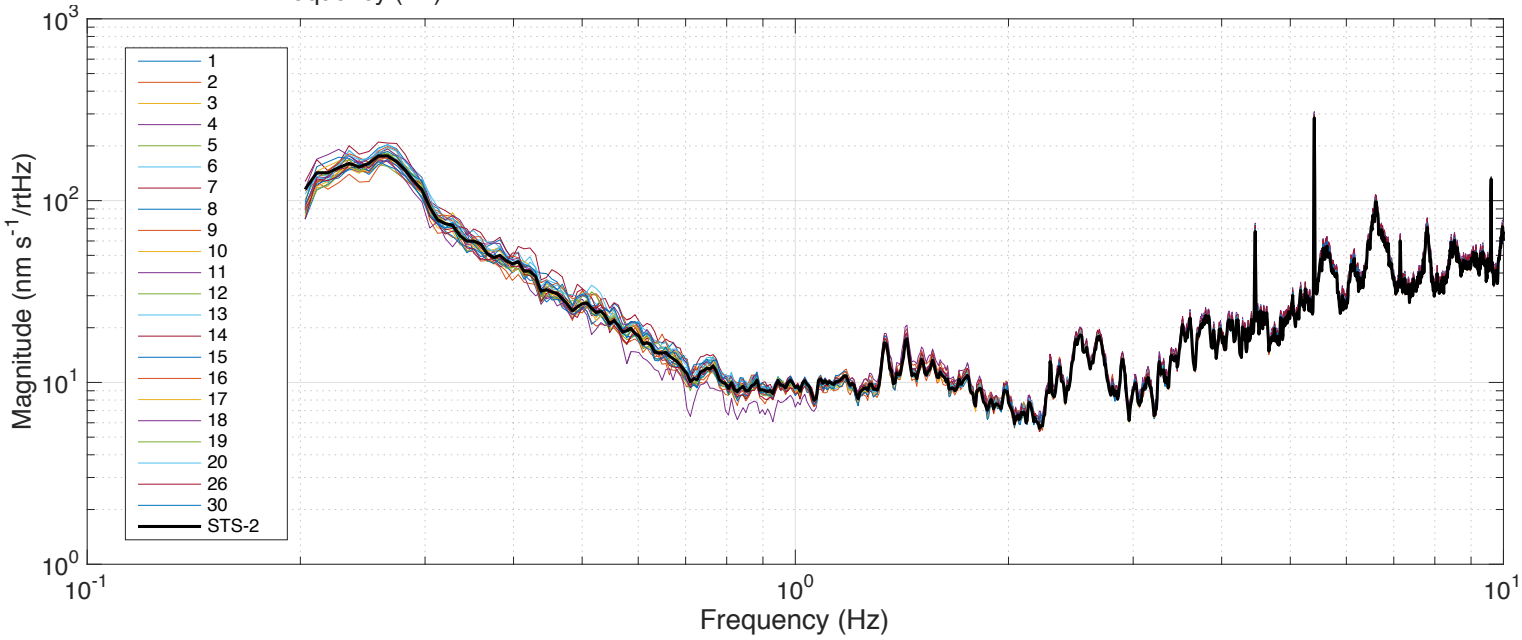
An array of 30 L4Cs positioned in the corner station at LHO.

We want to learn about the seismic field around the test masses so that the final NN array sensors can be positioned optimally



First Huddle Measurements





Thanks For Listening

References

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Other Modes

Measurement of other modes with torsional mode damped and filtered out of the excitation