
Scattering Noise Studies at LLO via Injection Techniques

Stephen Trembath-Reichert

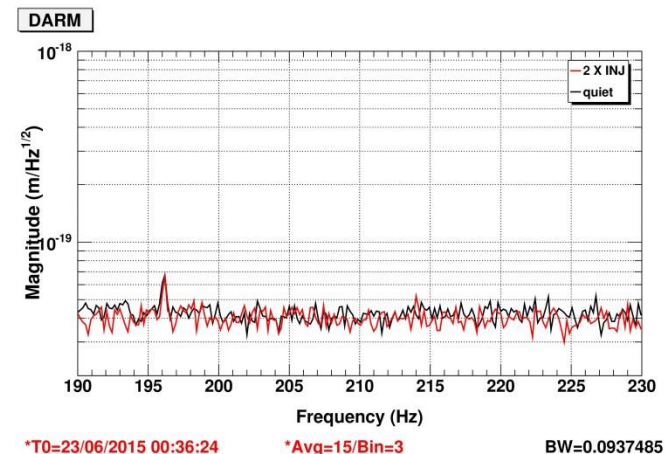
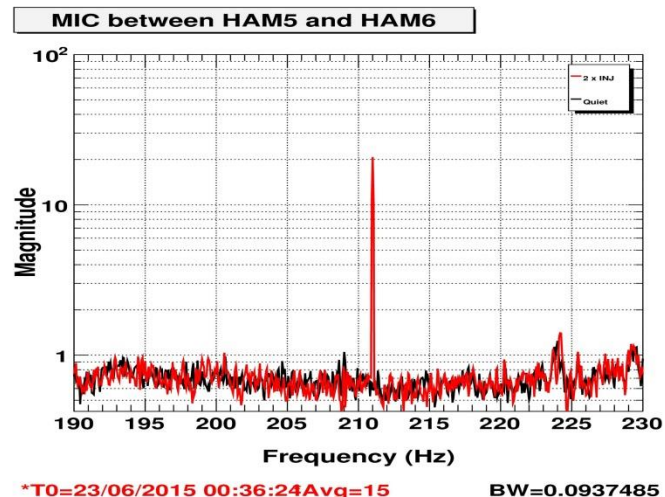
Mentors: Anamaria Effler, Valery Frolov

Overview

- Injection techniques
- Specific injections
 - » Acoustic injections
 - » Direct HAM6 ISI table injections
- Proposed noise creation mechanism
 - » Supporting evidence
- Noise Budget Plots
- What next?

What are “injections”?

- Introduce known disturbance/noise
- Examples:
 - » Acoustic (Speaker)
 - » Mechanical (PE Shaker)
 - » Electrical/Magnetic (Coil)
- How is this useful?
 - » Quantify noise coupling and ambient contribution
 - Linear/non-linear
 - » Show mechanism path



HAM6 Chamber

Advanced LIGO
Optical Layout, L1 or H1
with Seismic Isolation and Suspensions
G1200071-v3
J. Kissel Nov 4 2013

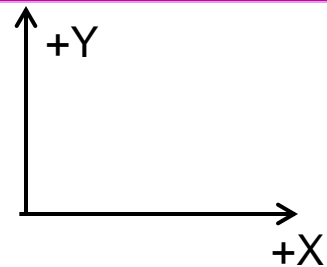
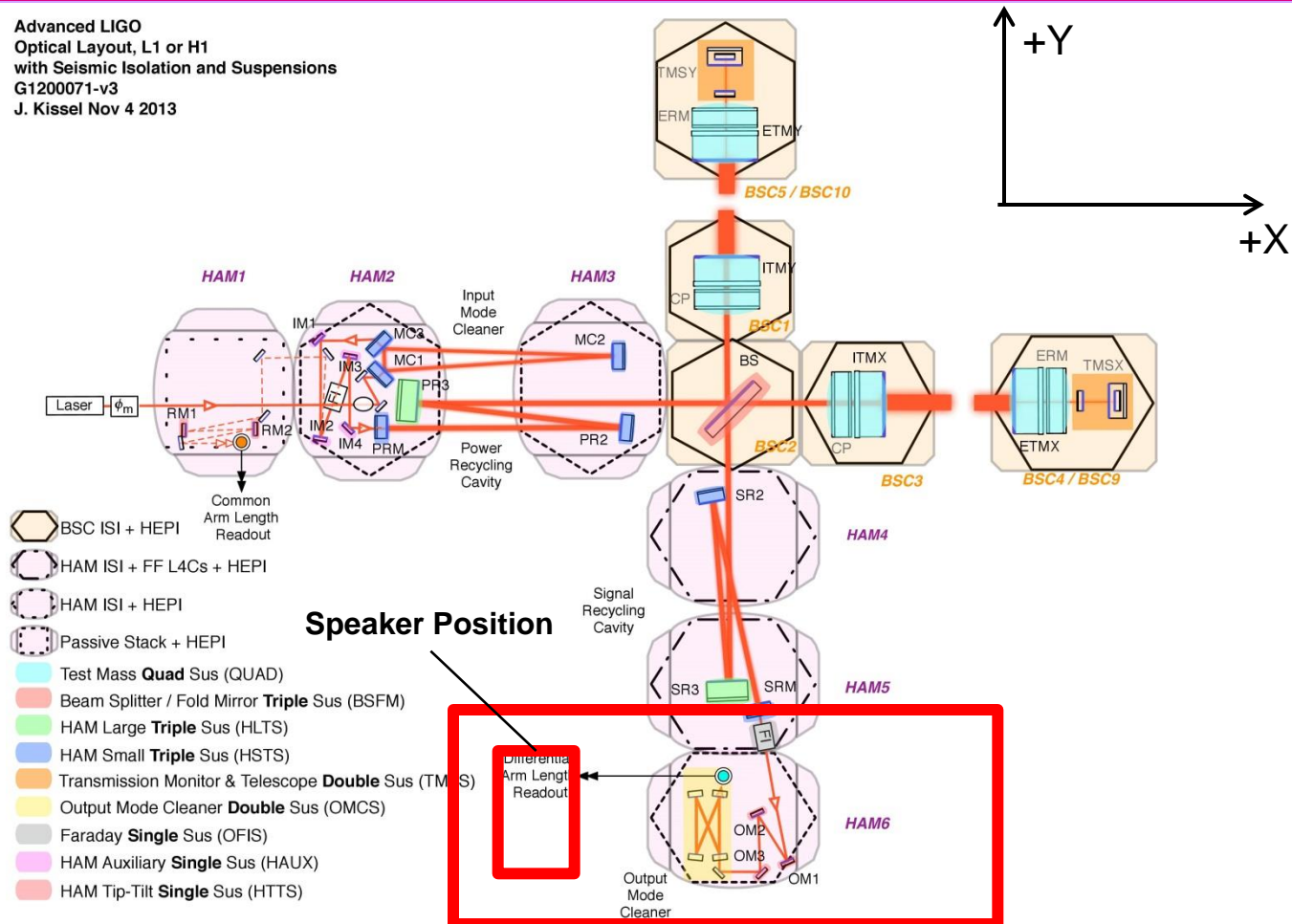
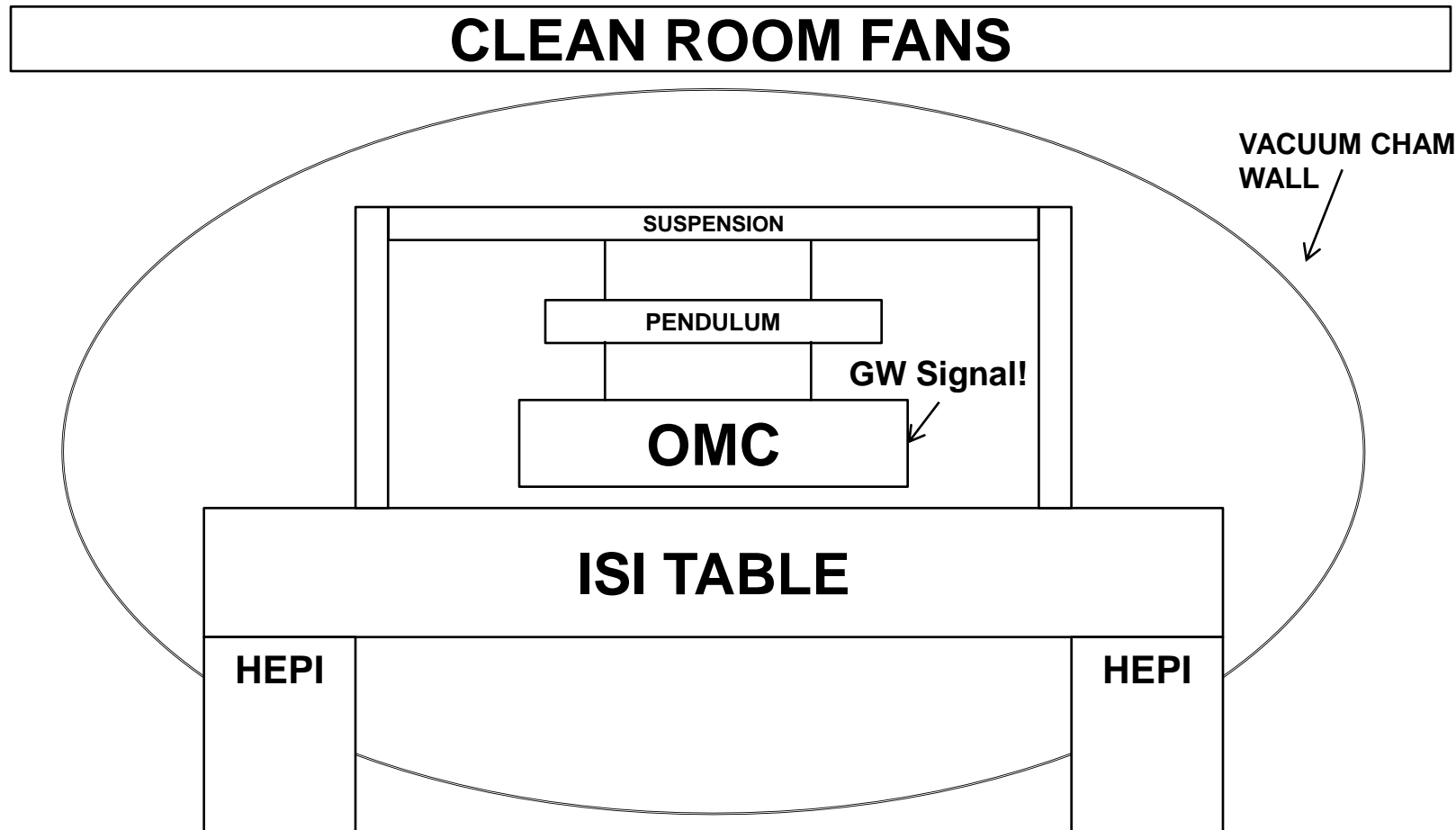


Image of HAM6



HAM6 Suspensions

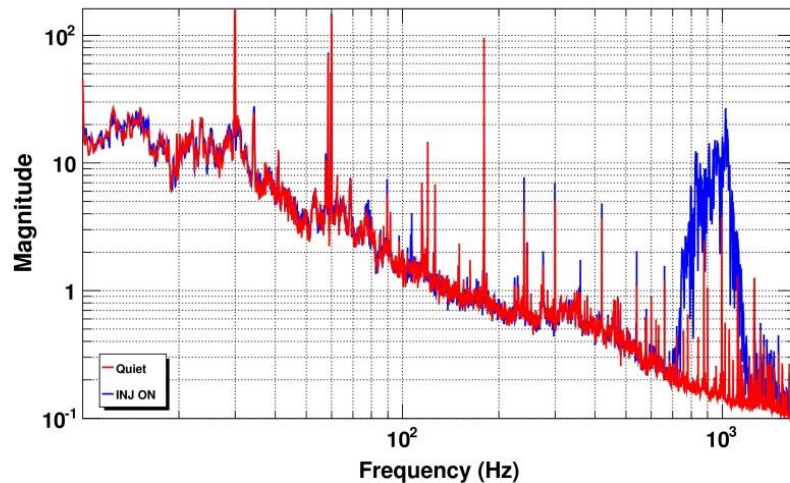


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HF Acoustic Injections

- Done using a large speaker pointing at the -X wall of HAM6

MIC between HAM5 and HAM6

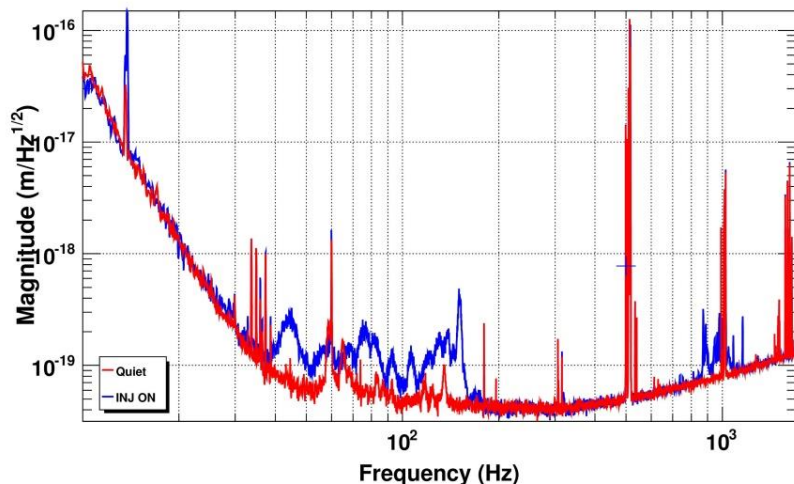


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*Avg=1/Bin=3L

BW=0.0937485

DARM

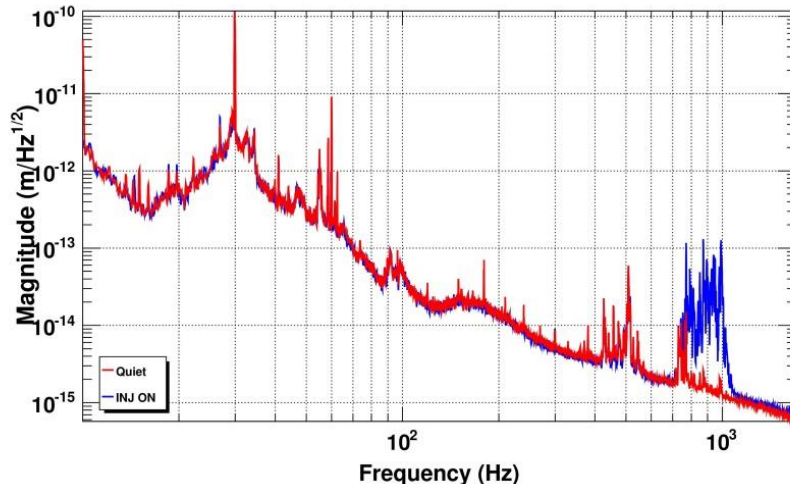


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HAM6 ISI X



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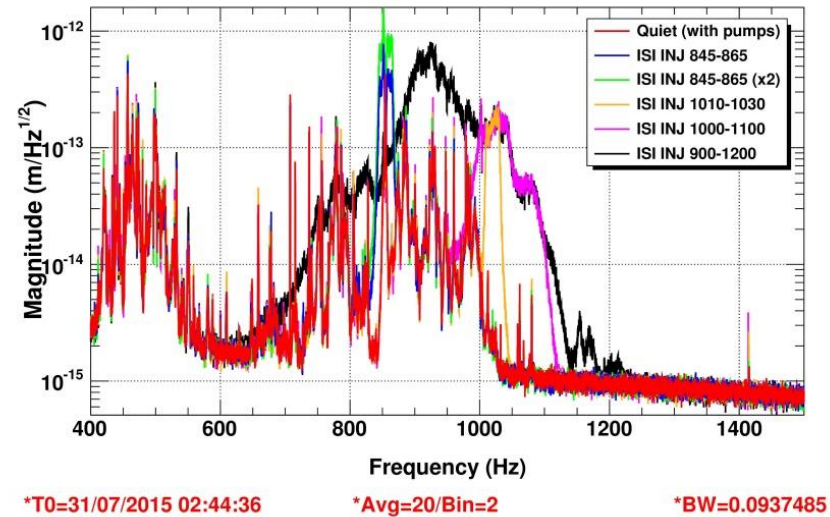
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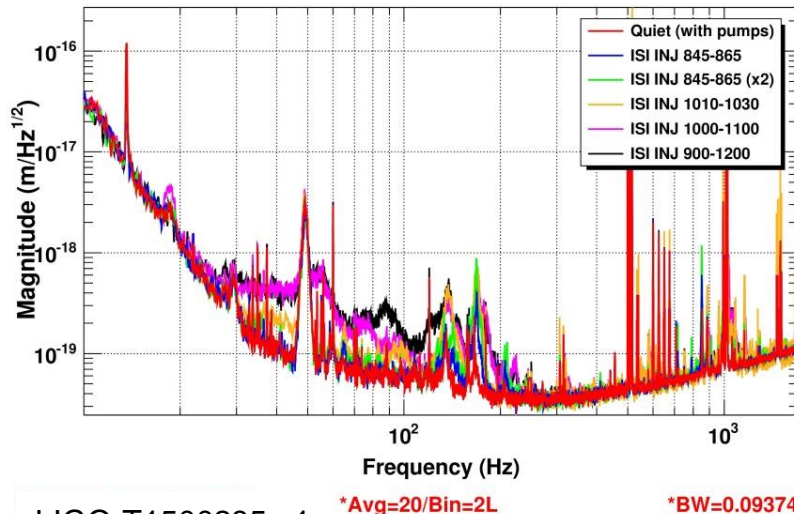
Direct ISI Table Injections

- Direct injections to the ISI table in HAM6
- Many injections over various bands to try to identify the noise causing mechanism
- 1020Hz peak is the 17th harmonic of the omnipresent 60Hz peak
- Model proposed by Denis Martynov

ISI (GS13) Y

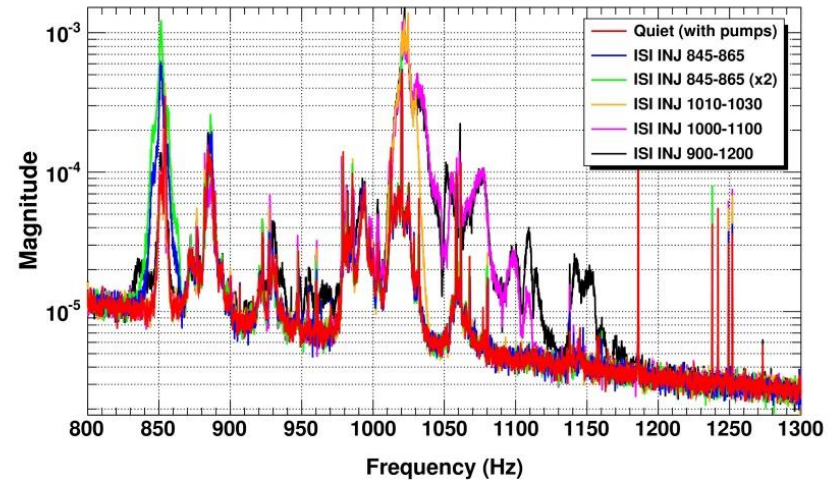


DARM

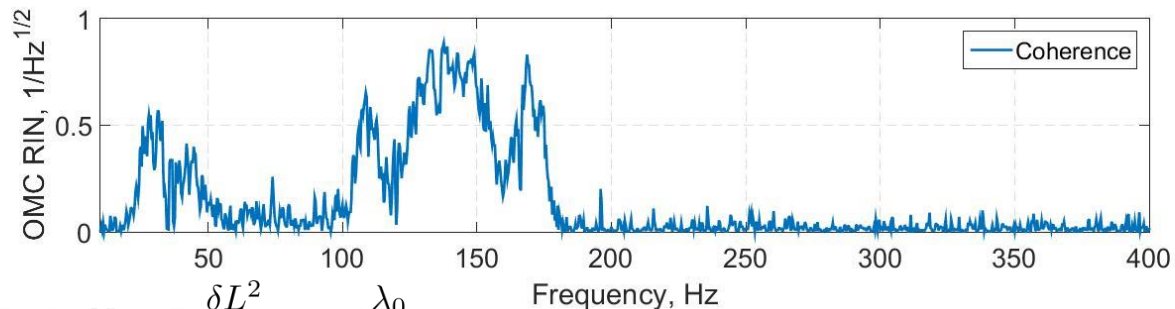
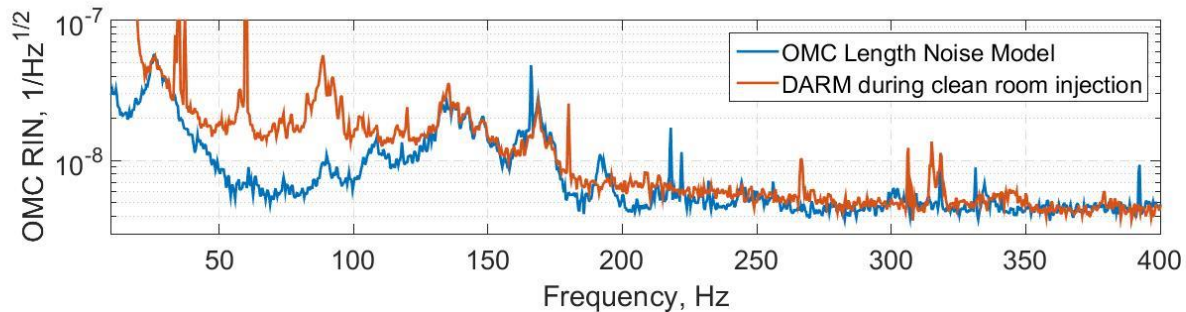


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OMC LSC SERVO OUT



OMC Down-conversion Model



$$P_{tr}RIN = P_0 \frac{\delta L^2}{a^2}, a = 4 \frac{\lambda_0}{\mathcal{F}}$$

$$\delta L = A \cos(\omega_1 t) + B \cos(\omega_2 t) \propto E_t$$

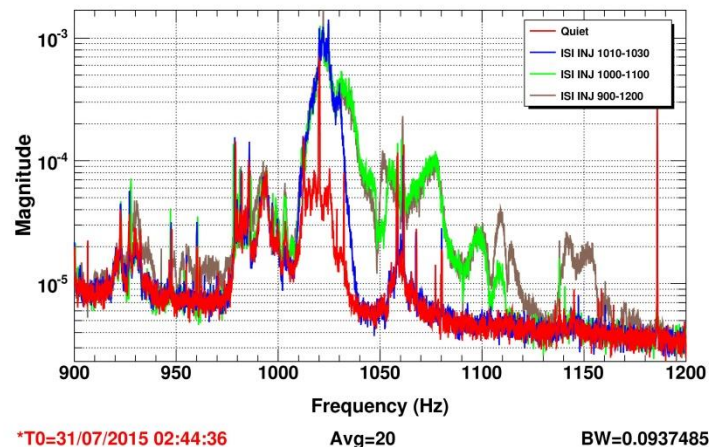
$$P_{det} = |E_t|^2 \propto \delta L^2 = A^2 \cos^2(\omega_1 t) + B^2 \cos^2(\omega_2 t) + 2AB \cos(\omega_1 t) \cos(\omega_2 t)$$

$$= \frac{1}{2} (A^2 + B^2 + A^2 \cos(2\omega_1 t) + B^2 \cos(2\omega_2 t) + 2AB \cos((\omega_1 - \omega_2)t) + 2AB \cos((\omega_1 + \omega_2)t))$$

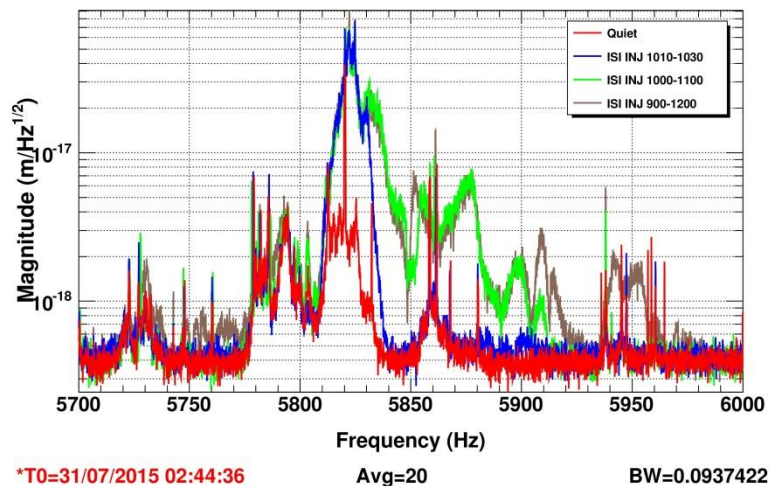
Down/Up-conversion from 4800Hz in DARM

- Evidence of down/up conversion due to beating with an expected peak in DARM
- 4800Hz is the modulation/demodulation frequency used in controlling the OMC cavity

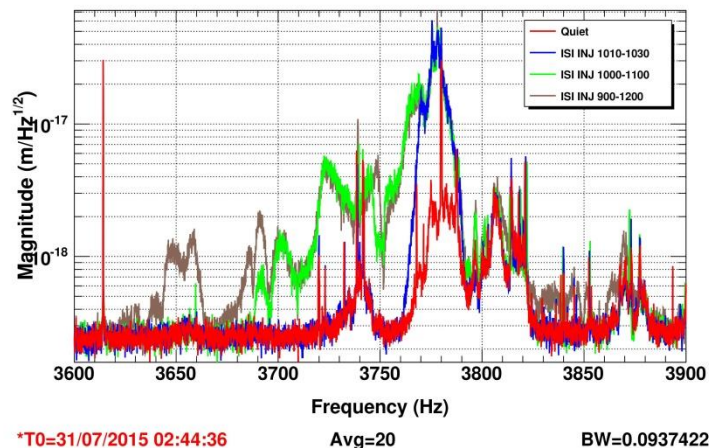
OMC LSC OUT



DARM below 4800Hz

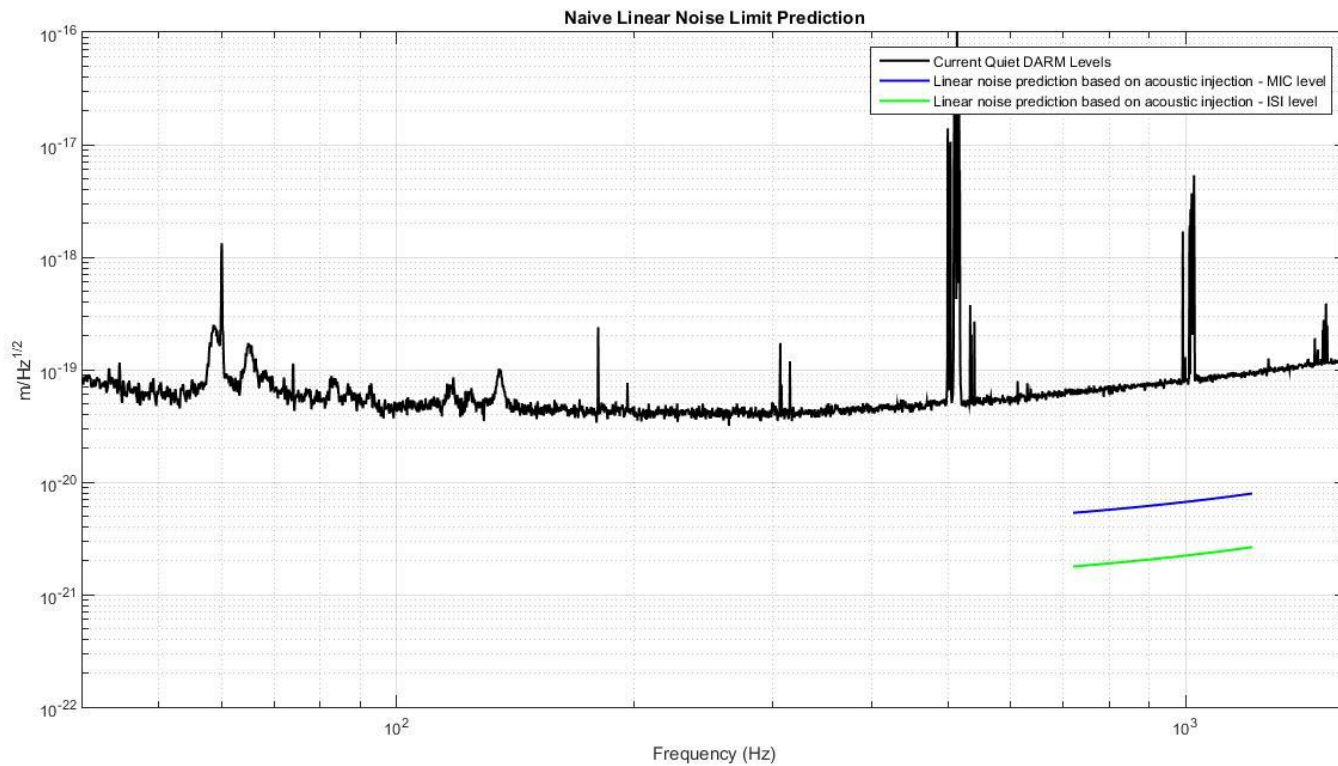


DARM above 4800Hz



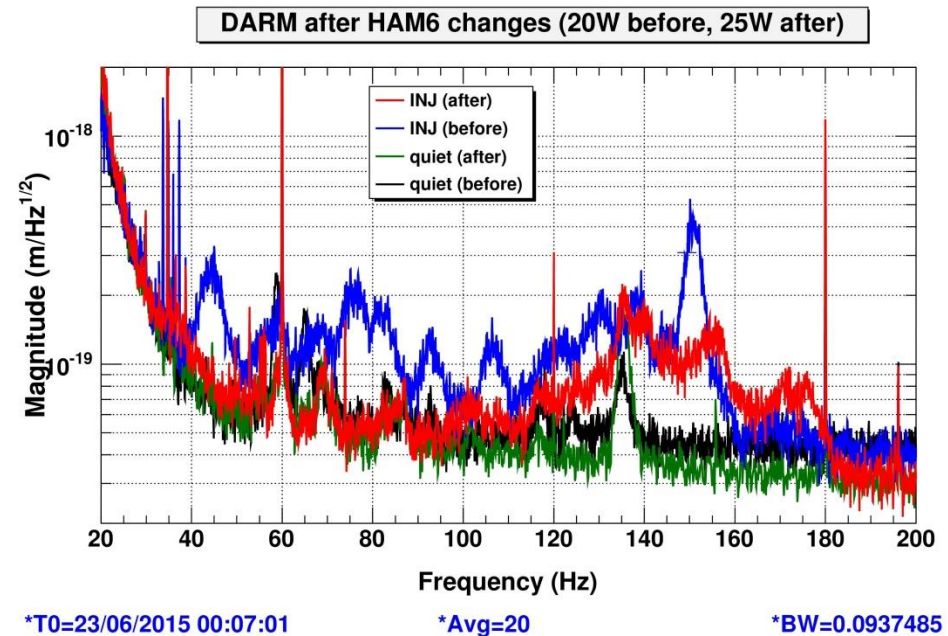
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Linear Noise Budget Plot



What next?

- How does ISI table noise get to the OMC?
 - » Double pendulum isolation = HF isolation!
 - » Scattering?
- Investigate other peaks shown in ISI during clean room injections
- Investigate other LF noise excited by injections not adequately explained by the aforementioned mechanism



References

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- Schofield, Robert. 'High Acoustic Coupling Likely Due To HAM6 ISI Blade Spring And Suspension Wire Resonances; Wire Damping Demonstrated'. *aLIGO LHO Logbook* 2015. Web. 2 July 2015.
- Schofield, Robert. 'Shaking Study Suggests Beam-Tube Baffle Scattering Noise Will Be Borderline Near 14 Hz, Below Noise Floor Elsewhere'. *aLIGO LLO Logbook* 2015. Web. 7 July 2015.
- Smith, Joshua. 'Tracking Down 1020Hz Line'. *aLIGO LLO Logbook* 2015. Web. 1 Aug. 2015.

Further Works

- Further scattering/noise studies conducted during this project can be found in the aLIGO LLO Logbook (alog.ligo-la.caltech.edu) under the following log numbers:
 - » 19450
 - » 19419
 - » 19315
 - » 19077
 - » 18825

Acknowledgements

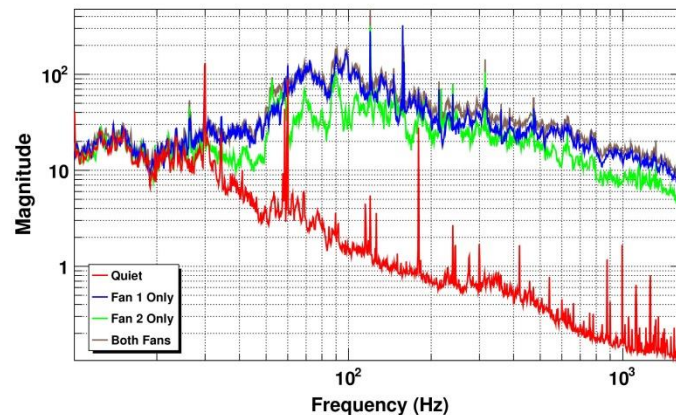
I'd like to thank:

- My mentors, Anamaria and Valera
- LLO staff
- LIGO SURF Program
- My fellow SURF/chauffer, John
- The National Science Foundation

Clean Room Fan Injections

- Both acoustic and mechanical injections to the entire chamber

MIC between HAM5 and HAM6

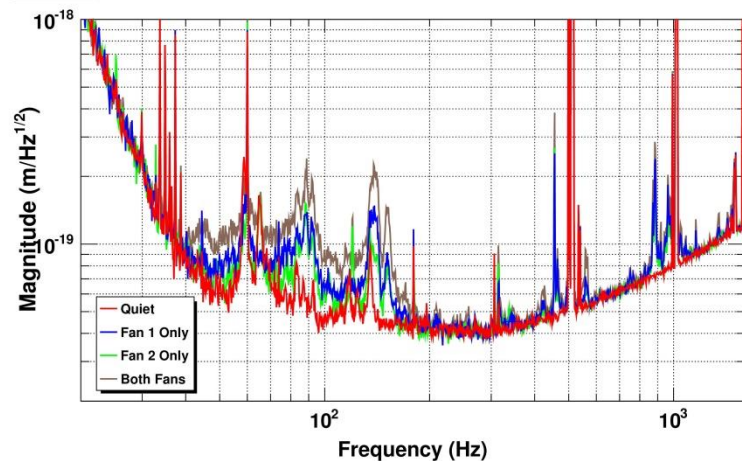


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DARM

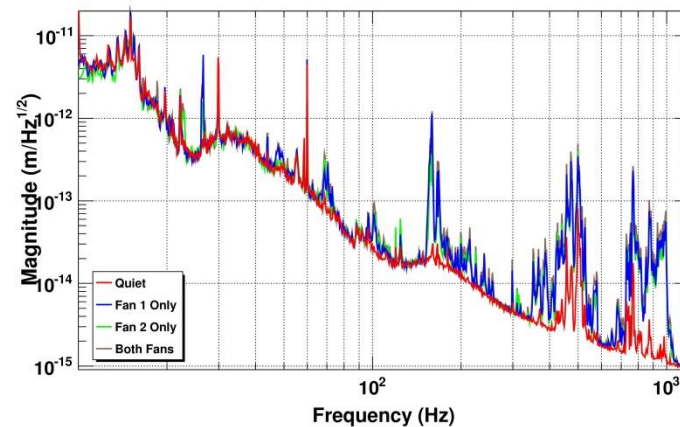


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HAM6 ISI Y



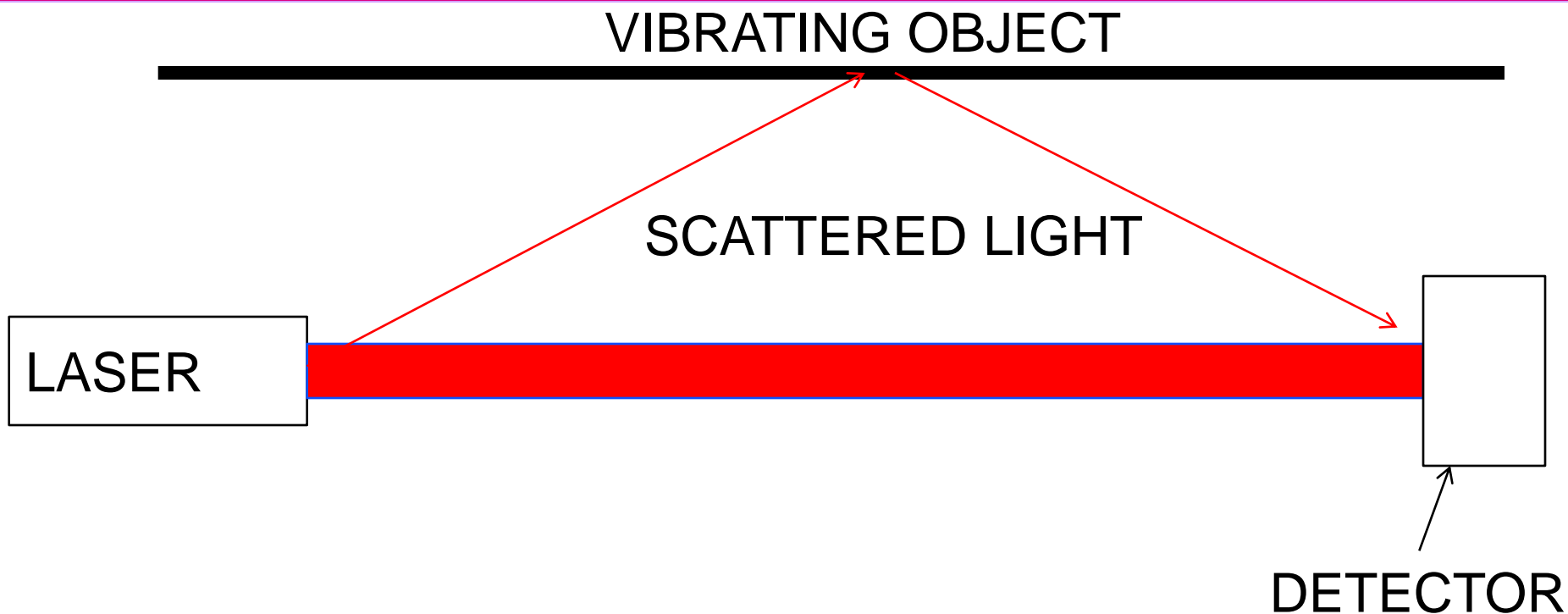
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What is scattering noise?



$$E = Ae^{i\omega_1 t} + B\cos(\omega_2 t)$$

Same as GW modulation!