Review of HAM Suspension Designs for Advanced LIGO

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HAM Isolation Requirements Review

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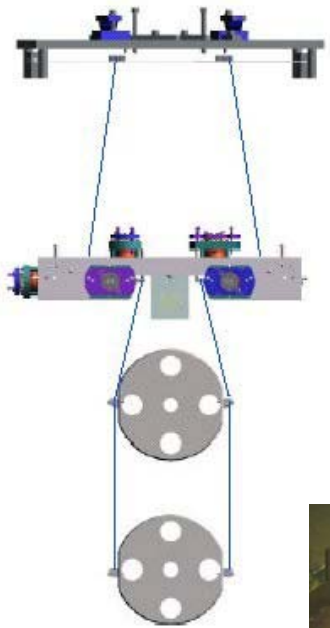
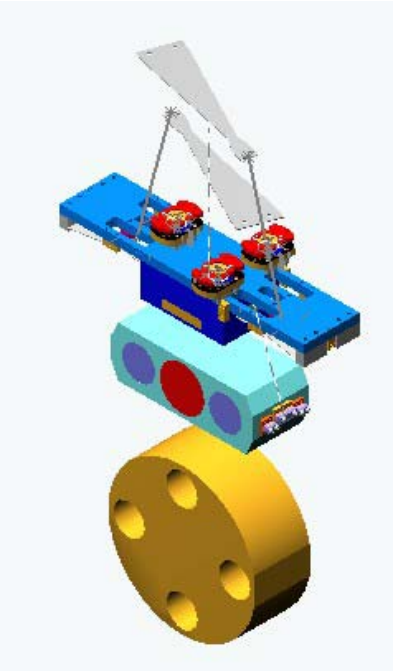
HAM Optics- Modecleaner Mirrors

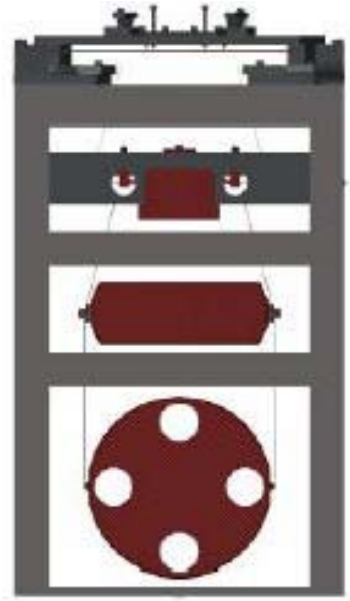
- Modecleaner suspension:
  - triple pendulum with two sets of cantilever blades
  - overall length 0.69 m (to optic centre)
  - optic size 15 cm diam x 7.5 cm thick
  - masses ~ 3kg, 3kg, 3kg
  - final stage on fused silica fibres
    - radius 75 micron, length 22 cm
  - no reaction chain
  - controls prototype built at Caltech and tested at LASTI



HAM Optics - Recycling Mirrors

- Recycling mirror suspension
  - triple pendulum with two sets of cantilever blades
  - overall length 0.64 m (to optics centre)
  - optic size 26.5 cm diam x 10 cm thick
  - masses ~12 kg, 12 kg, 12 kg
  - Truncated metal middle mass (c.f. modecleaner)
  - final stage on steel wires
    - radius 140 micron, length 25 cm
  - no reaction chain
  - detailed design carried out



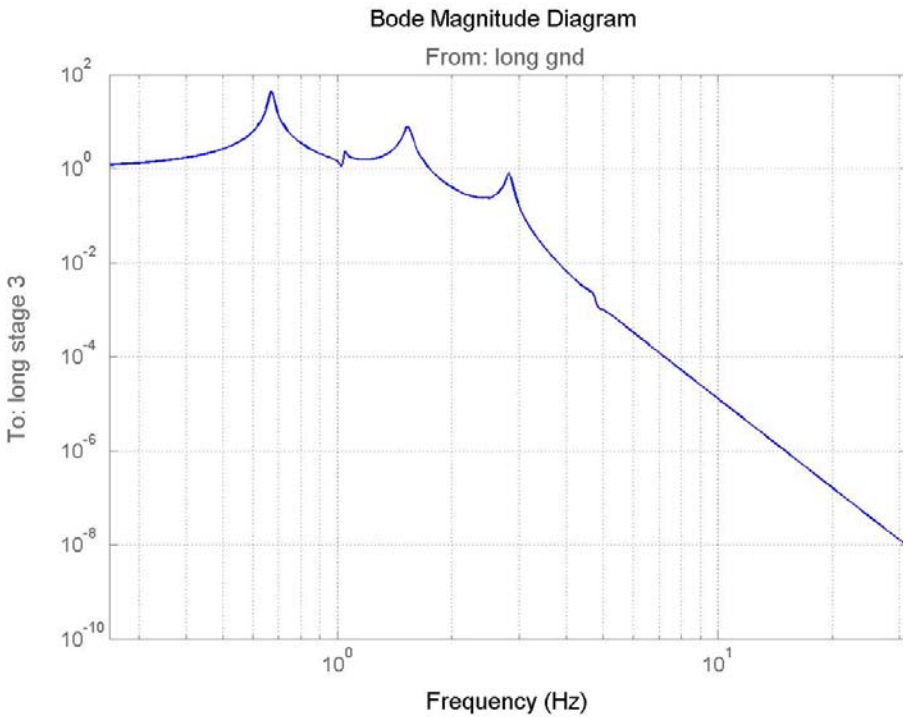


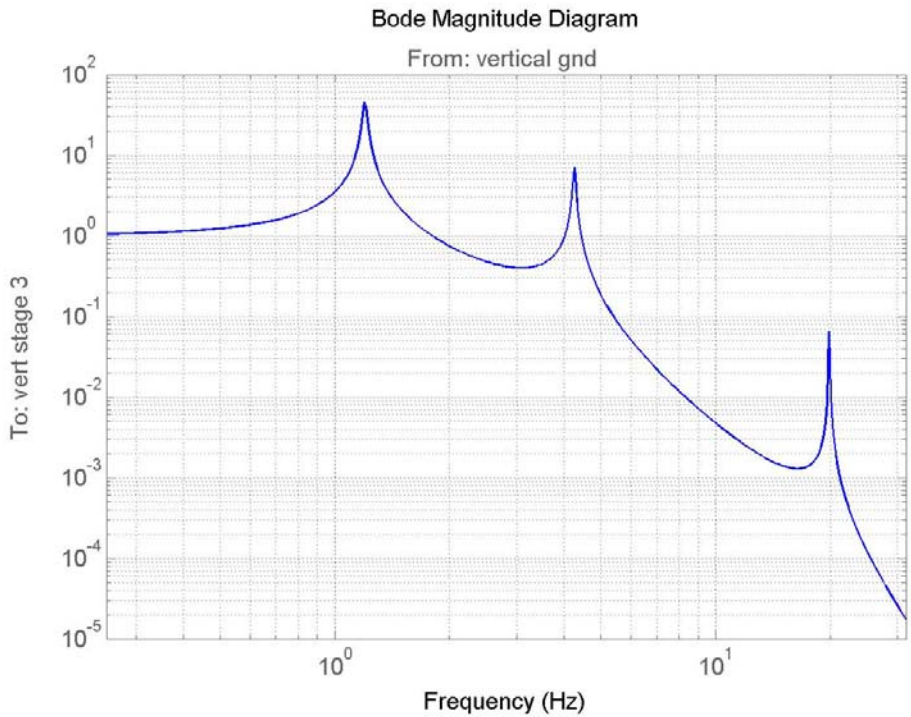
HAM requirements - reminder

- Modecleaner (MC)
  - Long. noise (all sources) 3 x 10^-17 m/rt Hz @ 10 Hz
  - Vert. noise (all sources) 3 x 10^-14 m/rt Hz @ 10 Hz
- Recycling mirror (RM)
  - Long. noise (all sources) 4 x 10^-16 m/rt Hz @ 10 Hz
  - Vert. noise (all sources) 2.2 x 10^-13 m/rt Hz @ 10 Hz
    (assumes coupling 0.0018 from vert. wedge)

- Conclusions
  - Satisfy MC for seismic isolation - RM should be OK.
  - Relaxed requirement for RM allows use of steel wires from suspension thermal noise considerations

MC Suspension: Transfer Functions





Long. TF at 10 Hz = 1.3 x 10^-5

Assuming current SEI DRD noise level, residual noise = 2.6 x 10^-18 m/rt Hz

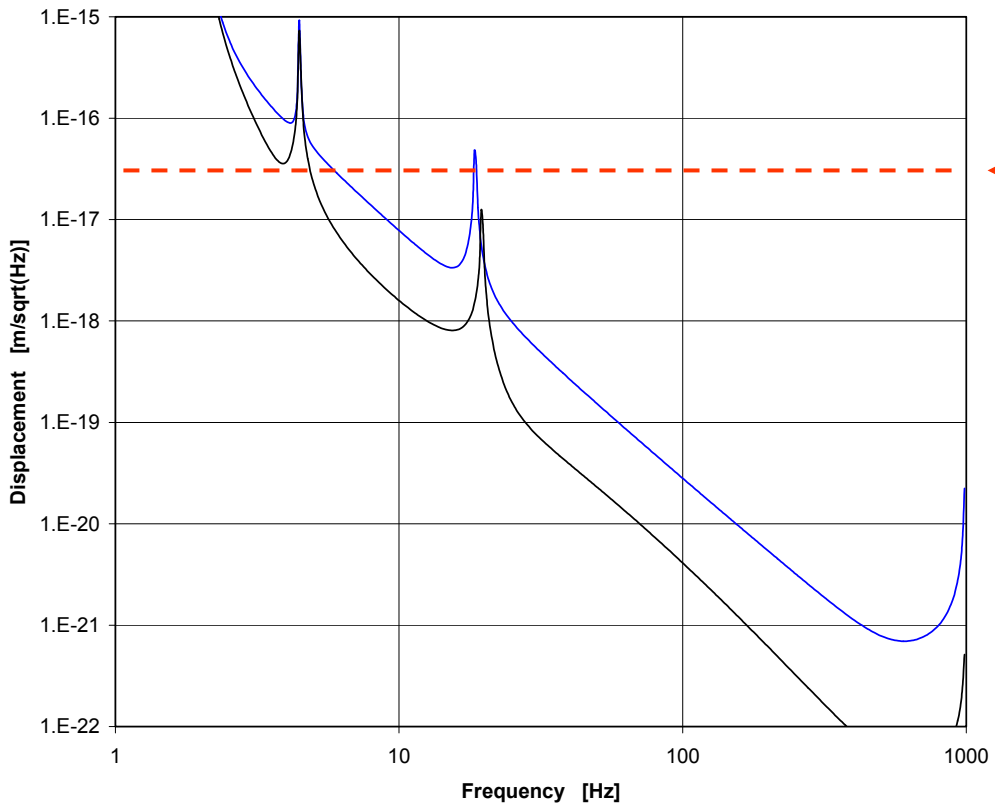
Damping time to 1/e ~10secs

Vert TF at 10 Hz = 4.7 x 10^-3

Assuming current SEI DRD noise level, and cross-coupling of 10^-3, residual noise = 9.4 x 10^-19 m/rt Hz

MC Suspension Thermal Noise

(Longitudinal and vertical summed quadratically)

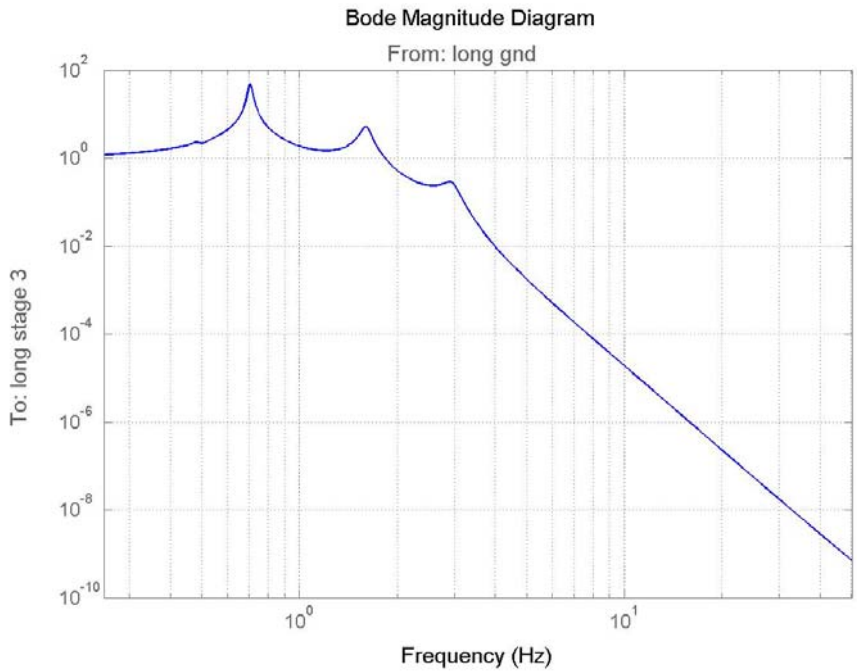


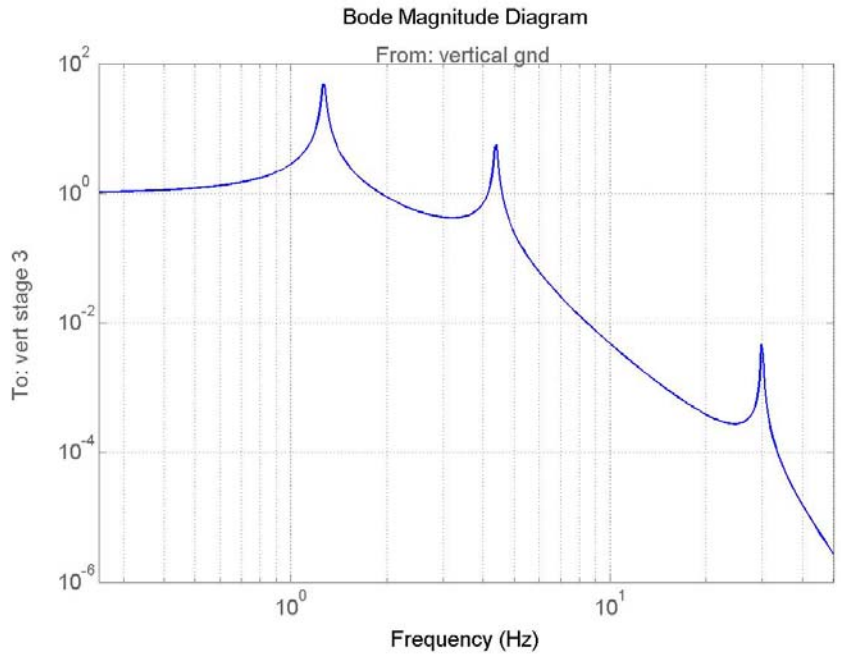
3 x10^-17m/rt Hz

Graph from G Cagnoli

lower curve: silica fibres with radius of 75 micron in the final stage (stress 0.4 GPa)
upper curve: steel wire with radius 40 micron in final stage (stress 1.4 GPa, high)
Noise at 10 Hz: 1.6 x 10^-18 m/rt Hz (silica)
7.7 x 10^-18 m/rt Hz (steel)

RM Suspension: Transfer Functions





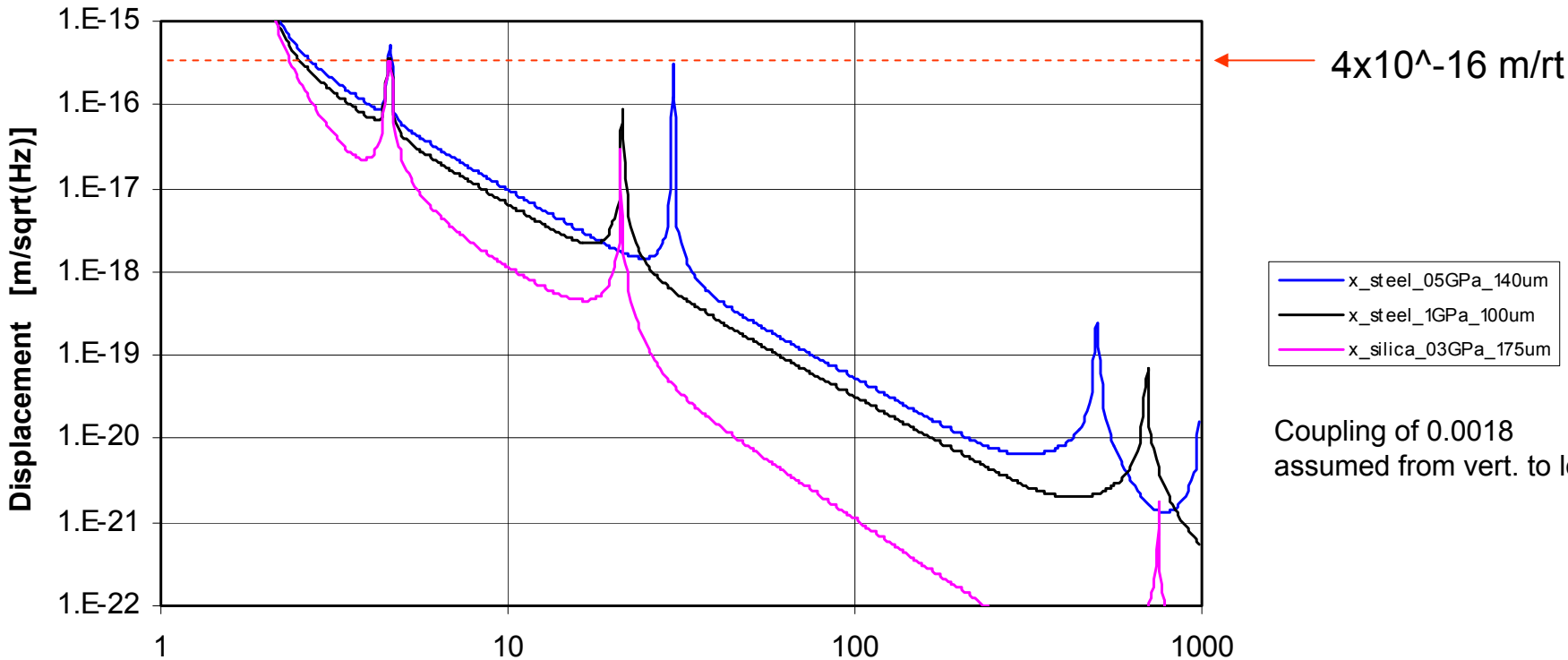
Long. TF at 10 Hz = 1.8 x 10^-5
Assuming current SEI DRD noise level, residual noise = 3.6 x 10^-18 m/rt Hz

Vert. TF at 10 Hz = 4.7 x 10^-3
Assuming current SEI DRD noise level, and cross-coupling of 0.0018, residual noise = 1.7 x 10^-18 m/rt Hz

Damping time to 1/e ~10secs

RM Suspension Thermal Noise

(Longitudinal and vertical summed quadratically)



Coupling of 0.0018 assumed from vert. to long.

Graph from G Cagnoli

lower curve : silica fibres with radius 175 micron (stress 0.3 GPa)
middle curve: steel wires with radius of 100 micron (stress 0.9 GPa)
upper curve: steel wires with radius 140 micron (stress 0.5 GPa)
Noise at 10 Hz: 1.1 x 10^-18 m/rt Hz (silica)
6.4, 9.4 x 10^-18 m/rt Hz (steel)

Backup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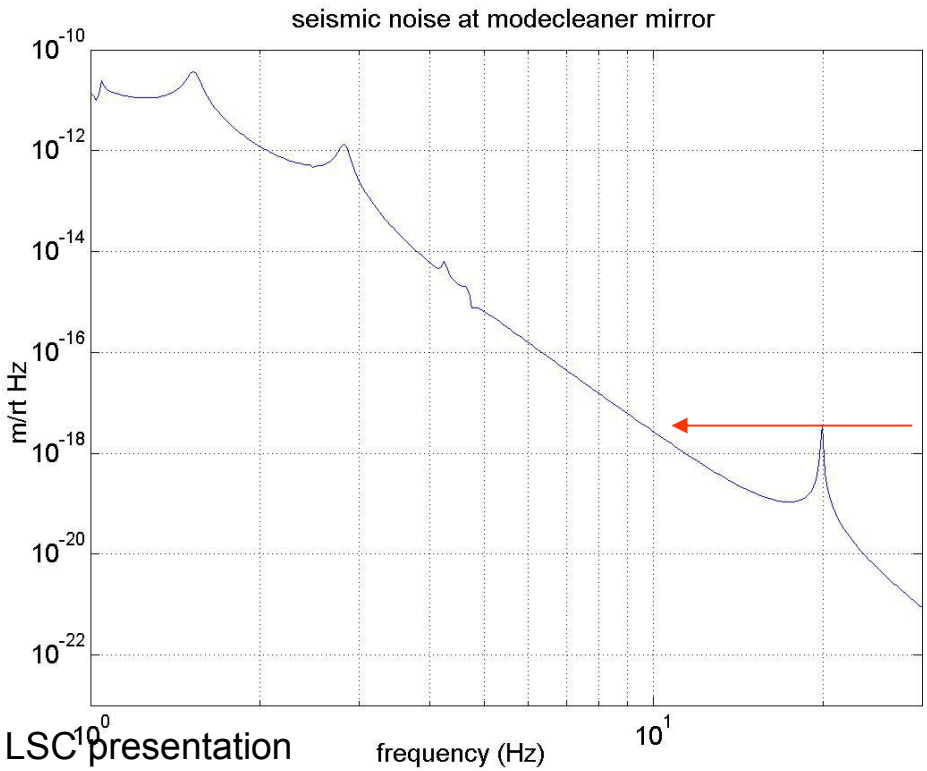
HAM Chambers

- Some input into any future re-evaluation of HAM requirements. Consider noise at modecleaner mirror (long. plus vert.)
  - Seismic noise 2.5 x 10^{-18} m/rt Hz @ 10 Hz (assuming current SEI DRD noise level)
  - Suspension thermal noise also approx. this level. (ref. conceptual design T 010103-03-D)
- c.f. Requirement: long + vert from all sources: $3\sqrt{2}$ x 10^{-17} m/$\sqrt{}$ Hz @ 10 Hz
- Conclusion: there is scope for re-evaluation of SEI requirements for HAM chamber.



2.5 x 10^{-18} m/$\sqrt{}$ Hz @ 10 Hz

Slide from LSC presentation
March 2005 G050117-00-R