Seismic Isolation for BSC optics from SUS+SEI - update

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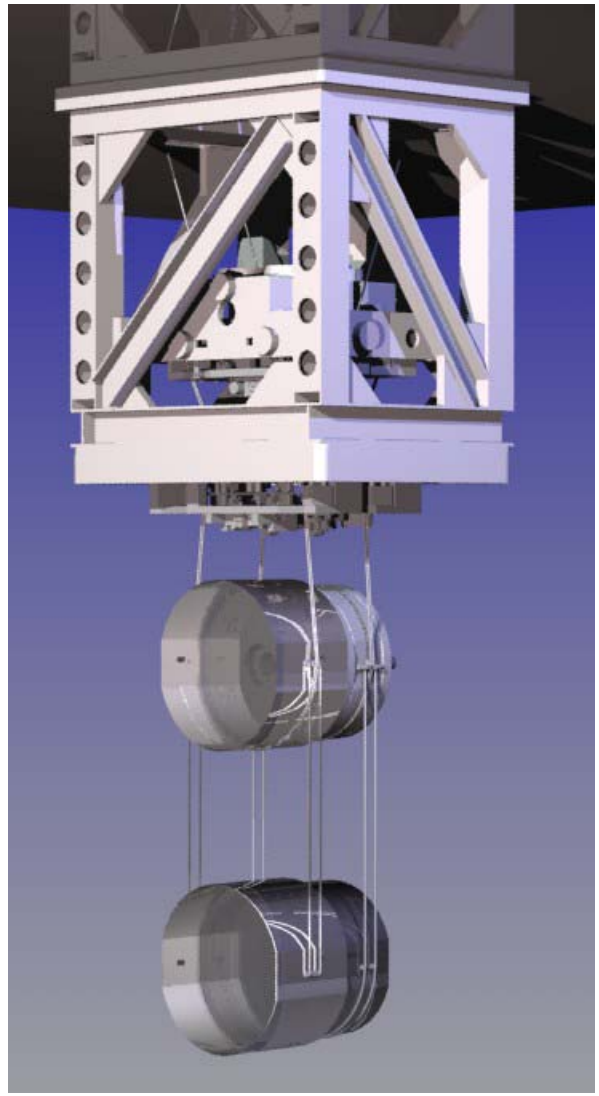
G050117-00-R

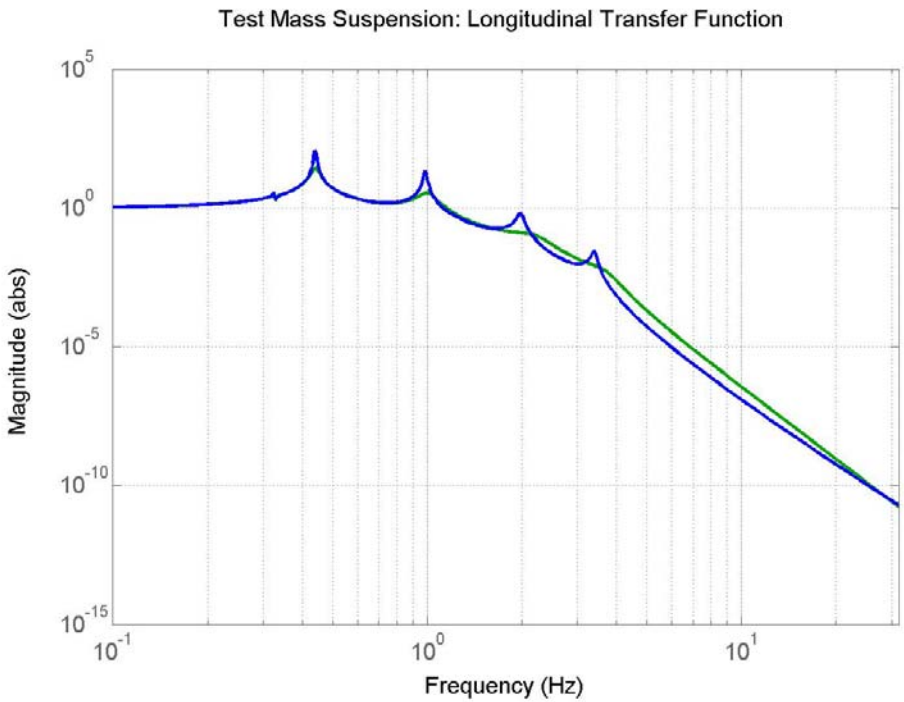
SUS: Quadruple Suspension for ETM/ITM

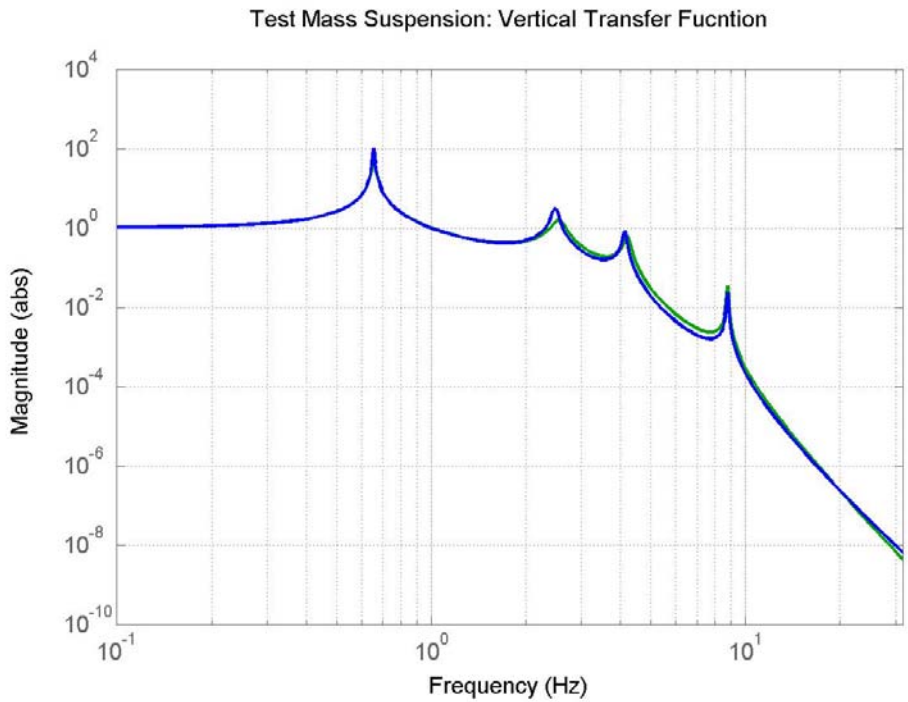
- Parameters for suspension
  - Test and penultimate masses : each 40 kg, 34 cm (diam) x 20 cm, silica
  - Other masses: 22 kg, 22 kg
  - Final stage: 60 cm silica ribbons, 1.1 mm x 0.11 mm,
    Vertical bounce mode: 8.8 Hz
    first violin mode: ~490 Hz
  - Overall length (suspension point to optic centre) 1.63 m
- MATLAB model used to compute transfer functions (update from M Barton not yet implemented - longitudinal TF will be unaffected, vertical TF will be slightly (<10%) larger than shown overleaf)
- SUS requirements taken from SUS DRD document T010007-02



CTorrie and M P-Lloyd

Longitudinal and Vertical Transfer Functions





green: simple active control, decay time, T ~ 10s

blue: eddy current damping (one unit, b=27 kg/s)
T ~ 50s (long) T ~30s (vert)

→ Long. TF @10Hz: 1.2×10^{-7}
Vert. TF @10Hz: 2.0×10^{-4}

Multiply by seismic platform target noise of 2×10^{-13} m/√Hz @ 10 Hz

Total noise = 2×10^{-13} m/√ Hz x √ [long^2+(0.001 x vert)^2)]

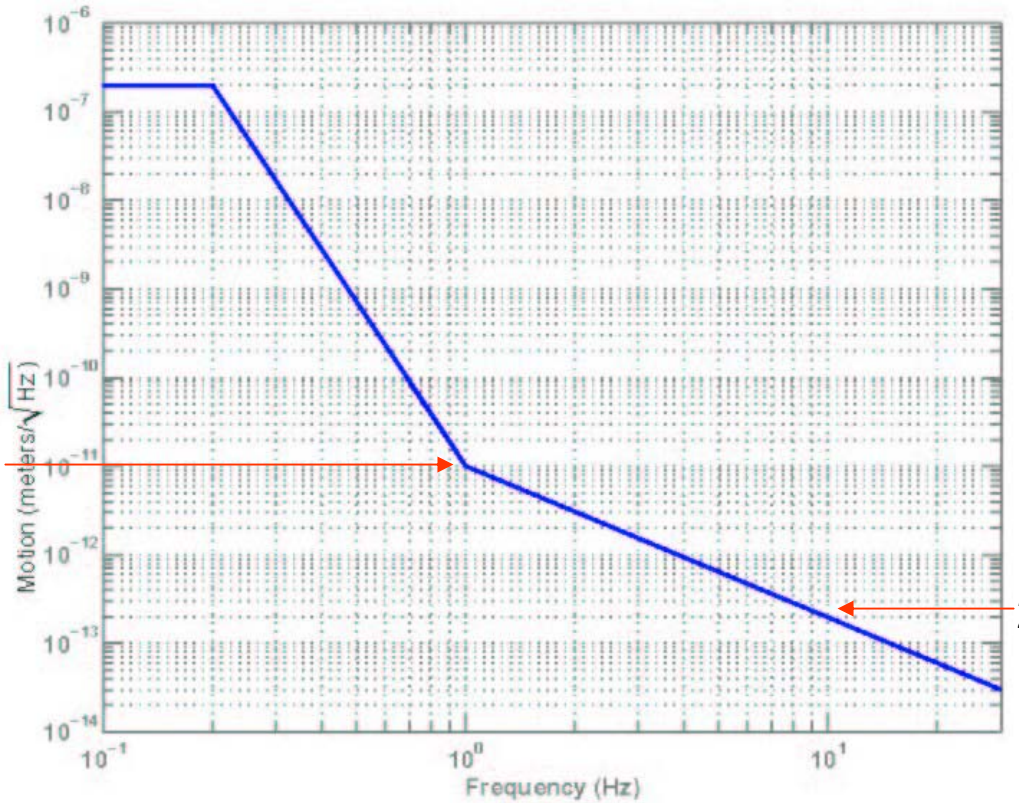
Total noise = 5×10^{-20} m /√Hz @ 10 Hz

c.f. requirement: 1×10^{-19} m/√Hz for combined long + vert

SEI displacement requirement

- Reference : Seismic Isolation Subsystem DRD (E990303-03-D)

10^{-11}m/√ Hz @ 1 Hz

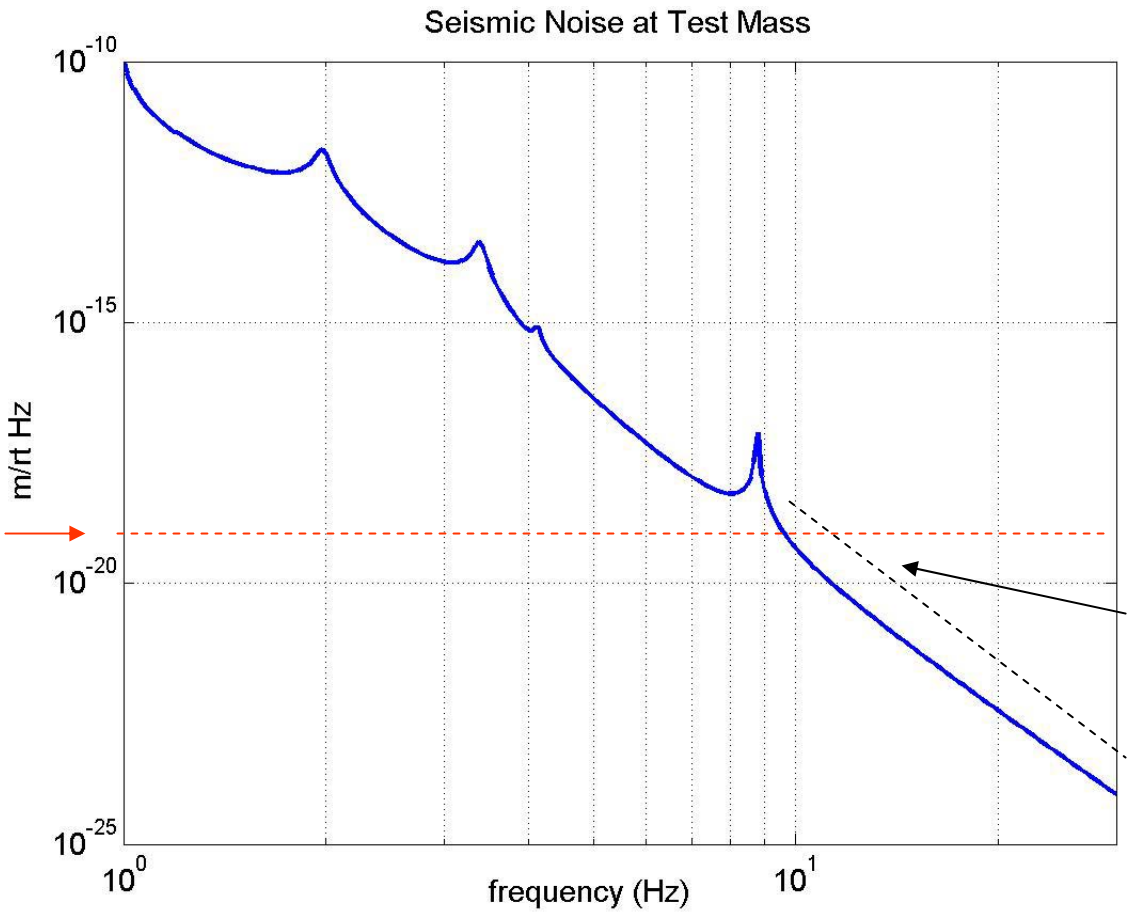


2 x10^{-13} m/√ Hz @ 10 Hz

Figure 2: SEI optics platform displacement requirement, applicable to all three translational degrees-of-freedom.

Seismic noise at test mass (combining SEI+SUS)

requirement :
10^{-19} m /rt Hz @ 10 Hz



If noise is 10 times worse, requirement is met at 11.3 Hz

Curve produced by multiplying SEI curve by √ [longTF^2+(0.001 x vertTF)^2)] where longTF and vertTF are the suspension transfer functions.

Other degrees of freedom?

- *Pitch and yaw requirements*: 1 x 10^{-17} rad/√ Hz @ 10 Hz
  - Pitch TF at 10 Hz ~ 4 x 10^{-8}, Yaw TF at 10 Hz ~ 7 x 10^{-7}
- To meet yaw requirement require residual yaw on seismic platform to be 1.4 x 10^{-11} rad/√ Hz
- c.f. residual displacement noise of 2 x 10^{-13} m/√ Hz over length scale of platform of ~ 1 m, giving ~2 x 10^{-13} rad/√ Hz
- Conclusion - factor of ~ 70 in hand

- *Transverse requirement:* 10^{-17} m/√ Hz (assuming 0.001 coupling into longitudinal)
  - Transverse TF ~ 4 x10^{-7}
  - Multiply by seismic platform target noise of 2 x 10^{-13} m/√Hz @ 10 Hz giving 8 x 10^{-20} m/√Hz
- Conclusion - factor of ~ 100 in hand

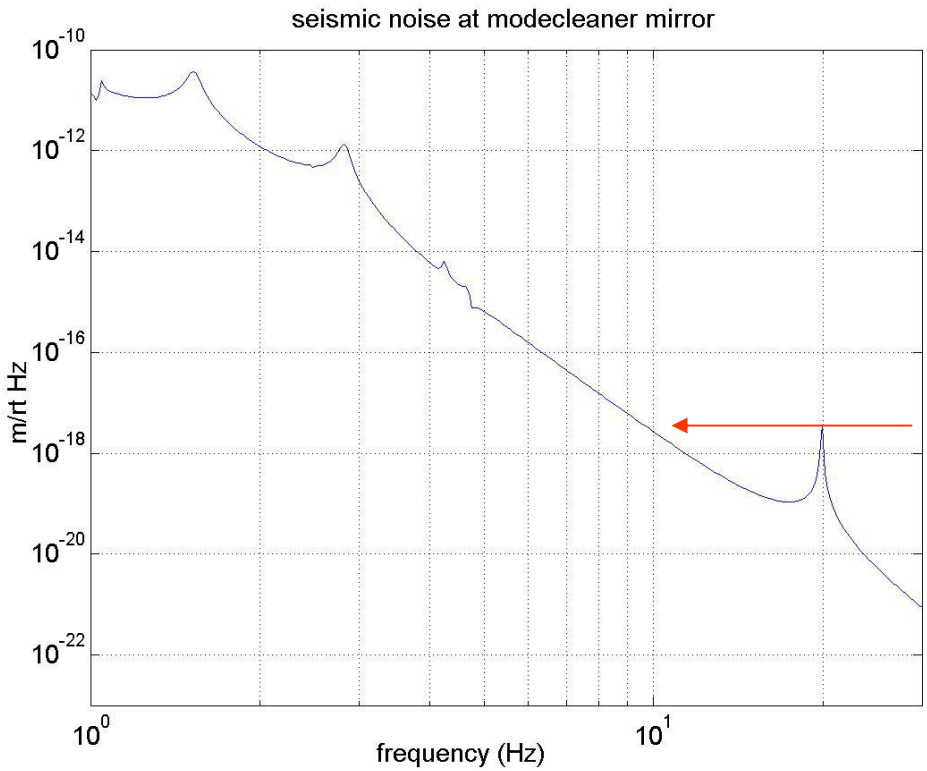
Beamsplitter

- Reference: Design of Beamsplitter Suspension for Advanced LIGO (T040027-00-R)
- Triple pendulum with silica fibres in final stage
- Requirement long. plus vert. noise (all sources) = 2×10^{-17} m/√ Hz @ 10 Hz
- Estimated noise
  - Seismic contribution: 4.6×10^{-18} m/√ Hz (assuming SEI noise as in SEI DRD), dominated by vertical contribution
  - Suspension thermal noise contribution: 2×10^{-18} m/√ Hz
  - Total (adding in quadrature) = 5×10^{-18} m/√ Hz @ 10 Hz
- Conclusion - factor of ~ 4 in hand

  (Design is preliminary - could reconsider suspension blade design to improve vertical isolation if necessary)

Finally - 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