Active Seismic Isolation for Enhanced LIGO Detectors

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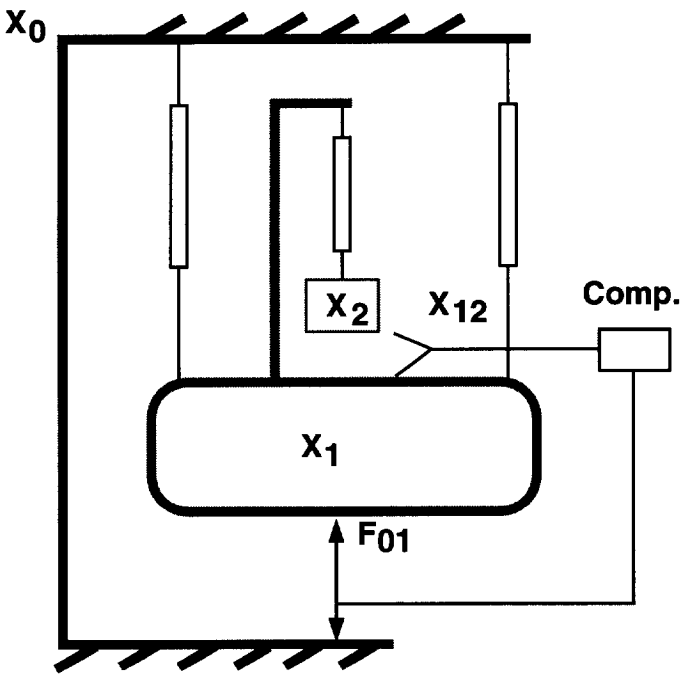
for the active isolation study groups in the LSC

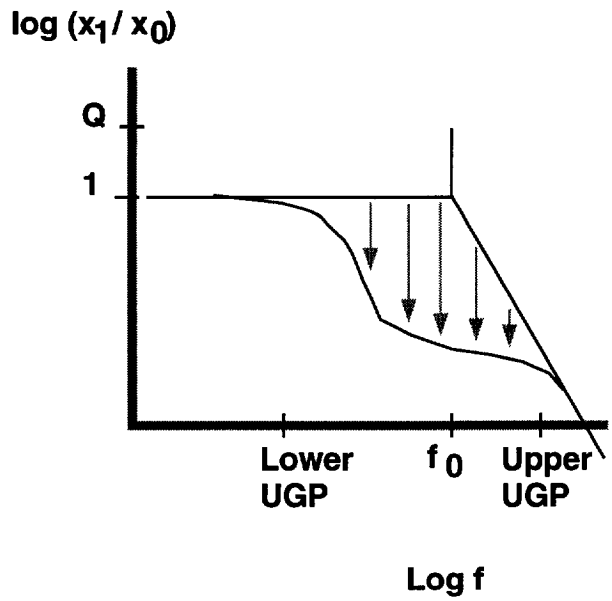
Advantages of Active Isolation

- Stiff suspensions are compact, stable and have lower stress.
- Active systems can attenuate internal noise and damp internal modes.
- Active systems can easily incorporate alignment, redistributing alignment commands from inner to outer stages.
- Active systems give a stiff suspension point for the high Q triple pendulum to react against.
- Active systems have greater flexibility, permitting multiple modes of operation.
- The sensors on active stages provide diagnostics of suspension performance without opening the vacuum system and disturbance monitoring.
- The stiff suspensions of active systems have a natural "fail-operate" mode.
- The active isolation system design an extensible design for the different needs of interferometer optics.

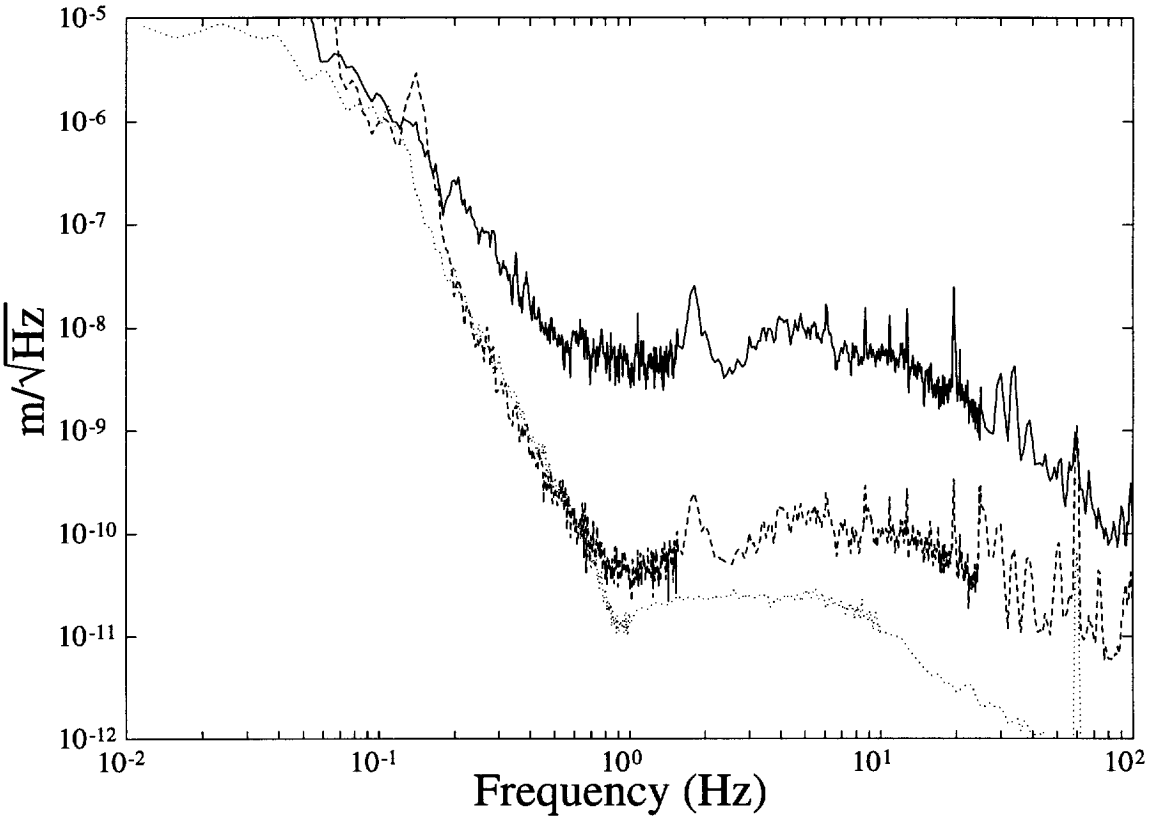
Active Mechanical Noise Reduction:

- Control forces are applied to a payload to reduce its motion with respect to an external reference frame or inertial space.





- error signal can come from local reference (shown) or global reference such as length or angle sensing interferometers.



Data from the 1994 single-stage JILA platform, showing the noise performance of a 6-DOF active isolation system. The lines are, top to bottom, the ground motion, the platform noise, and the measurement noise.

GW Community Experience: Active Reduction of Seismic Noise:

- Length Control Loops: RMS mirror position error reduced from of order micrometers to 1/10 picometer.

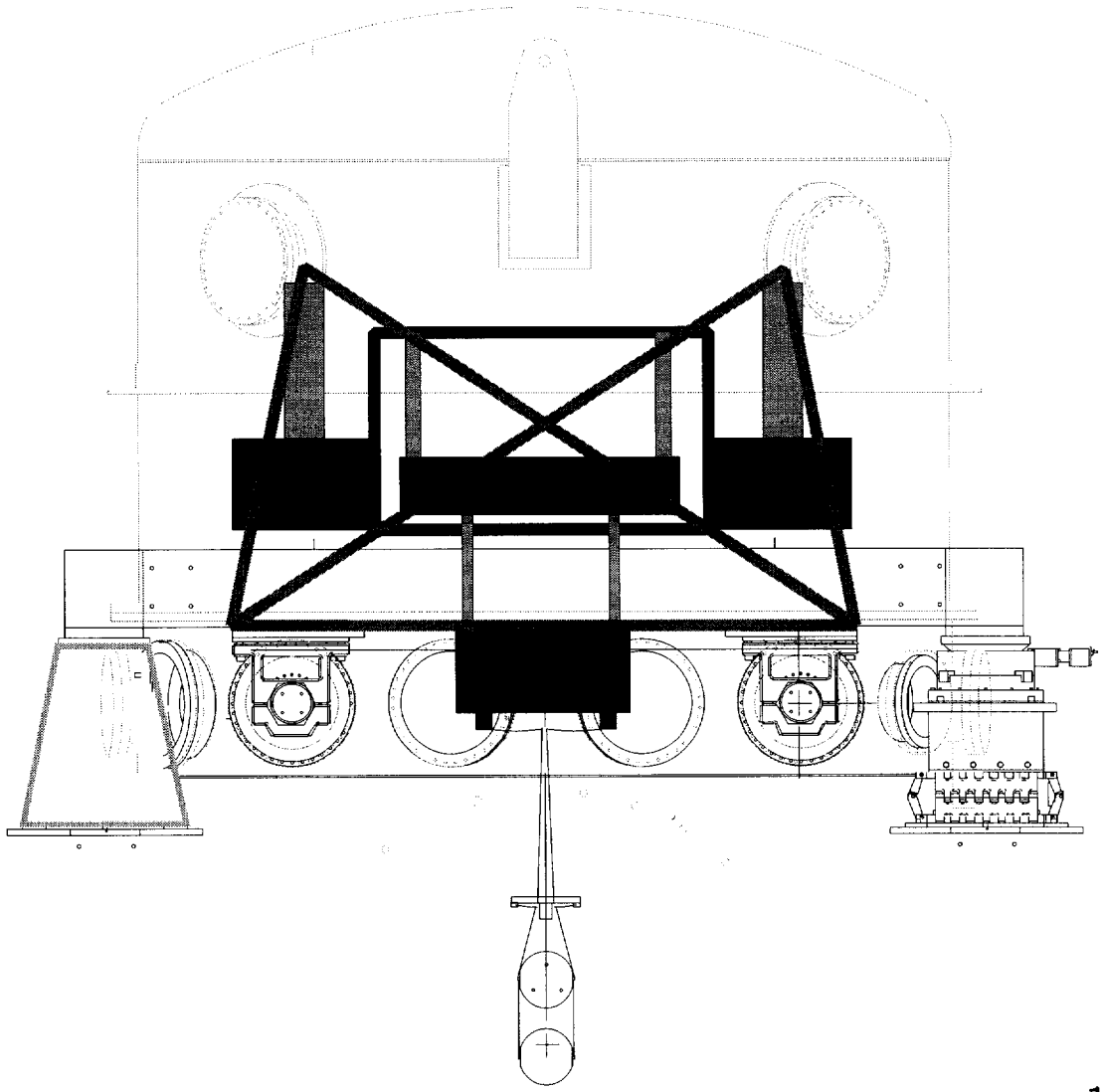
- Angle Control loops: RMS mirror angles reduced to order 10 nanoradians.

- *Many* vibration-reduction servo loops already under construction, some with several hundred hertz upper unity-gain frequencies:
  - 5 critical lengths (incl. mode cleaner)
  - 18 angles
  - 18 DOFs local damping control in suspensions
  - PSL loops, etc.

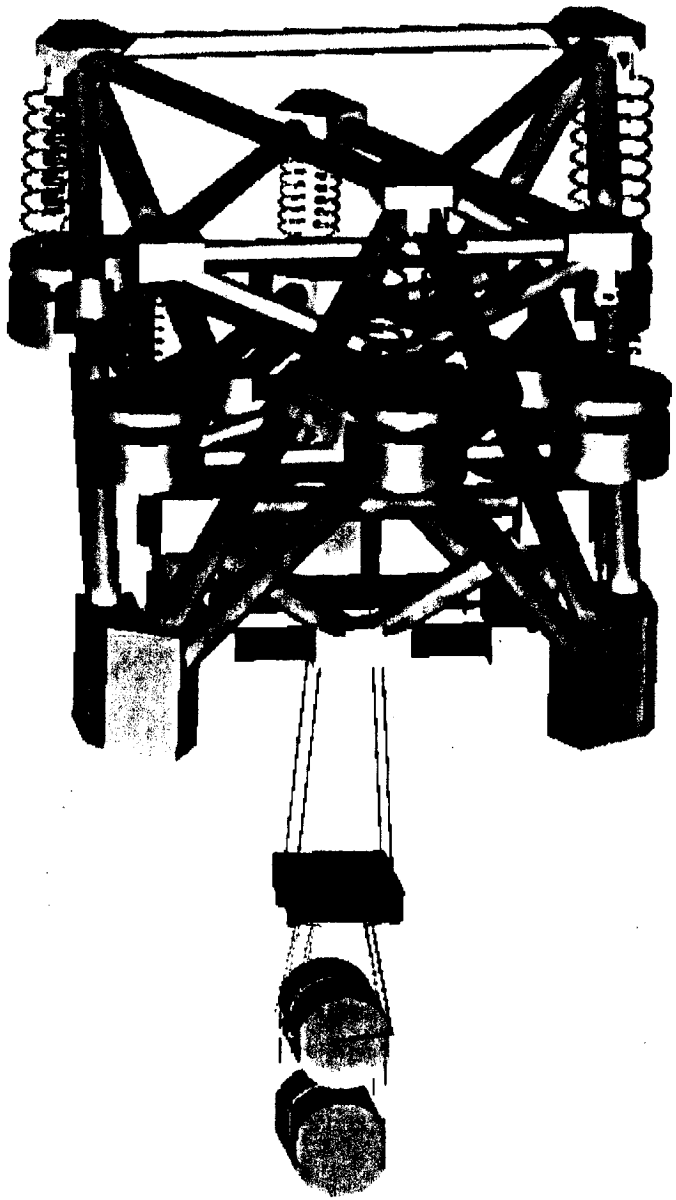
Design Example: Two active plus one passive stage system:

- Two stages of active allows greatly reduced upper unity gain frequency in main inteferometer length control loop.

- Passive layer plus triple pendulum provides majority of isolation in the GW band.



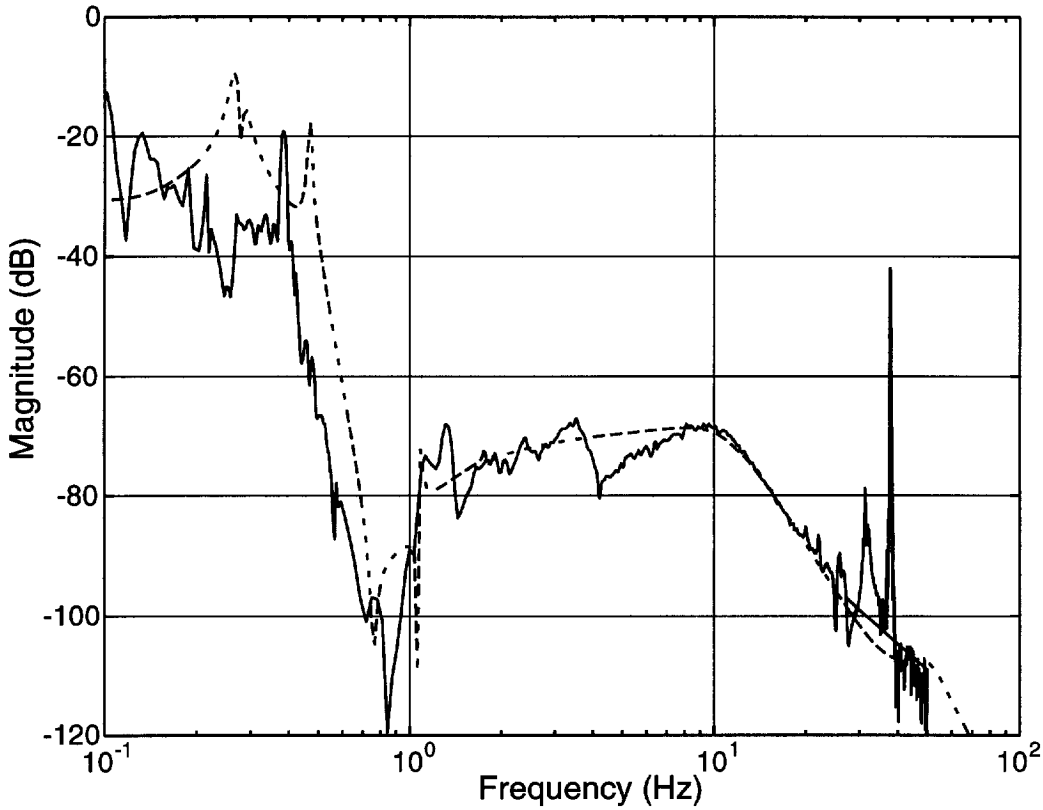
1 Hz - Two Stage Active Isolation



THE Stanford GRAVITY WAVE GROUP

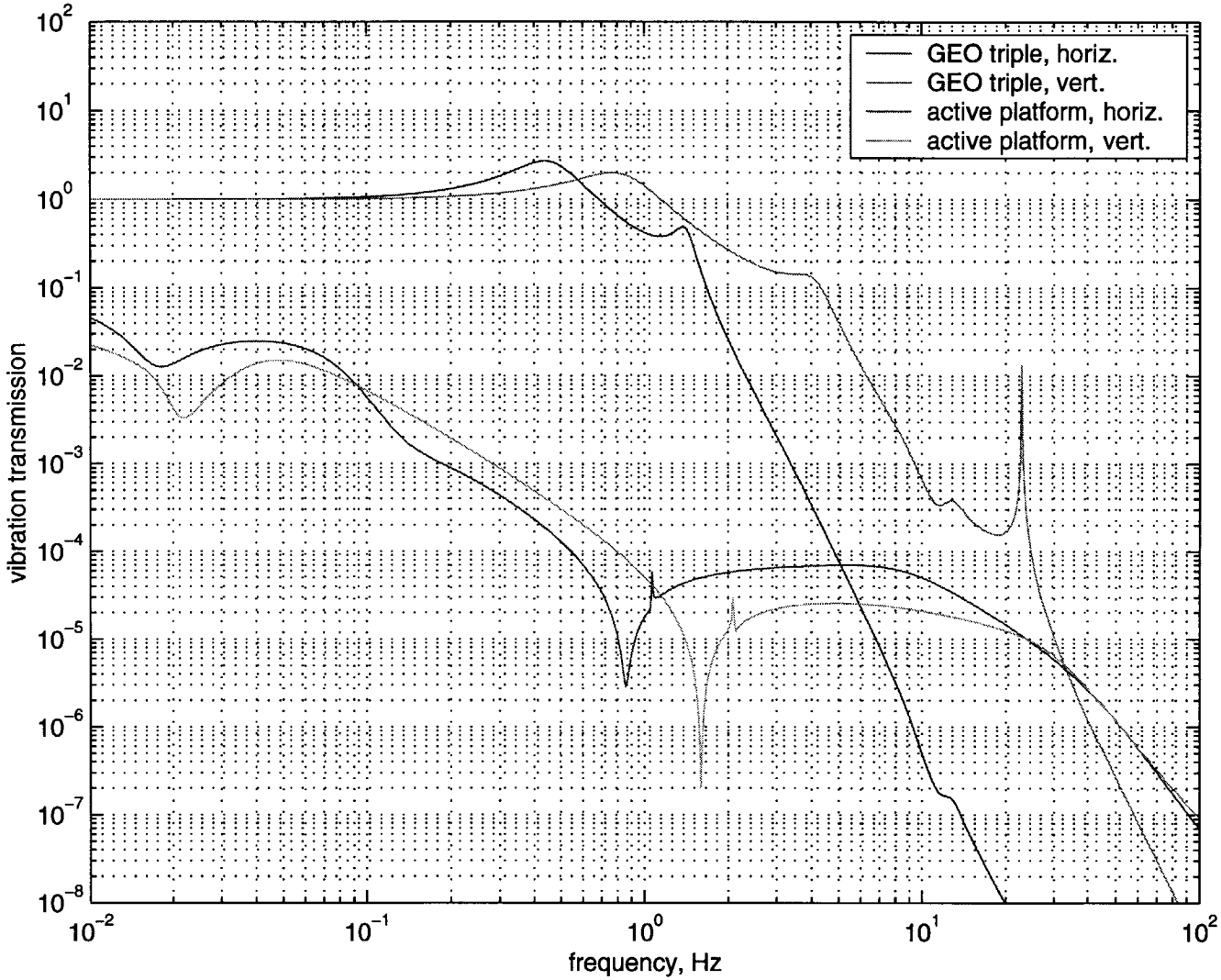
Modeling:

- Model is slightly modified from Matlab code developed to design JILA platform; this has been extensively tested against hardware performance over several years.

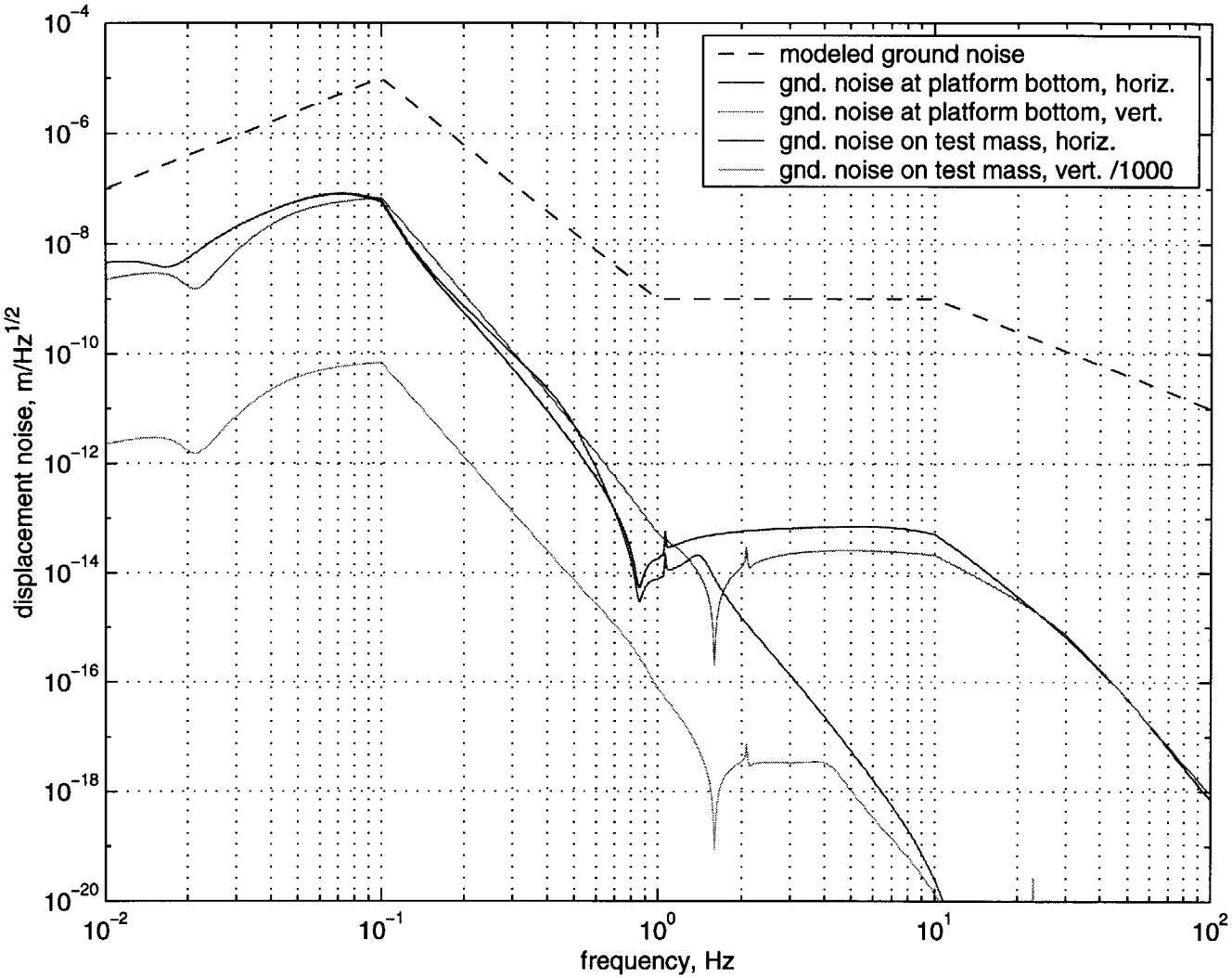


JILA driven horizontal transfer function.

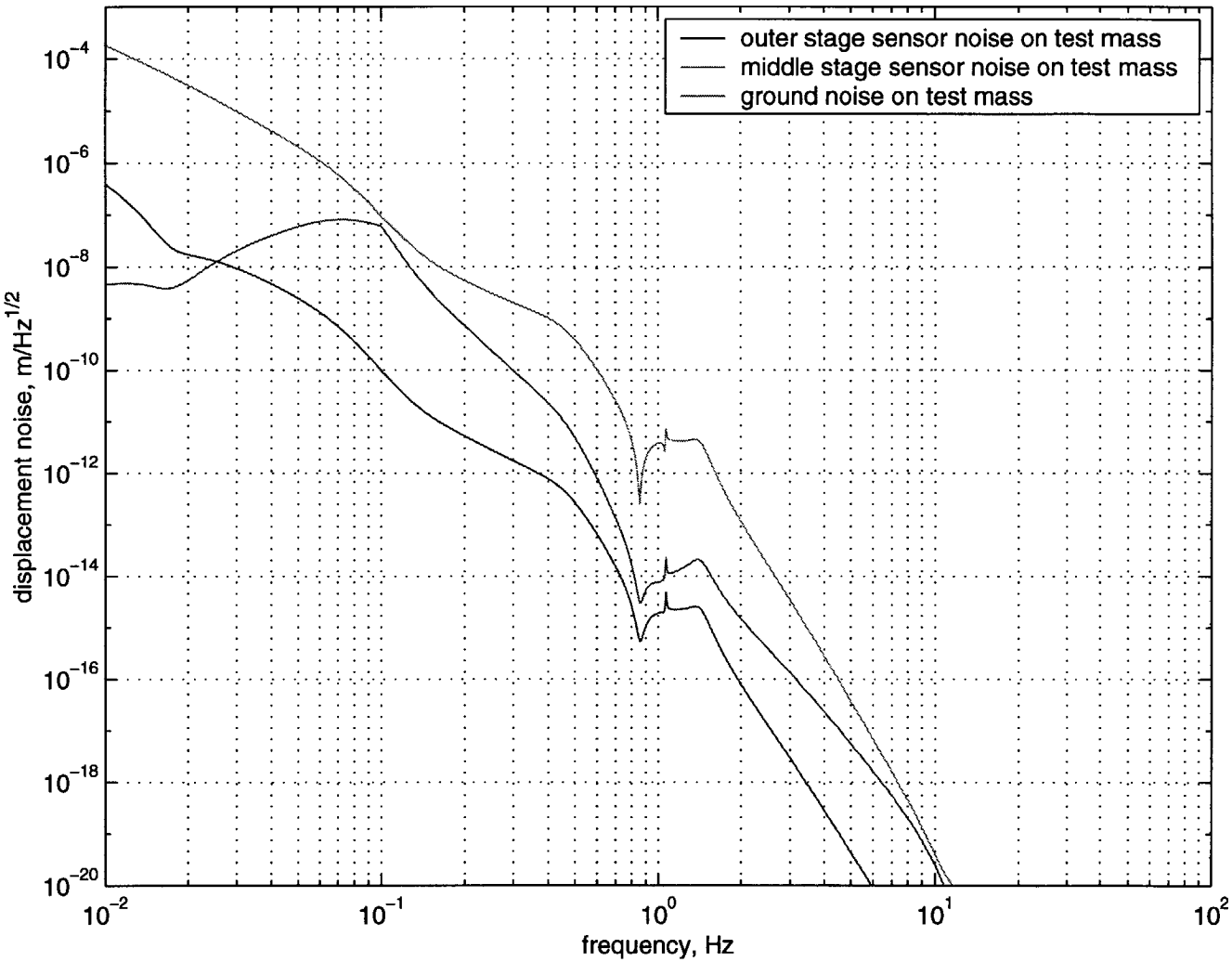
- Fully 3D, all rigid-body Degrees Of Freedom modeled.



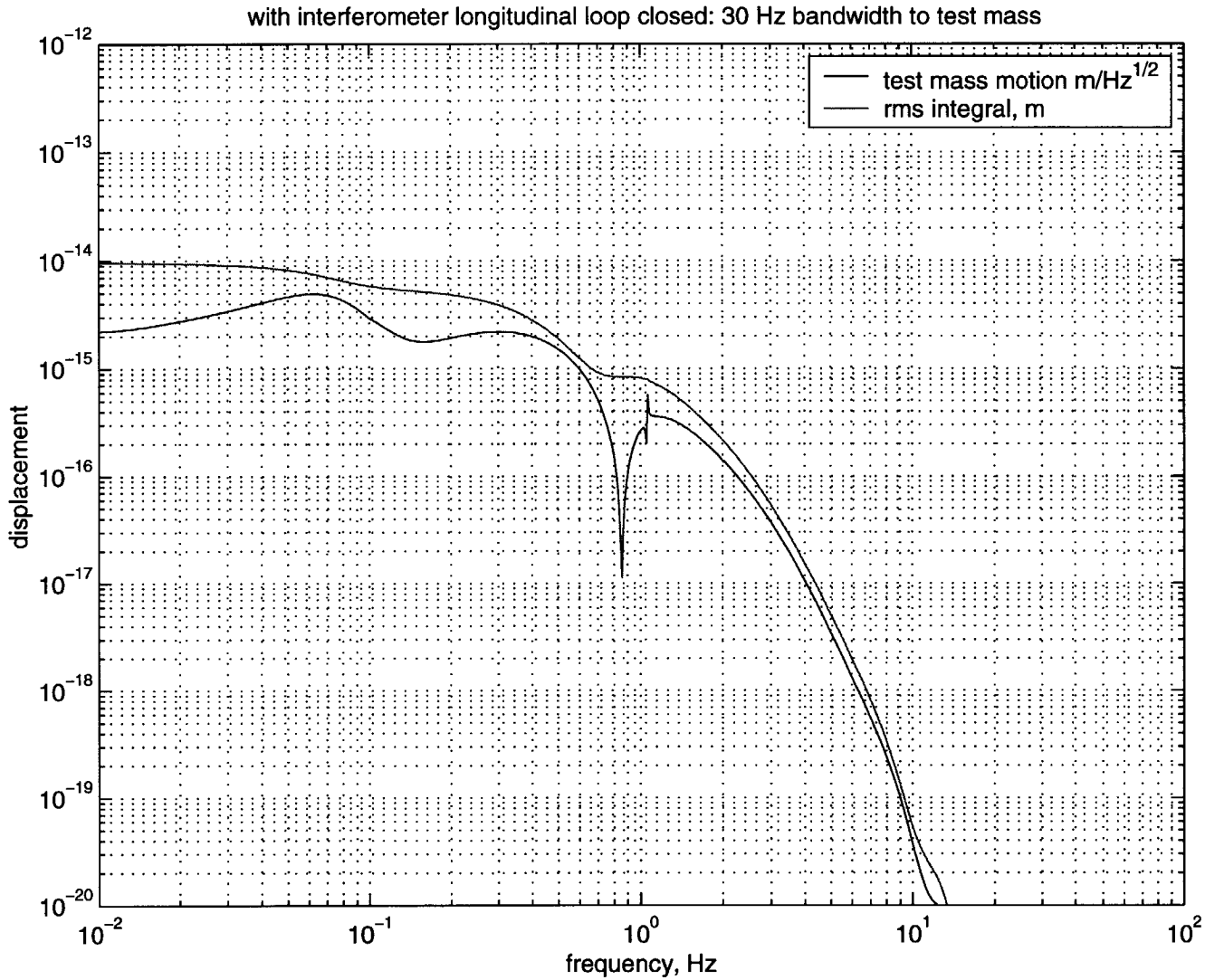
Modeled triple pendulum and siesmic isolation system transfer functions.



modeled source ground noise, residual ground noise at the inne
stage, and on test mass.



active isolation sensor noise appearing at test mass compared wi ground noise.



Residual test mass noise when the interferometer is locked with 30 Hz appr
mate upper unity gain frequency of feedback to the test mass, and the right-to-
RMS integral of that noise, showing the 10^{-14} m goal met.

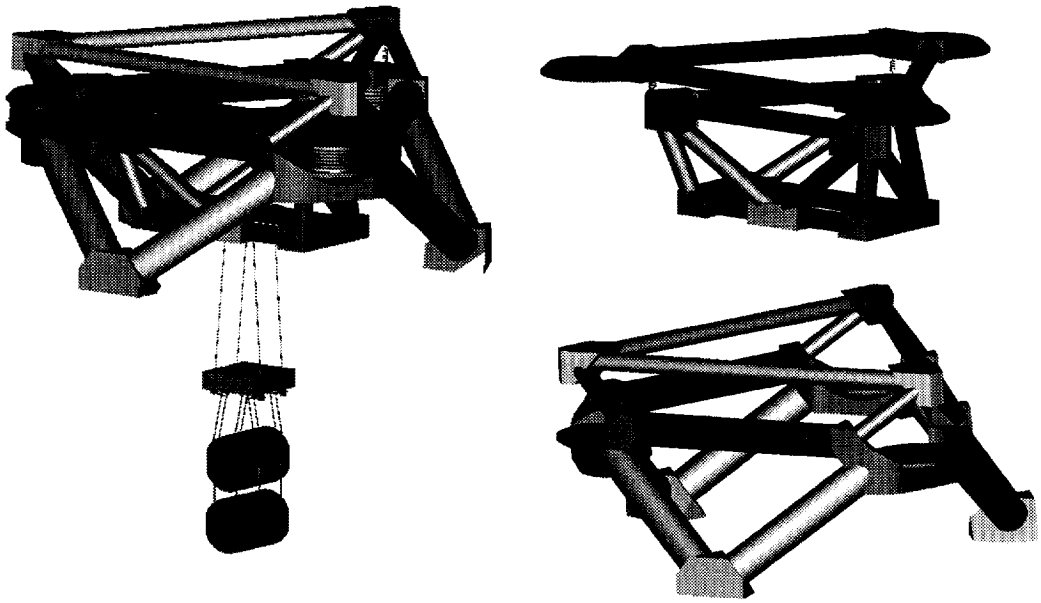


Figure 4. On the left is the "13 Hz design". The triple pendulum (purple and green) is hung from cantilevers on the suspension point platform (blue and grey). The suspension point platform is suspended by springs from the isolation platform (red) which hangs by offload springs from the support table (green). The isolation platform is also supported by 3 2-DOF active isolators supported by the support table. On the right is the support platform (below) and the active platform and suspension point platform (above).

GEO Triple Pendulum

In order to properly design the isolation system, we need to know the performance of the triple pendulum system. A rough sketch of the GEO triple pendulum is shown below in figure 5. The lengths and masses are:

L1=90cm, Top mass=30kg; L2=50cm, Intermediate mass=30kg; L3=35cm, Test mass=30kg

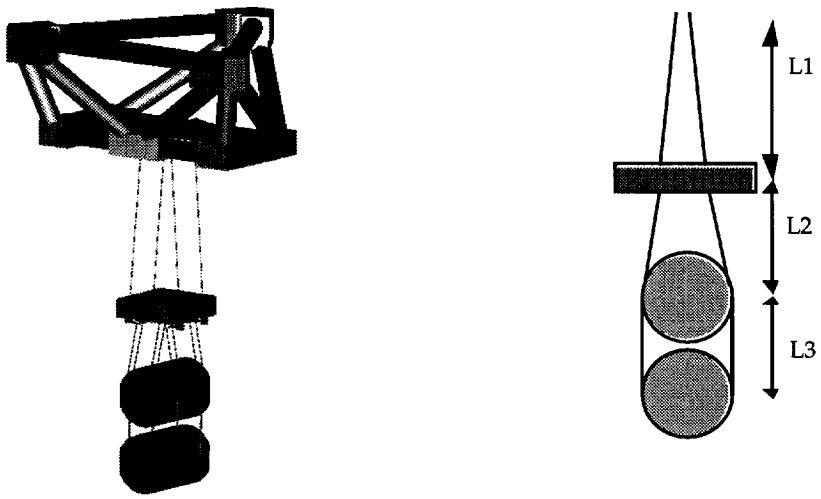
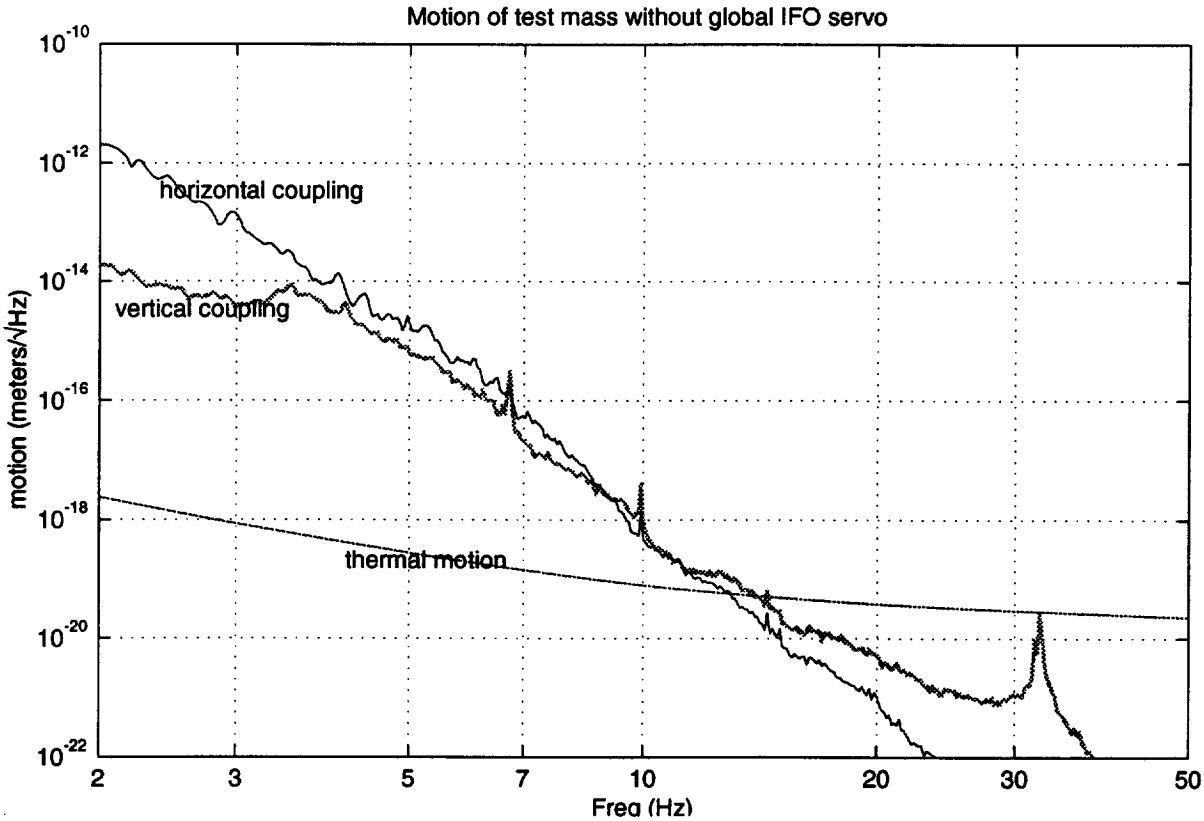
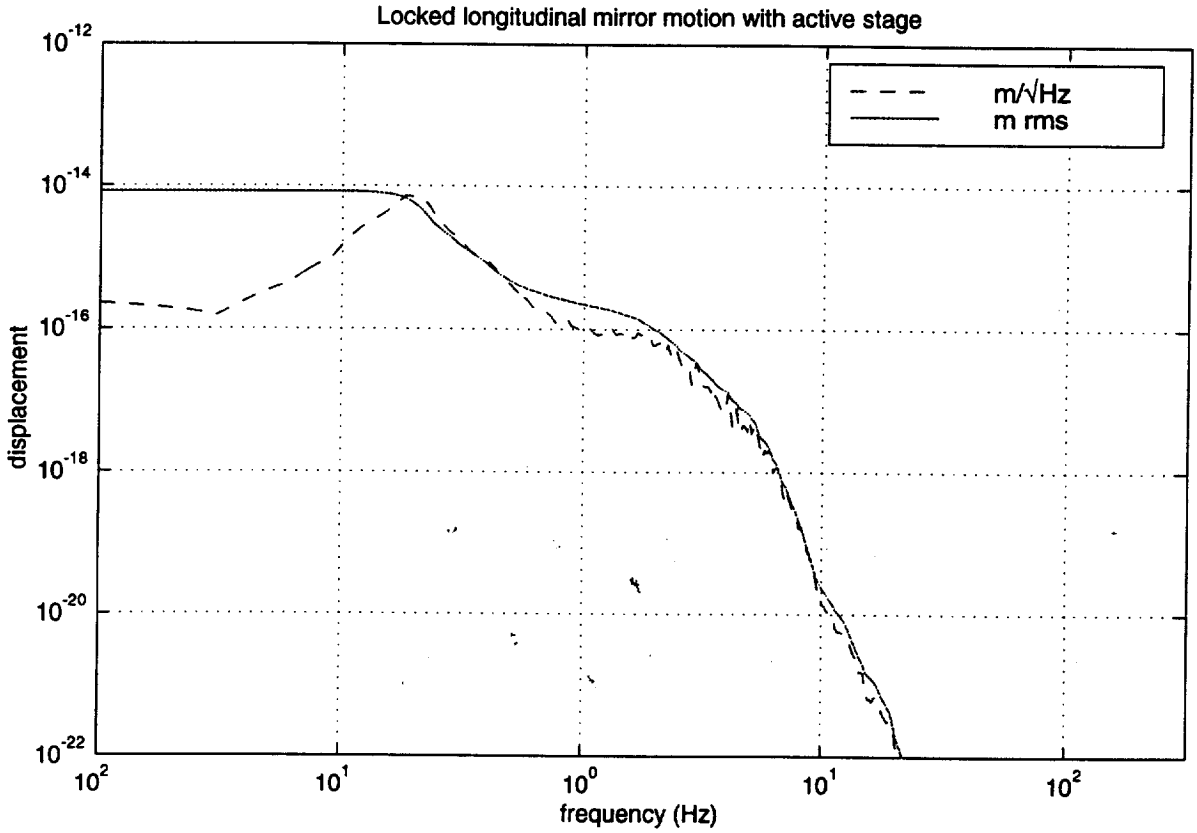


Figure 5. GEO triple suspension attached to the suspension point platform by a set of cantilevers.


Motion of test mass without global IFO servo
horizontal coupling
vertical coupling
thermal motion
motion (meters/√Hz)
Freq (Hz)


Locked longitudinal mirror motion with active stage
m/√Hz
m rms
displacement
frequency (Hz)

Note 1, Linda Turner, 08/17/99 08:26:36 PM
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