



The University Of Western Australia

School Of Physics

Honours Presentation

Modelling and Testing of a Vibration Isolation Chain

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Supervisors:

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Dr Ju Li

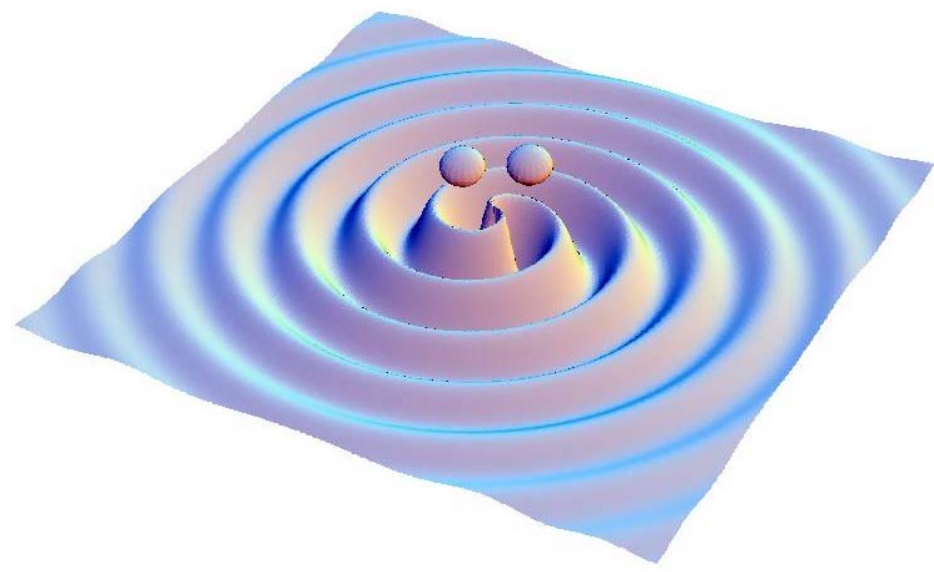
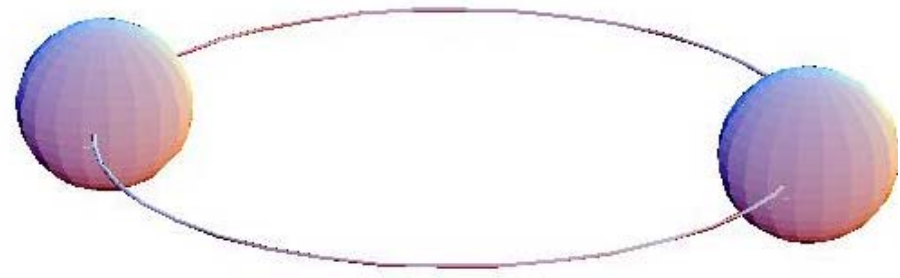
Dr John Winterflood

Presentation Overview

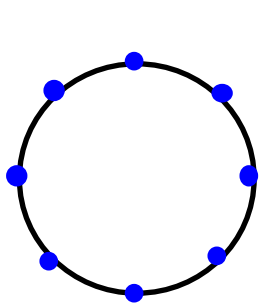
- > **Gravitational Wave interferometer and vibration isolation**
- > **The Isolation Chain**
- > **Modelling and mass distribution**
- > **Testing of Two Stage Chain**
- > **Testing of Three Stage Chain**
- > **Conclusions**

Gravitational Waves

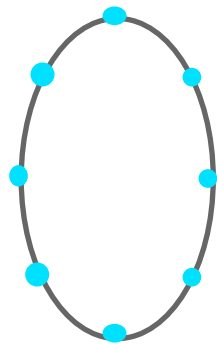
- **Predicted by Einstein with theory of General Relativity**
- **Fluctuations in curvature of space-time**
- **Analogy to sound waves where medium is spacetime itself (although transversal wave, not longitudinal)**
- **Generated by time varying mass quadrupole moment.
i.e. non spherical motion**



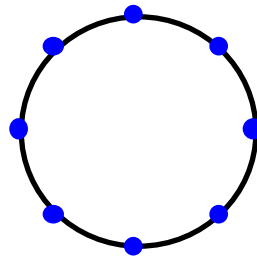
Asymmetrical deformations



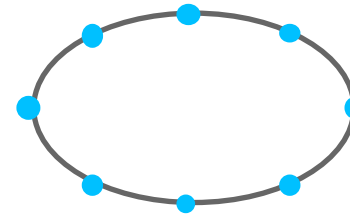
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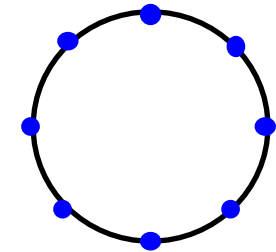
$\pi/2$



π

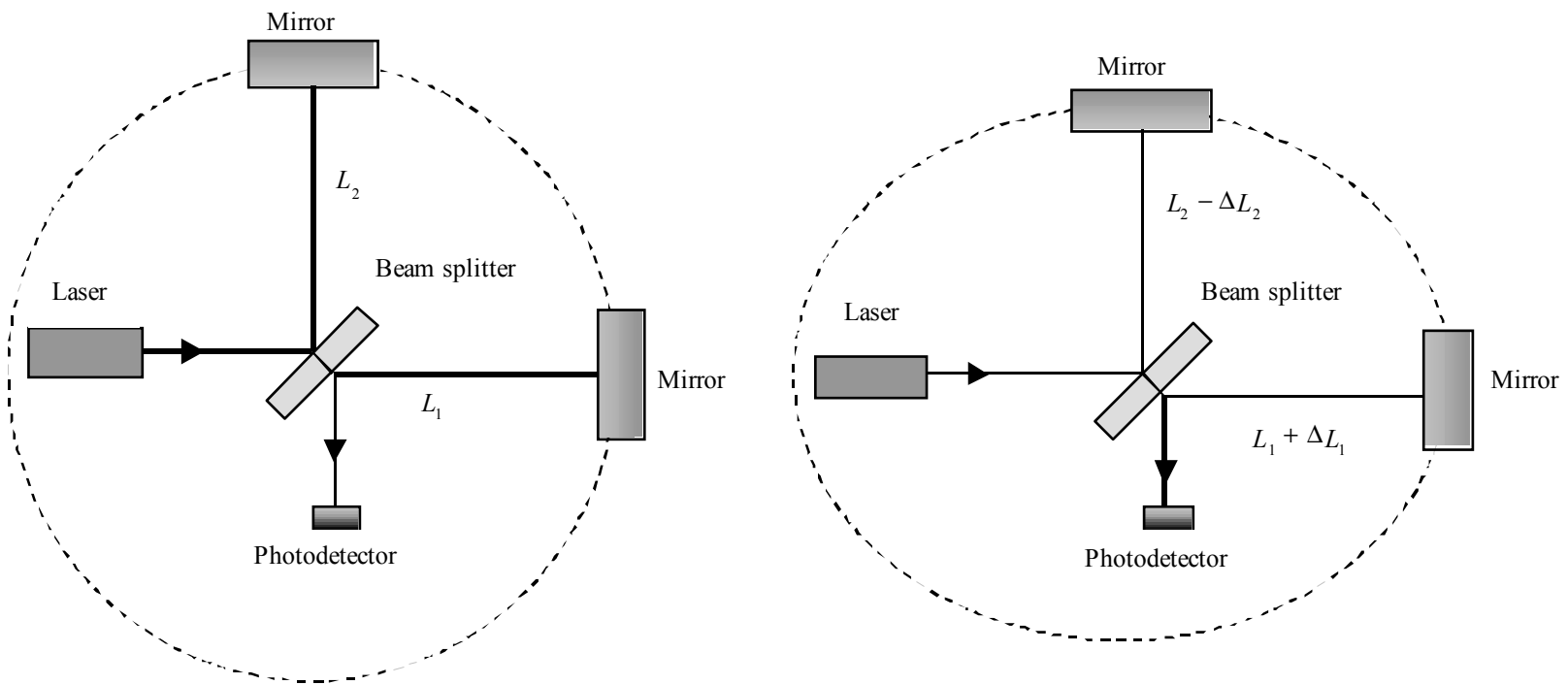


$3\pi/2$



2π

The interferometer

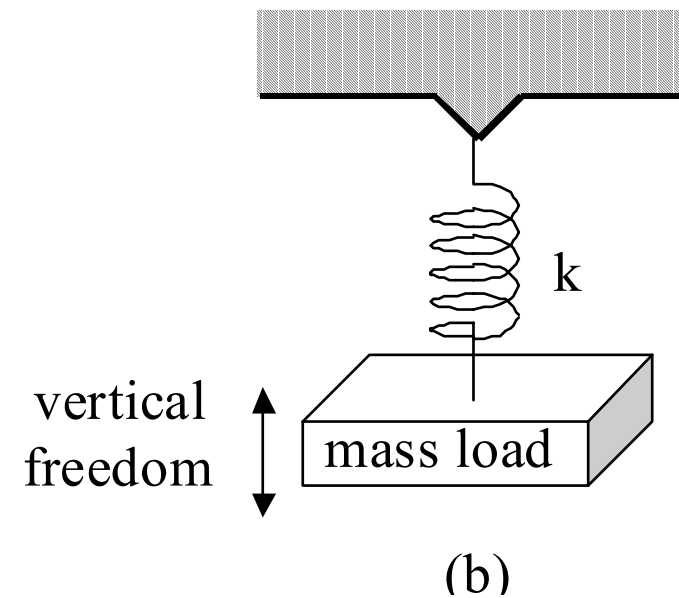
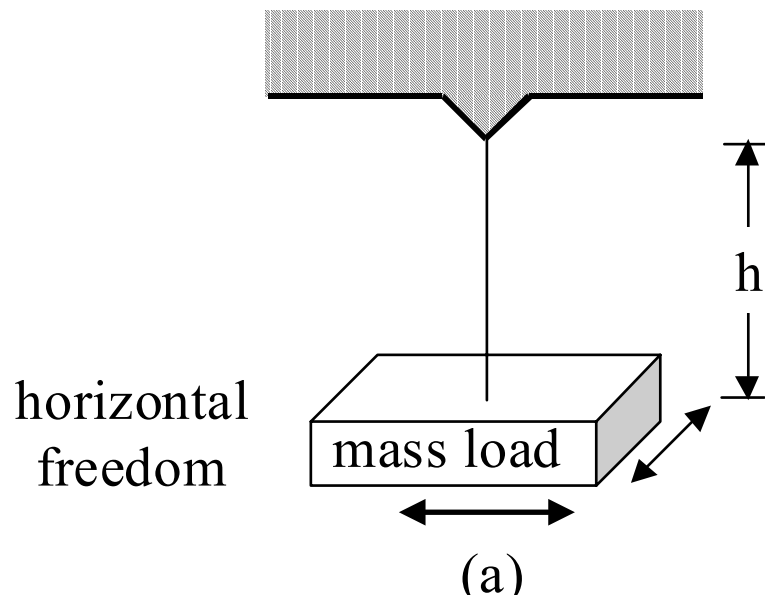


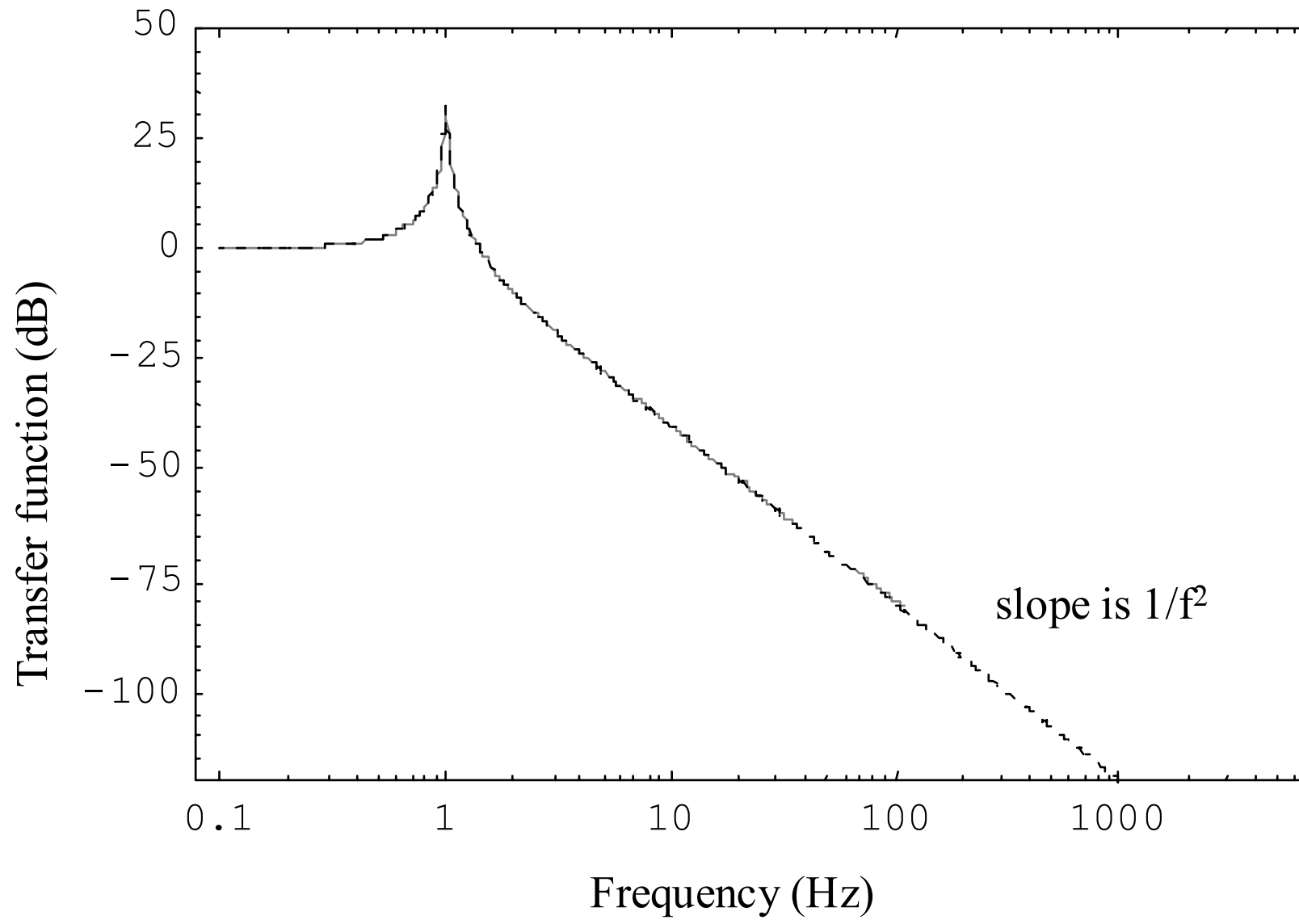
GW will cause shift of fringes in interference pattern

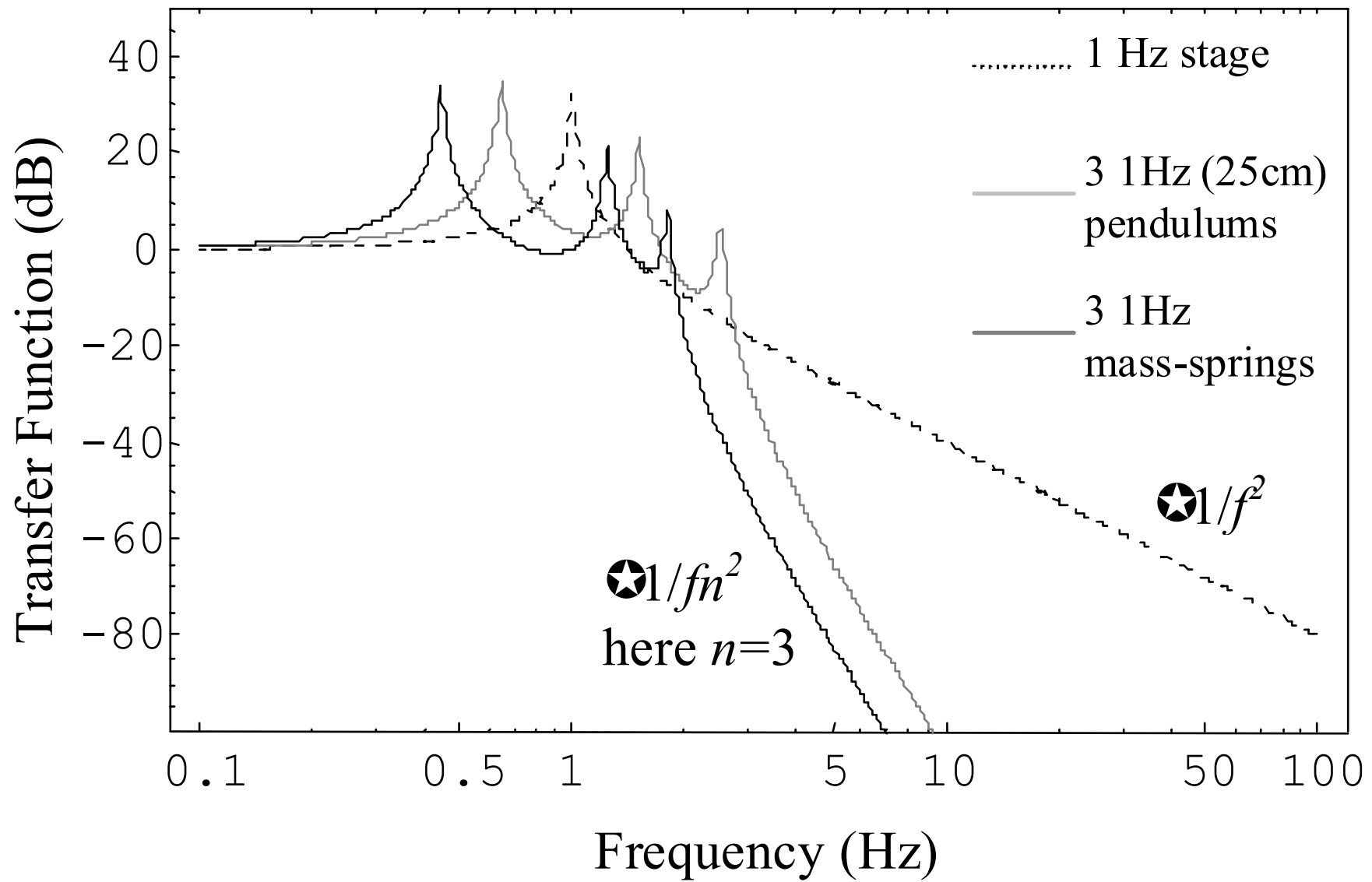
Need for Isolation

- **Need approximately 10 orders of magnitude of isolation!**
- **Need to reduce low frequency motion to facilitate job of control system in keeping the optical cavity locked.**

Vibration isolation





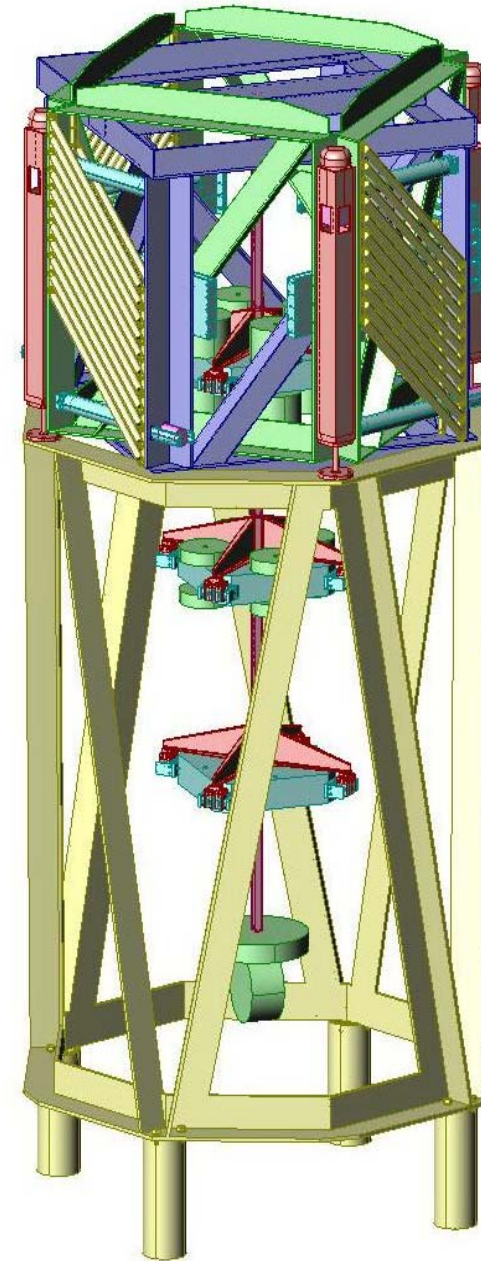
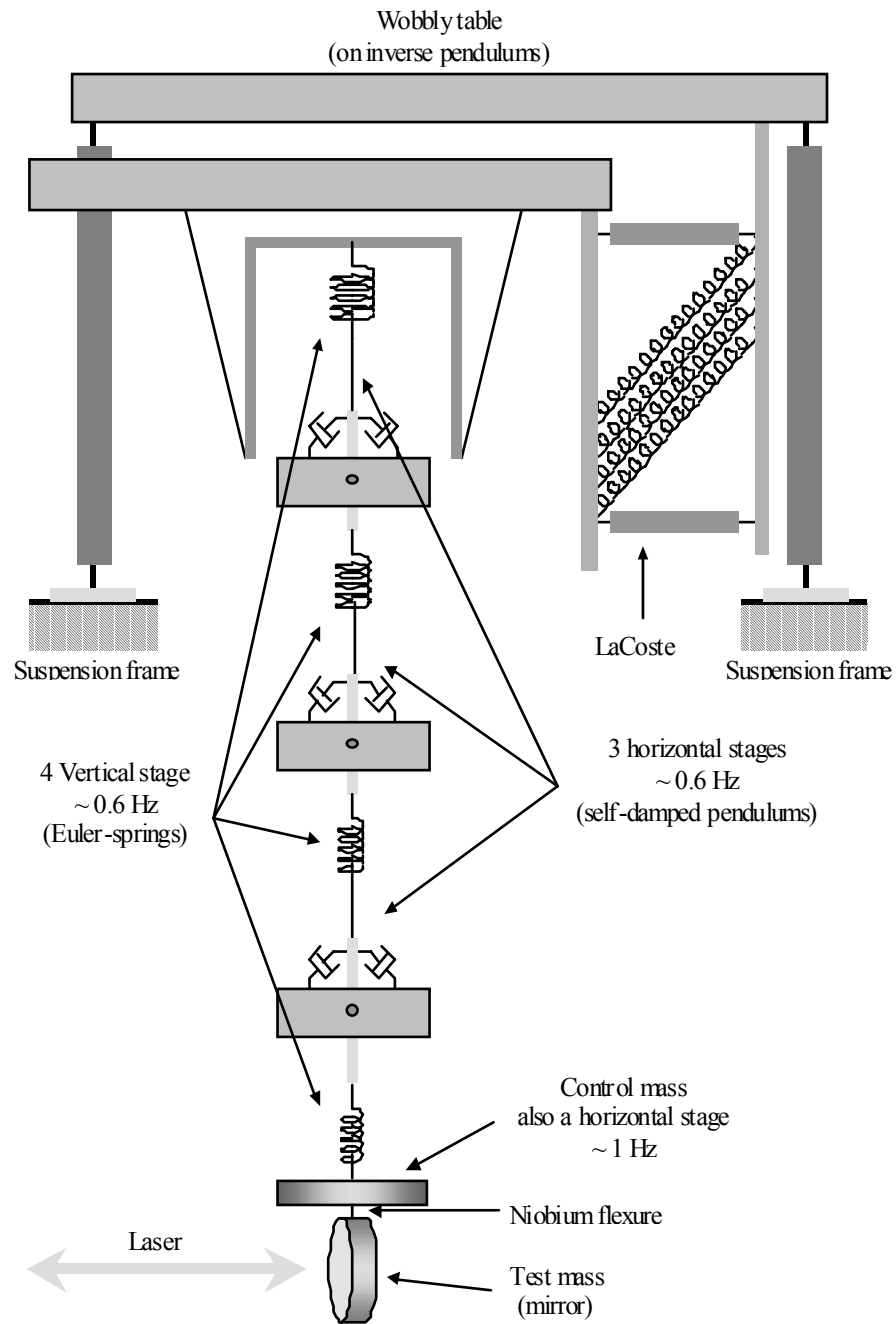


The Isolation Chain

Cascade stages to increases isolation

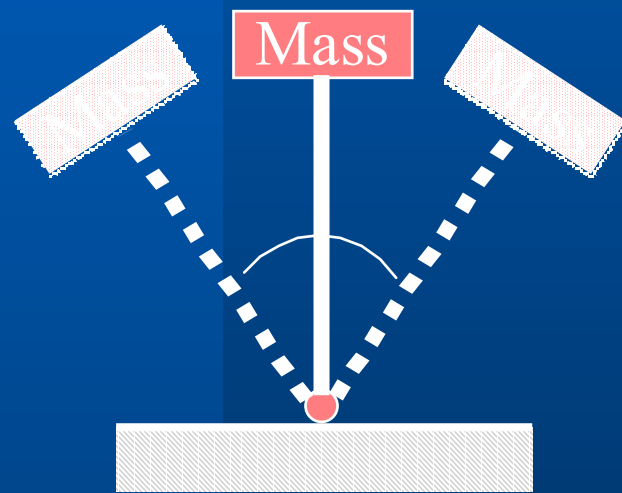
The components of the chain include:

- **An Ultra Low frequency pre-isolator**
 - “wobbly table” based on inverse pendulums (horizontal)
 - LaCoste Linkage (Vertical)
- **A Low-frequency Roberts linkage**
- **Three 3D isolation stages**

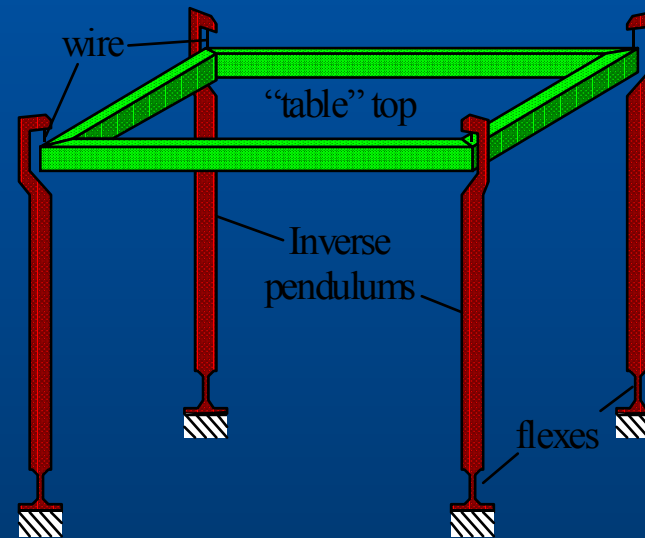


The Wobbly table

The “wobbly table” can be seen as a square table where each leg is an inverse pendulum

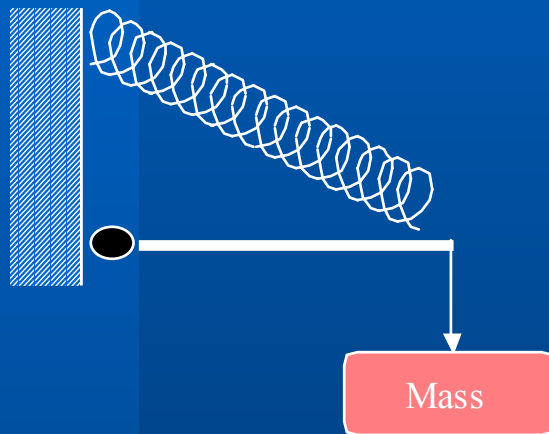


An Inverse Pendulum

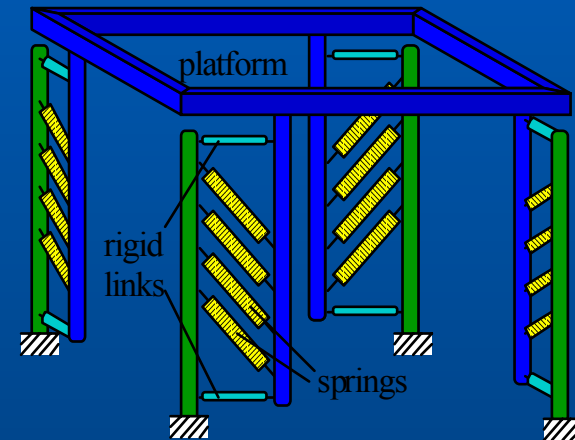


The wobbly table
Each leg is an inverse pendulum

The LaCoste Linkage



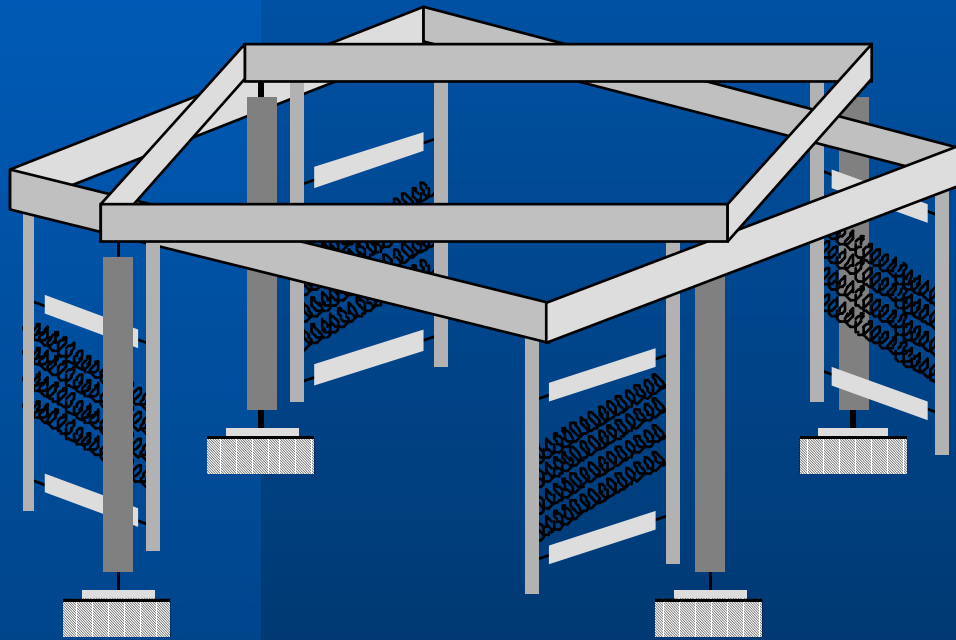
Simple LaCoste Linkage



Four LaCoste Linkage
on each leg of the wobbly
table

With careful tuning , can obtain very low frequencies
in the order of 0.05 Hz (20s period).

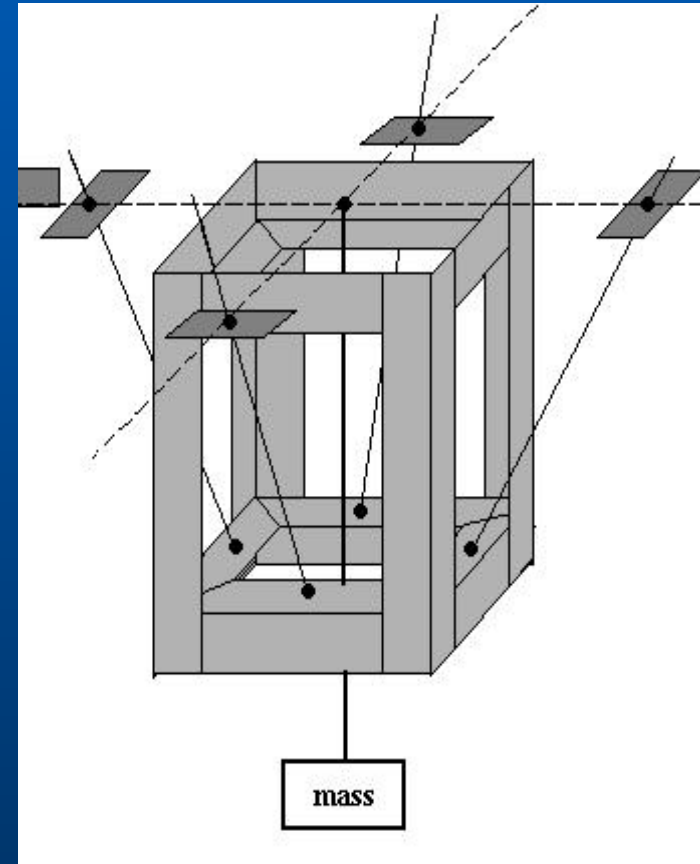
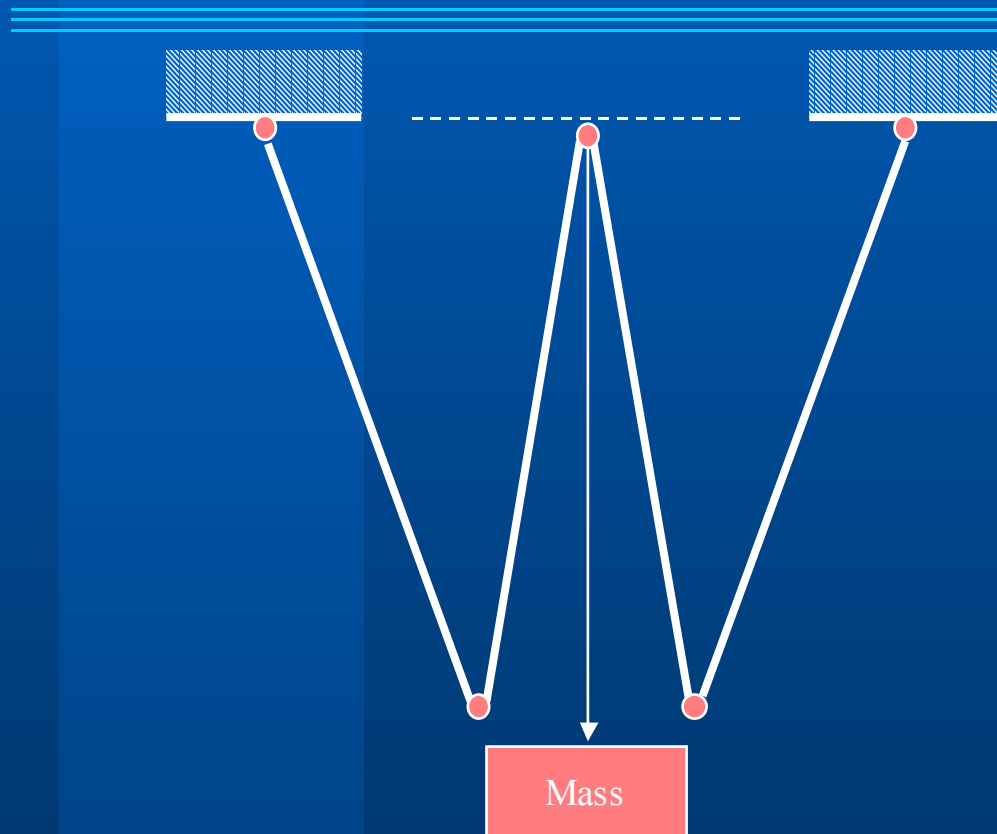
The pre-isolator



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The Roberts Linkage

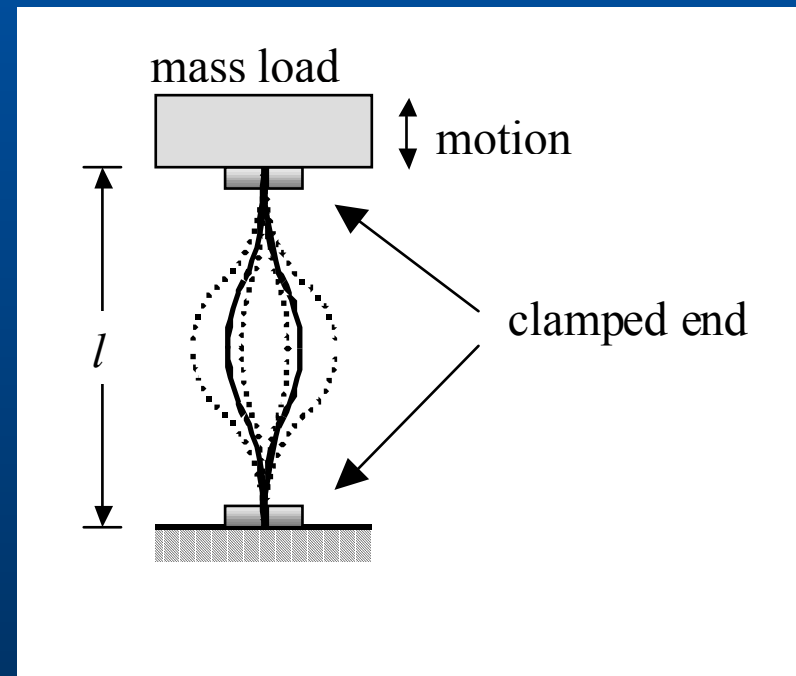


The 3D isolators

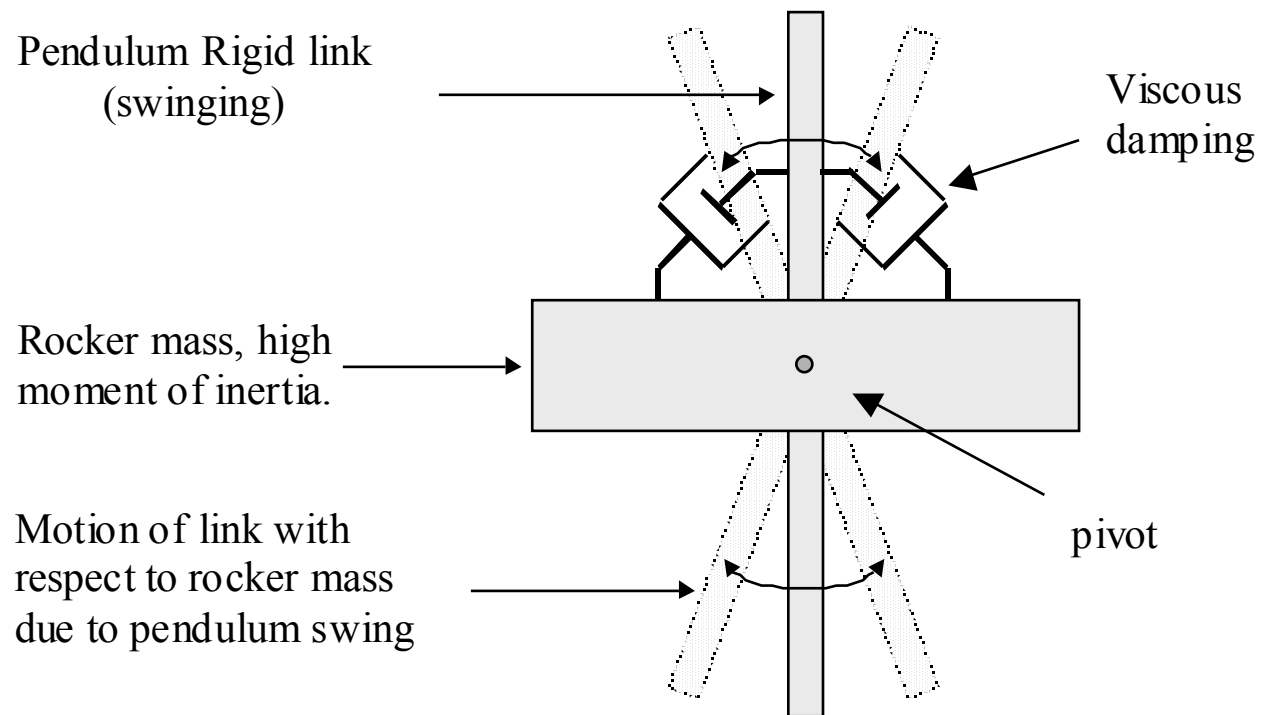
Combines a pendulum (horizontal) and a spring loaded suspension for next stage (vertical)

Vertical Isolation is achieved with Euler springs.

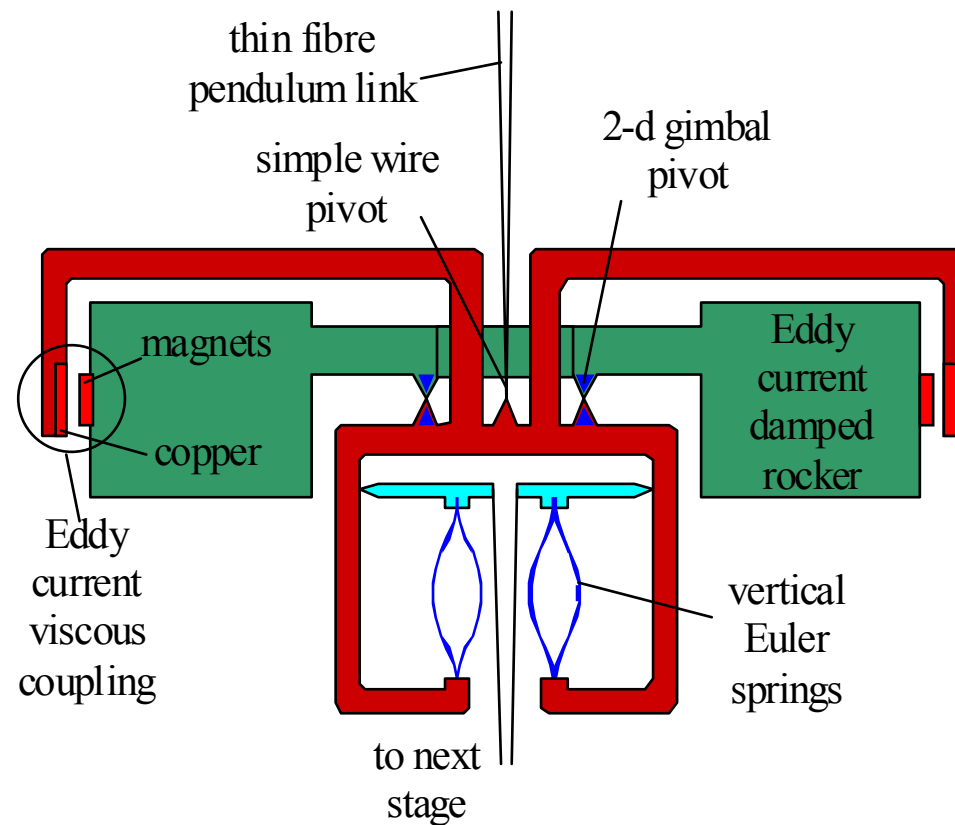
- Compressed up to buckling
- Behaves as a linear spring

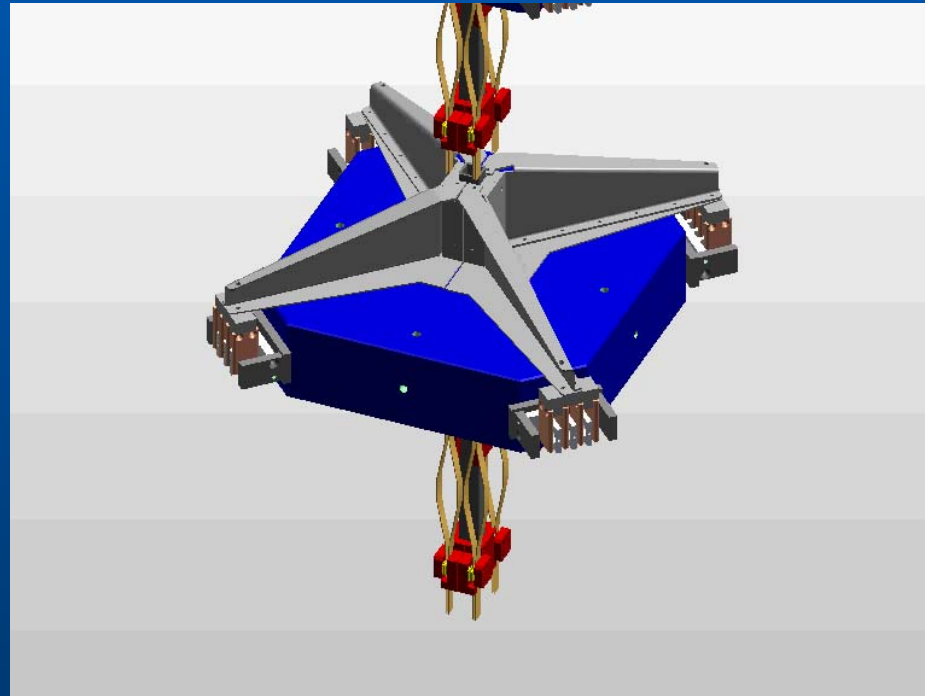


The Self Damped Pendulum



The self Damped pendulum



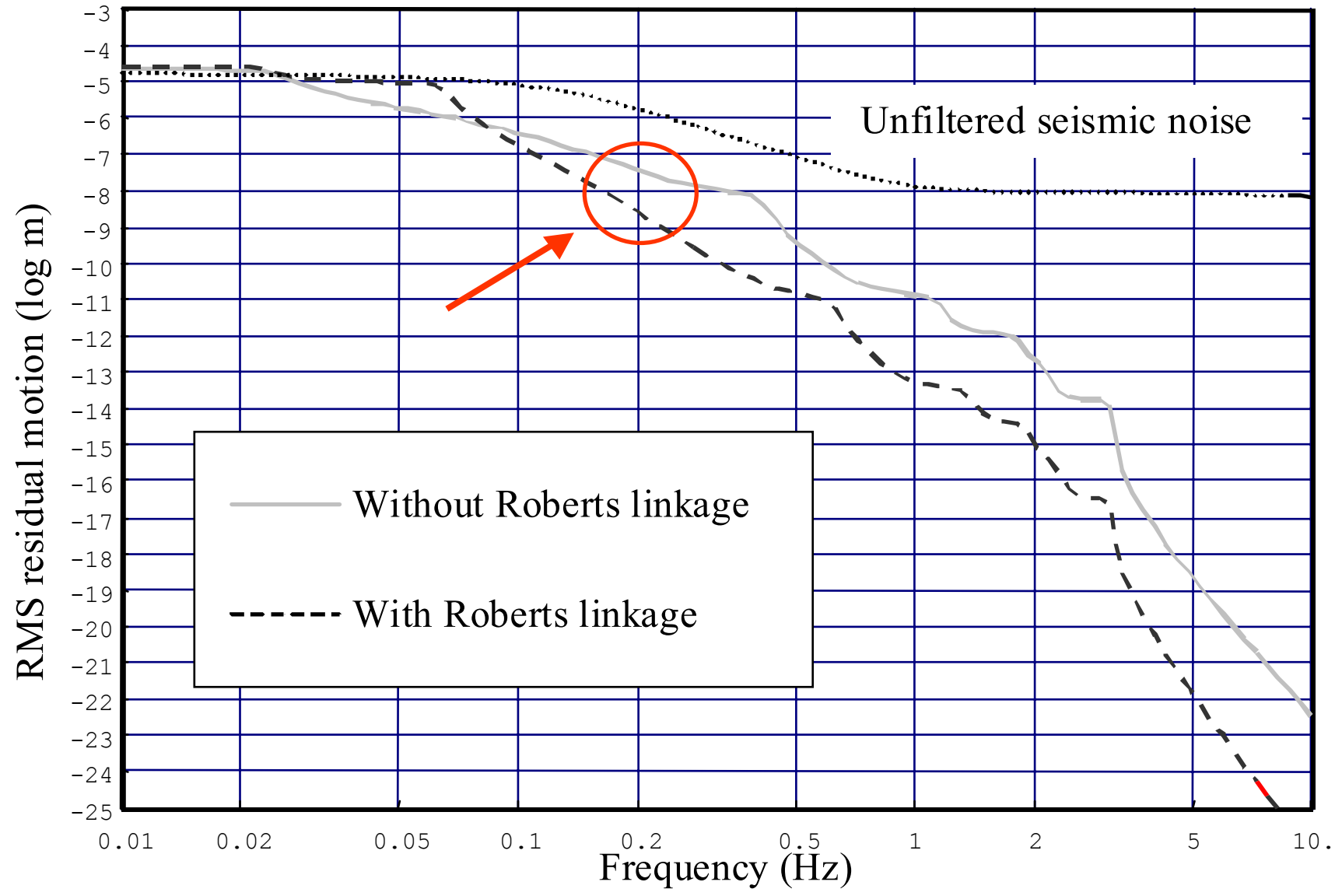


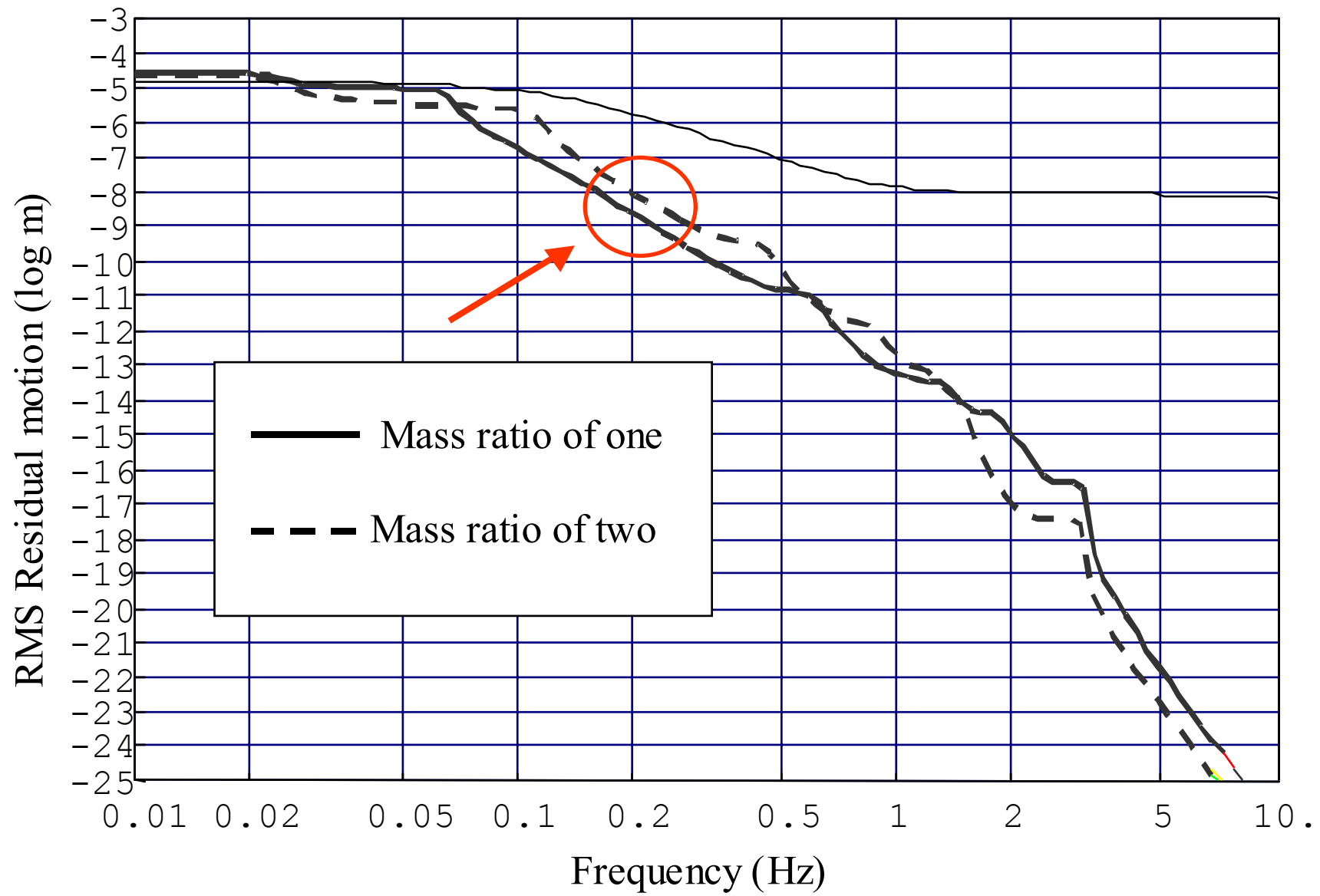
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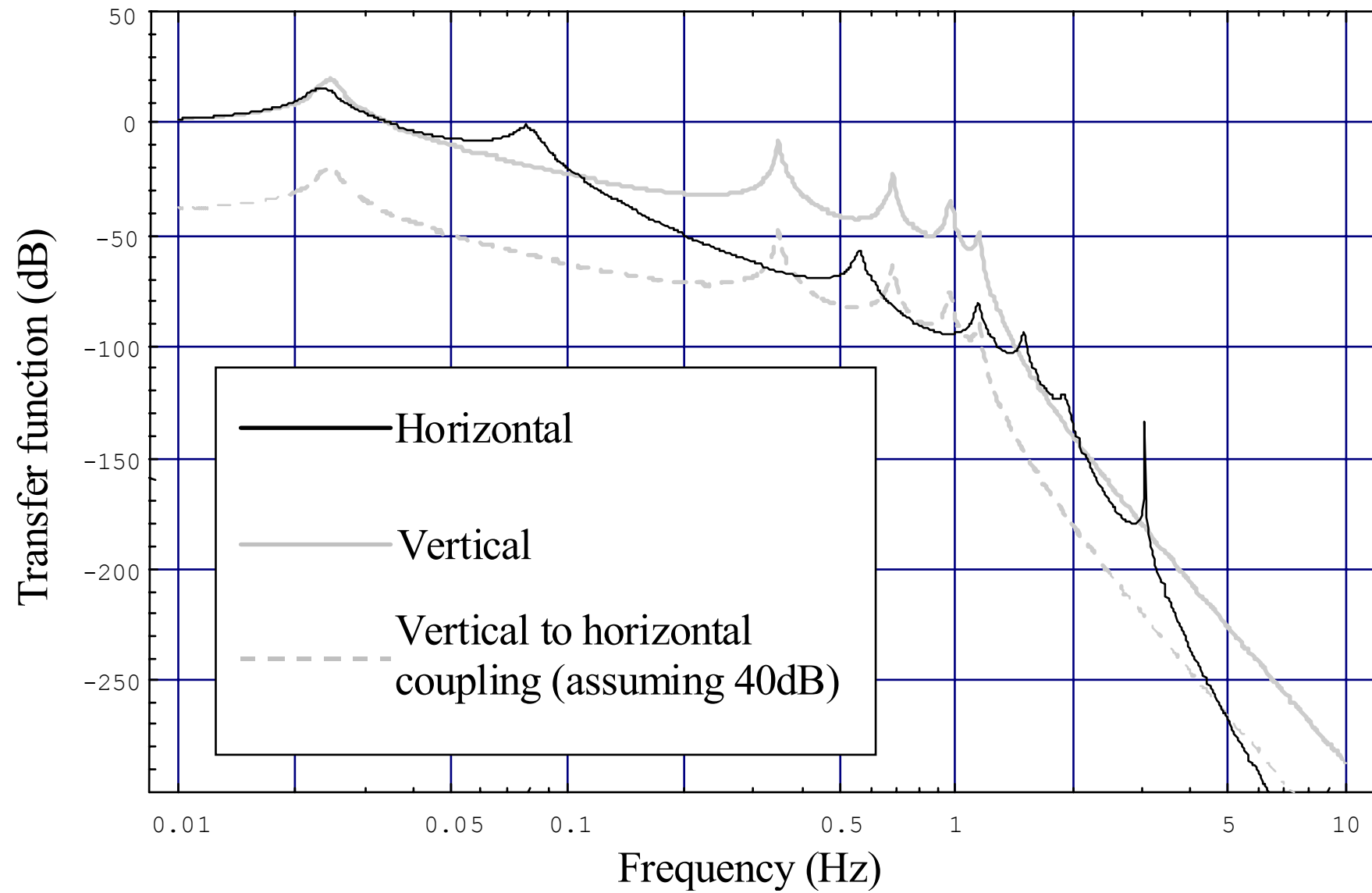
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Modelling

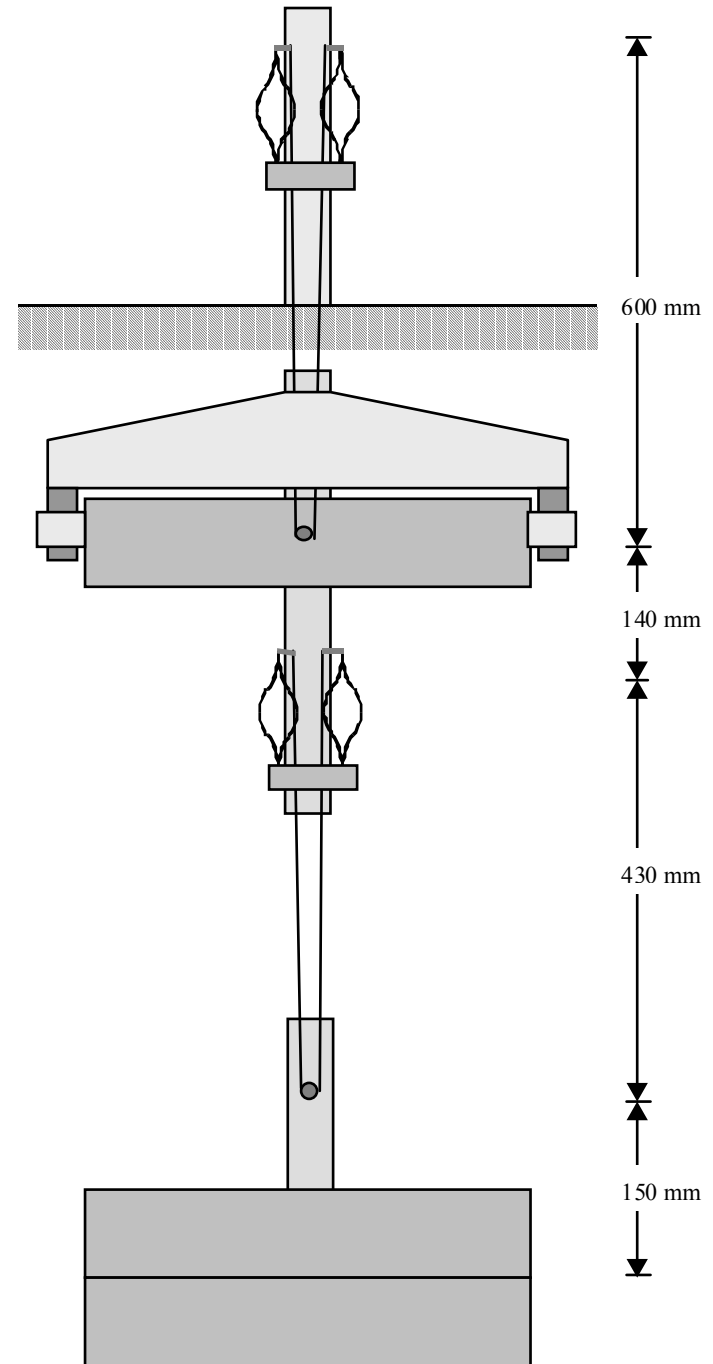
- > **Used model developed by Dr. John Winterflood of UWA**
- > **Test effect of second horizontal pre-isolation stage**
- > **Used to test different mass distribution**
Especially: compare mass ratio of 1
with mass ratio of two.

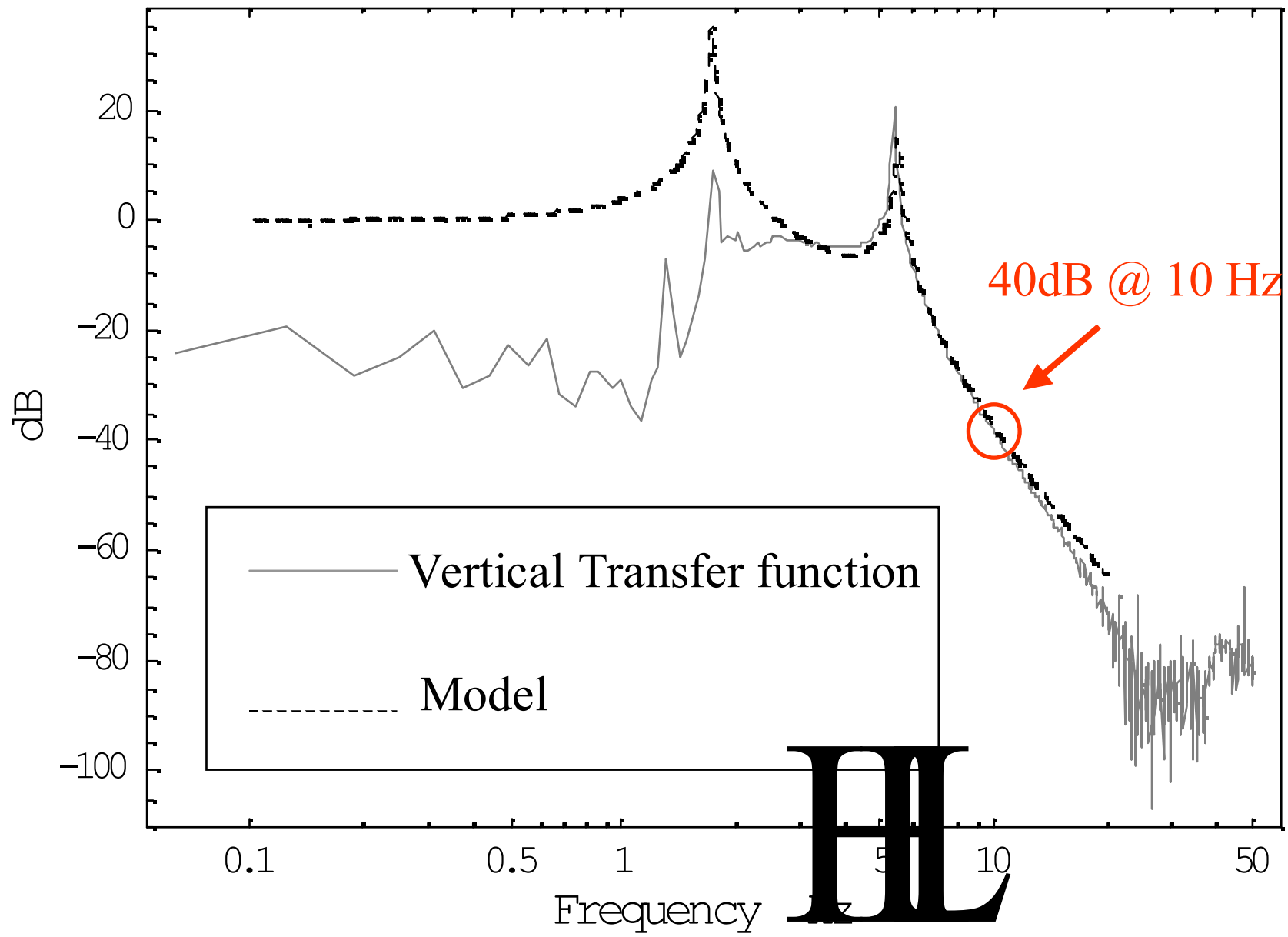


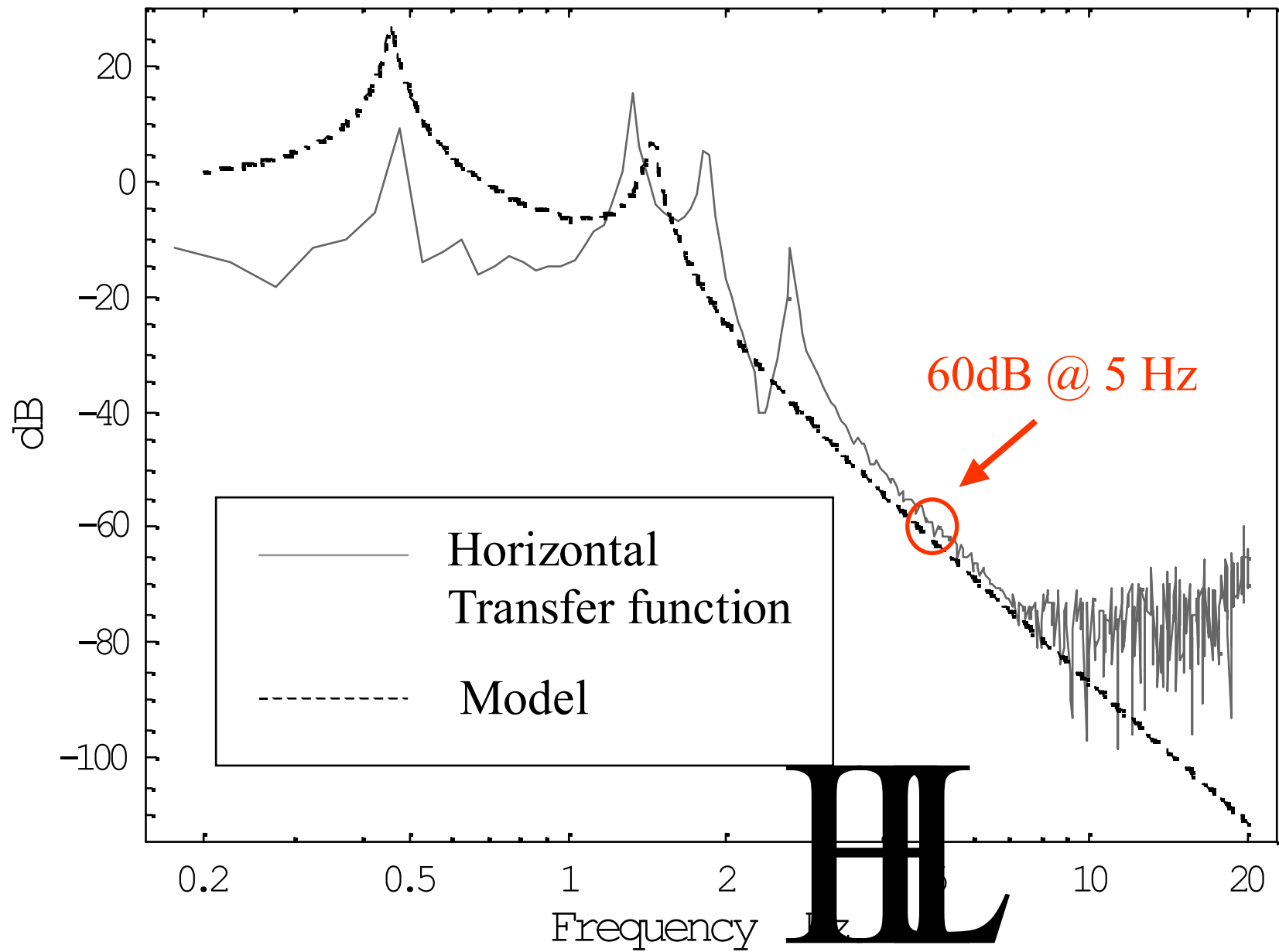




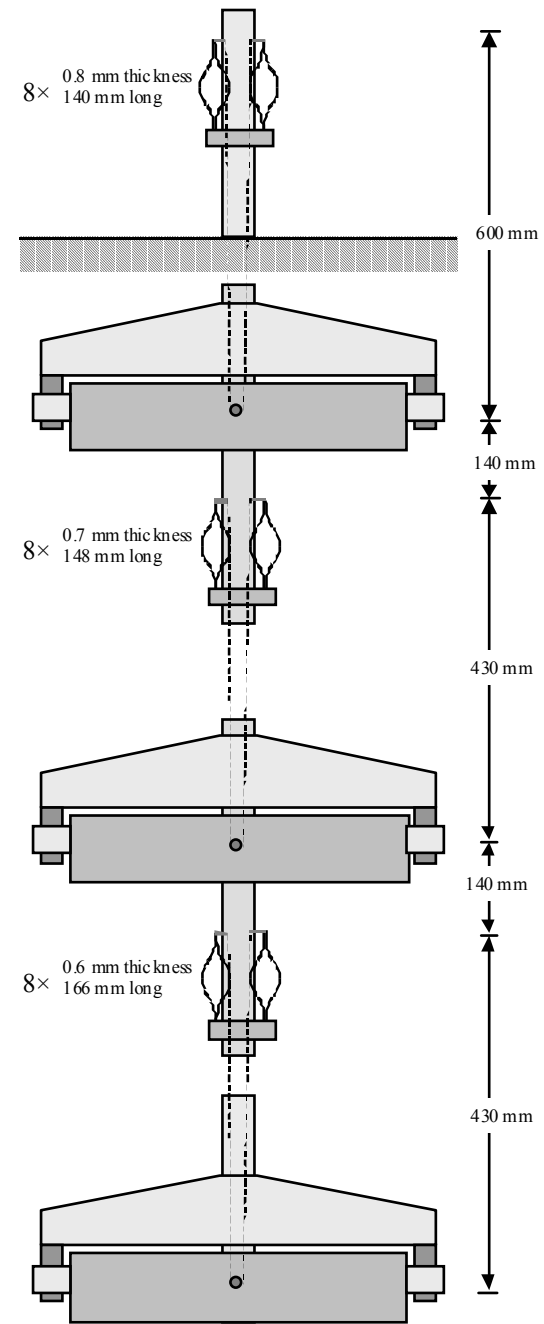
Testing of two-stage 3D isolator

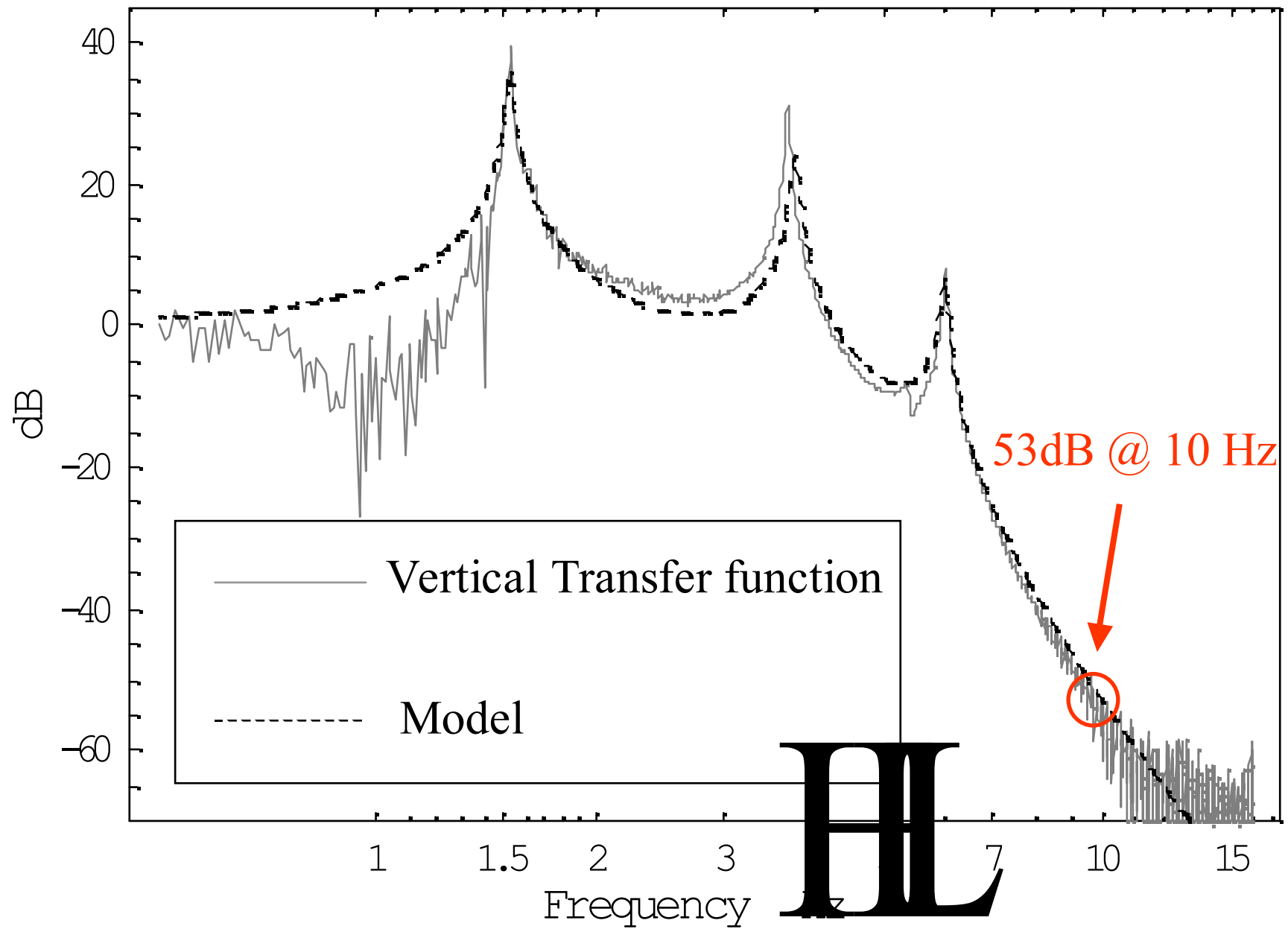


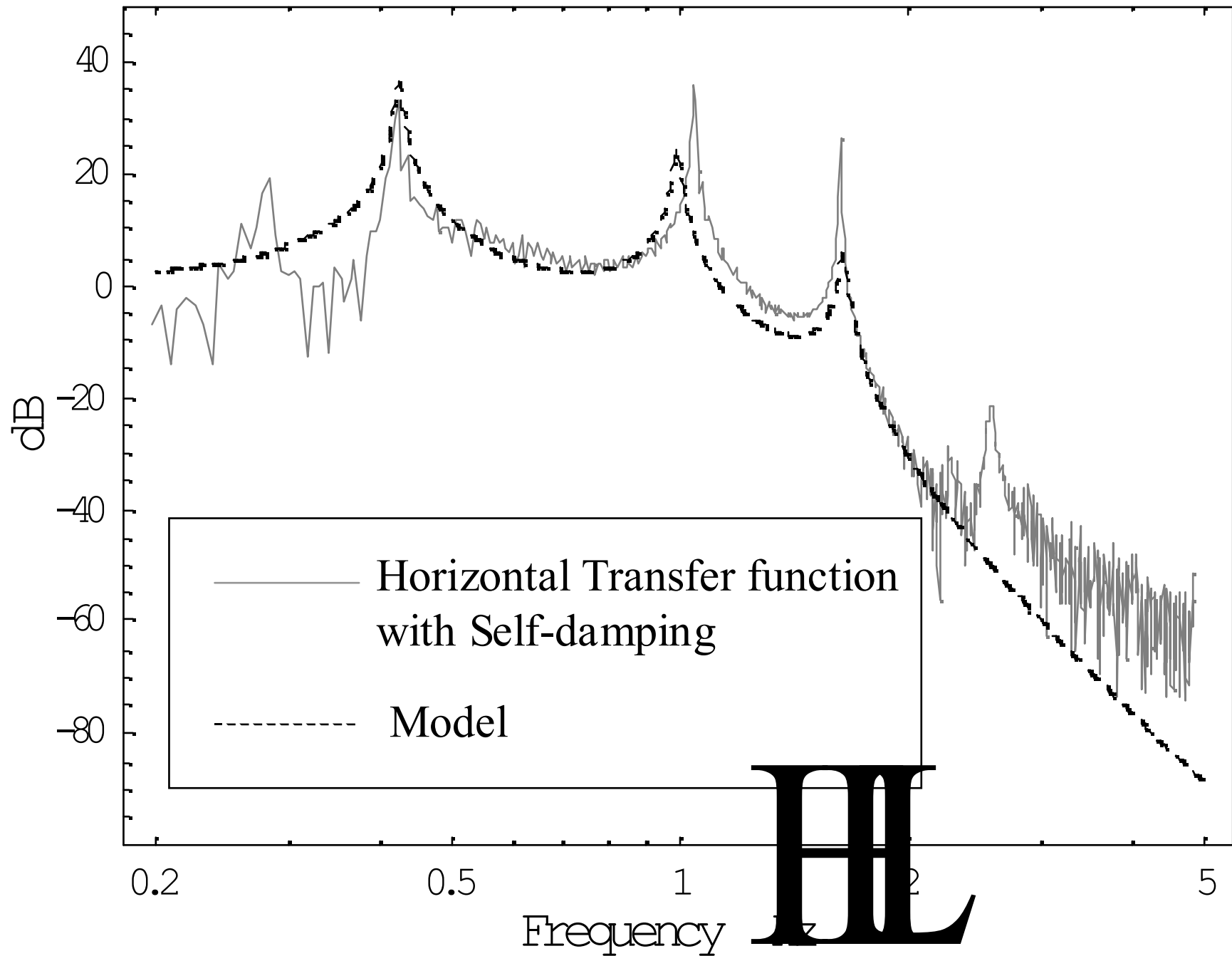


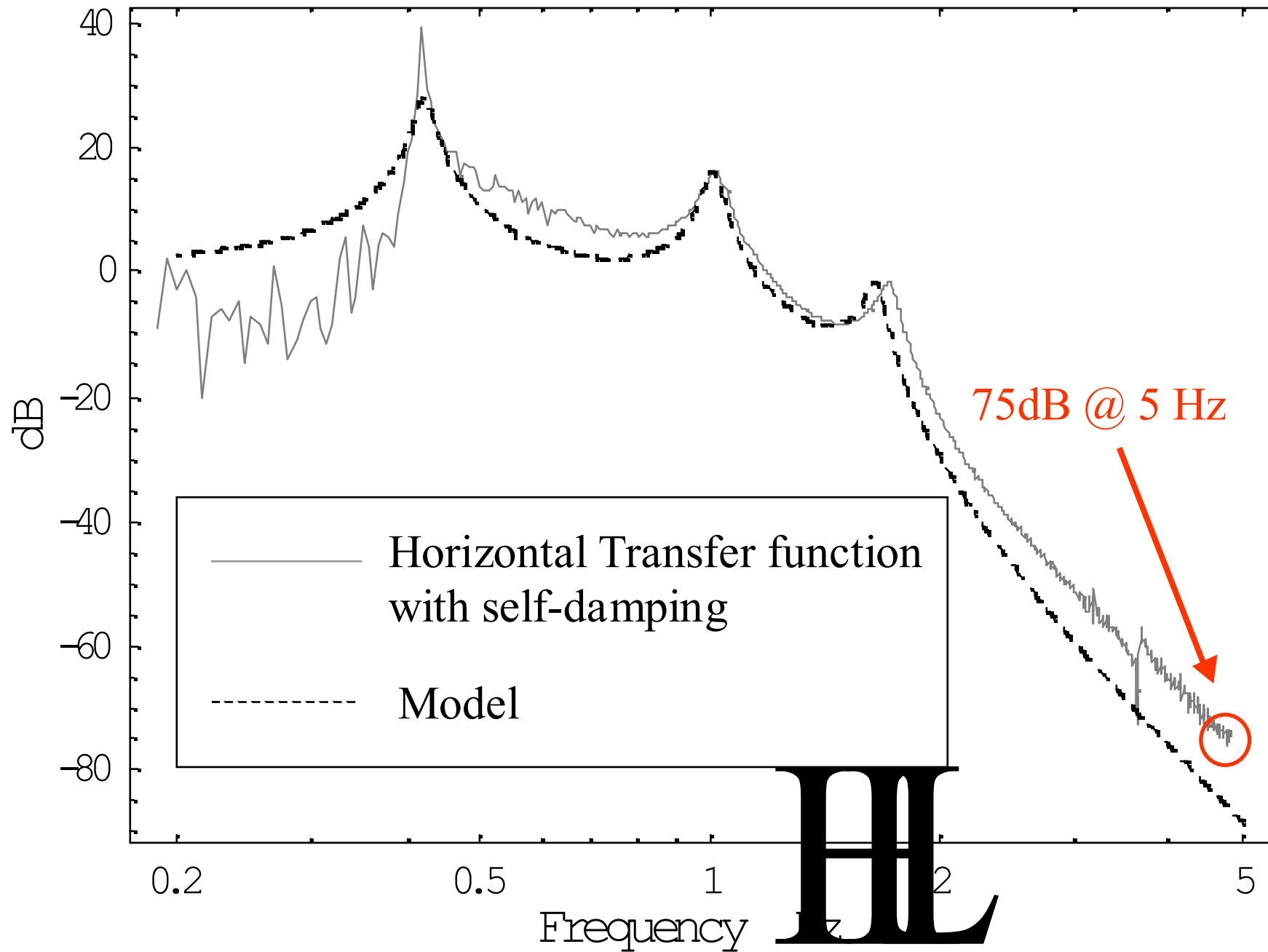


Testing of three-stage isolator









Tuning self damping

- **Problem: resonant frequency of rocker mass pivoting on flexure is lower than frequency of lower pendulum mode**
- **Lower frequency by adding weight on top of rocker mass
∴ Introduce some inverse pendulum effect**
- **Complicated by the fact that flexures are not symmetric, different resonant frequencies in X and Y direction.**

Q-values

Other way of optimising self-damping:

Make rocker mass motion almost critically damped

Number of copper plates	Q-value of the rocker mass
1	9.5
2	4.4
3	1.8
4	1.5
5	1.3
6	1.2

Conclusion

- **Robert Linkage is worth adding into chain**
- **Use mass ratio of 1 for lower stages**
- **Vertical Transfer functions are in close agreement with the model**
∴ Euler stages behave as expected
- **Self-Damping provides adequate damping for higher modes, but not the lowest one**

The End

Bonus animation:

