Update on eddy-current damping experiments

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LIGO-G030453-00-Z

Outline of talk

- Motivation for eddy-current damping
- Description of Glasgow experimental set-up
- Experimental results with comparison to MATLAB models
- Conclusions from ECD experiments
- Extension to Quadruple pendulums
- Further developments

Motivation

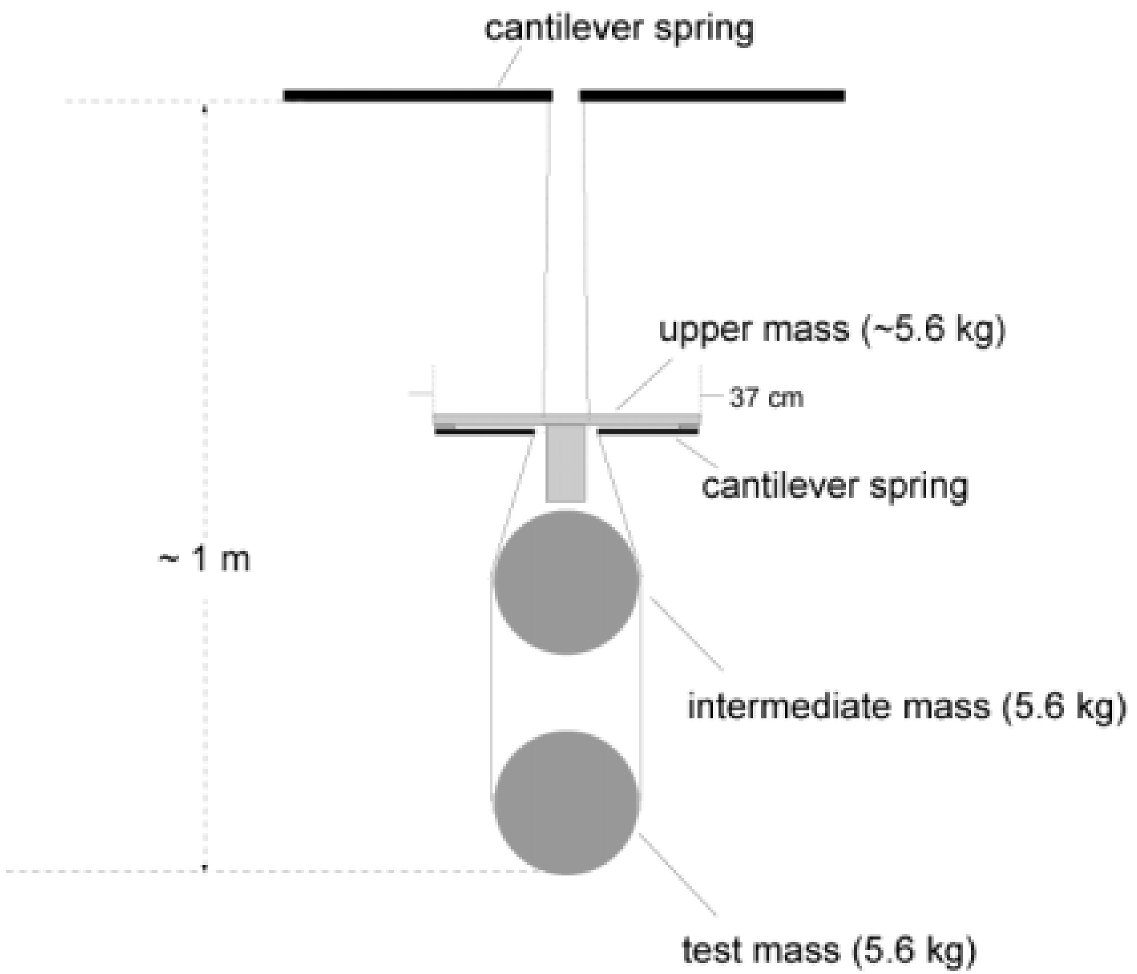
- Advanced LIGO suspensions have more stringent requirements on local control sensor noise
- Investigation of passive damping scheme:

  Eddy-current damping as a replacement or supplement to active damping for some or all of the modes of the pendulums
- Research program was set up to test eddy-current damping of a triple pendulum suspension in Glasgow

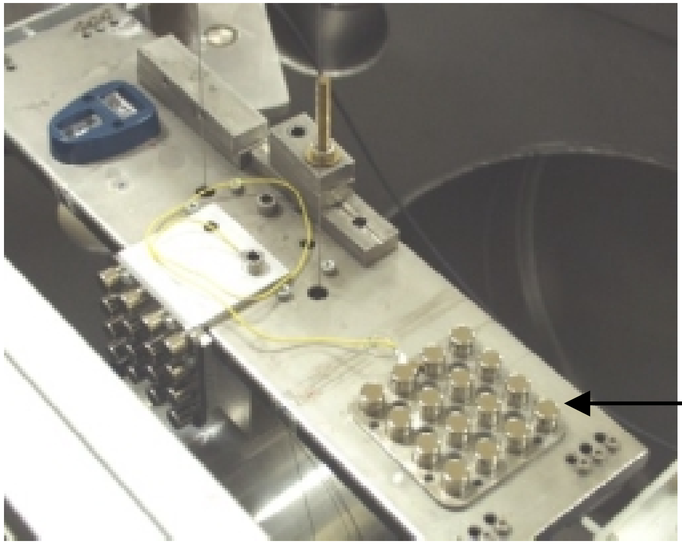
Background

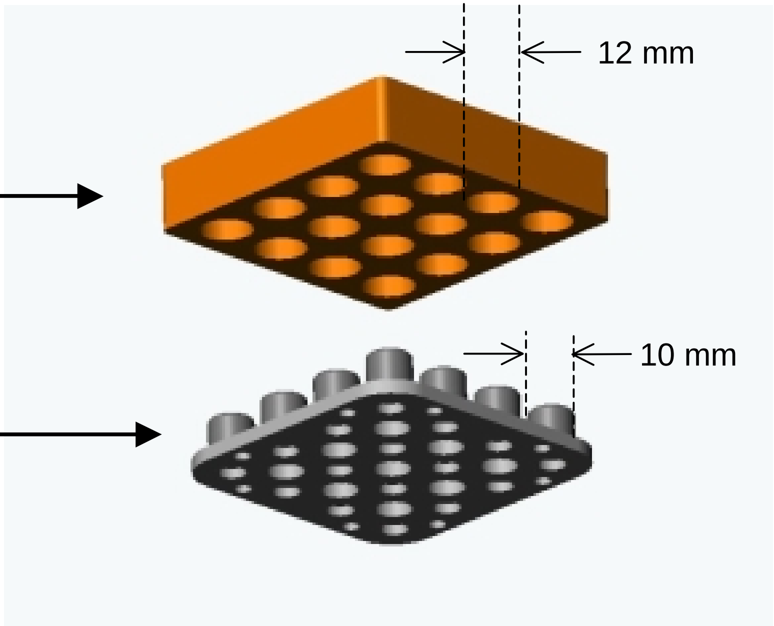
- A magnet moving inside a non-magnetic conductive tube has its motion retarded
- Retardation force is proportional to velocity of magnet- viscous damping
- Effectiveness of eddy current damping depends on the resistance of the current paths in the conductive material
  - Select high conductivity material in order to improve the damping $\longrightarrow$ Copper is the best choice from a performance/cost standpoint

Schematic of Glasgow prototype suspension:



Eddy Current Damping Tests at Glasgow

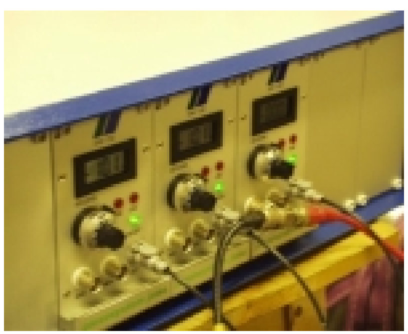


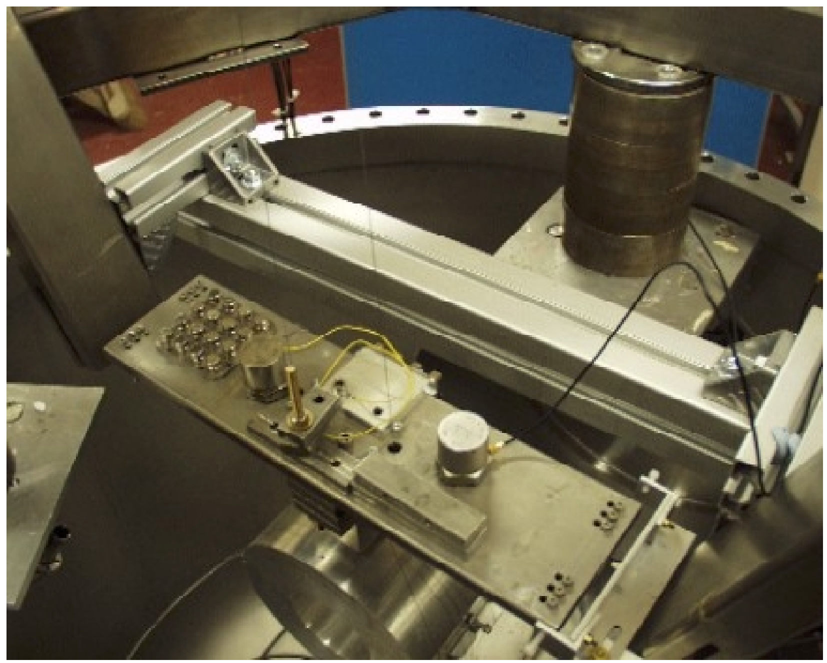


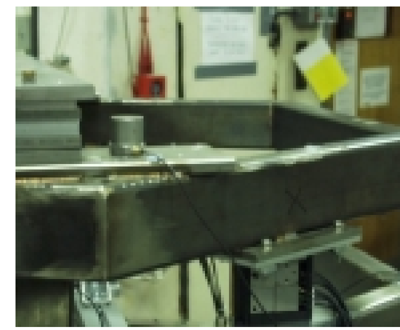
- Set up on Glasgow prototype triple pendulum
- Two 4x4 NdFeB magnet arrays mounted on uppermost mass for investigating vertical and longitudinal damping
- Magnet array moves within Cu block with corresponding array of holes

Final Set-up: Accelerometers in place

- Each actuator is connected up to an individual driver
- Two accelerometers used in the test: one on the upper mass, the the other on the support structure (‘ground’)

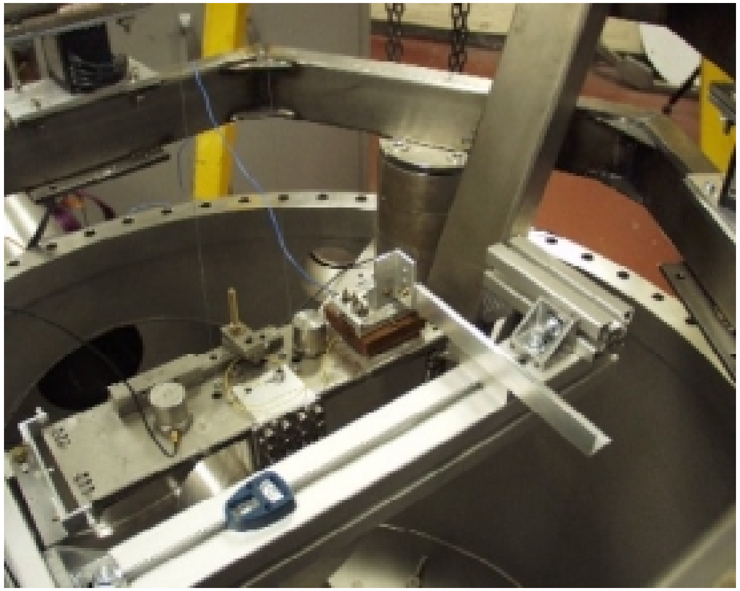


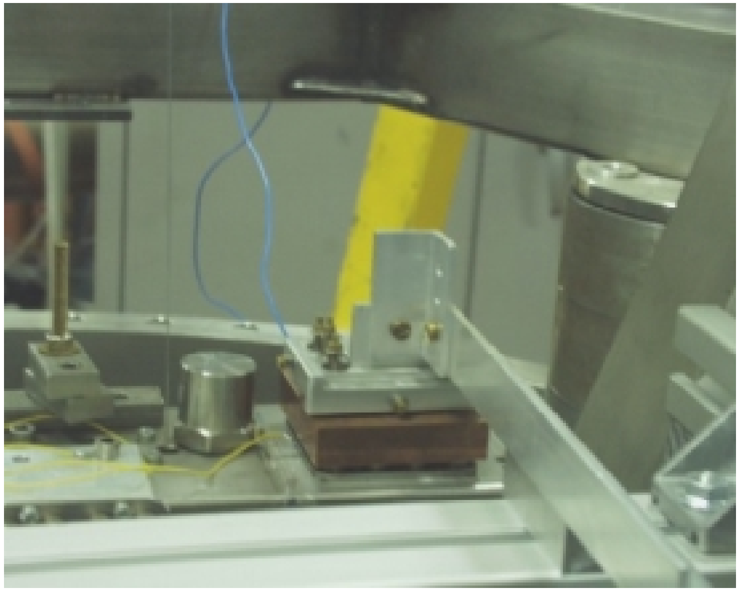




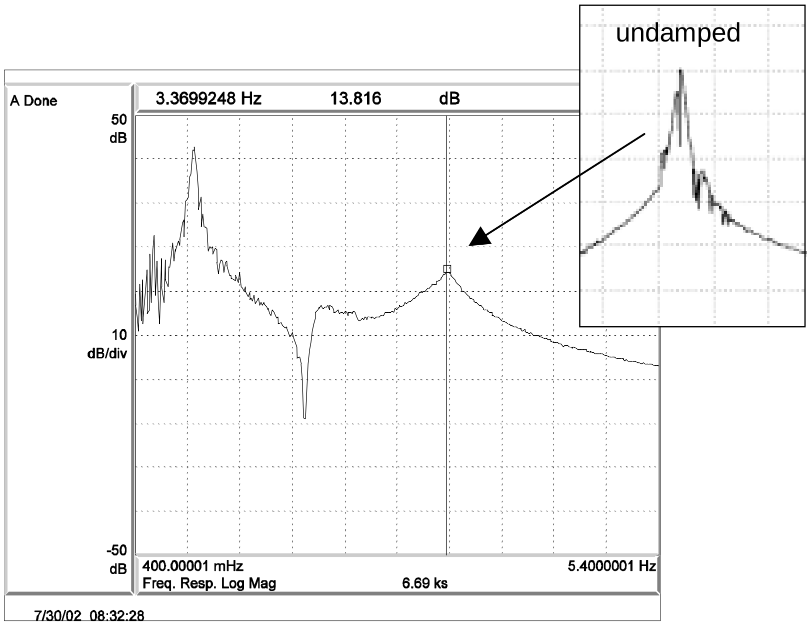
Vertical Damping test

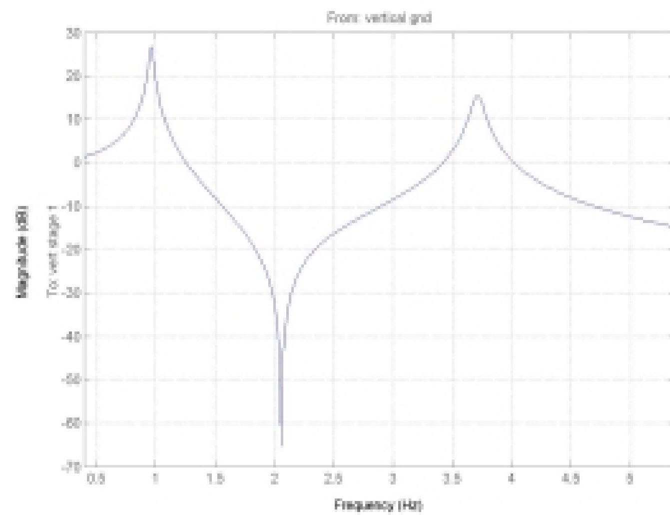
- First eddy current damper installed above upper mass





Vertical transfer function





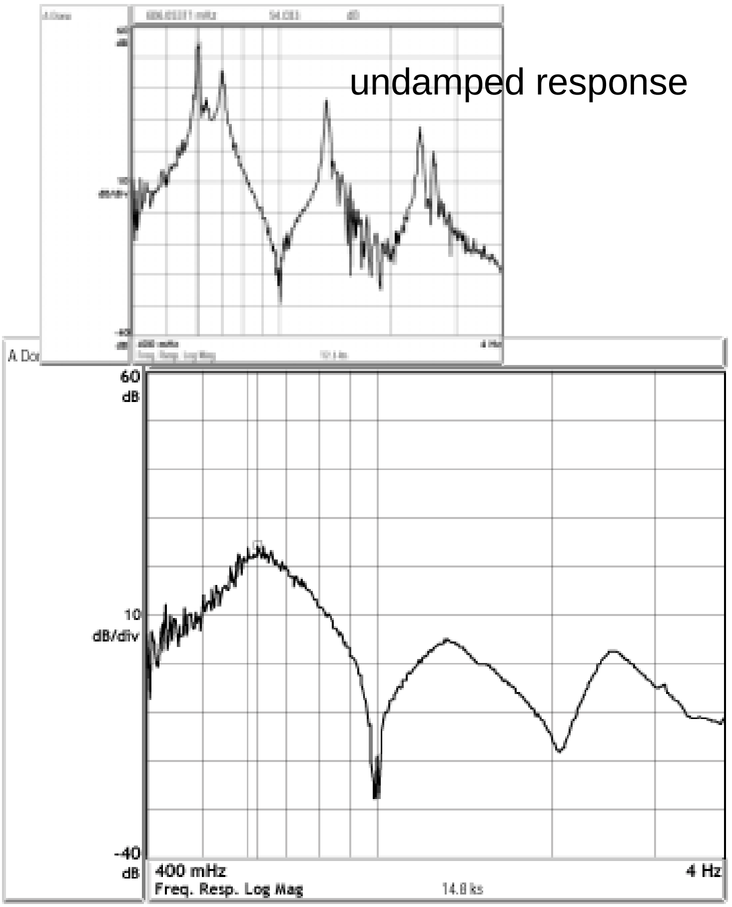
Experimental results

MATLAB Model

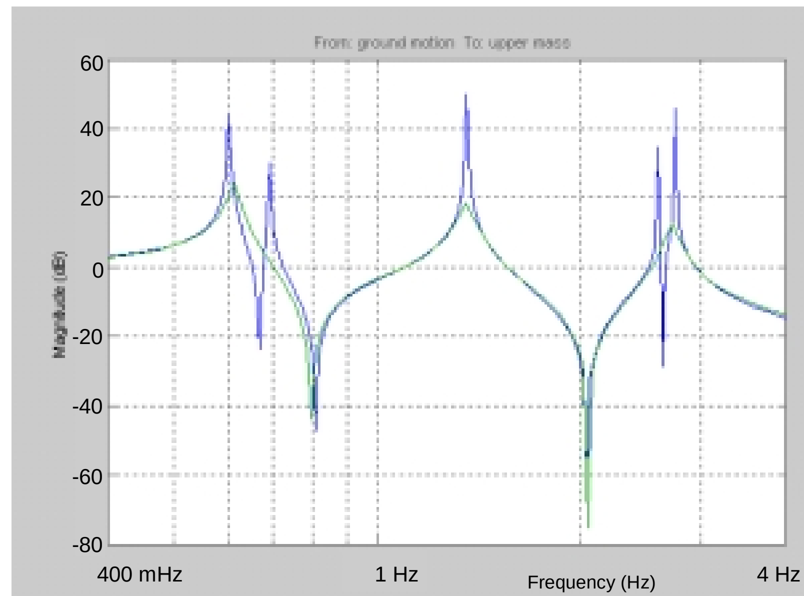
Upper peak: Two modes close together (vertical and pitch)

Longitudinal transfer function

undamped response



Blue curve-undamped response
Green curve-damped response (b~6 kg/s)



Experimental results

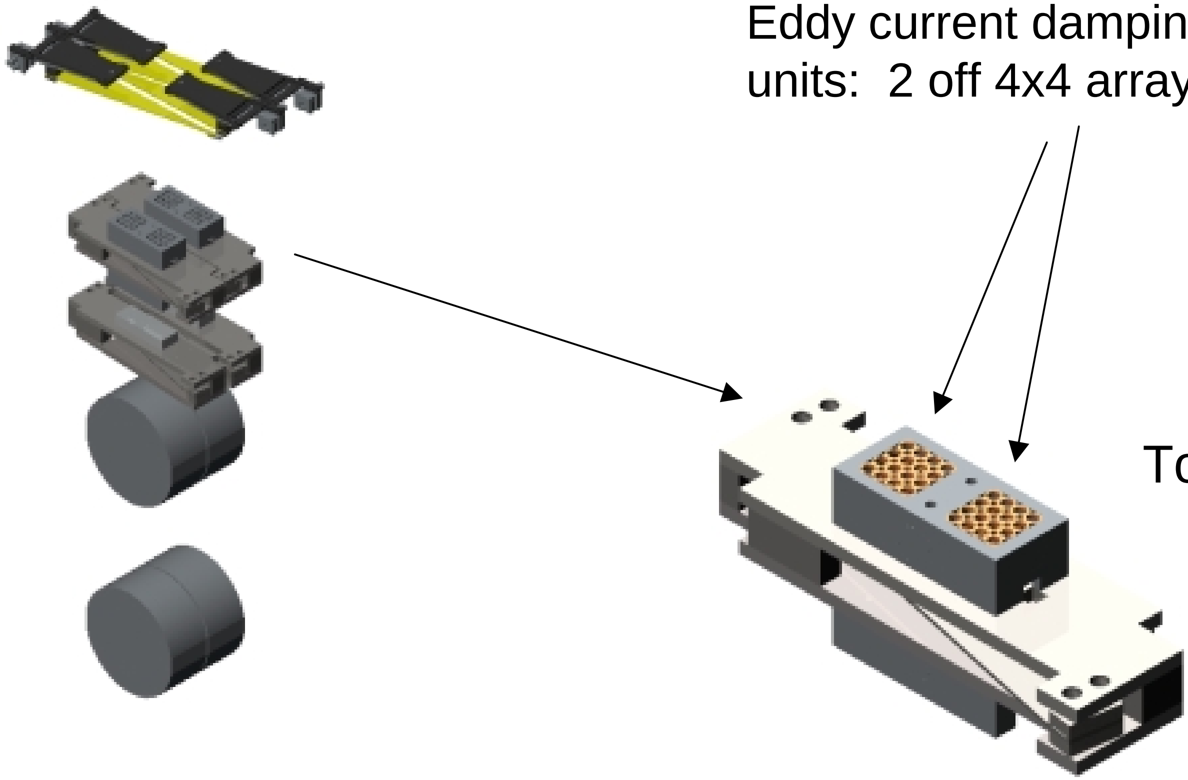
MATLAB Model

Conclusions from ECD experiments

- A damping constant of 5.4 ± 0.5 kg/s (for a single array) was estimated fom these results
- This compares favourably to the value calculated from basic theory (assuming that the wall thickness is thin compared to the other radial dimensions)
- First results + modeling indicate triple pendulums can be adequately damped using eddy currents
  - modecleaners with single arrays
  - heavier recycling mirrors with ~ 3 such arrays
- Quadruple pendulum requires damping force ~ 25 times a single array

ECD of Quadruple Pendulum

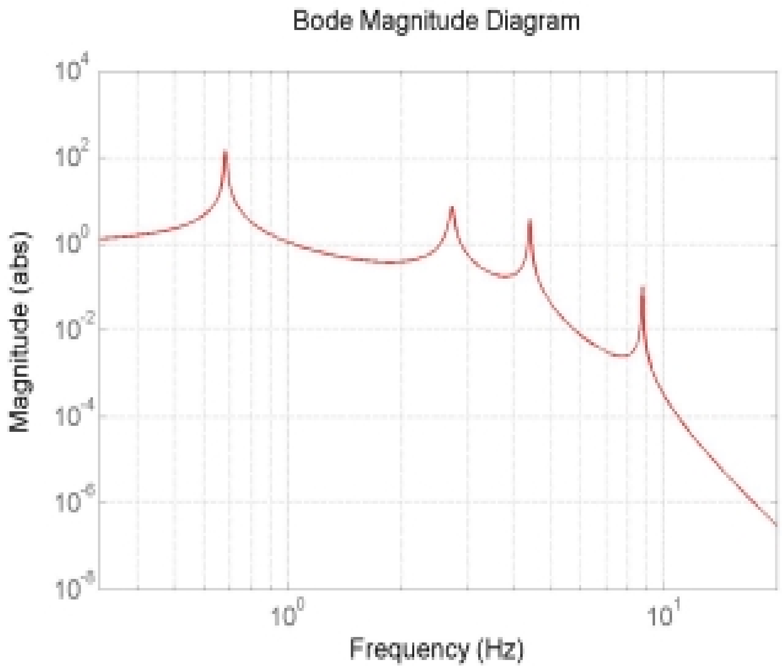
Eddy current damping (ECD)
units: 2 off 4x4 arrays

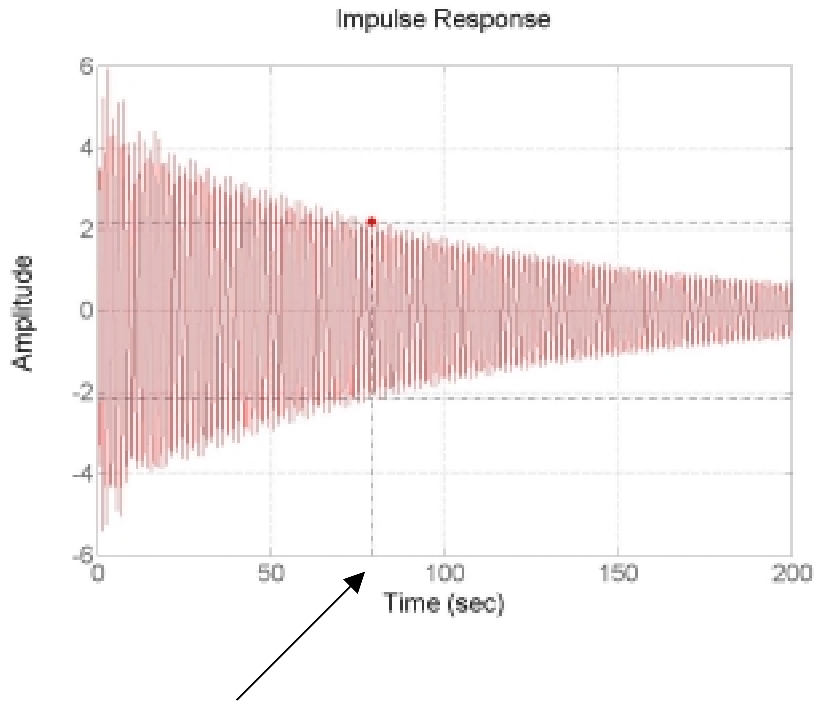


Top mass

Diagrams from C Torrie / M Perreur-Lloyd

VTF and Impulse Response with ECD (2 units)





Decay time to 1/e: ~80 secs

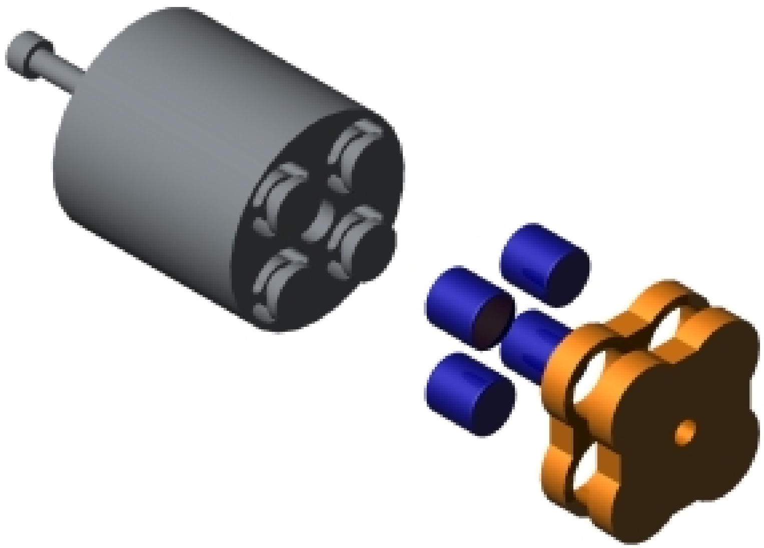
Norna Robertson

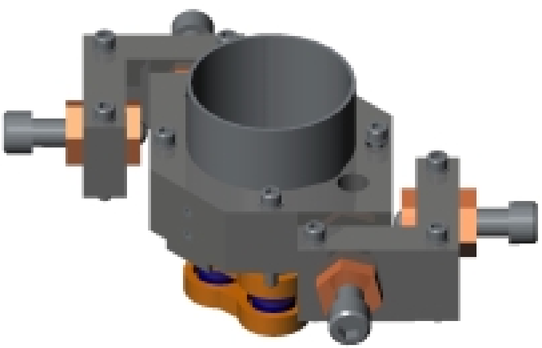
Further developments:

- Mounting magnets on support will reduce potential coupling to external magnetic fields (earth's field and other fields eg. from isolation table actuators)
- Optimise geometry of magnet array/copper block to:
  - Minimise excess mass of copper material in block (important consideration for quad suspension)
  - Allow accurate alignment of Cu unit/magnet array

Revised lightweight design with adjuster

2x2 array eddy current damper assembly- for a single pendulum test suspension at CALTECH





‘Olympic Ring’
design

Calum Torrie, Mark Barton