Update on Activities in Suspensions for Advanced LIGO

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LSC meeting, Hanford, Aug 20th 2002
(Plenary Instrument Science Session)

DCC Number: LIGO-G020333-00-Z

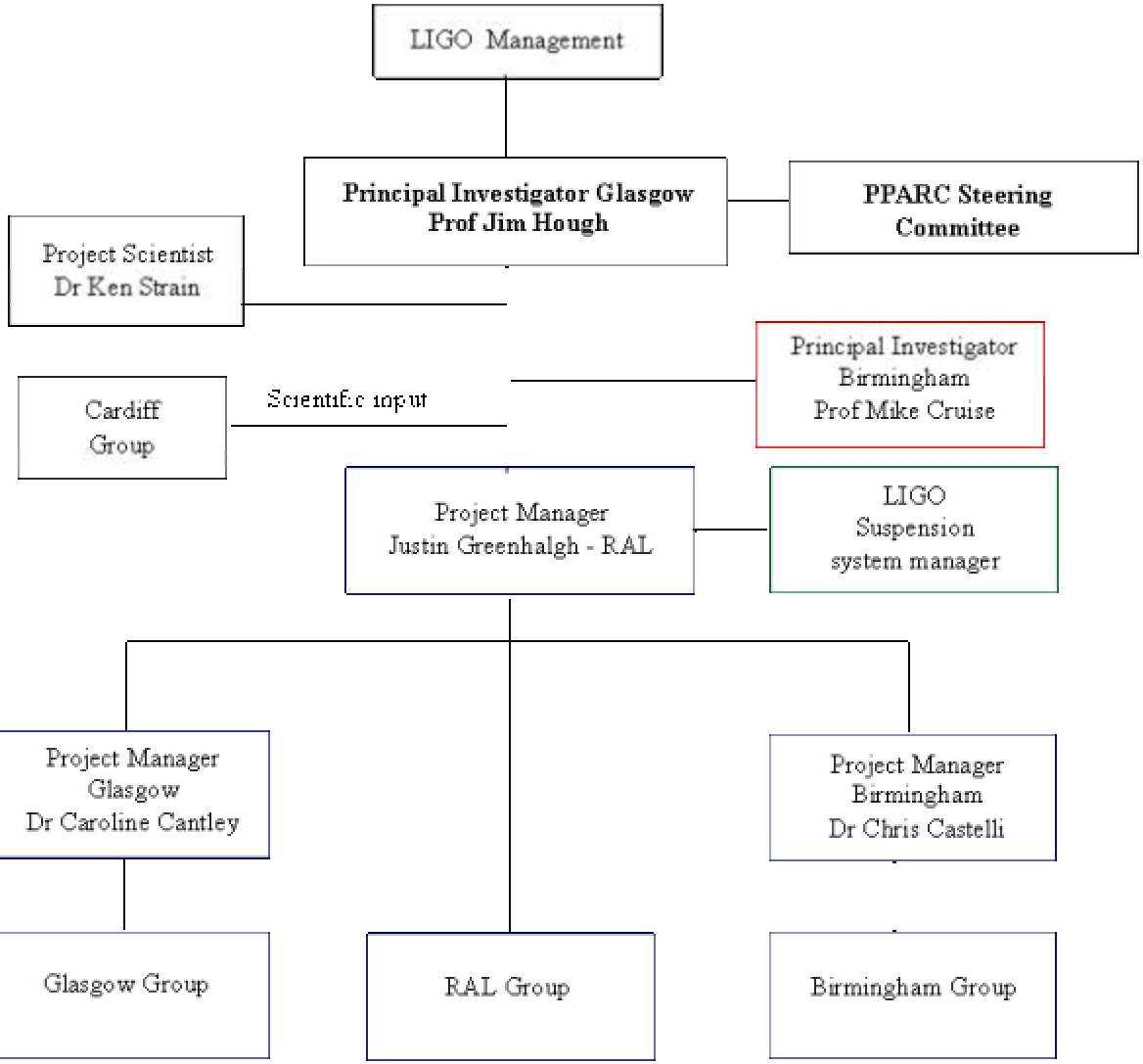
Summary of Topics

- GEO (UK) PPARC proposal for funding for Advanced LIGO
- Quadruple pendulum design update – with particular reference to low-frequency cut-off
- Active and eddy current damping of suspensions

GEO (UK) PPARC Proposal for Advanced LIGO

- Proposal for funding submitted to Particle Physics and Astronomy Research Council (PPARC) for contribution to Advanced LIGO
- Total requested ~ £ 8.8 million, (~$12M) to supply Advanced LIGO with
  - Technologically advanced suspension systems based on GEO designs
  - Electronic sensing/actuation systems for control
  - Sapphire blanks for test masses for one interferometer
- Builds on UK experience in gravitational waves research and in particular in GEO
- Directly involves several UK groups
  - Glasgow University
  - Rutherford Appleton Laboratory (RAL)
  - Birmingham University

PPARC Proposal: Organisational Plan



PPARC Proposal: Roles of Groups

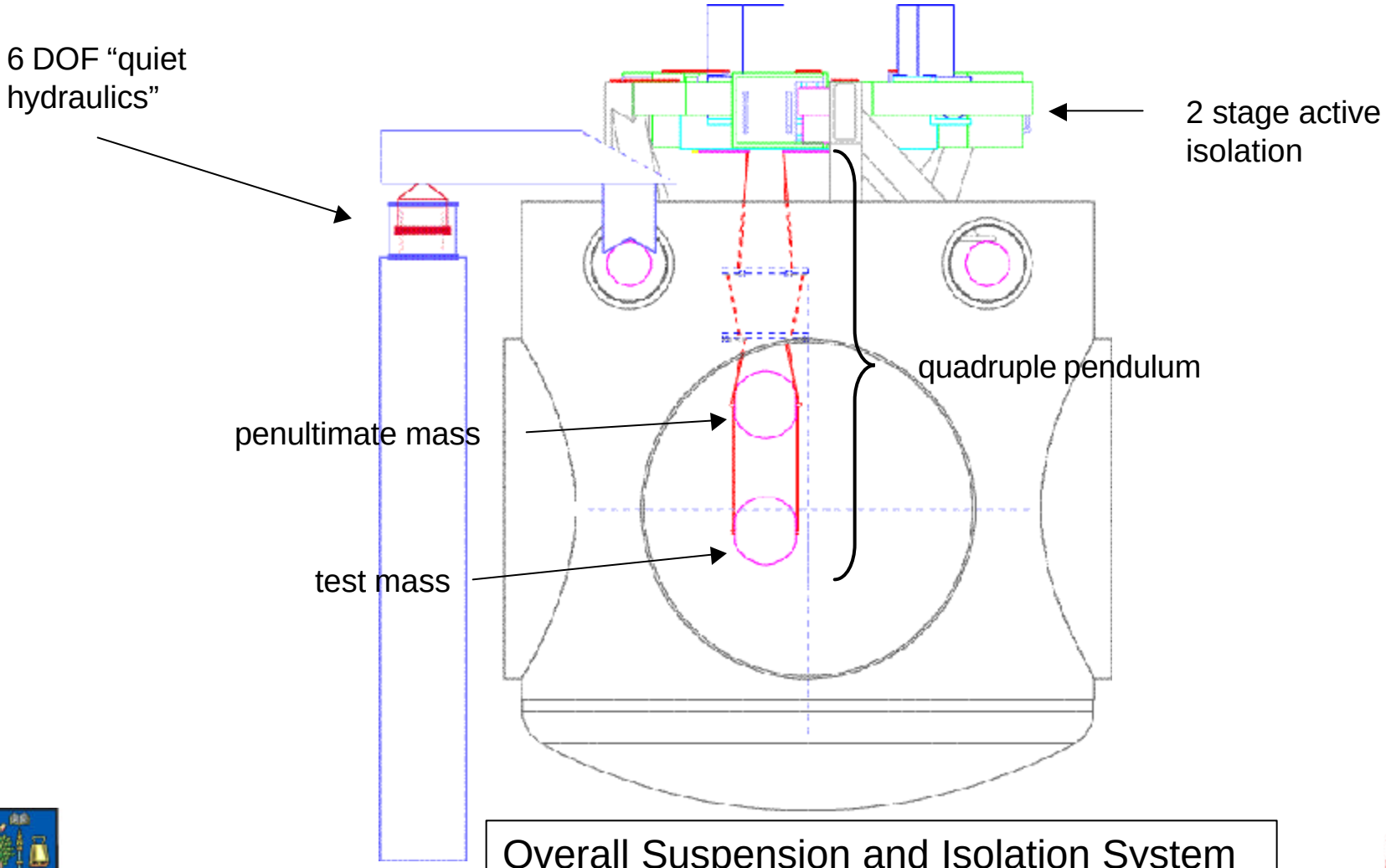
- **Glasgow**: overall science management, “problem solving”, scientific support through installation and commissioning, optical material procurement
- **RAL**: overall project management, develop final designs and manufacture 28 BSC suspensions (including noise prototypes), participate in installation of LASTI noise prototypes and first 2 units at each site
- **Birmingham**: design and supply analogue electronics for local control and global control for all suspensions (HAM and BSC) ~1000 channels

All in close collaboration with LIGO Lab

PPARC Proposal - Status

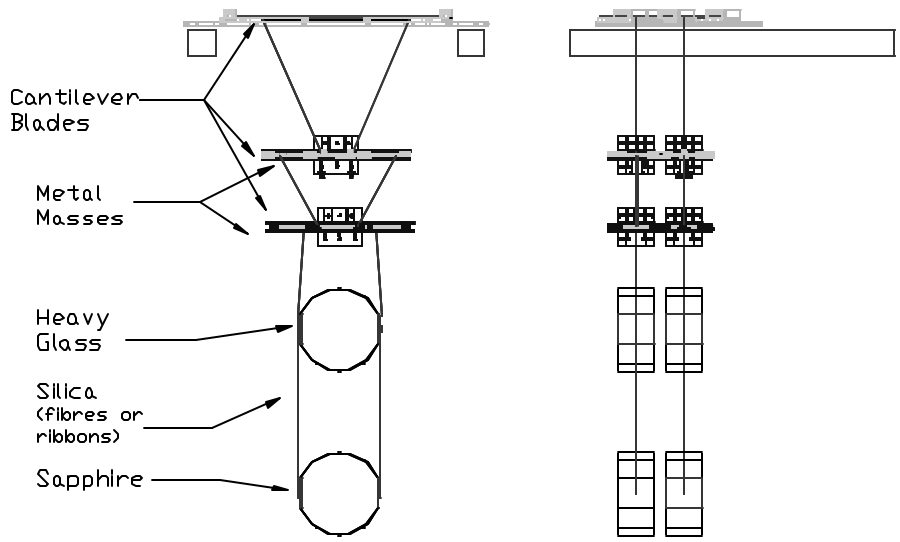
- Proposal submitted end June 2002
- Site visit to Glasgow by review committee 29/30 July 2002
- Site visit to Birmingham (date not yet fixed)
- Proposal goes to Projects Peer Review Panel for consideration in December 2002
- Funding requested to start Oct 2003 for 5 years

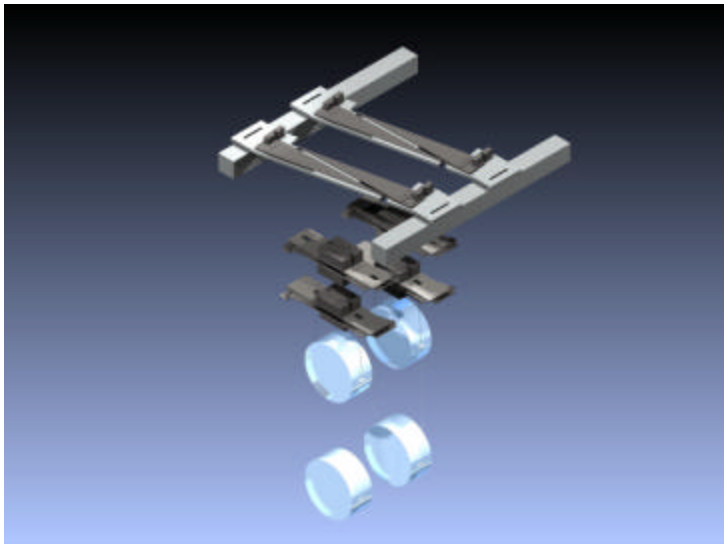
Update on Quadruple Pendulum Design for Advanced LIGO



Overall Suspension and Isolation System
BSC Chamber

Quadruple Pendulum Design





Conceptual design as presented at MARCH LSC meeting:

Test mass: 40 kg sapphire, 31.4 cm x 13 cm
Penultimate mass: 72 kg (heavy glass)
Overall length: 1.7 m (from top blade to centre of mirror)
Ribbons : length 60 cm, X-section 113 μm x 1.13 mm, stress 770 MPa
Highest vert. mode ~8 Hz, first violin mode ~490 Hz

Update on Quadruple Pendulum Design contd

Since March LSC meeting, recommendations in document “Low-frequency Cutoff for Advanced LIGO” (DCC T020034-00-D) have been accepted:-

- highest vertical mode frequency at 12 Hz or lower
- violin mode fundamental frequency at 400 Hz or higher
- horizontal thermal noise specified at 10^-19 m/ √ Hz or lower at 10 Hz, per test mass
- technical noise sources (including local damping) at level to allow observations down to 10 Hz.

=> implications for quad design

Update on Quadruple Pendulum Design contd.

- Possible changes to conceptual design
  - No requirement for further development of ultra dense (~7 g/cc) heavy glass for penultimate mass
    - Use sapphire or SF4 (heavy glass w/ density 4.8 g/cc) – highest vertical mode ~ 9 Hz, or
    - Use silica – highest vertical mode ~10.4 Hz
  - Consider increasing fibre length to allow use of silica with vert. mode <10 Hz, and violin mode > 400 Hz
    - e.g. 70 cm – vert mode 9.6 Hz, violin mode 420 Hz

    - has consequences for manufacturability, overall length (installation and accommodation in BSC chambers)

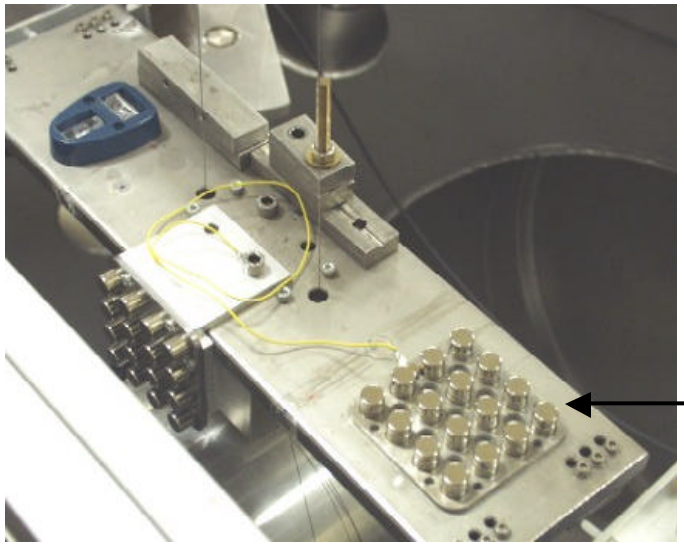
Damping of Pendulum Modes

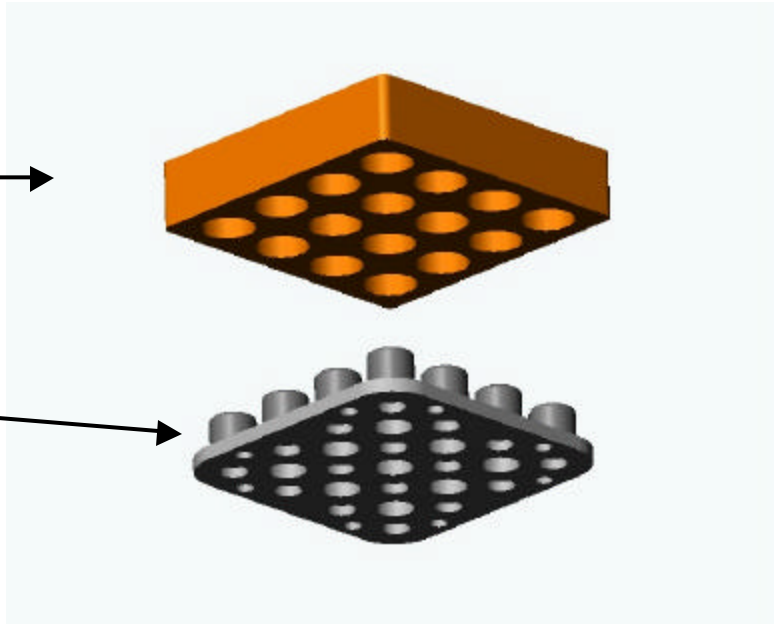
Final bullet from “cutoff” recommendations

- *“Technical noise sources (including local damping) at level to allow observations down to 10Hz”*

  Difficult requirement for local damping!
  - typical shadow sensors 10^-10 m/ √ Hz, range 1 mm
  - mechanical isolation -sensed point to mirror ~2x10^-7 @ 10 Hz
  - target sensitivity 10^-19 m / √ Hz @ 10Hz
- Possible courses of action
  - After acquisition of lock, use interferometric global sensing as signals for damping – for longitudinal pitch and yaw
  - Develop better sensor, possibly combination coarse/fine sensor
  - Use eddy current damping

Eddy Current Damping Tests at Glasgow



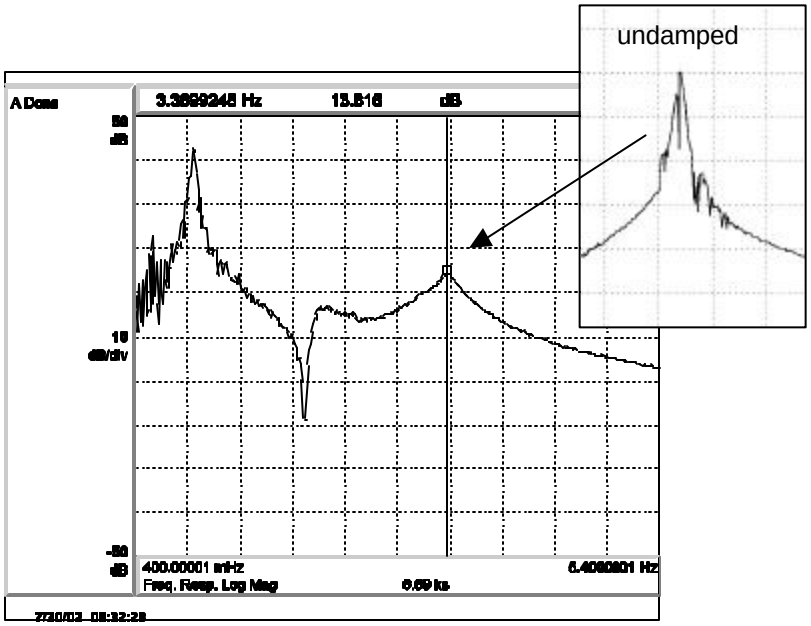


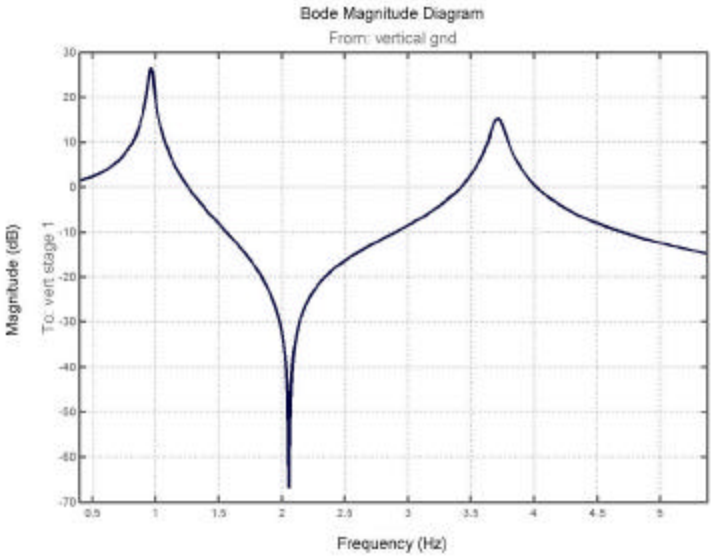
- Set up on GEO prototype triple pendulum
- Two 4x4 NdFeB magnet arrays mounted on uppermost mass for investigating vertical and longitudinal damping
- Magnet array moves within Cu block with corresponding array of holes
- Damping constant b ~ 5 N / (m s^-1) per array
- Vertical damping investigated to date

(Mike Plissi et al, Glasgow)

Eddy Current Damping Tests at Glasgow

contd





Experimental results

MATLAB Model

Vertical transfer function from “ground” to uppermost mass with damping
Two peaks: vertical modes at ~ 1Hz (Q~26,) and ~3.5 Hz (Q~13)
Upper peak: Q lower than expected from model: - appears to be two modes close together (vertical and pitch)

Eddy Current and Active Damping - Conclusions

- First results + modeling indicate triple pendulums can be adequately damped using eddy currents
  - modecleaners with single arrays (per degree of freedom)
  - heavier recycling mirrors with ~ 3 such arrays
- Quadruple pendulum requires damping force ~ 20 times a single array.
  - use better conductor for block (e.g. Be) + cooling with peltiers ?

General Conclusion

- Pursue research on both active and eddy current damping