Update on Suspension Activities for Advanced LIGO

Caroline A. Cantley
University of Glasgow for the GEO600 Group

LSC Meeting, Livingston, March 2003
(Technical Plenary Session)

DCC Number: LIGO-G030038-00-Z

Summary of topics

- Status of GEO (UK) PPARC proposal for funding for Advanced LIGO
- Glasgow/Hannover collaboration with LIGO & RAL
- Update on monolithic silica suspensions in GEO600
- Modecleaner and recycling mirror triple pendulum design (including cantilever blades/OSEM's)
- Update on eddy current damping of pendulum modes
- Silica ribbon pendulum loss measurements

Quadruple pendulum update will be presented by N.Robertson (Stanford) at SWG session.

GEO (UK) PPARC proposal for Advanced LIGO

- Proposal submitted to Particle Physics and Astronomy Research Council (PPARC) for UK contribution to Advanced LIGO (June 2002)
- Requested £8.8M (~$12M) to supply:
  - Technologically advanced main suspension systems based on GEO600
  - Electronic sensing/actuation systems (OSEM's)for control
  - Sapphire blanks for test masses of one interferometer
- GEO600 style silica suspension technology and multiple stage pendulums replace wire-loop single stage suspensions
- Directly involves several UK groups
  - Glasgow University / GEO600 team
  - Rutherford Appleton Laboratory (RAL)
  - Birmingham University
  - Cardiff University

LIGO CLRC IGR GEO 600 CARDIFF UNIVERSITY THE UNIVERSITY OF BIRMINGHAM

PPARC proposal: roles

- GLASGOW
  Overall science management; troubleshooting; scientific support through installation and commissioning; optical material procurement.
  Project Manager: Caroline Cantley

- RAL
  Overall UK project management; development of final designs (with input from Glasgow GEO600/Caltech/Stanford) and manufacture 31 BSC suspensions (inc. noise prototypes); installation of LASTI noise prototypes and 2 first articles at each site.
  Overall UK Project Manager: Justin Greenhalgh

- BIRMINGHAM
  Design/supply analogue electronics for local control and global control for all suspensions (BSC quads & HAM triples) ~1217 channels
  Project Manager: Chris Castelli

- CARDIFF
  Advisory role - scientific input

All in close collaboration with LIGO Lab

PPARC proposal: status

- Proposal submitted to PPARC *(June'02)*
- Review Committee site visits to Glasgow *(July'02)* and Birmingham *(Oct'02)*
- Joe Dehmer (Director of Physics Program at NSF) met with Ian Halliday (Chief Executive of PPARC) *(Jan '03)*
- Proposal approved by PPARC Science Committee *(Feb'03)*

Awaits formal ratification by PPARC Council
24 Mar 2003

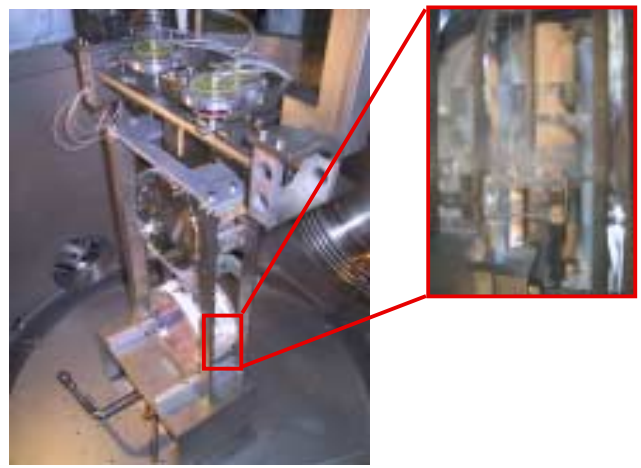
Funding requested from June'03 to Sept'08

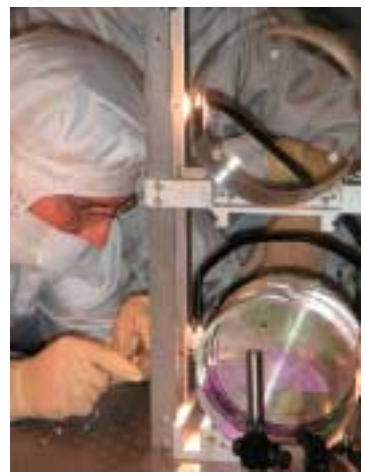
Suspension collaboration

- Suspension collaboration infrastructure now being developed (UK project/LIGO/Stanford)
  - Bi/tri-weekly telecons and frequent exchanges
    - C.Torrie in Glasgow last December
    - M.Perreur-Lloyd on second month at Caltech in last 6 months
    - C.Cantley visiting Caltech/Stanford in April
  - Strong bonds with RAL
    Justin Greenhalgh, first involved with Glasgow GEO600 engineering design in 1980's, will be UK Advanced LIGO Project Manager and is now setting up his team at RAL.

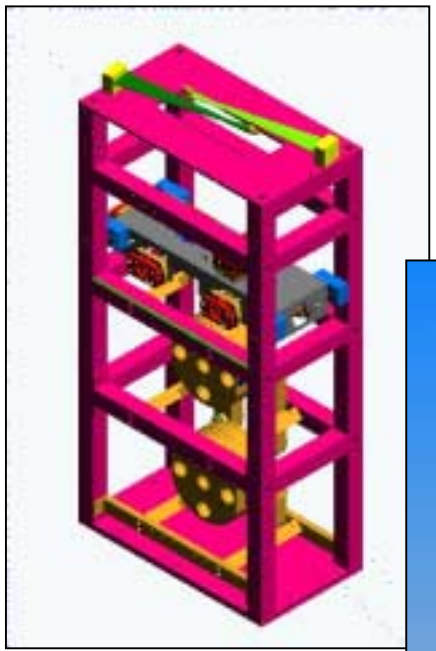
Monolithic silica suspensions in GEO600

- All five main mirrors now on monolithic silica suspensions!!
  - End test masses installed *(Jun'01)*
  - Near test masses & beamsplitter installed *(Dec'02)*
  - only interferometer to use this technology as yet
- Mode frequencies and Q's are currently being investigated
  - e.g. highest mass internal Q~3E6 at 11kHz (possibly limited by couplings to other resonances)
  - e.g. violin fundamental mode Q's typically 1E6 at 600Hz (Teflon applied to damp peaks)

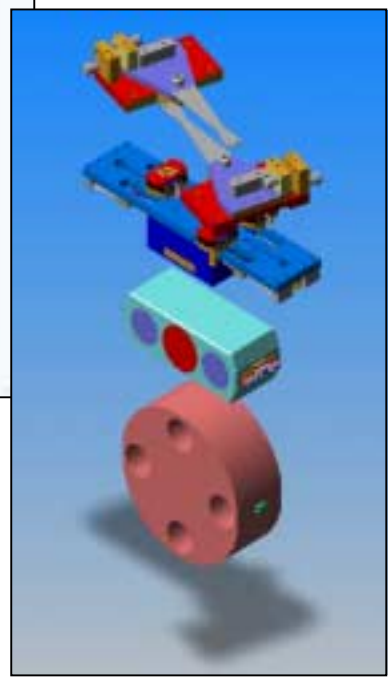




Mode cleaner & recycling mirror suspension design for Advanced LIGO



Mode Cleaner

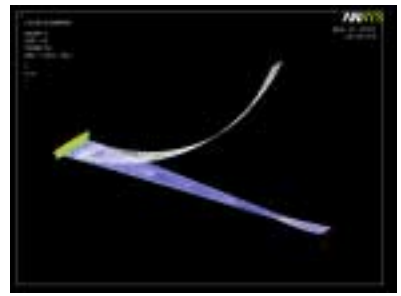


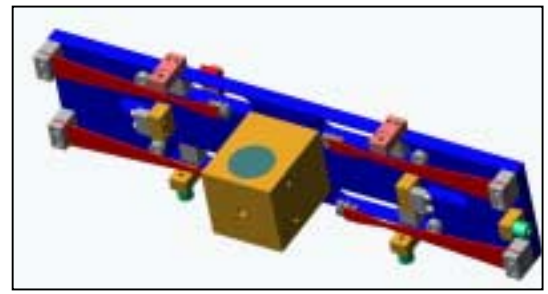
Recycling Mirror

- Glasgow/Hannover working closely with LIGO Lab on design of Mode Cleaner and Recycling Mirror triple suspensions
- Prototypes being designed for testing at LASTI (MIT)
- Design of:
  - pendulum geometry (mode frequencies/coupling; available space)
  - cantilever blades (used for enhanced vertical isolation)
  - support structure (rigidity/accessibility)
  - sensors/actuators (OSEM's) + associated electronics
- Engineering software tools:
  - Matlab / ANSYS / Solidworks
- Virtual conference room for storage, sharing and converting files – currently being investigated

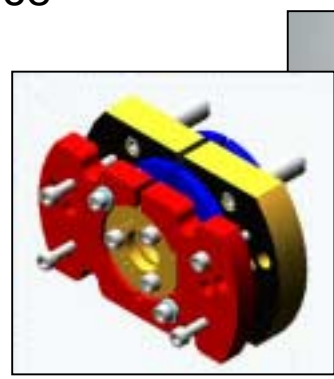
Cantilever blade & hybrid OSEM design

- Cantilever blade design
  - FE analysis versus experimental on various blade designs
    - MIT quad / Adv LIGO MC / GEO600
  - Work has highlighted importance of variations in fabricated blade thickness



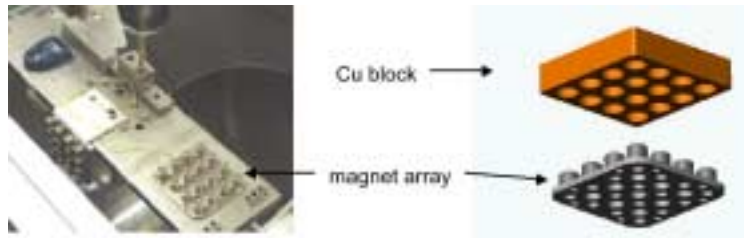


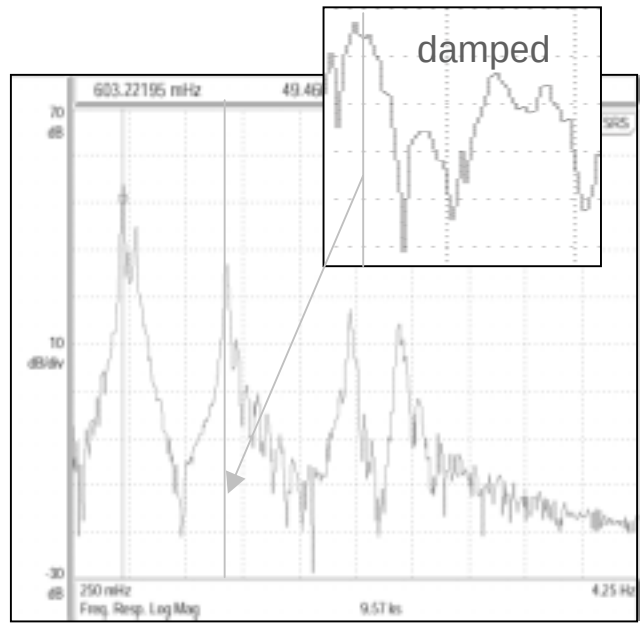
- Hybrid OSEM design (GEO & LIGO I)
  - Improving adjustability – optimise performance
  - Improving reliability
    - Current design issues
      - overcoming problems of residual magnetism in stainless steel heads
      - safeguarding against short circuits



Eddy current damping of pendulum modes

- Damping of pendulum modes required for lock acquisition
- GEO prototype triple used for testing
- Damping applied at top mass
- Two 4x4 NdFeB magnet arrays with Cu blocks
- Damping constant measured to be b ~ 5N/(m/s) per array
- Vertical and horizontal damping now tested
- TRIPLES can be adequately damped using ECD
- Not suitable for QUADS - increased mass
- Enhanced ECD by cooling may be impractical due to cooling system vibration
- Low noise active damping schemes to be developed e.g. double loop feedback as per Losurdo/Passuello (Virgo)

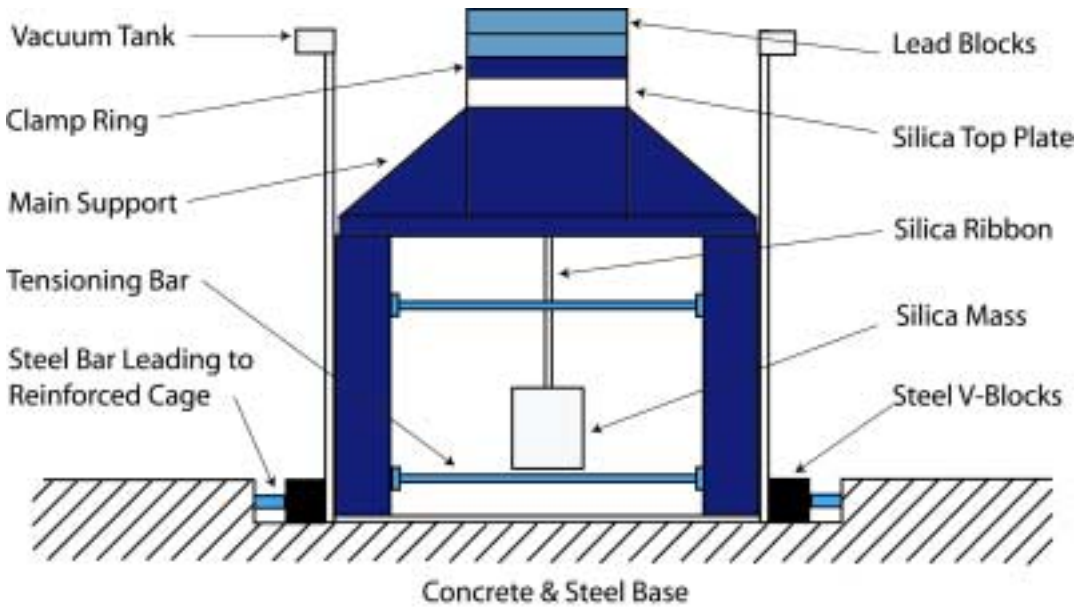




Horizontal (longitudinal) modes

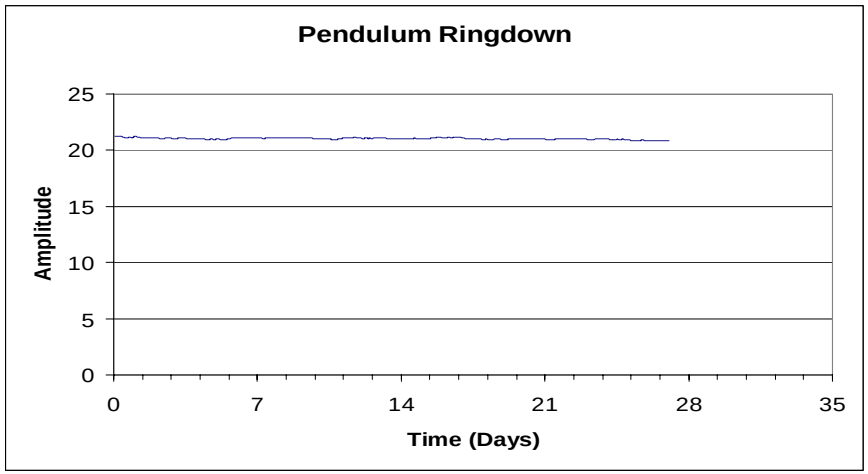
Silica ribbon pendulum losses – experimental set-up

- Pendulum mass displaced by mechanical pusher then released
- Rigid support structure (minimising recoil losses)
- Pendulum design [f ~ 1Hz]
- m=400g; l=30cm; 1.2mm x 0.12mm Suprasil2 ribbon



(Heptonstall, Cagnoli, Strain & Hough)

Silica ribbon pendulum losses – initial results

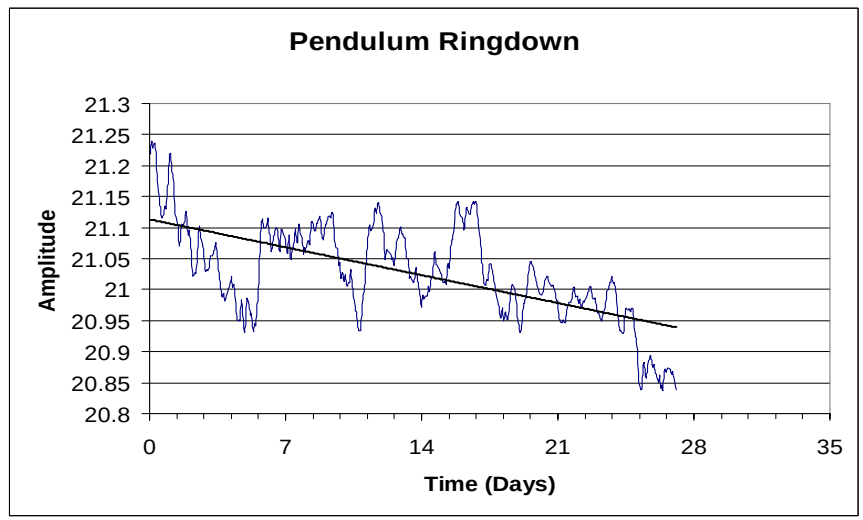


Four week ringdown test

Measured Q ~ 8.8E8

Highest measured Q for a linear pendulum

(Heptonstall, Cagnoli, Strain & Hough)



Silica ribbon pendulum losses – current investigations

- Must confirm pendulum not being significantly driven by seismic noise
- Investigation of:
  - correlation between pendulum motion and seismic background during ‘ringing up’ periods of decay
  - changes in slope of decay curve using reduced amplitude initial displacement
  - ‘ringing up’ of stationary pendulum

(Heptonstall, Cagnoli, Strain & Hough)

What's next?

- Outcome of PPARC Council Meeting on 24th March
- Start of UK project June '03
- Continue to provide design input to Advanced LIGO suspensions and associated actuators/electronics
- Development of alternative low noise active damping schemes for pendulum modes
- Continuing investigations with high Q silica ribbon pendulum