Update on Aspects of the Suspension Design for Advanced LIGO

N. A. Robertson[1,2], H. Armandula[3], S. Aston[4], M. Barton[3], C. A. Cantley[2], D. Coyne[3], A. Grant[2], R. J. S. Greenhalgh[5], J. Hough[2], R. Jones[2], N. Lockerbie[6], K. Mailand[3], R. Mittleman[7], M. Perreur-Lloyd[2], M. Plissi[2], L. Ruet[7], J. Romie[3], D. H. Shoemaker[7], C. Speake[4], O. Spjeld[8], K. A. Strain[2], C. Torrie[3], A. Vecchio[4], I. Wilmut[5]

[1]Stanford University, [2]University of Glasgow, [3]LIGO Laboratory California Institute of Technology, [4]University of Birmingham, [5]Rutherford Appleton Laboratory, [6]University of Strathclyde, [7]LIGO Laboratory Massachusetts Institute of Technology, [8]LIGO Livingston Laboratory

Suspension Conceptual Design for Advanced LIGO

- LIGO: Laser Interferometer Gravitational Wave Observatory
- Advanced LIGO: proposed upgrade with ~ x10 better sensitivity
- Suspension design for Advanced LIGO
  - reduce thermal noise:
    40 kg silica* mirror suspended on silica ribbons
  - enhance isolation:
    four stage pendulum with 3 stages of cantilever blade springs for vertical isolation
  - minimise noise from control:
    damping at top mass and use of reaction pendulum
- Target suspension noise level for main optics (test masses):
  10^{-19} m/√ Hz at 10 Hz

*silica now chosen as test mass material

(lower support structure removed for clarity)

Quadruple Pendulum Prototype

- All-metal to test mechanical design, control aspects and installation and alignment procedures
- Construction of suspension and associated support structure underway
- Design of installation fixtures underway
- Full testing from Autumn 2005

Pendulum construction

Cantilever blade testing

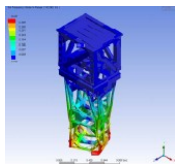
Top and second mass

Support structure

Assembly in two separate pieces (upper and lower)

Second and third mass

Bottom three masses

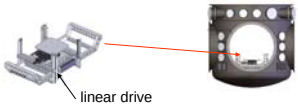


FEA analysis of structural resonances

Installation Fixtures

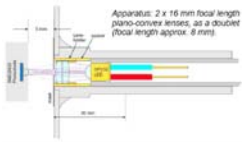
- Articulated arm for transport of quad lower assembly into vacuum chamber

- Adjustable table for translation and lift

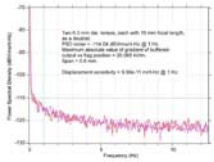


Sensor Development

- Development of compact, robust optical shadow sensor/electromagnetic actuator units for local control (damping of pendulum modes)
- Sensor performance: 0.6mm (peak-peak) working range
  sensitivity 1x10^{-10}m√Hz at 1 Hz

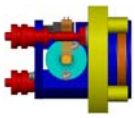


LED and photodiode assembly



Noise performance

Mechanical assembly with positional adjustments



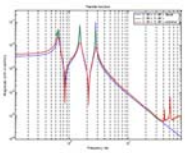
Prototype fabrication

Triple Pendulum Prototype

- All-metal triple pendulum prototype for modecleaner mirror constructed and assembled at Caltech for initial tests
- Shipped to full scale testbed facility at MIT
  - Testing and development of installation procedure
  - Characterisation of behaviour and comparison to model

Bench testing

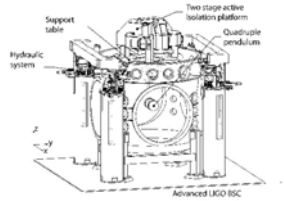
Installation in tank at MIT



Longitudinal transfer function:
top mass drive to top mass position
green (damping off) red (damping on)
blue: MATLAB model

Ongoing and Further Work

- Development and testing of silica ribbon fabrication using CO_2 laser technology and of assembly procedure for monolithic silica suspension (discussed elsewhere)
- Construction of prototype incorporating silica ribbons and masses
- Test of overall alignment, isolation and suspension system at LASTI:
  - external hydraulic pre-isolator
  - two-stage active isolation platform
  - quadruple pendulum



Acknowledgements.
The authors would like to thank colleagues in the LIGO Scientific Collaboration for their advice and interest in this work. The authors acknowledge financial support from the following agencies and universities: National Science Foundation, Particle Physics and Astronomy Research Council, the Universities of Glasgow, Birmingham and Strathclyde. The work at Stanford University is supported by NSF grant PHY-0140297. The work at the LIGO Laboratories and Observatories is supported by NSF grant PHY-0107417.