Update on development of Advanced LIGO quad noise prototype

Norna A Robertson (for Caroline Cantley)
on behalf of Advanced LIGO Suspension Team

LSC Meeting, LSU, August 16th 2006

LIGO-G060380-00-K

Advanced LIGO SUS team

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  MIT: P. Fritschel, K. Mason, R. Mittleman, D Ottaway, L. Ruet, B Shapiro, D. Shoemaker
  LHO: B. Bland, D. Cook
  LLO: J. Hanson, H. Overmier, J. Romie, G. Traylor

- **GEO600**:
  Glasgow: M.Barton, G. Cagnoli, C. Cantley, A. Cumming, D. Crooks, A. Grant, A. Heptonstall, J. Hough, R. Jones, I. Martin, M. Perreur-Lloyd, M. Plissi, D. Robertson, S. Rowan, K. Strain, K. Tokmakov, C. Torrie, H. Ward
  Universitat Hannover: H. Lueck

- **Stanford University**: N. Robertson (also GEO/Glasgow)

- **Rutherford Appleton Laboratory (CCLRC)**: J. Greenhalgh, T. Hayler, J. O'Dell, I. Wilmut

- **University of Birmingham**: S. Aston, M. Cruise, R. Cutler, A. Freise, D. Hoyland, D. Lodhia, C. Speake, A. Vecchio.

- **Strathclyde University**: N. Lockerbie

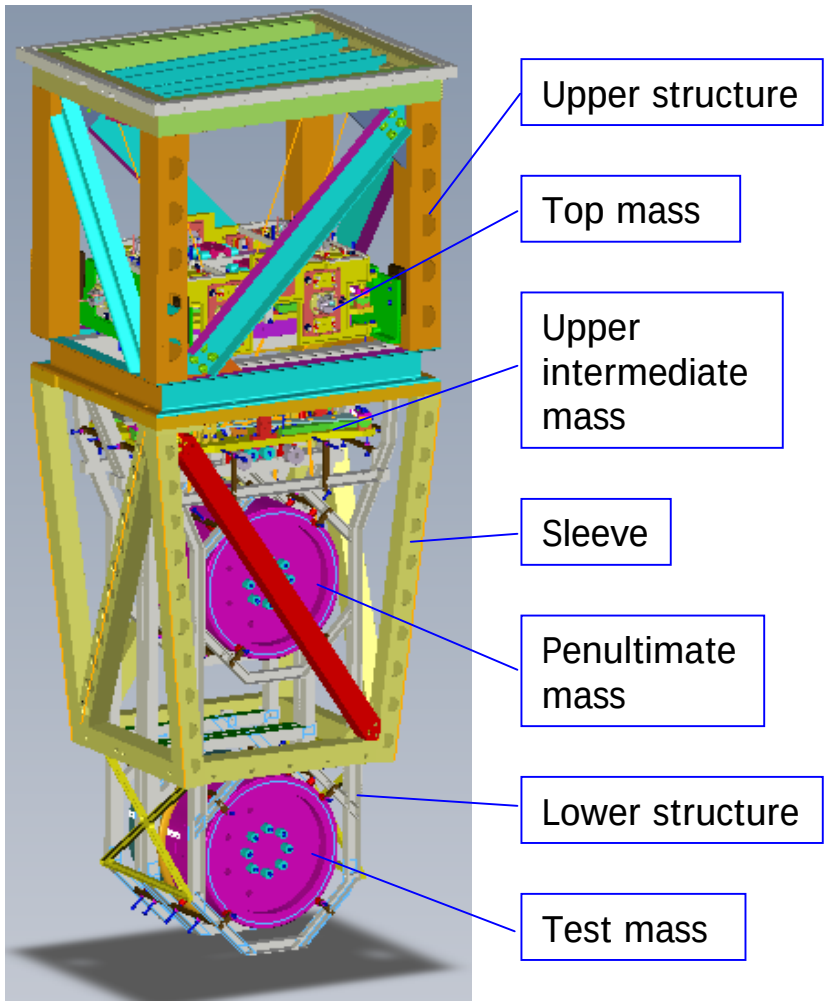
Noise prototype status

- Controls prototype
  - LASTI installation complete
  - Characterisation and testing well underway (Rich Mittleman talk)
  - Completed by end of ‘06

- Noise prototype
  - PDR #3 has successfully taken place
    - Documents on RAL website June 16th
      - www.eng-external.rl.ac.uk/advligo/_review
    - PDR was held on July 10th
    - Outcome was positive, formal outcome expected soon
    - Entering noise prototype procurement stage

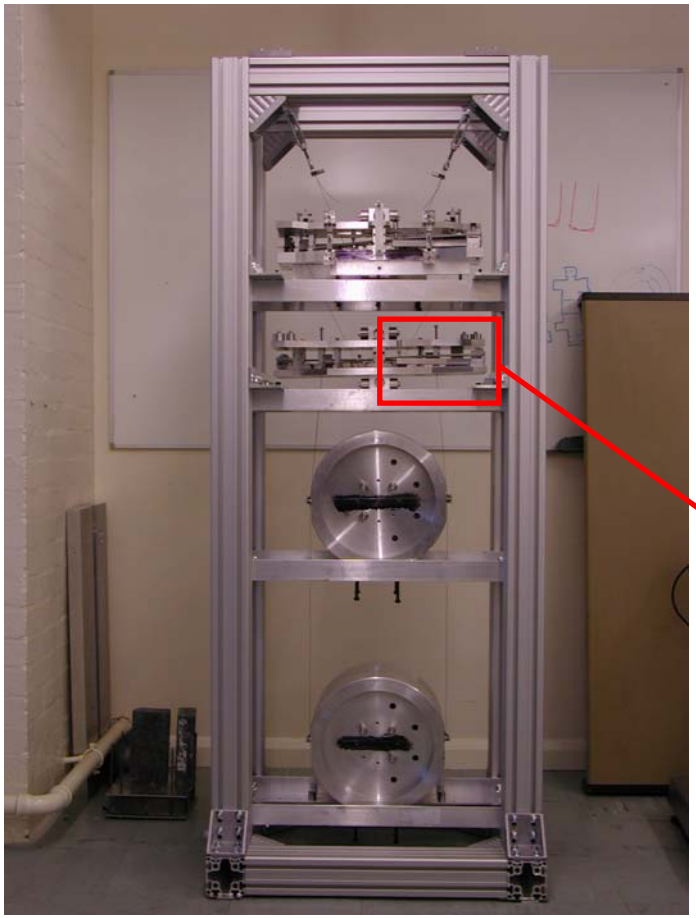
- Noise prototype schedule
  - Fabricate & initial assembly in UK (Jun to Dec ‘06)
  - Assemble at LASTI (commences spring ‘07)
  - LASTI tests (complete by spring ‘08)

Quad noise prototype



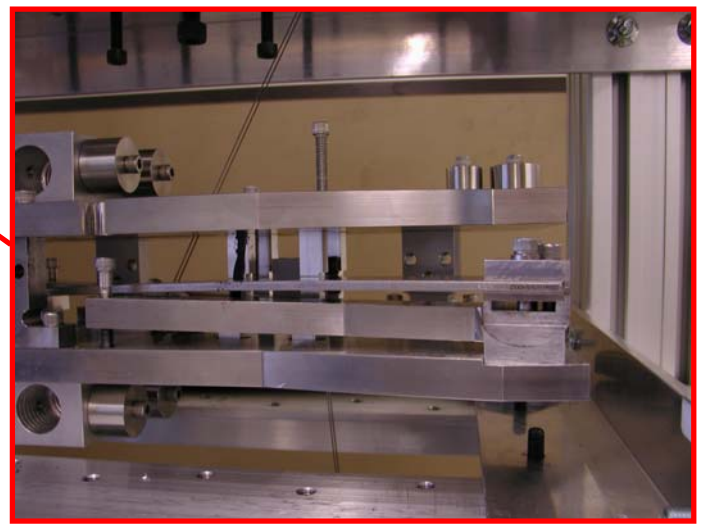
- Mechanical suspension design
  - Top & UI mass design
  - Blades
  - Clamps
  - Adjustment & alignment
- Silica stage design
  - Penultimate mass
  - Test mass
  - Silica ears
  - Ribbons
- Support structure design
  - Assembly & installation
  - Earthquake stop design
  - Stiffness versus mass
- OSEMs & electronics
  - Design
  - Performance
  - Fabrication

Adjustment/alignment prototype - the RAL “marionette”



“Marionette” at RAL

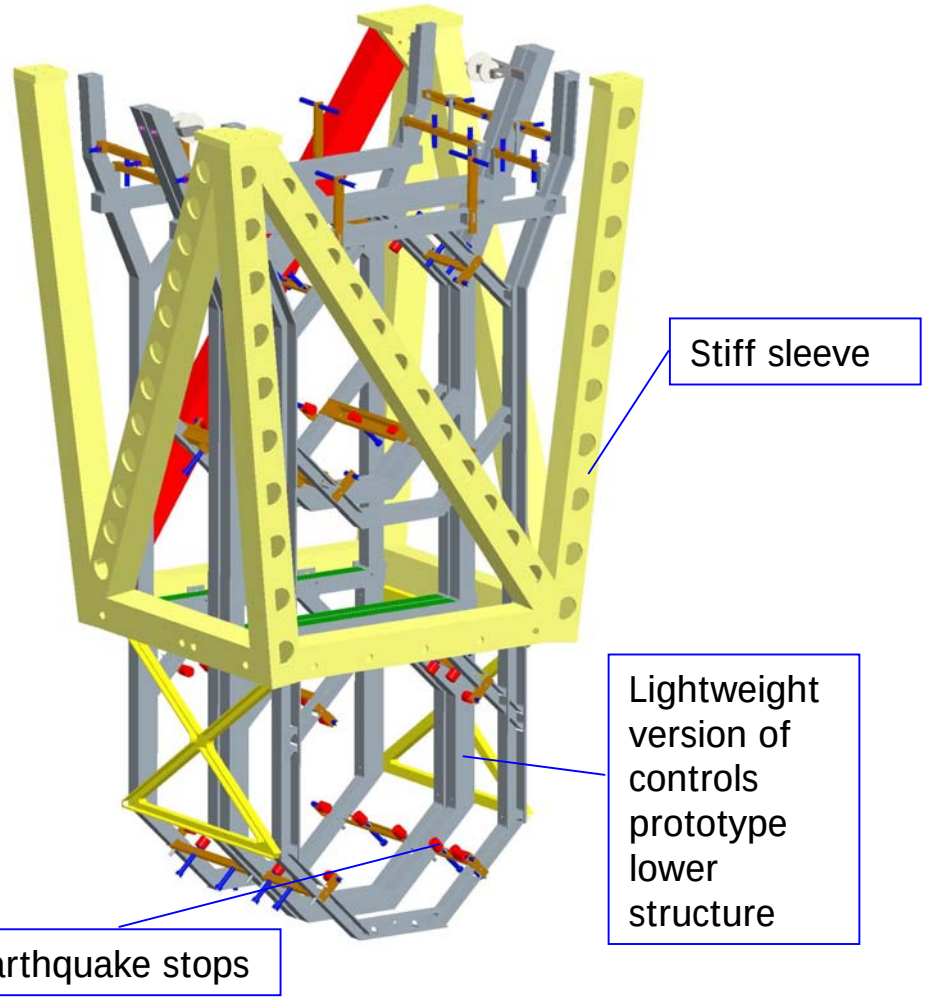
- Single chain close to noise prototype design
- Being used to check proposed adjustment / alignment methods at RAL
- Initial assembly did not use wire jigs (not ready in time)
- Suspended for several weeks
- Some large tilts but not yet clear if due to absence of alignment tools



Blade tip height adjuster

Support structure design

- Must meet functionality requirements, mass budget and stiffness requirements
- Optimise stiffness v. mass
- Change from controls to noise design
  - Structure now features a welded “sleeve” for stiffness and a lightweight version of the controls prototype lower structure
  - Decouples assembly & earthquake stop requirements from stiffness requirements
- Structure stiffness currently being checked
- To comply with SEI platform requirements,
  1st resonance ideal target > 100 Hz



Structure frequency

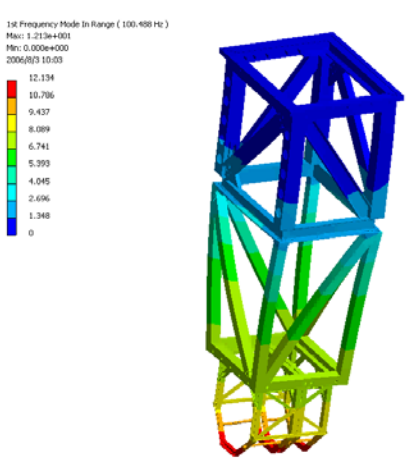
- Initial results encouraging
- Sleeve structure tested on shaker table at RAL
  - FEA 213 Hz; test 203 Hz (Δ 2%)
- Upper structure fixed to steel blocks for initial test of resonant frequencies
  - FEA 246 Hz; test 210 Hz (Δ 15%)

Sleeve structure on shaker table at RAL

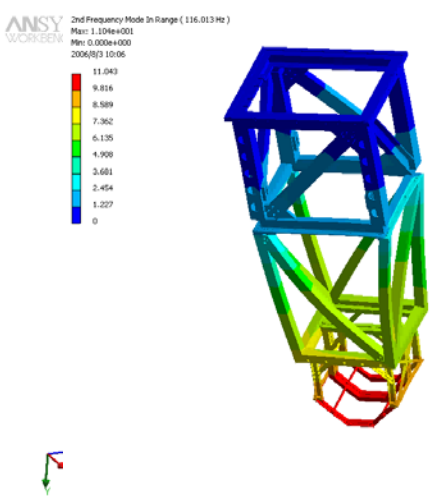
Upper structure at RAL

Structure frequency (cont'd)

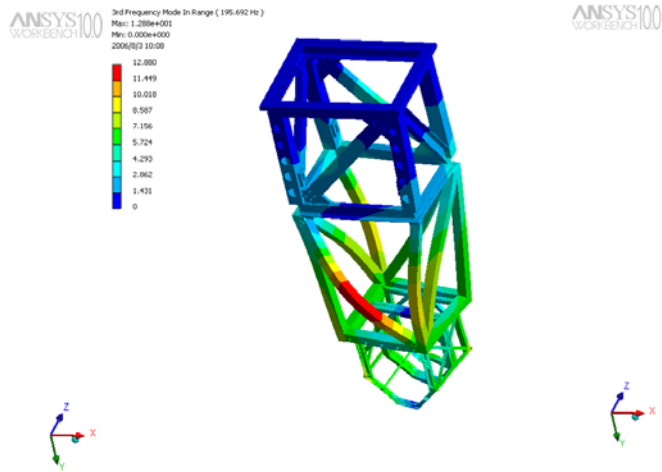
- FE & test comparisons encouraging for individually tested upper structure and sleeve
- Experimental impact testing of 'upper structure + sleeve' just commencing – will provide further check on FE predictions
- Impact testing on full structure will take place prior to LASTI installation



Predicted 1st mode 100 Hz



Predicted 2nd mode 116 Hz

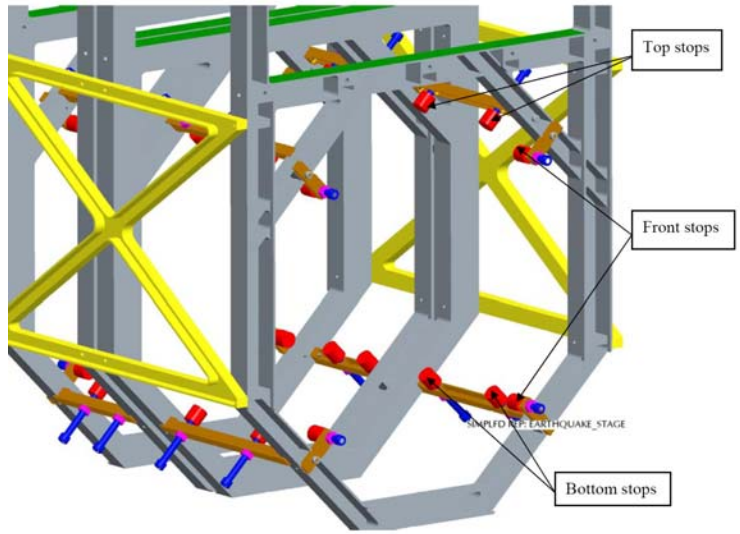


Predicted 3rd mode 196 Hz

Upper structure + sleeve model

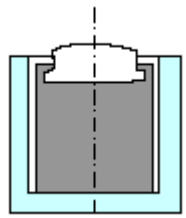
Earthquake stop design - Newton's cradle

- Earthquake stop properties
  - Compliant
    - Flourel FC2180 will be used (vacuum compatible)
  - Reduce risk of mass charging
    - Silica tip
- Various stop design options being considered
- Newton's cradle rebound experiment being used to measure damping behaviour of Flourel material at RAL
- Total number of stops to be made ~ 1200



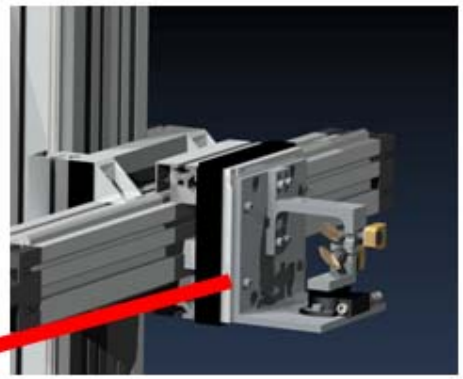
Earthquake stop positions in lower structure

Newton's cradle experiment



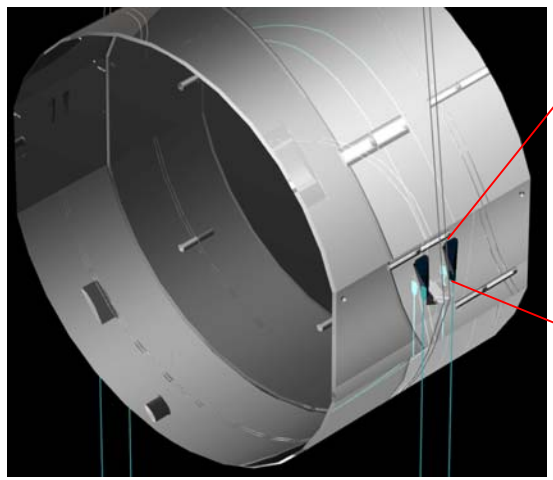
Option - Silica tip push-fit into Flourel.

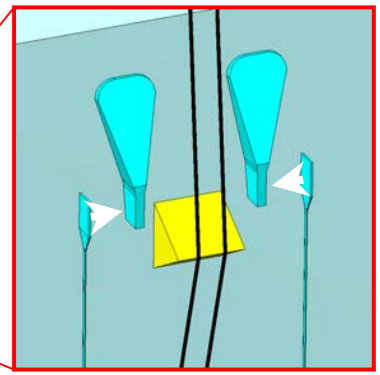
CO_2 laser machine for ribbon/fibre pulling & welding



- CO_2 laser pulling of ribbons and fibres
- Prototype machine developed at Glasgow
- Replica will be sent to LASTI for assembly of noise prototype quad suspension in spring '07

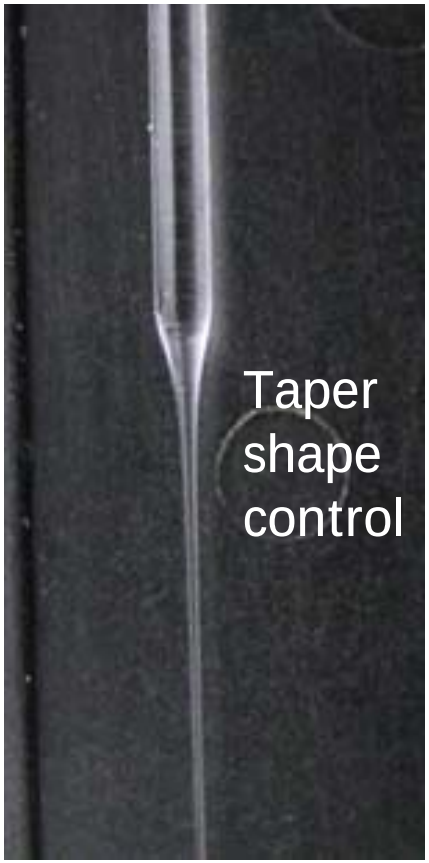
Glasgow CO_2 laser pulling & welding machine – welding configuration



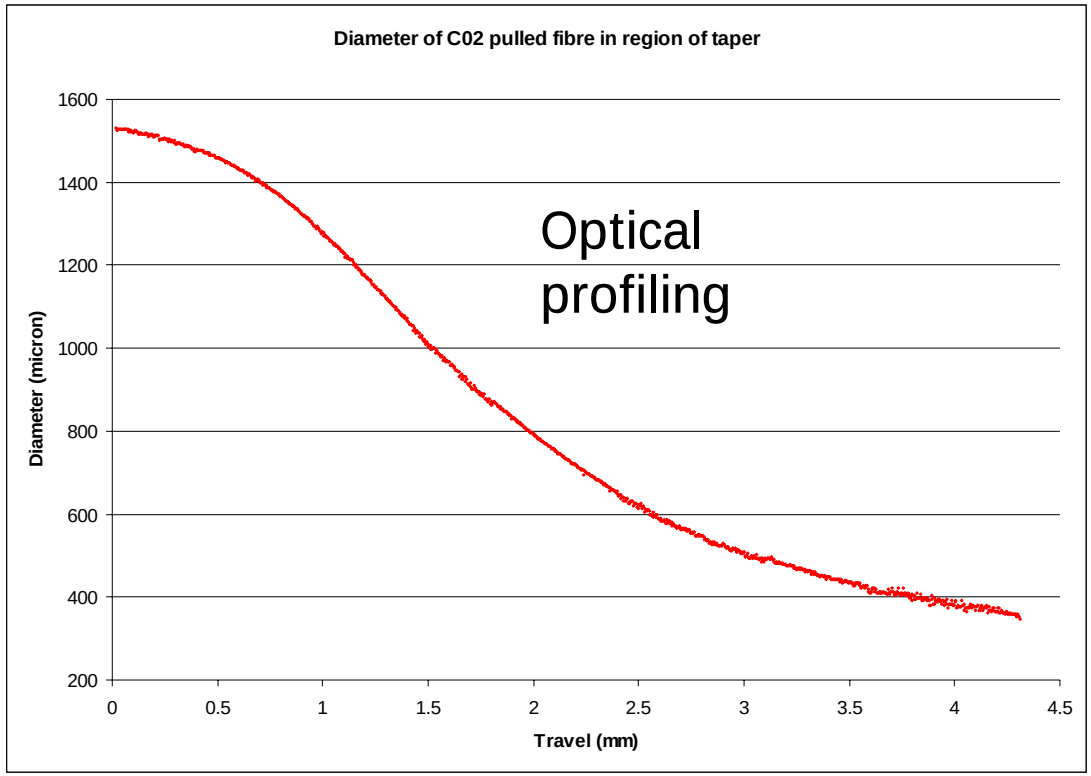


Ribbons welded to silica ears bonded to mass

Characterisation



Example fibre approximately 400 mm diameter pulled from 1.5 mm silica rod

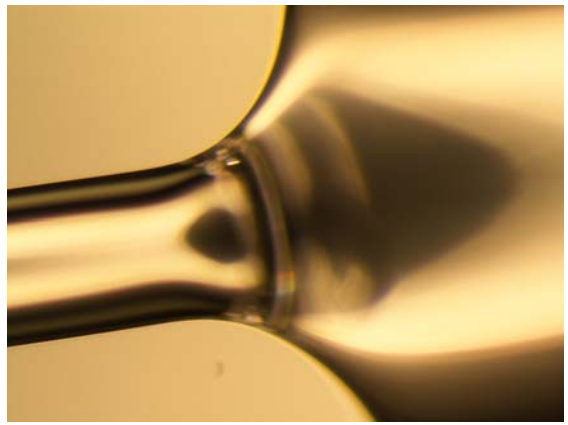


Measured diameter profile across the fibre in the region of taper using optical edge detection system developed in Glasgow

Characterisation (cont'd)

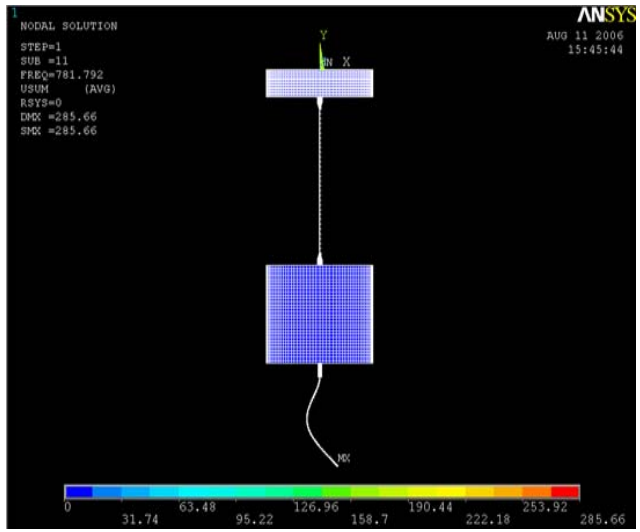
- Measurements of mechanical loss in flame pulled ribbons
  - Fits theory well
  - Within AdvLIGO requirements
- Extending to laser pulled ribbons and fibres for comparison
- FE analysis of energy loss in welded fibres currently being conducted
- Strength testing of flame and laser fabricated fibres & ribbons ongoing

Further detail on ribbon/fibre work in next talk by Alastair Heptonstall



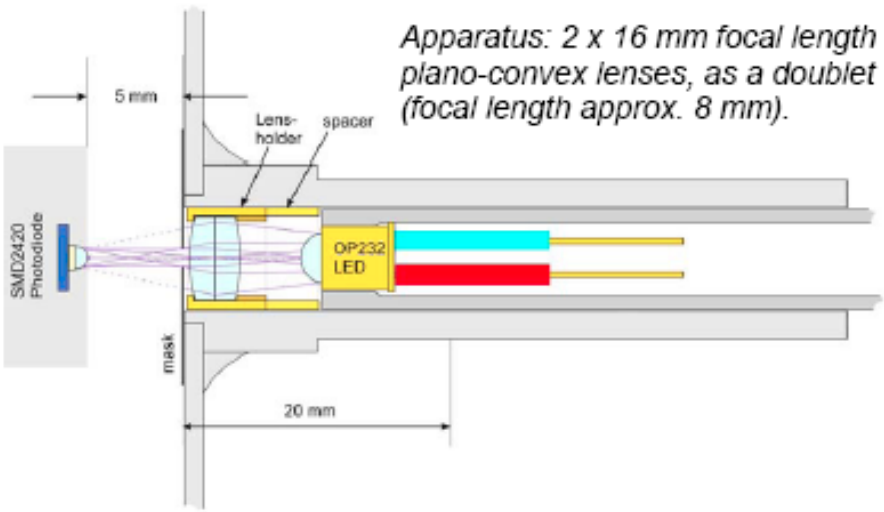
Laser weld

FE model for energy loss prediction

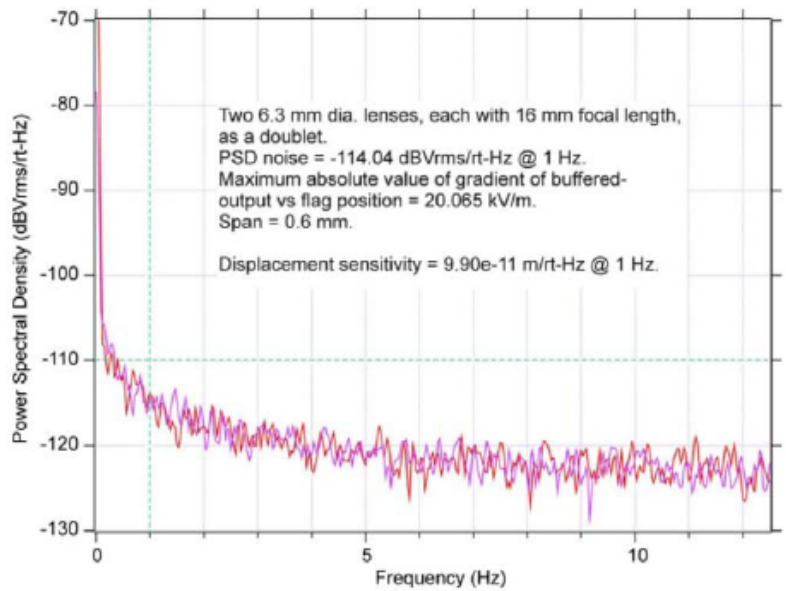


OSEM development

- Sensor Performance Study (UoB in collaboration with Strathclyde)
- Target sensing range ≈ 0.7mm (peak-peak)
- Target noise performance
  - (1-10 Hz) = 3×10^{-10}m/√Hz
  - (10-20 Hz) = 1×10^{-10}m/√Hz



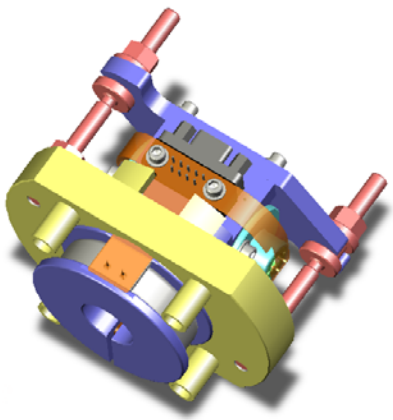
Sensor configuration



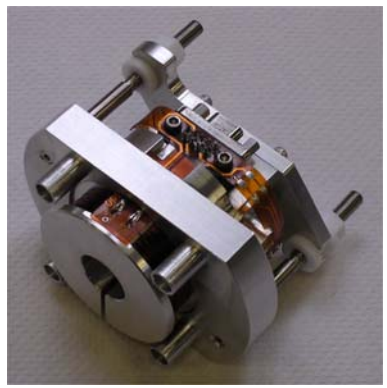
Displacement sensitivity 9.9 E -11 m/rtHz at 1Hz

OSEM status

- 3D CAD Model, 2D Part and Assembly Drawings are complete (soon to be submitted for approval)
- Manufacturing Study has been completed
- A number of prototypes have been fabricated and assembled at B'ham
- Ready to place orders for the Noise Prototype production run of 155 Units (pending approval of the design)
- To be assembled and installed in noise prototype at LASTI in Apr '07



Noise Prototype OSEM
(Solidworks Model)



Noise Prototype OSEM
(Prototype Unit)

Future plan

- Work proceeding well towards quad noise prototype installation at LASTI commencing Apr ‘07
- Continuing work in lead up to this:
  - Mechanical suspension system (RAL)
    - Suspension components
    - Support structure
    - Assembly & installation procedures
  - Ribbons/fibres & monolithic suspension (Glasgow)
  - OSEMs / electronics (Birmingham with Strathclyde)
- Timescales
  - Supply CO_2 machine to LASTI Mar ‘07 – assembly on site
  - Noise prototype delivered Mar ‘07
  - Assembly & install noise prototype at LASTI - Apr to Sept ‘07