Noise Prototype OSEM Development

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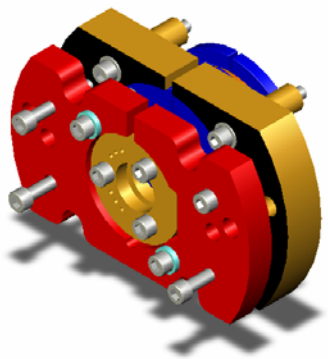
LIGO-G060116-00-K

Presentation Overview

- Advanced LIGO Approach to Damping
- OSEM Development:-
  - Sensor
  - Opto-Electronic
  - Mechanical
  - In-vacuum Electronics
- Fit and Function Tests
- Current Status
- Future Work
- Interferometer Status

Advanced LIGO Approach to Damping

- Geometric Hybrid OSEM's:-
  - The approach of using Hybrid OSEM's plus eddy-current damping (ECD) for the quad suspensions is preferred over interferometric techniques
  - This approach includes incorporating potential performance improvements into the Controls Prototype Hybrid OSEM sensor

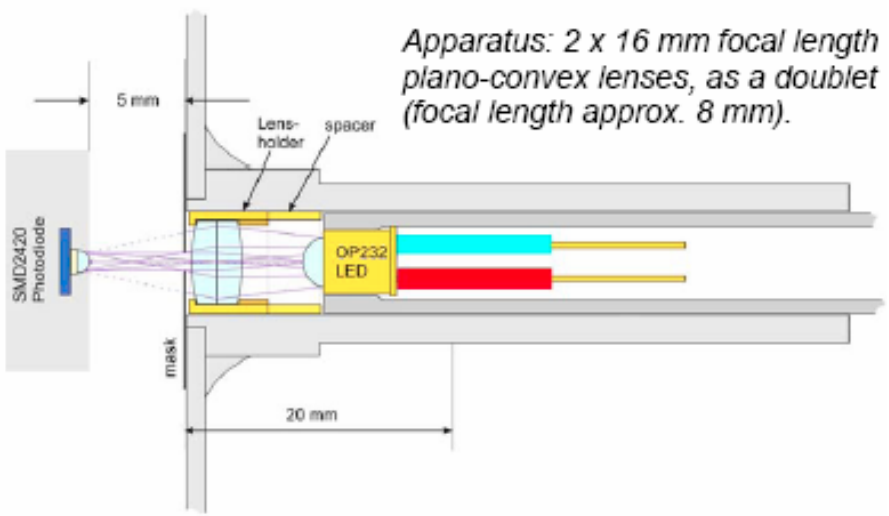


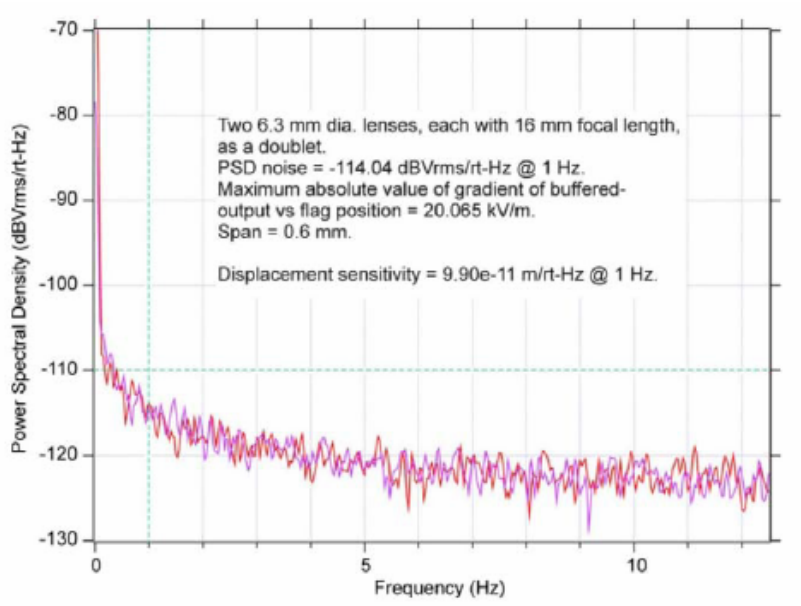
Hybrid OSEM

- Interferometric Based OSEM's:-
  - Continue R&D on the interferometric sensor, as a possible back-up solution in the (unlikely) event that the Hybrid and ECD solution is later found to be inadequate

Sensor Development

- Sensor Performance Study (in collaboration with N. Lockerbie):-
  - Target Sensing Range of 0.7mm (peak-peak)
  - Worst Case Noise (1-10Hz) = 3×10^{-10}m/√Hz
  - Worst Case Noise (10-20Hz) = 1×10^{-10}m/√Hz





(n.b. noise figures given are in conjunction with the sensor electronics, *see T050110-00-K*)

Opto-Electronic Development

- Sensor Components:-
  - Honeywell Surface-Mount Emitter (SME2470) Replaced with Optek leaded device (OP232)

TO-46 Package

Hermetically Sealed

Kovar

(n.b. anode-to-case)

  - Honeywell Surface-Mount Receiver (SMD2420) Replaced with Centronics leaded device (BPX65)

TO-18 Package

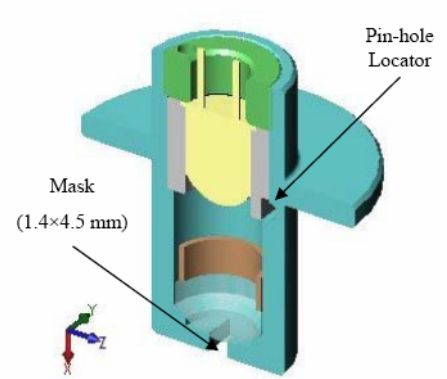
Hermetically Sealed

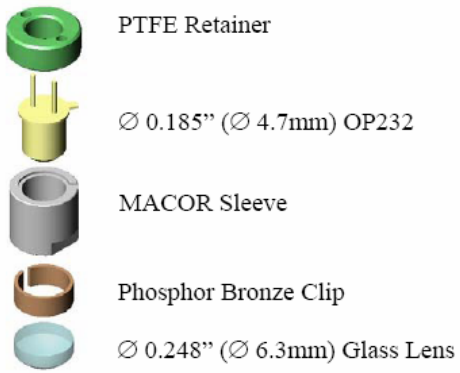
Steel

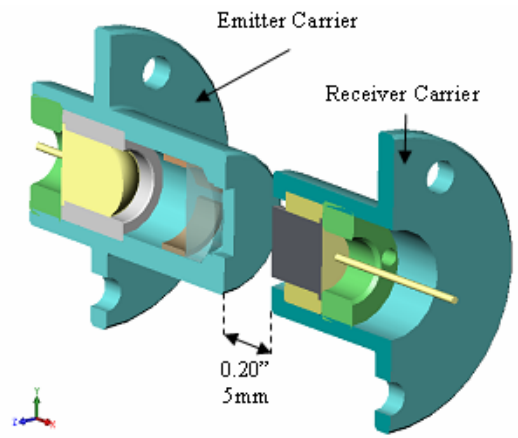
(n.b. cathode-to-case)

Mechanical Development (i)

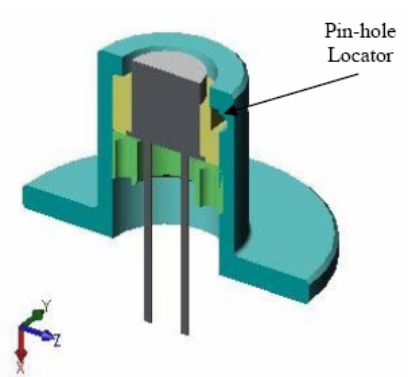
- Sensor Carrier Assemblies:-
  - Tx Carrier

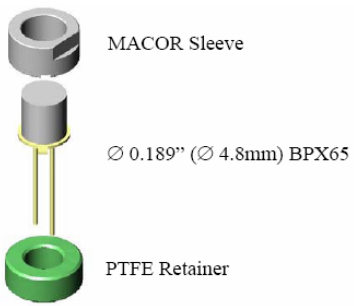






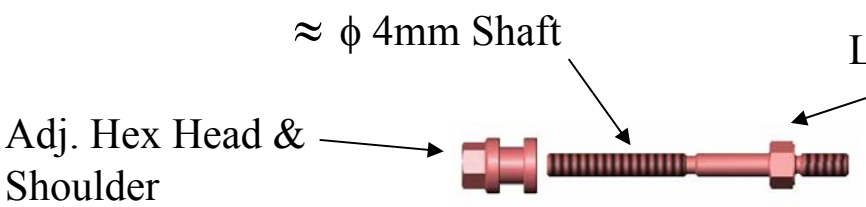
  - Rx Carrier

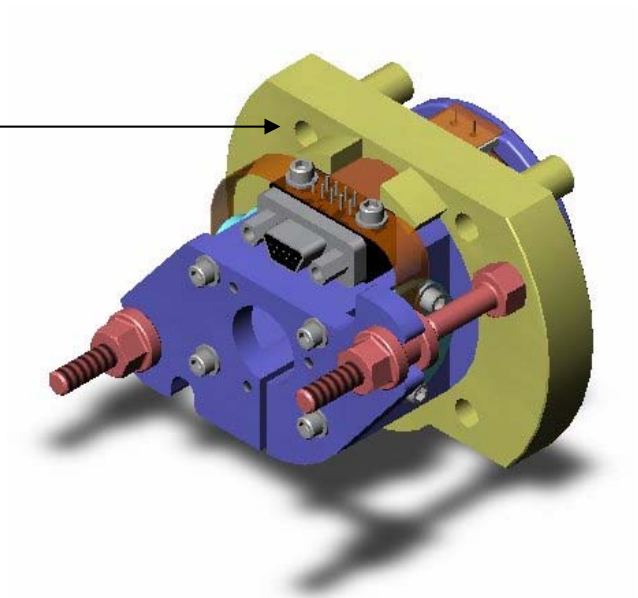




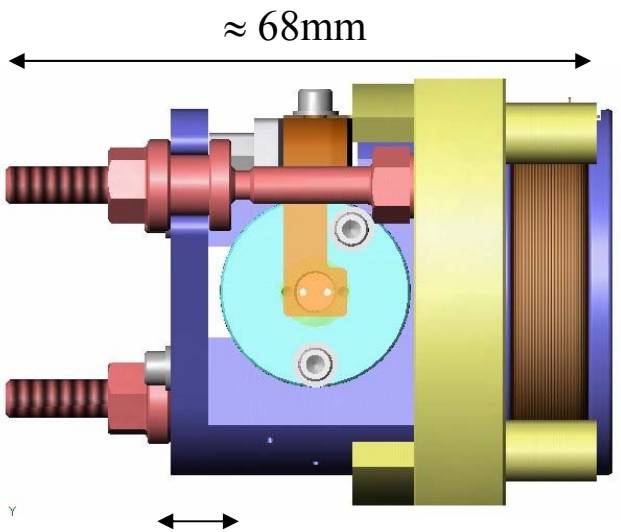
Mechanical Development (ii)

- OSEM Mechanical Adjustment:-





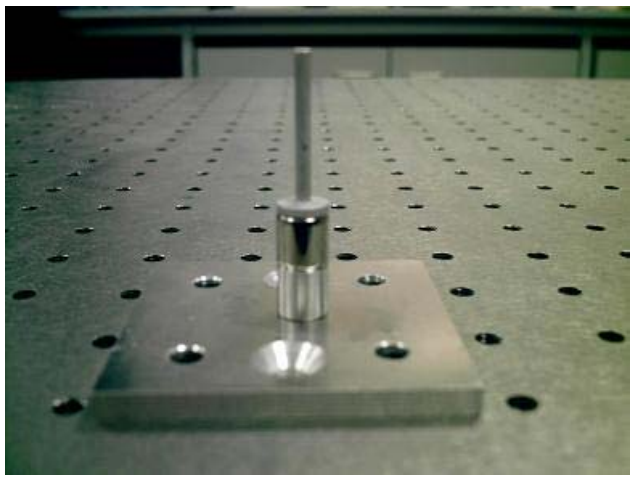
Allow ≈ 1.4mm (p-p)
***y* & *z* axis**



≈ 10mm (p-p)
***x*-axis**

Mechanical Development (iii)

- OSEM Magnet and Flag Assembly:-
  - Working with an alternative design provided by Ian Wilmut (RAL)



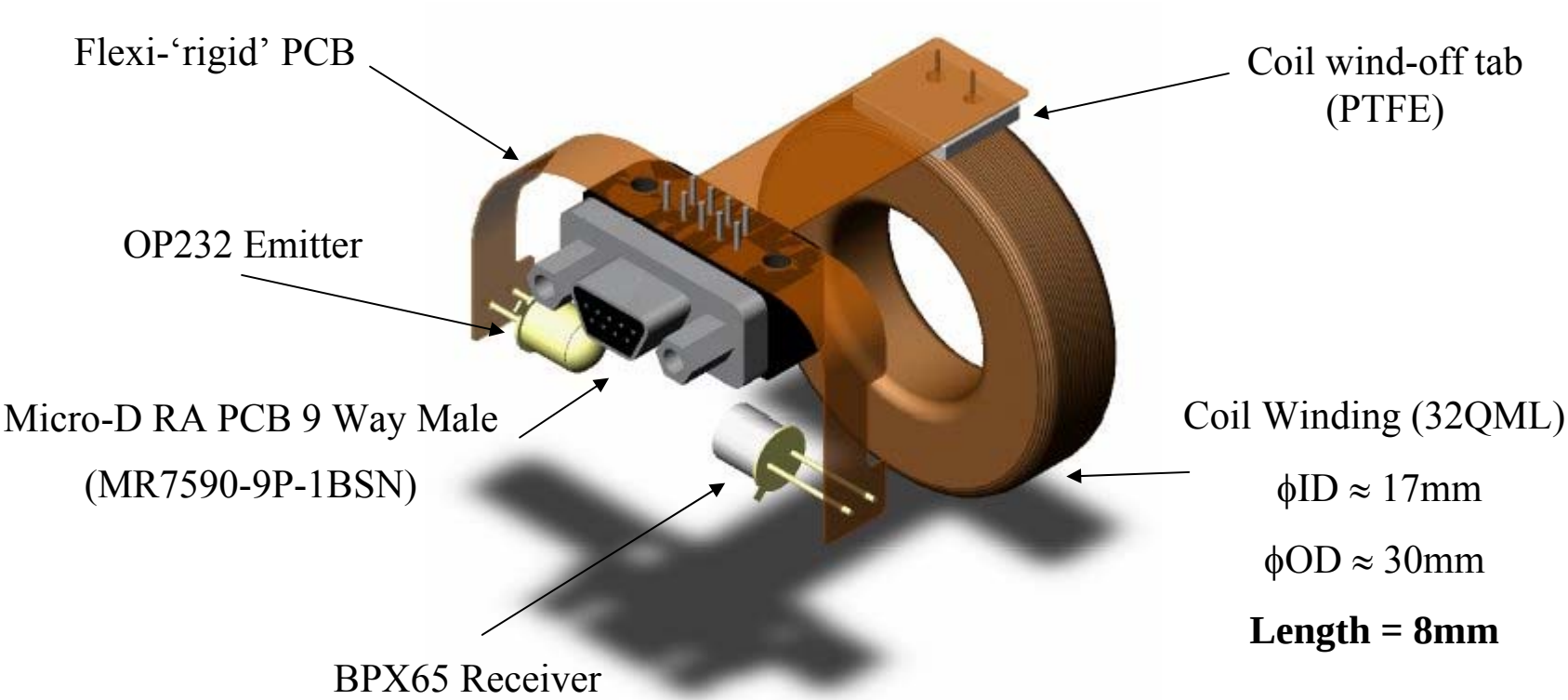
Conventional vac-seal bonded assembly

Alternative magnetic flag mount

(n.b. for further description and test report *see T060017-00-K*)

In-vacuum Electronics Development (i)

- OSEM Inter-Connect Development:-

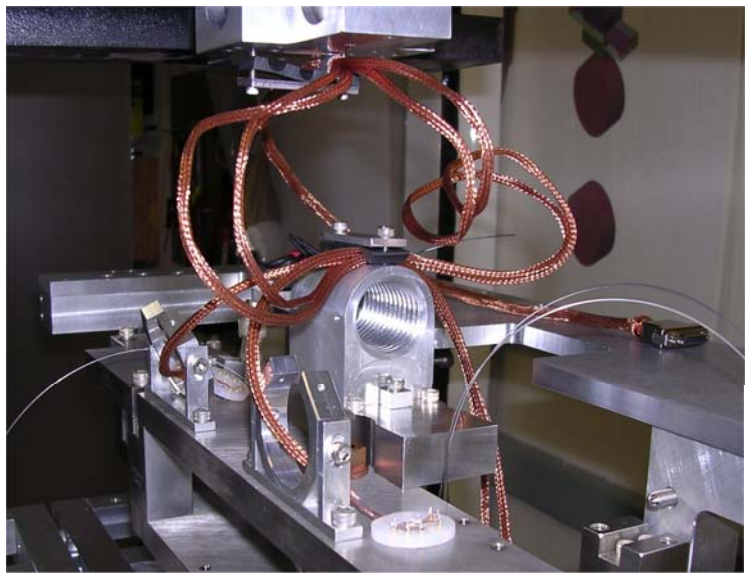


- Includes revised pin-outs for Controls Prototype OSEM compatibility

In-vacuum Electronics Development (ii)

- OSEM Pigtail:-
  - Controls Prototype Harness

Shielded Pigtail (Micro-D 25W - pin-plate x 4)

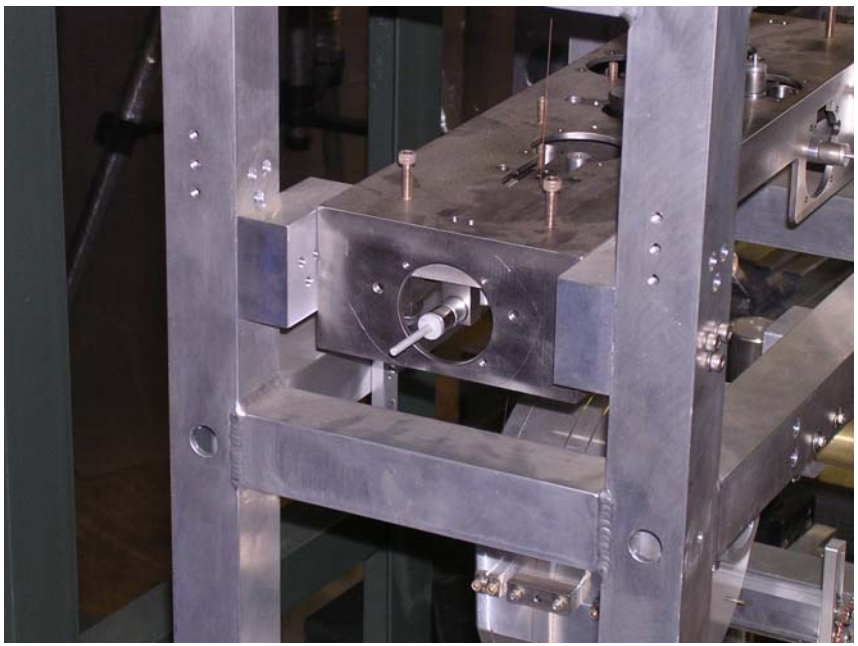


Harness routing tests at Catech (Quad)

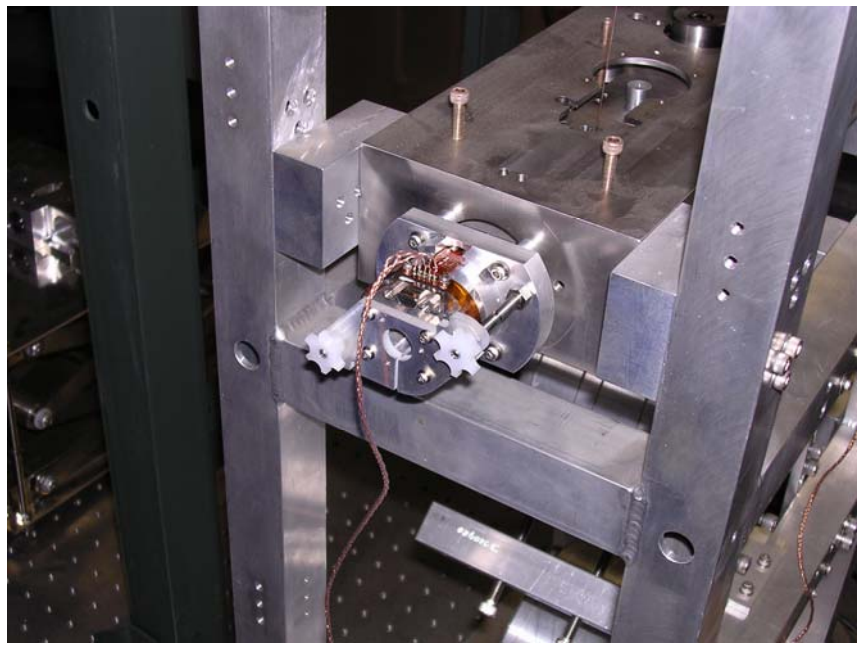
  - Under consideration is an alternative harnessing scheme that would alleviate the need to route sensor channels to global control OSEM's

Fit and Function Tests

- Triple test at Caltech (July 2005)
  - Successful fit and function test of the Noise Prototype OSEM carried out at Caltech, using a Controls Prototype Triple Suspension (MC)



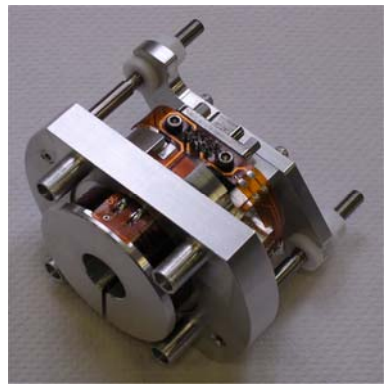
Top Mass with Extended Flag Fitted



Top Mass with OSEM Mounted

Current Status (i)

- Material UHV Qualification Status:-
  - Sensor components (IRLED & PD) are clear
  - Micro-D (Glenair) connectors are clear
  - Flexi-circuit is still under test (but raises no concerns)



Noise Prototype OSEM

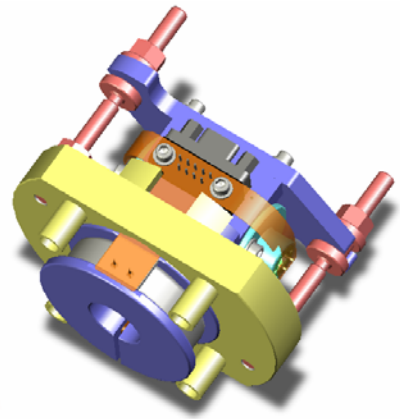
- Production of Prototypes:-
  - Low quantity (5) units to produce for initial testing
  - Flexi-rigid circuits re-worked & fabricated
  - Fabrication carried out in-house with some external contracts placed

- Key Features Addressed:-
  - Oversized holes *(see T040111-00)*
  - Refined PTFE adjustment nut heads (9/32 AF)
  - Revised Coil Geometry, for stronger actuators *(see T060001-00-K)*
  - Semi-automation of coil winding task (evaluate & document the winding process)
  - New coil wind-off PTFE tab (adopted during winding process)

OSEM Status (ii)

- 3D CAD Model and 2D Part Drawings (Stephen Brookes):-
  - Import existing parts into LIGO templates
  - Drawings updated to adhere to LIGO requirements

- Manufacturing Study:-
  - An initial assessment concluded we could not do all the fabrication in-house
  - Obtaining quotes from external contractors



Noise Prototype OSEM
(Solidworks Model)

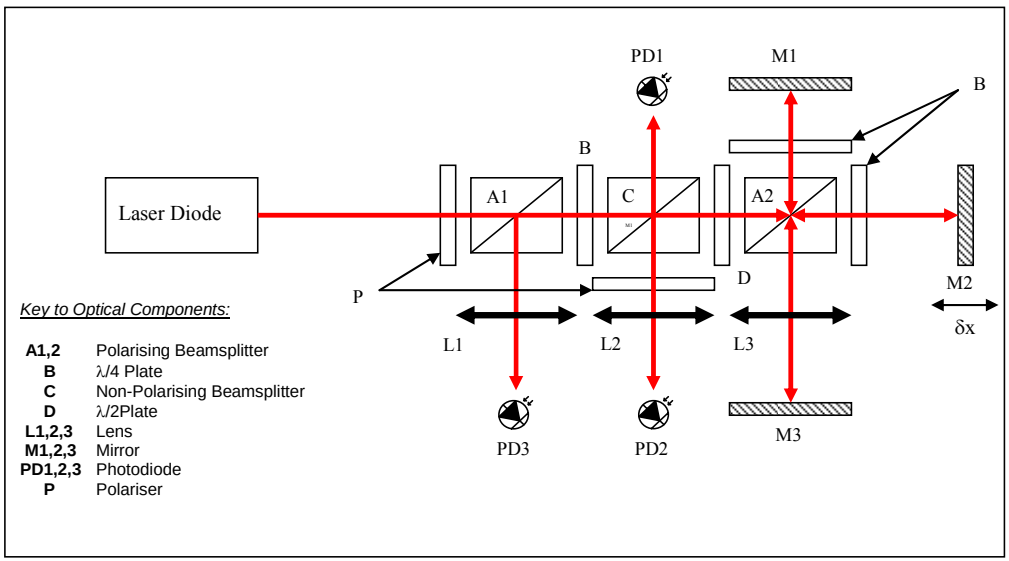
- Prototype Assembly and Characterisation:-
  - 5 OSEM's cleaned and assembled
  - Automated Test Equipment (ATE) used to measure key parameters
  - ATE equipment identified a production issue with the flexi-circuit, which has been raised with supplier. Issue under investigation.

Future Work

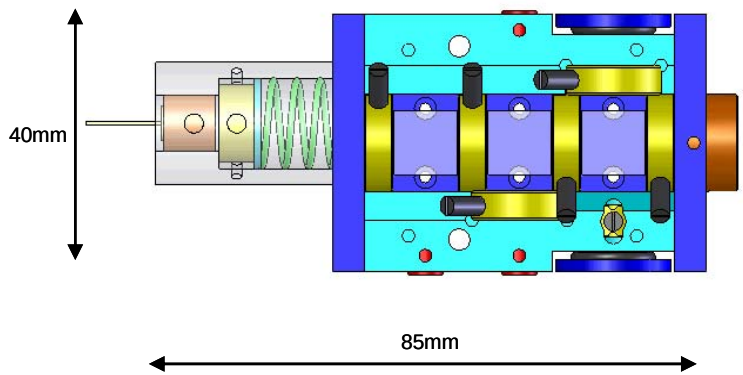
- Check and sign-off 2D OSEM drawings (internal)
- Submit 2D OSEM drawings for LIGO approval
- Release drawings and place into configuration control
- Begin manufacture of Noise Prototype OSEM's (155 units):-
  - Place external contracts
  - Produce an initial batch of 30 units (to be used for 'dirty' assembly at RAL)
  - Fabricate remaining parts
  - Assemble all devices
- Clean and ship all units and electronics to LASTI (Nov'06)

Interferometer Status (i)

- To ensure good low frequency stability we need to avoid active parts that can age, thermally expand, generate heat, exhibit hysteresis, e.g. piezo's etc
- Development of a polarisation-based homodyne fringe interpolation interferometer, using a compact and robust design:-



Optical Layout (co-axial scheme) [1]

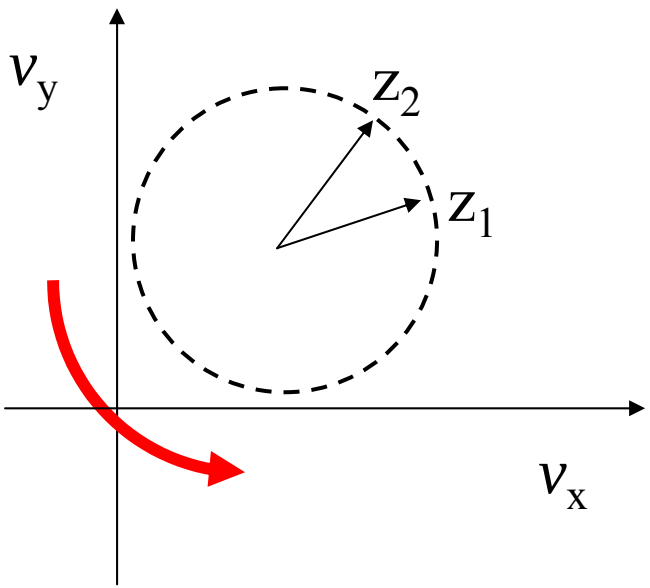


3D-CAD Model (Solidworks)

[1] C. C. Speake and S. M. Aston. "An interferometric sensor for satellite drag-free control". IOP, Class. Quantum Grav. 22 (2005) S269–S277.

Interferometer Status (ii)

- Homodyne fringe interpolation:-
  - Fringe intensities I_1 , I_2 are 90° out of phase (PD2 & PD3)
  - Target mirror motion generates a circular Lissajous figure with I_1 , I_2 plotted as v_x , v_y



$$\Delta\phi = \arctan\left(\frac{(v_{y2} - v_{yo})}{(v_{x2} - v_{y0})}\right) - \arctan\left(\frac{(v_{y1} - v_{yo})}{(v_{x1} - v_{y0})}\right)$$

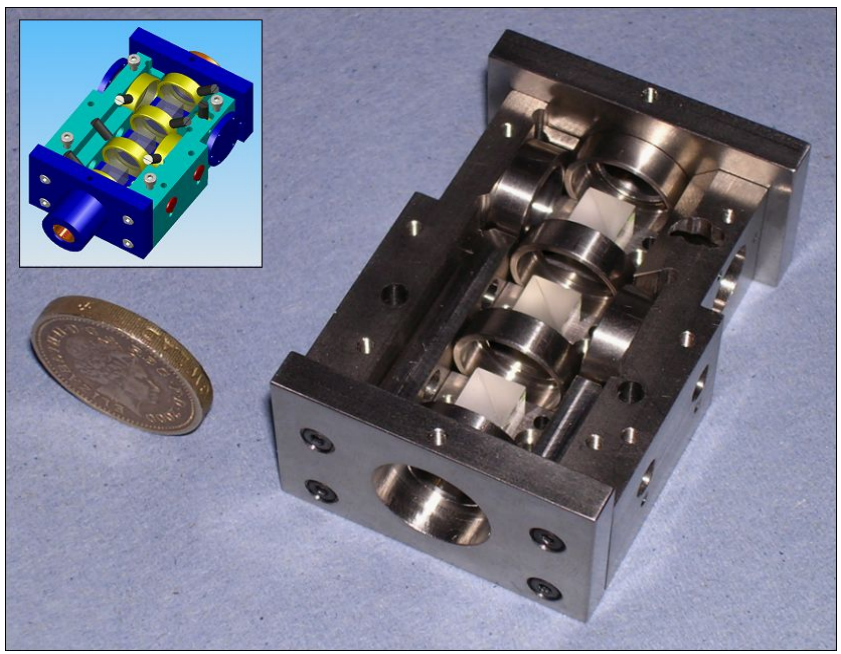
$$\Delta z = \frac{\Delta\phi}{2\pi} \cdot \frac{\lambda}{4}$$

$$\delta z \approx \frac{\delta I}{I}\frac{\lambda}{8\pi} = \frac{1}{\sqrt{N}}\frac{\lambda}{8\pi} mHz^{1/2}$$

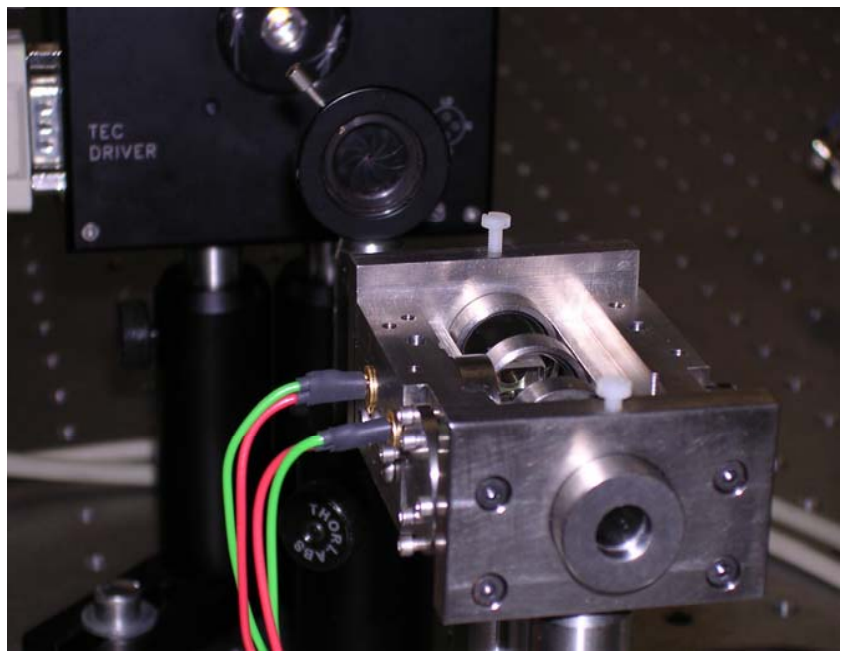
N is number of photons per second on detector

Interferometer Status (iii)

- Prototype Fabrication and Testing:-



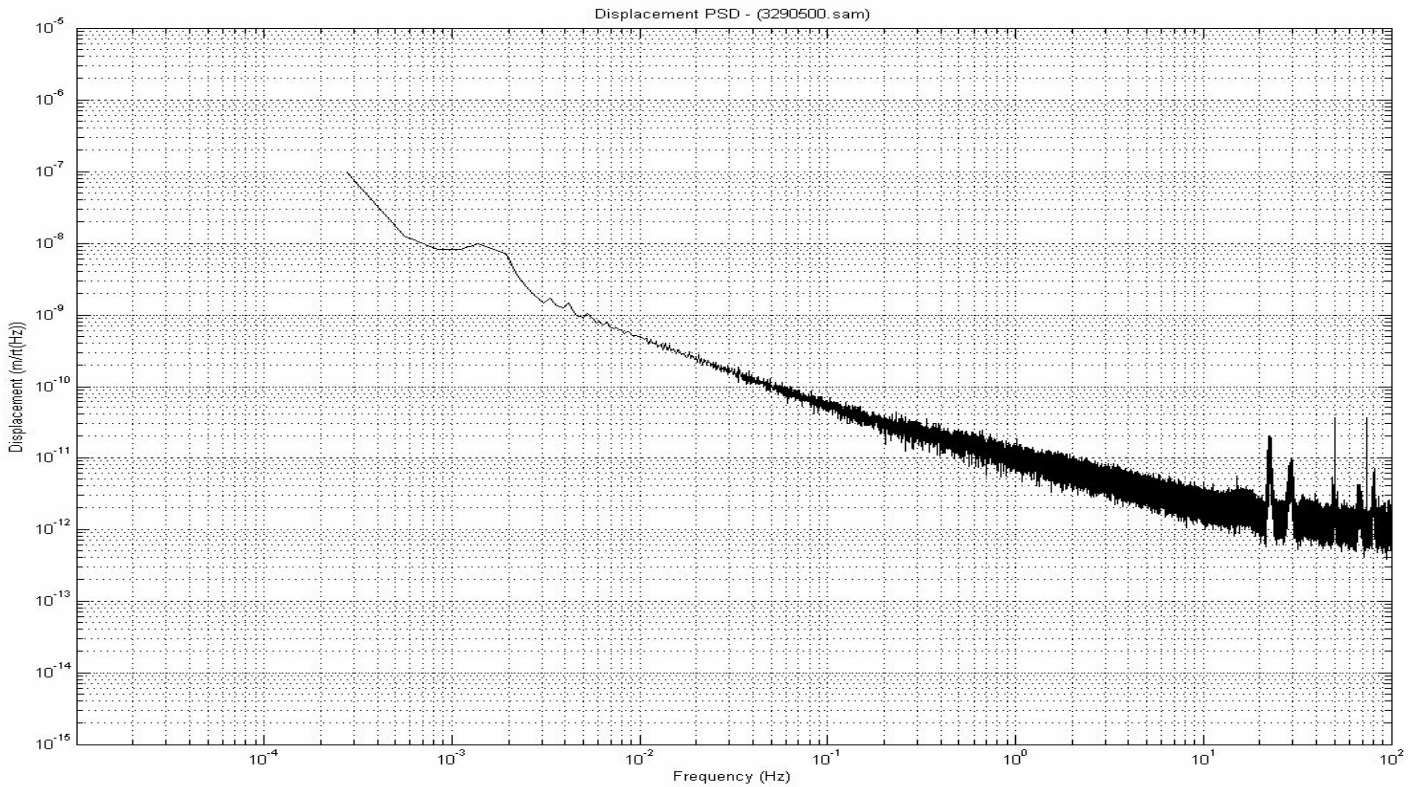
Prototype Device and UV Cured Optical Assembly



Bench-top Set-up & Alignment

Interferometer Status (iv)

- PSD Sensitivity Plot (9hrs):-



- Utilising an 850nm Laser Diode (VCSEL) with ≈ 100ηW of optical power incident upon photodiodes. Shot noise limited above 20Hz.