UNIVERSITY OF BIRMINGHAM

Advanced LIGO UK Work Package 4 Update

OSEMs and Electronics

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(on behalf of the ALUK WP4 team)

University of Birmingham

LSC / VIRGO Joint Meeting - Caltech
17th – 20th March 2008

G080088-00-K

LIGO GEO 600 IGR Science & Technology Facilities Council CARDIFF UNIVERSITY University of Strathclyde

Presentation Overview

- **B-OSEMs**
  - Fabrication Status
  - FRR/FDR Review
- **Electronics**
  - Noise Prototype Status
    - Coil Drivers
    - Satellite Boxes
    - Electrostatic Drive
    - Violin Mode Dampers
  - Full Production Plans
- **Interferometric Sensor**
  - Brief Discussion
- **Summary**

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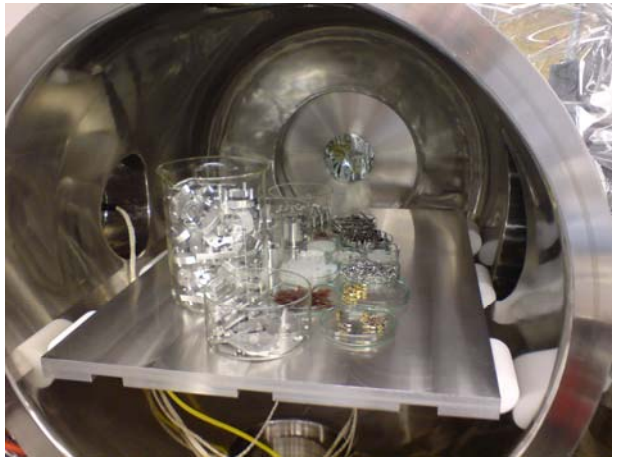
B-OSEM Fabrication Status

- Noise Prototype deliverables:-
  - ~50 units cleaned, baked, assembled, tested and shipped to US
  - Employed in LASTI Quad, OMC, and tip/tilt suspensions
  - 31 units remaining to be delivered
- Full production (654 units inc spares) will commence imminently (following outcome of review) for a duration of ~12 months



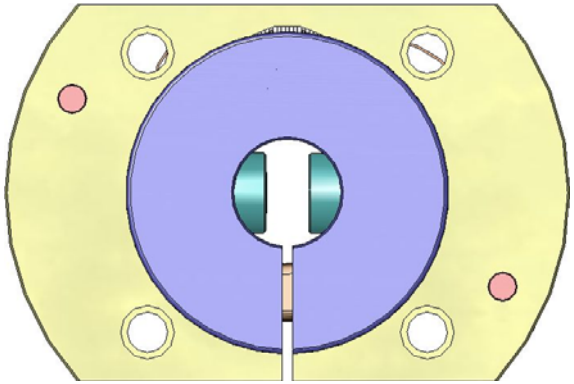
Pre-assembly bake-out oven

Clean-room assembly suite

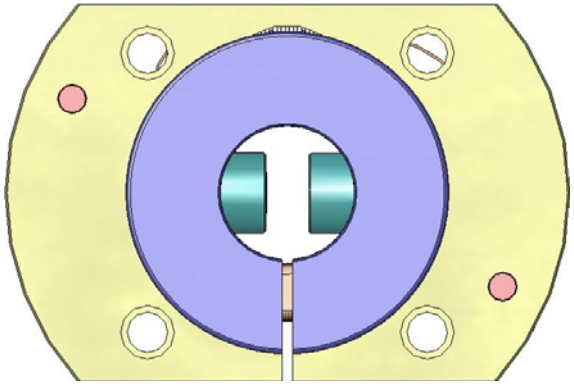
Assembled BOSEMS at testing station

B-OSEM Fabrication Readiness Review (FRR) / FDR

- Review teleconference conducted on 29th February 2008
- Received final panel report 18th March 2008, L080022-00-E
- Immediately addressed key fabrication issues raised
- For example, coilformer / magnet / flag clearance:-
  - There is margin in the design to increase the aperture diameter and improve visibility when carrying out installation and alignment



Existing ∅ 0.5” [12.7mm] aperture

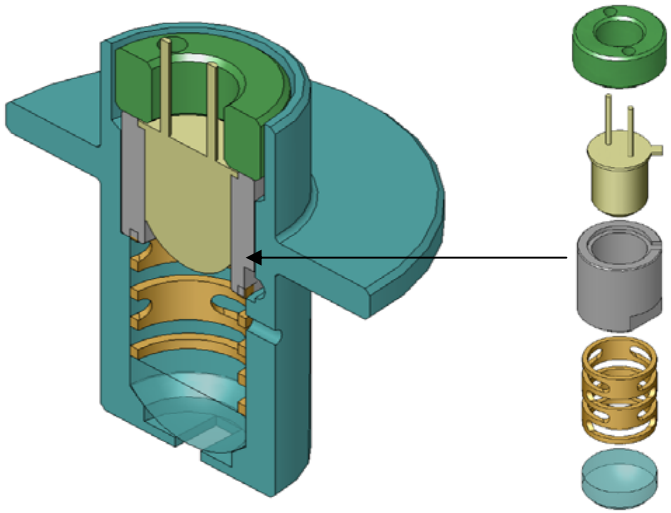


Revised ∅ 0.625” [15.9mm] aperture

⇒ Aperture diameter increase of 0.125” [3.2mm] available

B-OSEM Fabrication Readiness Review (FRR) / FDR

- Sensitivity at 1Hz = 3×10^{-10}m/√Hz, at 10Hz = 1×10^{-10}m/ √Hz
- Additional low frequency noise:-
  - Meets sensitivity requirement at 1Hz
  - Potentially an improvement of factor ~3 available
    - Determined by thermal environment of IRLED



Section through Emitter Carrier Assembly

PEEK Retainer

∅ 0.185” [∅ 4.7mm] OP232

MACOR Sleeve

Phosphor Bronze Spring Clip

∅ 0.248” [∅ 6.3mm] Lens

MACOR, k = 1.46 W/m.K

Alumina, k = 35 W/m.K

Emitter Part Explosion

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Noise Prototype Electronics Status

- Satellite Boxes:-
  - 5 Units (20 Channels)
- Coil Drivers:-
  - Top Mass, 3 Units (12 Channels)
  - Upper Intermediate Mass, 1 Unit (4 Channels)
  - Penultimate Mass, 1 Unit (4 Channels)
- n.b. sufficient channels to support the Quad suspension tests at LASTI
- Units are undergoing further testing at Caltech (J. Heefner *et al*)
- Plan to install electronics at LASTI in 2nd week of April 2008

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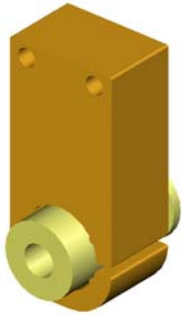
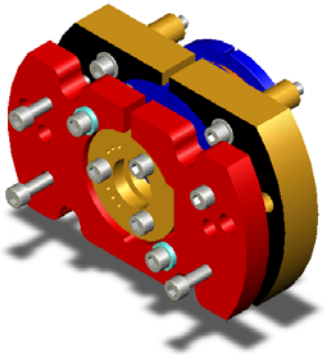
OSEM Development



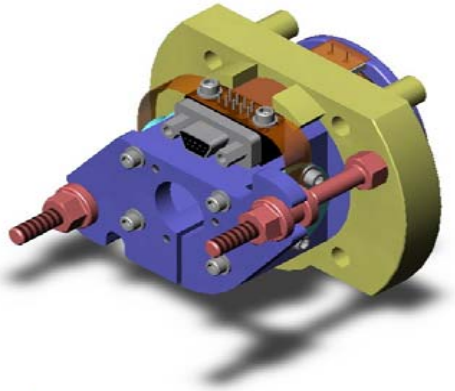
Initial LIGO

(OSEM)



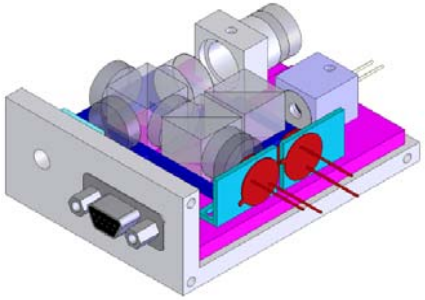
Advanced LIGO

Controls Prototype (Hybrid OSEM)



Advanced LIGO

Noise Prototype (B-OSEM)



Advanced / Ultimate LIGO

(Interferometric OSEM / EUCLID)

Interferometric OSEM Development (EUCLID)

- For Advanced LIGO the approach of using B-OSEMs plus eddy-current damping (ECD) for the quad suspensions is preferred over interferometric techniques

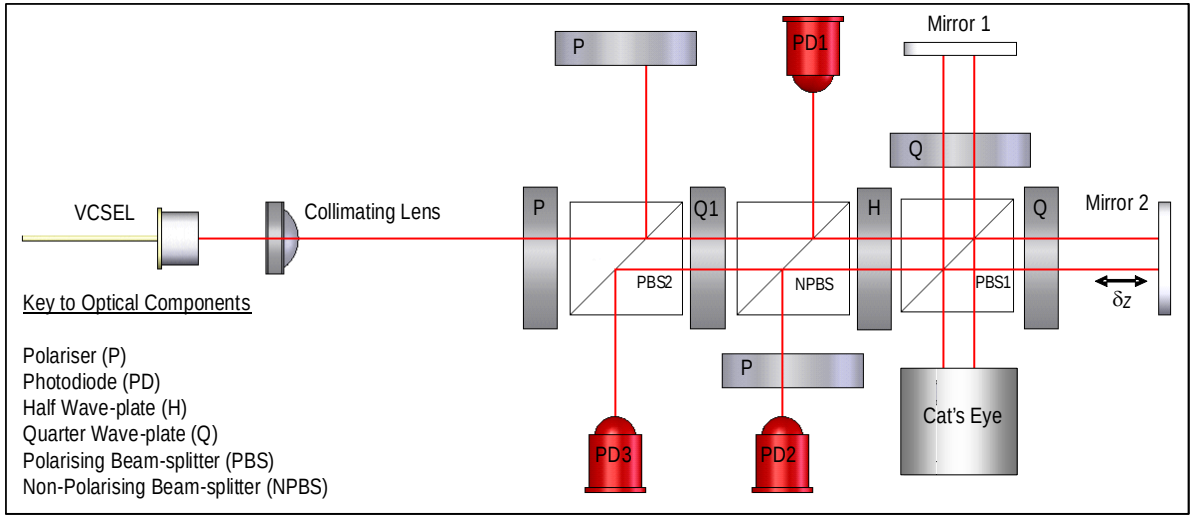
- However, R&D on the interferometric sensor has continued, as a possible back-up solution in the (unlikely) event that the B-OSEM and ECD solution is later found to be inadequate

- Potentially other locations where interferometric sensing may be advantageous (wherever you need high sensitivity and an improved operating range over optical-shadow or capacitive sensors)

- This has led us to develop a compact interferometer - EUCLID

Design Motivation

- To ensure good low frequency stability we needed to avoid active parts that can age, thermally expand, generate heat, exhibit hysteresis, e.g. piezo's etc. This naturally led to a Homodyne Interferometer
- Required to be compact and robust against misalignment

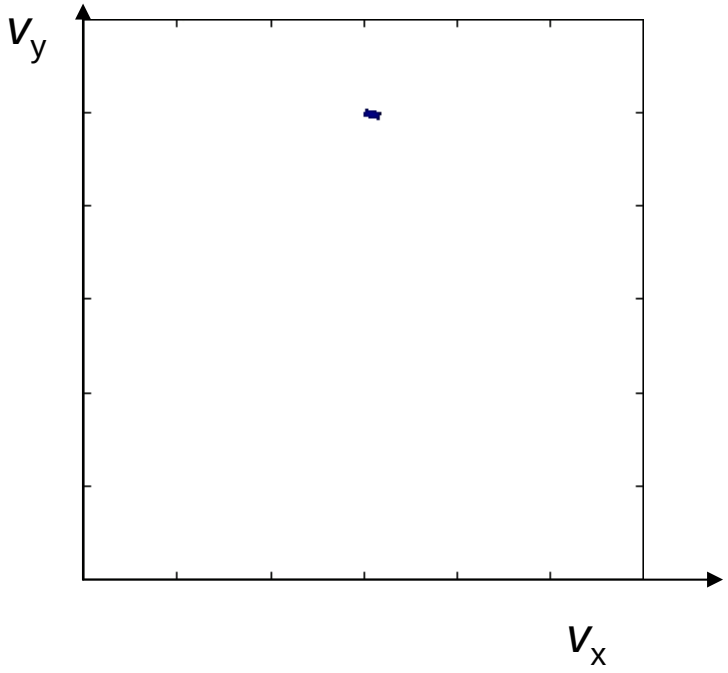


Optical Layout [1]

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

Fringe Interpolation Method

- Fringe intensities I_2, I_3 are 90° out of phase
- Motion of target mirror generates a circular Lissajous figure with I_2, I_3 plotted as v_x, v_y



$$\Delta\phi = \arctan\left(\frac{\left(v_{y_2} - v_{y_0}\right)}{\left(v_{x_2} - v_{x_0}\right)}\right) - \arctan\left(\frac{\left(v_{y_1} - v_{y_0}\right)}{\left(v_{x_1} - v_{x_0}\right)}\right)$$

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

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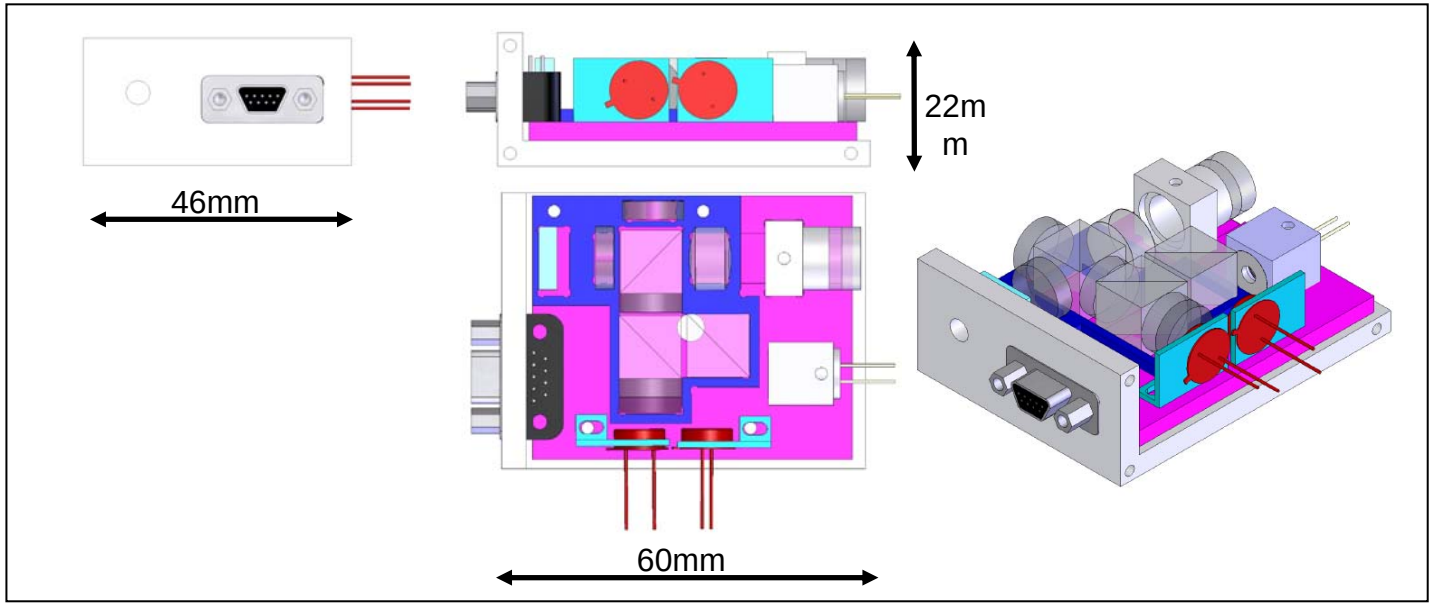
Preliminary EUCLID Specifications

- Resolution of 1 pm/√Hz over a large working range > 5mm
- Compact dimensions of 60mm x 46mm x 22mm
- Robust against misalignment +/- 1.5°
- Constructed with LIGO UHV compliance in mind



EUCLID CAD Model

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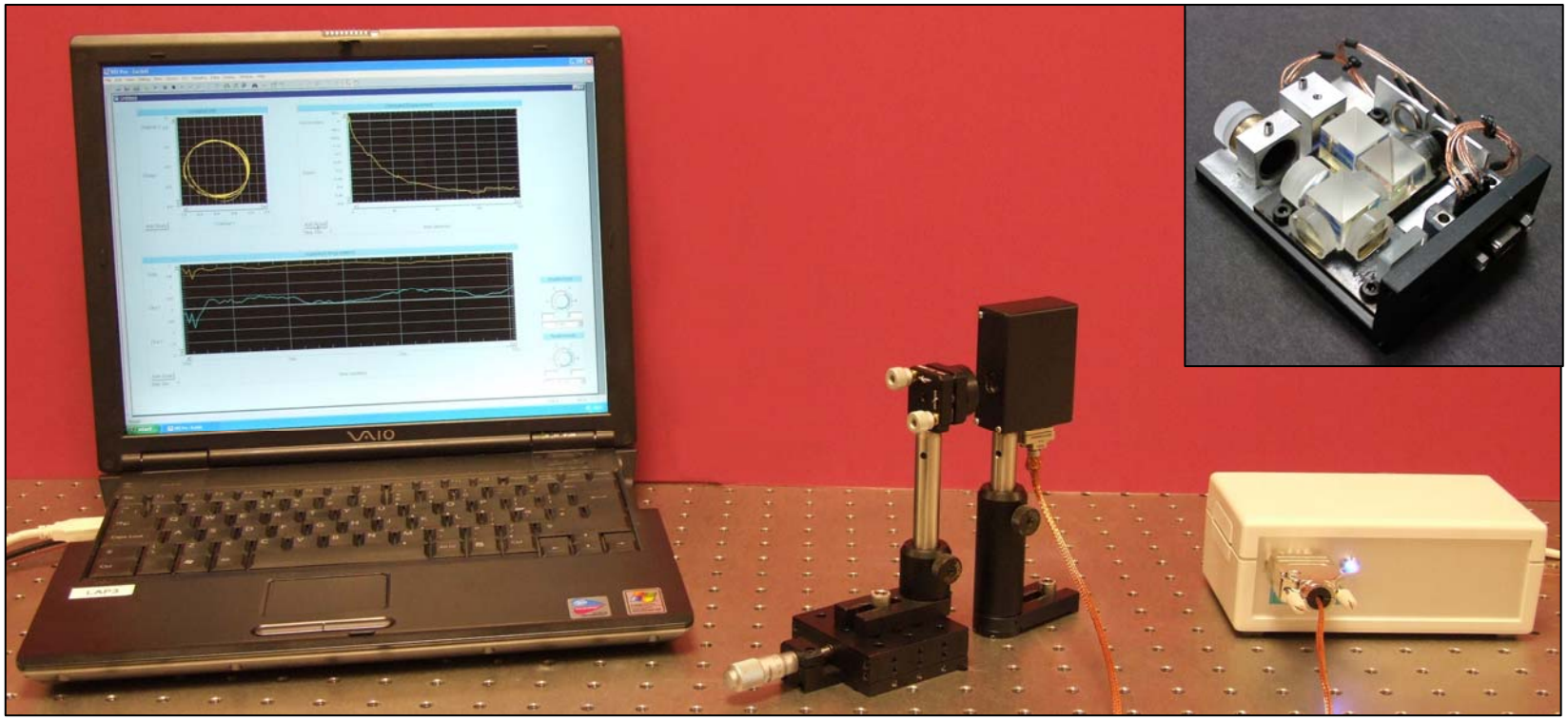
Prototype EUCLID

- Recently fabricated, assembled and aligned prototype
- Characterisation is ongoing



Prototype and support equipment. (Inset: with cover removed)

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To Summarise

- Over the next 4-6 weeks we shall complete all Noise Prototype B-OSEM deliveries. Our goal is to ensure these remaining units are delivered as close to the “final-article” configuration as is feasible and the delivery schedule allows

- Feedback from the FRR/FDR has been addressed with models, drawings and documentation being updated. Drawings to be signed-off and released under DCN. Orders to be placed with contractors for full production imminently

- Feedback on the performance and production issues associated with the coil drivers is being provided by the US team. This will be incorporated into the UK’s next pre-production cycle (Summer 2008)

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Thank You

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