Prototyping HoQIs on a Suspended Interferometer

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HoQI Design

Design considerations

- Size
  - Needs to fit in space constrained by suspensions (eg BBSS)
- Interface with gravitational wave control and data systems
  - CDS and Virgo-style DAQ
- Noise performance
  - Noise constraint set by OmniSens
- Alignment and ease of use
- Maintaining high fringe visibility

HoQI Design and Output

$$P_{PD1} = \frac{P_{in}}{8}(1 + a\sin(\Delta\phi))$$

$$P_{PD2} = \frac{P_{in}}{8}(1 - a\cos(\Delta\phi))$$

$$P_{PD3} = \frac{P_{in}}{8}(1 + a\cos(\Delta\phi))$$

Photodiode measurements

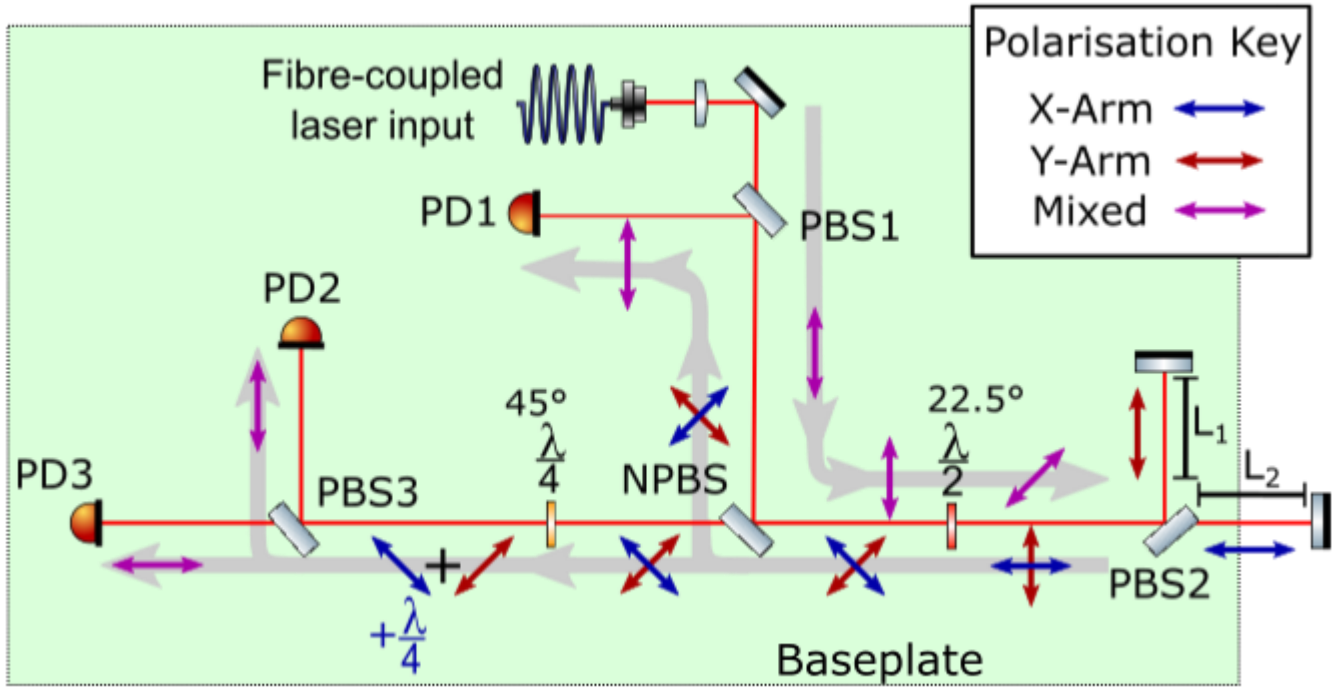
$$P_{PD1} - P_{PD2} = \frac{\sqrt{2}aP_{in}}{8}\sin\left(\Delta\phi + \frac{\pi}{4}\right)$$

$$P_{PD1} - P_{PD3} = \frac{\sqrt{2}aP_{in}}{8}\sin\left(\Delta\phi - \frac{\pi}{4}\right)$$

Manipulation

$$\frac{P_{PD1} - P_{PD2}}{P_{PD1} - P_{PD3}} = \tan(\Delta\phi)$$

Extracting Δϕ



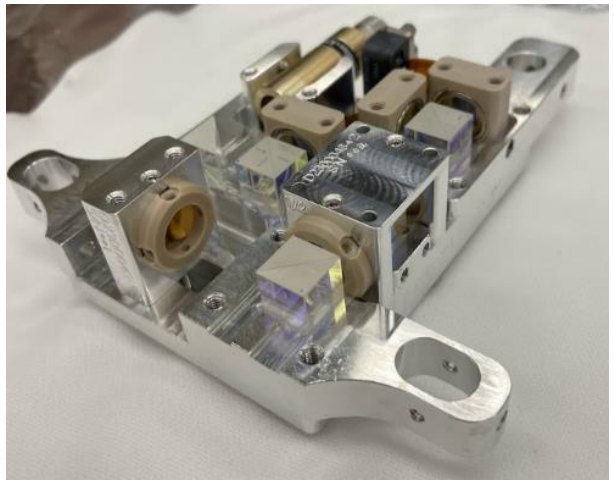
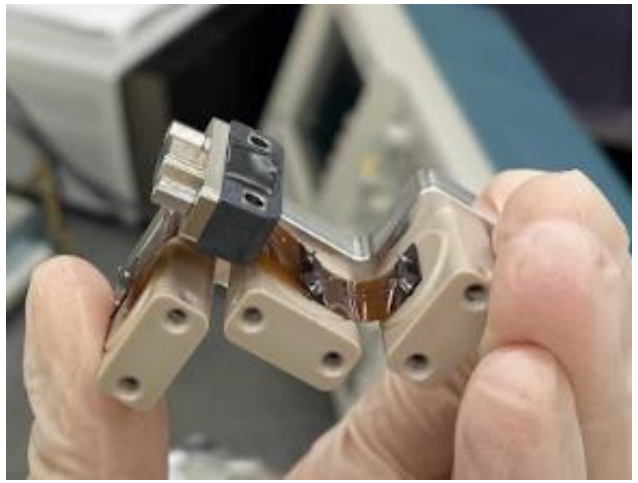
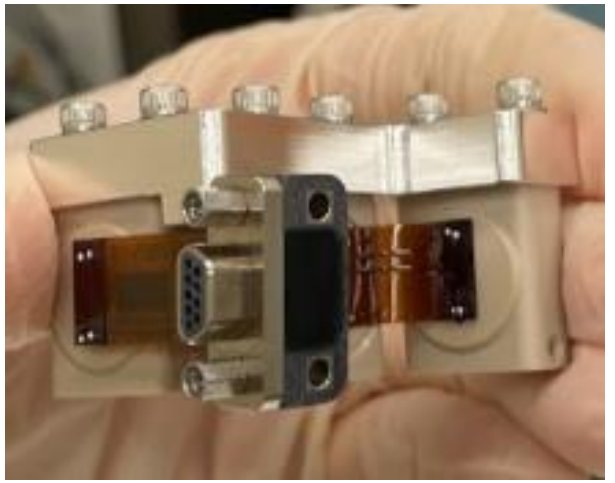
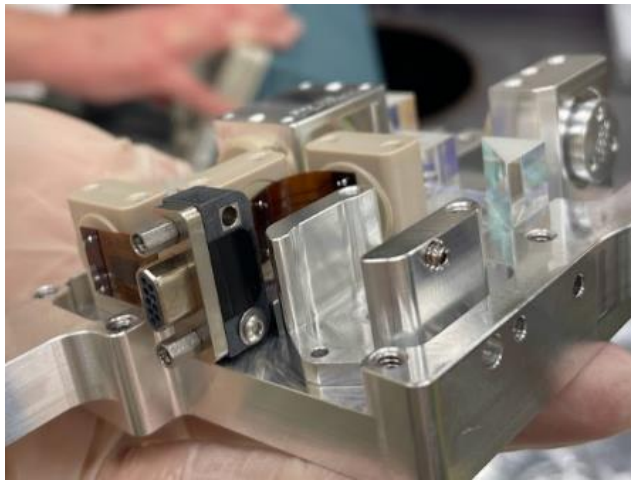
- Inherently calibrated signals
- Signal processing gets rid of dependence on input power and fringe visibility

Key Optical Design Features

- Aim to reduce non-linearity and maximise/maintain fringe visibility
- This is done through a well-aligned system and matching photodiode gains
- We have not observed significant non-linearity in any well aligned system thus far, especially when the fringe visibility is above the critical value
- Critical fringe visibility = 0.5
  - Found through experiment, reduced performance below this
- Clean input polarisation using the transmission of PBS
  - Previous published design used reflection
- Good quality optical fibre and strain relief important
  - Found empirically, vacuum feedthrough particularly important

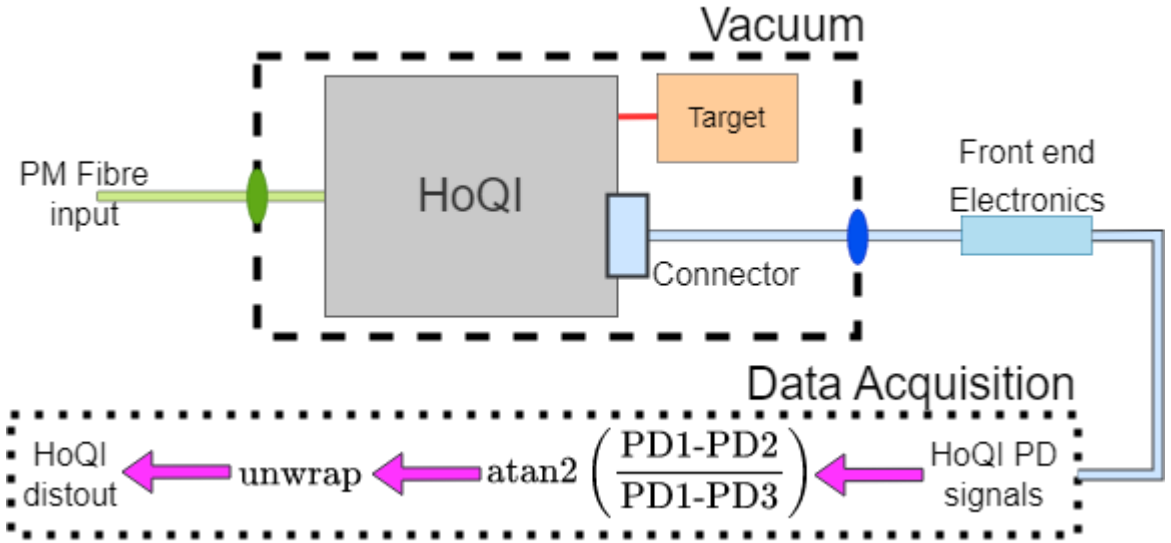
Mechanical and Electrical

- Since the previous publication the mechanics have been re-designed for ease of production
- Signal from photodiodes goes through a Kapton flexi circuit
- Had some issues with the previous design of this which has now been resolved
  - Less bends, reinforcements around pins and 90° connector

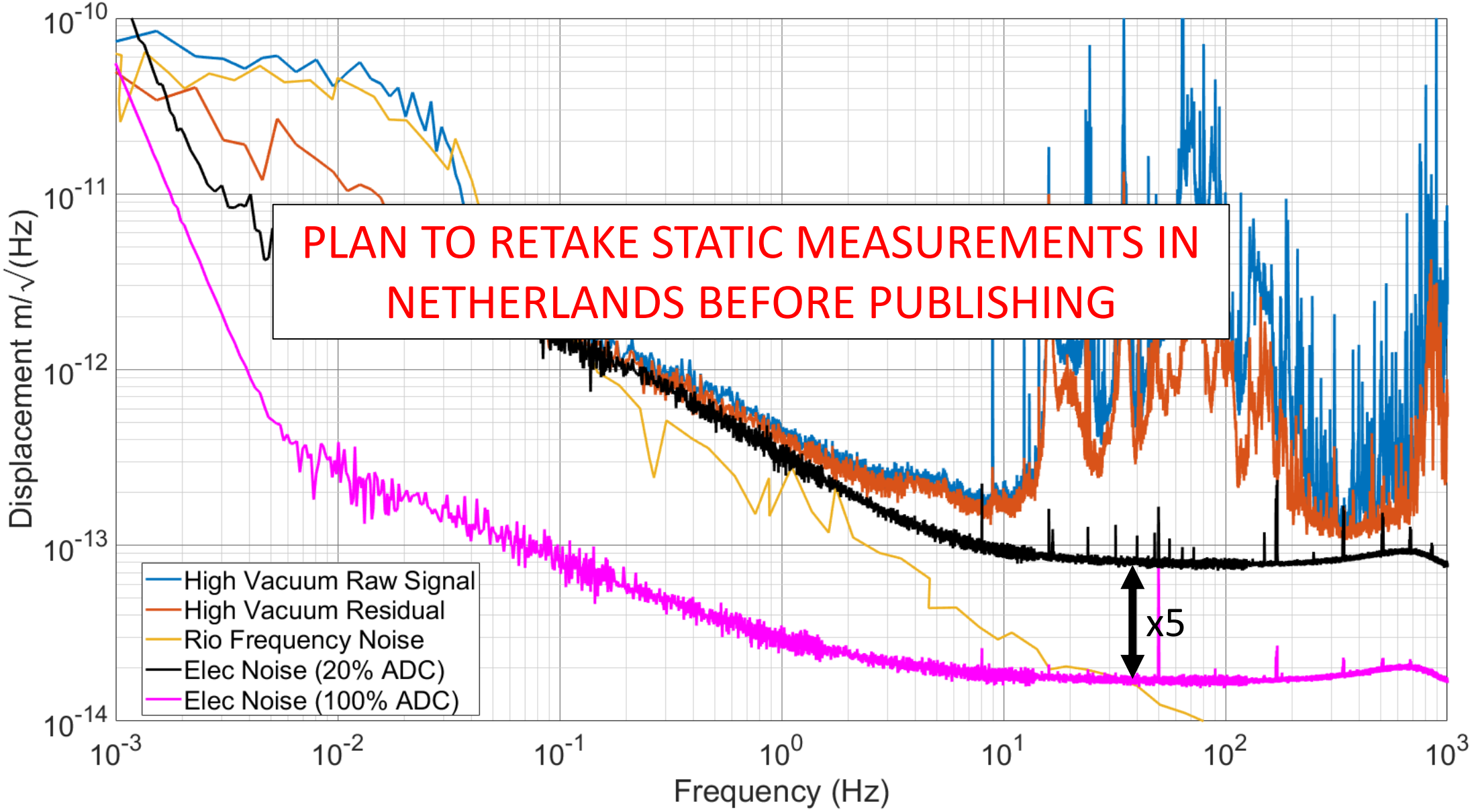
Optomechanical interface, Mounting and Signal and Optics Chain

- Two options for target optics: mirrors or retroreflectors
  - Mirrors better robustness to translation, poor rotational robustness
  - Retroreflectors (hollow, gold-coated) good robustness to both
  - Depends on system which optic is optimal
- Mounting to suspensions done using same mechanics (CAMs) as BOSEMs

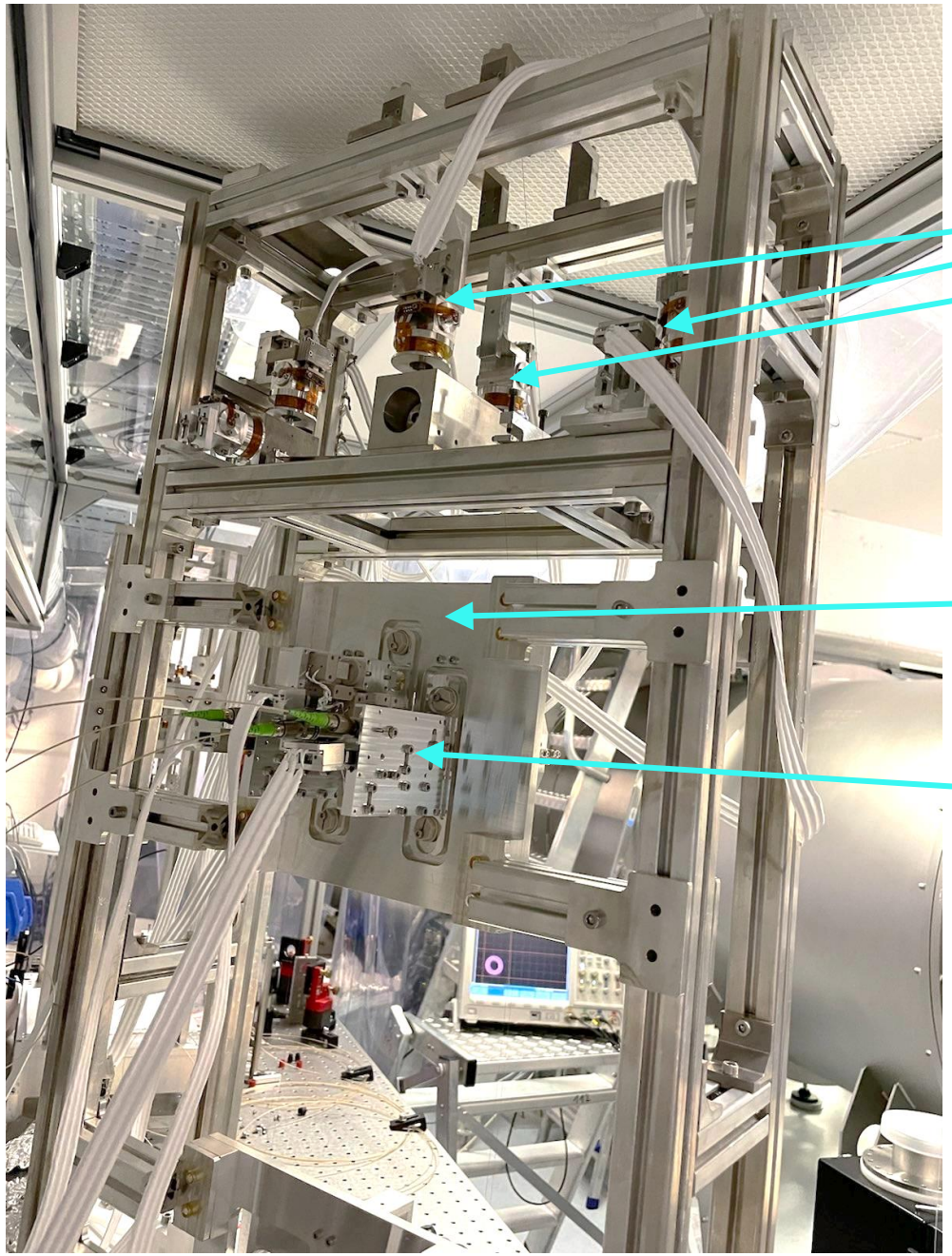


Static Measurements

Static measurements taken at UoB



Beamsplitter Suspension measurements with HoQIs



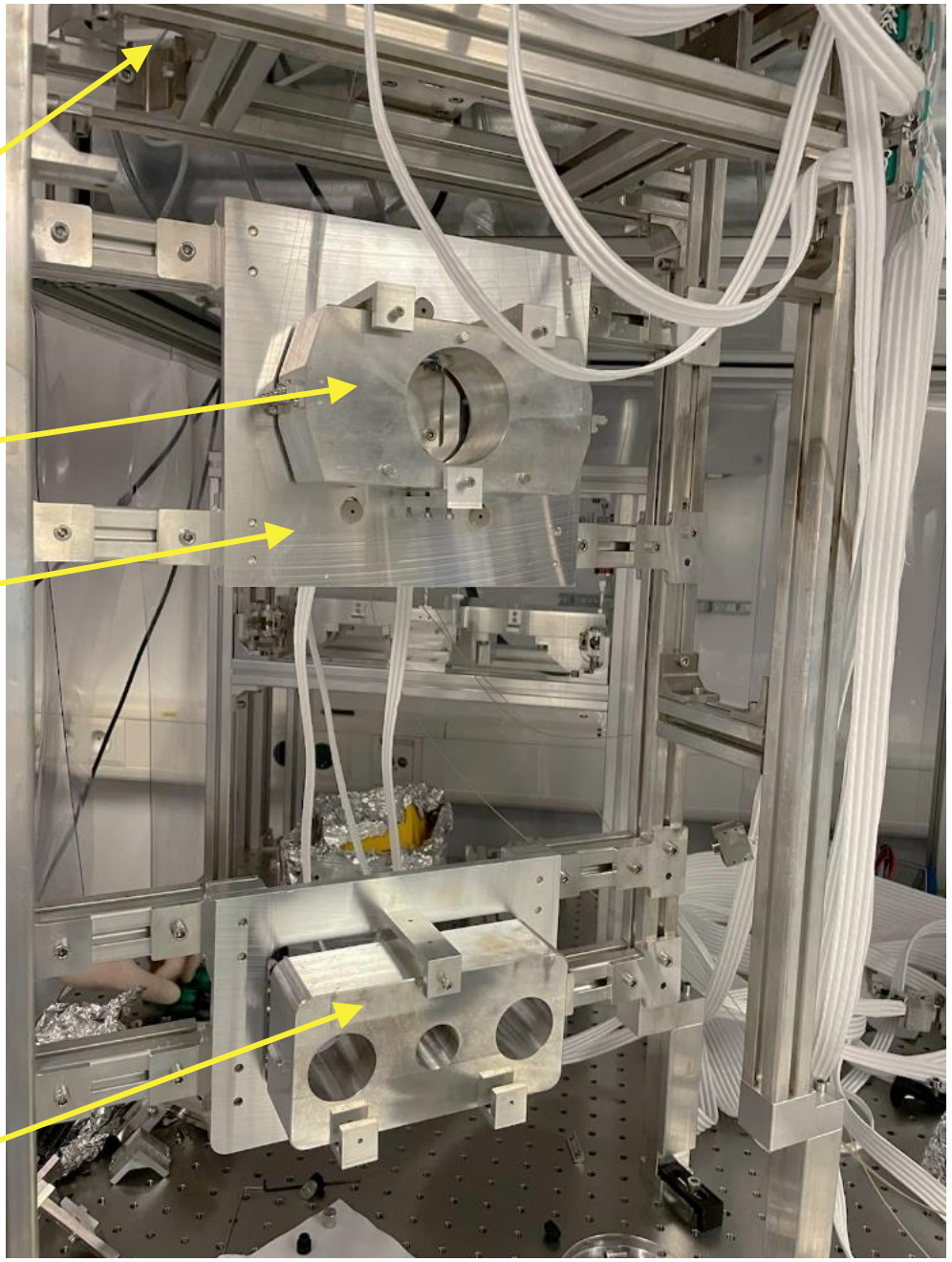
7x BOSEMS,
measuring and
damping top mass

IM

IM tablecloth

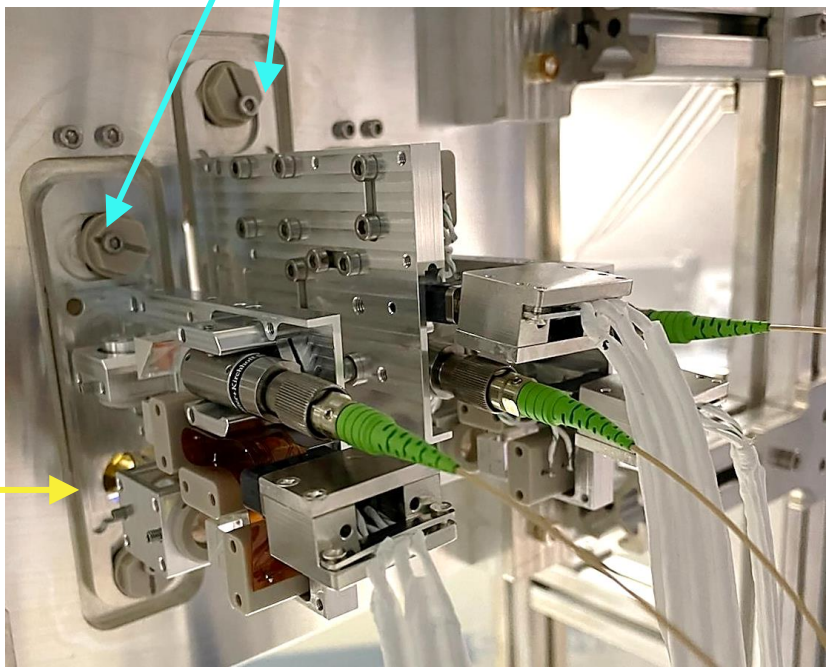
3x HoQIs,
Measuring IM

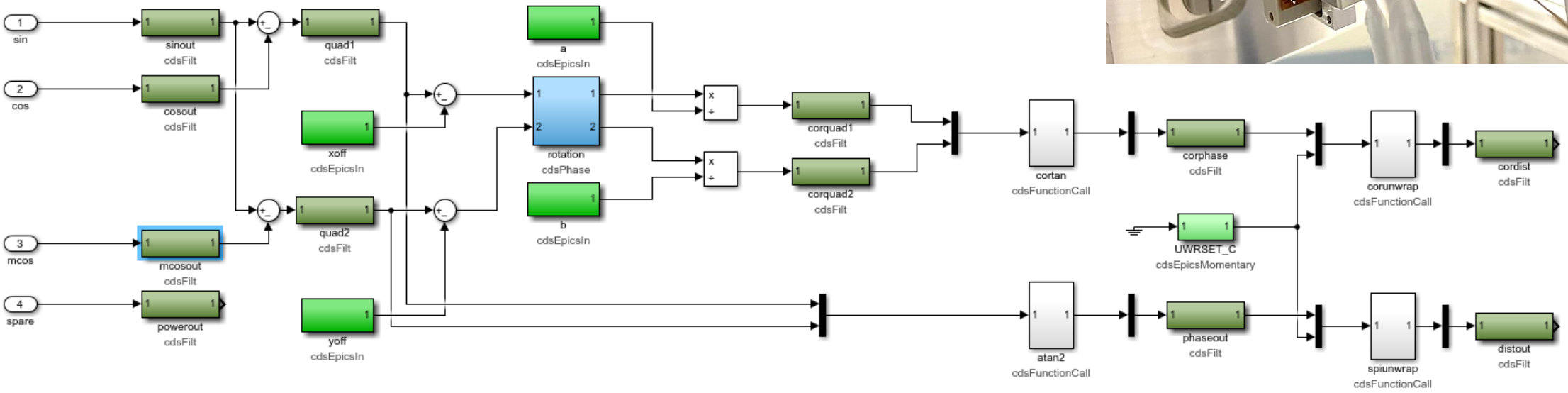
Dummy beamsplitter



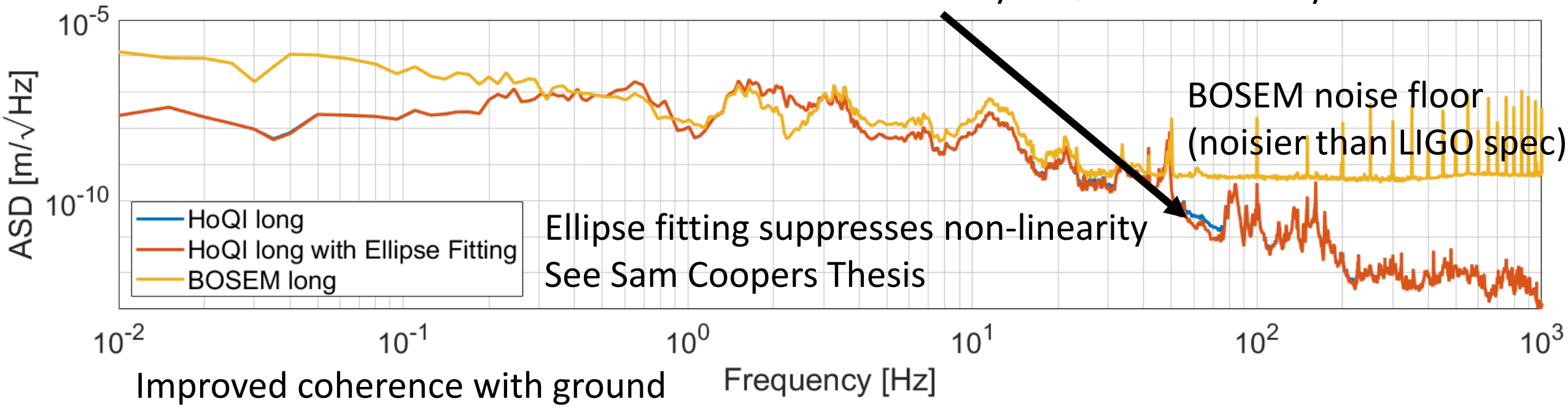
AEI Measurements and Integration

- Measurements were taken whilst suspension sat on a regular optics bench (no isolation) inside a clean tent (high air flow)
- Bolted to plate and adjusted with CAMs
- LIGO-style CDS used

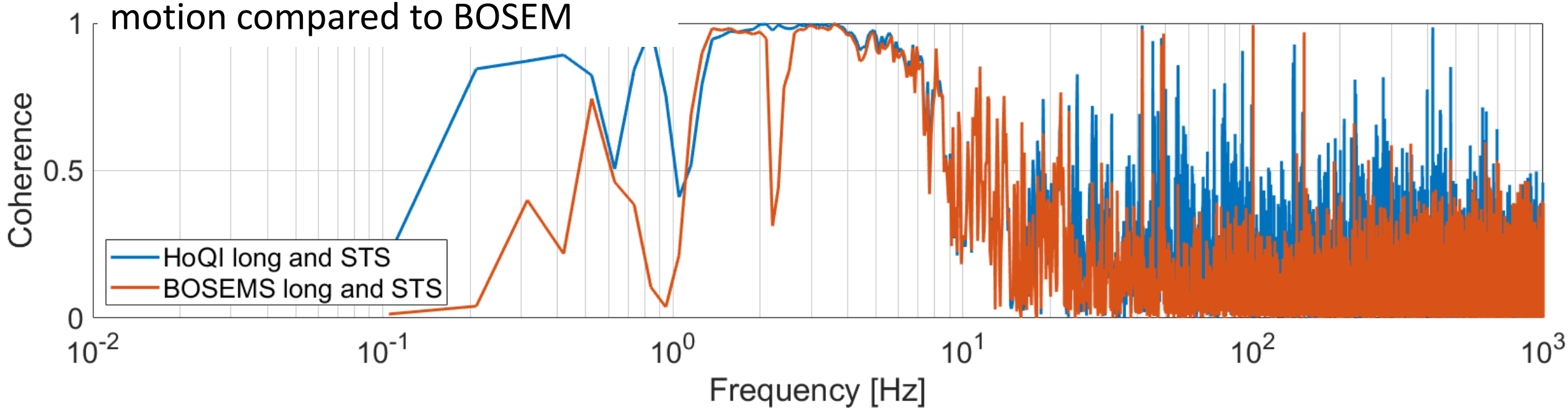




Small effect of EF = minimal non-linearity → Non-linearity a non-issue

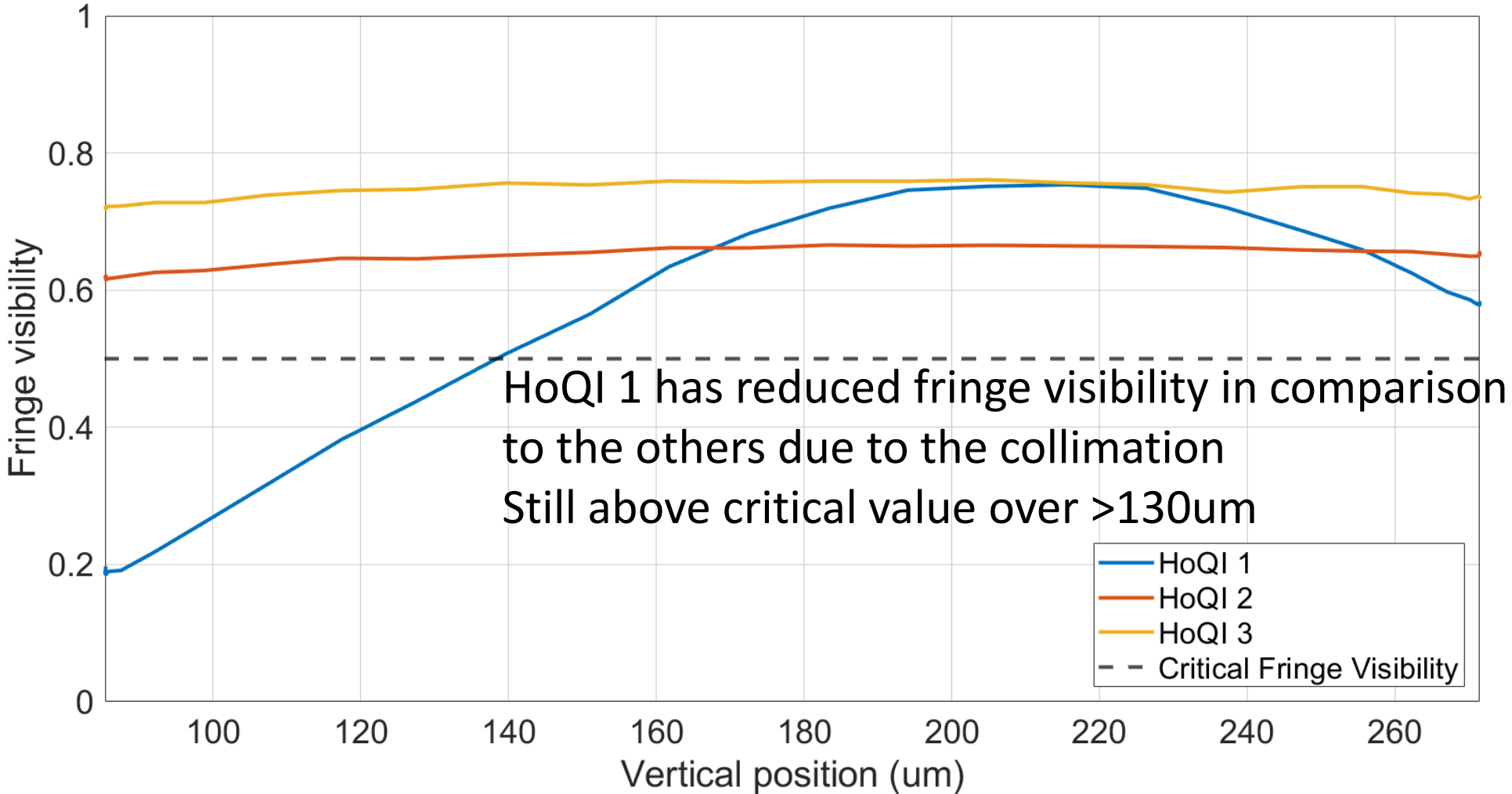


Improved coherence with ground motion compared to BOSEM



Fringe Visibility Robustness Testing

- Used BOSEMS to drive suspension vertically (degree of freedom not measured by HoQIs) and measured fringe visibility as a function of position



Conclusions

- HoQI design has matured and has been adapted for practical use in many systems
- Revised static noise performance measurements are to be taken before publication
- Three HoQIs were constructed, installed and integrated at the AEI 10m prototype
- HoQIs demonstrate they can measure motion below the BOSEM noise floor and with better coherence to the ground (main source of motion)
- The fringe visibility robustness and non-linearities were shown not to be a problem in a dynamic system