UNIVERSITY OF BIRMINGHAM | GRAVITATIONAL WAVE ASTRONOMY

ET EINSTEIN TELESCOPE

A 6D INTERFEROMETRIC INERTIAL ISOLATION SYSTEM

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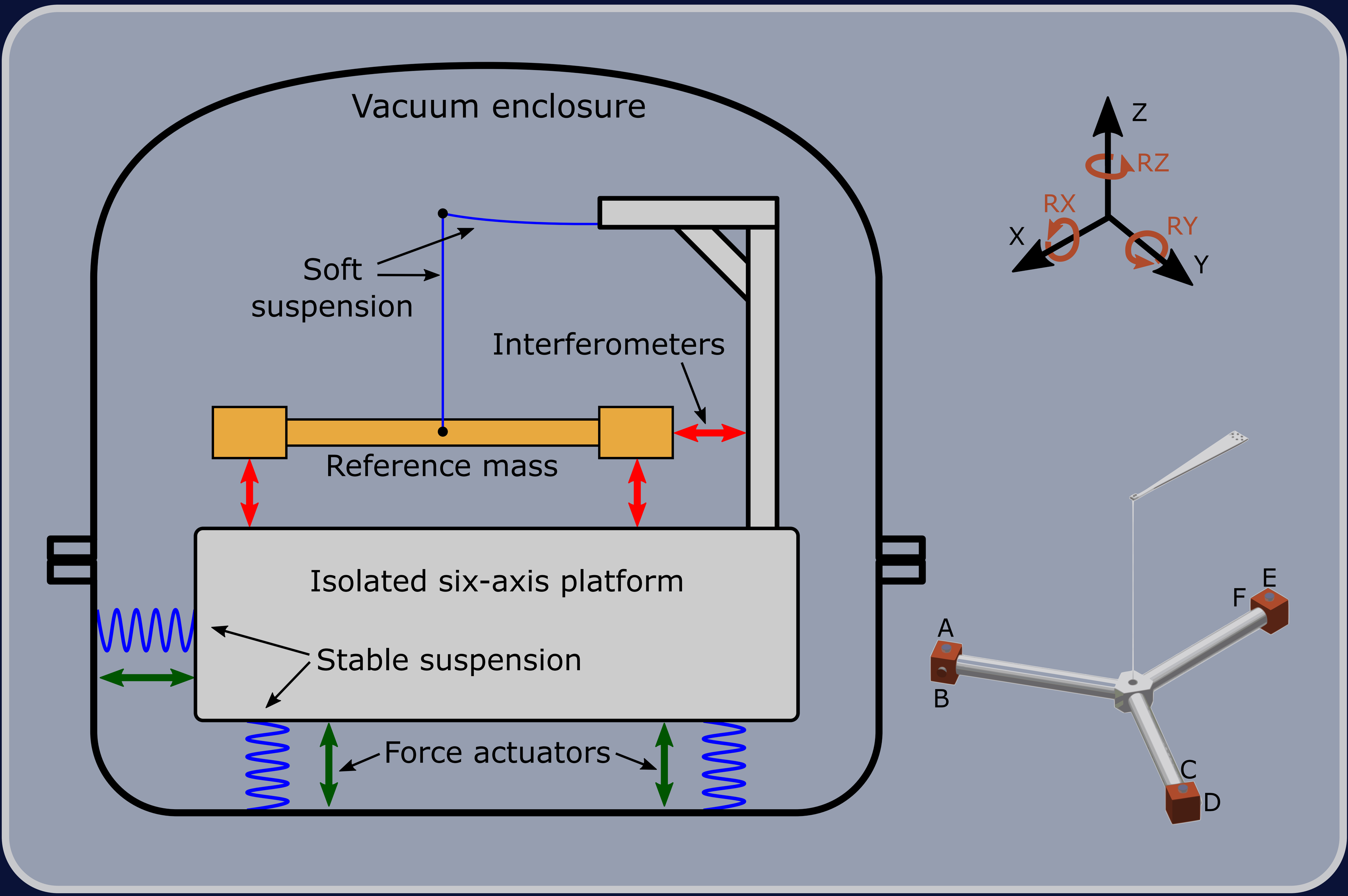
ET Symposium, 11-12 April 2019, Italy



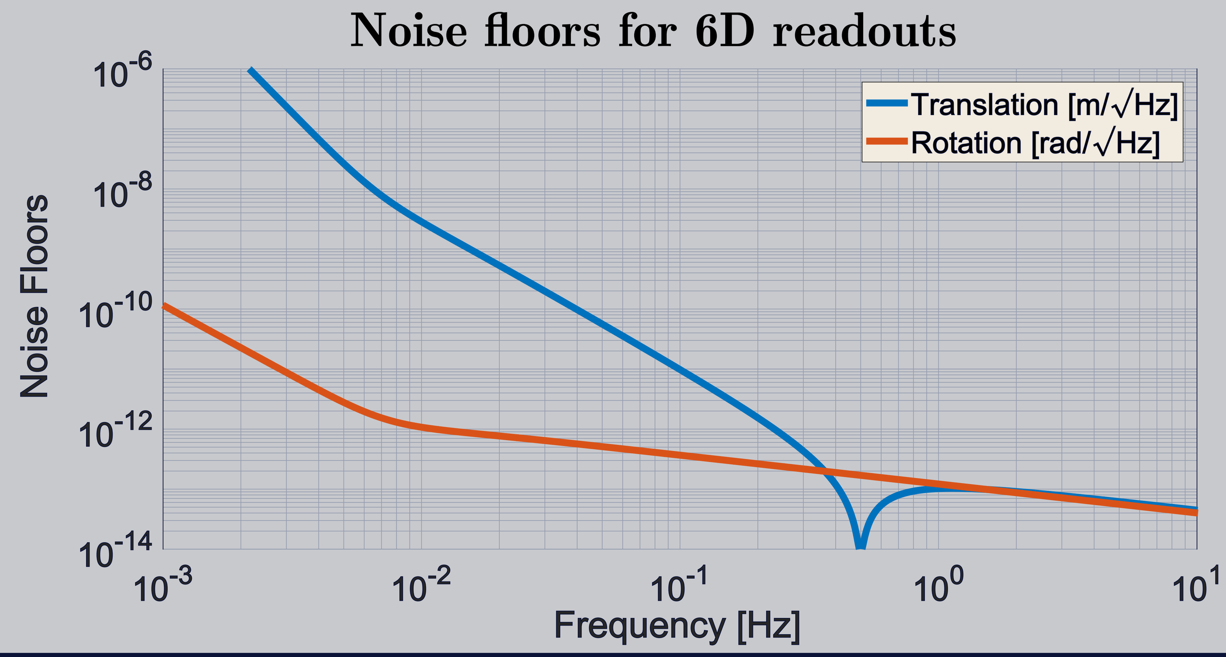
A brief description

The 6D system uses a single mass as an inertial reference for **all 6 degrees of freedom**. The reference mass is softly suspended by a single fused-silica fibre and sensed by 6 interferometers. An active platform is controlled with high-gain to stabilise the interferometer outputs, creating a virtual 'drag-free' environment around the reference, suppressing motion in all degrees of freedom.

READOUTS

Tilt motion is injected into translational motion of the platform as $\mathbf{g/\omega^2}$. To suppress this, the resonance is reduced by 2 orders of magnitude compared to the translational one (**500mHz to 5mHz**).

Noise floors for 6D readouts



INTRODUCTION

Ground-based detectors are strongly limited at low frequencies **[5 - 30 Hz]**. Unlocking these frequencies requires the development of new technologies, and will allow terrestrial detection of new, and more distant sources [2]. Additionally, source localisation and forewarning will provide opportunities for spectacular multi-messenger observations.

Low frequency technical noise is driven by vibration, but the inertial sensors used in seismic isolation systems are limited by several factors:

Tilt coupling	**Sensor noise and blending**
Dynamic range	**Mechanical cross coupling**

We propose a new kind of inertial isolation system that can overcome these limitations by a combination of materials, interferometry and design.

NOISE BUDGET

Care must be taken to shield the reference mass from stray forces due to the noises listed in the table.

Noise source	**Rotation [rad/$\sqrt{Hz}$]**	**Translation [m/$\sqrt{Hz}$]**
Thermal noise	$6{,}7 \times 10^{-17}$	$2{,}12 \times 10^{-15}$
Stray Magnetic Fields (@ 0,1 Hz)	4×10^{-14}	5×10^{-14}
Residual Gas Noise (@ 0,1 Hz)	2×10^{-14}	$2{,}3 \times 10^{-14}$ @ 10^{-6} mbar
Temperature gradients (@ 0,1 Hz)	5×10^{-15}	10^{-14}
Readout Noise (HoQI)	$1{,}2 \times 10^{-13}$	$9{,}12 \times 10^{-14}$

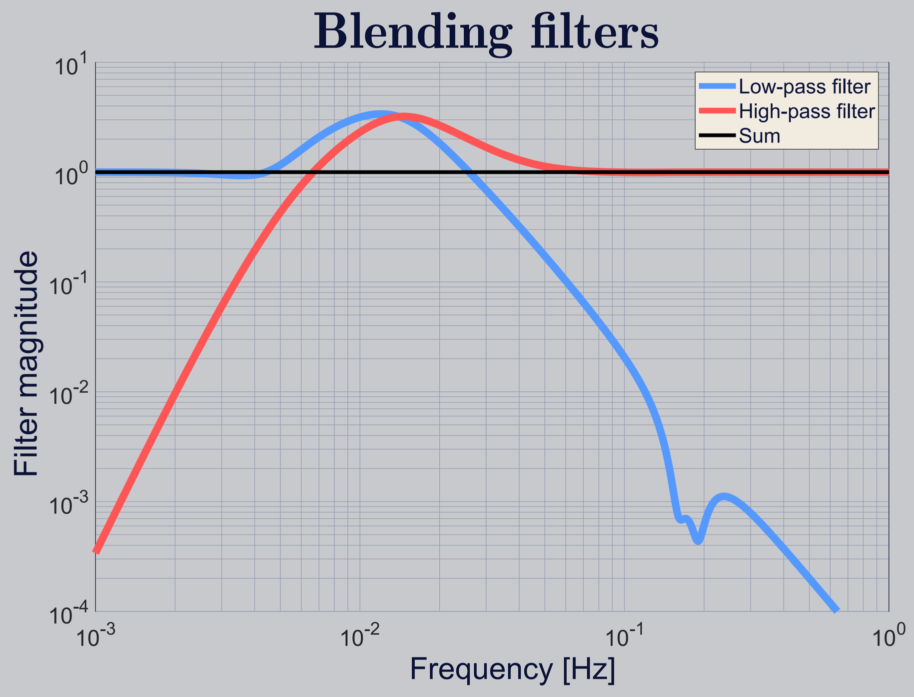
These risks are minimised by:

1. **Non-magnetic materials** and no signicant sources of magnetic field noise near the reference mass.
2. **Gold-coated** end-masses to conduct away local surface charges.
3. **High thermal conductivity** materials attenuating temperature gradients.
4. **Compact** end-masses, and sufficient clearance between mass and surrounding structures to minimise residual gas noise.

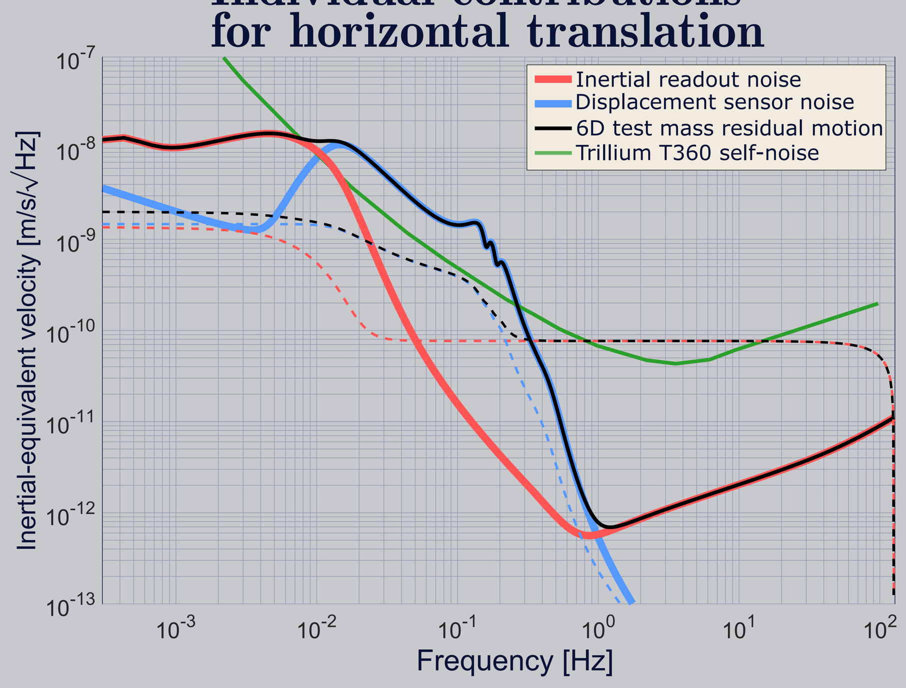
PERFORMANCES

Sensor fusion, or **"blending"**, is the combination of information from different sensors, within a real-time control system. In the case of 6D, the two sensors that will be blended are the conventional **displacement sensors** that position the six-axis platorm, and the **reference-mass intereferometers** that sense the inertial motion.

Blending filters

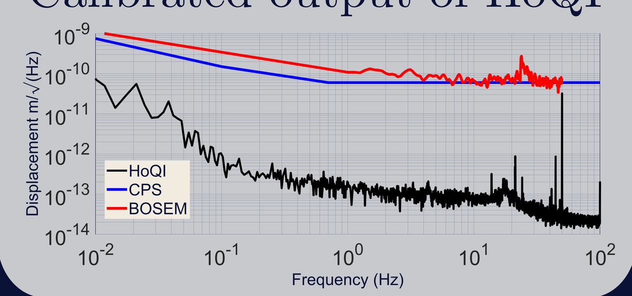


Individual contributions for horizontal translation

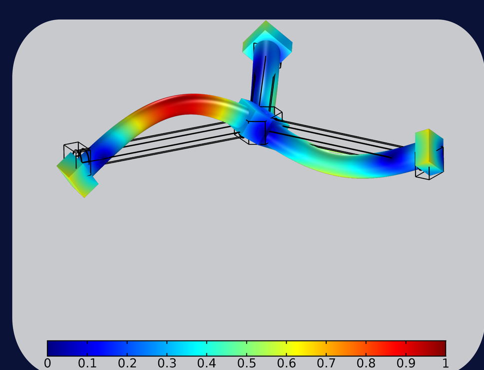


Interferometric readout used to improve vibration isolation: **HoQI** [3]

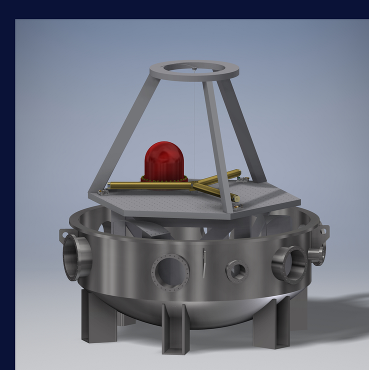
Calibrated output of HoQI



FEA simulations on the reference mass



CAD model of the 6D chamber



Contacts

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References

[1] C. Mow-Lowry, D. Martynov, **A 6D interefrometric inertial isolation system,** arXiv:1801.01468v1
[2] H. Yu et al., **Prospects for detecting gravitational waves at 5Hz with ground-based detectors** Phys. Rev. Lett. 120, 141102 (2018)
[3] S. Cooper et al, **A compact, large-range interferometer for precision measurement and inertial sensing,** CQG, Vol. 35, N.9 (2018)

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