6D inertial seismic isolation

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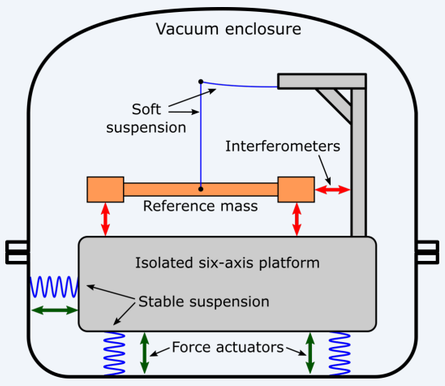
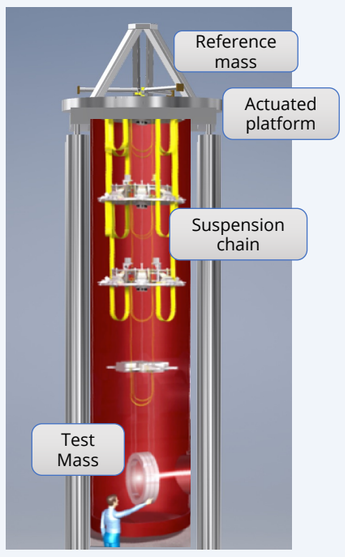
6D Concept



Impose the inertial stability of the reference mass on the isolated platform using active feedback.

- Reference mass is suspended by fused silica fibre
- Position of the reference mass is measured by interferometric sensors.
- Active platform is actuated to follow the reference mass (as drag-free satellites)
- All DOF are sensed

Mow-Lowry and Martynov, 2019 *CQG* 36 245006



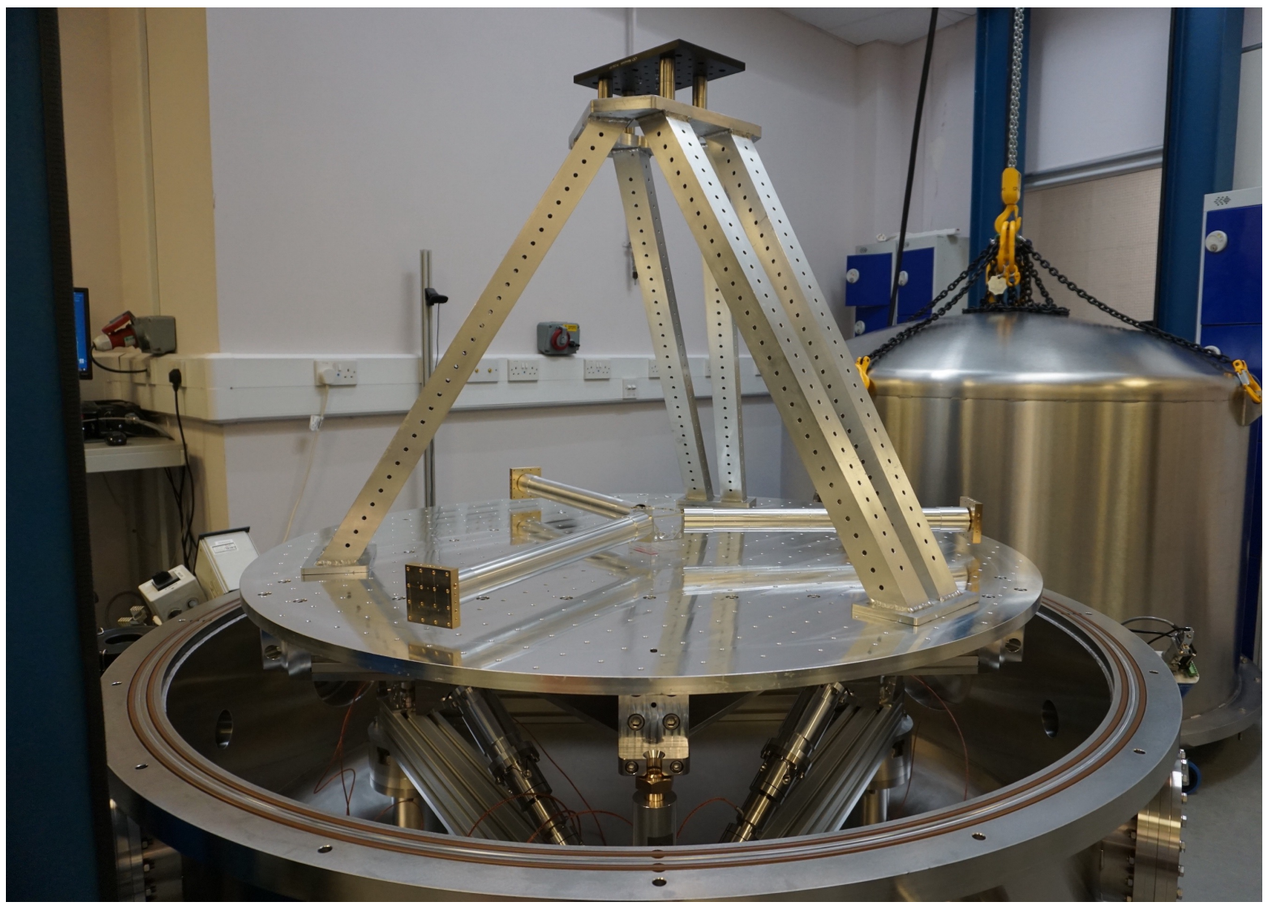
6D v1

Aim: to test the concept. Key features:

- Fused silica suspension
- 4 kg / 120 cm diameter Reference Mass
- Interferometric HoQI readout for low noise
- BOSEMs for absolute position sensing
- Piezo actuated platform
- Coil-magnet actuation of the test mass
- Suspension is stiff in Z

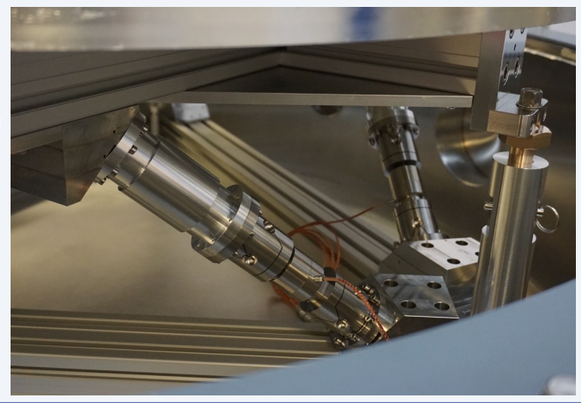
DoF	Resonant frequency
X, Y	0.6 Hz
RX, RY	5 mHz (tunable)
Z	5 Hz
RZ	0.5 mHz

6D v1 status



Actuated platform is recently installed in the vacuum chamber.

Characterization and tests of this platform are about to start



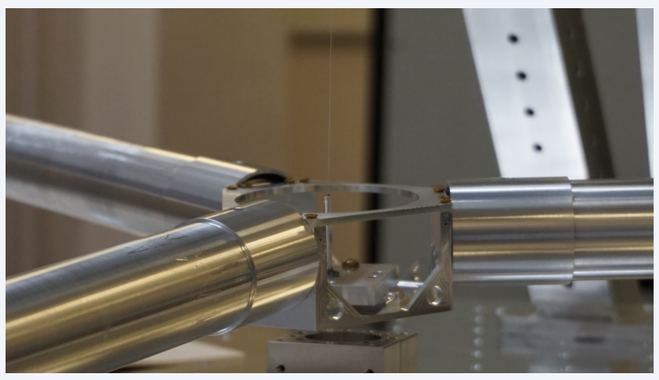
Sensors

Homodyne Quadrature Interferometers (HoQI)

- Variety of tests is done,
- New design is developed
- Tests on the smaller suspended mass are ongoing to investigate the performance on the free-swinging mass

See posters by S. Cooper and J. van Dongen

Suspension



Fused silica suspension is tested for a smaller mass (up to 700g). Full Reference mass suspension is planned soon.

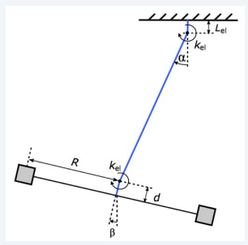
Fibres are pulled in the University of Glasgow

Reference mass suspended close to centre of mass to
a) low tilt resonant frequencies
b) minimize horizontal -> tilt coupling

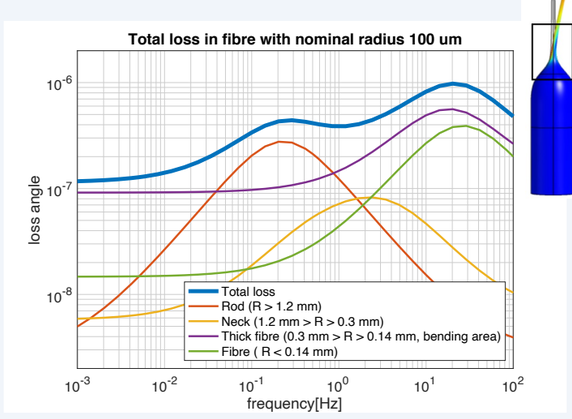
Bending occurs near the ends of the wire

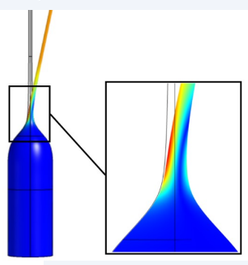
We use gravitational anti-stiffness to compensate the fibre stiffness

$$k_{tot} = k_{elastic} - k_{grav}$$



FEA with the measured shape of the neck:
Bending occurs in the thicker part of the fibre, so the stress is below limits for reasonable tilt angles





Suspension drifts

Drift tests are ongoing. We have tested the drift for a fibre tension smaller than nominal. Measured drift in RZ is about 1 mrad in 3 days.

In the nearest plans – investigating in the tilt drift as it is unknown. The 6D setup tilt frequency is very low and the bending point of the fibre is close to the centre of mass, which is unusual.

Centre of Mass tuning

To set tilt frequency 5±1 mHz we need set RM height with dz_{COM} = 4um tolerance.

To set TM in horizontal position with error less than 0.5mm at the end of arm, tolerance for $dx_{COM} \approx 10$ nm

We use a small mass m installed on the Reference mass (RM) to adjust the CoM position. The m is mounted to the piezo stick-slip stage which can be connected in vacuum conditions with a removable connector.

Moving mass m = 20g on the TM, m could be optimized to improve range or tolerances

CoM tuning was tested in air with a 1 m long beam suspended with tilt resonant frequency 20 mHz

System dynamics

We developed a Mathematica model of the 6D based upon Perry Forsyth's (ANU) TorPeDo model.
It provides transfer functions to lab frame positions and sensors, produces sensing and actuation matrices.
In future, the model will be compared with actual measurements and coefficients updated.

Actuation study

For actuation, we use BOSEM coils with shielding magnets mounted to the reference mass. Using couples of magnets:

- Reduce force (system extremely soft)
- Reduce force from external magnetic fields