

Addressing coupling limitation in low-frequency active isolation systems with Fiber-Optic Gyroscopes

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Belgian-Dutch GW meeting – Louvain-la-Neuve

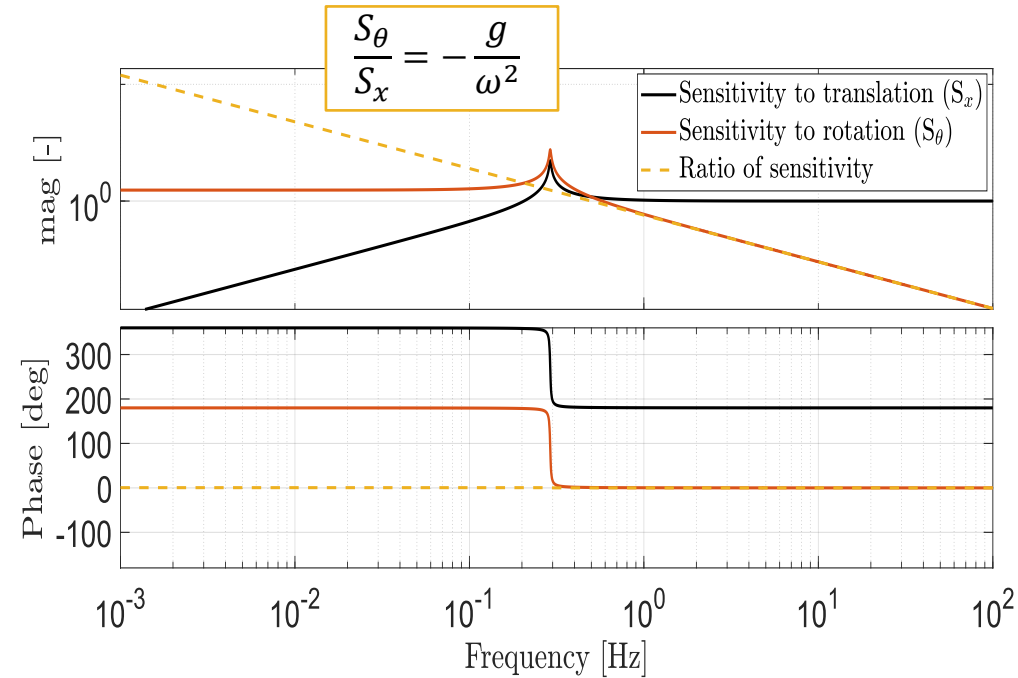
8th-10th Octobre 2026

Rotation-translation coupling

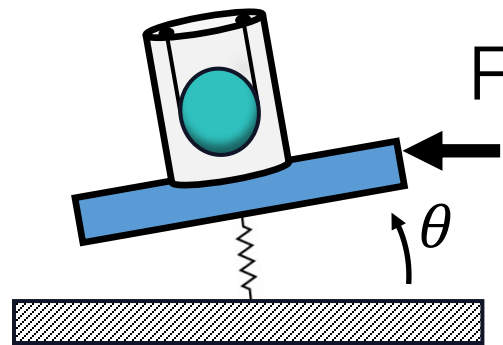
ETEST



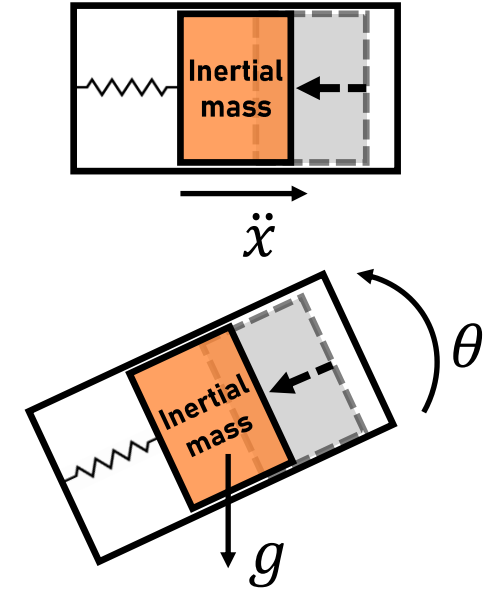
3 horizontal sensor/actuator pairs
3 vertical sensor/actuator pairs



Actuator



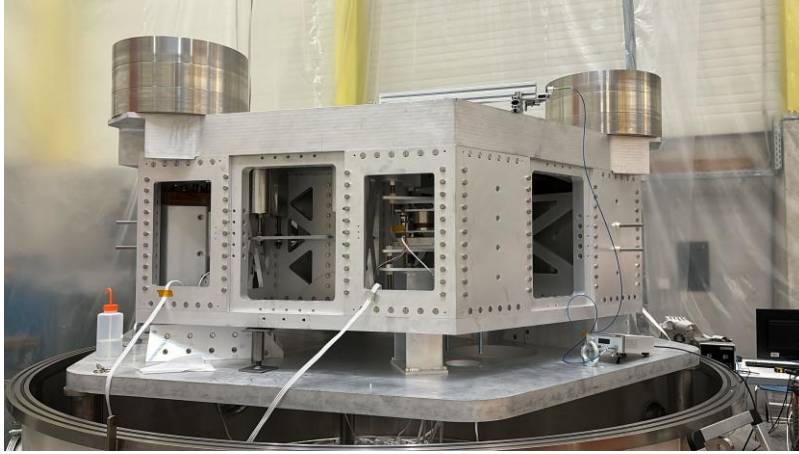
Inertial sensor



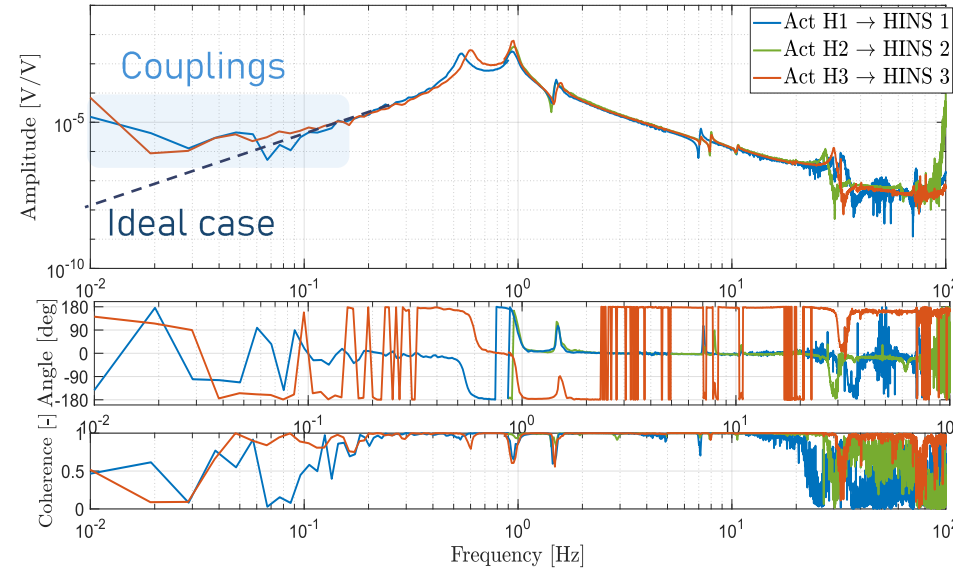
Difficult to isolate at low
frequency (< 0.1 Hz)

Rotation-translation coupling

Active platform



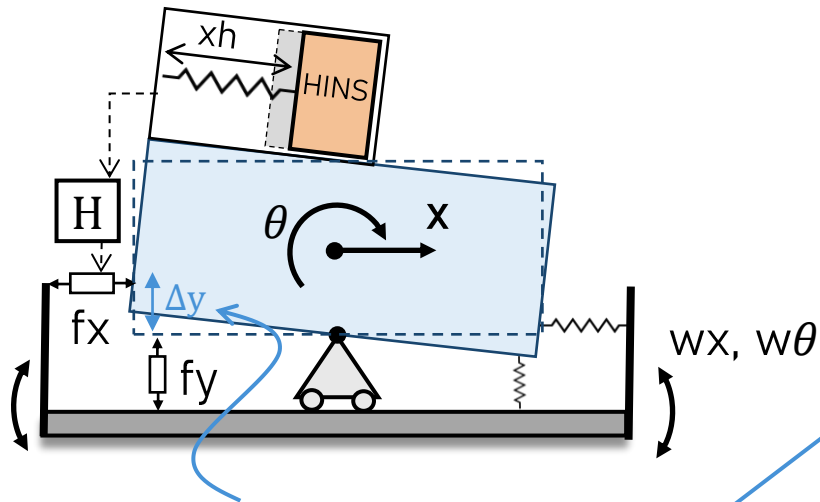
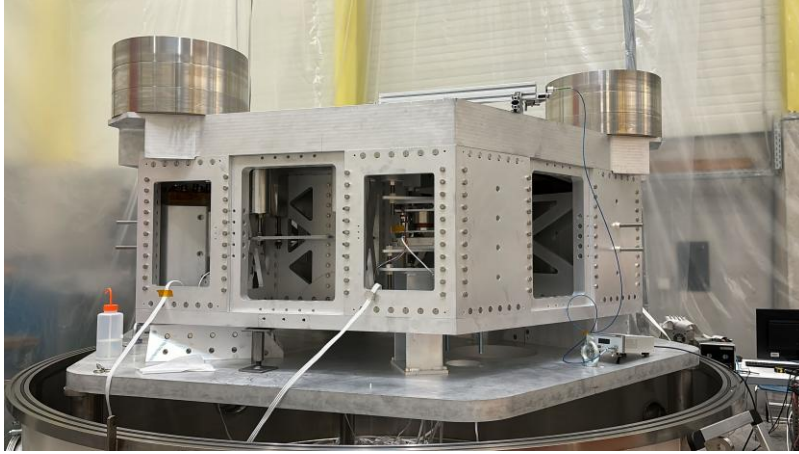
TF: Horizontal actuators to horizontal sensors



Large couplings
strongly limit
isolation
performances at low
frequency (< 0.1 Hz)

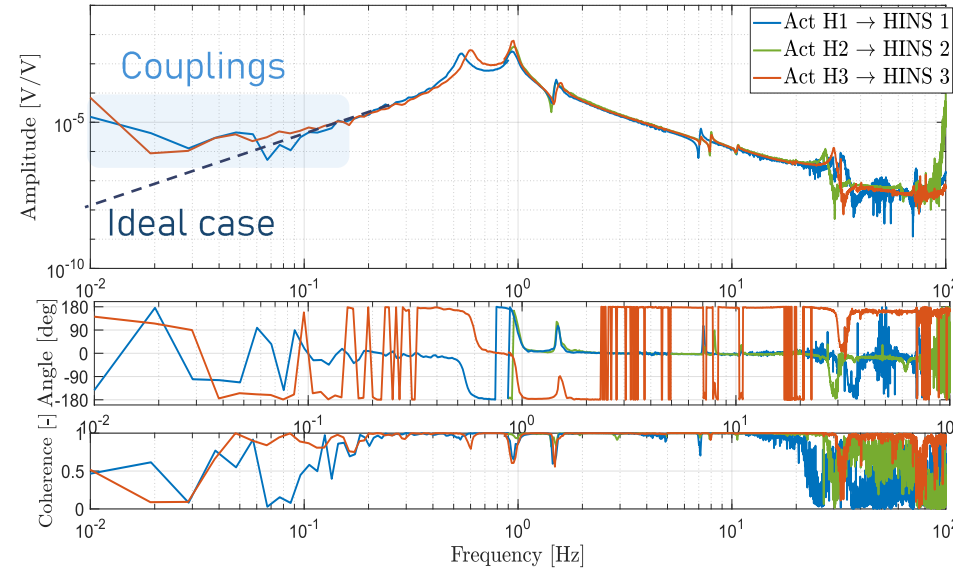
Rotation-translation coupling

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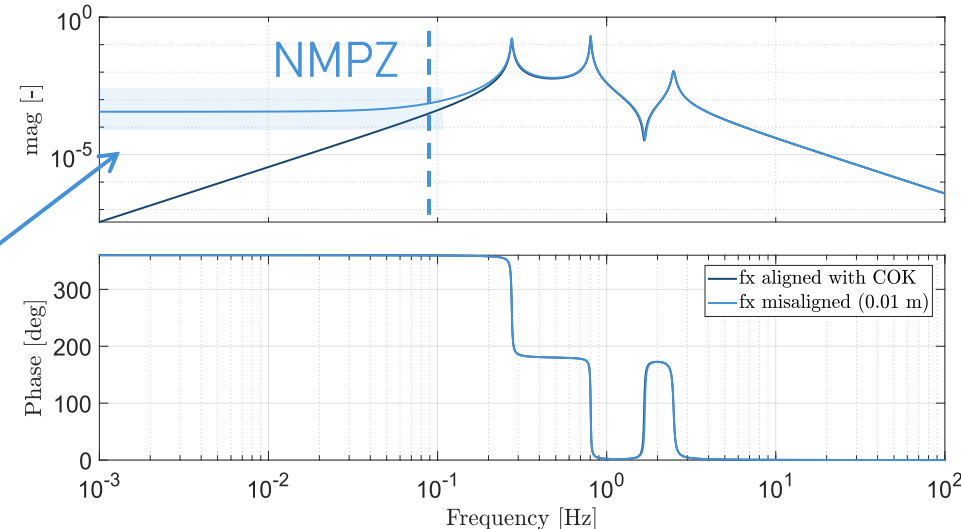
Misalignment of actuator w.r.t
Center of Stiffness

TF: Horizontal actuators to horizontal sensors



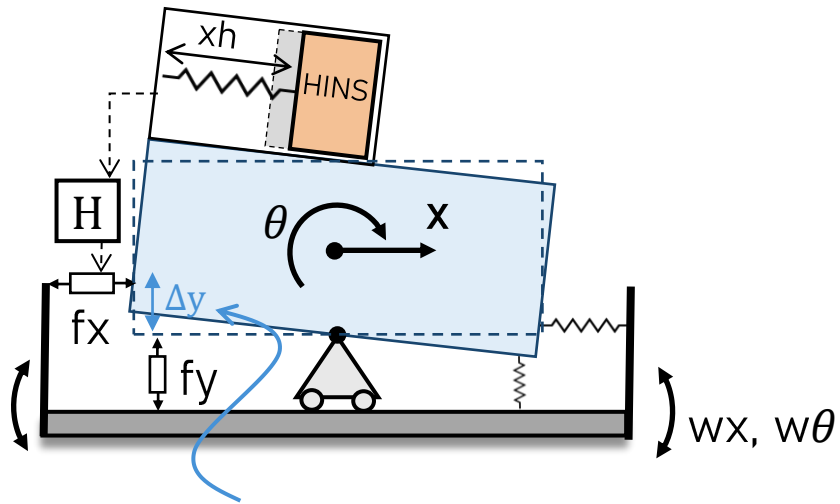
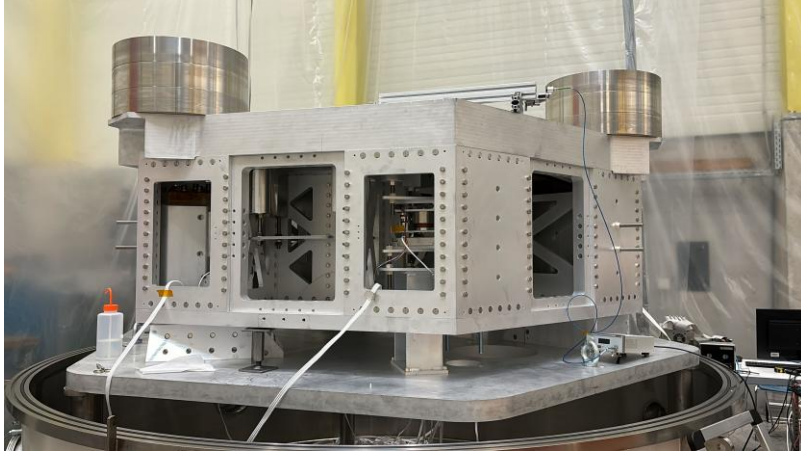
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TF: Actuator f_x to HINS

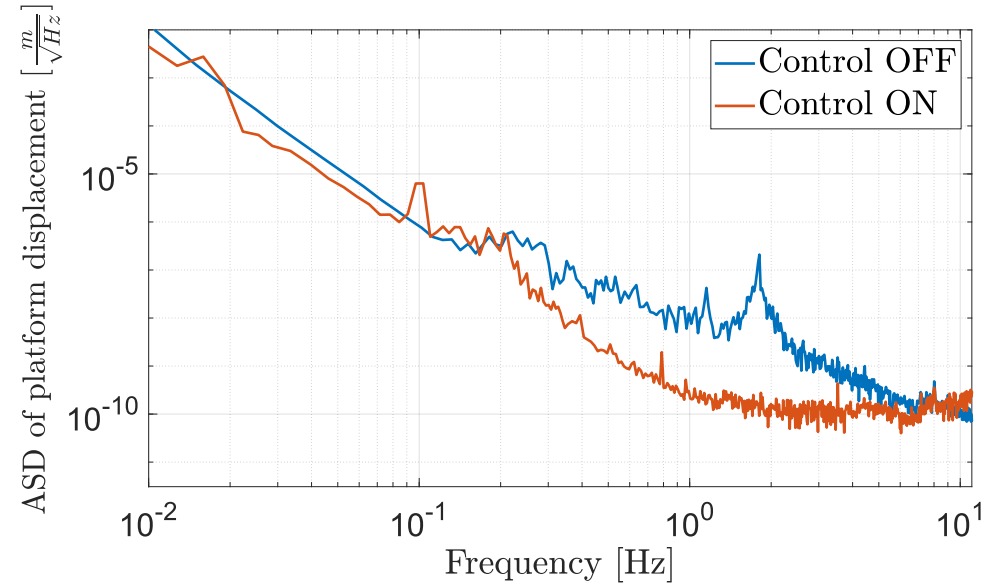


Rotation-translation coupling

Active platform



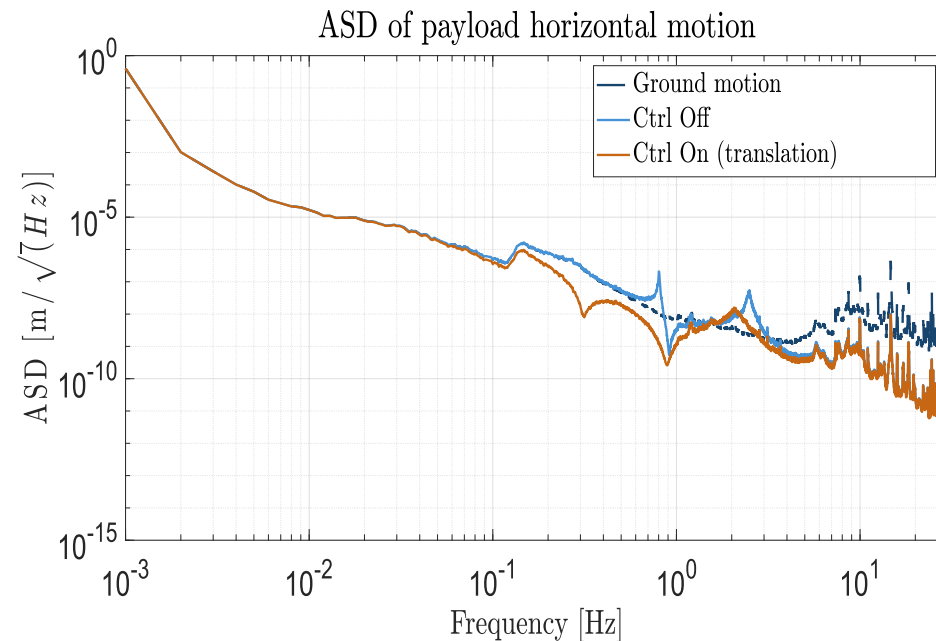
Misalignment of actuator w.r.t
Center of Stiffness



Large couplings
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performances at low
frequency (< 0.1 Hz)



- Limited isolation BW
- Limited control gain



Addressing rotation-translation coupling

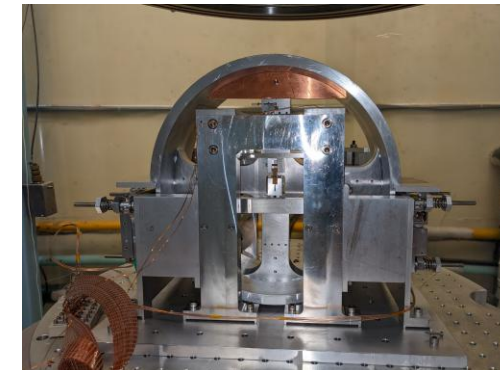
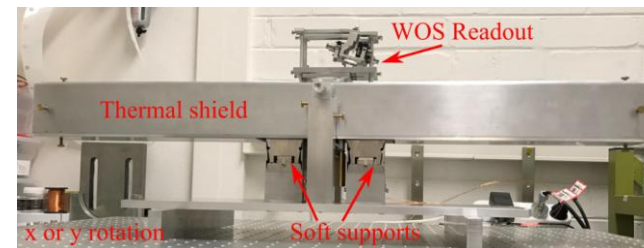
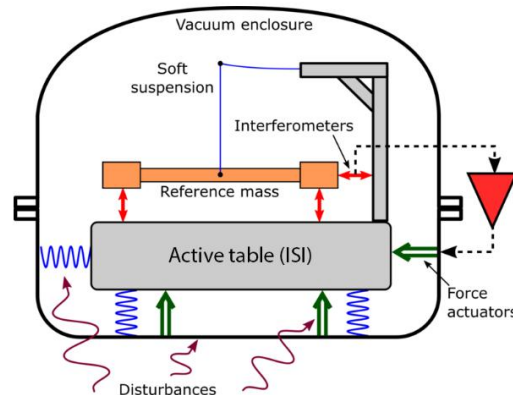
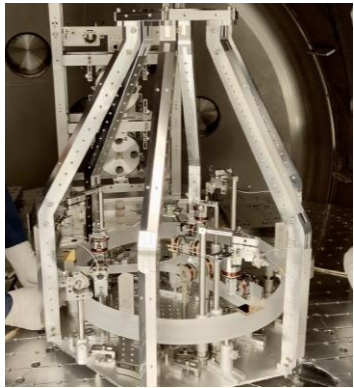
- **Physical decoupling** (Sensor & actuator design/placement)
 - Practical limitations
 - Precision level

Addressing rotation-translation coupling

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 - Practical limitations
 - Precision level
- **Decoupling algorithm** (based on model or experiment)
 - Model-experiment matching
 - Sensor noise/cross-axis sensitivity

Addressing rotation-translation coupling

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 - Precision level
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 - Model-experiment matching
 - Sensor noise/cross-axis sensitivity
- **Additional sensors** (sensor correction, active isolation)
 - Sensor noise/cross-axis sensitivity
 - Control limitation



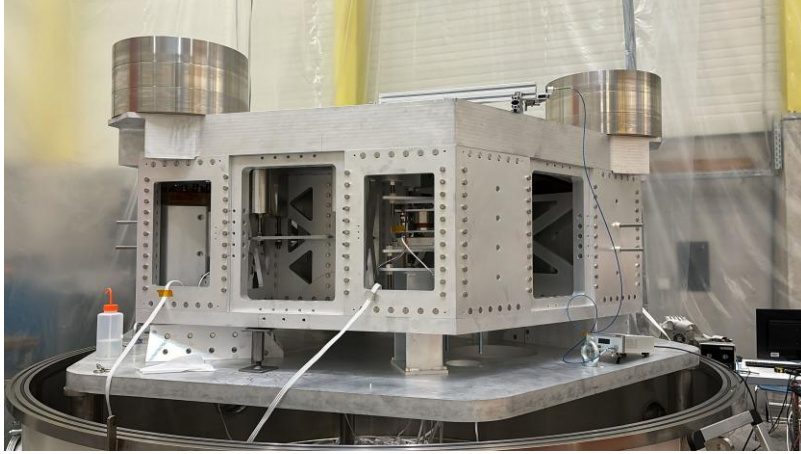
C-6D (Ubhi et al. 2026) OmniSens (Saffarieh et al. 2025)

ALFRA (McCann et al. 2021)

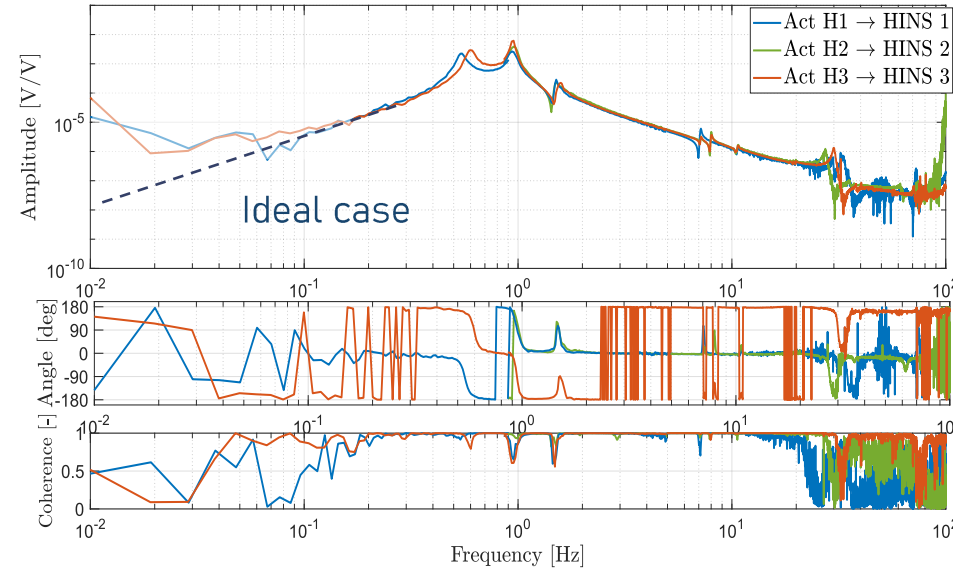
CRS (Ross et al. 2023)

Gyroscope solution

Active platform



TF: Horizontal actuators to horizontal sensors



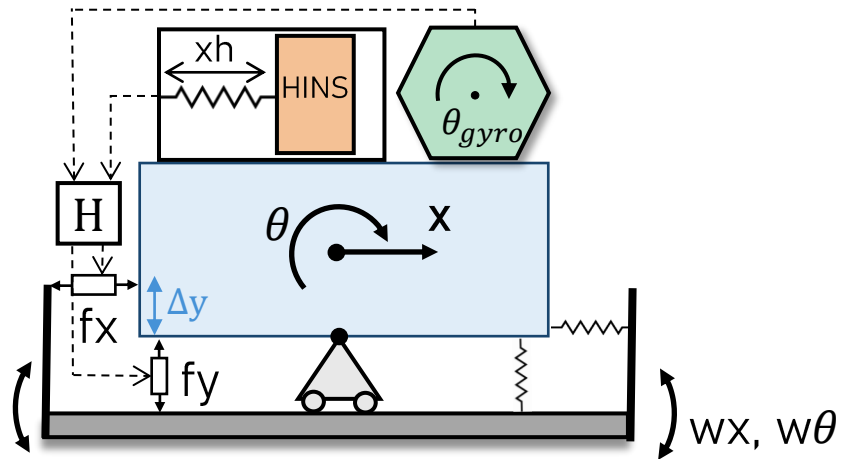
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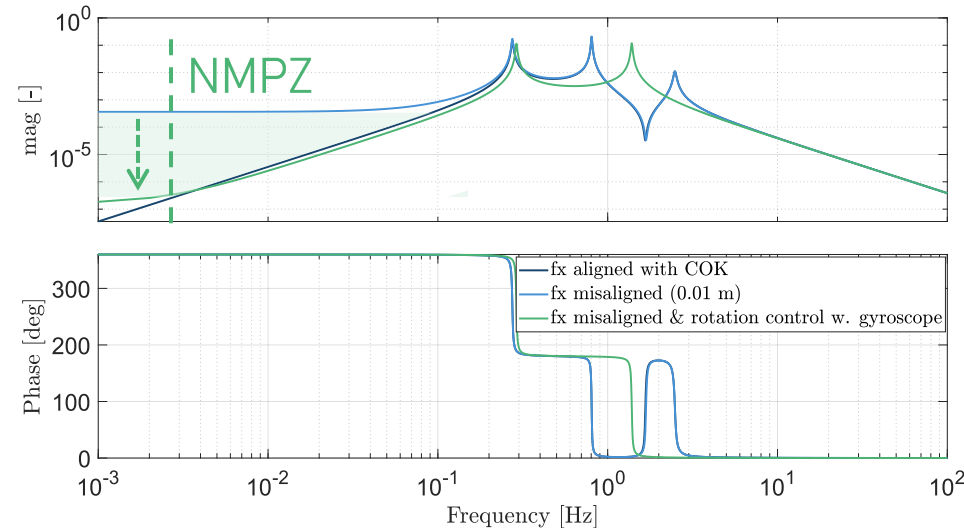


Controlling the rotation
decreases coupling effect



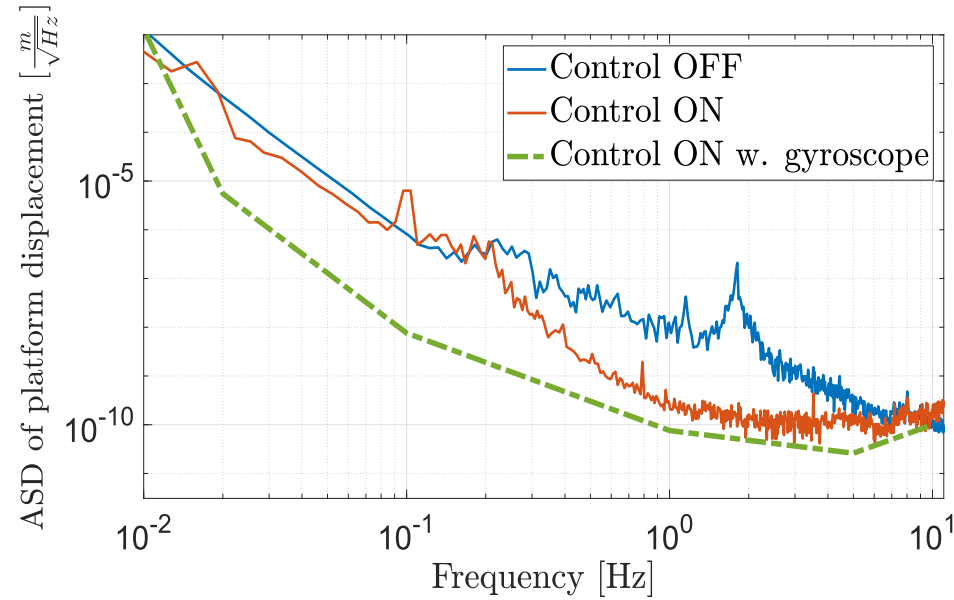
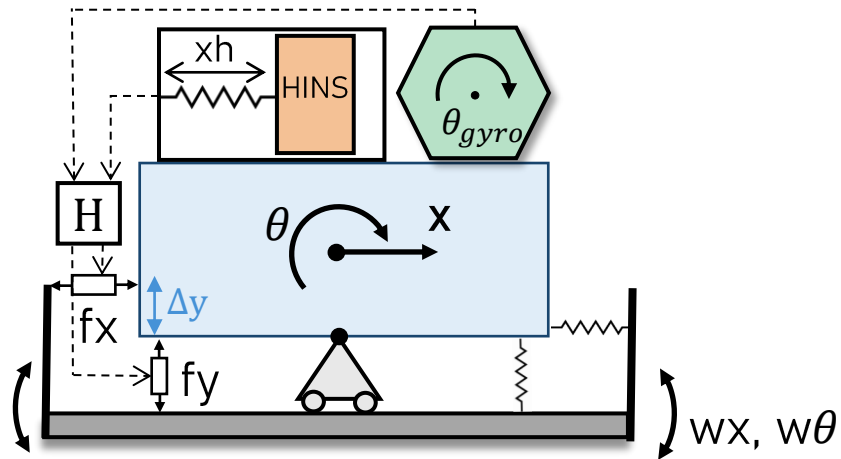
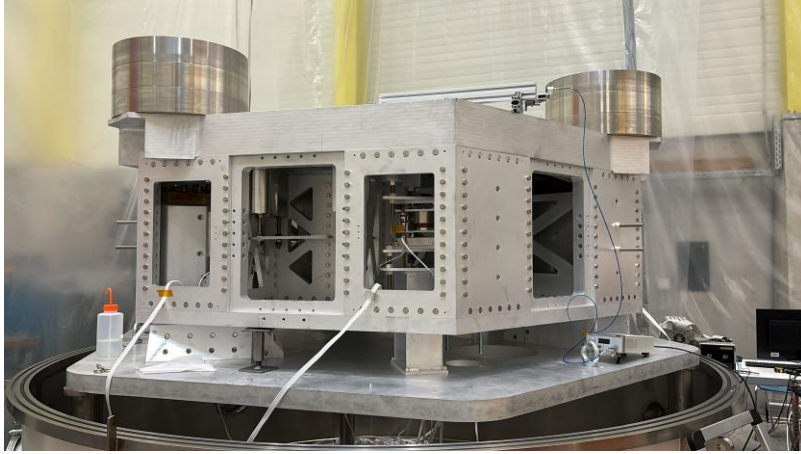
Addition of a gyroscope measuring θ_{gyro}

TF: Actuator f_x to HINS



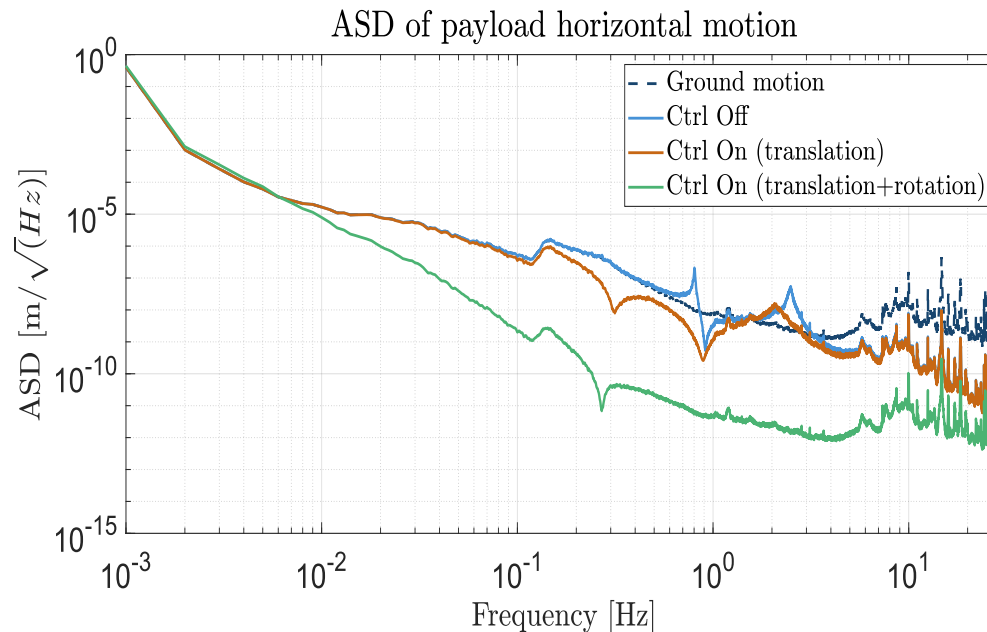
Gyroscope solution

Active platform



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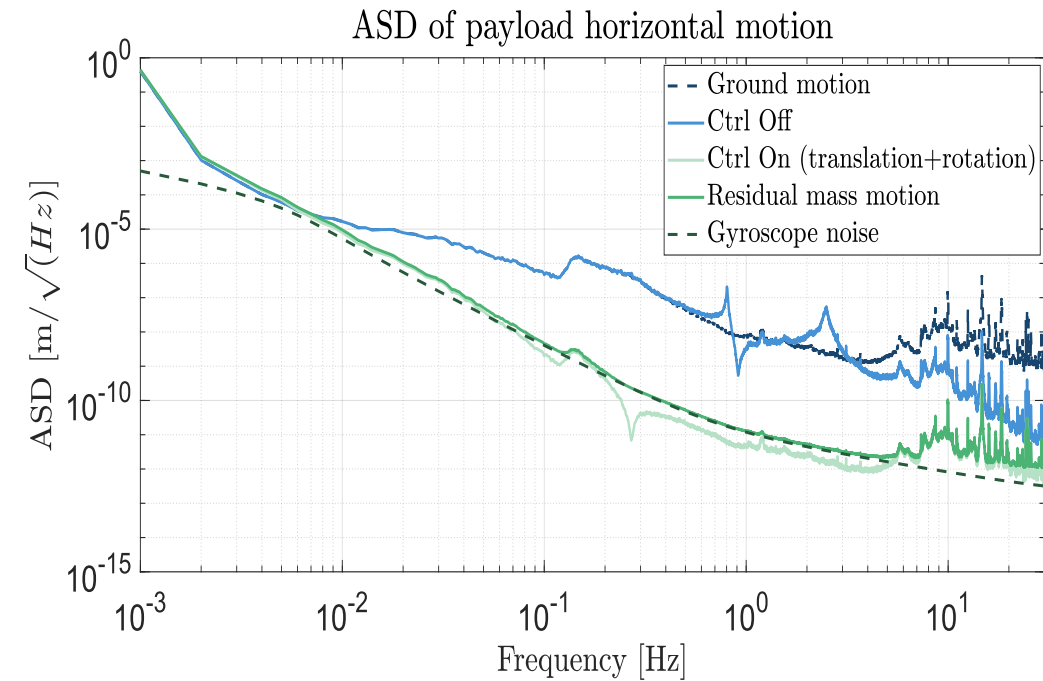


Controlling the rotation
decreases coupling effect

Larger bandwidth and
level of isolation

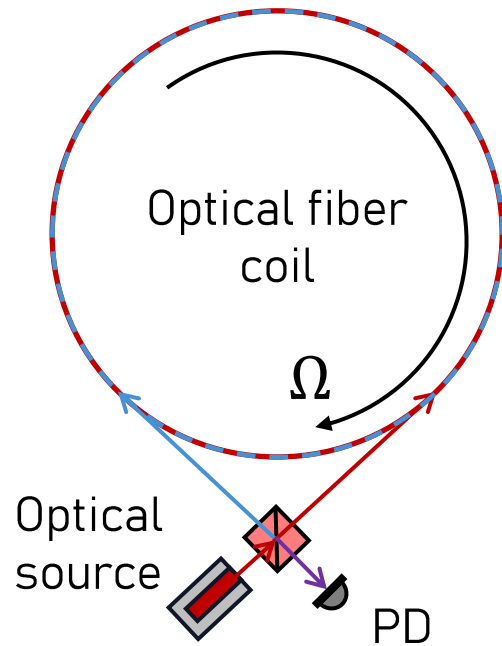
Requirement

- Resolution $\sim 0.1 \text{ nrad}/\sqrt{\text{Hz}}$
- No cross-coupling sensitivity



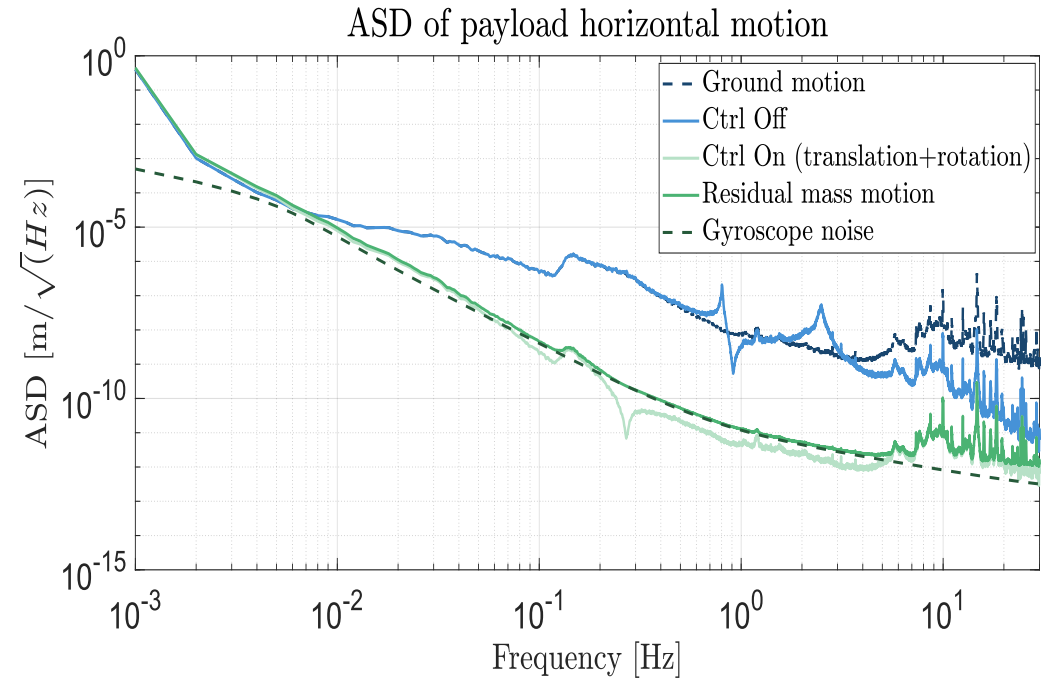
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Sagnac interferometer

$$\Delta\phi = \frac{2\pi LD}{\lambda c} \Omega$$



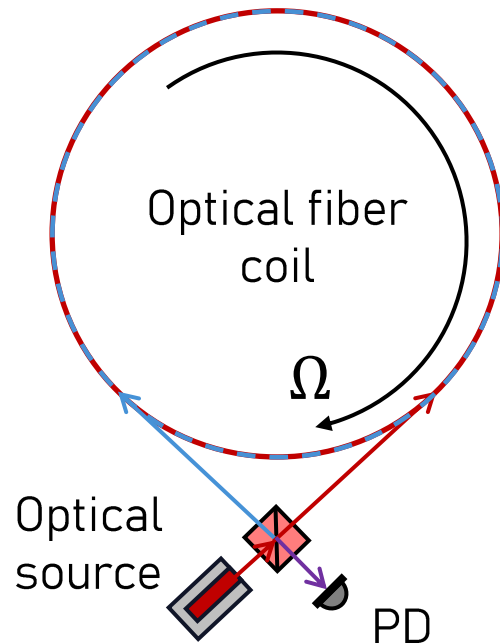
BlueSeis FOG



G-ring RLG

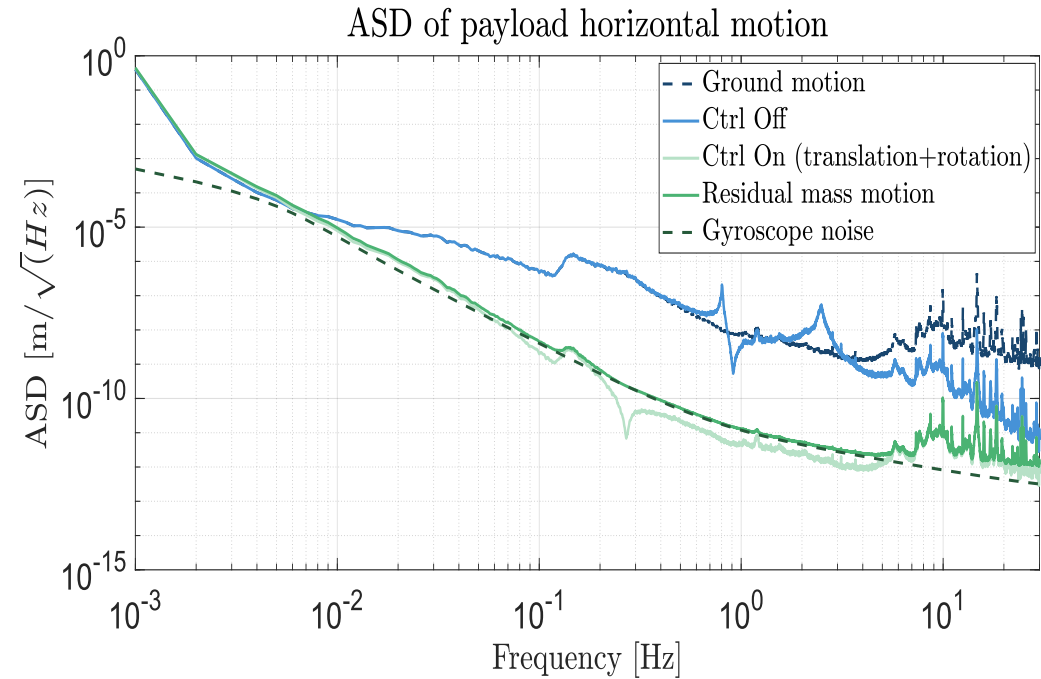
Requirement

- Resolution $\sim 0.1 \text{ nrad}/\sqrt{\text{Hz}}$
- No cross-coupling sensitivity
- Robust
- Flat transfer function

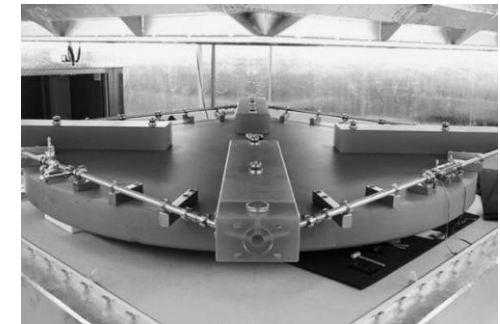


Sagnac interferometer

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BlueSeis FOG



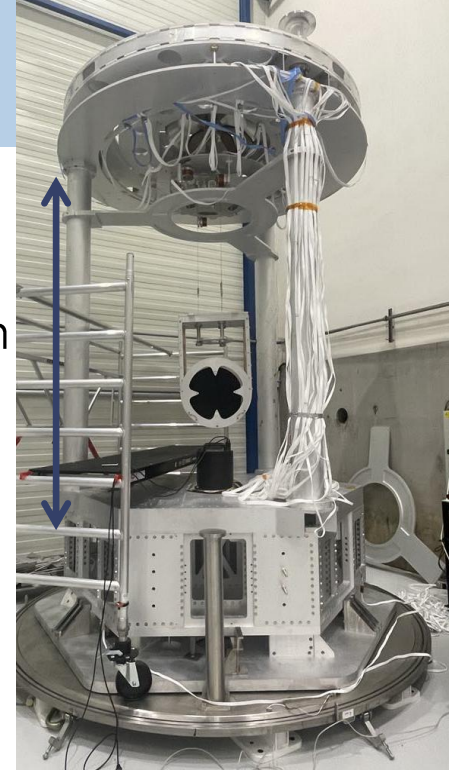
G-ring RLG

Maximising sensitivity

$$\Delta\phi = \frac{2\pi \textcolor{red}{L} D}{\lambda c} \Omega$$

Increasing sensitivity by increasing dimensions

2.5m

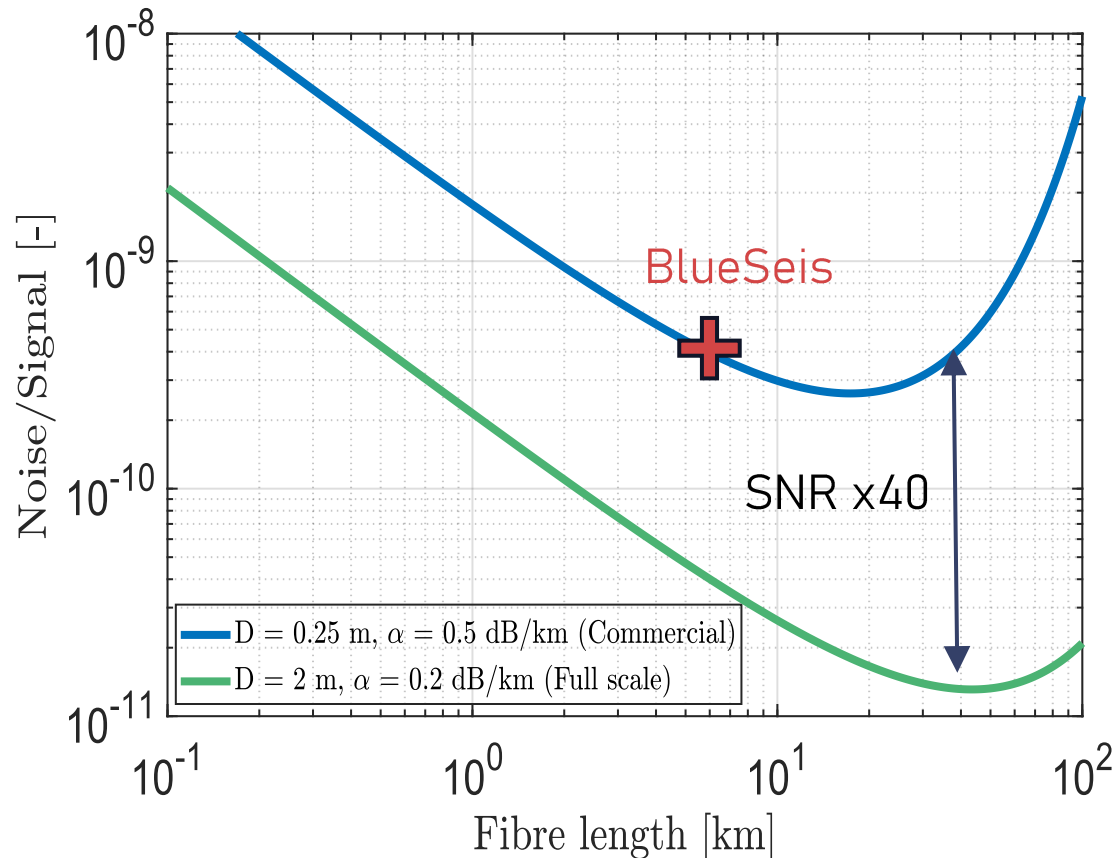


Maximising sensitivity

$$\Delta\phi = \frac{2\pi \textcolor{red}{L} \textcolor{red}{D}}{\lambda c} \Omega$$

Increasing sensitivity by increasing dimensions

BUT some noises are also dimensions dependent



Shot noise

$$N_{shot} = \sqrt{h\nu \cdot P_0 e^{-\alpha \textcolor{red}{L}}} \text{ [W}/\sqrt{\text{Hz}}]$$

Sagnac signal

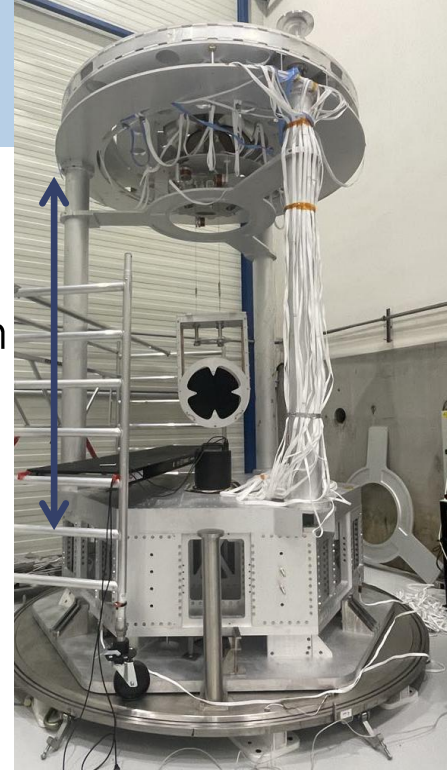
$$S_{\Omega} \propto P_0 e^{-\alpha \textcolor{red}{L}} \cdot \frac{2\pi \textcolor{red}{L} \textcolor{red}{D}}{\lambda c} \text{ [W}/(\text{rad/s})]$$

SNR

$$\frac{N_{shot}}{S_{\Omega}} \propto \sqrt{\frac{h\nu}{P_0 e^{-\alpha \textcolor{red}{L}}}} \cdot \frac{\lambda c}{2\pi \textcolor{red}{L} \textcolor{red}{D}} \text{ [rad/s}/\sqrt{\text{Hz}}]$$

Optimal dimensions to maximize SNR

2.5m



Additional important noise sources

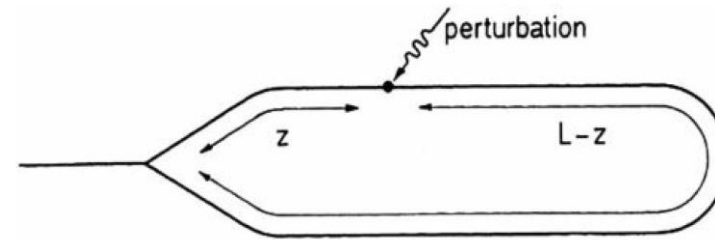
Shupe effect

Local variation of fibre refractive index
→ Local speed variation of one beam
→ Induced phase shift

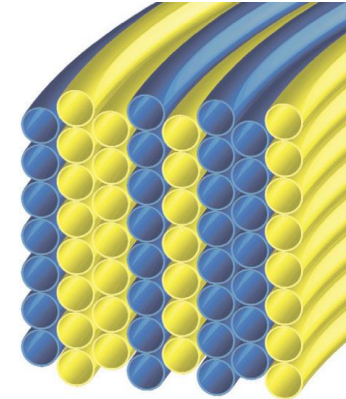
- Temperature induced
- ❖ Need specific winding pattern

And more...

- Important at low frequency
- Fibre length dependent



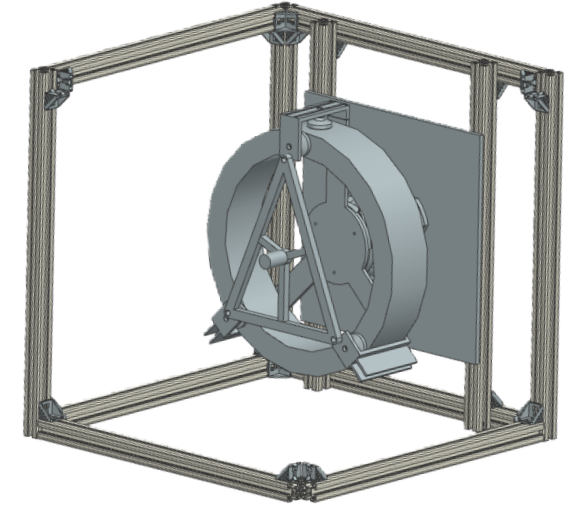
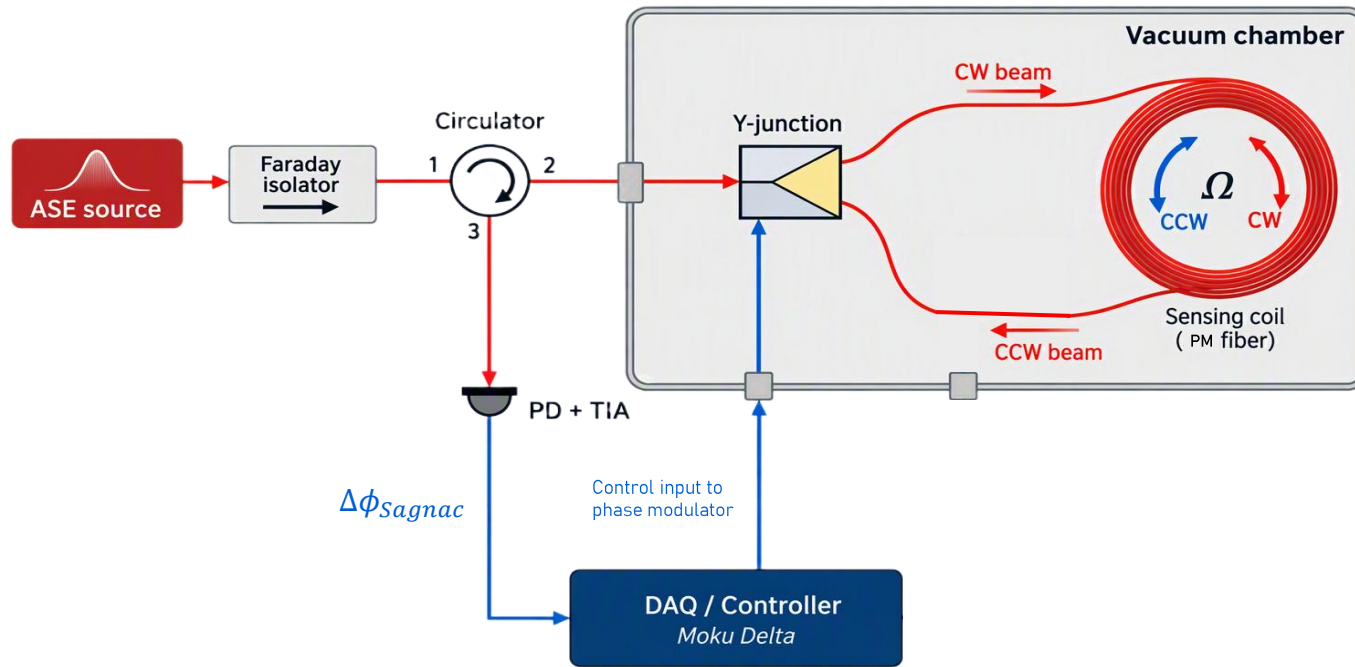
Phase shift generated by perturbation



Both beam remain close through their propagation

Needs modelling to optimise FOG parameters

First implementation with Blueseis coils



- Hands on FOG technology
- Investigating limitations
- Noise modelling
- Vacuum compatible set-up → better thermal stability

Coming soon...

Thank you for your attention !

Contact:

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