

Compact optical accelerometer for low frequency sensing

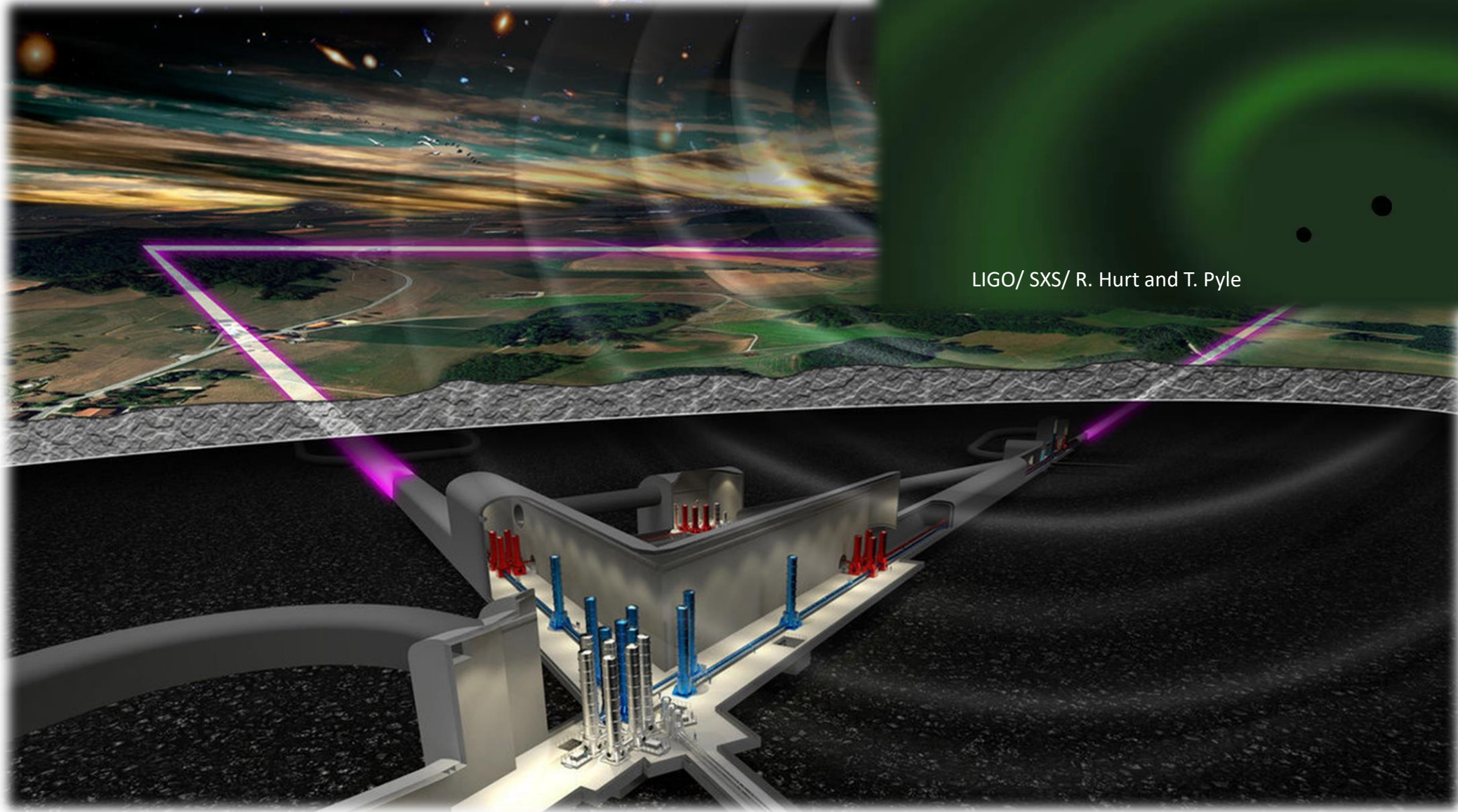
Anthony Amorosi, Amez-Droz Loïc, Christophe Collette (supervisor)

2nd year PhD at ULiège & ULB (Belgium)

Measuring By Light

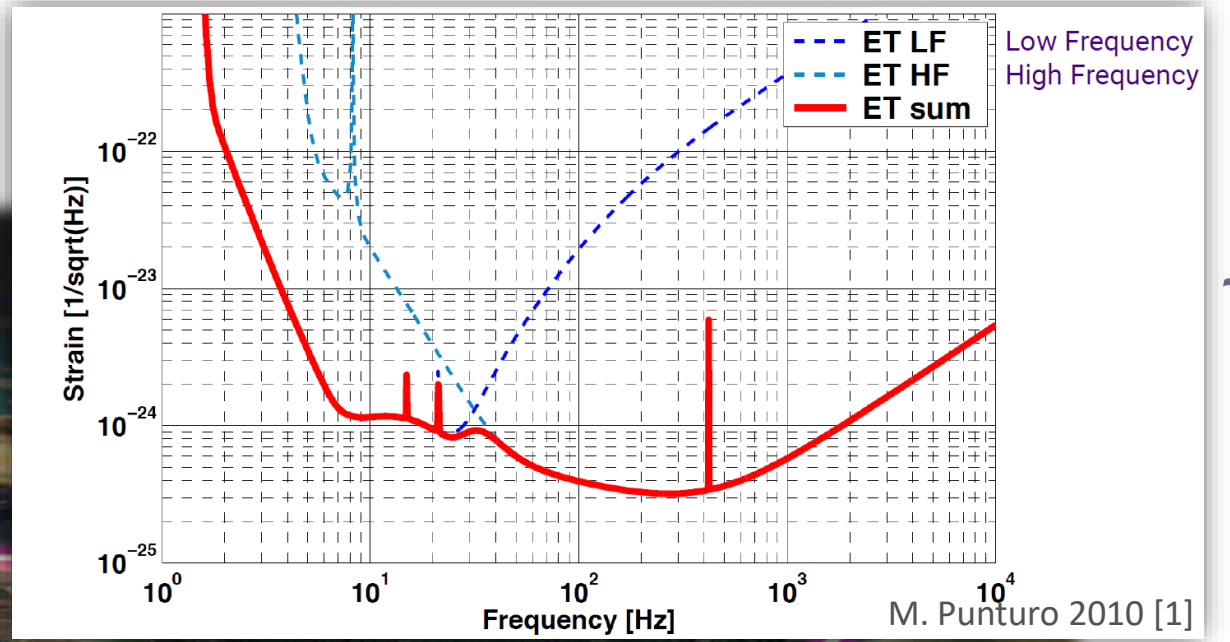
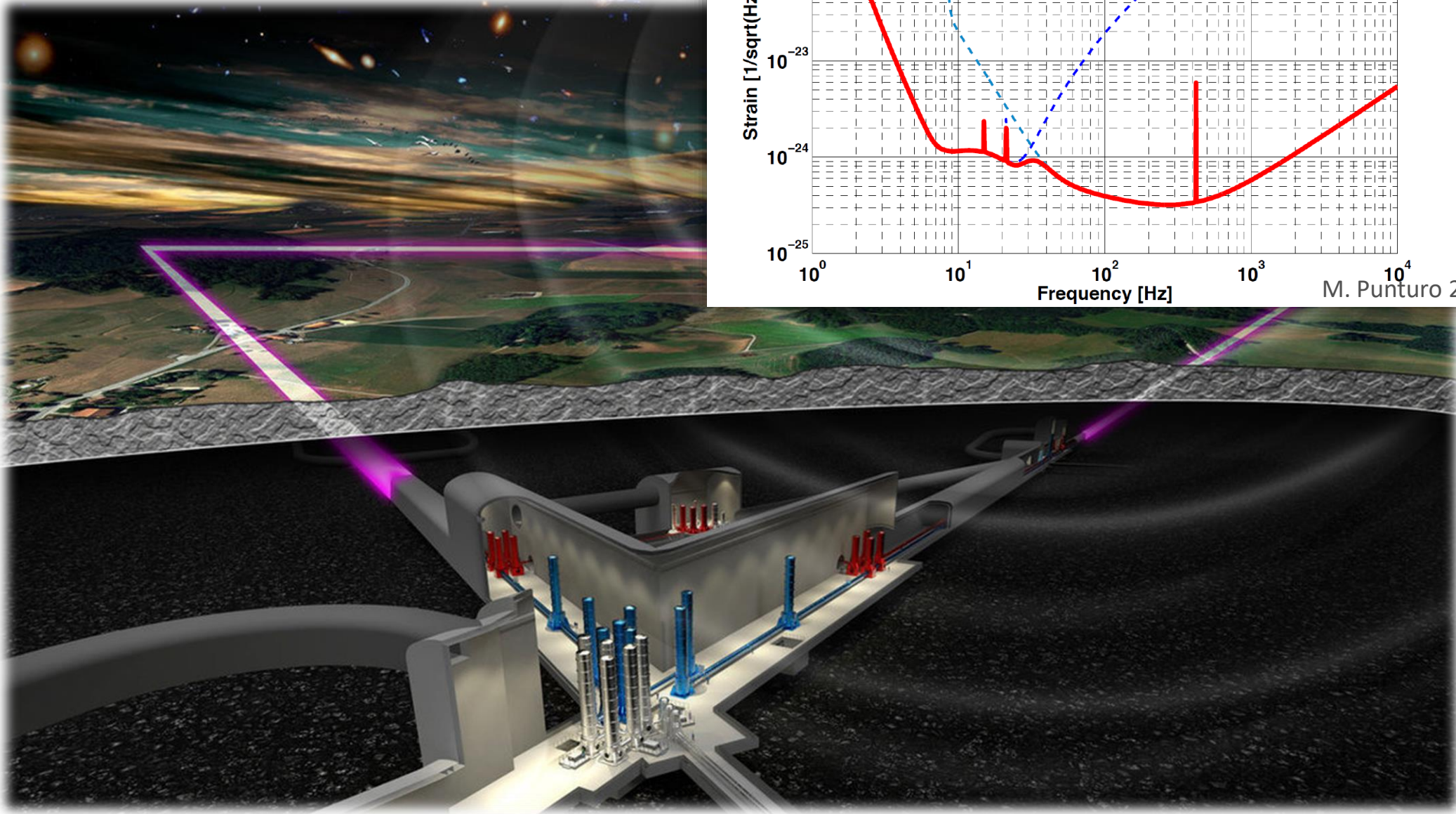
March 29, 2023

The Einstein Telescope

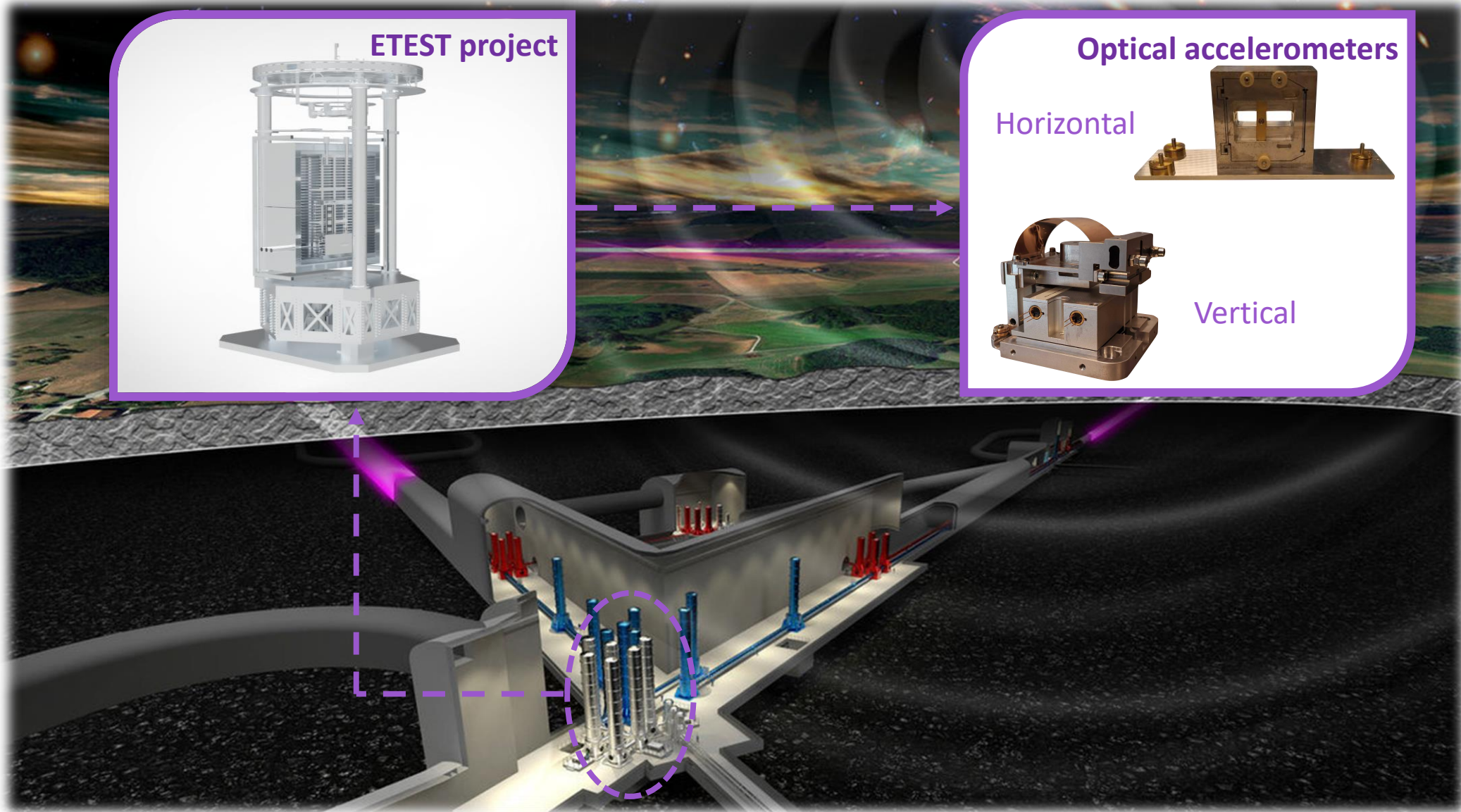


LIGO/ SXS/ R. Hurt and T. Pyle

The Einstein Telescope



The E-TEST project



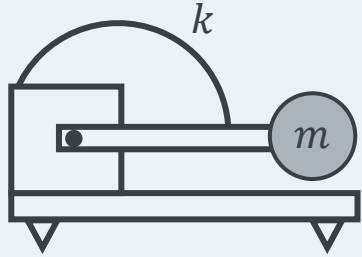
Outline

- Einstein Telescope & E-TEST project
- Optical vertical accelerometer for active inertial control
 - Mechanical design
 - Optical readout
 - Performances & noise budget
- Conclusion and future work

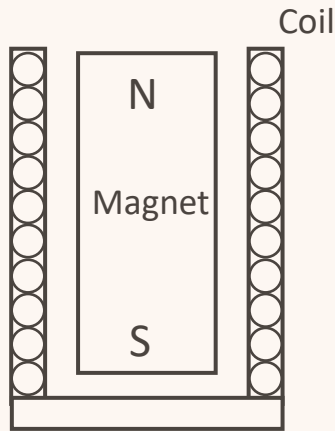


Inertial sensor working principle

Low stiffness mechanics



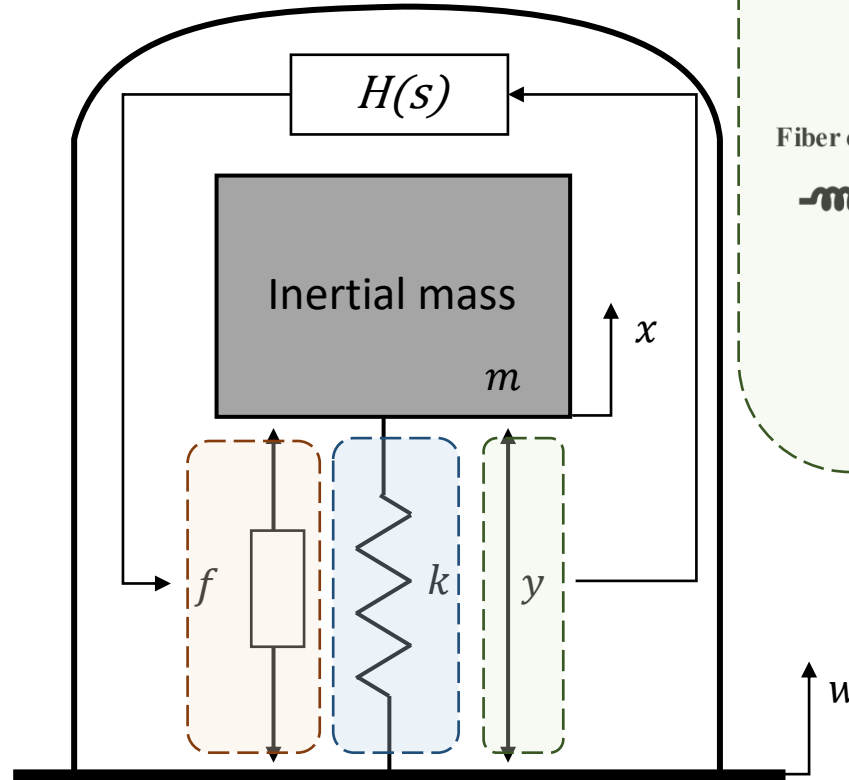
Low natural frequency.
Compact & light.



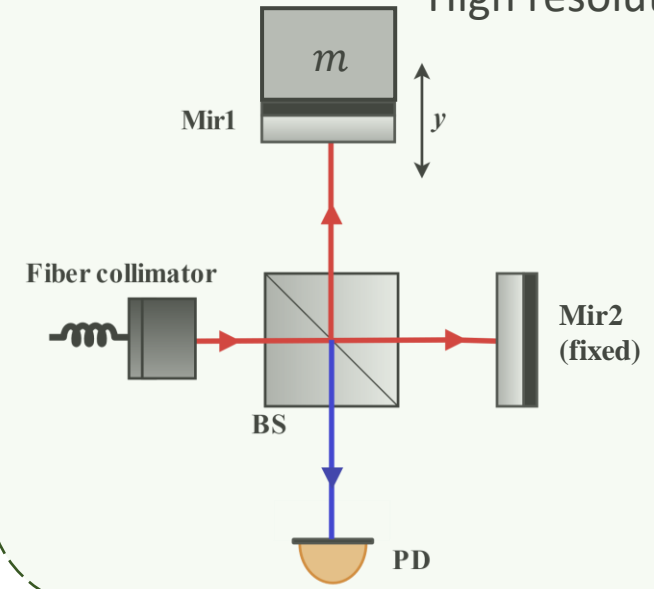
Low noise injection.
Improved linearity and bandwidth.

Contactless actuation

Inertial sensor



High resolution.

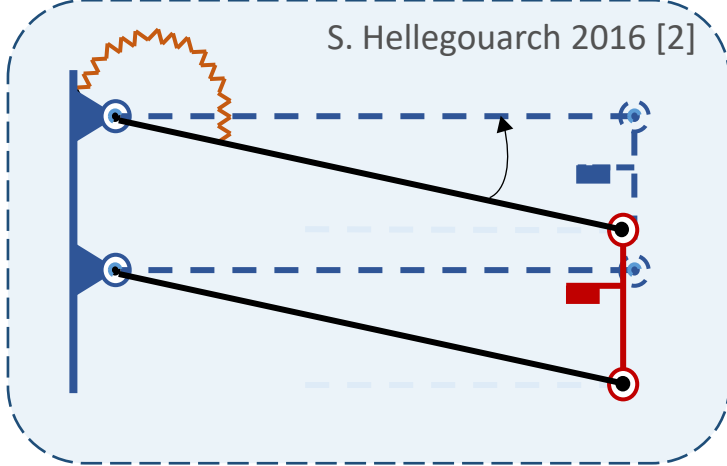


Contactless readout

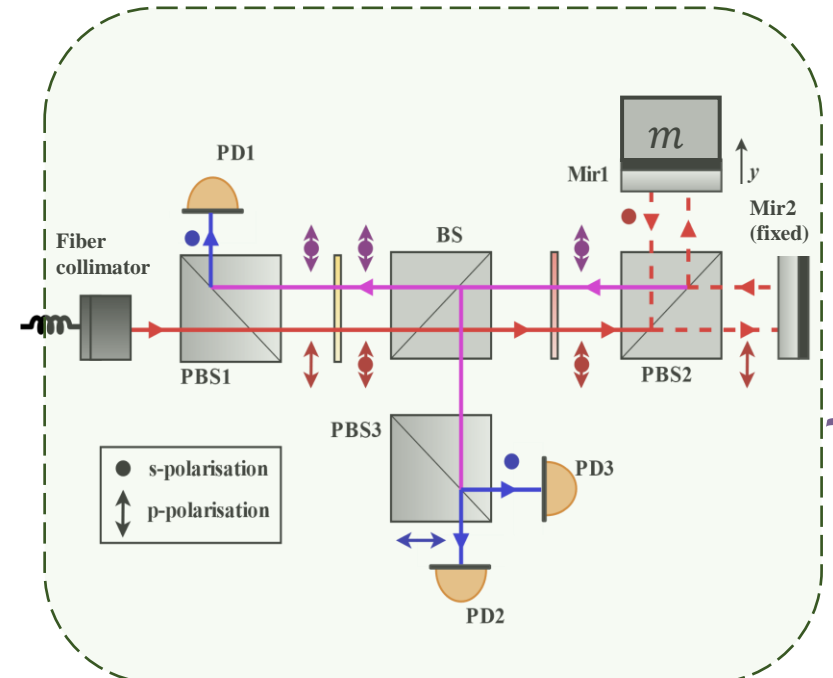
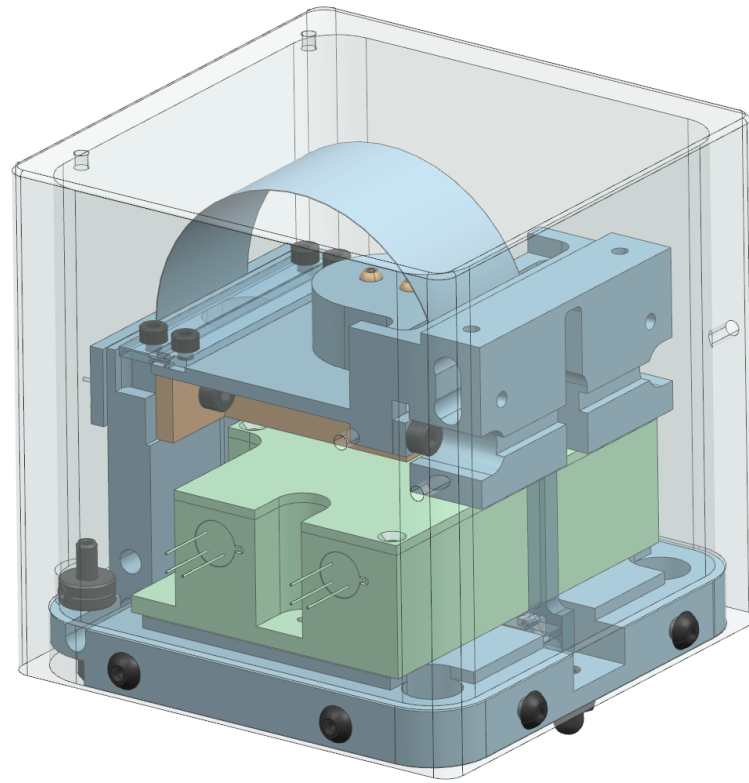
μ - Vertical INterferometric inertial Sensor

4-bar translation guiding

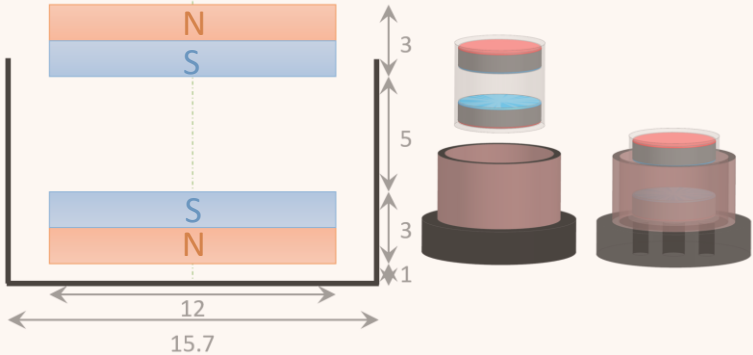
S. Hellegouarch 2016 [2]



μ VINS

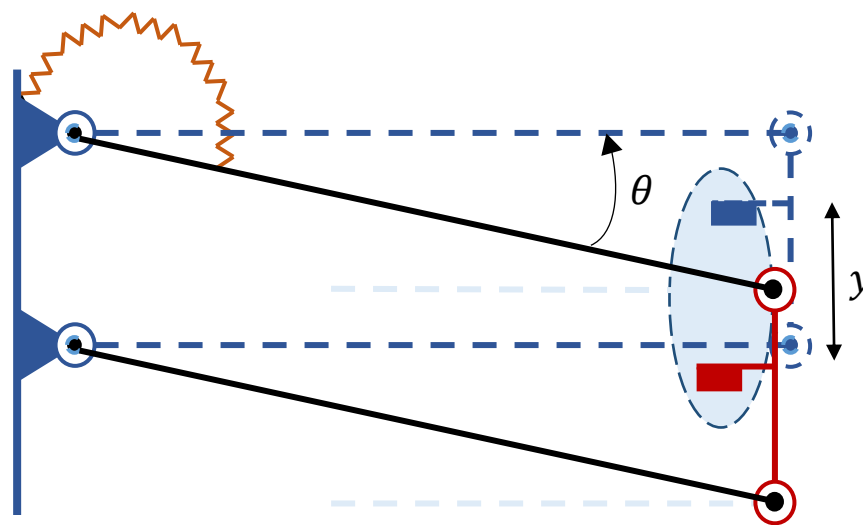
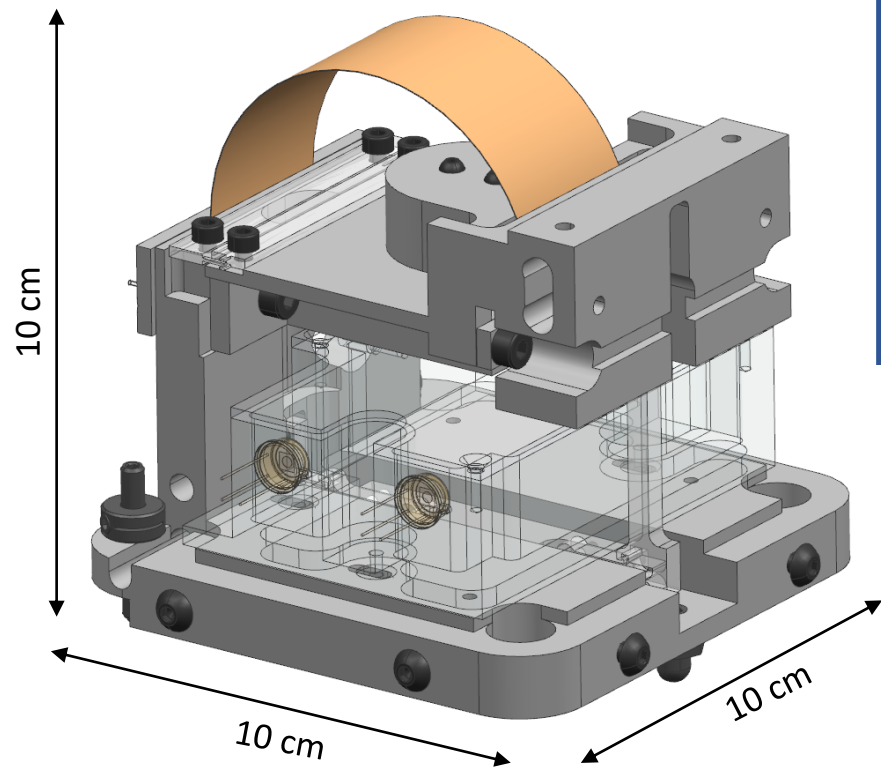


Homodyne quadrature
Michelson interferometer



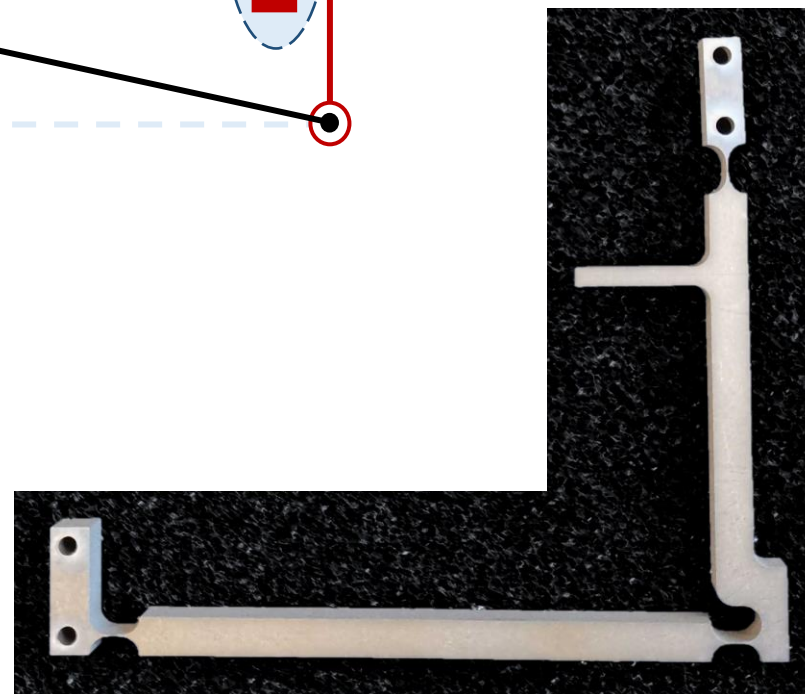
Quadrupole
magnet actuator

Low stiffness mechanical guide

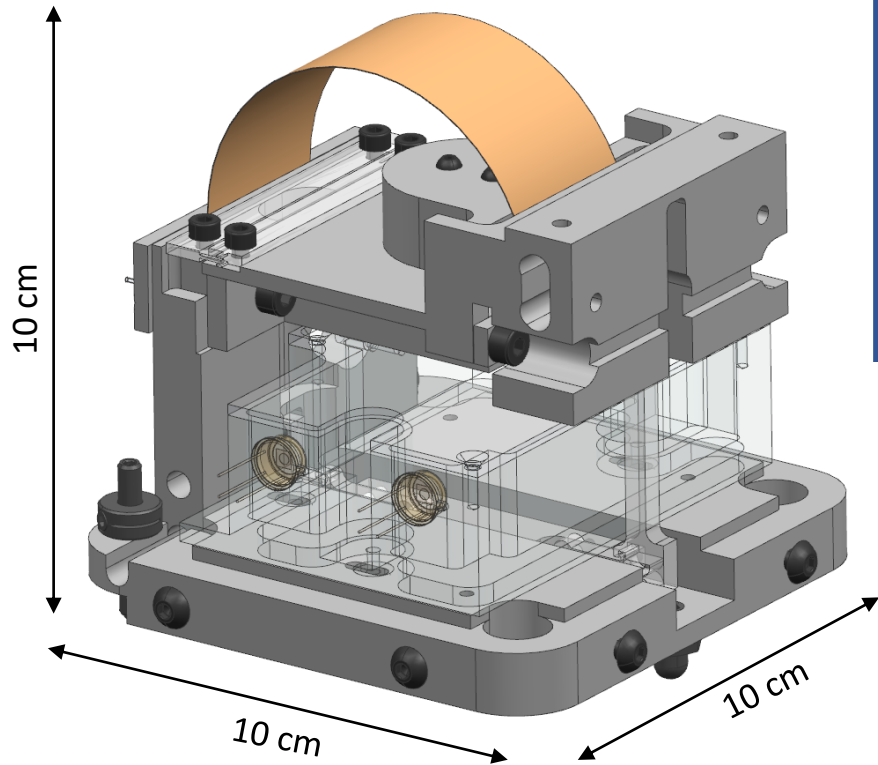


Linear, angle-maintaining,
motion of the mirror.

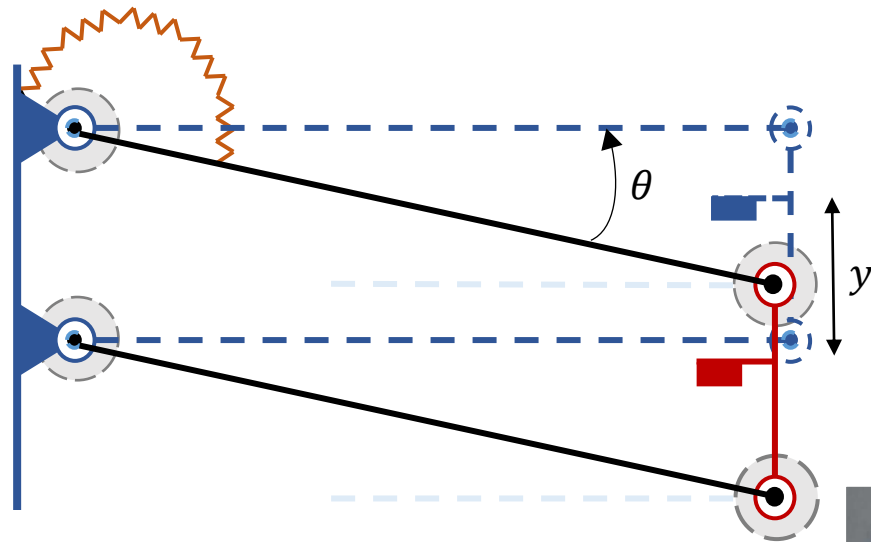
Titanium guiding



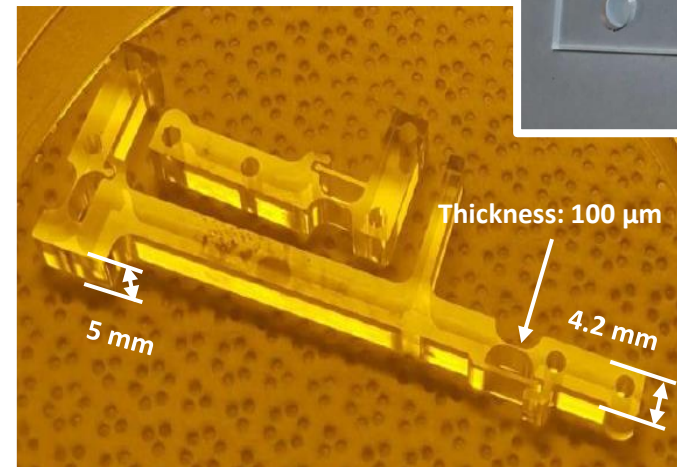
Low stiffness mechanical guide



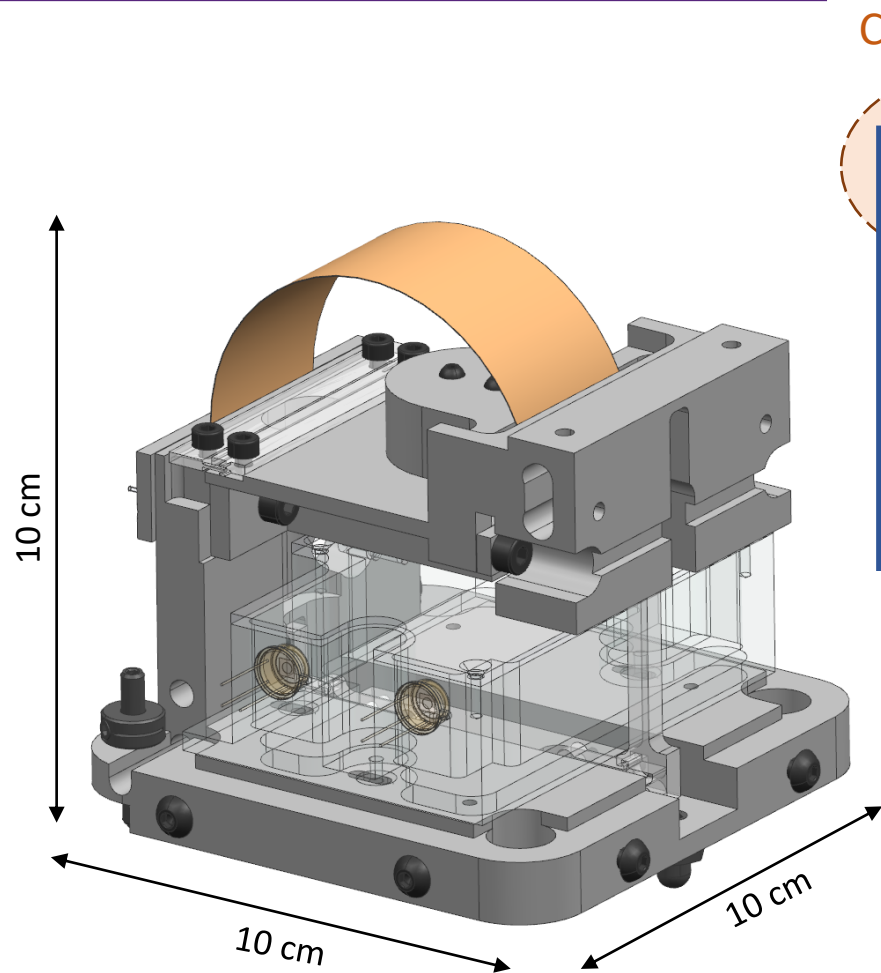
CuBe leaf-spring



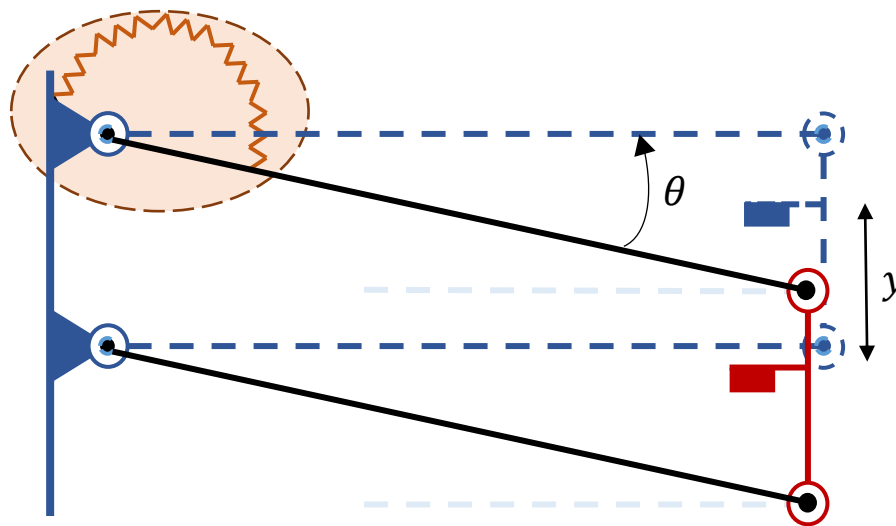
Low dissipation fused-silica joints.



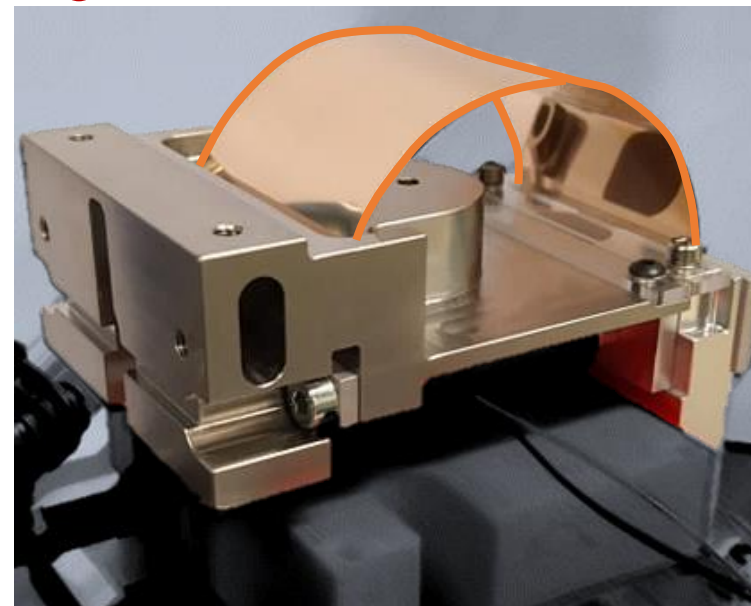
Low stiffness mechanical guide



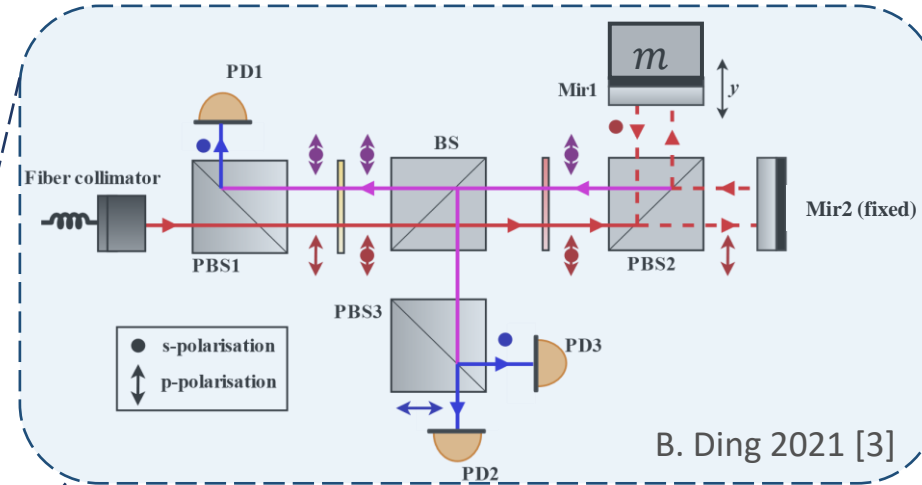
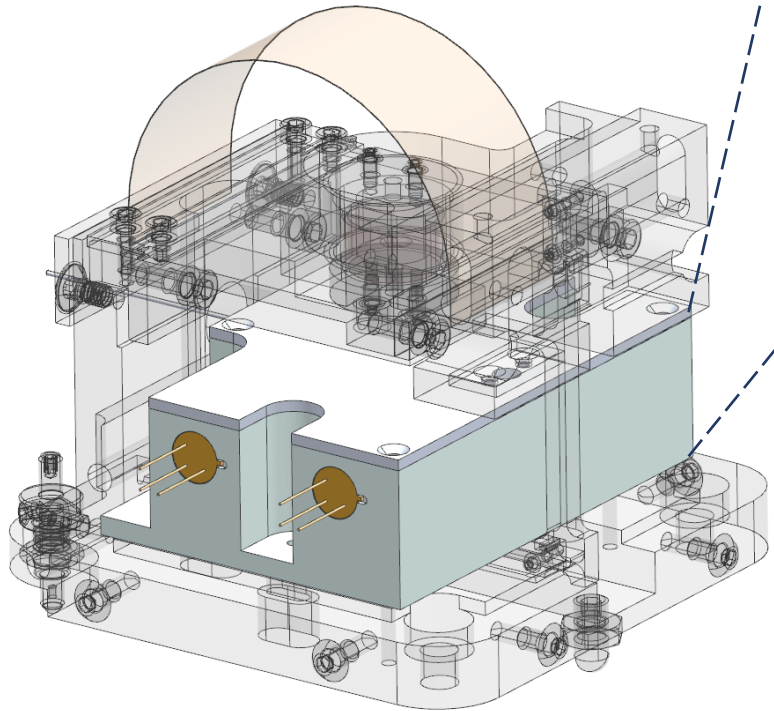
CuBe leaf-spring



2.8 Hz natural frequency suspension.

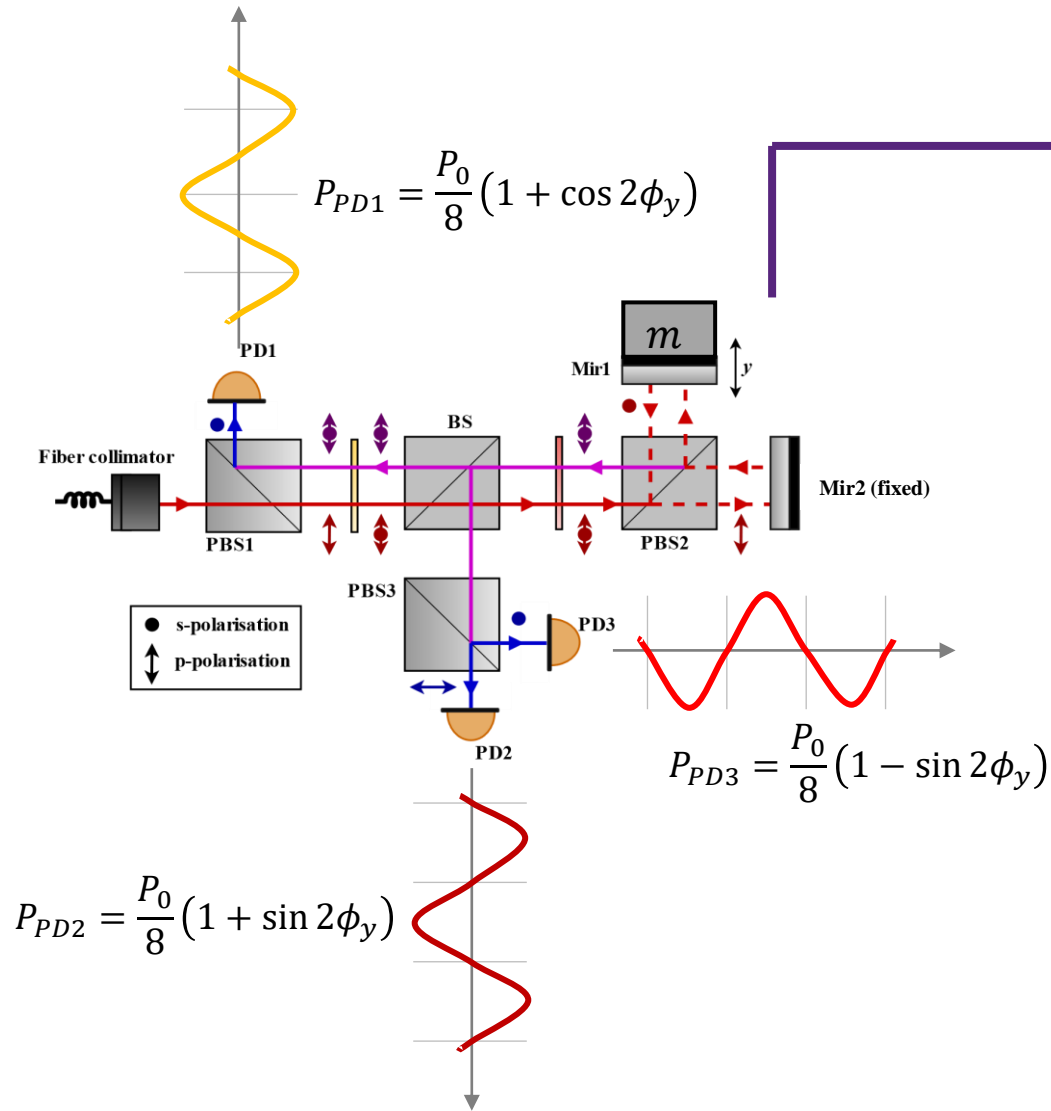


Interferometric readout



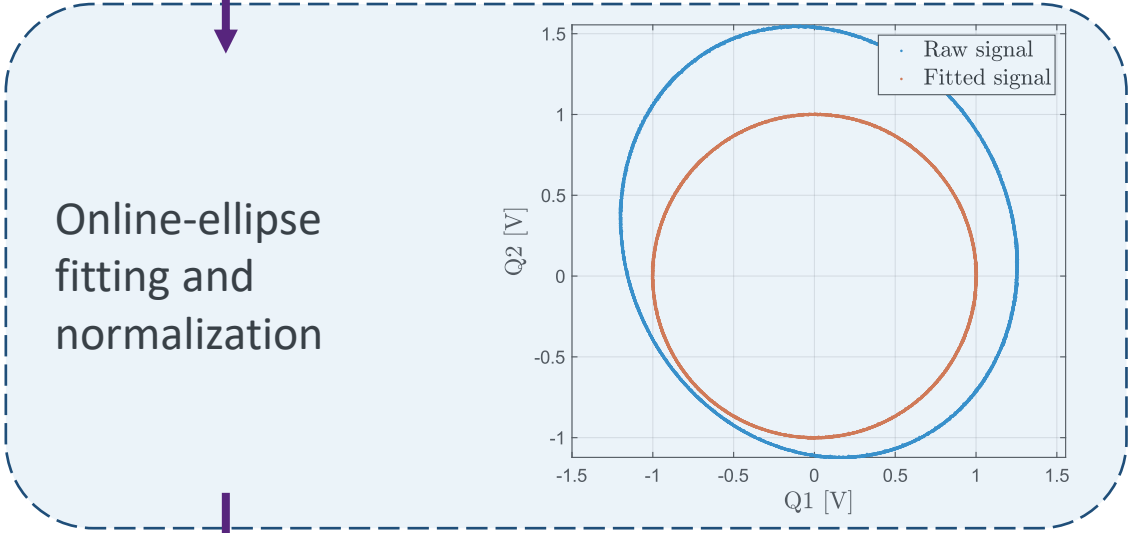
Homodyne, quadrature, Michelson interferometer
- sub-picometer resolution
- Long range reading

Interferometric readout



Common-mode noise rejection

$$Q_1 = P_{PD1} - P_{PD3}$$

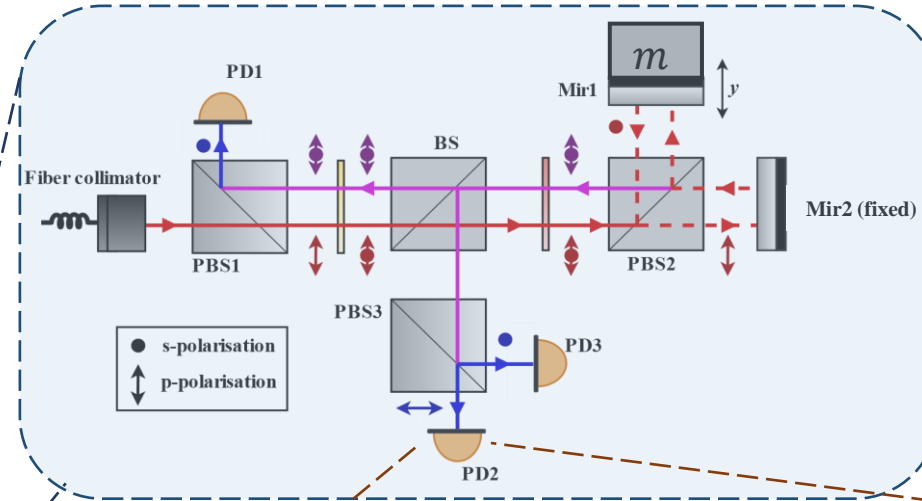
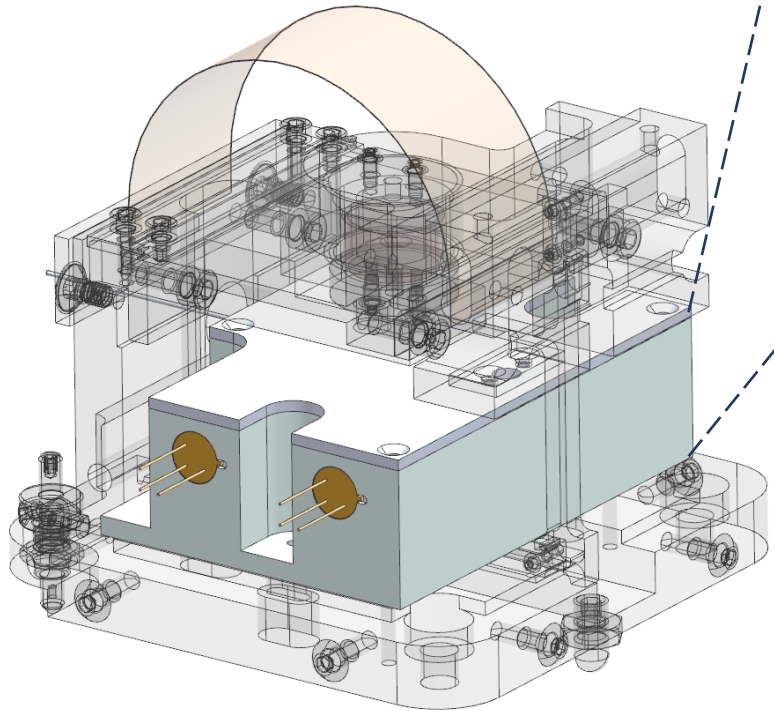
$$Q_2 = P_{PD1} - P_{PD2}$$


Fringe demodulation

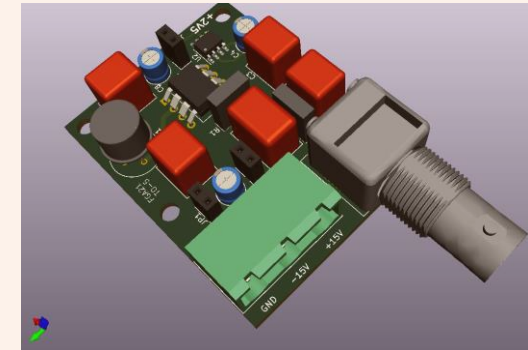
$$y = \frac{\lambda}{4\pi n} \left(\arctan \left(\frac{Q_2}{Q_1} \right) - \frac{\pi}{4} \right)$$

Interferometric readout

Homodyne, quadrature, Michelson interferometer



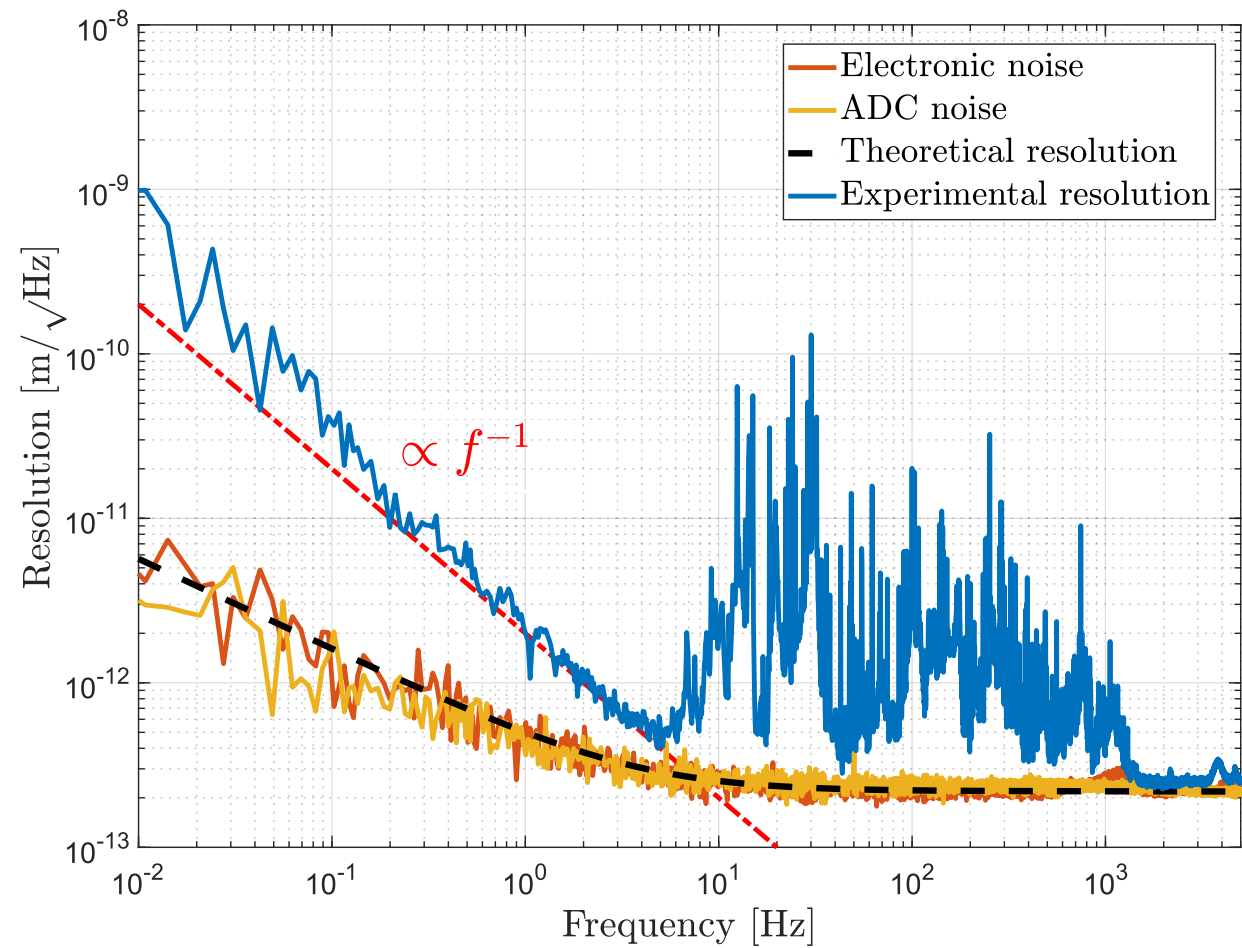
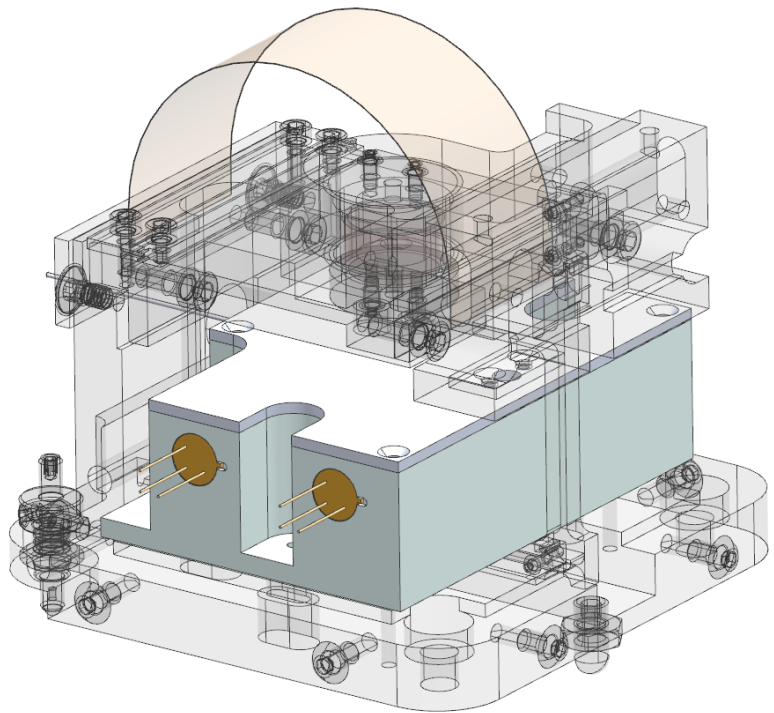
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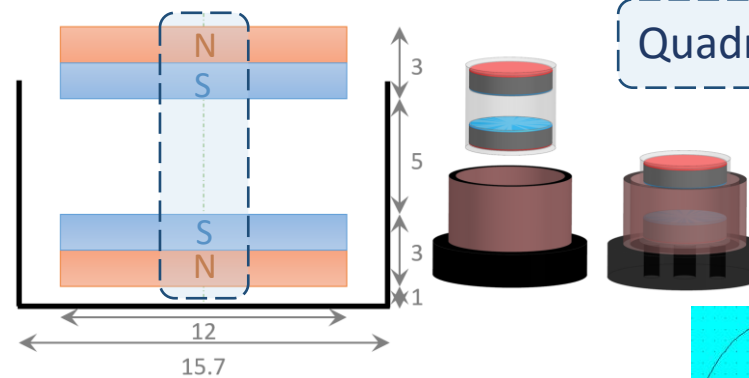
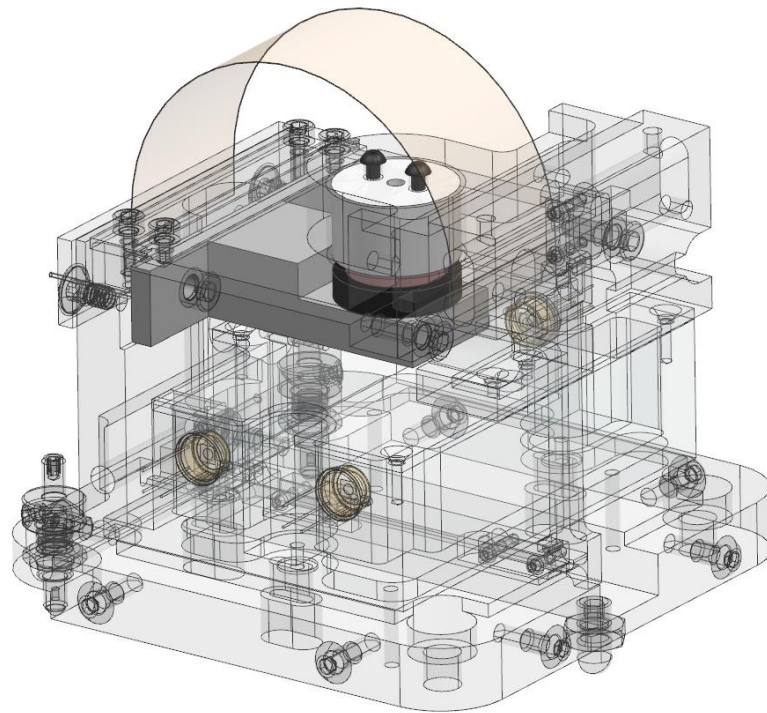
FGA21 InGaAs
photodiode

Low noise, precision,
LT1792 custom amplifier

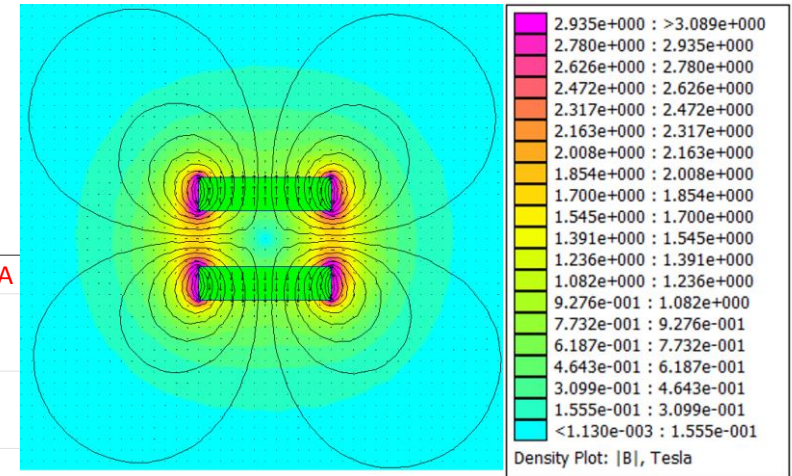
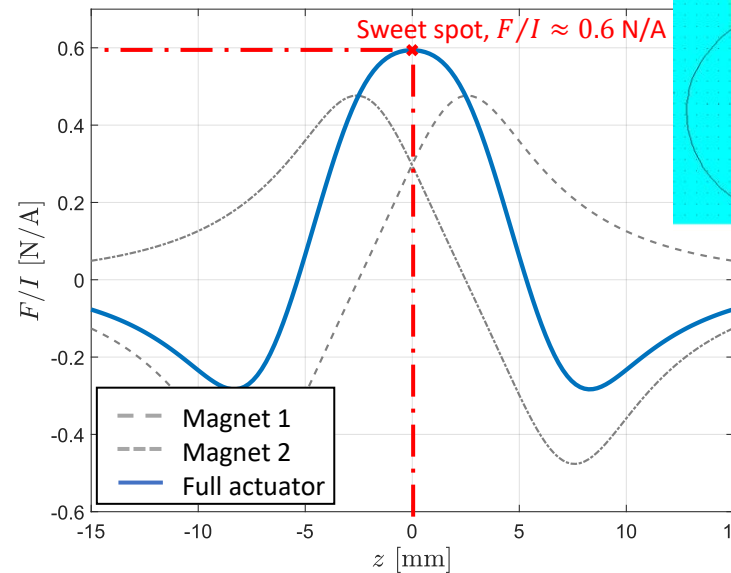
Interferometric readout



Quadrupole voice-coil actuator

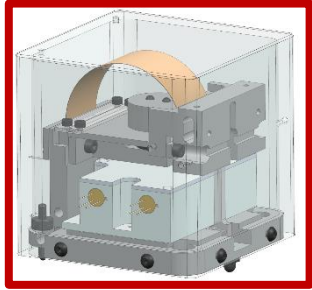


Quadrupole, selfshielded, magnet.



Numerical optimization of the geometry.

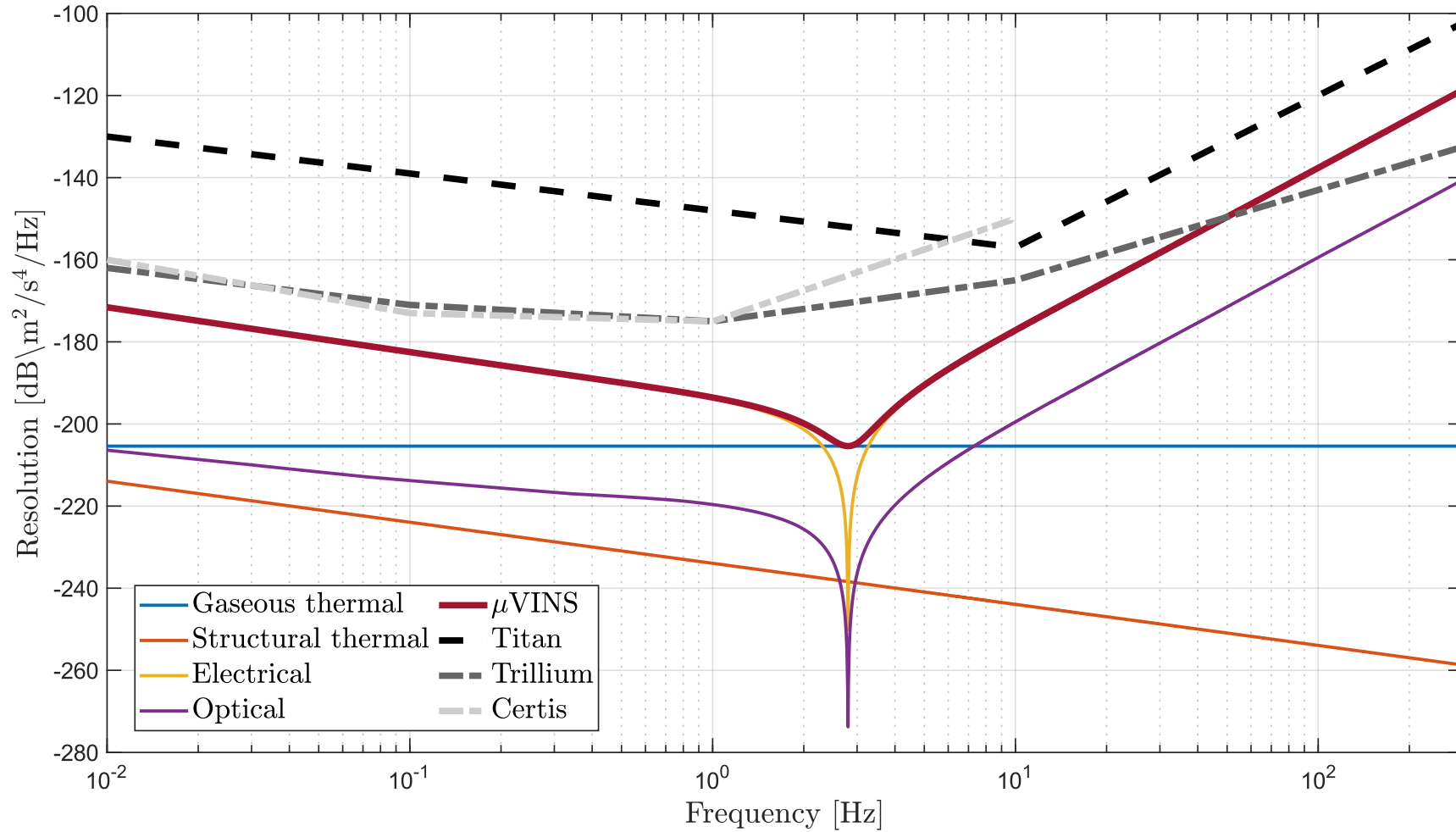
Noise budgeting



μ VINS



Guralp certis



Titan



Trillium

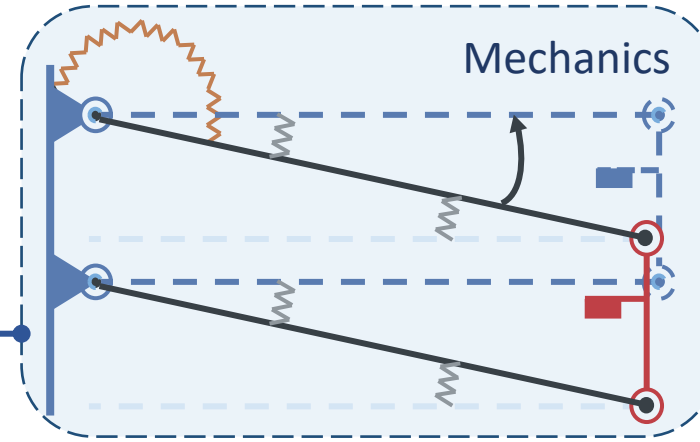
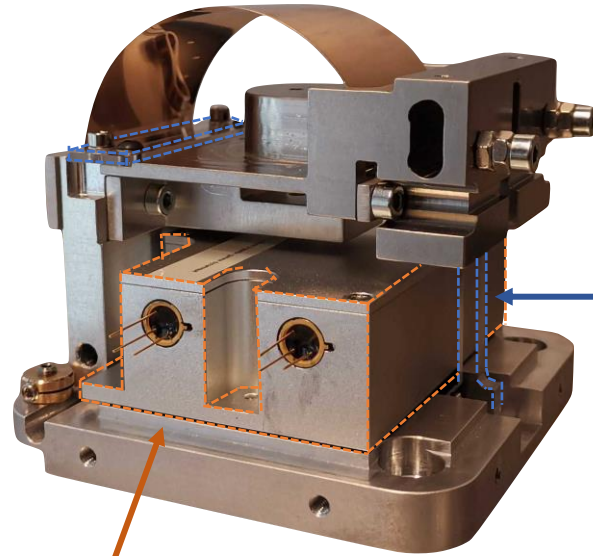


Outline

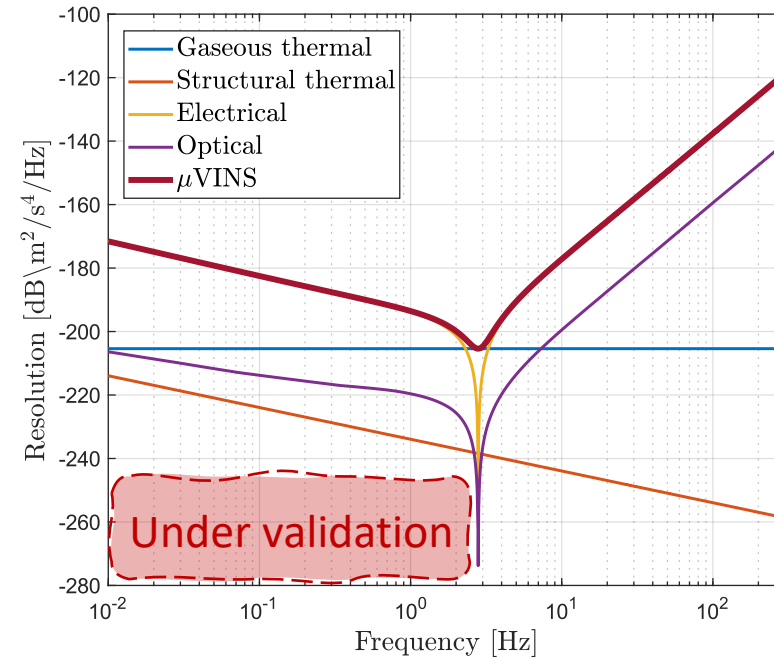
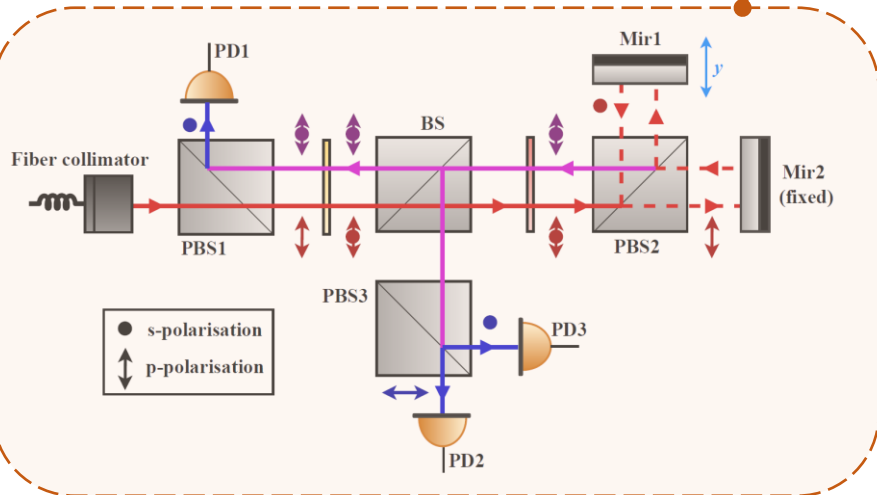
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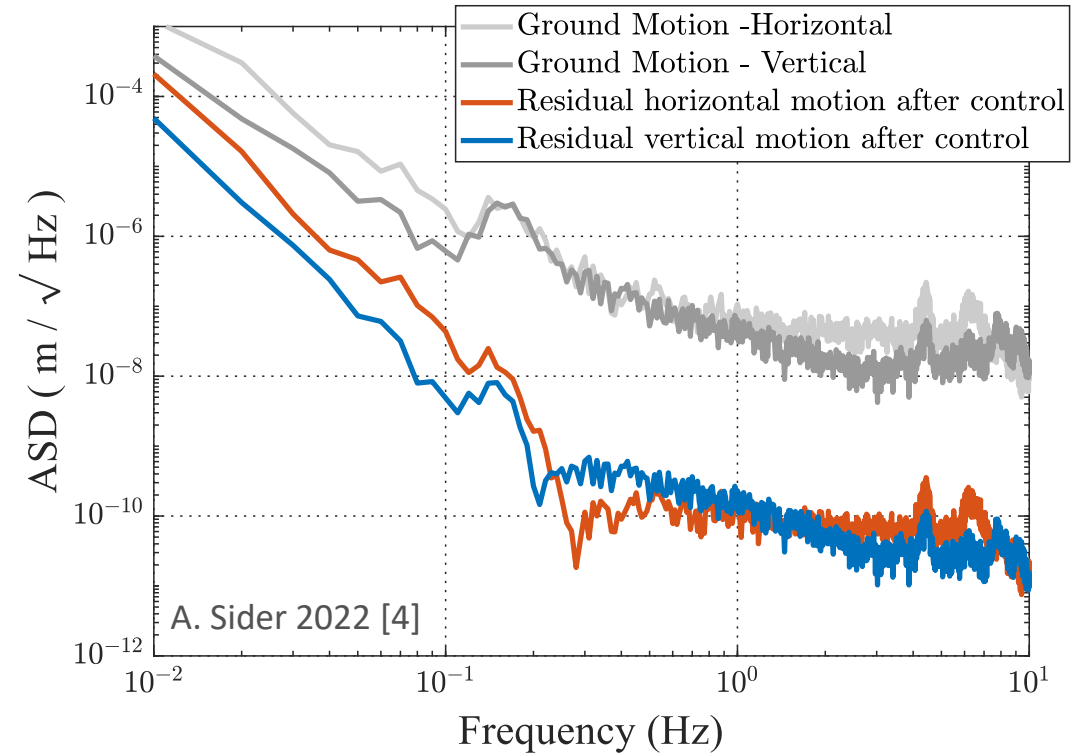
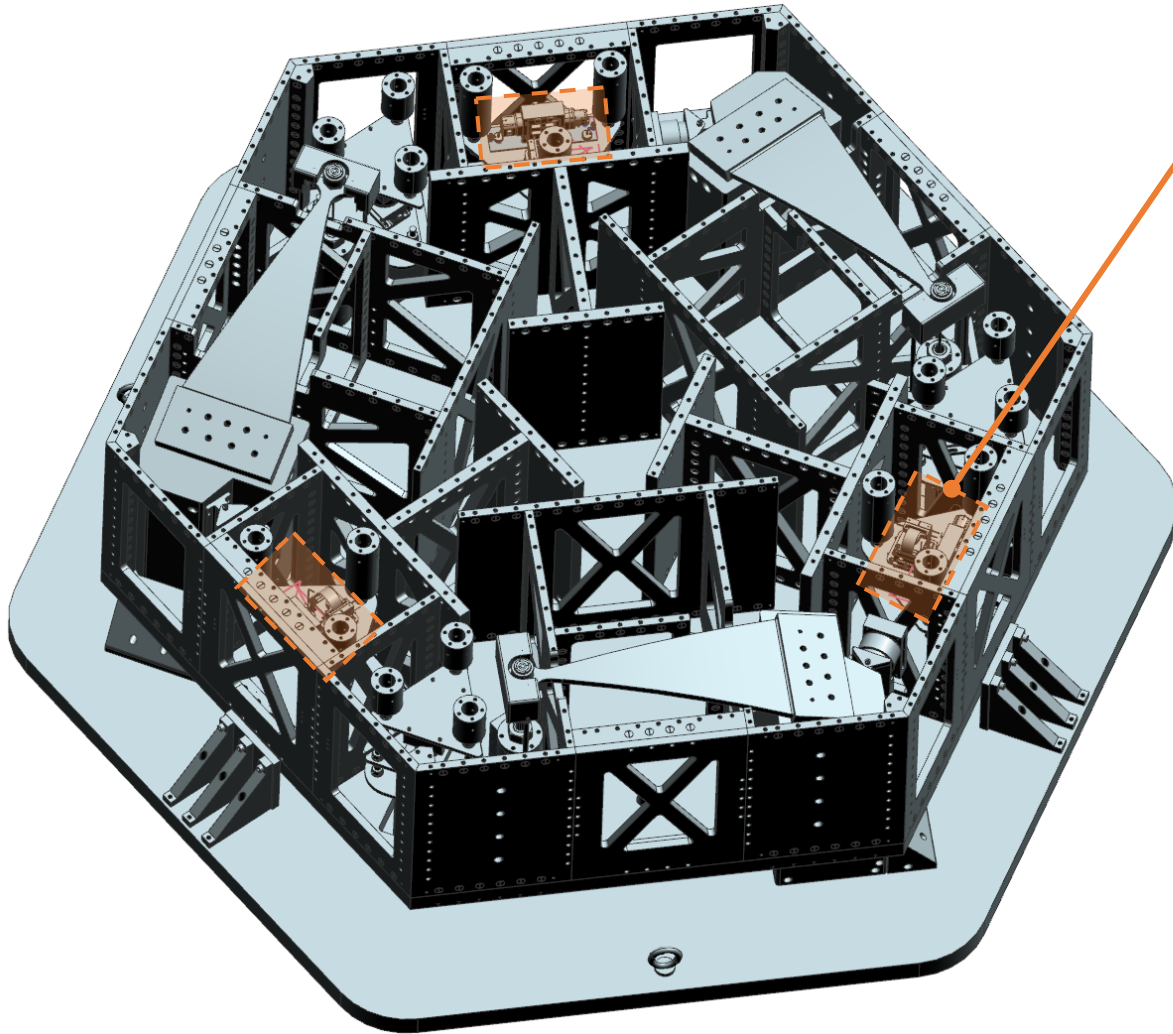
μ VINS testing campaign



Quadrature optical readout



Integration in the ETEST platform



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[2] Hellegouarch, S., Fueyo Roza, L., Artoos, K., Lambert, P., & Collette, C. (2016). Linear encoder based low frequency inertial sensor. International Journal of Optomechatronics, 10(3-4), 120-129.

[3] B. Ding, "Development of High Resolution Interferometric Inertial Sensors," Ph.D. dissertation, Université Libre de Bruxelles, 2021.

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Thank you for your attention!

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