



# Towards a Soundcheck accelerometer: sensor testing at the E-TEST cold platform

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Joris van Heijningen

Giacomo Bruno

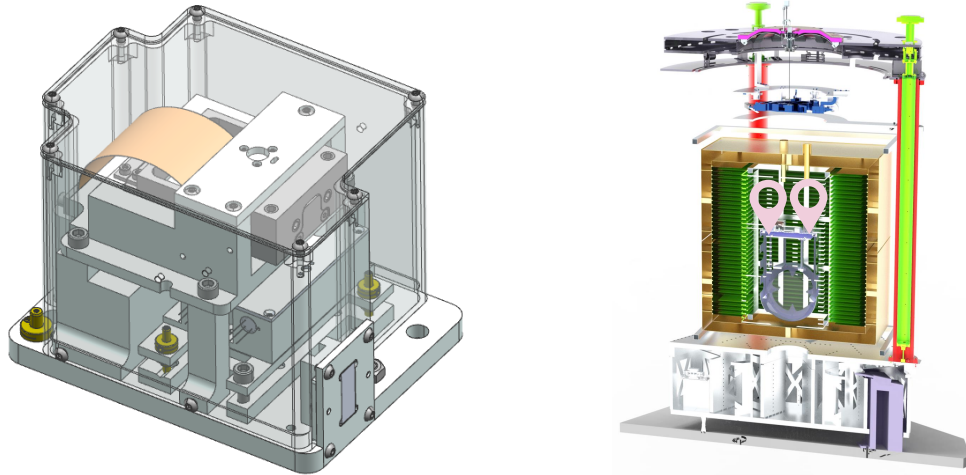


# Cryogenic inertial sensors E-TEST → LGWA

## Vertical cryogenic inertial sensor

Vertical leaf spring with open-loop homodyne quadrature readout

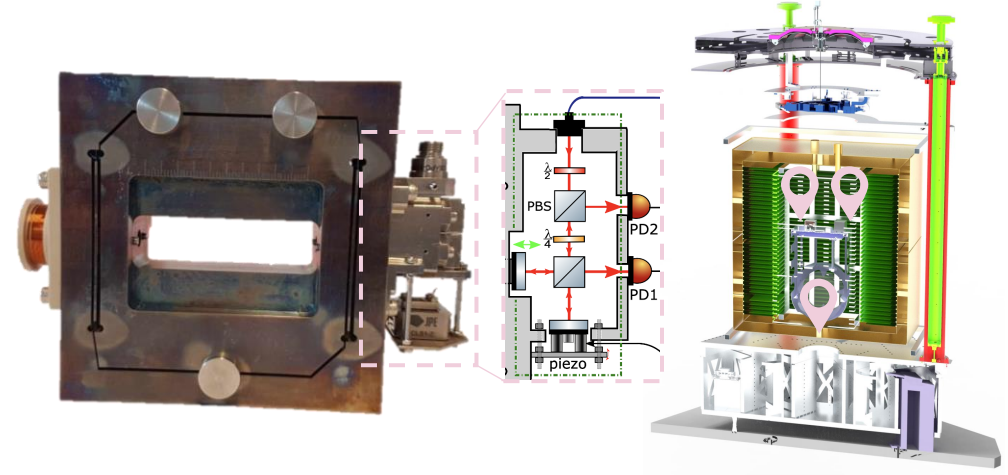
→ Towards an (almost) TRL9 cryogenic inertial sensor ←



## Horizontal cryogenic inertial sensor

Horizontal Watt's linkage with closed-loop homodyne interferometric readout

→ Towards the superconductive cryogenic inertial sensor (CSIS) ←

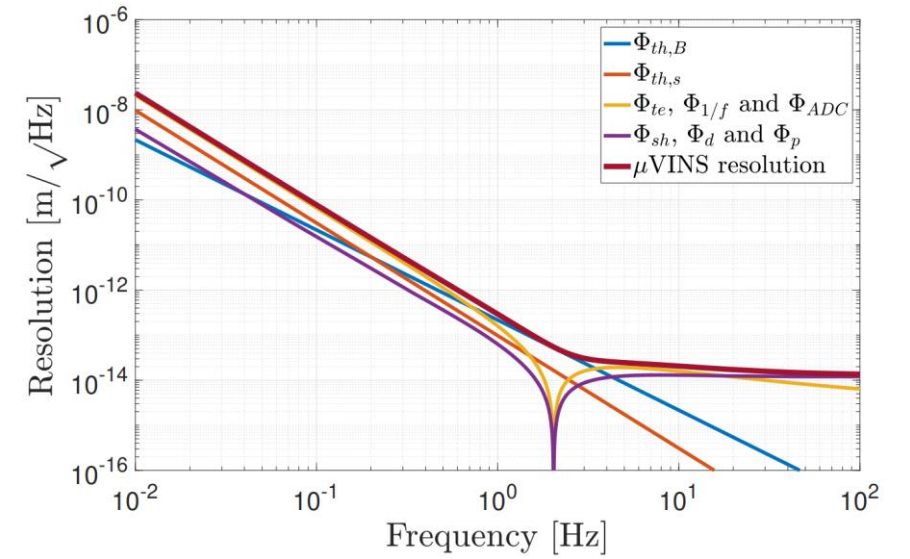
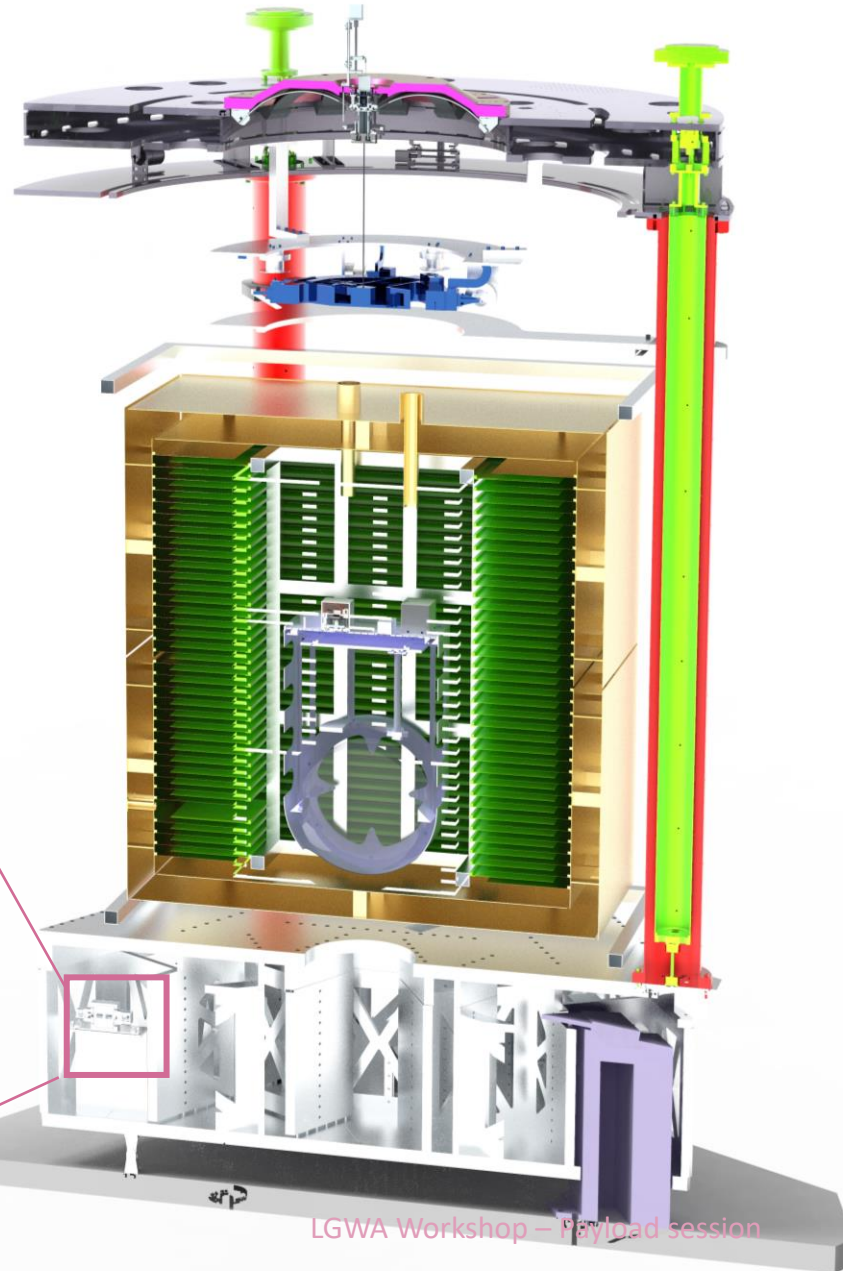




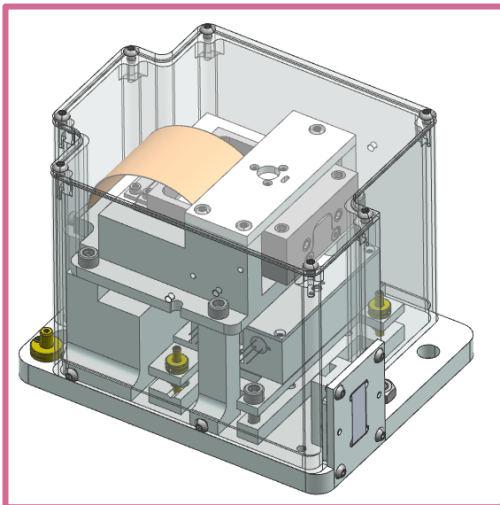
# Vertical cryogenic inertial sensor



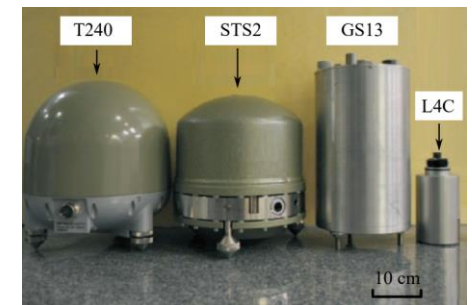
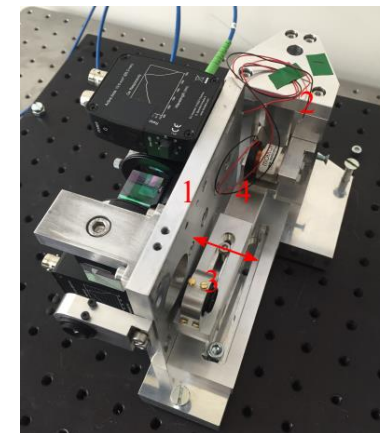
# Baseline



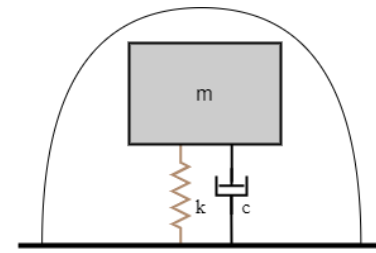
&



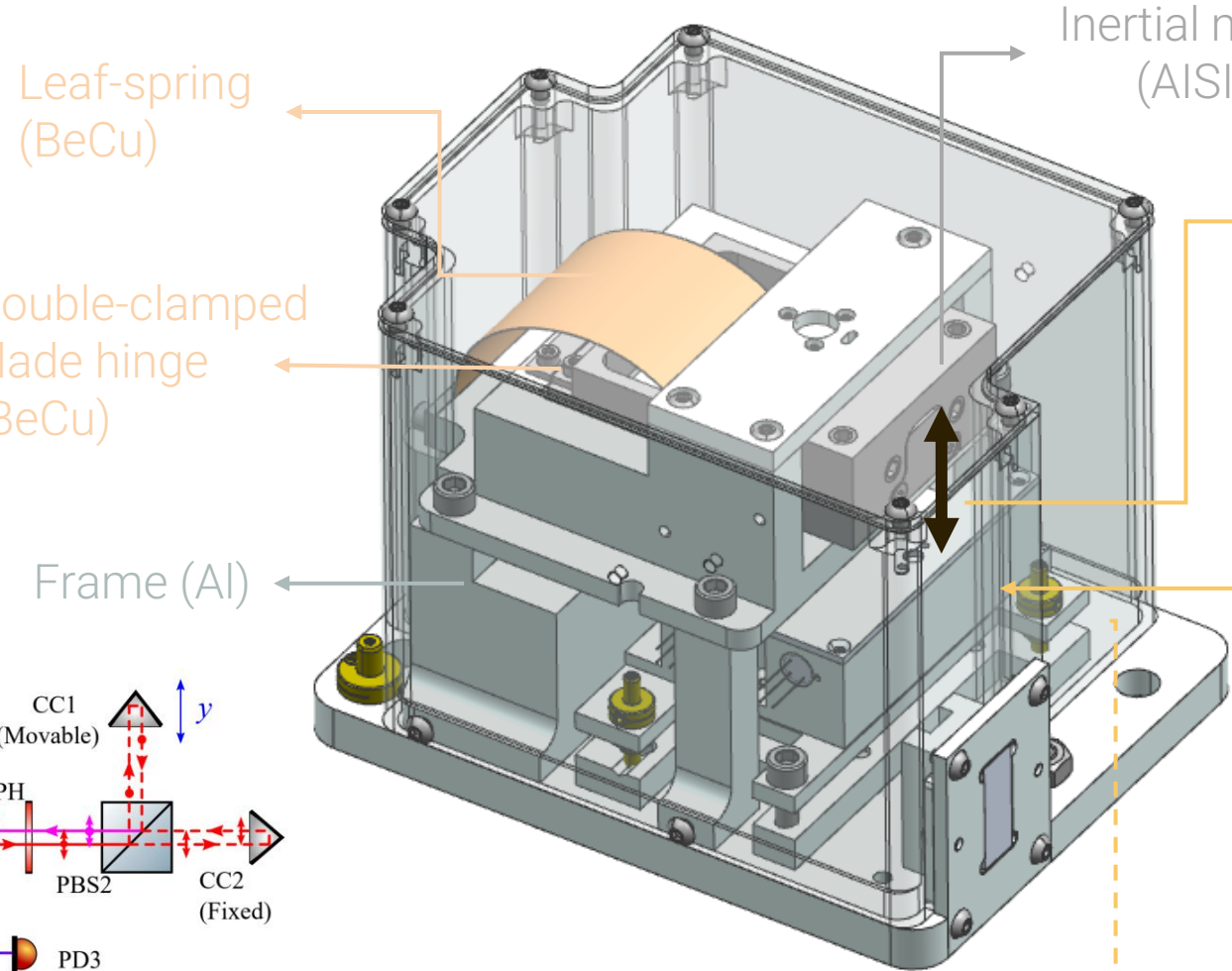
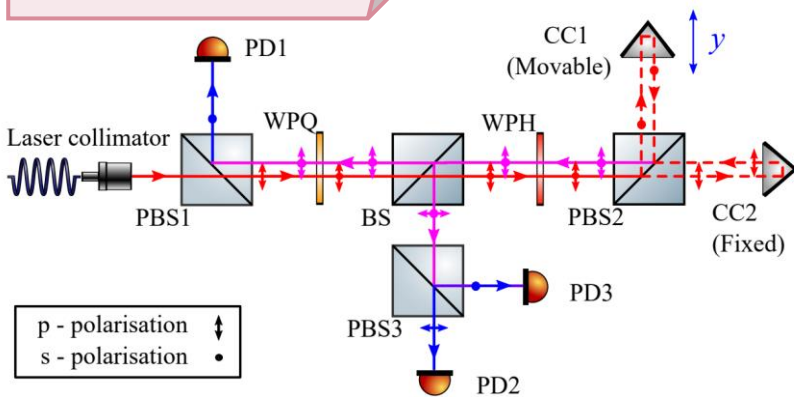
EVINS = E-TEST Vertical Inertial Sensor



# Adaptation of E-MNS to cryogenic conditions

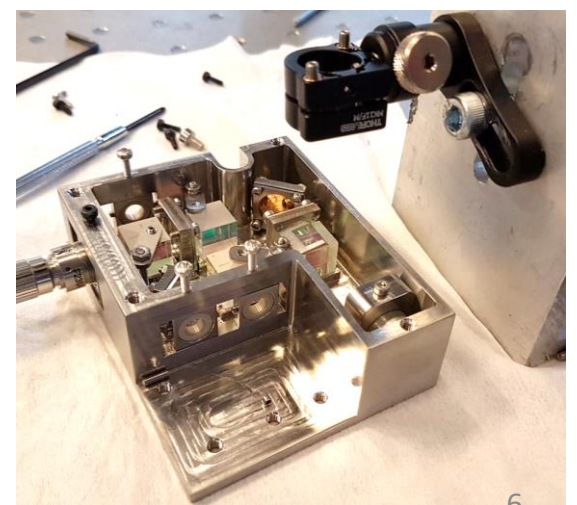


Optical elements are influenced by the temperature



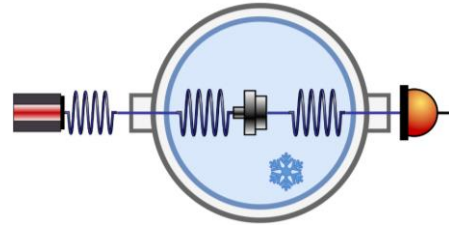
Open-loop

Homodyne quadrature IFO for parallel R&D and comparison with homodyne architecture



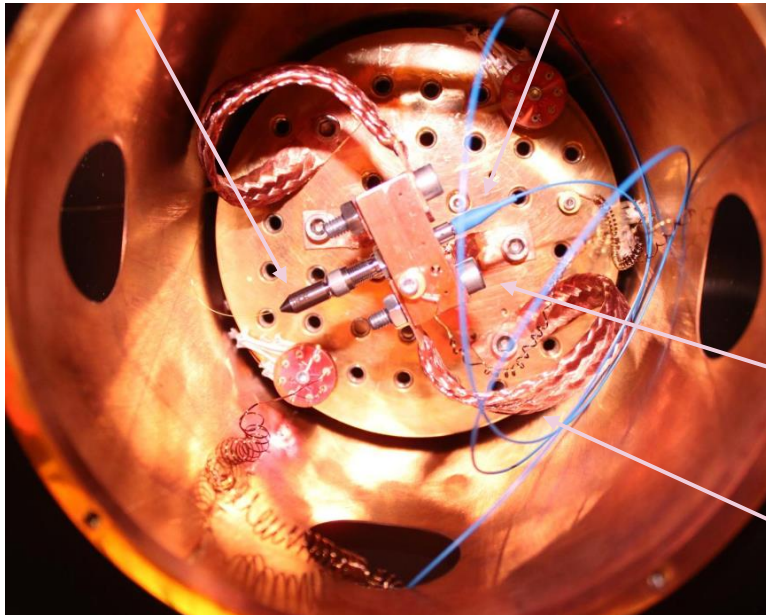
# Test of 1550 nm optical elements in cryogenic conditions

## Collimators



Open optical fiber

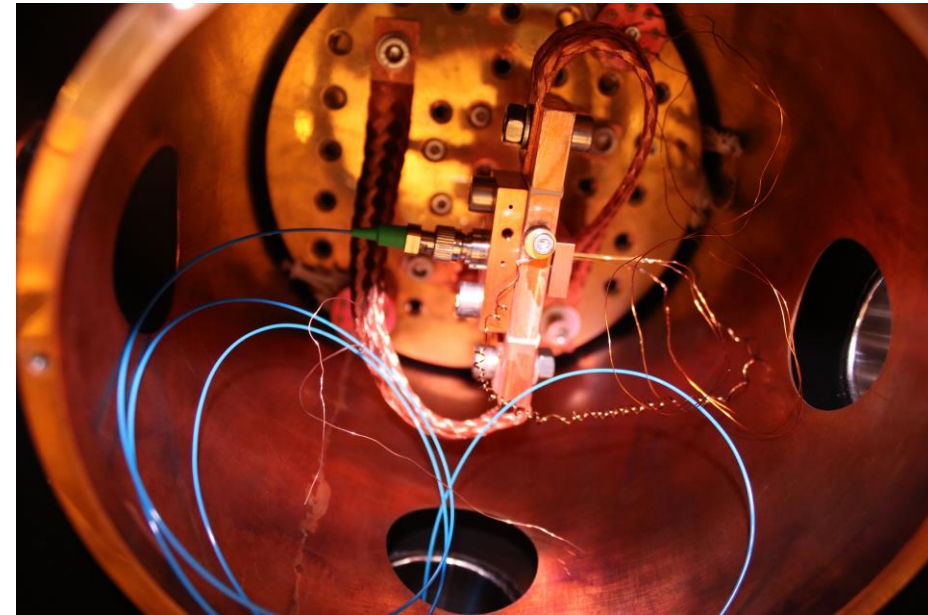
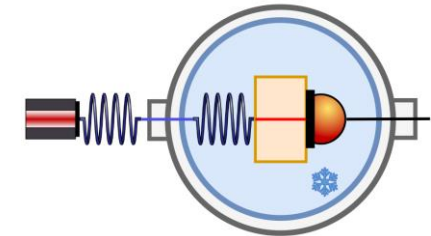
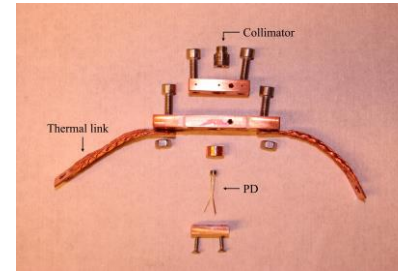
Collimator



Temp. sensor

Thermal link

## Photodiodes

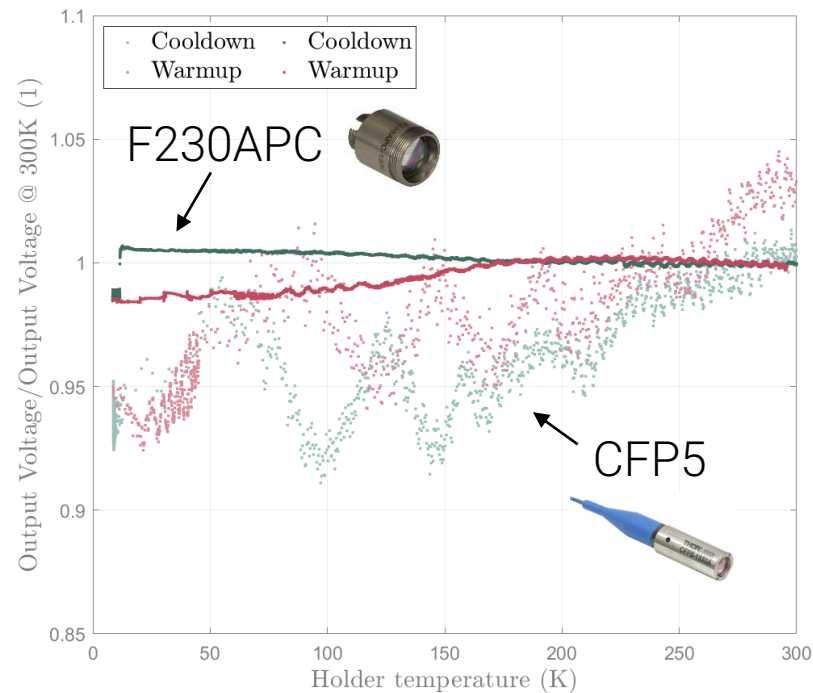


# Test of 1550 nm optical elements in cryogenic conditions

## Collimators

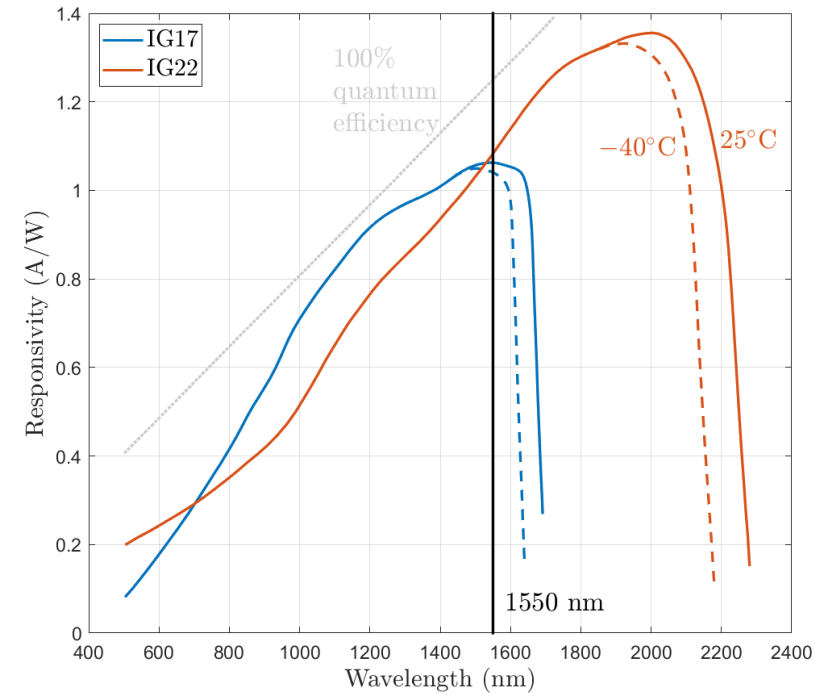


Relative decrease in voltage <math>< 2.2\%</math>



More sensitive to temperature fluctuations

## Photodiodes



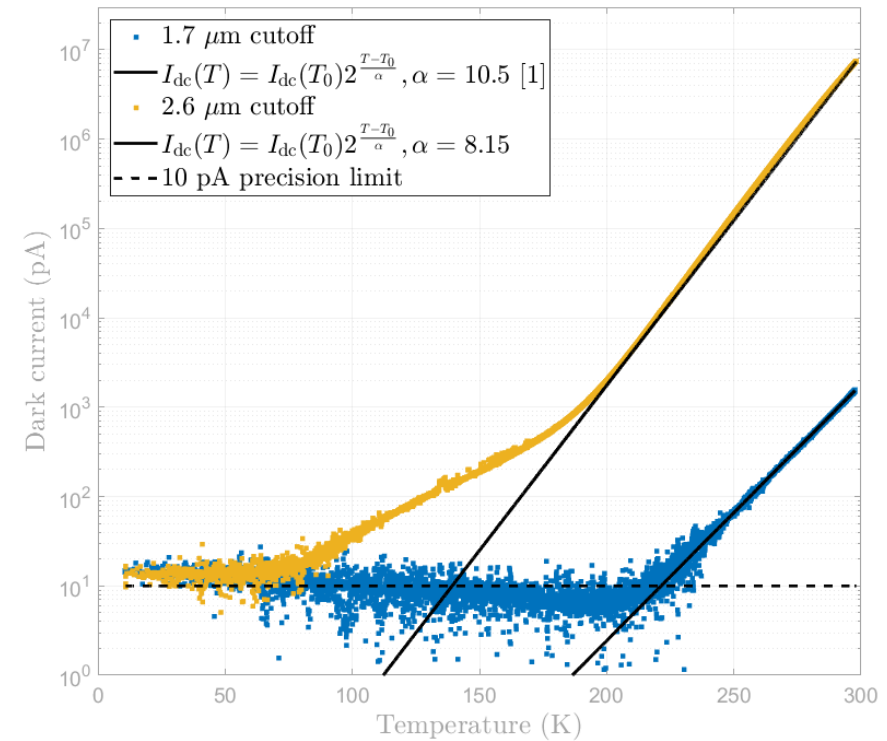
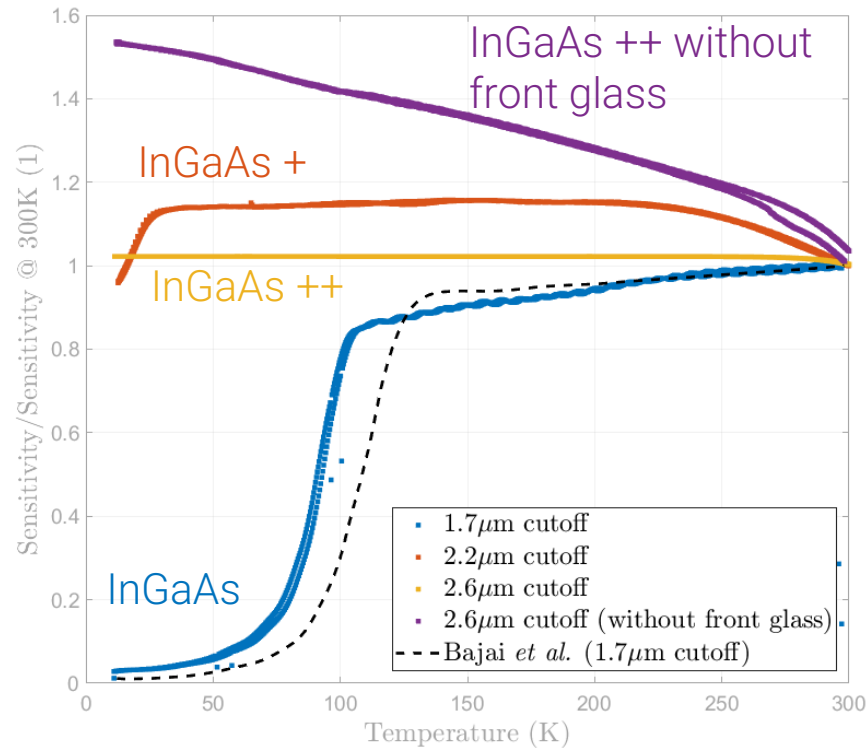


# Test of 1550 nm optical elements in cryogenic conditions

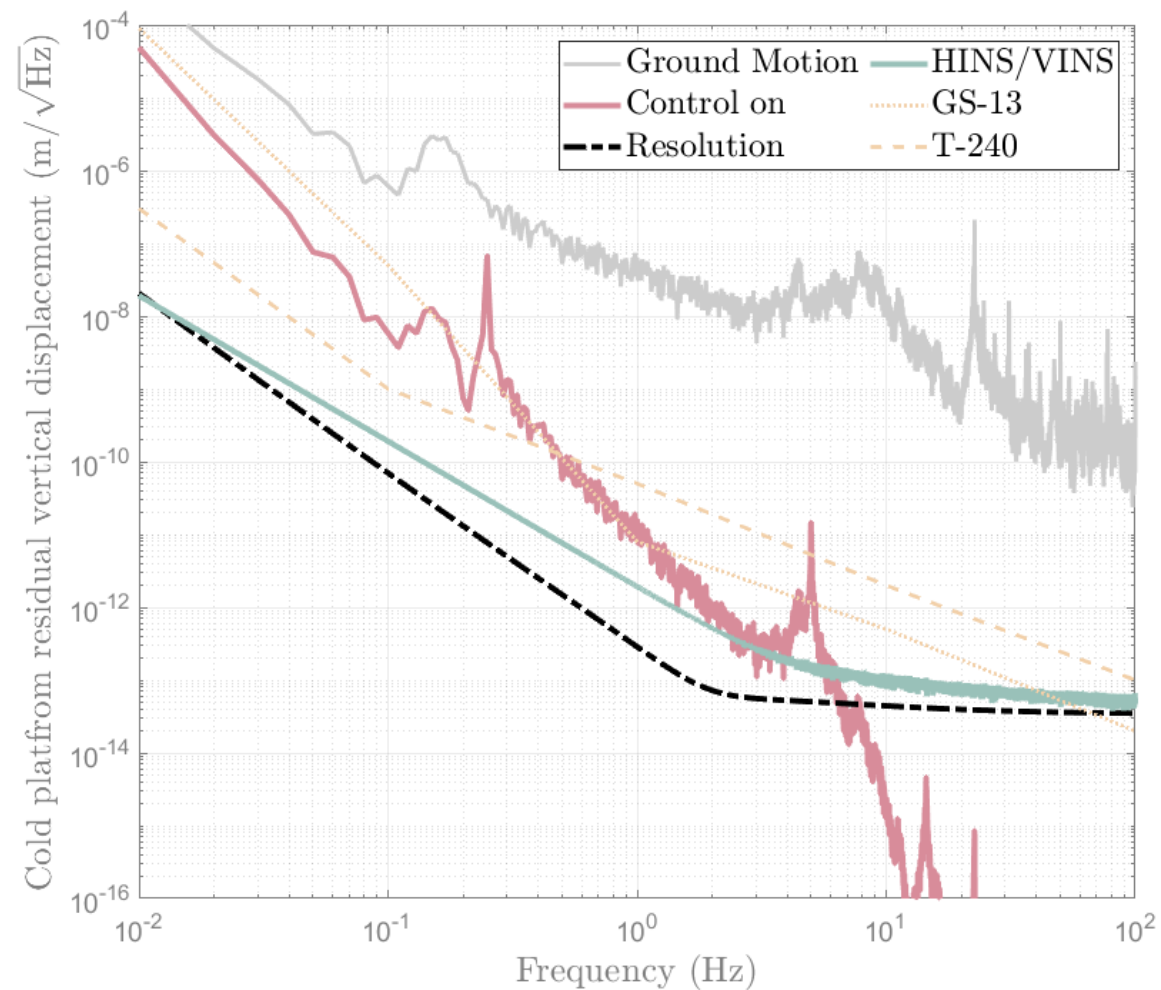
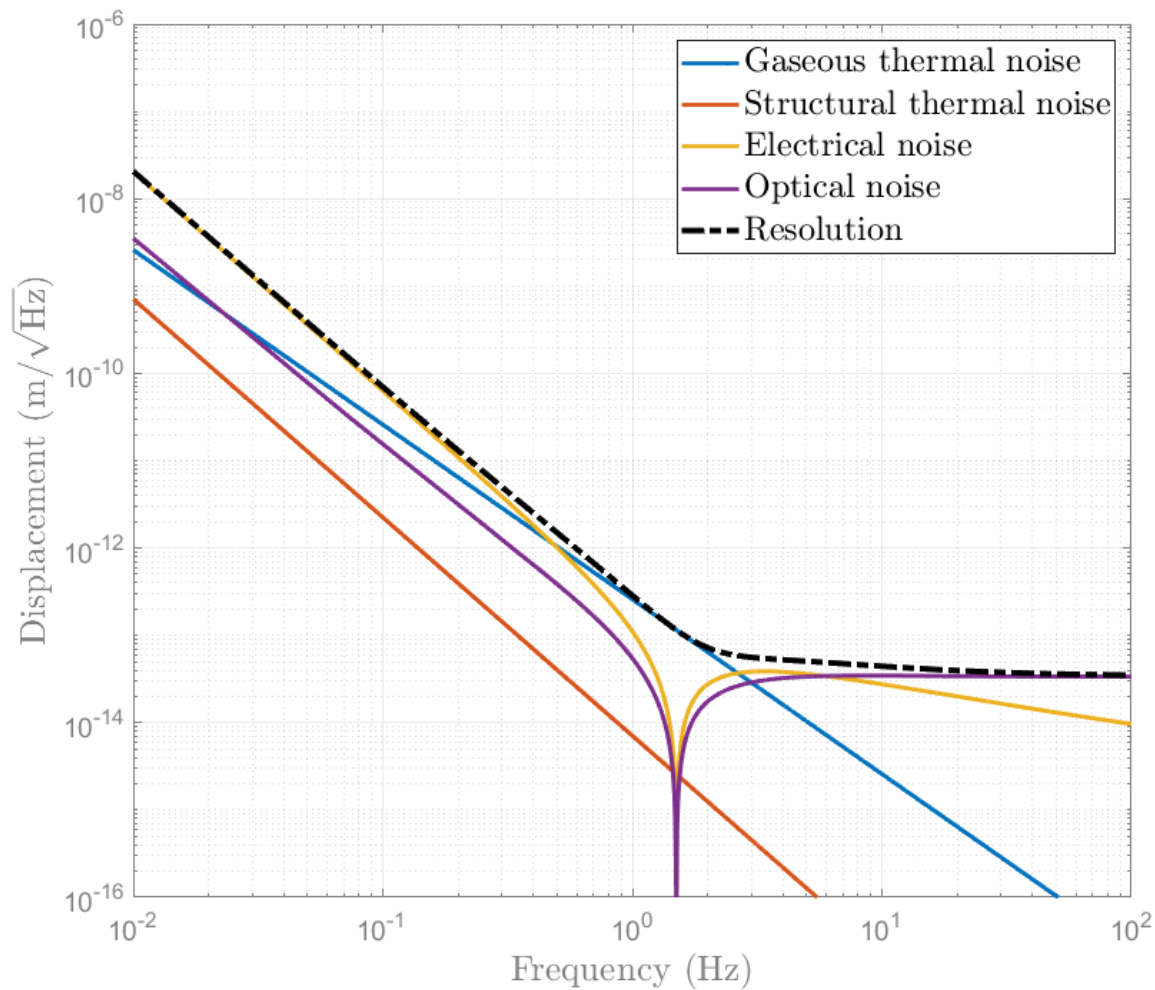
## Photodiodes

Constant improvement of the responsivity

[1] Zhang *et al*, 1997 <https://ui.adsabs.harvard>  
 [2] Bajpai *et al*, 2022 [arxiv 2203.10427v1](https://arxiv.org/abs/2203.10427v1)



# Expected sensitivity

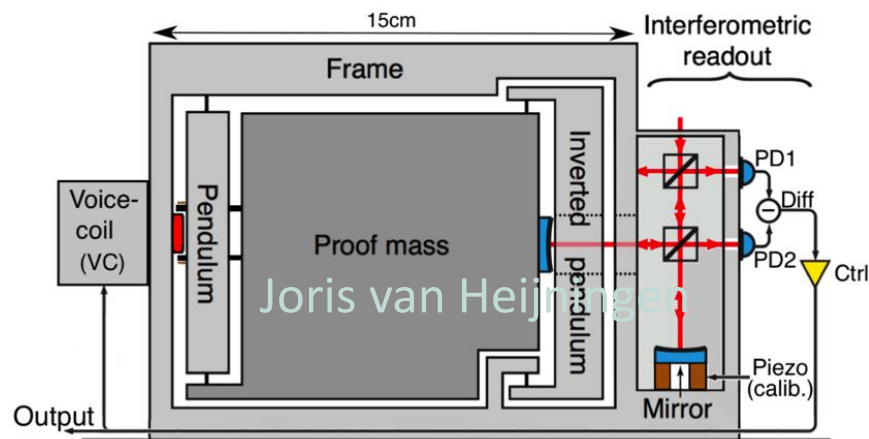




# Horizontal cryogenic inertial sensor



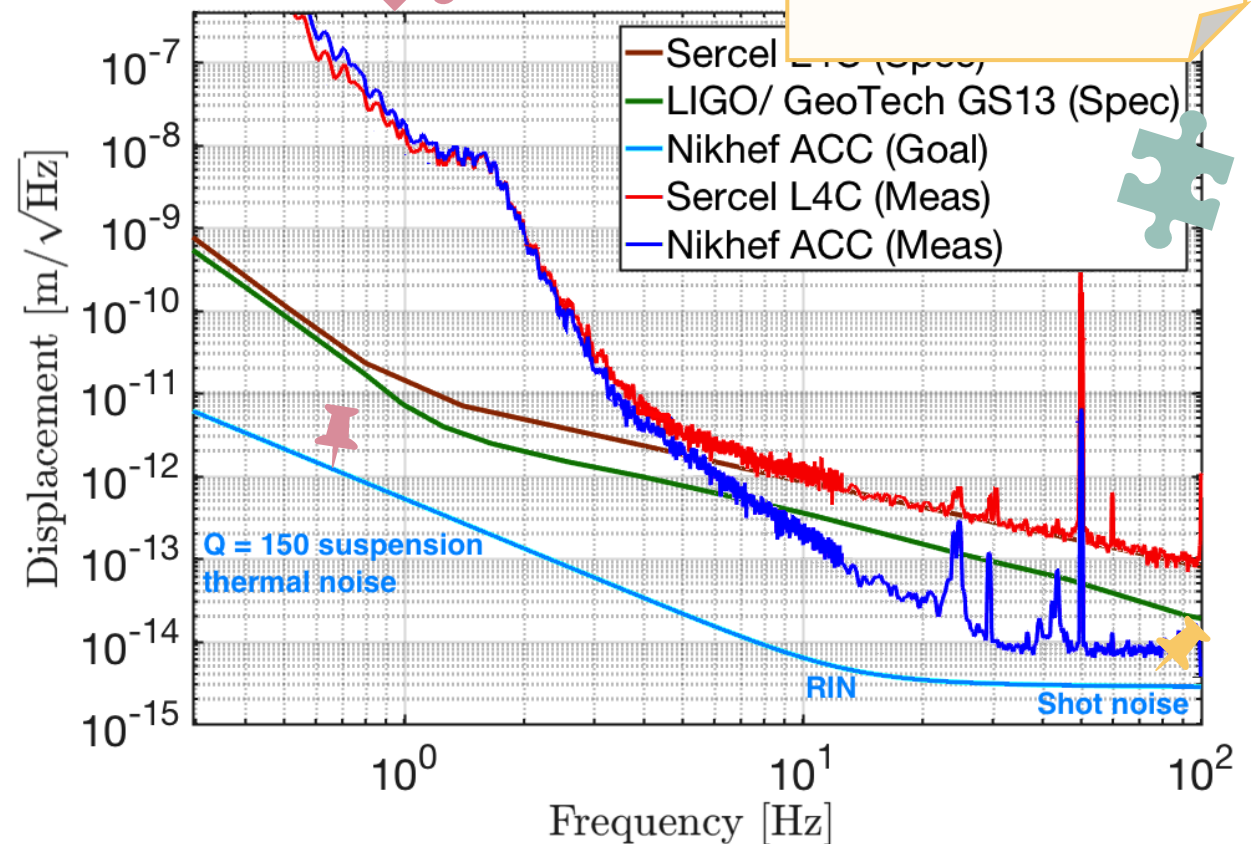
# Horizontal inertial sensor baseline



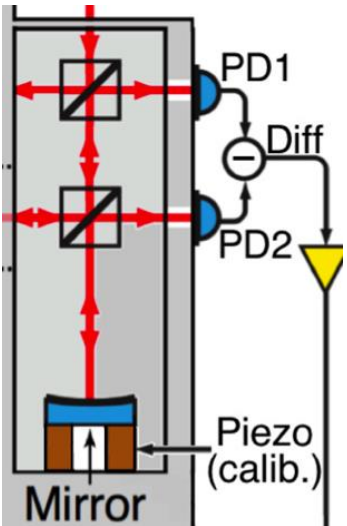
Joris van Heijningen

Improve Q-factor with low loss actuators

Improve shot noise by improving the interferometric readout

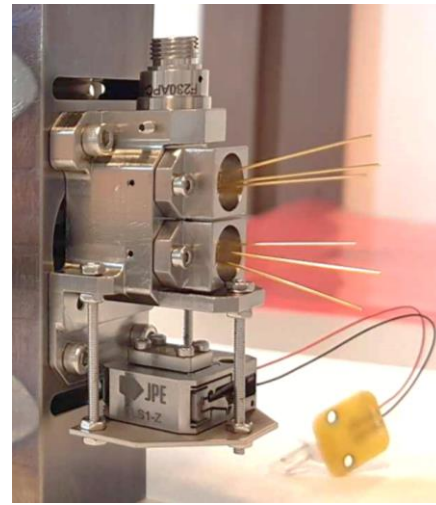


# Om-scale interferometric readout



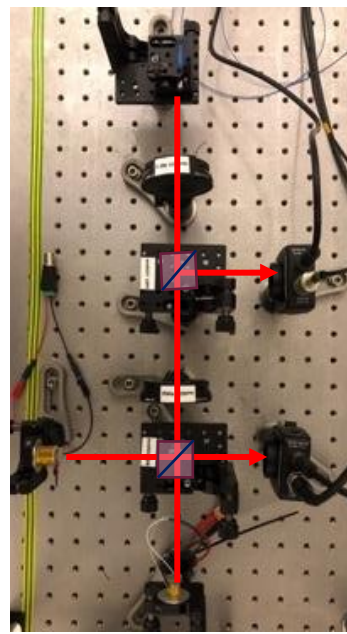
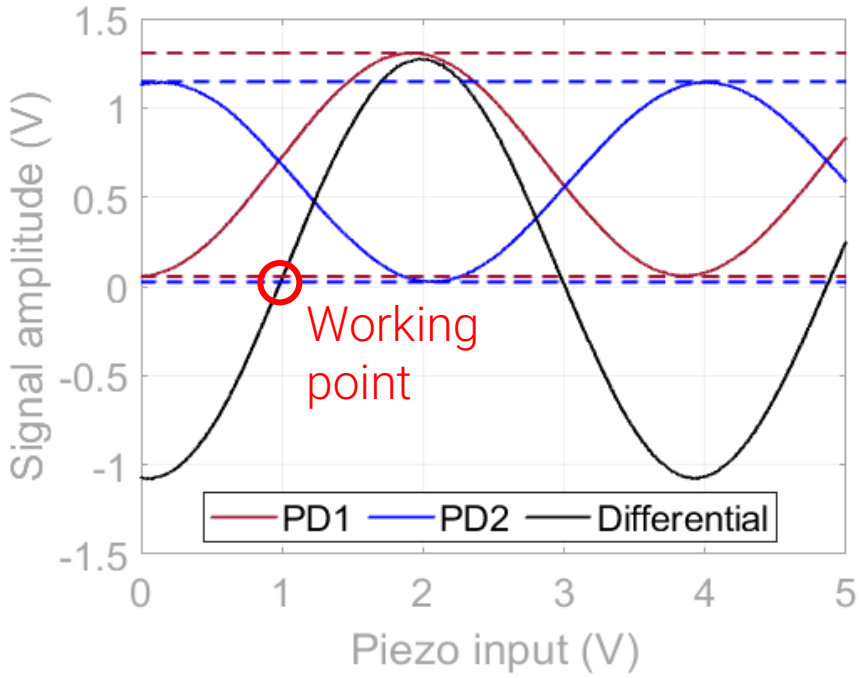
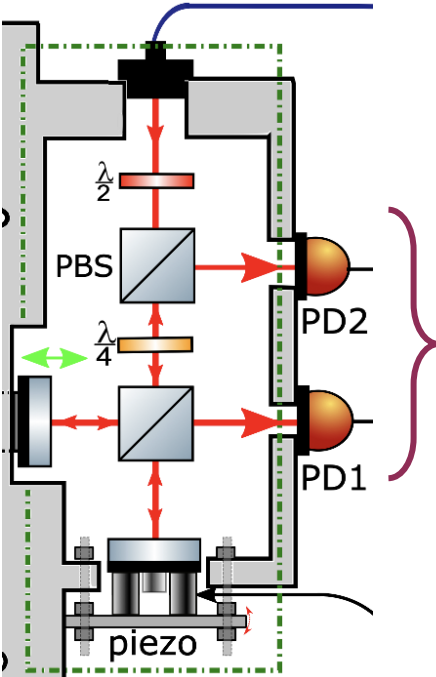
## Differential signal

All common mode noises are decreased to shot noise level



## Polarizing optics

All light end up to the PDs so 41% less shot noise at same input power and less heat load

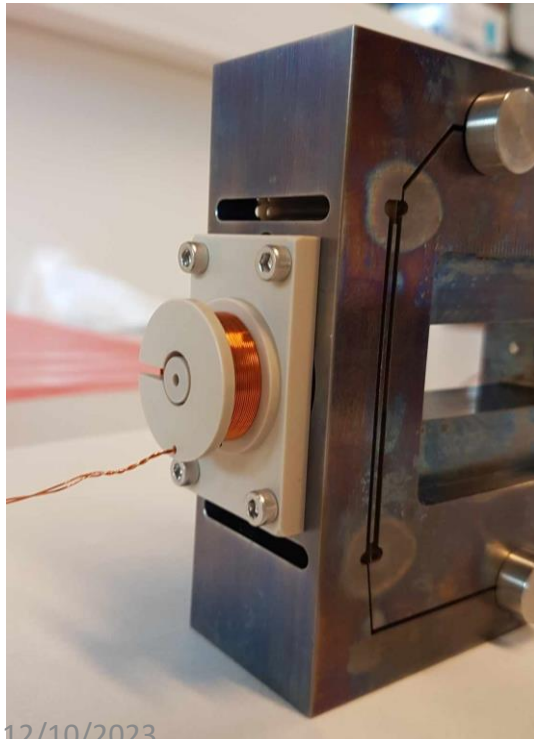
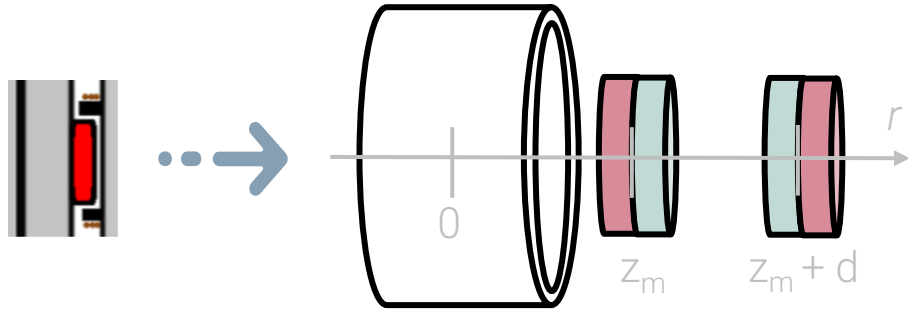


# Low-loss actuation: shielded-magnets voice-coil actuator

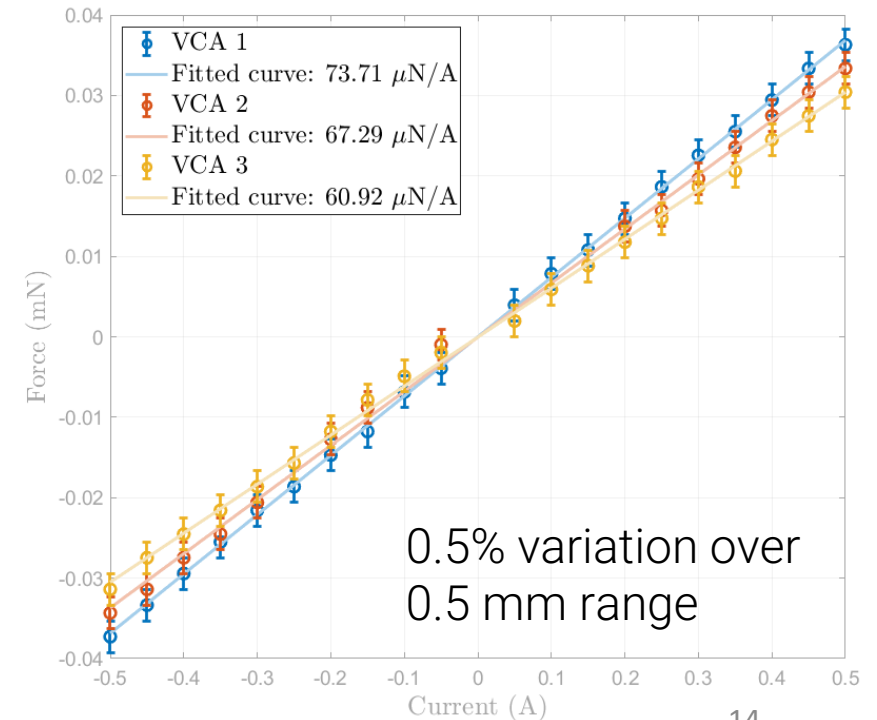
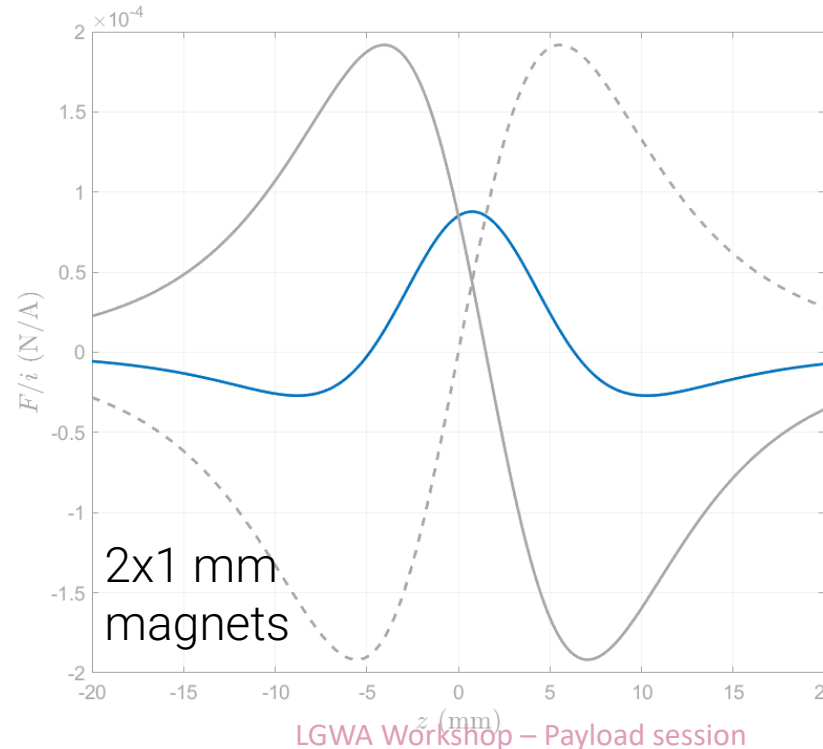


## Shielding-magnets VCA

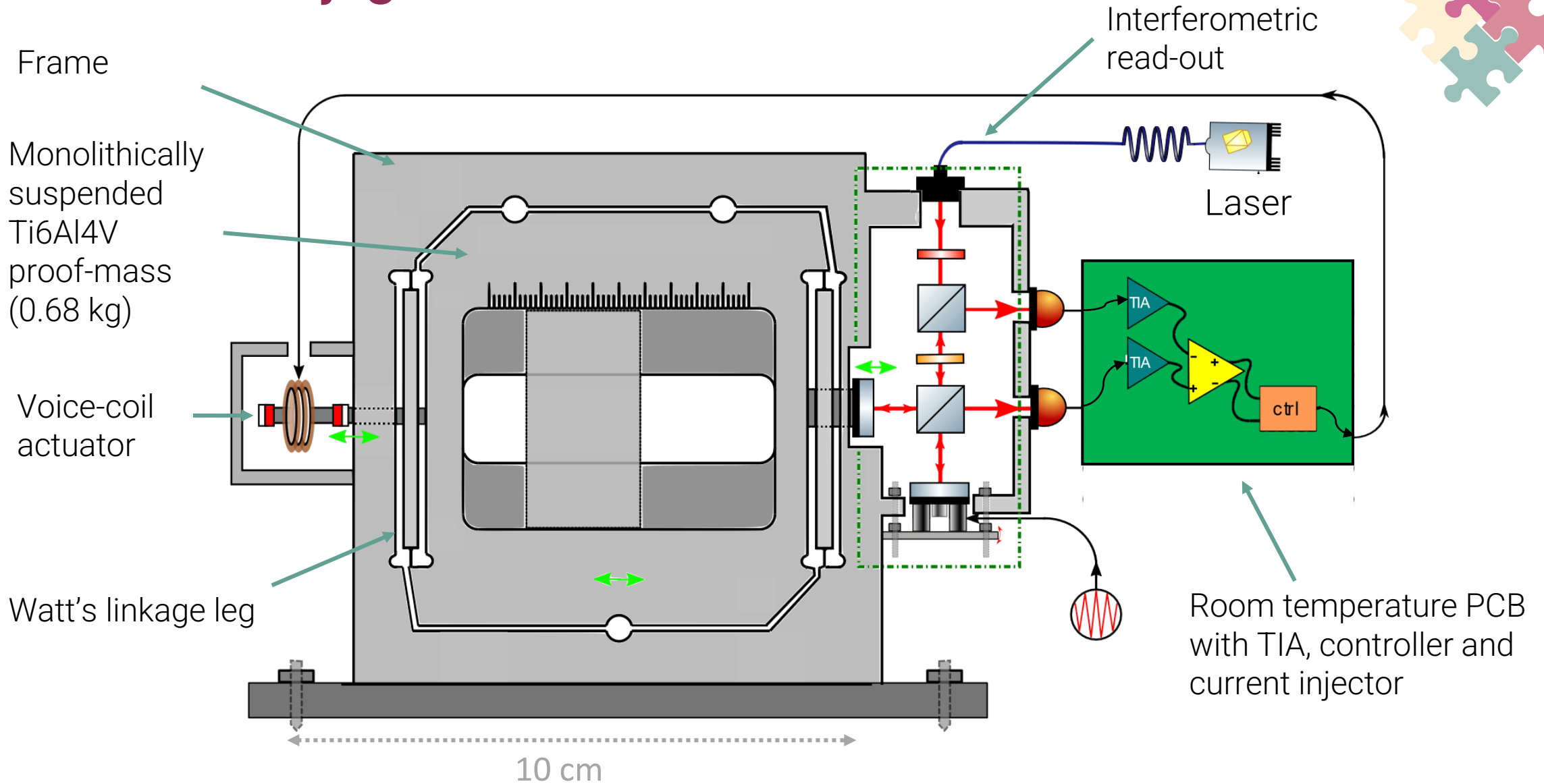
Cancel far-field magnetic field from agents and decreases eddy-current damping



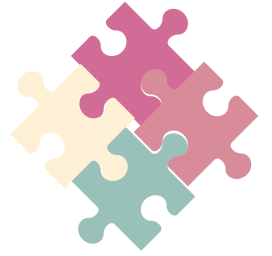
12/10/2023



# Horizontal cryogenic inertial sensor for E-TEST



# Horizontal cryogenic inertial sensor for E-TEST

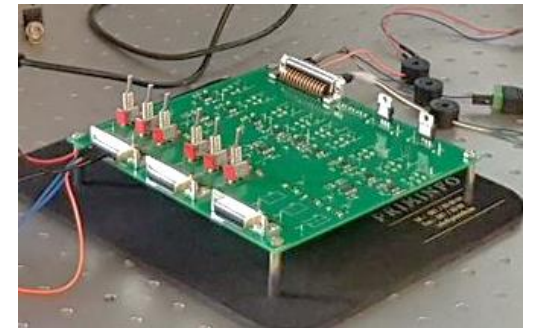
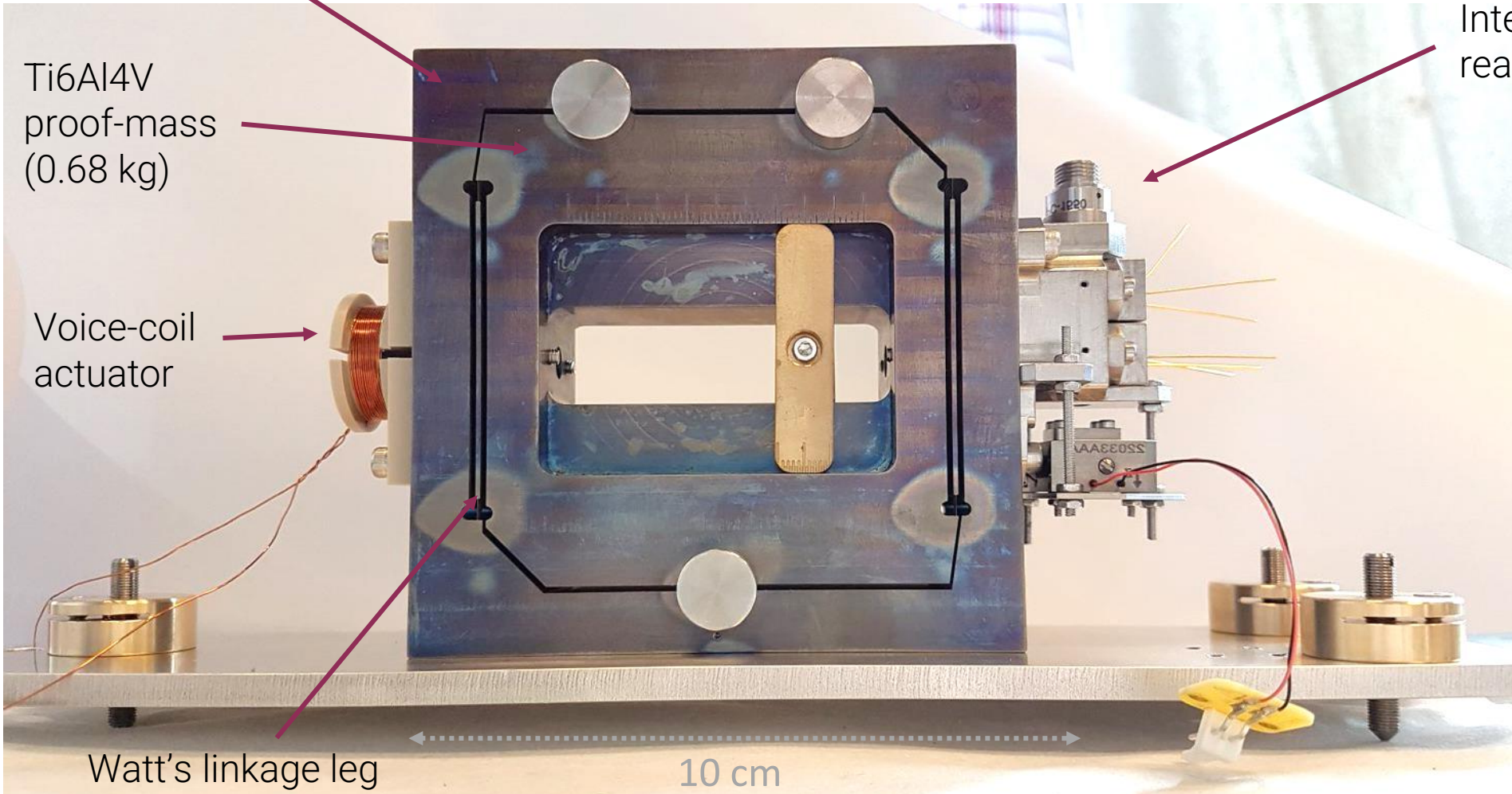


Frame

Ti6Al4V  
proof-mass  
(0.68 kg)

Voice-coil  
actuator

Interferometric  
read-out



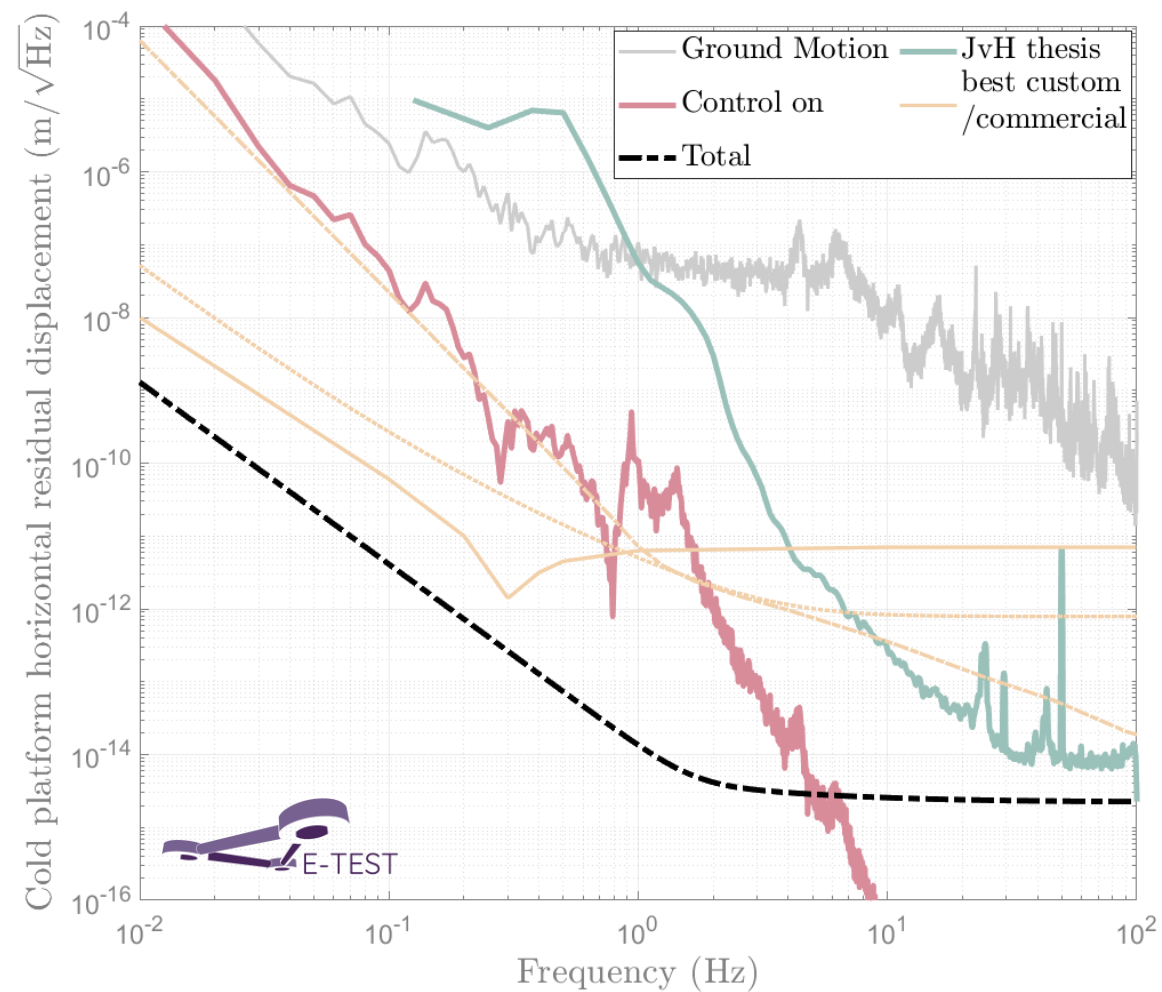
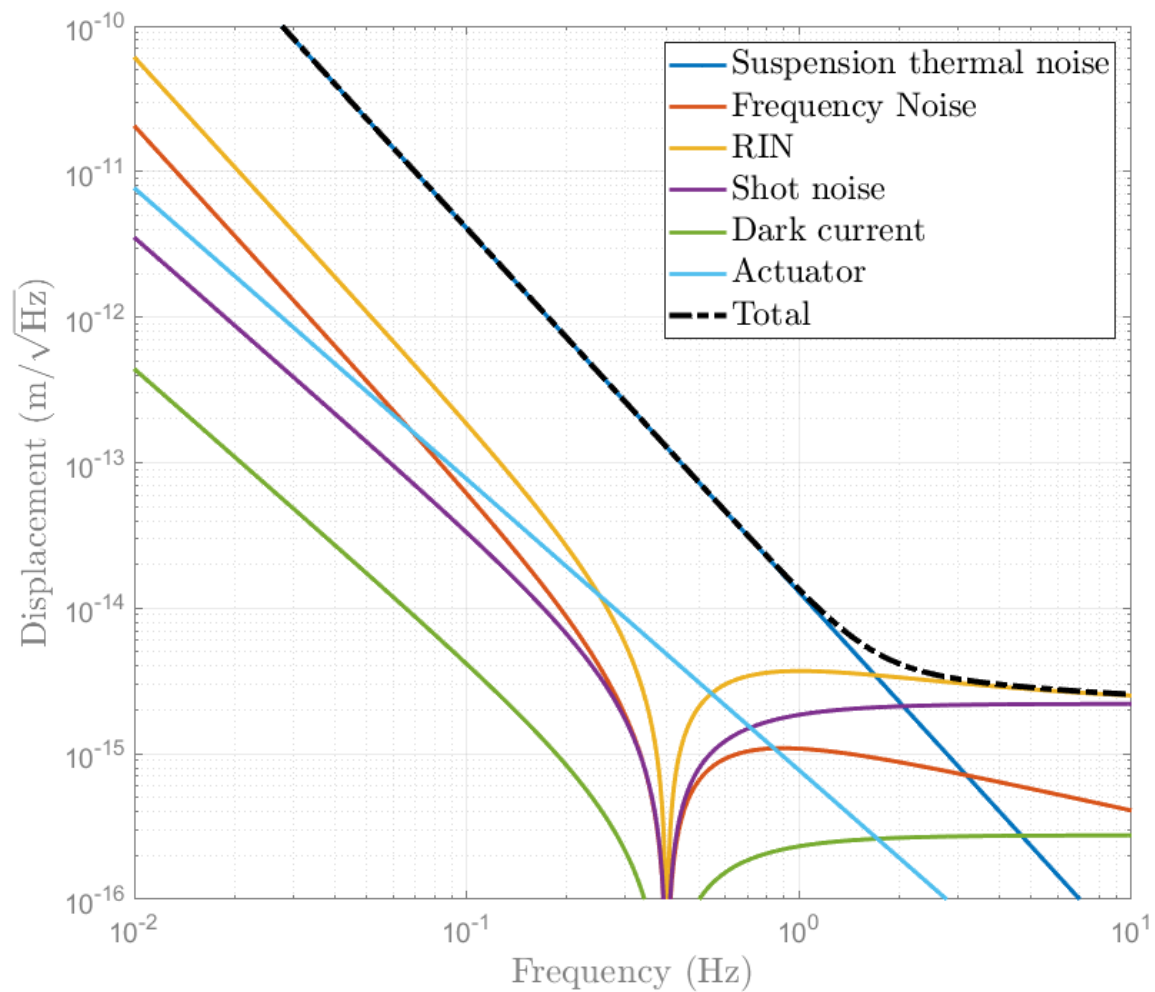
Room temperature PCB  
with TIA, controller and  
current injector

Watt's linkage leg

10 cm



# Expected sensitivity

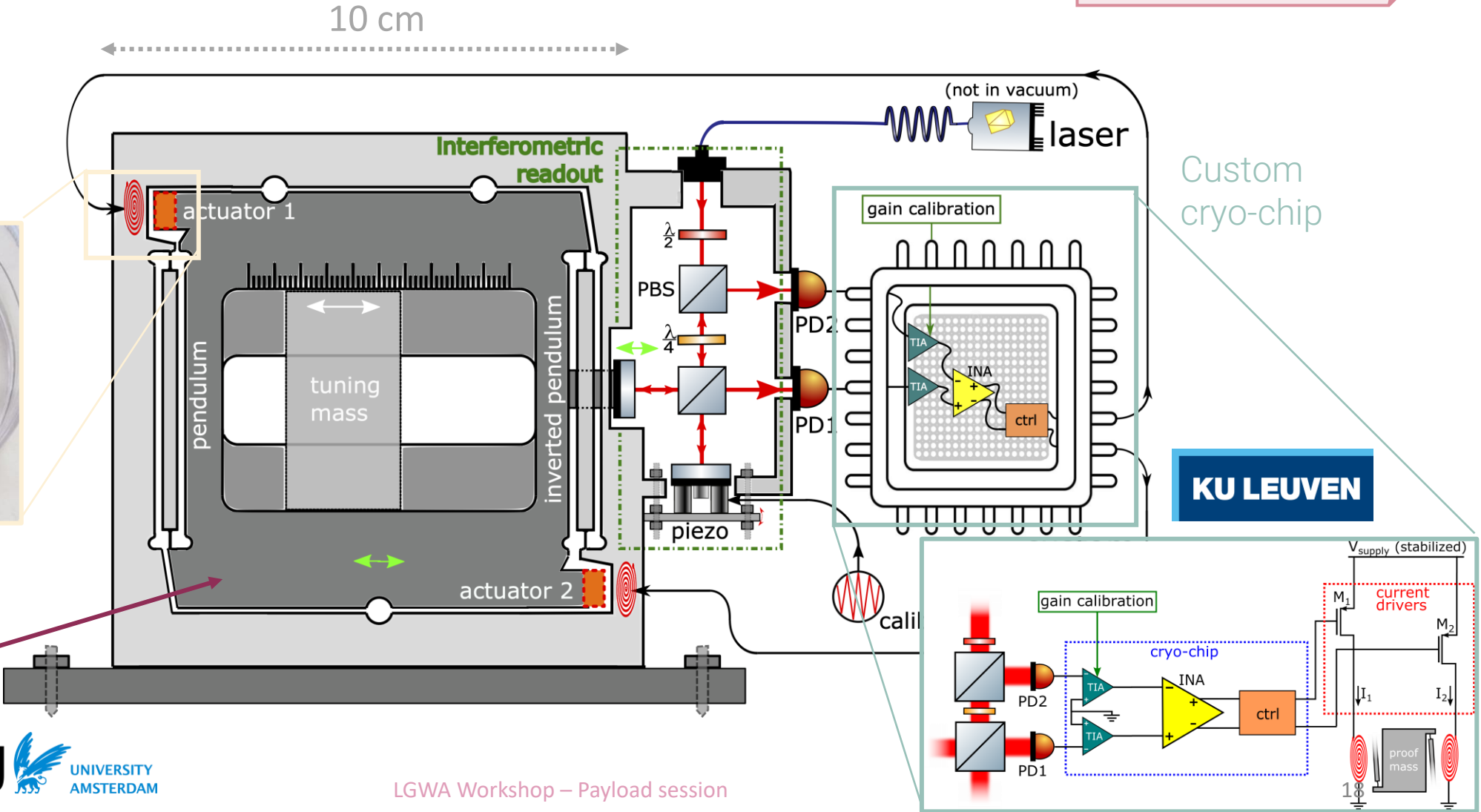


# Further development – towards LGWA sensor

Cryogenic Superconductive Inertial Sensor



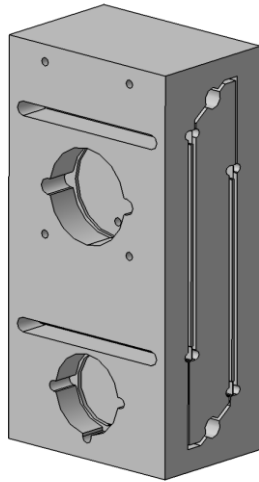
Superconductive actuator



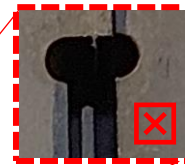
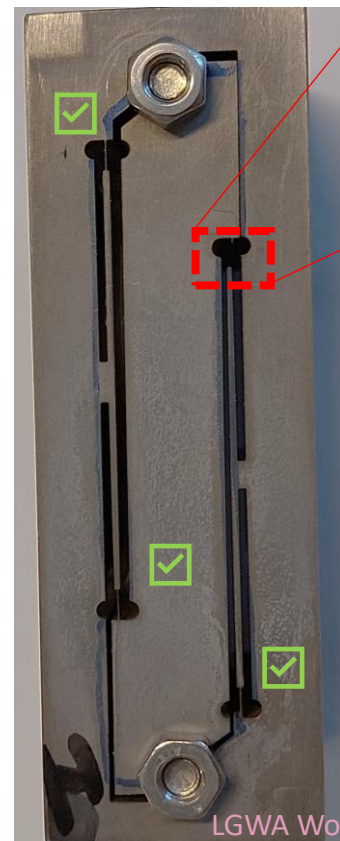
Niobium proof-mass (10kg)

# Further development – Niobium proof-mass

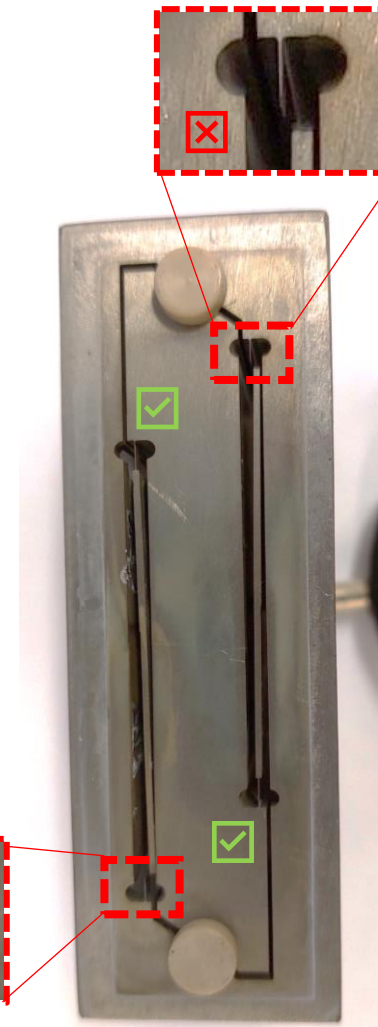
Small test blocks with a compressed proof mass to test interfaces between milled holes and the spark-erosion cuts including the delicate flexures.



Machining by Mike de Jong, VU  
Amsterdam EDM specialist



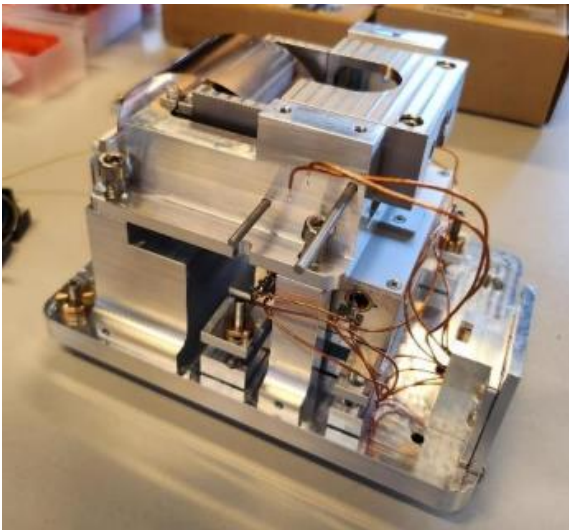
→  
Cutting machine  
alignment +  
annealing



# Summary

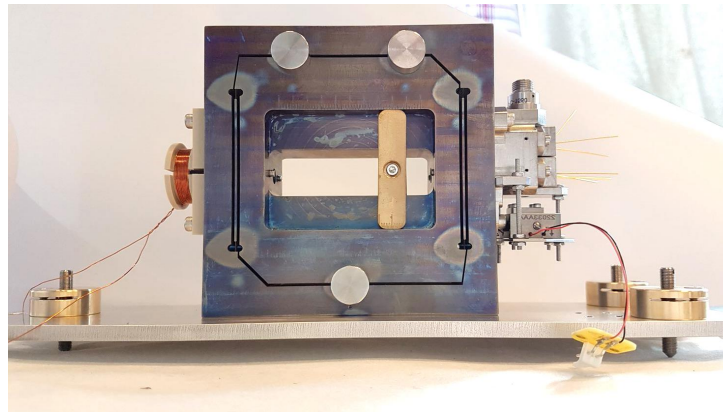
## Vertical sensor

Development of a first prototype operating in **open-loop** with a leaf-spring suspension mechanism and an homodyne quadrature interferometer



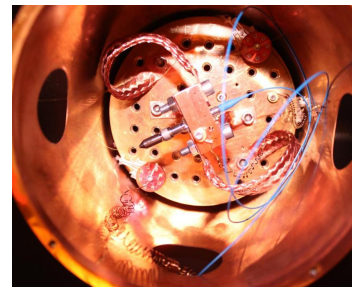
## Horizontal sensor

Development of a first prototype operating in **closed-loop** with a Watt's linkage mechanism, an homodyne interferometer and a shielding magnets voice-coil actuator

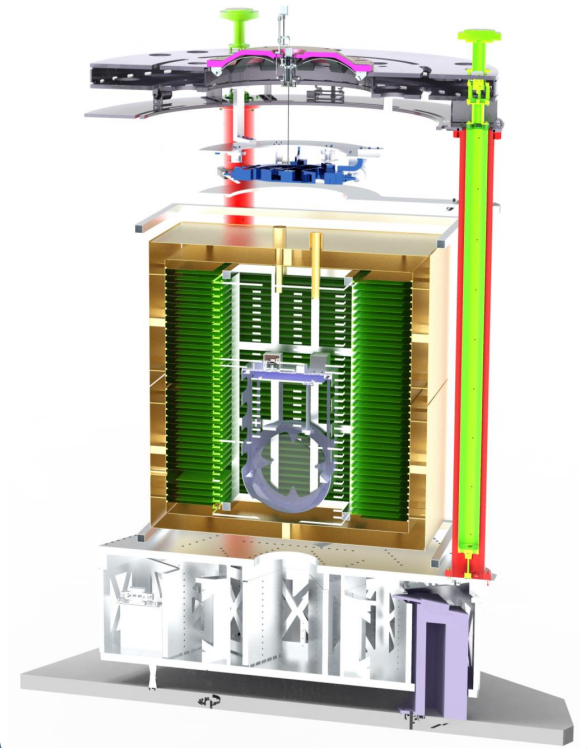


## 1550 nm optics

Validation campaign of 1550nm optical elements at cryogenic temperature



Testing of the prototypes in E-TEST quiet and cold environment to learn and further improve the designs



Thank you

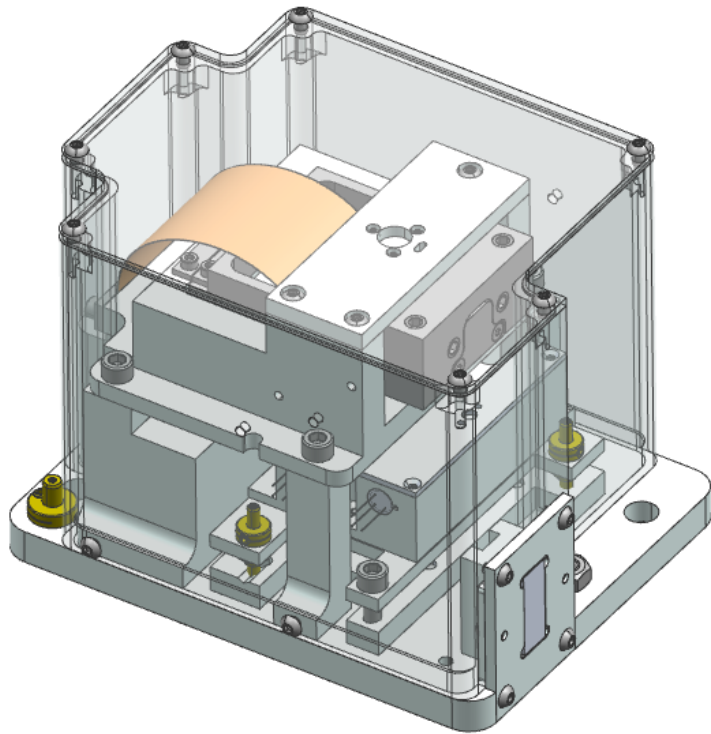


# Backup

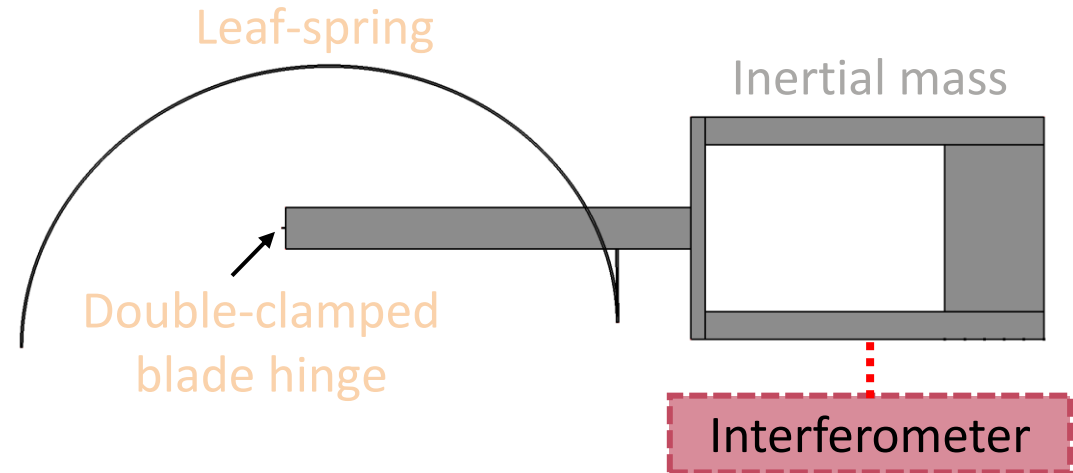
# Adaptation of E-MNS to cryogenic conditions

Alignment is important!

- Fringe visibility
- Sensitivity to couplings

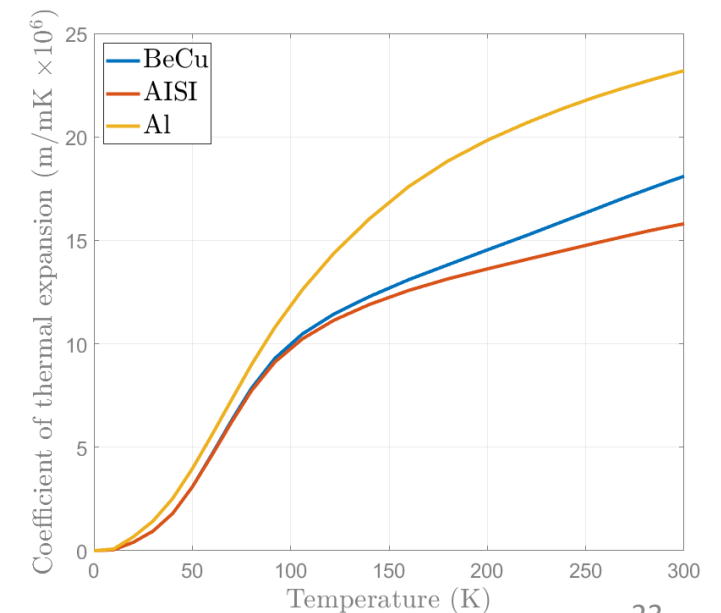


Total mass  
CoM  
Inertia



Due to thermal effects in the leaf-spring, a mis-alignment of  $\theta = -12.8 \text{ mrad}$  and a stress increase of 53.48 %

⚠ Young modulus change with temperature ongoing implementation. First results: a 10% increase in E already seems dramatic (+0.23 rad)  
LGWA Workshop – Payload session



# Interferometer architectures

