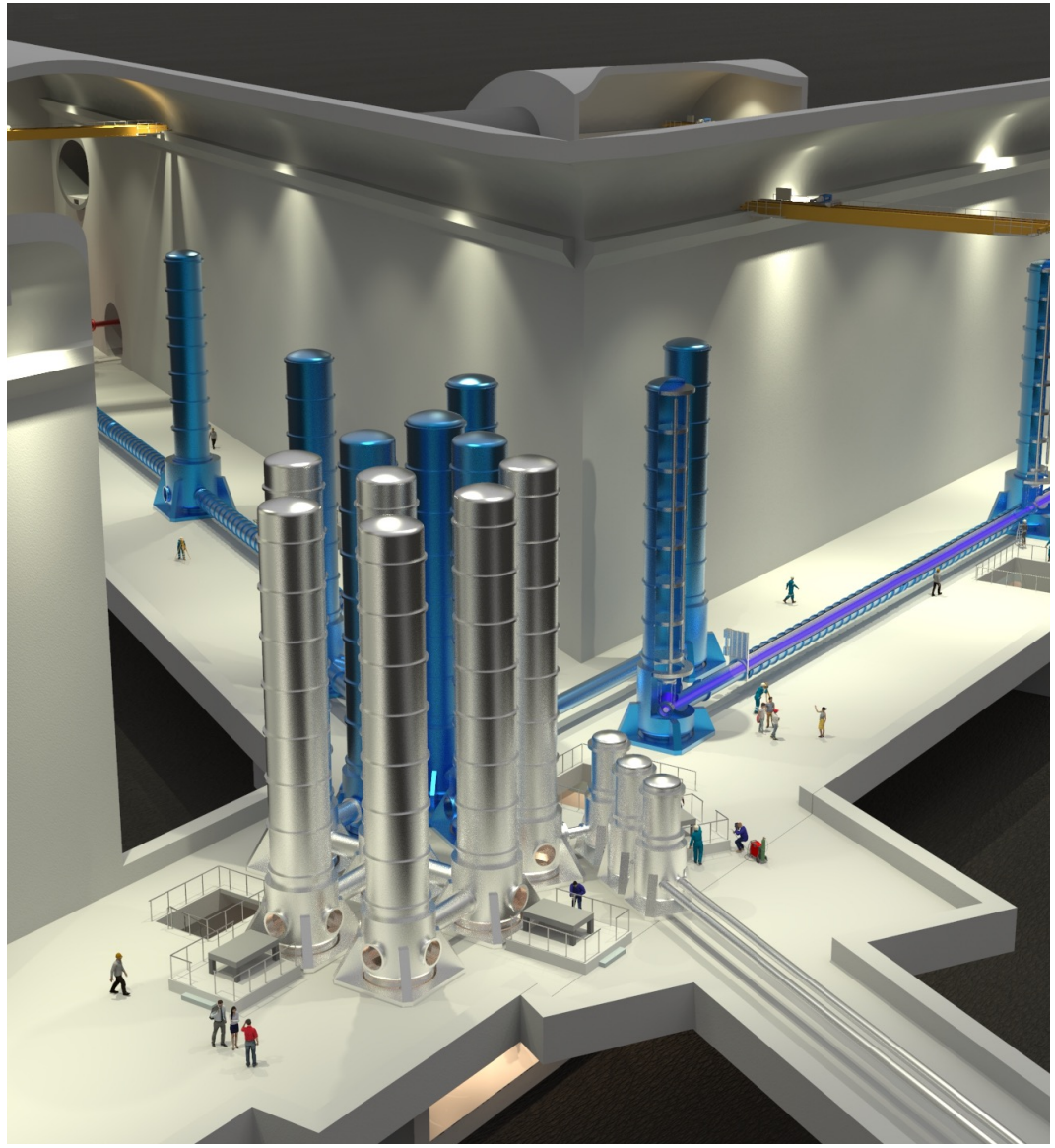
E-TEST : Einstein Telescope EMR Site and Technology

Chrisrtophe Collette

14.10.22



ETEST objectives

- Large mirror
- Cryogenic temperature
- Isolated at low frequency
- Compact suspension
- Capitalize on existing existing infrastructure at CSL

E-TEST as part of the Einstein Telescope ecosystem

ETpathfinder

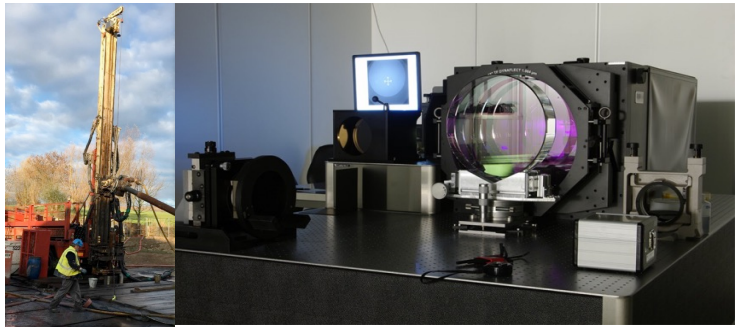
Objective: Development of a model infrastructure for testing new gravitational wave detector technologies and concepts in a complete interferometer in an ET-like environment

Location: UMaastricht-NL

Budget: € 14,8 million

Duration : 2019 – 2022

E-TEST



Objective: Development of ET-technology

- Geological exploration of the EMR and determination of the optimal ET location.
- Developement of advanced prototypes for cryogenics, optics and seismic isolation.

Location: CSL ULiège - BE

Budget: € 15,0 million

Duration : 2020 – 2023

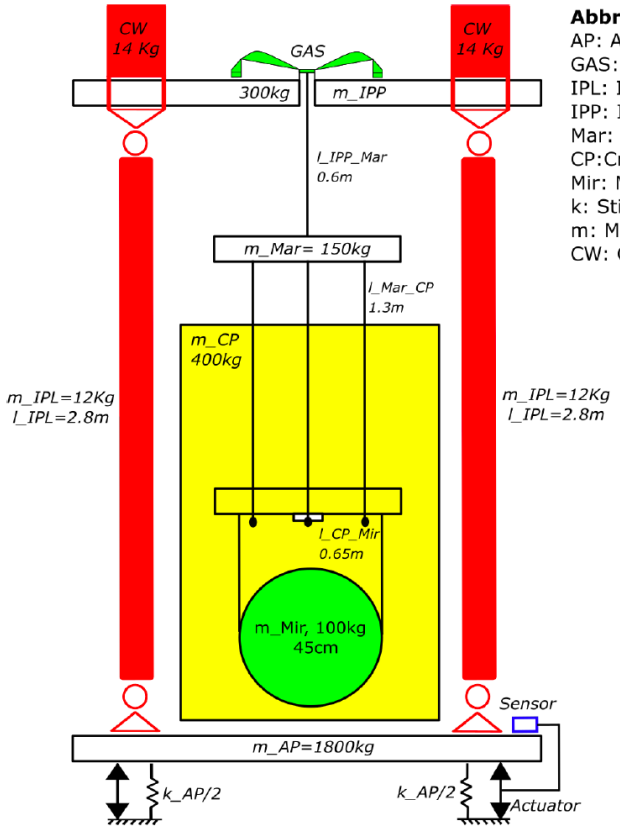
ET2SMEs

Objective: Promotion of cooperation between SMEs, large companies and R&D institutions that deal with ET-relevant key technologies in a broad understanding and towards multiple application fields by initiating SME-driven cross-border R&D projects.

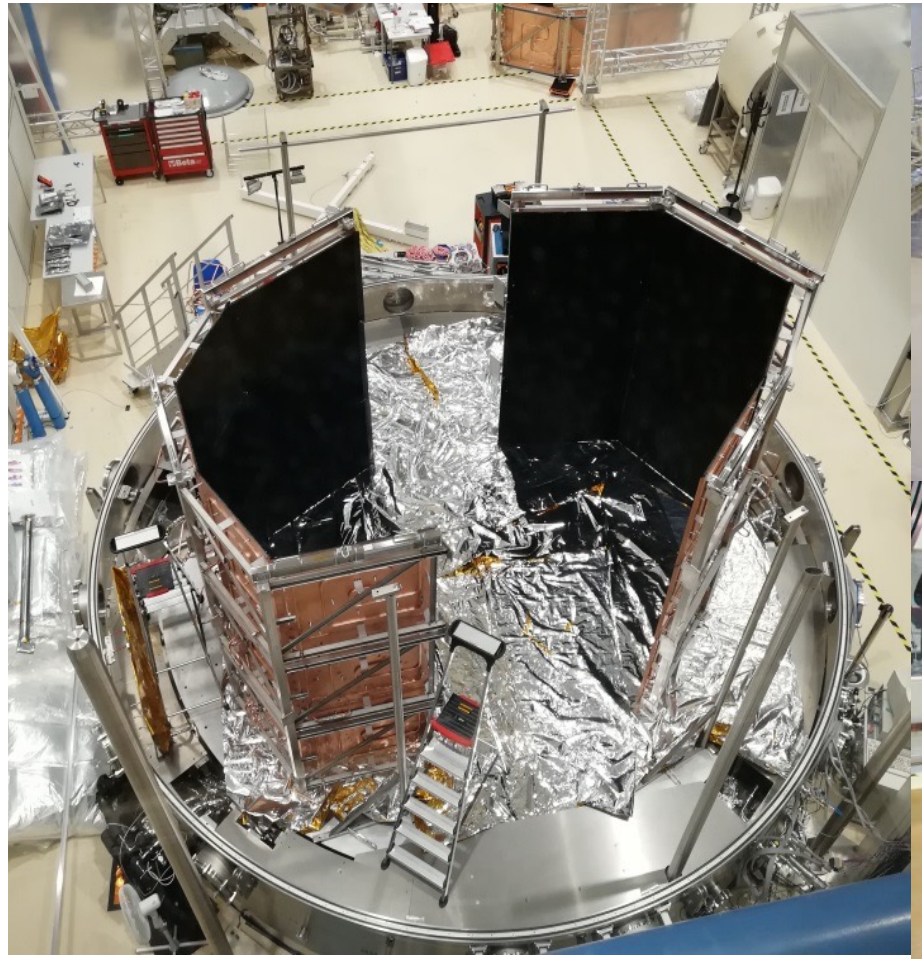
Budget: € 2,23 million

Duration : 2021 – 2023

Prototype E-TEST



Abbreviation:
AP: Active Inertial Platform
GAS: Geometric Anti-Spring
IPL: Inverted Pendulum Leg
IPP: Inverted Pendulum Platform
Mar: Marionette
CP:Cryostat+Cold Platform
Mir: Mirror
k: Stiffness
m: Mass
CW: Counter Weight



Liège Space Center

Hybrid (active + passive) isolation
Radiative cooling

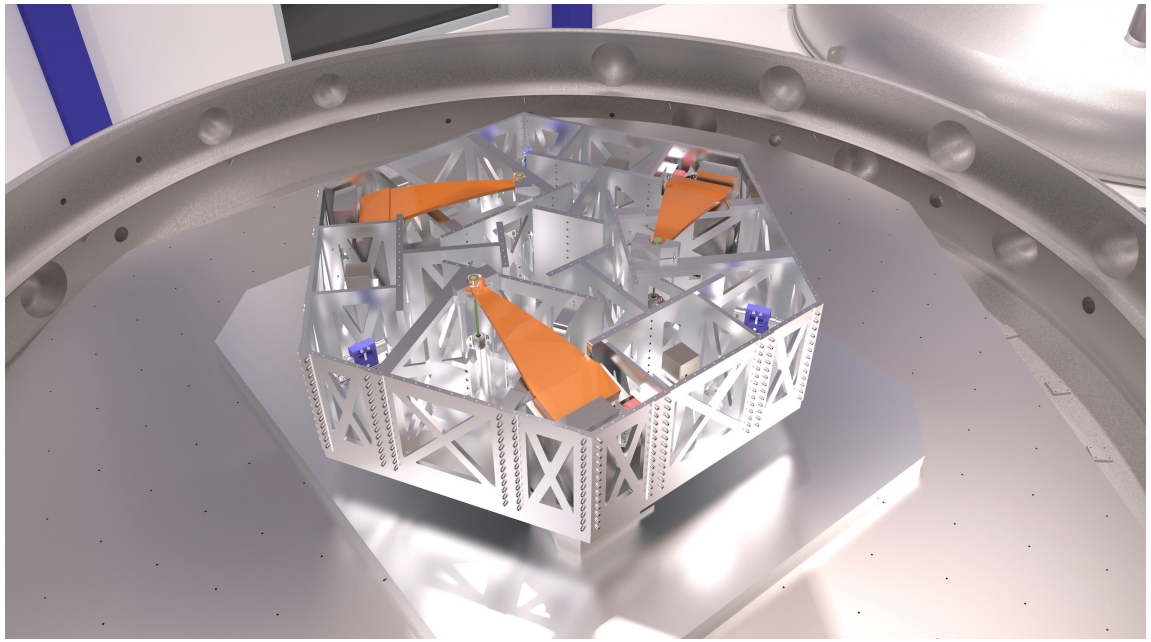
Submitted: 12/2021
Revised: 03/2022

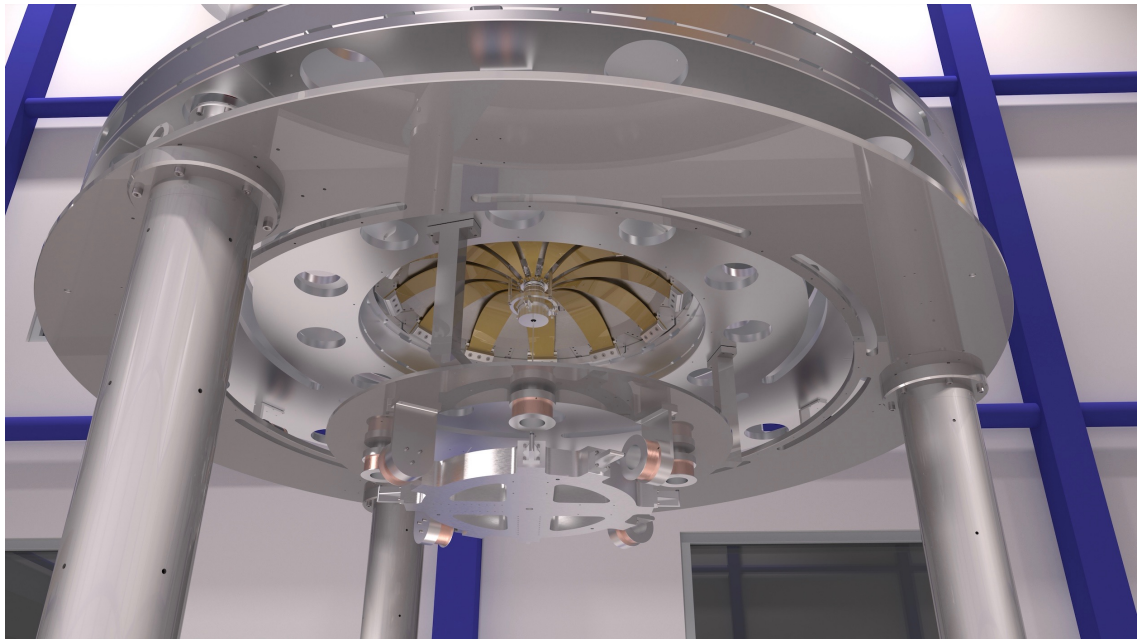
Vibration isolator
1)GAS filter
2)Inverted pendulum (IP) platform
3)Marionette
4)IP legs
9)Active platform

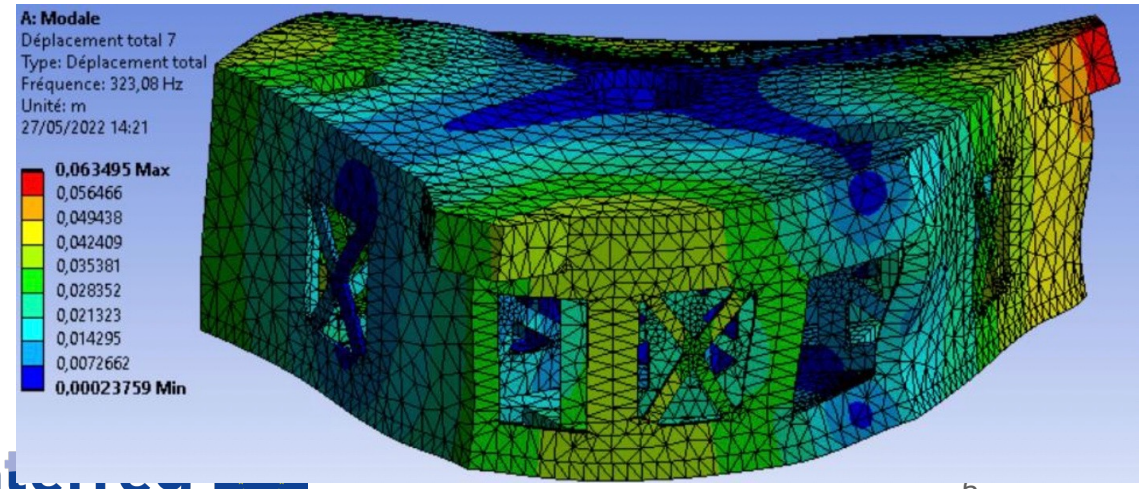
Cryogenic payload
5)heat exchanger and cold platform
7)25K inner thermal shield
8)80K outer thermal shield

Mechanical design

- Production drawings of the whole prototype finished TODAY !
- Tender documents in preparation
- Goal: publish EU-wide tender for these four systems next week !





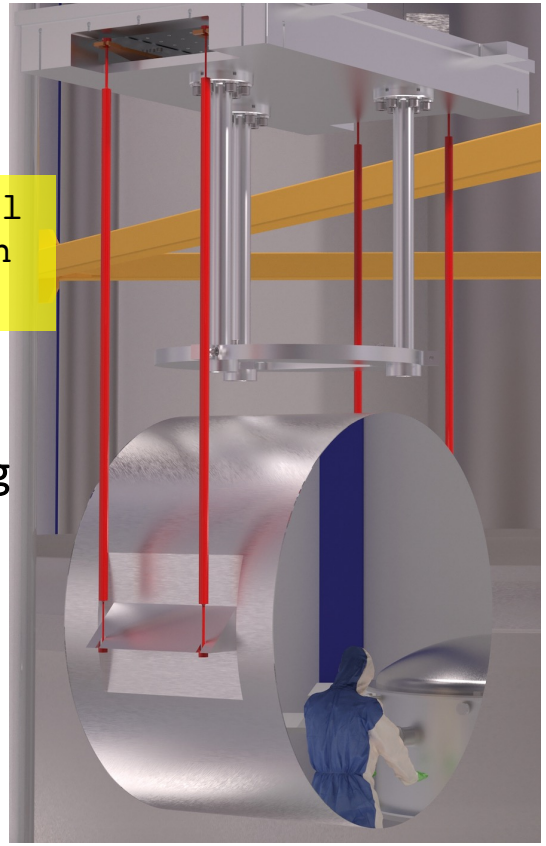


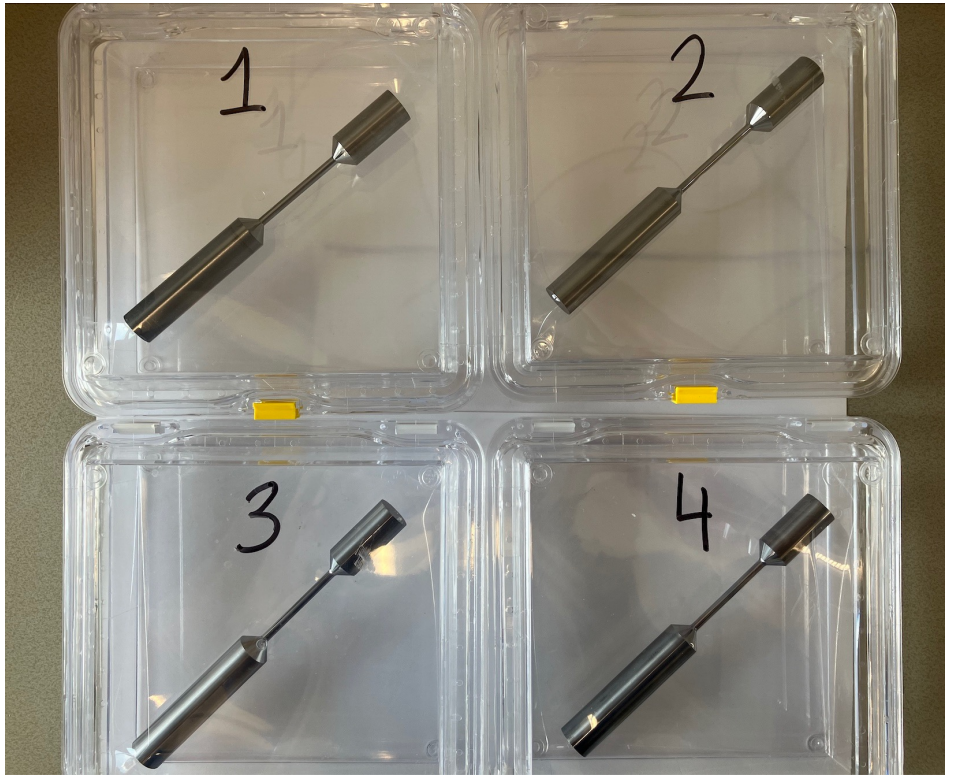
Crystalline silicon mirror suspension

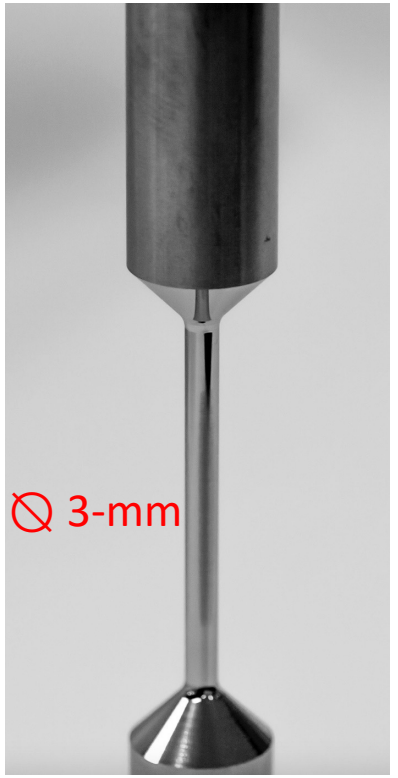
- Crucial technology aspect for ET: no proven solution exists
- Four SPDT machined samples delivered by Wielandts UPMT

single crystal Si suspension rods

450-mm diameter, 100-kg





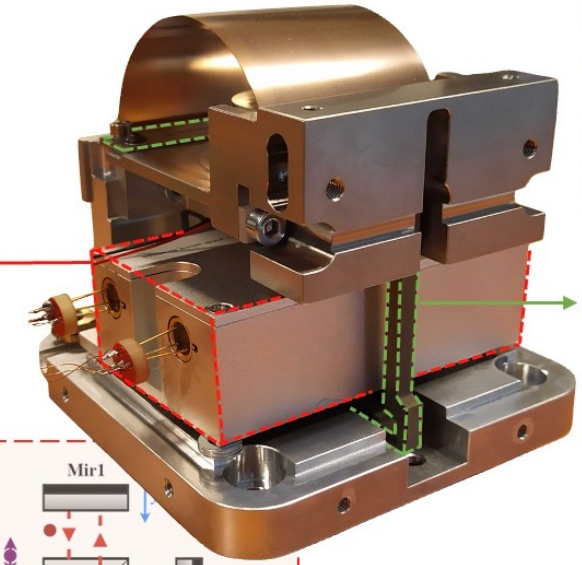


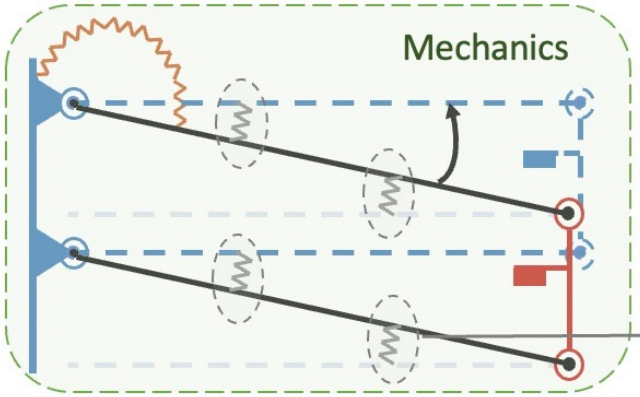
- involved University of Twente for the annealing process and Universita' di Perugia for mechanical loss vs T and tensile strength measurements
- ET2SME partners Mat-Tech (NL) and MaTecK (D) will do R&D on Si-metal interfaces
- found the raw material supplier for the full size long rods, IMPEX (NRW region)

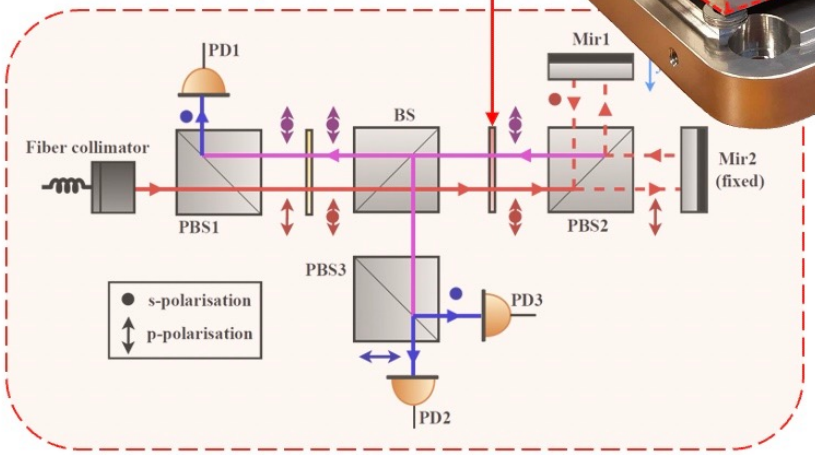
Inertial sensors development

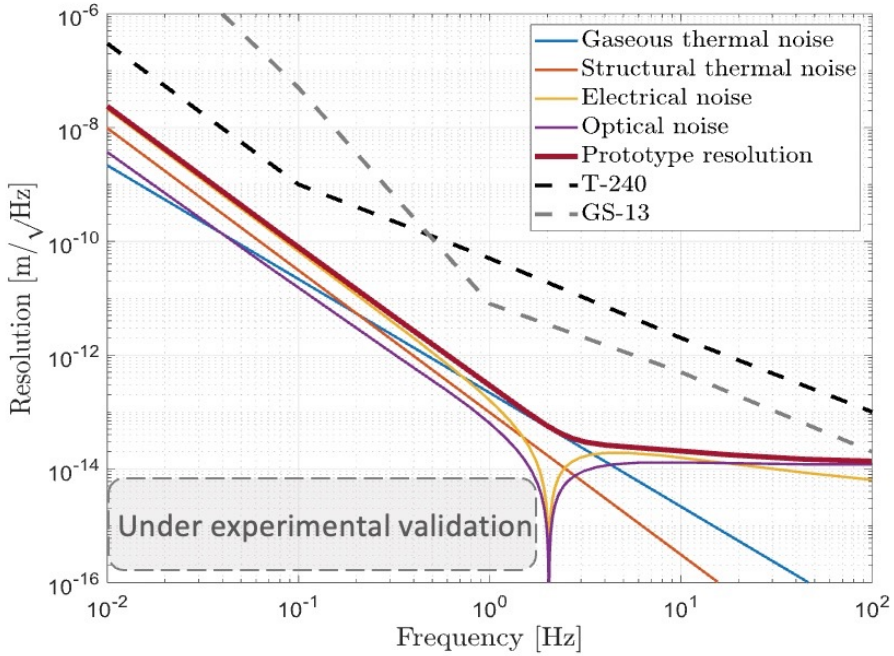
Precision Mechatronics Laboratory

Included in the active platform:
3 vertical
3 horizontal









Anthony Amorosi (PML)

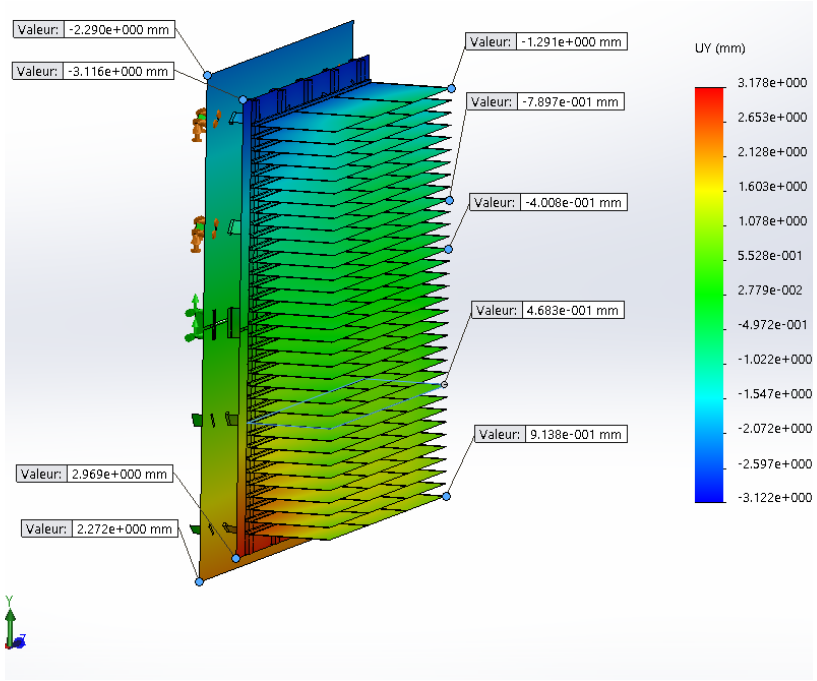
E-TEST Einstein Telescope EMR Site & Technology

Interreg Euregio Meuse-Rhine European Regional Development Fund

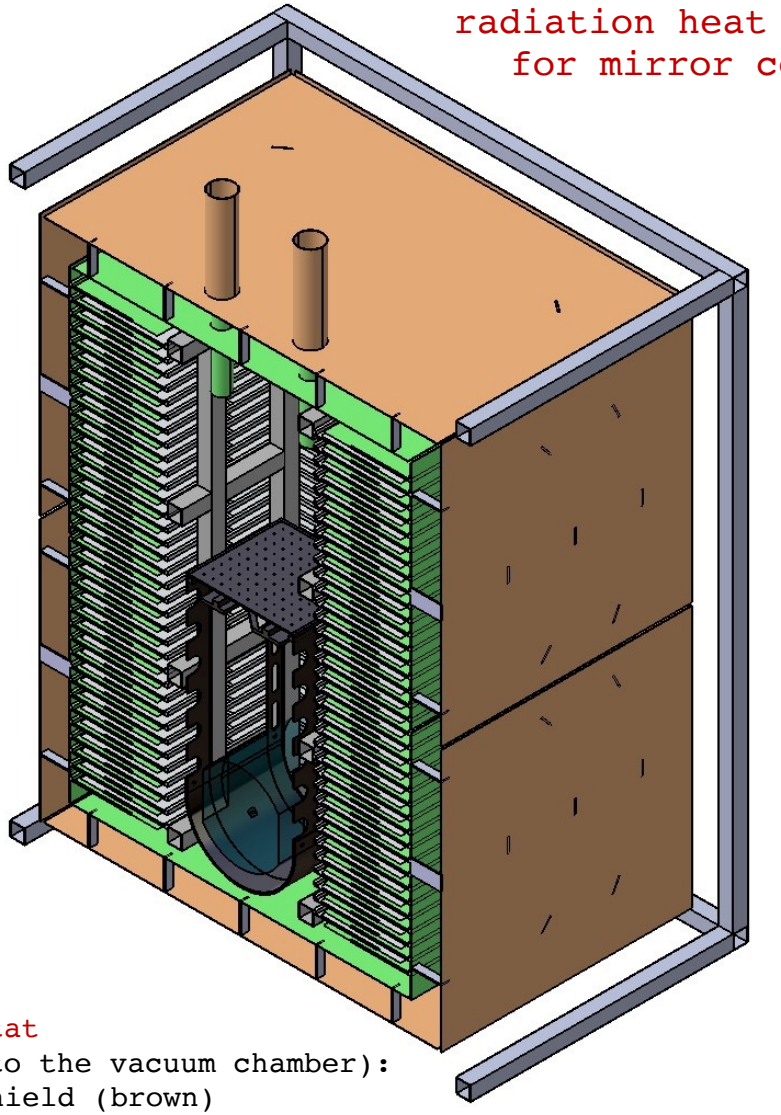
EUROPEAN UNION

Cryostat development

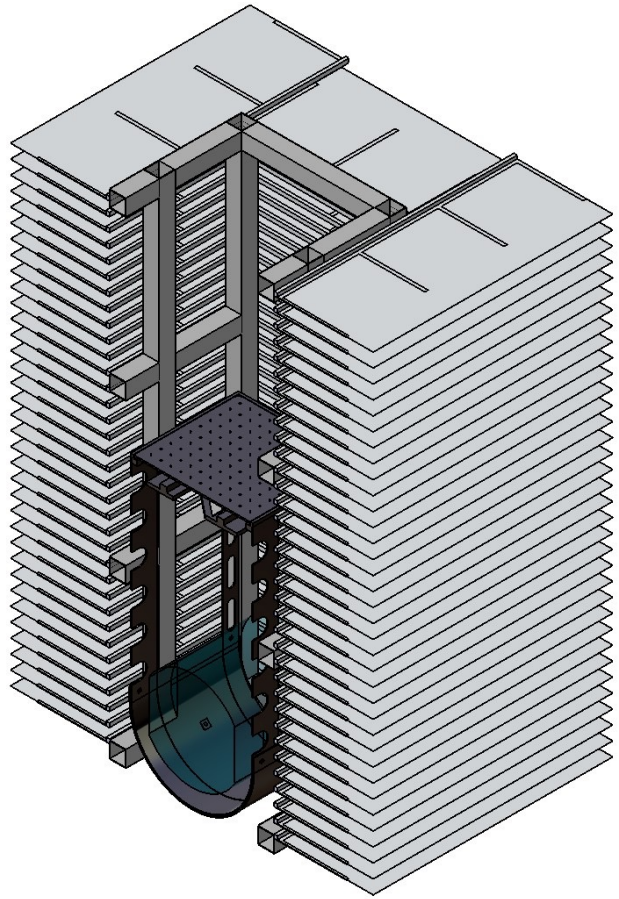
- ✓ overall dimensions: 1.8x1.6x2 m^3
- ✓ conventional radiator design with horizontal fins (25K)
- ✓ three 30-mm diameter optical feedthroughs towards the mirror



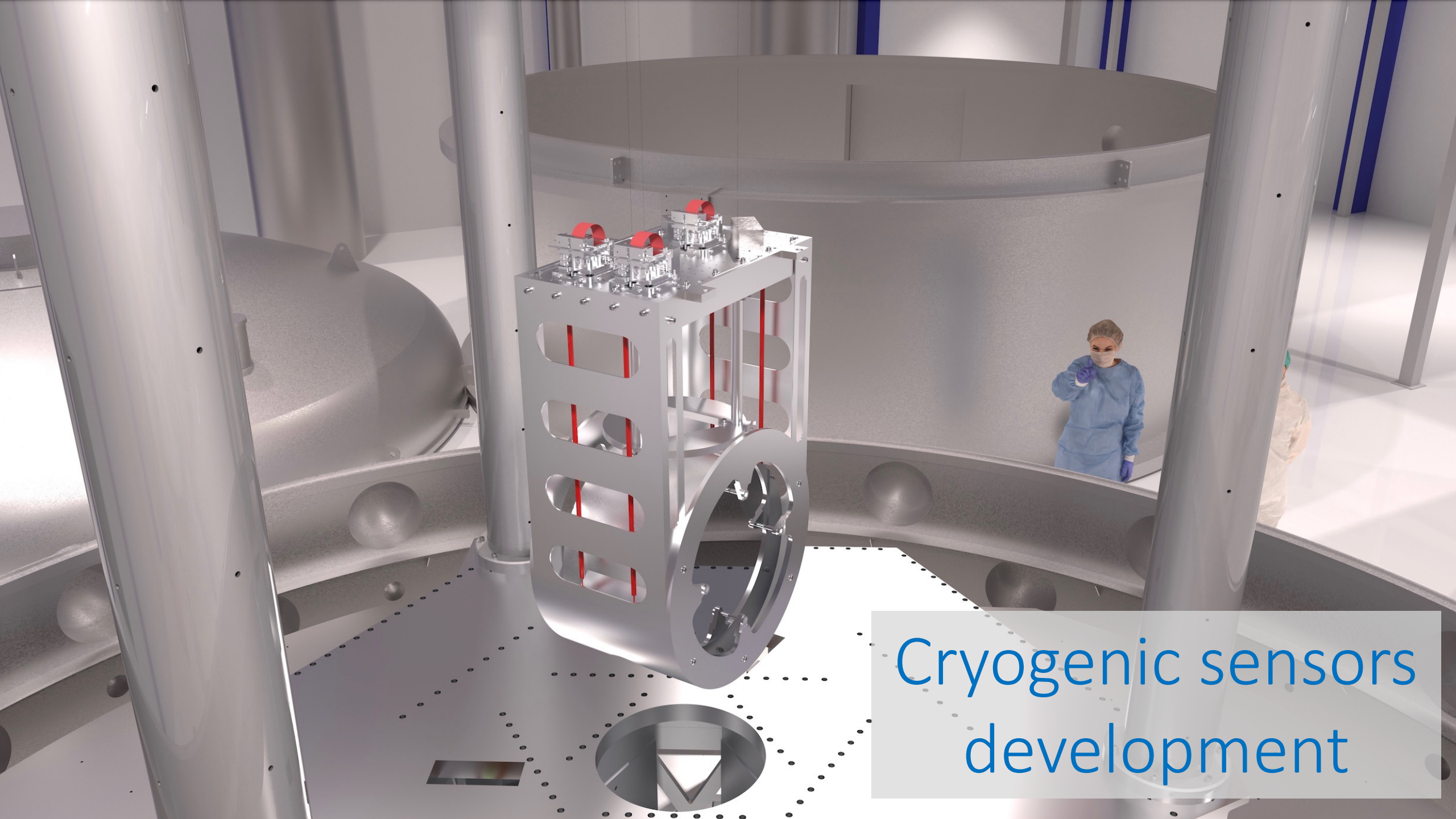
radiation heat transfer for mirror cooling



Outer cryostat
(connected to the vacuum chamber):
- 80K LN2 shield (brown)
- 25K GHe panels (green)



Inner cryostat
suspended and conductively linked to the silicon mirror

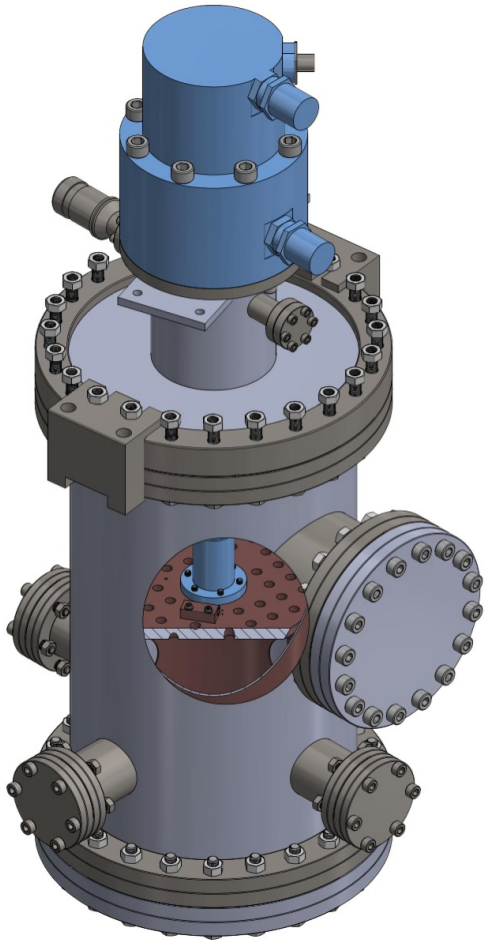


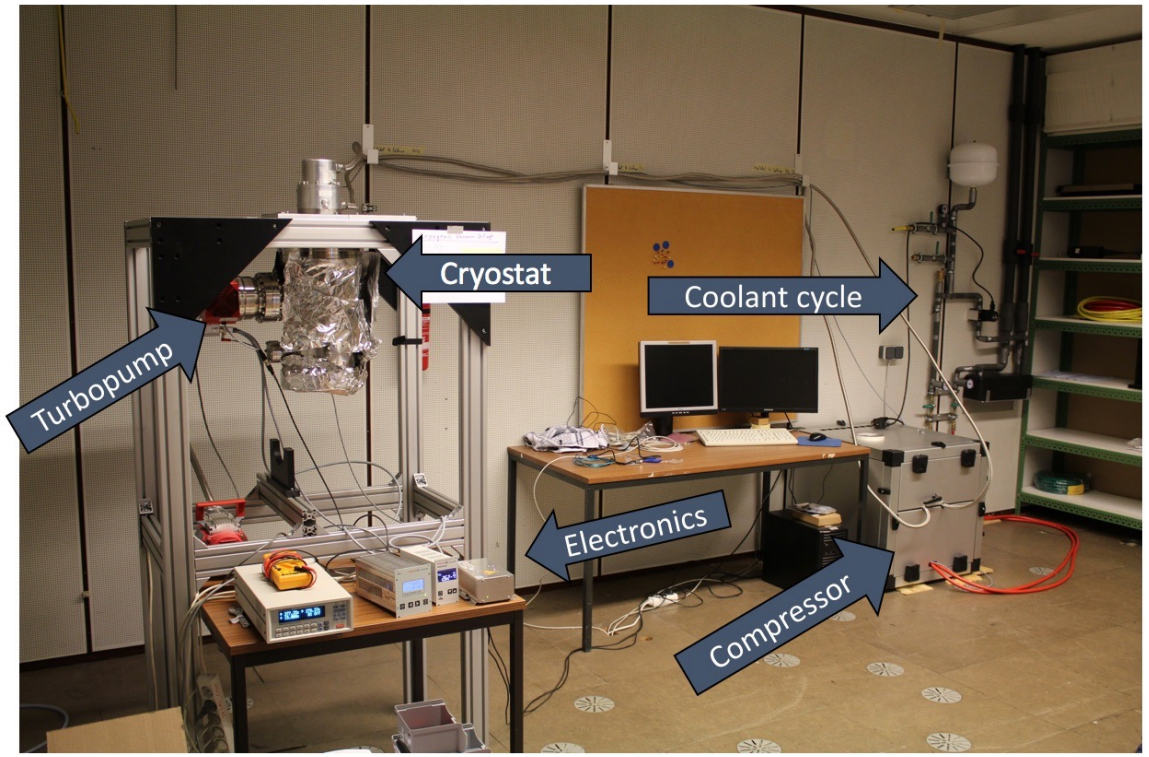
Cryogenic sensors development

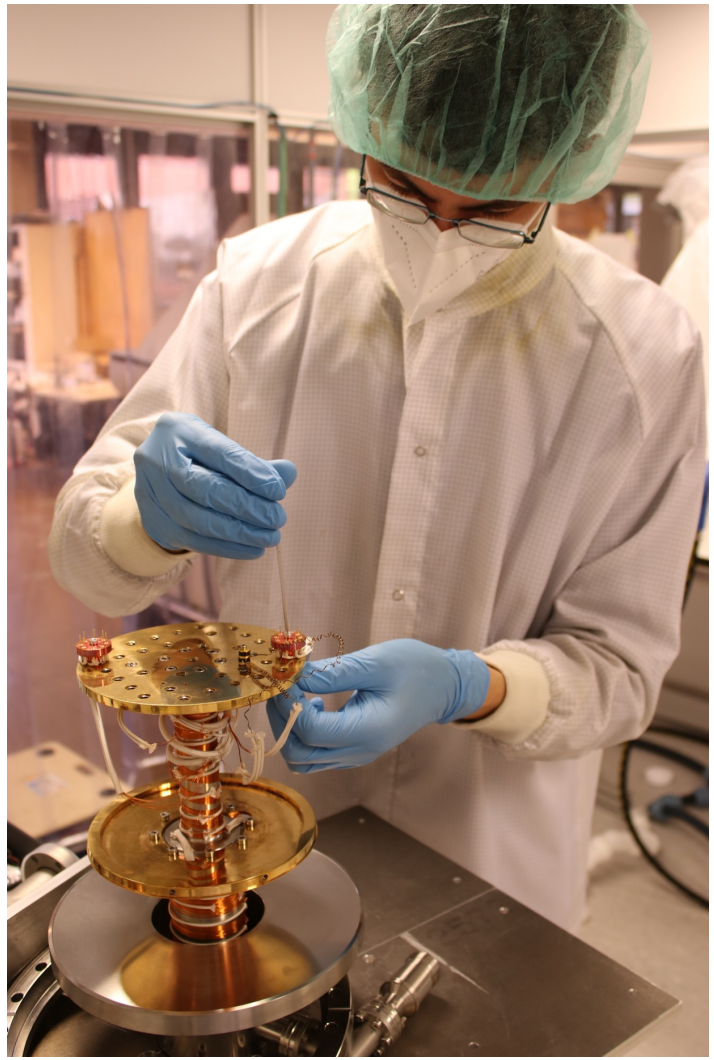
Cryogenic test bench

R. Joppe, T. Kuhlbusch,
P. Revathi

RWTH AACHEN UNIVERSITY



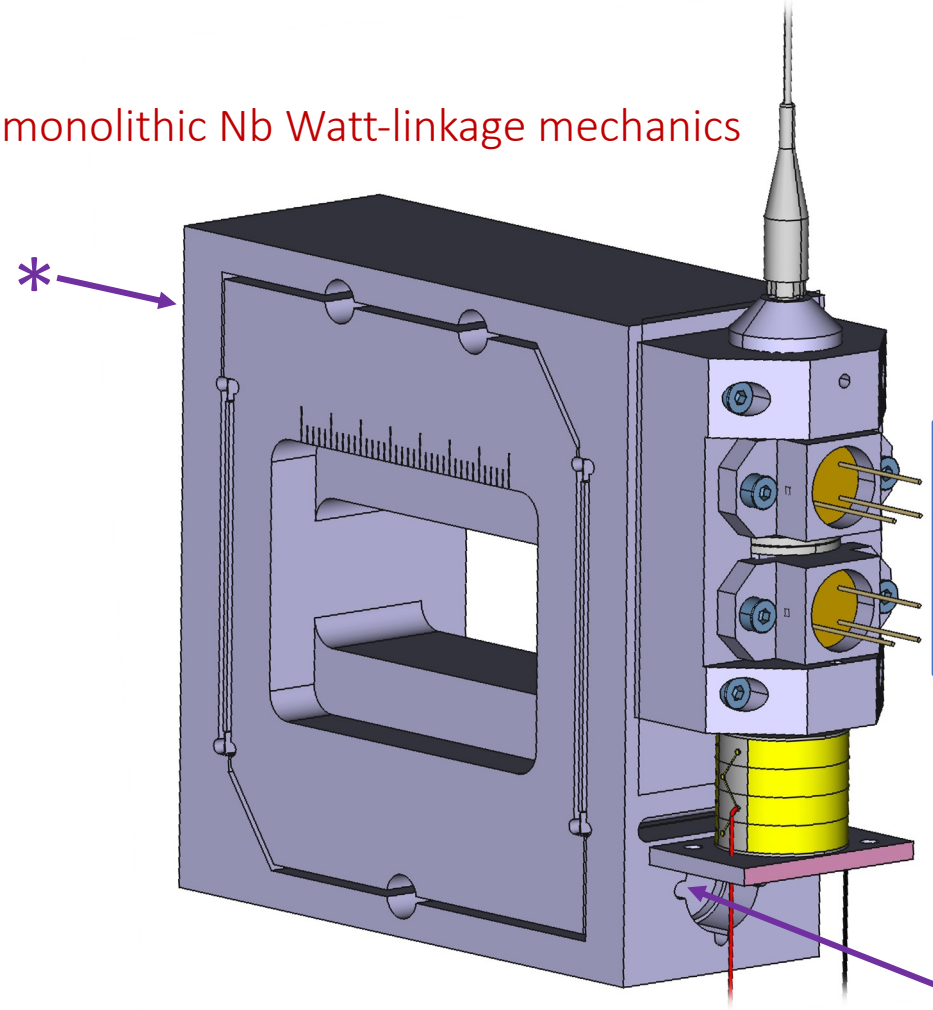




- Closed-cycle cryostat providing up to 1W cooling power at 10K
- Vacuum level: better than 10^{-9} mbar
- Usable volume: cylindrical 15x15cm
- Fast turnaround and low running costs
- Useful for testing materials, components and assemblies

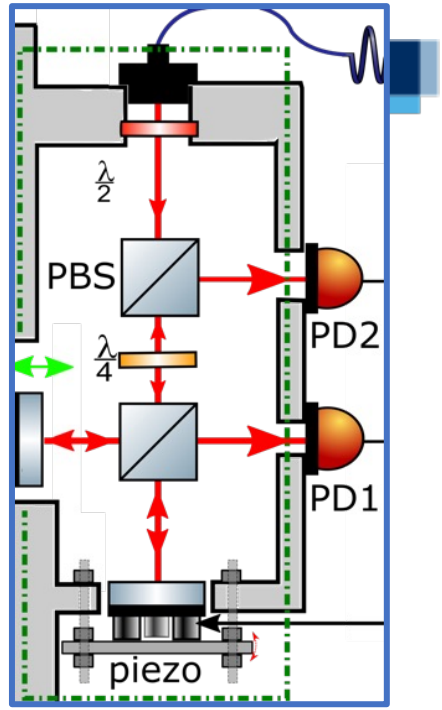
Cryogenic superconducting inertial sensors (CSIS)

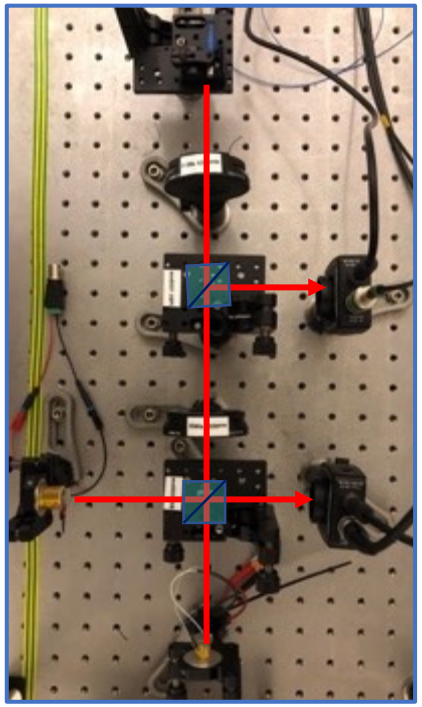
monolithic Nb Watt-linkage mechanics



interferometric readout

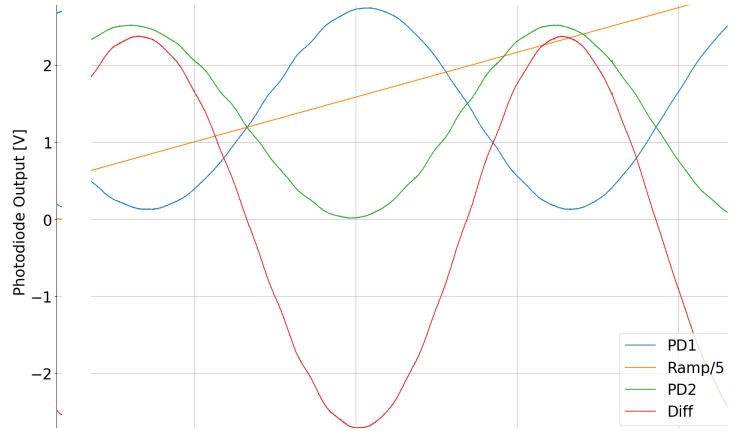
Using polarizing optics, all light ends up at PDs, so 41% less shot noise at same input power and less heat load.





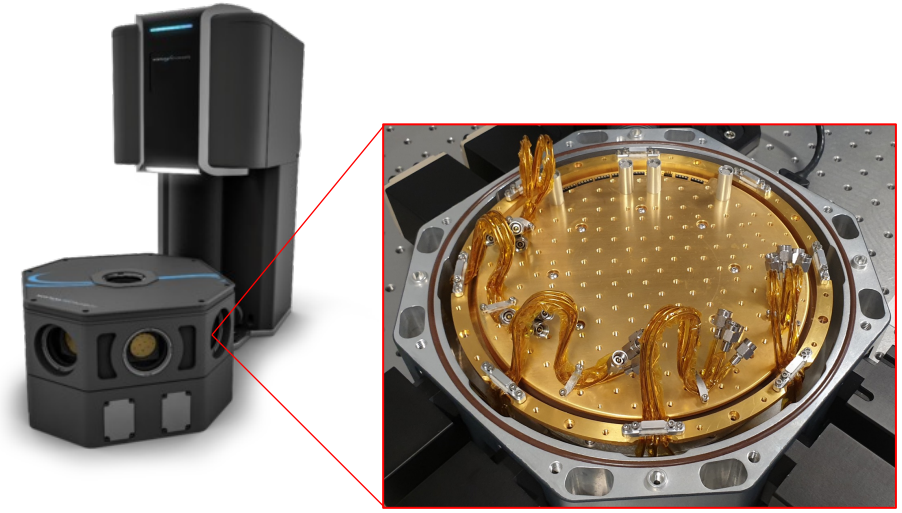
superconducting coil

slots to install actuators
for force-balance operation

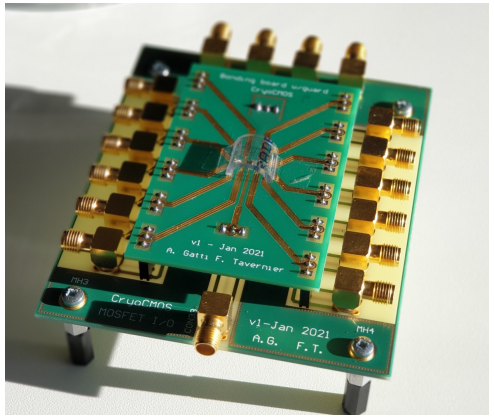


Custom CMOS chips for sensor signal conditioning at low temperature

- Device models from foundries are unreliable at very low T => characterization of test structures is crucial
- Two developments:
  - custom CMOS cryo-chip in cold inertial sensors for near test mass control/monitoring (coll. with UCLouvain)
  - cryo-CMOS front-end for a custom mode-localization MEMS accelerometer based on weakly coupled resonators



LHe cryostat and cryogenic test chamber



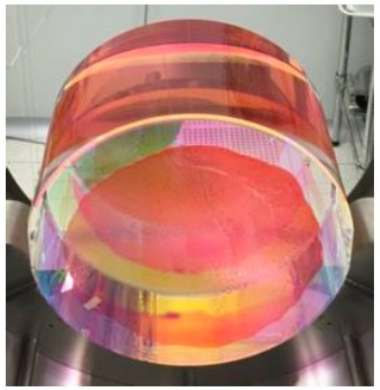
Ultralow leakage PCB

MOSFET at cryogenic temperature have OFF-state leakage at fA level, very challenging to measure

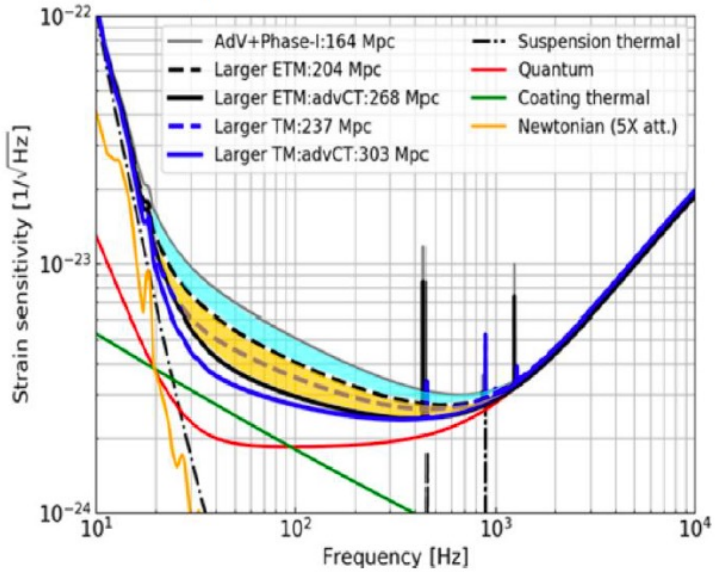
Credit: Alberto Gatti

Silicon Mirror Coating –Overview

- State of the art:
  Noise of amorphous coatings are the main performance limitation for GW telescopes, especially the thermal noise
- ETEST approach: single-crystal oxide mirror coatings
- Current activities
  - Setup of Cr_2O_3 thin film thickness set
  - More data expected next time

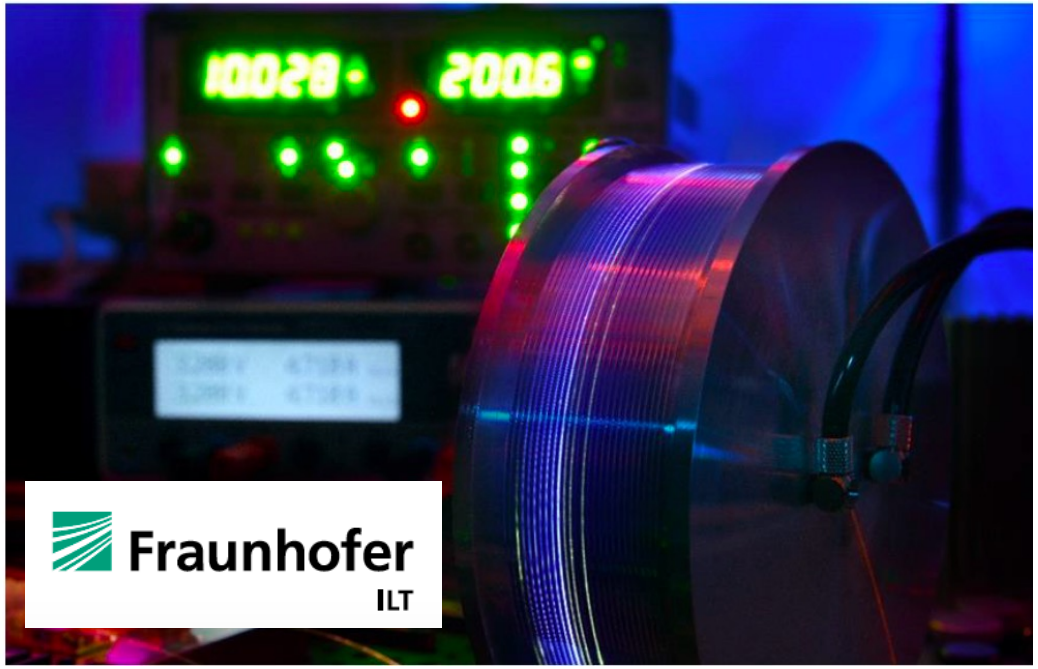


Mirror performance | Noise sources



KU LEUVEN

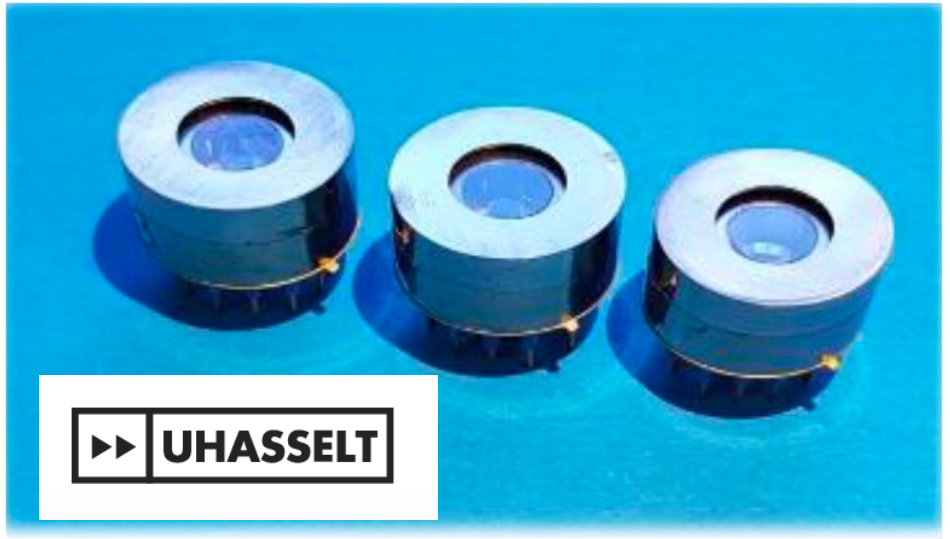
High stability laser development

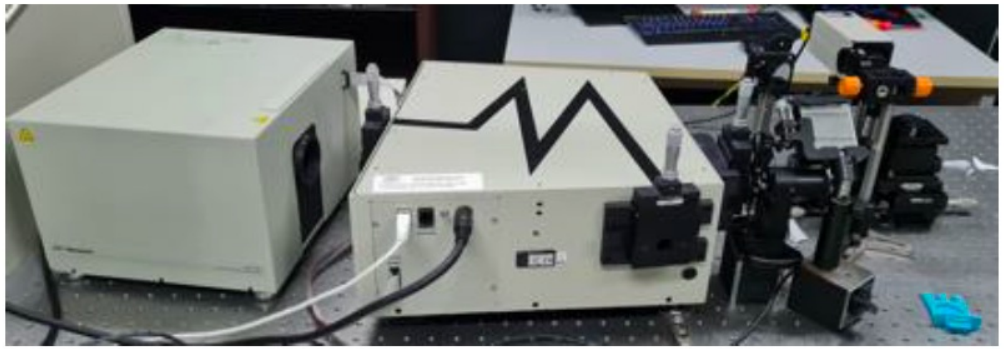


Requirements:

- High stability
- Narrow linewidth
- Wavelength: 2090 nm
- Power: 5-10 W

Photodiode optimisation

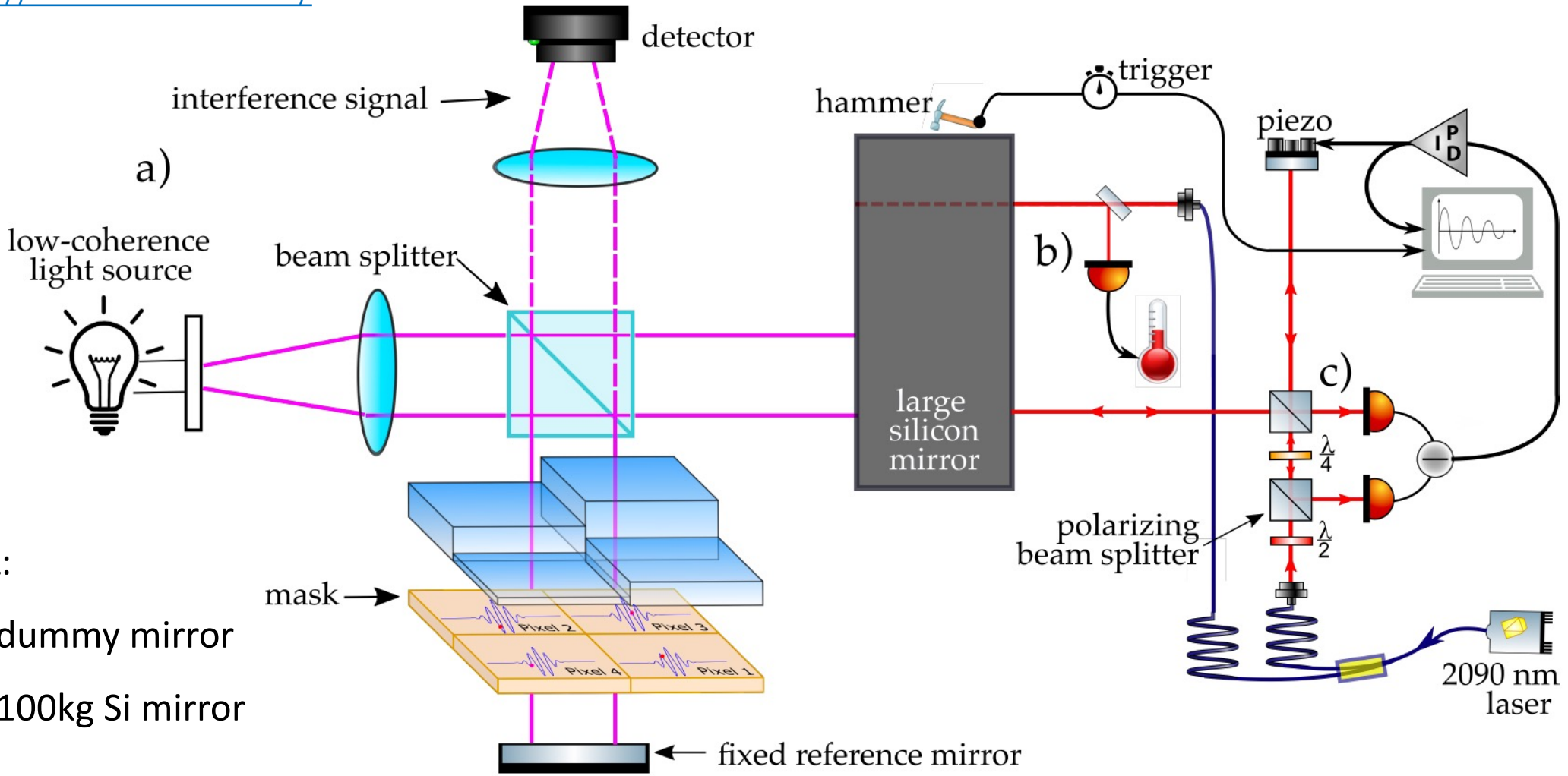




Assessment strategy

a) White light interferometry (residual stress)
b) Temperature measurement
c) Quality factor

https://www.etest-emr.eu/



Tests at CSL:

2023: with dummy mirror

2024: with 100kg Si mirror