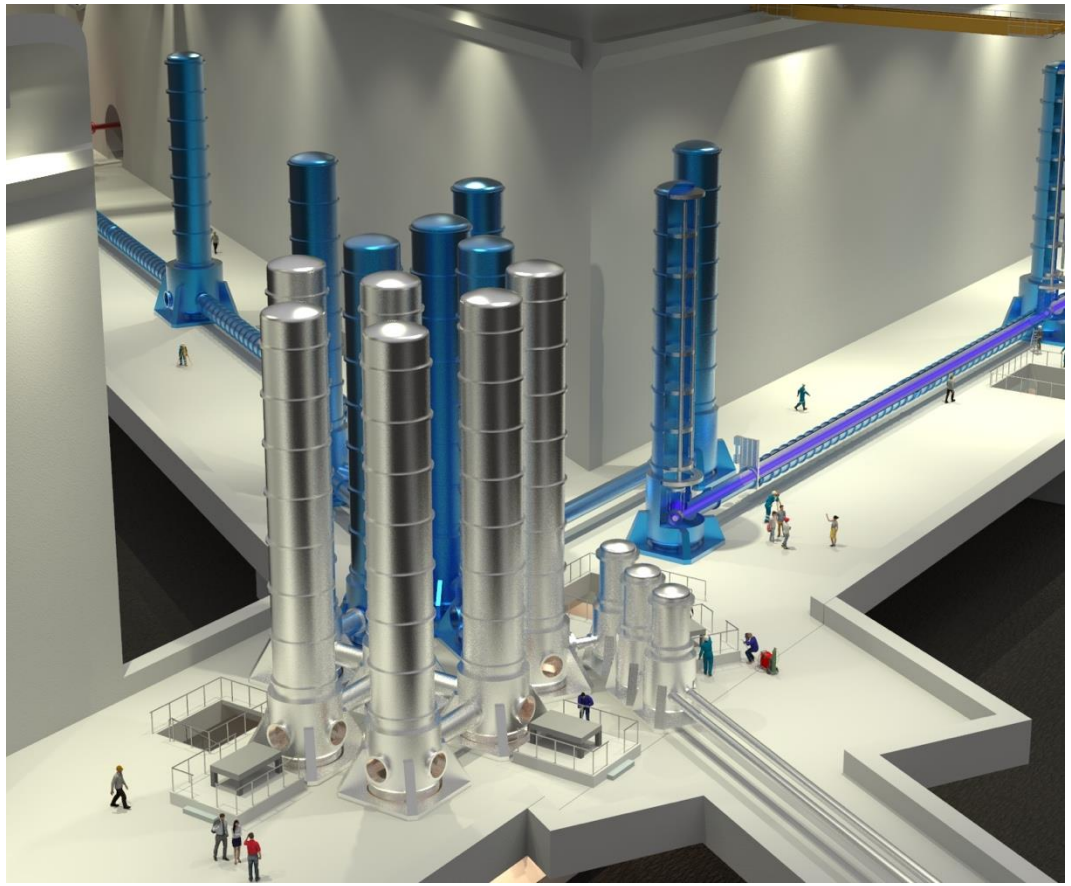
The E-TEST Prototype

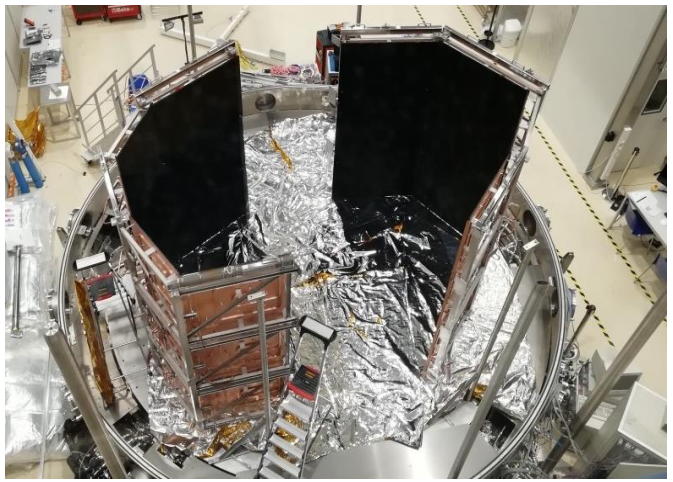
Christophe Collette

01.03.2024



Objectives

- Large mirror (100 Kg)
- Cryogenic temperature (20 K)
- Radiative cooling
- Isolated at low frequency (0.1-10 Hz)
- Compact suspension (4.5 meters)



Partners

Precision Mechatronics Laboratory

CSL Centre Spatial de Liège

RWTH Aachen University

KU Leuven

Nikhef

UCLouvain

micas KU Leuven

Fraunhofer ILT

E-TEST Einstein Telescope EMR Site & Technology

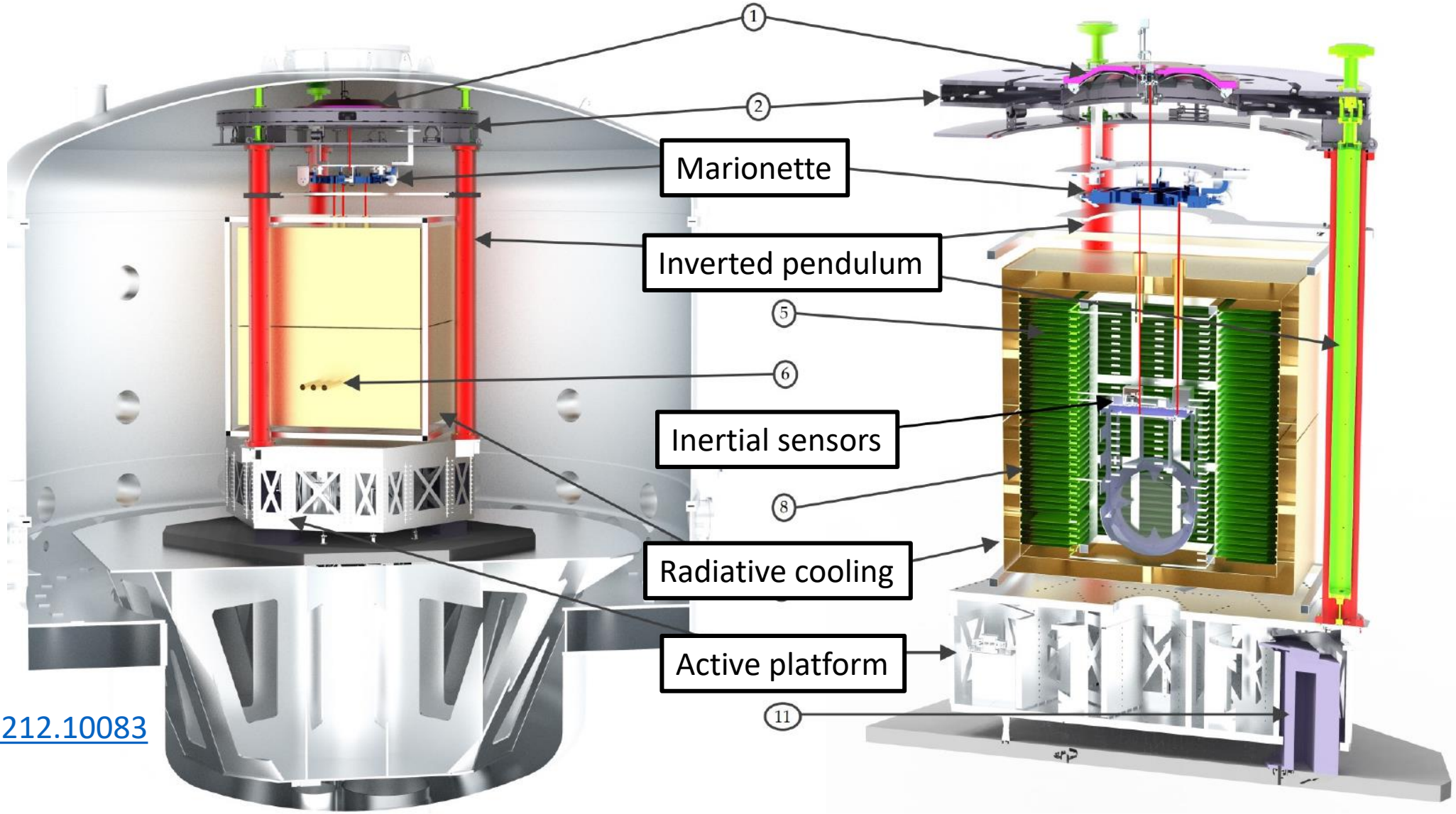
Interreg Euregio Meuse-Rhine European Regional Development Fund

European Union

Conceptual design

Submitted: 12/2021
Revised: 03/2022

https://arxiv.org/abs/2212.10083

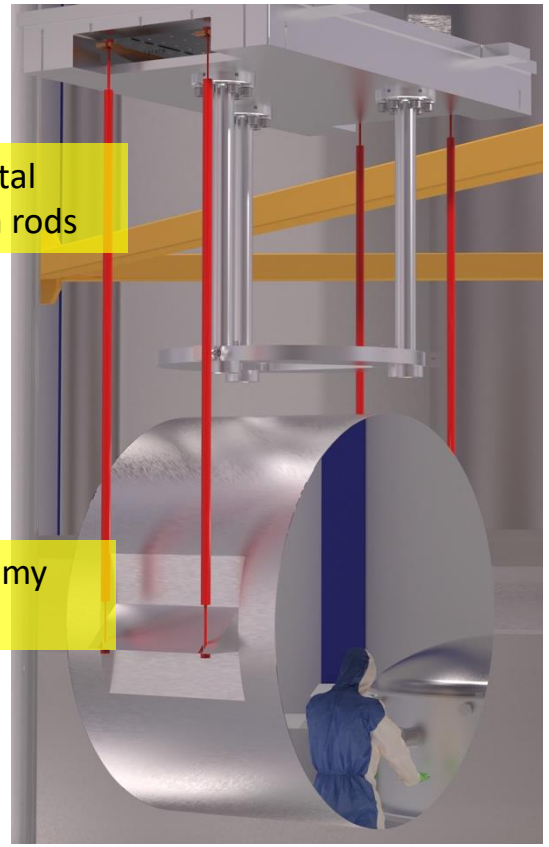


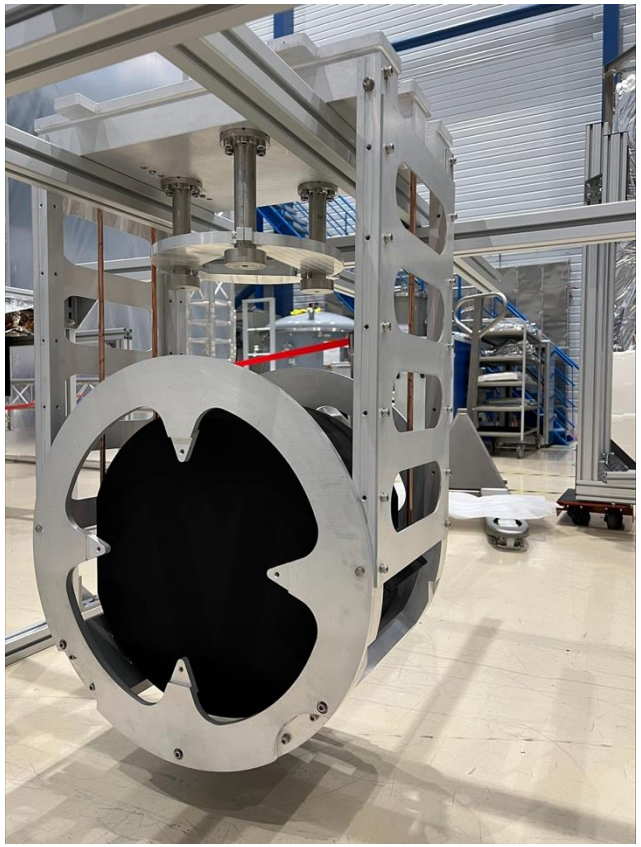
100 kg test mass & suspension

- Crucial technology aspect for ET: no proven solution exists
- Four machined samples delivered
- Silicon mirror ordered (delivery end of 2024)

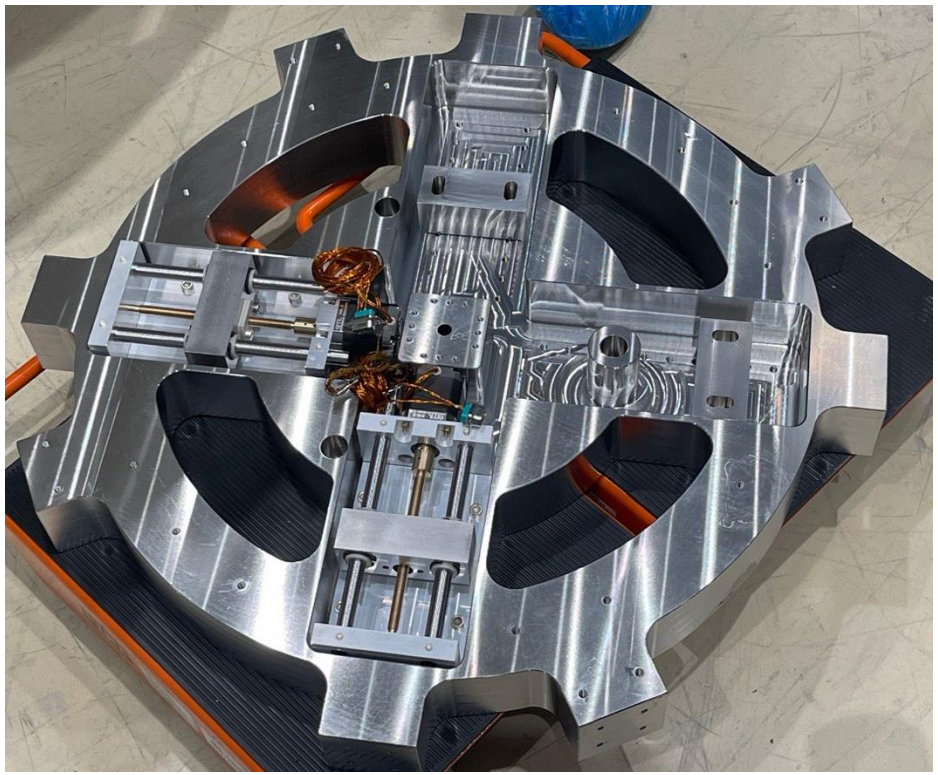
single crystal
Si suspension rods

Al-6061 dummy
mirror





Marionette



Contact: Alessandro Bertolini (Nikhef)
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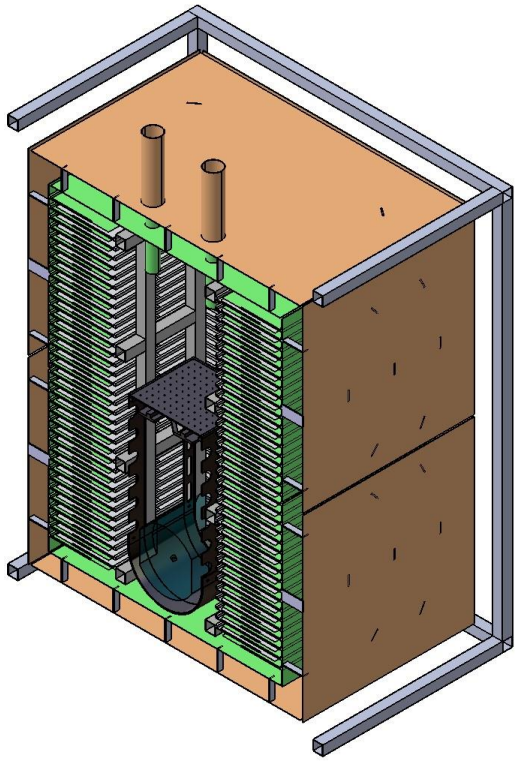
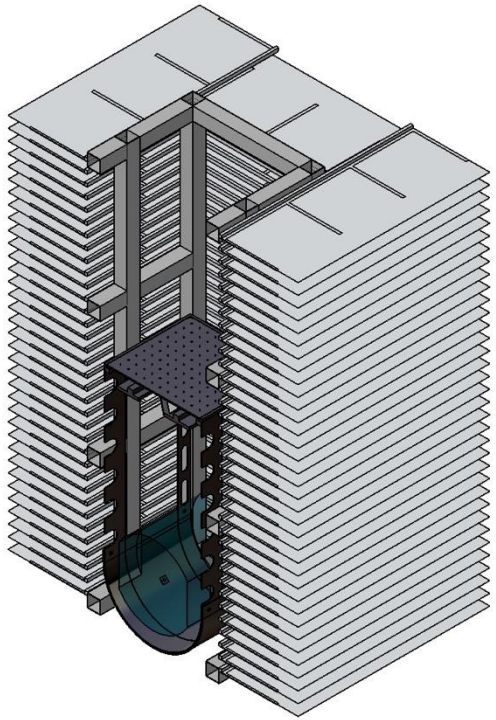
Cryostat development

- ✓ overall dimensions: 1.8 x 1.6 x 2 m^3
- ✓ conventional radiator design with horizontal fins (25K)
- ✓ three 30-mm diameter optical feedthroughs towards the mirror



Outer cryostat:
80K LN2 shield (brown)
25K GHe panels (green)



Inner cryostat suspended and conductively linked to the silicon mirror

Contact: Cedric Lenaerts (CSL)
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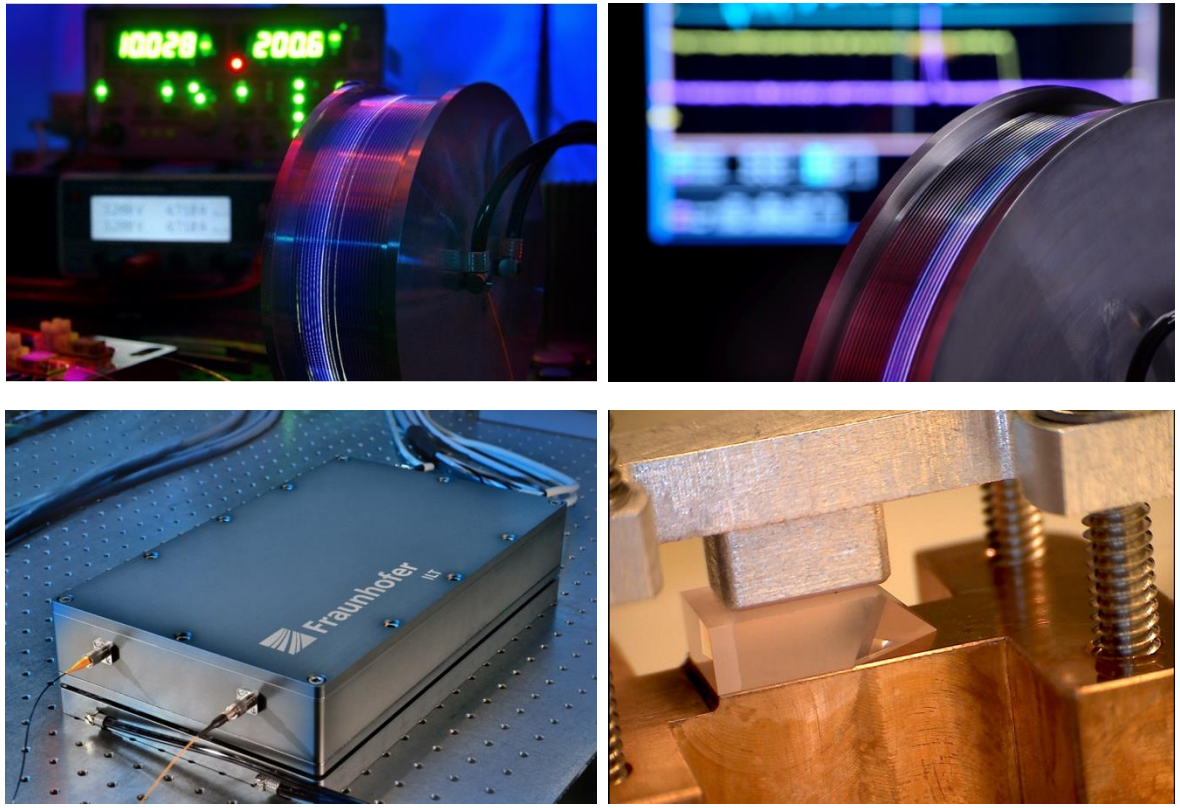
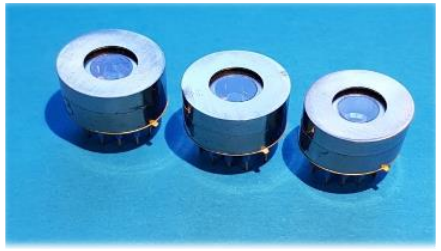
Laser Development at Fraunhofer ILT

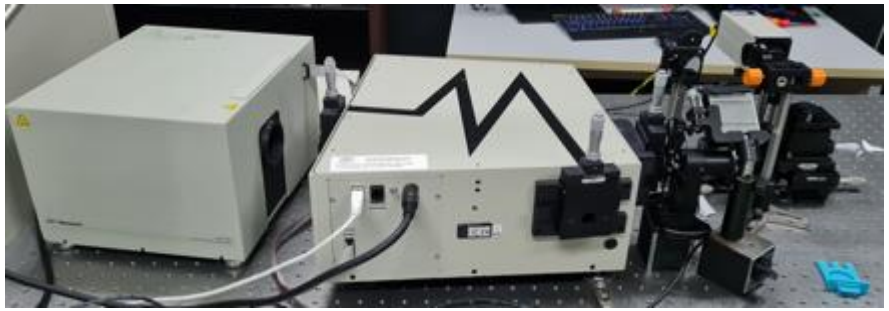
- Goal: Development of high stability lasers at 2 µm wavelength
- Successful demonstration of critical laser parameters for NPRO and multi-stage fiber amplifier
- Ho:YAG NPRO
  - 400 mW output power with excellent beam quality and linear degree of polarization
- Holmium-doped fiber amplifier
  - >10 W output power with excellent beam quality, narrow linewidth, linear degree of polarization
  - Relative intensity noise (RIN) analysis performed
    → Good results without stabilization
    → RIN @ 100 Hz approx. 10^{-5} $1/Hz^{0.5}$

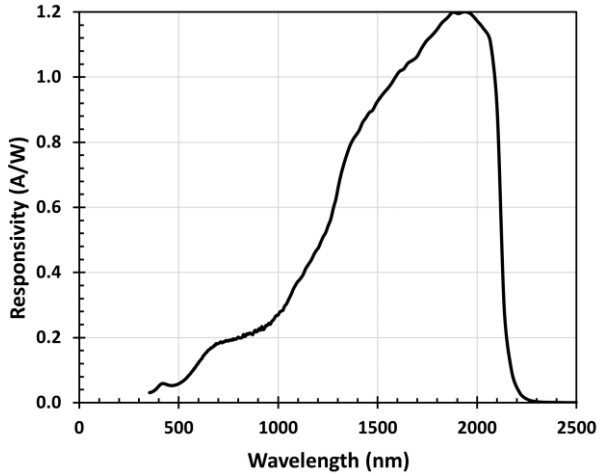


Photodiode developments

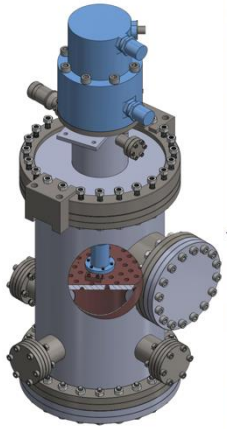
- Desktop detection system successfully setup
  - InGaAs diode (Noise equivalent power 1^{-13} W/Hz^{-2}
  - Suitable for detection at 2.1 micron using lock-in detection
- Setup successfully extended to homodyne detection (based on a principle used at LIGO)
- Novel setup for suppression of back-action noise proposed and theoretically modelled
  - Principle: Compensation of two mirror movement using negative radiation pressure
- Next step: Assembly of final functional desktop system to be integrated with E-Test prototype

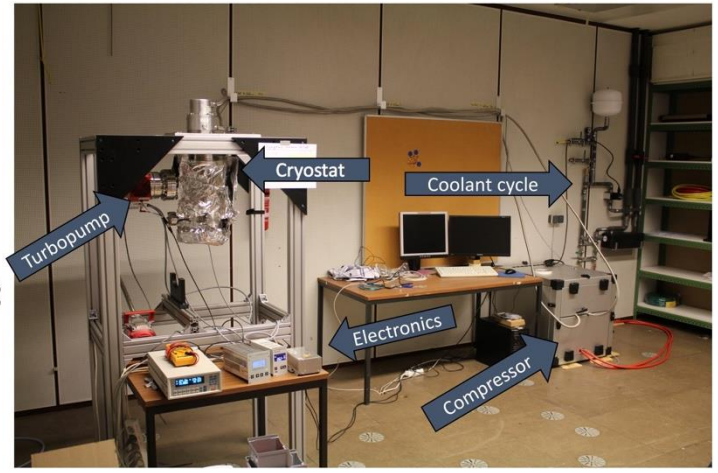






Cryogenic test bench





- Closed-cycle cryostat with 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

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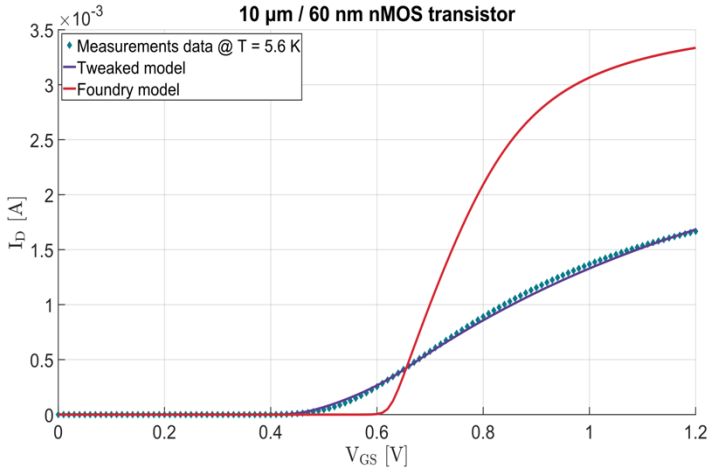
Custom CMOS chips for sensor signal conditioning at low temperature



- Major achievement in cryogenic CMOS structures modeling: faithful representation over the full range of gate-channel geometries
- Custom Au-plated parts for photodiode test setup received

FOUNDRY MODEL	OUR CRYO-MODEL (SO FAR)
Error* up to 65 %	Error* < 5.7 %

*Maximum current error in saturation and linear region of operation

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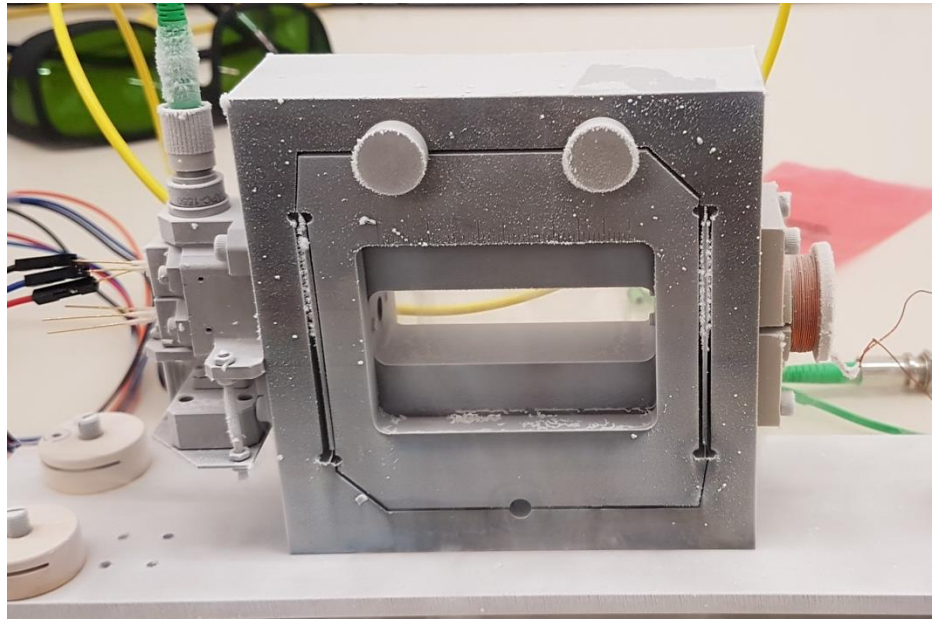
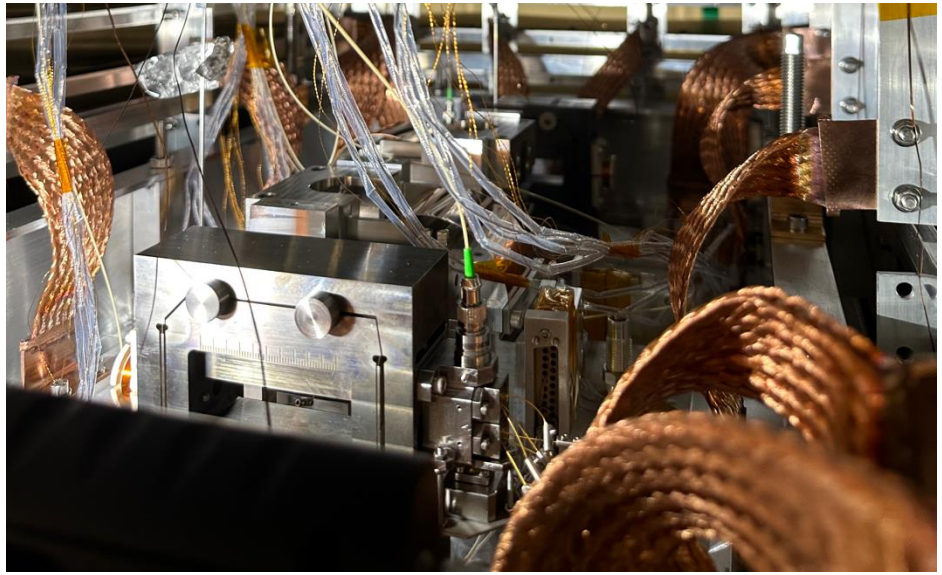
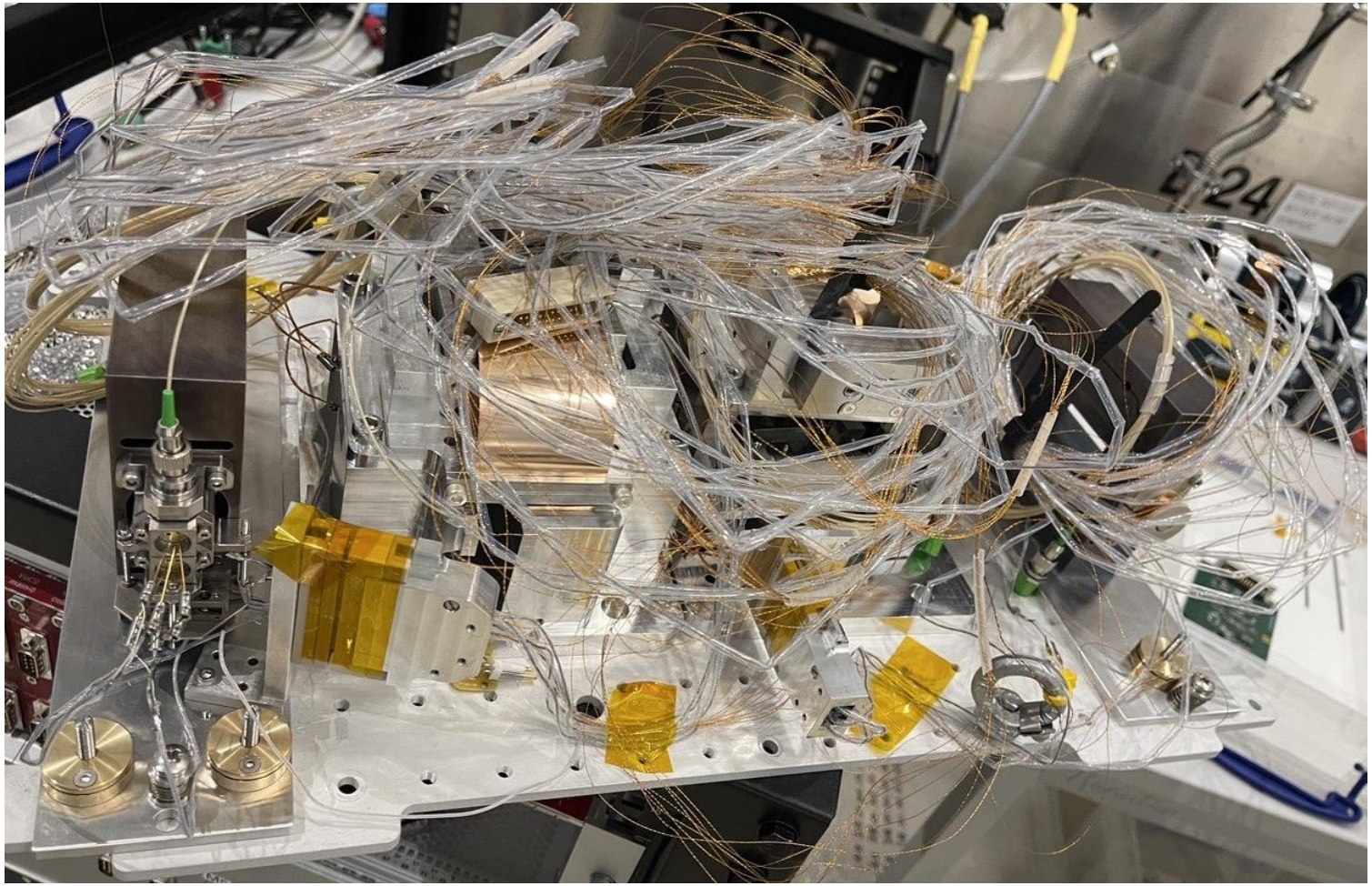
Cryogenic inertial sensors

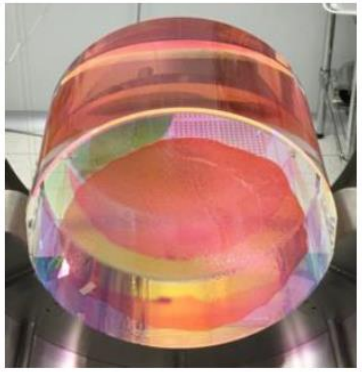




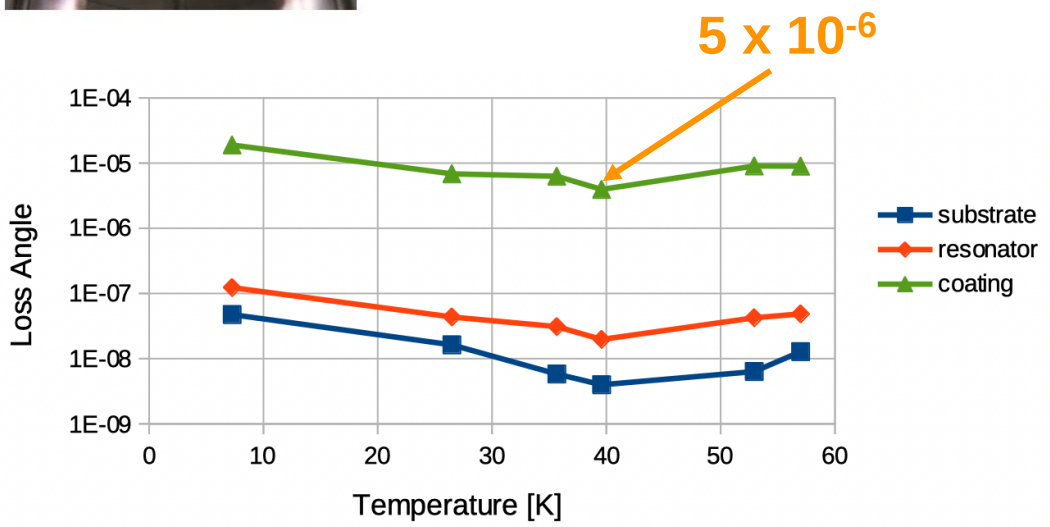


Silicon Mirror Coating

- Phase 1: Selection of appropriate materials
  - Challenge: Reduce mirror coating noise
- Phase 2: Molecular beam epitaxy
  - Production and analysis of 500 nm Cr_2O_3 / Al_2O_3
- Phase 3: Record low mechanical losses
  - Achieved 5 x 10^{-6} loss angle at 40 K
  - Dilution factor = 0.0034
- Phase 4: Next steps
  - Optimize Cr_2O_3 / Al_2O_3
  - Start with Ga_2O_3 / Al_2O_3
  - Assemble 300 mm tool

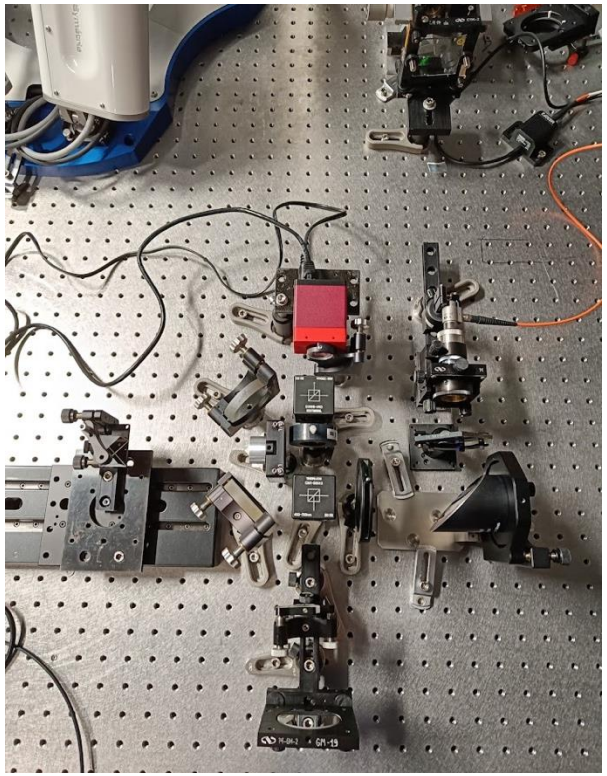


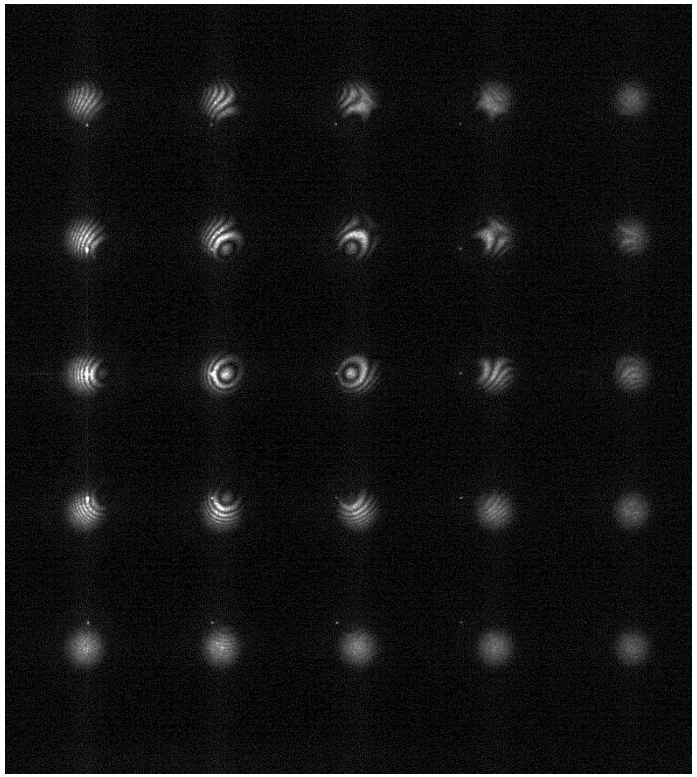
Approach:
Single-crystal oxide coating

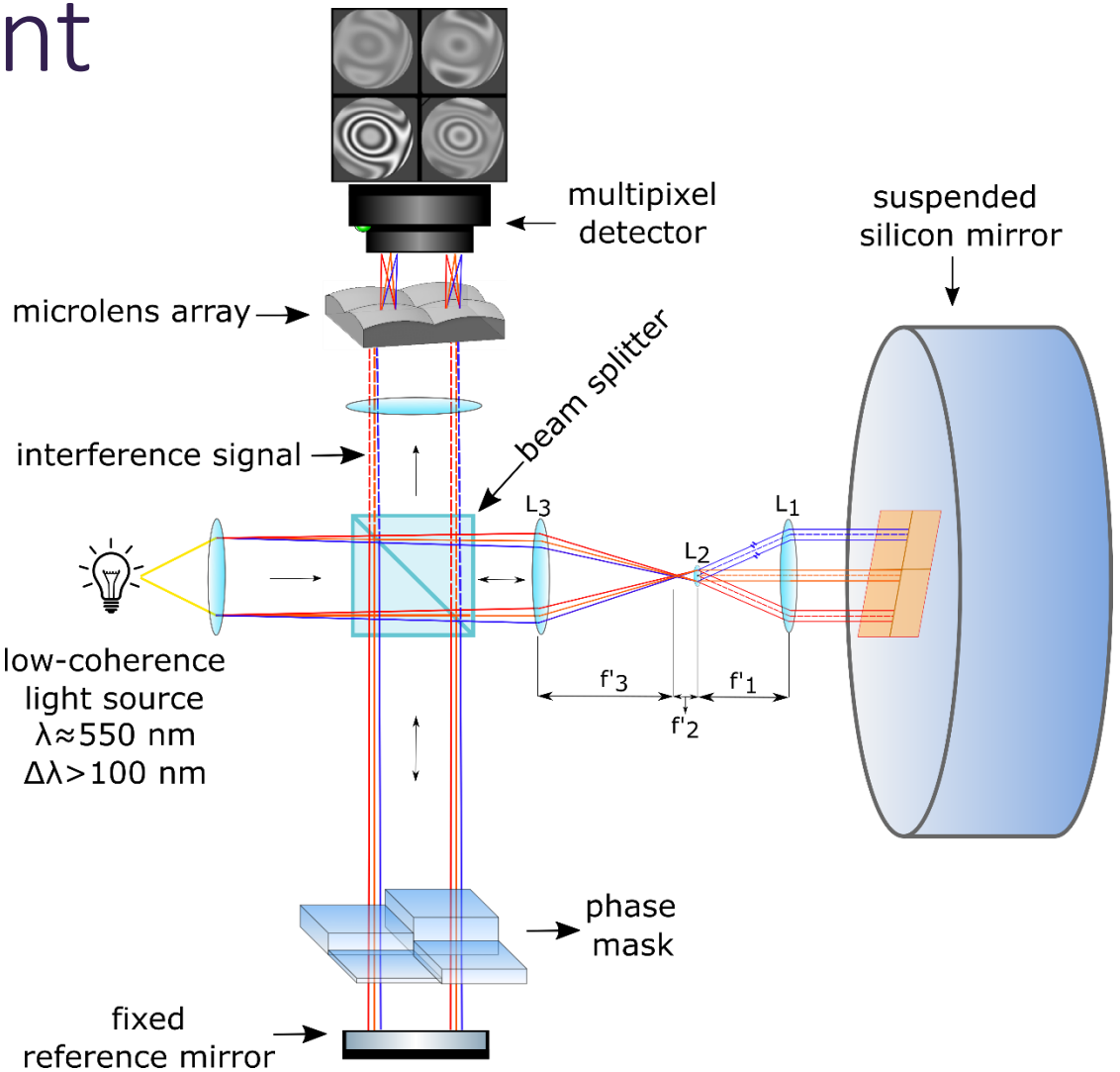


Silicon mirror measurement

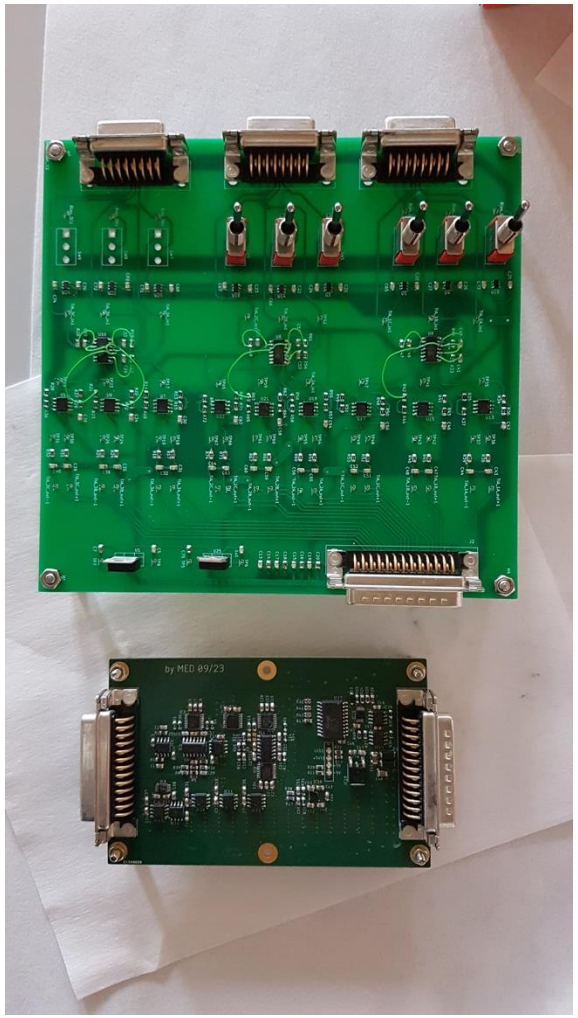
Objective : Measurement of local values of vibration and topology change with white light interferometry

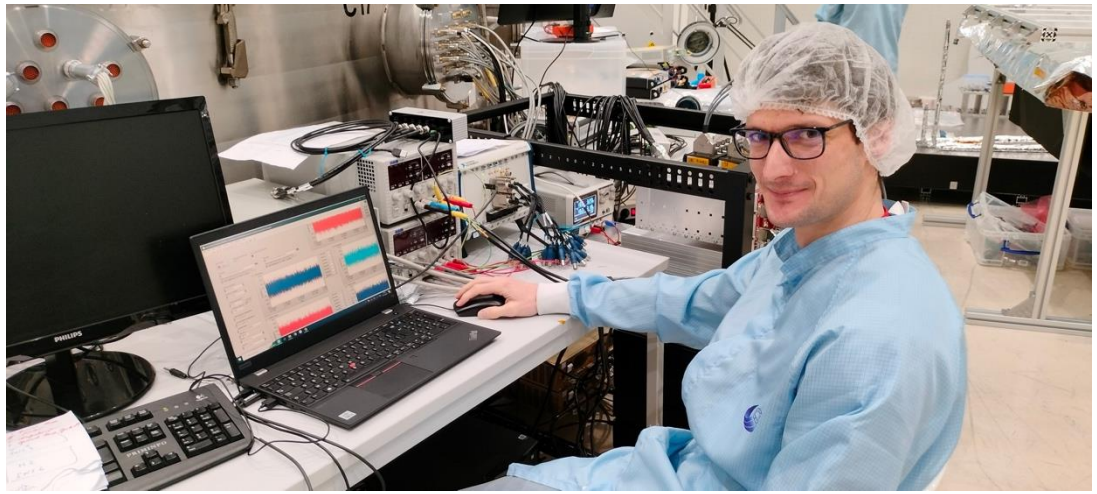


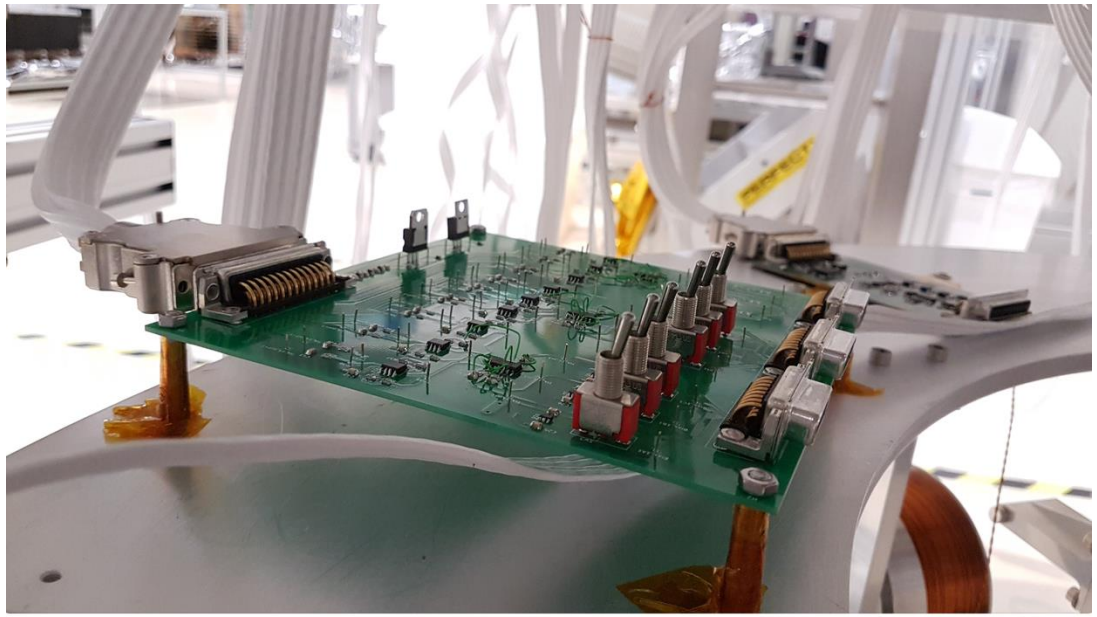




Electronics and control

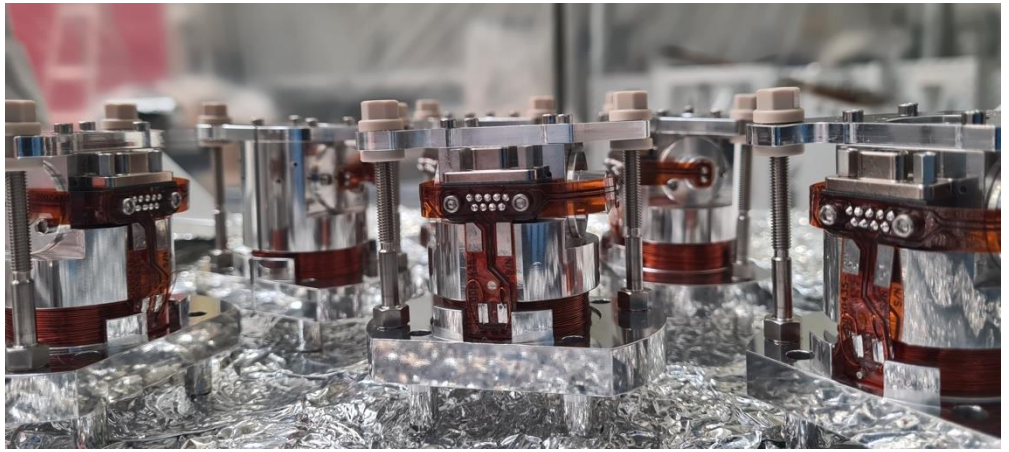






Assembly of the prototype

AMOS
ADVANCED MECHANICAL & OPTICAL SYSTEMS



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CSL CENTRE SPATIAL DE LIÈGE
UCLouvain

Final installation at CSL

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Lionel Jacques (CSL)
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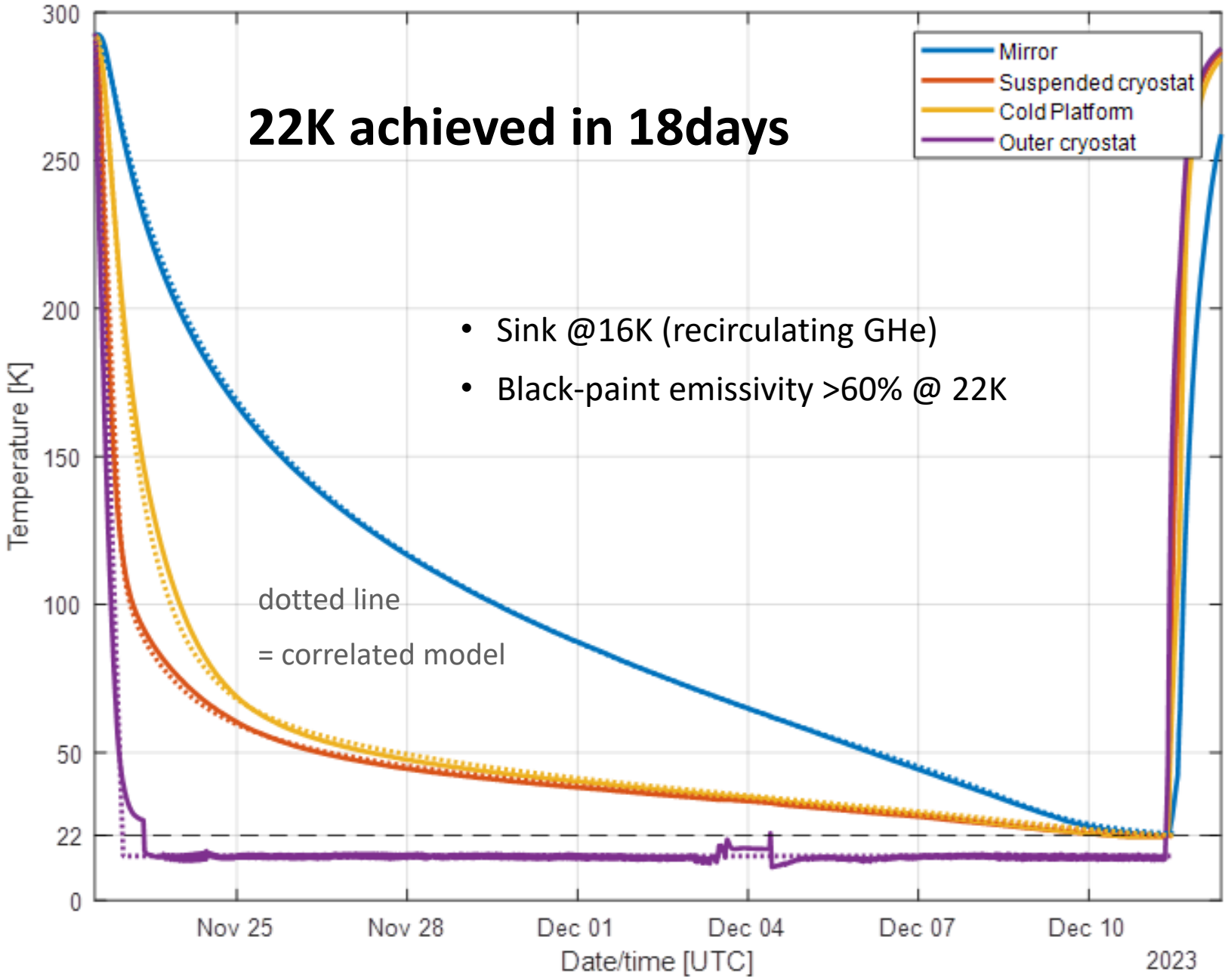
CENTRE SPATIAL DE LIÈGE

22K achieved in 18days

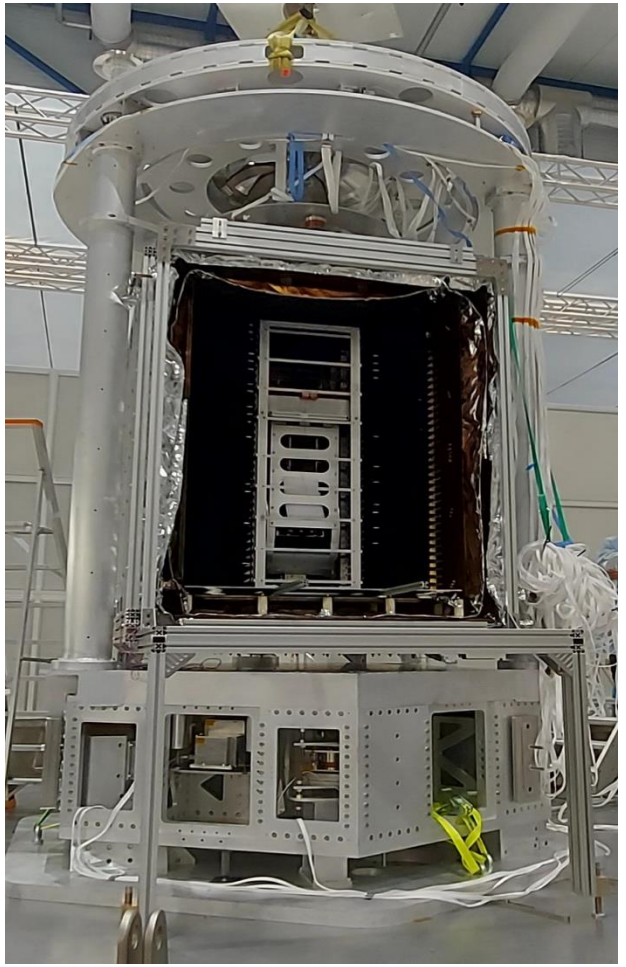


- Sink @16K (recirculating GHe)
- Black-paint emissivity >60% @ 22K

dotted line

= correlated model

After integration of outer cryostat including LN_2 shield and GHe panels



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E-TEST becomes CRISTAL

Summary @ plan

- Fully assembled prototype combining :
  - 100 kg test mass
  - Low frequency seismic isolation
  - Radiative cooling strategy
- Innovative techologies developed:

  Laser, photodiodes, coating, interferometry, inertial sensors, heavy suspensions, electronics.
- 1st run in focal 6.5: 11/2023
- 2nd run in the new chamber: 12/2024

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