E-TEST : Einstein Telescope EMR Site and Technology

Dr. Chiara Di Fronzo

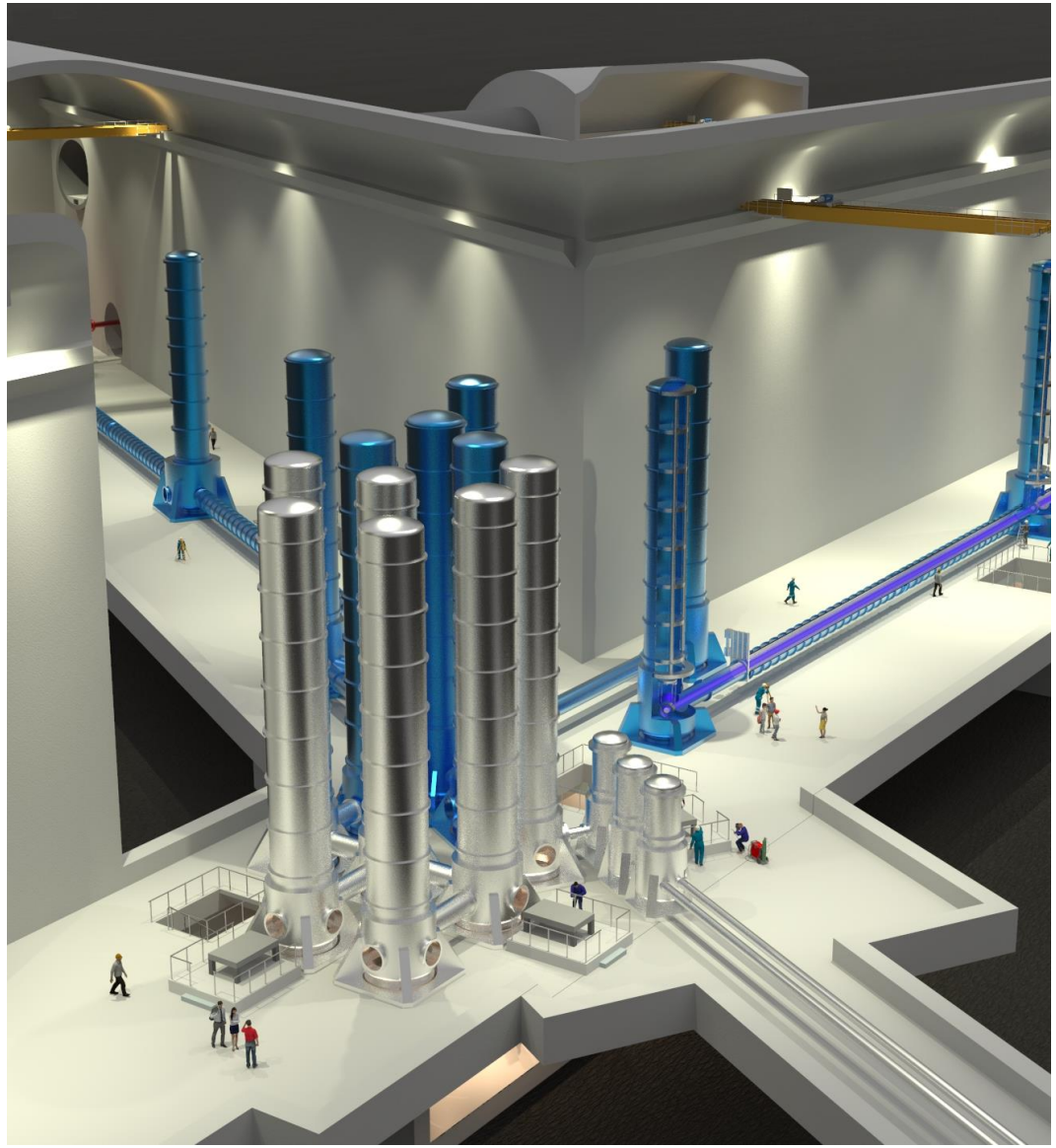
On behalf of Prof. Christophe Collette

08.05.2023

E-TEST Einstein Telescope EMR Site & Technology

Interreg Euregio Meuse-Rhine European Regional Development Fund

EUROPEAN UNION



E-TEST objectives

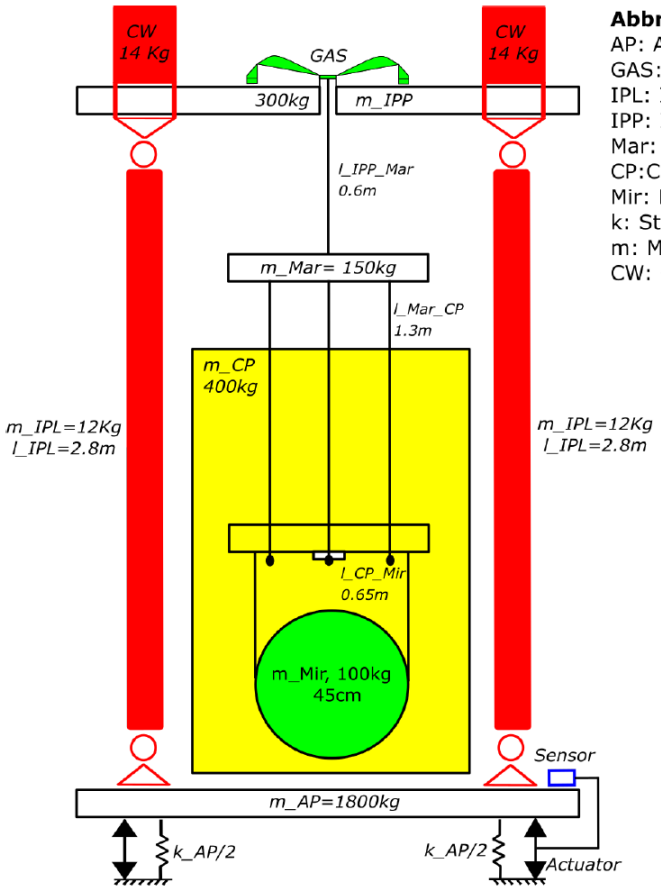
- Large mirror (100 Kg)
- Cryogenic temperature (10-20 K)
- Isolated at low frequency (0.1-10 Hz)
- Compact suspension (4.5 meters)

E-TEST feasibility strategy

E-TEST is a project funded by the Interreg Euregio Meuse-Rhine and ET2SME consortium, which allow us to capitalize on existing infrastructure at Centre Spatial Liège (CSL) for the construction of the facility.

Precision Mechatronics Laboratory
CSL CENTRE SPATIAL DE LIÈGE
RWTH AACHEN UNIVERSITY
KU LEUVEN
Nikhef
UCLouvain
micas KU LEUVEN
Fraunhofer ILT

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

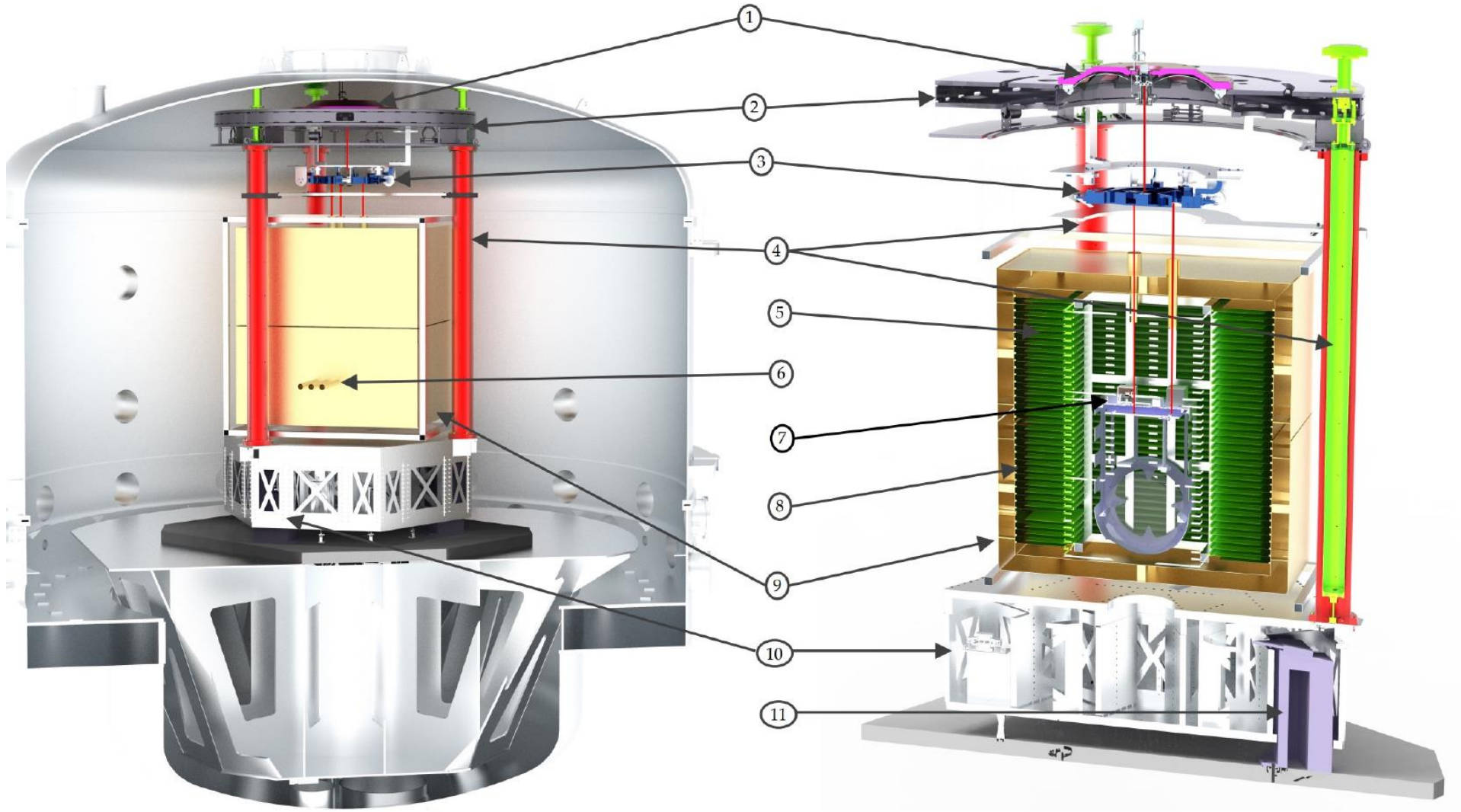
Liège Space Center

Hybrid (active + passive) isolation
Radiative cooling

Submitted: 12/2021
Revised: 03/2022

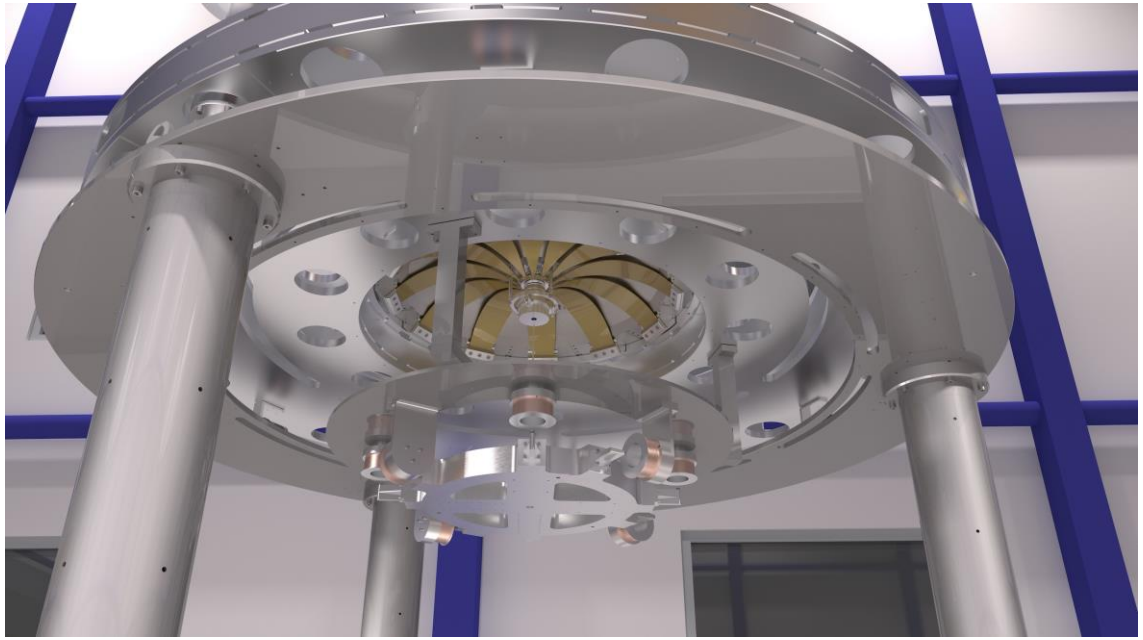
Vibration isolator
1) GAS filter
2) Inverted Pendulum (IP) platform
3) Marionette
4) IP legs
10) Active platform

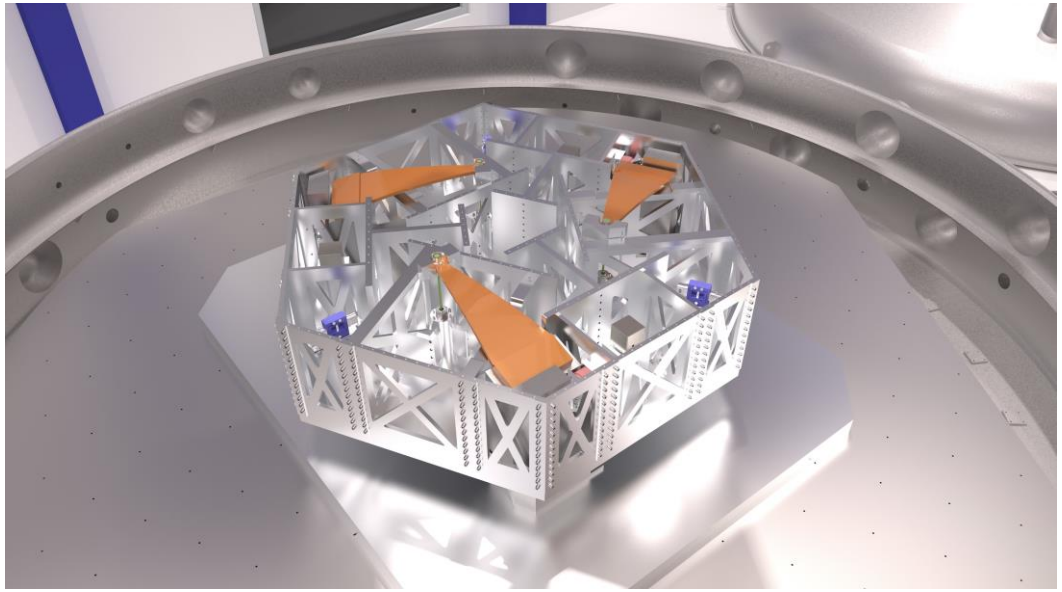
Cryogenic payload
5) Heat exchanger and cold platform
7) 25K inner thermal shield
8) 80K outer thermal shield

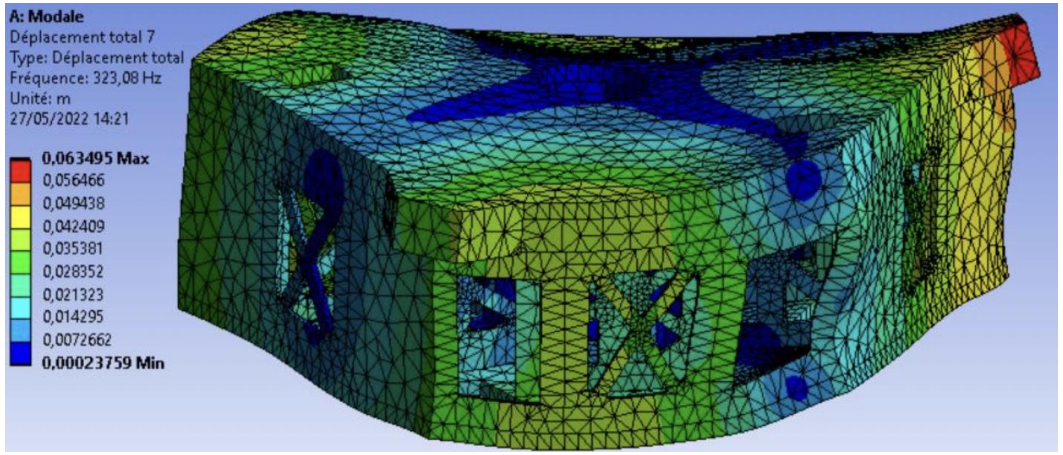


Mechanical design state-of-the-art

- Production drawings of the whole prototype finished!
- All mechanical parts in production
- Start assembly in May 2023







Contact: Ameer Sider (PML)
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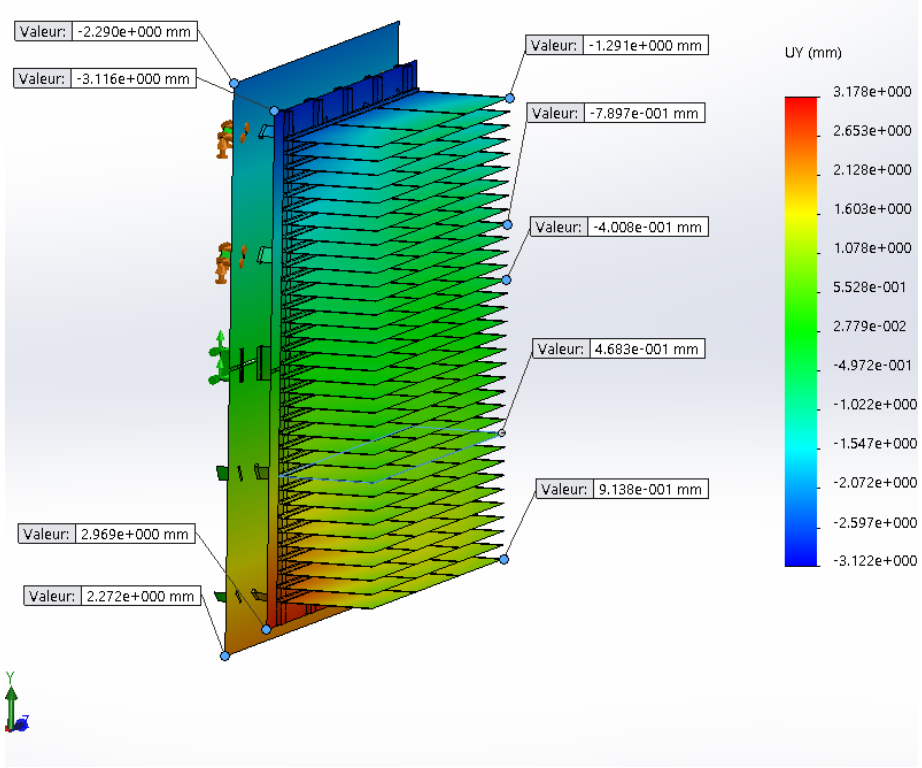
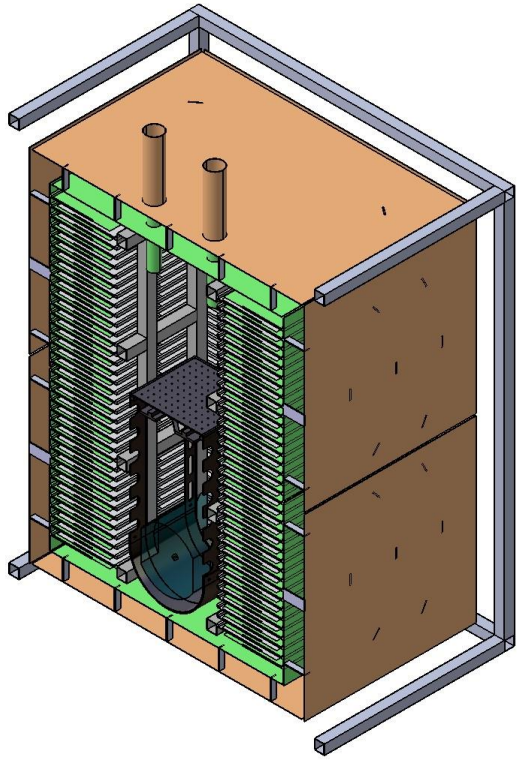
Cryostat development

- ✓ 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

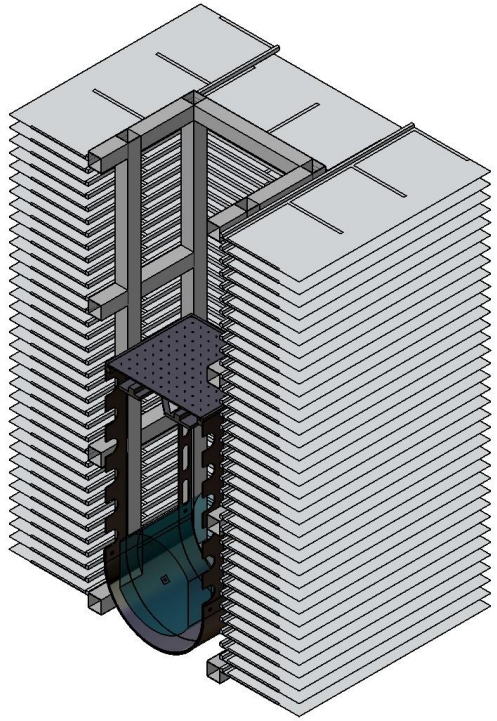


radiation heat transfer for mirror cooling



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

Contact: Cedric Lenaerts (CSL)
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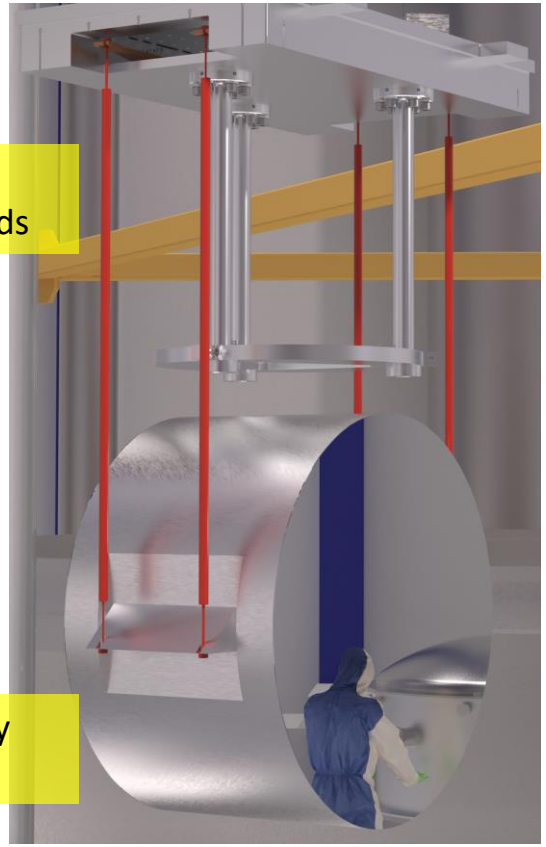
Ultra-cold vibration control

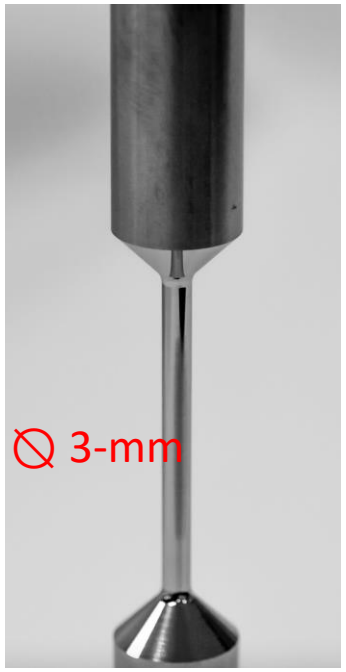
Crystalline silicon mirror suspension

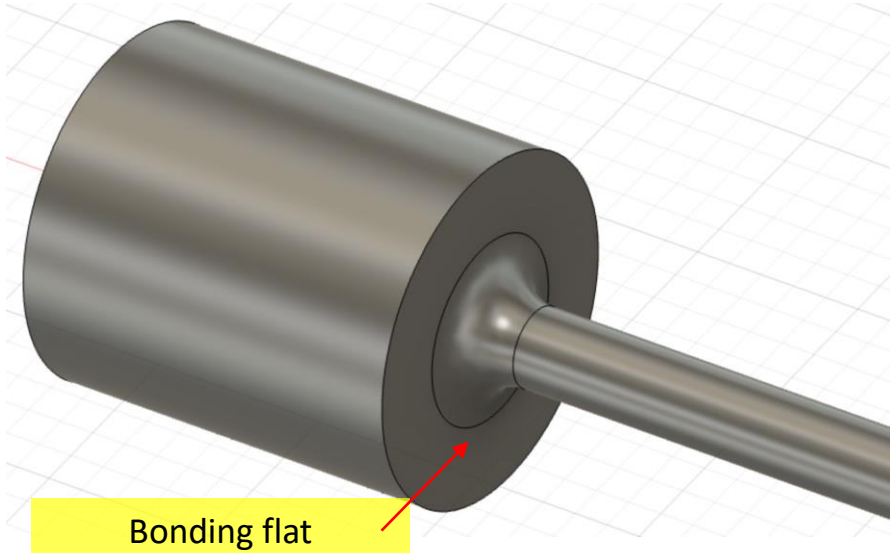
- Crucial technology aspect for ET: no proven solution exists
- Four machined samples delivered



single crystal Si suspension rods

Al-6061 dummy mirror





- All samples, including the new ones with bonding flats, sent to Università 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

Contact: Alessandro Bertolini (Nikhef)
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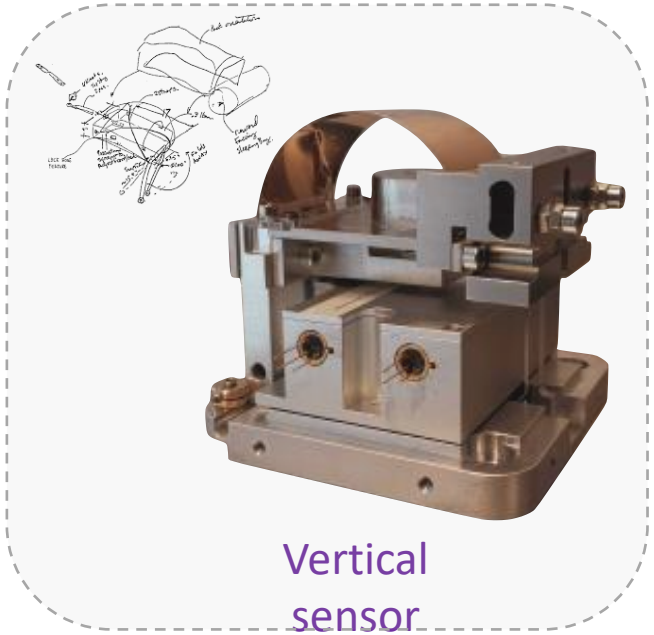
Ultra-cold vibration control

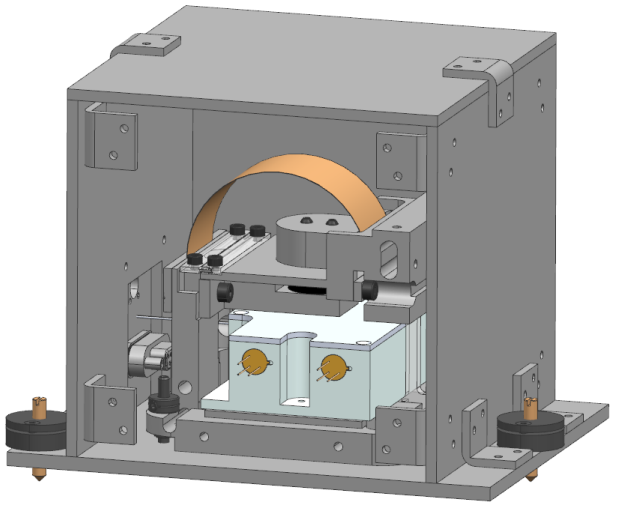
Inertial sensors development for active seismic attenuation at low frequency

Precision Mechatronics Laboratory

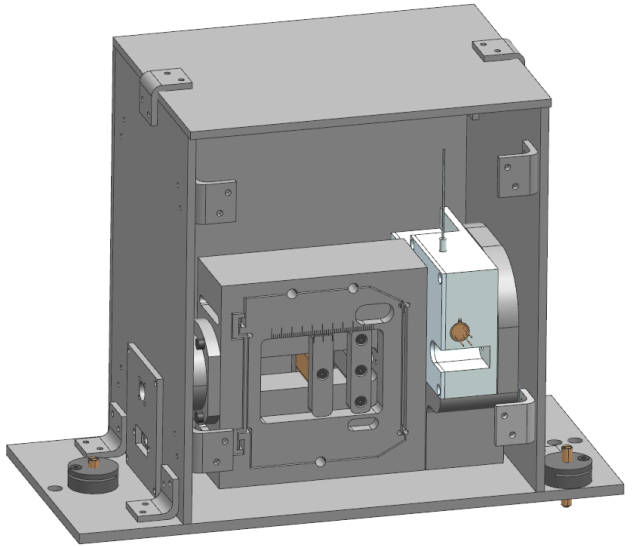
- Laboratory prototype is getting turned into its final design
- Production drawings in progress; manufacturing starting in the coming weeks



Vertical sensor prototype



Vertical sensor



Horizontal sensor

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Loïc Amez-Droz (PML)
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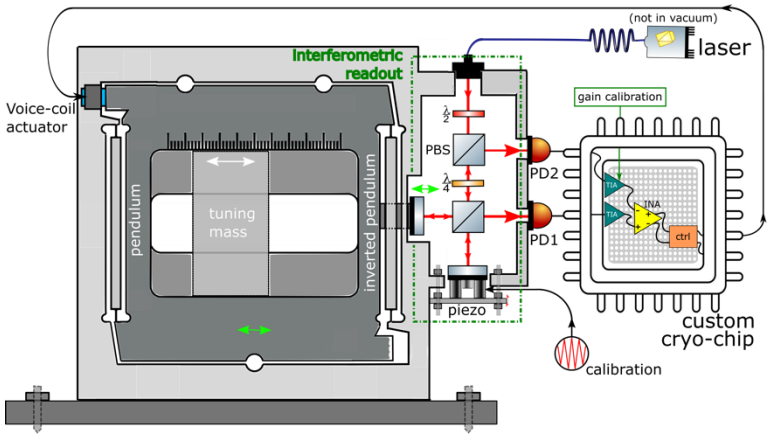
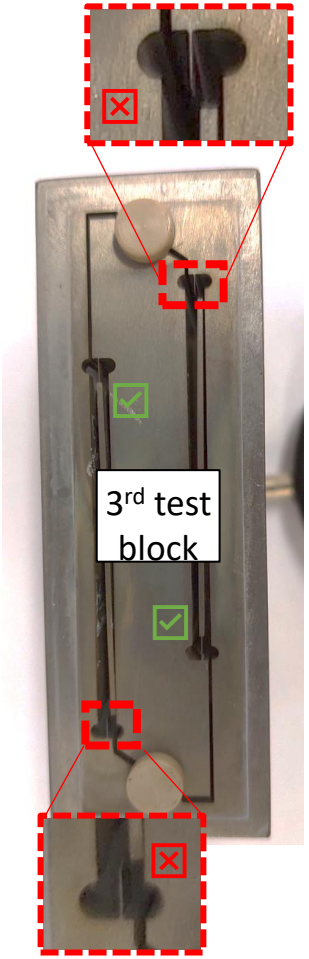
Ultra-cold vibration control

Cryogenic inertial sensors

CSIS-H





Mechanics: new manufacturing test of the flexures in niobium failed. We may change titanium alloy (TiAl6V4) if still not working.

Actuator: while superconducting coil actuator development is ongoing, switch to shielding-magnet voice-coil actuators to avoid eddy-current damping.

Morgane Zeoli (PML)
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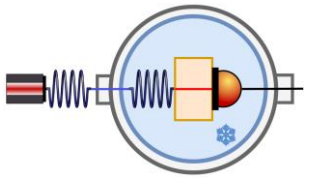
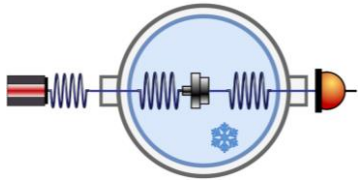
Interferometric readout development for CSIS-H/V

PD test



Collimator test

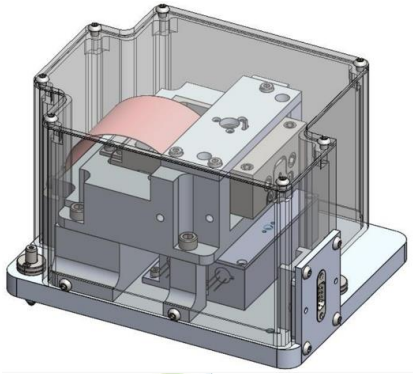


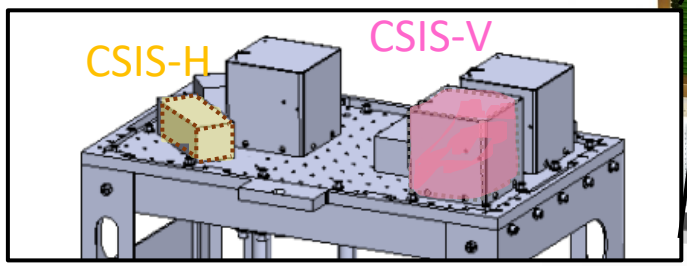
Planned for this week !

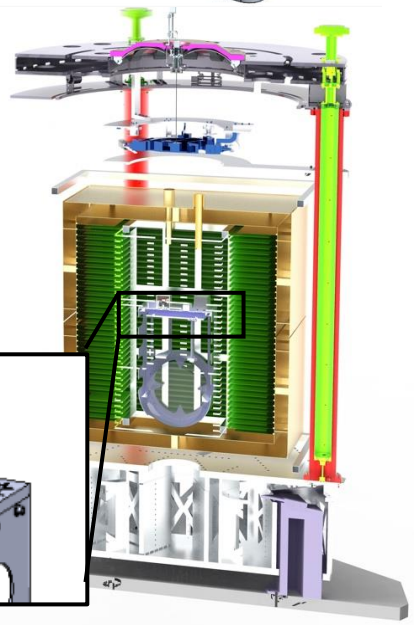
1st test: Assess photodiodes & collimators performances at 20K.
2nd test: Asses influence of cold in polarizing optics
3rd test: Test full IFO assembly
4nd test: Test full sensor

CSIS-V

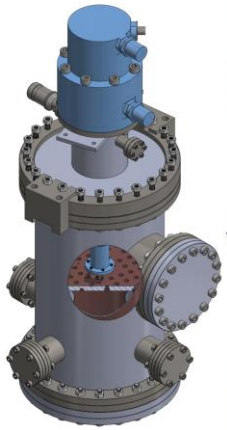
Ongoing development

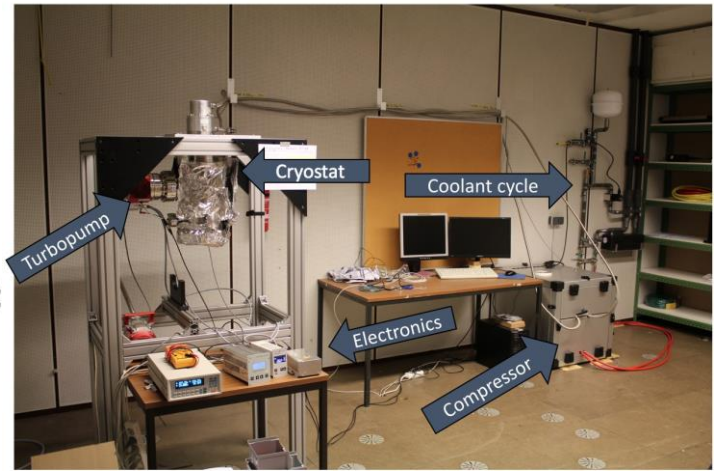




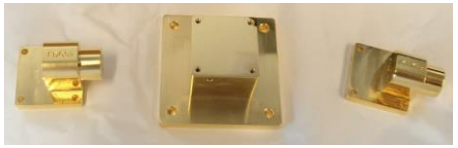


Cryogenic test bench

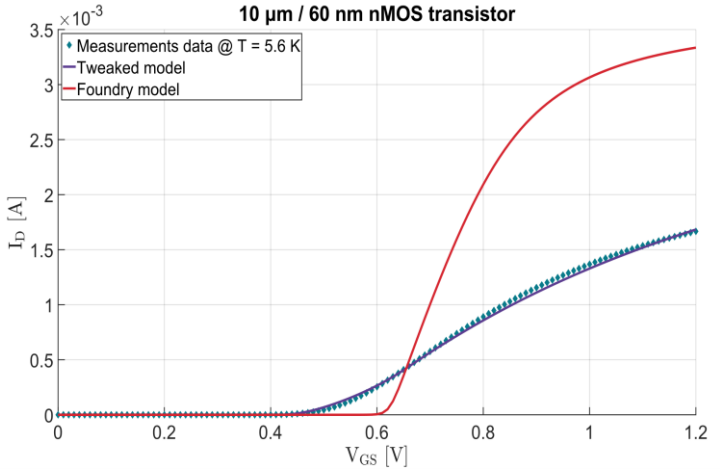




- Closed-cycle cryostat providing up to 1W cooling power at 10K
- Vacuum level: better than 10^{-9} mbar
- Usable volume: cylindrical 15x15cm
- Fast turnaround and low running costs
- Useful for testing materials, components and assemblies



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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Contact: Alberto Gatti
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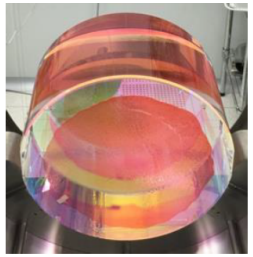
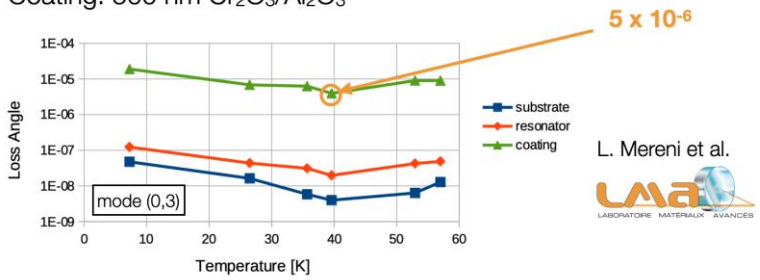
Silicon Mirror Coating

- 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



Mechanical losses

- Coating: 500 nm Cr_2O_3/Al_2O_3



L. Mereni et al.

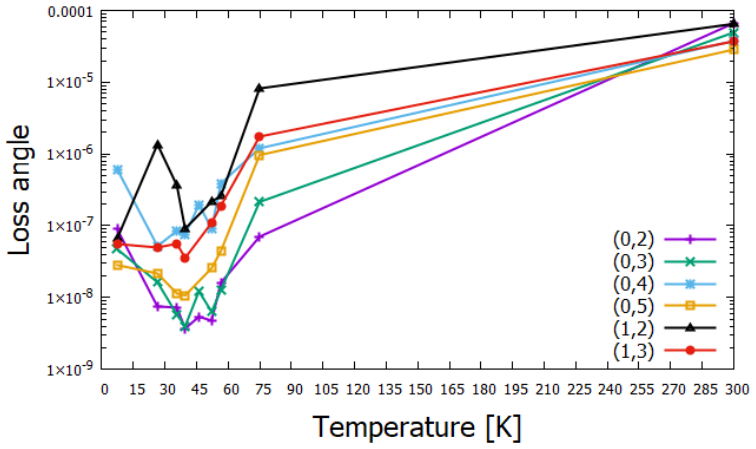
- Dilution factor= 0.0034

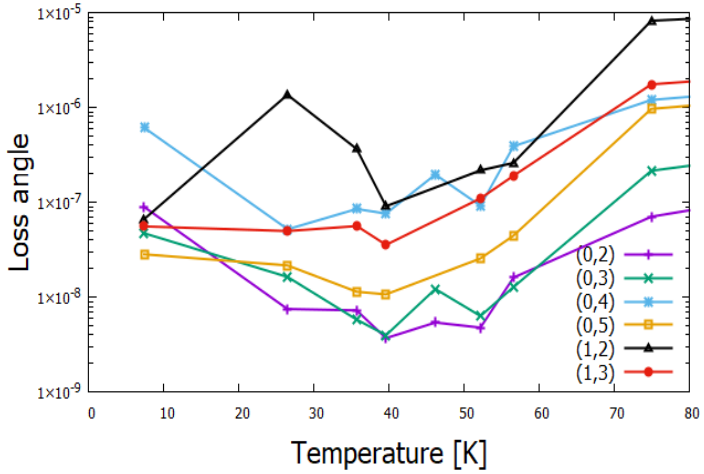
Assumptions:

$d_{coating}$ = 500 nm
$d_{substrate}$ = 0.3 mm
$Y_{coating}$ = 260 GPa
$Y_{substrate}$ = 385 GPa

First tests:

- Cryogenic measurements of crystalline substrates
  - Analysis of mechanical loss with respect to the temperature
    - Different lines correspond to different wave modes
- Preliminary result: Minimum of the loss angle at 40 K
  - Origin yet unknown, further analysis will follow
- Next step
  - Deposit Cr2O3 thin film on the characterized substrates and measure new combination





Contact: Jean-Pierre Locquet
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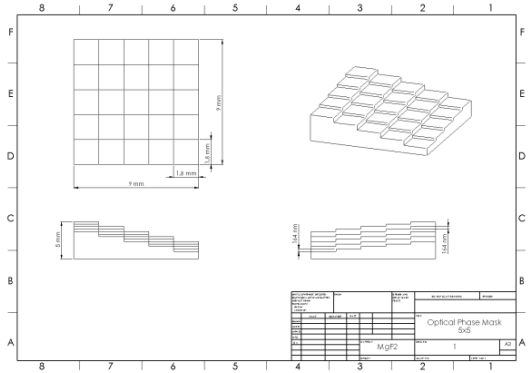
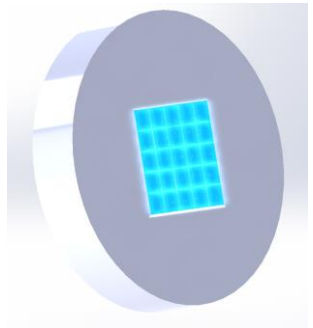
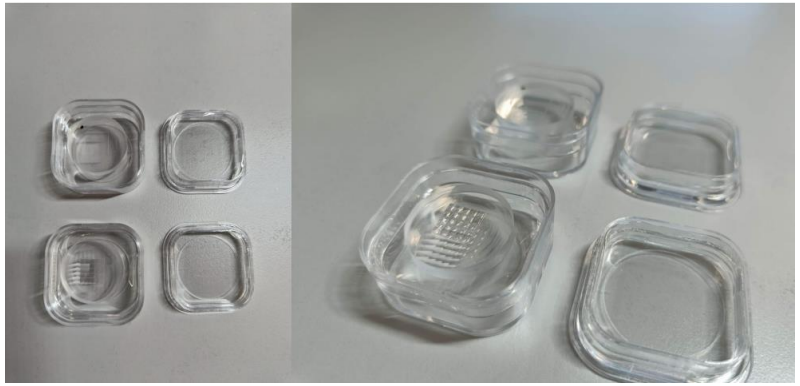
Silicon Mirror Manufacturing & Test

- Experiment purpose
  - Characterization of the cryogenic mirrors for GW detectors on operation
- Added value
  - Measurement of local values of vibration and topology change instead of a single absolute value of the full mirror
- Current tasks
  - Optical design development
  - Custom optical phase mask arrived and experiments on proof of concept are being performed



Phase mask



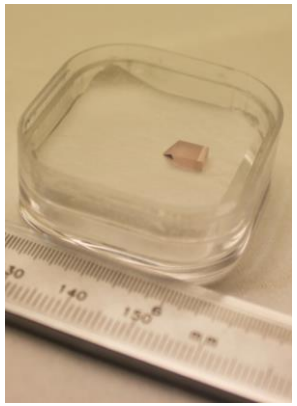


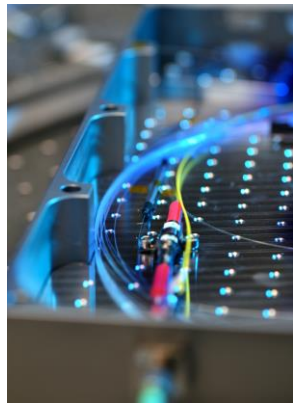
Contact: Jesus Vilaboa Perez (CSL)
jvilaboaperez@uliege.be

Laser Development

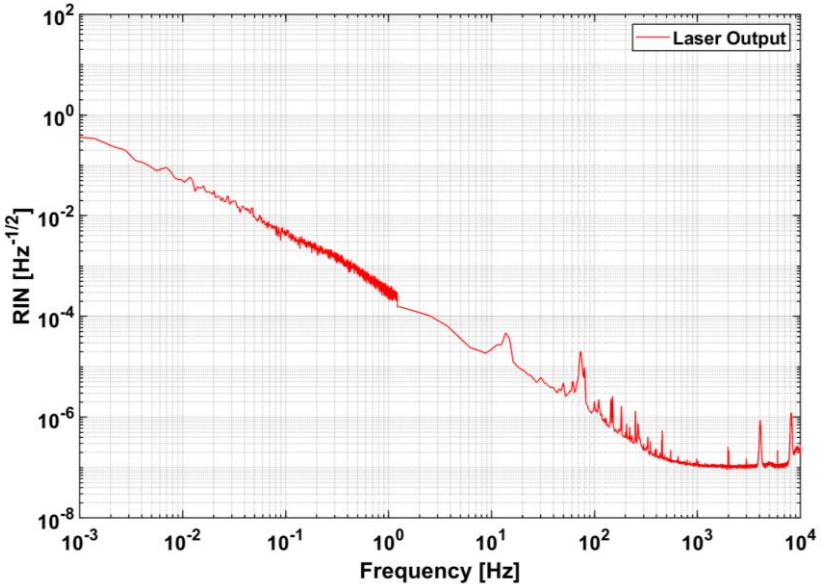
Fraunhofer ILT

- Requirements:
  - High stability, Narrow linewidth
  - Wavelength: 2090 nm, Power: 5-10 W
- Approach:
  - Solid state laser seed source (Ring-Oscillator / Non-Planar Ring-Oscillator)
  - Two-stage holmium-doped fiber amplifier
  - Internal stabilization mechanisms
- Current activities
  - Setup of final stages and power stabilization





- Status: Most fiber laser requirements successfully demonstrated
  - Output power, spectrum, polarization, …
  - Current analysis: Relative Intensity Noise (RIN)
- Holmium-amplifier (Ho1) preliminary results without stabilization
  - Low frequencies: High RIN expected
    → No thermal stabilization
  - Mid frequencies: Good results without stabilization
    → RIN @ 100 Hz is app. 10^{-6} 1/√Hz
    → Already very close to the project goals
- Next steps: Active power stabilization and further improvement of setup



Contact: Patrick Baer (ILT)
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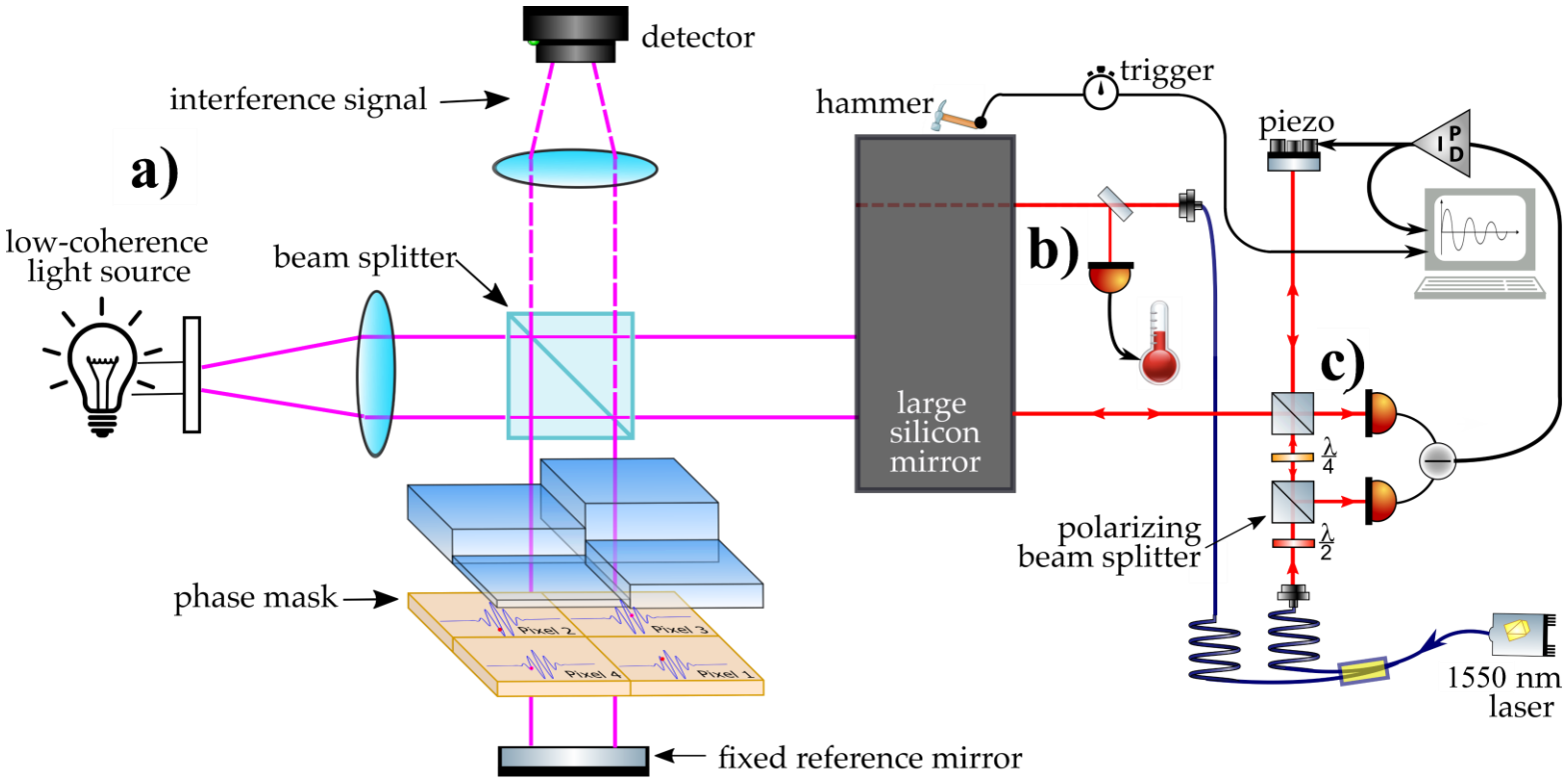
Final validation of the prototype

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



Tests at CSL timeline:

2023: with dummy Al mirror

2024: with 100kg Si mirror

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Useful links:

TDR
https://arxiv.org/abs/2212.10083
E-TEST Project website
https://www.etest-emr.eu/
PML website
http://www.pmlab.be/