Testing The LISA Instrument

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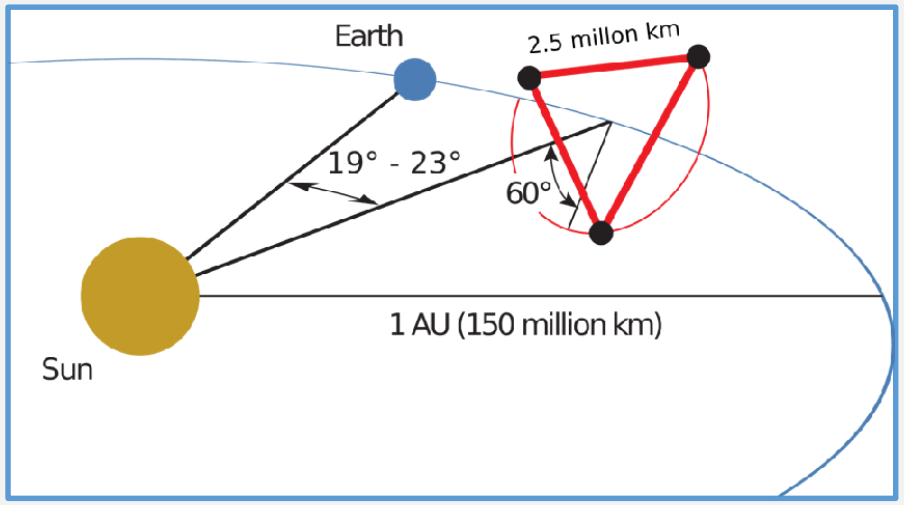
Technical challenges of LISA

Long distance interferometry with free floating test-masses.



Instrument performances :

- $\lesssim 3\ mHz$: acceleration noise

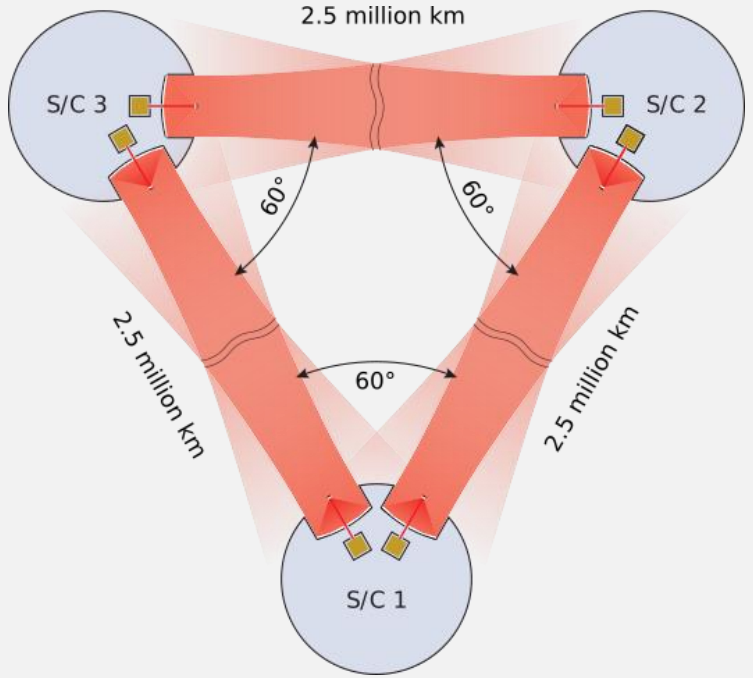
$$\approx 0.1 \frac{1\ mHz}{f}\ fg/\sqrt{Hz}$$

Demonstrated by LISA Pathfinder

- $\gtrsim 3\ mHz$: metrology noise

$$\approx 10\ pm/\sqrt{Hz}$$

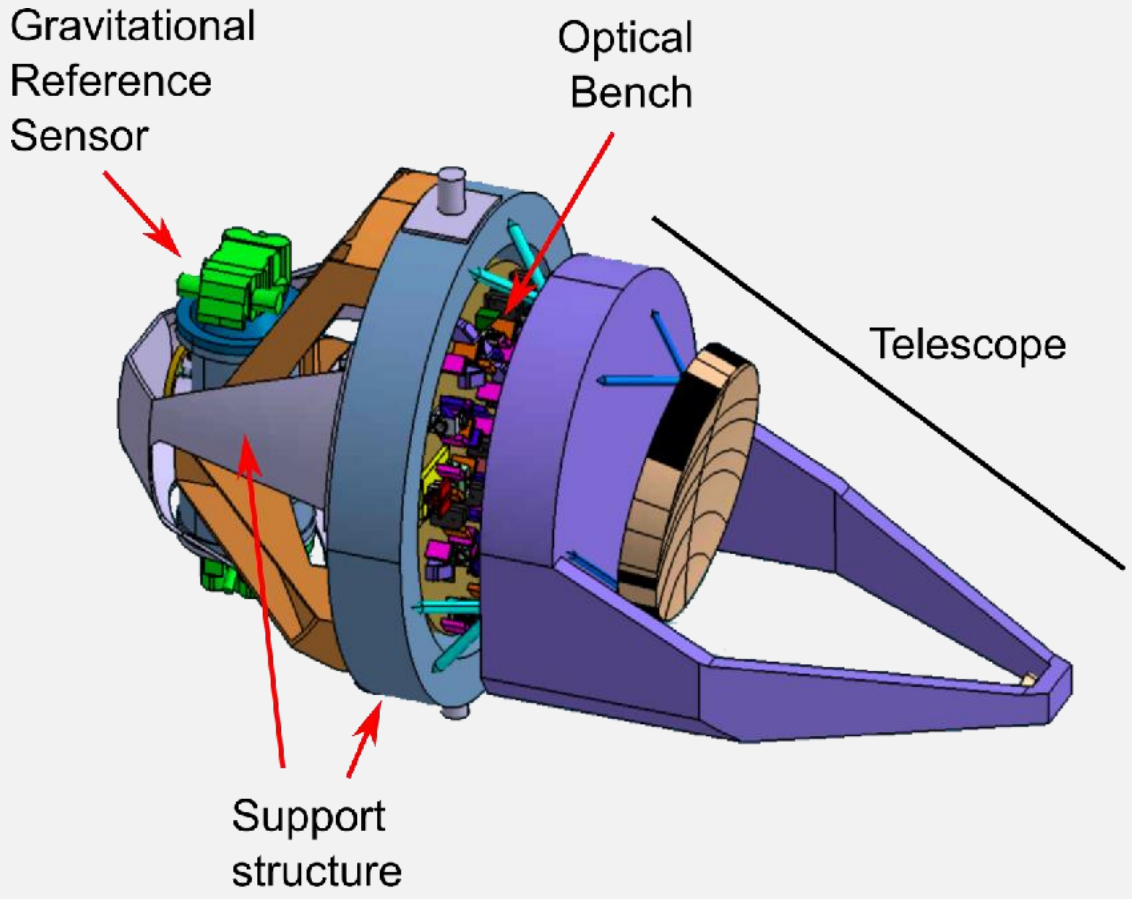
Demonstrated on ground with dedicated test benches



Payload systems

Instrument:

- Telescope
- Optical bench
- Gavitational Reference System (GRS)
- Phasemeter
- Frequency distribution system
- Laser source + stabilisation
- Support structure



Payload systems

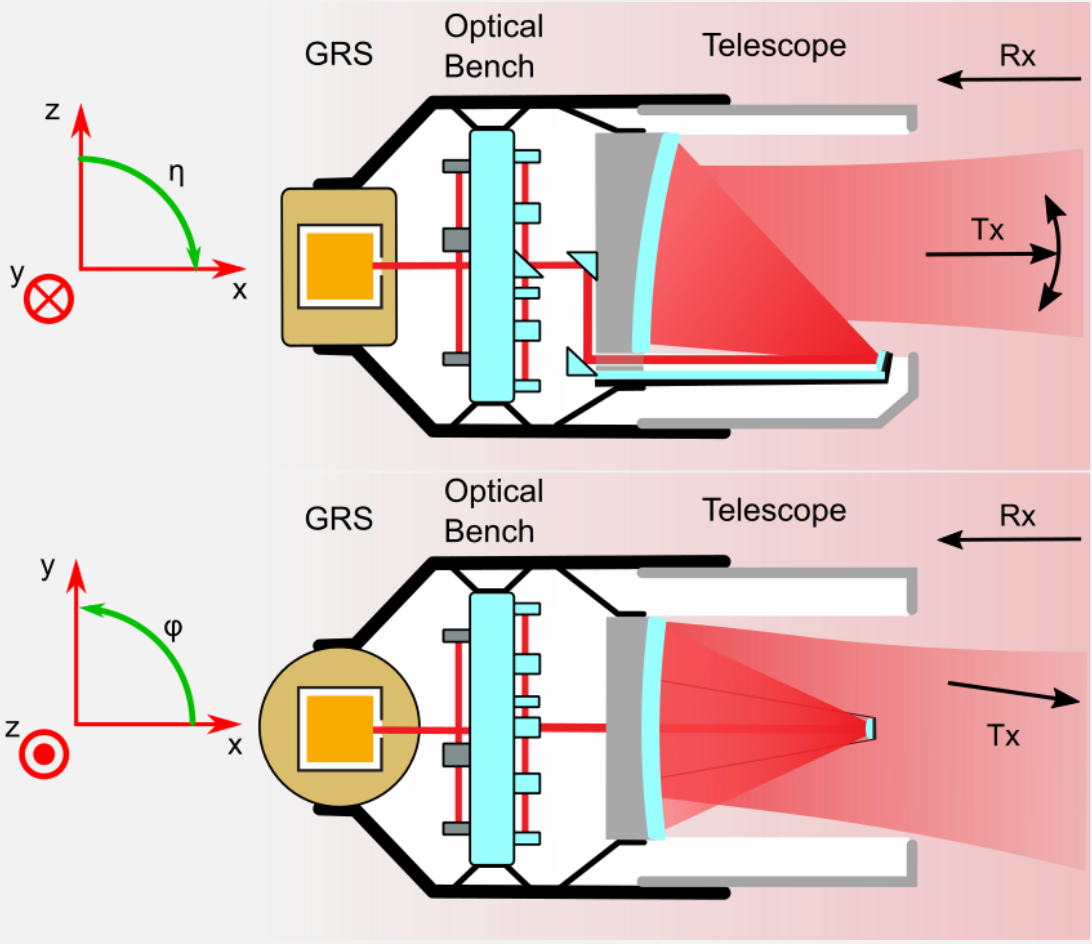
Two levels of integration:

Interferometric Detection System (IDS):

- Optical bench + phasemeter + Laser
- Validation step for the metrology concept of LISA

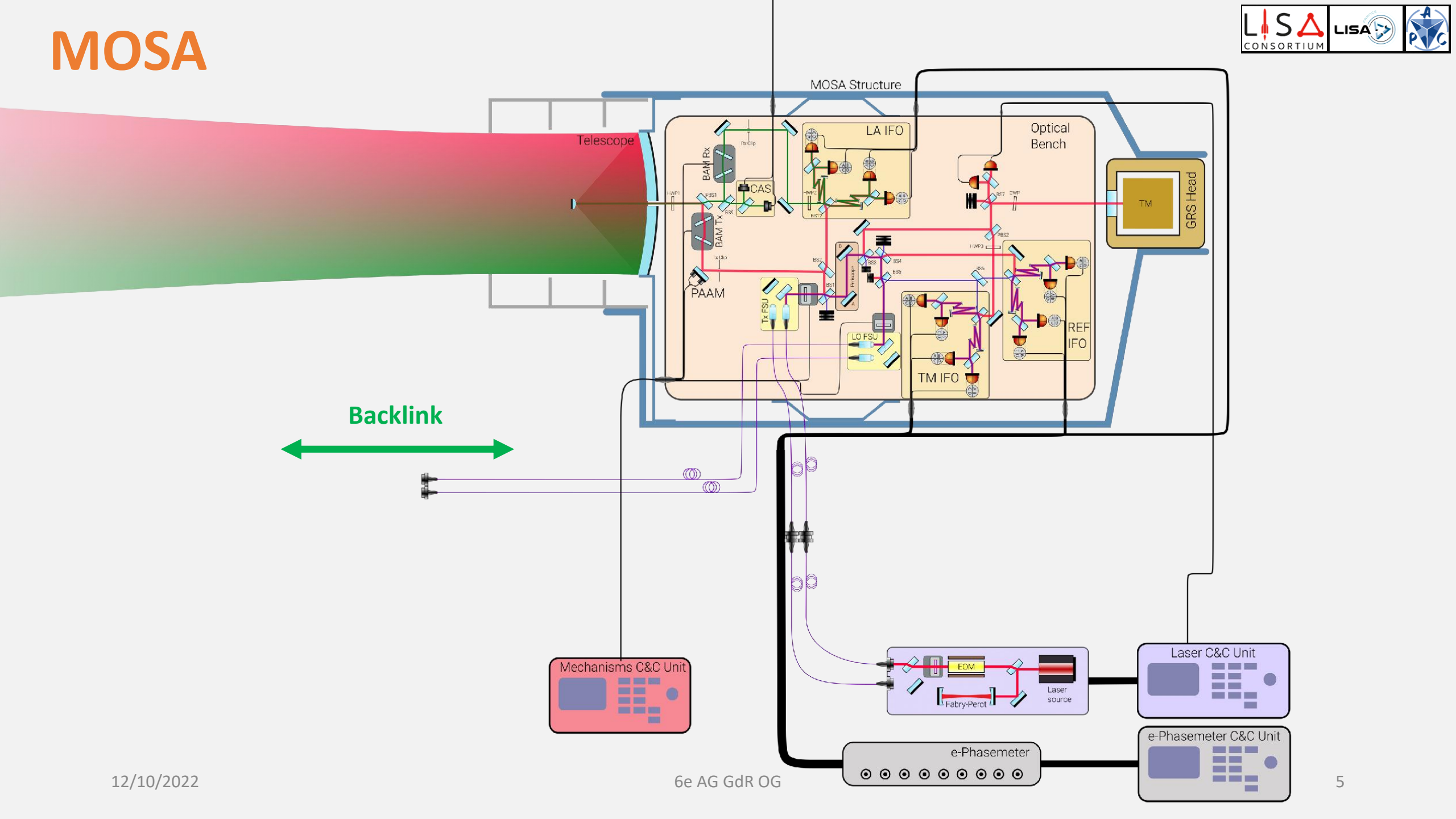
Movable Optical Sub-Assembly (MOSA):

- IDS + Telescope + GRS + Structure
- Fully integrated optical instrument
- Validation & tuning step for the QM and FM performance

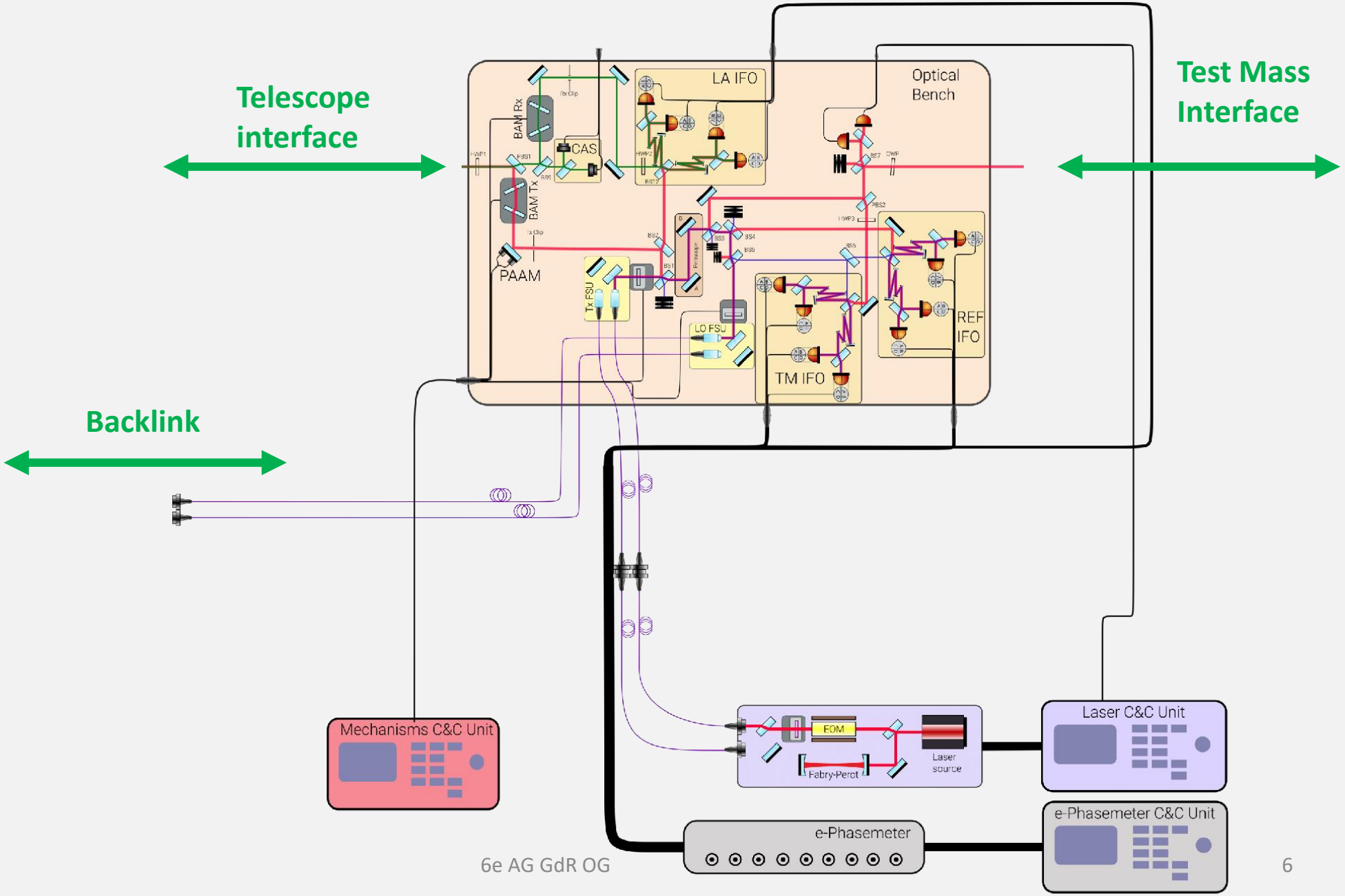


Validation of the instrument performance is complex!

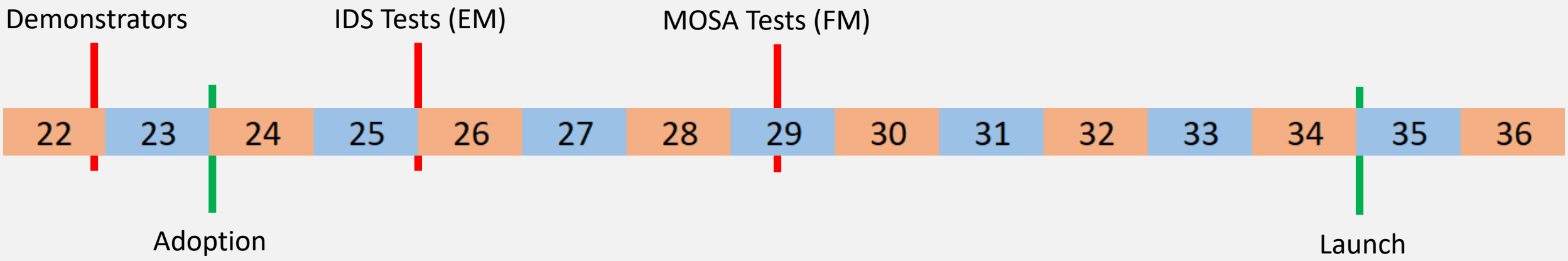
MOSA


MOSA Structure
Telescope
BAM Rx
BAM Tx
CAS
LA IFO
Optical Bench
TM
GRS Head
PAAM
Tx FSU
LO FSU
TM IFO
REF IFO
Backlink
Mechanisms C&C Unit
EOM
Fabry-Perot
Laser source
Laser C&C Unit
e-Phasemeter
e-Phasemeter C&C Unit

IDS


Telescope interface
Test Mass Interface
Backlink
Optical Bench
LA IFO
BAM Rx
CAS
BAM Tx
PAAM
Tx FSU
LO FSU
TM IFO
REF IFO
Mechanisms C&C Unit
EOM
Fabry-Perot
Laser source
Laser C&C Unit
e-Phasemeter
e-Phasemeter C&C Unit

Timeline



CNES, APC, ARTEMIS/OCA, CEA/IRFU, L2IT, LAM, SYRTE/Obs. de Paris

Testing the IDS

Goal: to validate the metrology concept of LISA

Only integration step where direct measurement can be performed seperately on long arm and test-mass interferometers

Calibration & Functional tests:

- Power stabilisation
- Low-power transponder lock
- Telescope angular field of view and DWS response
- Tilt-to-length (TTL) compensation concept
- Acquisition chain of the phase
- …

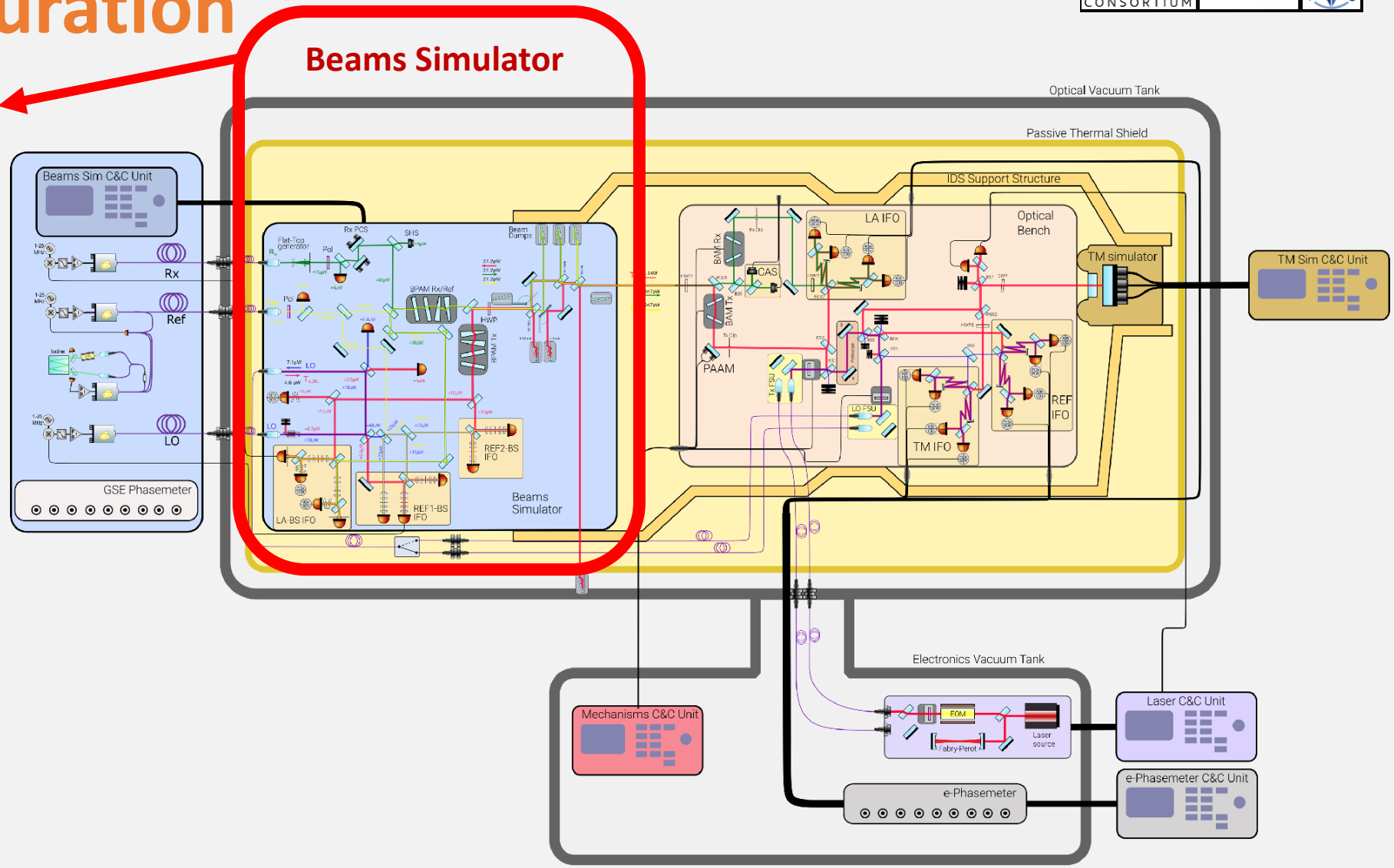
Performance tests:

- Optical path length stability
- TTL measurement on received beam
- Tilted TM performance

Dedicated Ground Support Equipment (GSE) is required to simulate the optical interfaces

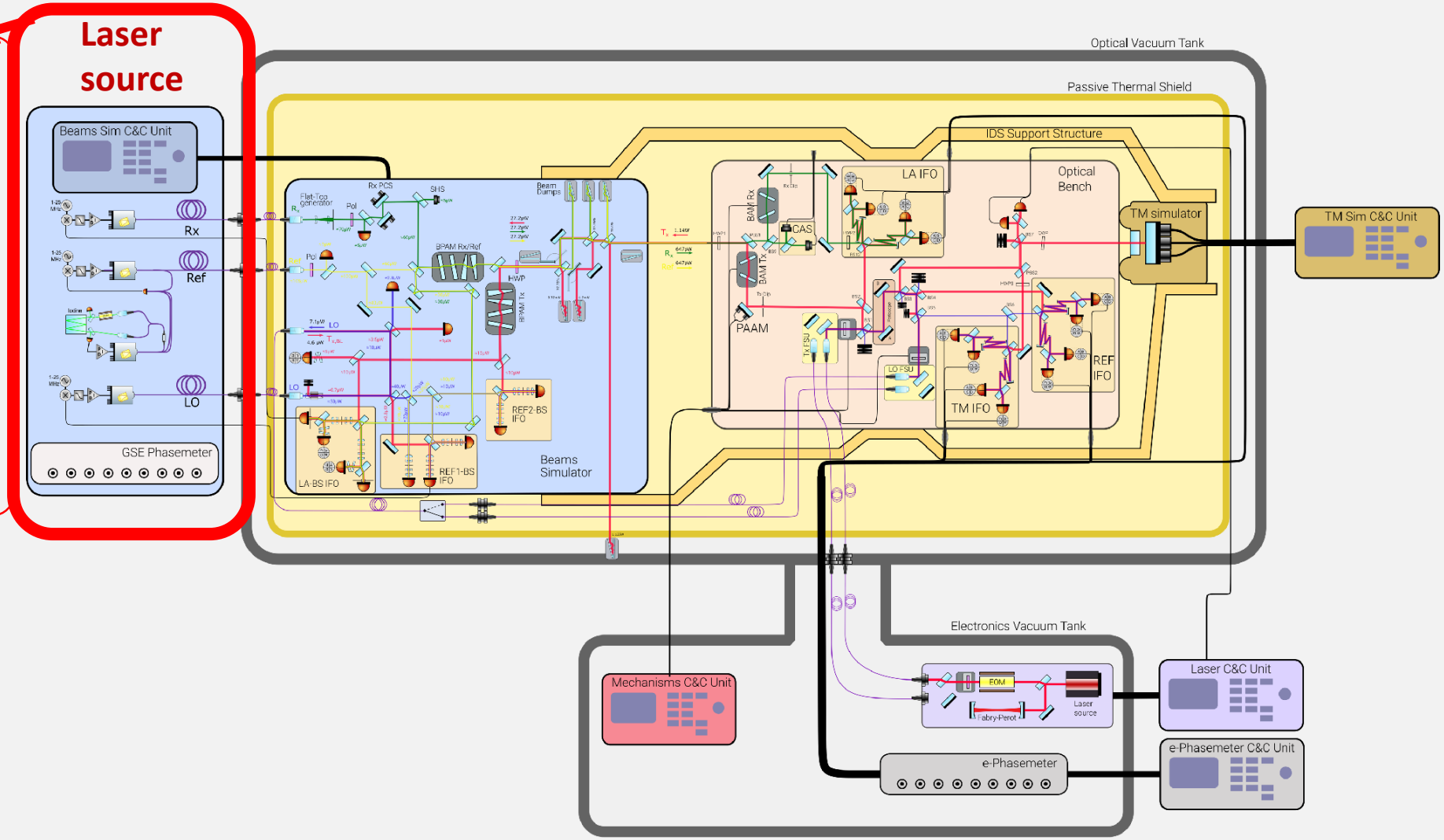
IDS test configuration

- Transmits low power, flat top phase locked beam
- Receives “high power” beam
- Simulates satellite jitter at a fixed phase point



IDS test configuration

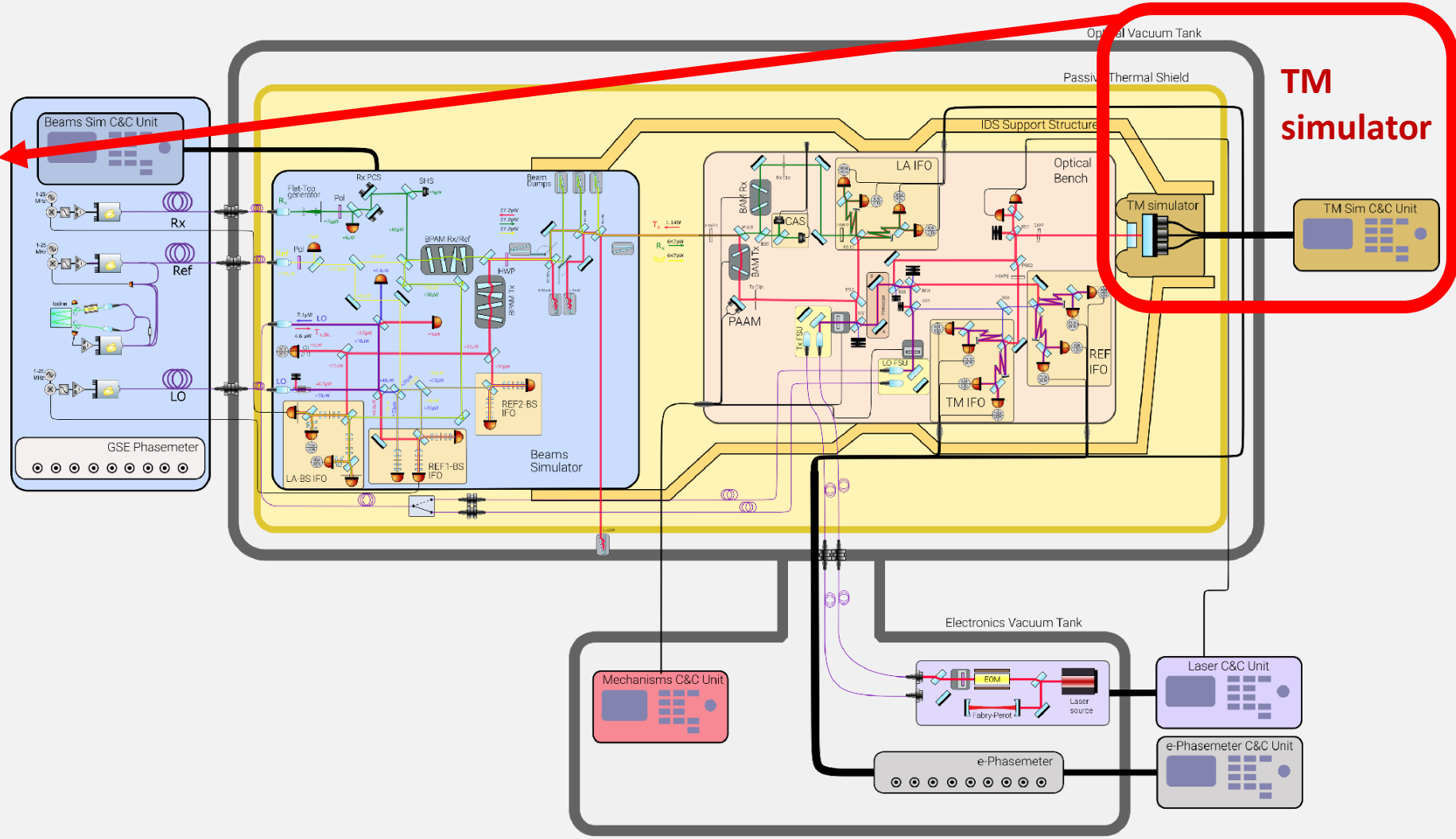
- “Master” laser referenced to iodine frequency
- Generates phase locked Ref, Rx and LO beams with 1 - 25 MHz frequency offsets
- Power stabilized beams



IDS test configuration

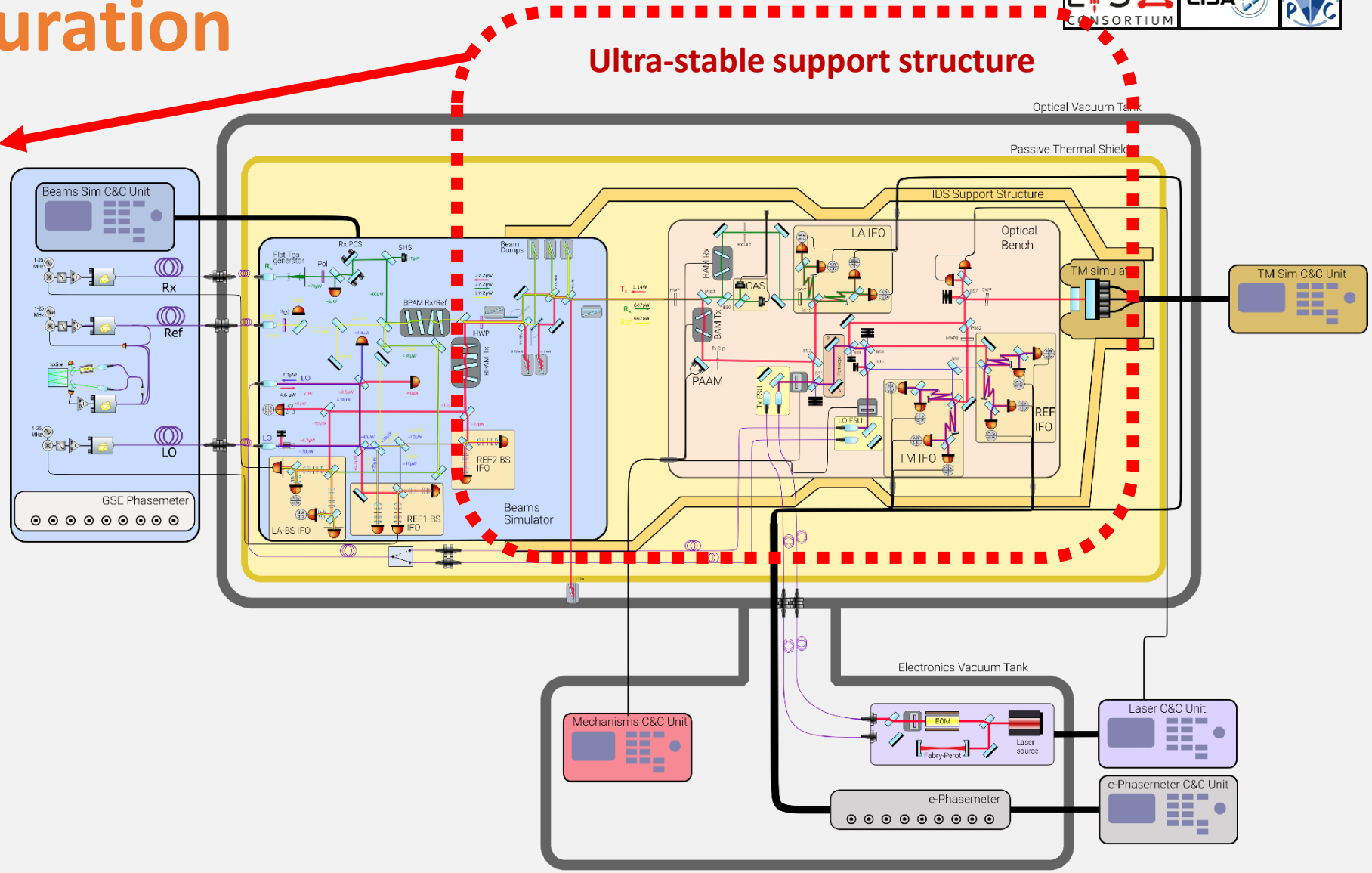
Test Mass I/F :

- Gold coated mirror with high OPL stability
- Tip, tilt & piston actuations
- Representative optical interface



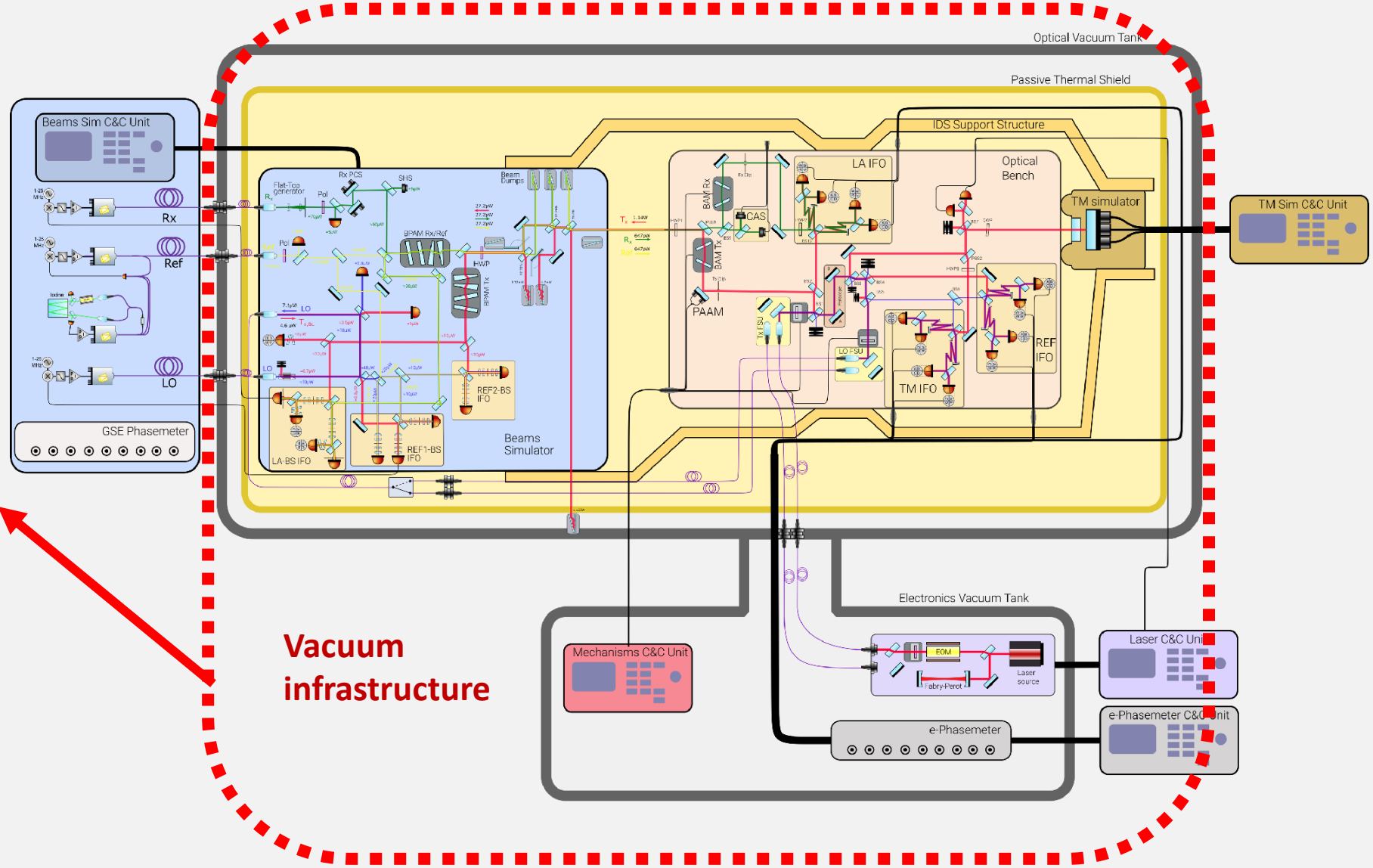
IDS test configuration

- Support structure linking the OB with the Beams and TM simulators
- Must be ~pm stable

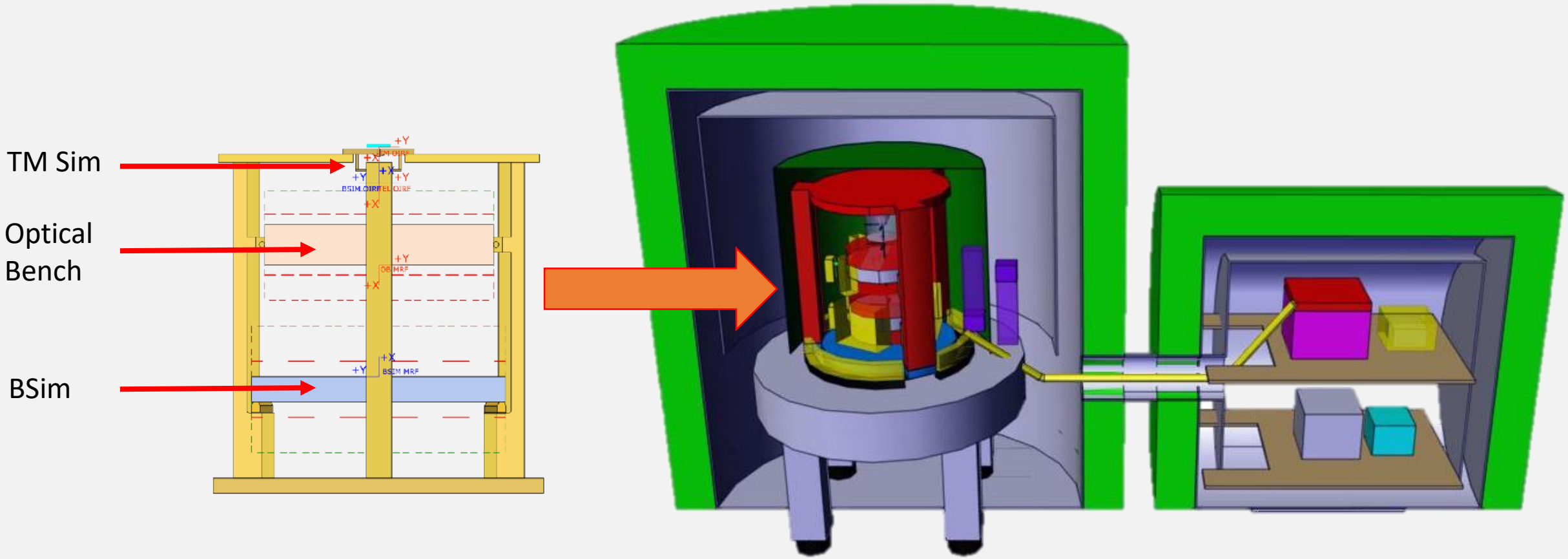


IDS test configuration

- Two chambers : electronics and optical
- Filter environment disturbances:
  - Temperature fluctuations
  - Seismic noise and vibrations



IDS test configuration



IDS tests are to be completed by 2026

Testing the MOSA

Tests conducted on qualification (QM) and flight (FM) models.

Goals:

- To check the metrological functionalities and general « good health » after instrument integration
- To check the interferometric performance with respect to prediction
- To measure and **reduce** TTL coupling
- To identify the contributors to stray light

/!\ On FM, test-mass is grabbed and cannot be used for interferometry

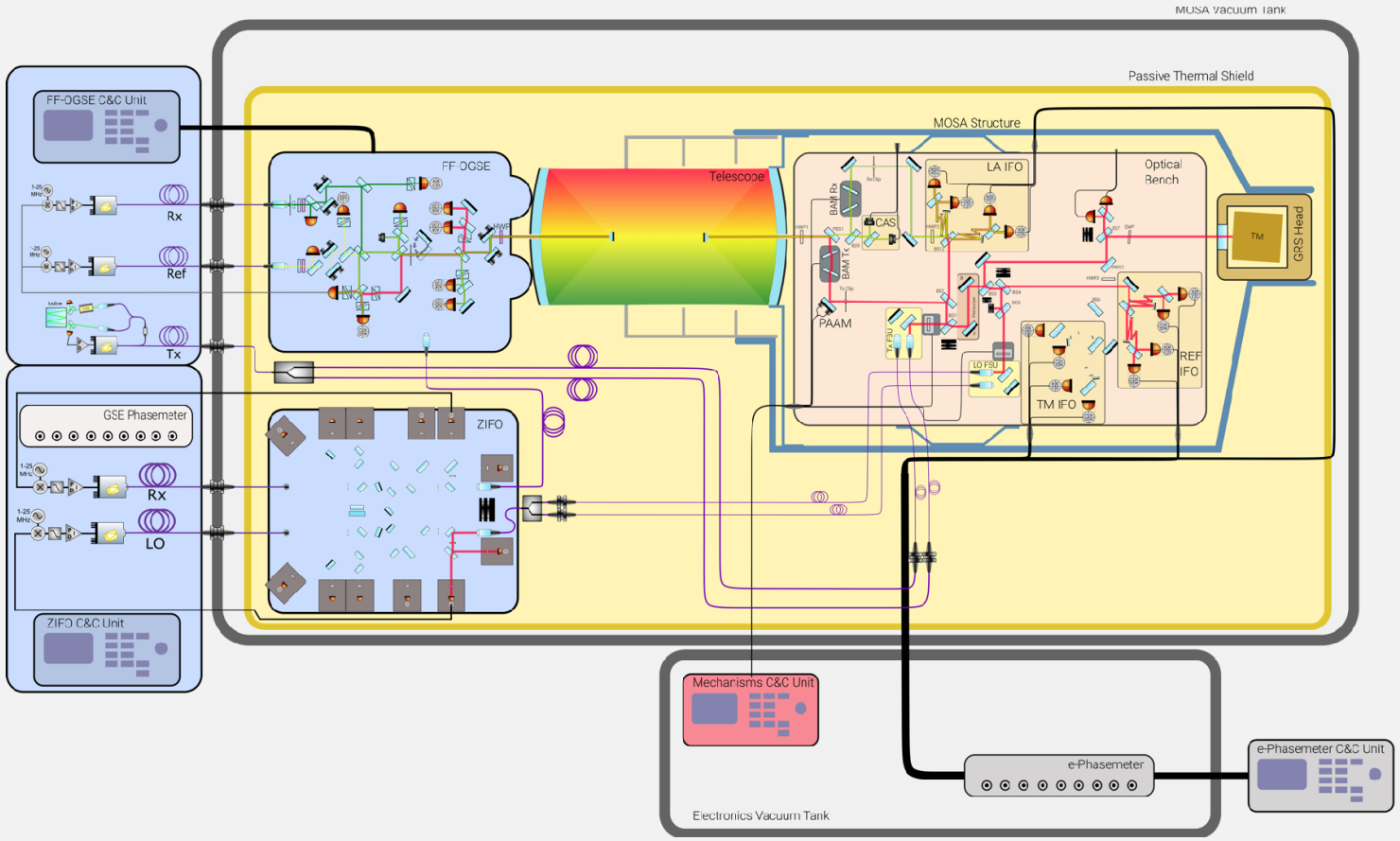
Different GSE are to be developed and delivered by the consortium

MOSA tests configurations

Measurement and reduction of TTL coupling

Different strategies for the transmitted (Tx) and received (Rx) beams:

- Tx: reconstructed from beam centering and emitted wavefront
- Rx: direct measurement using the FF-OGSE (Far Field Optical Ground Support Equipment)

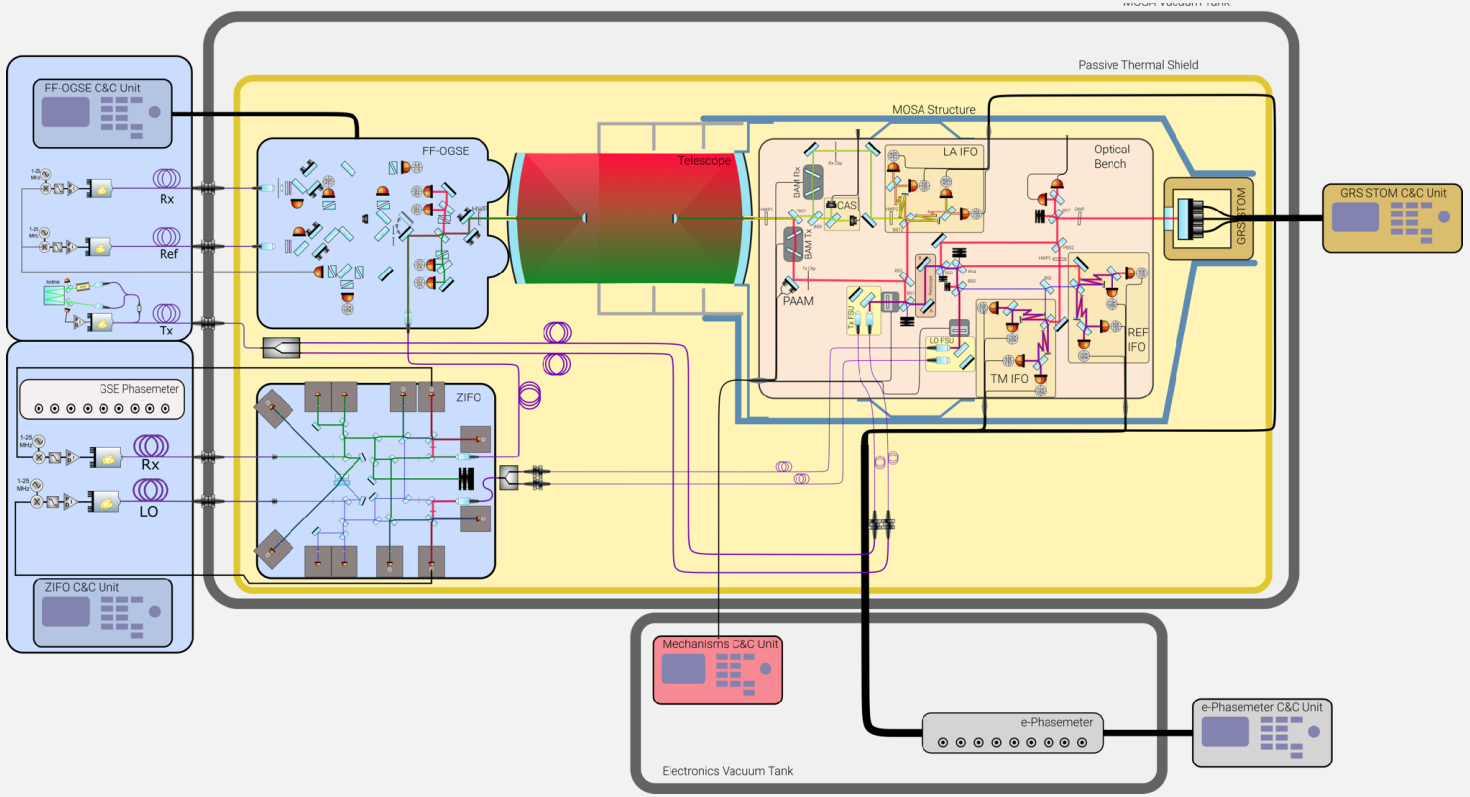


MOSA tests configurations

Interferometric performances verification

Measuring OB stability against test benches stability

Only at QM level with a TM simulator!

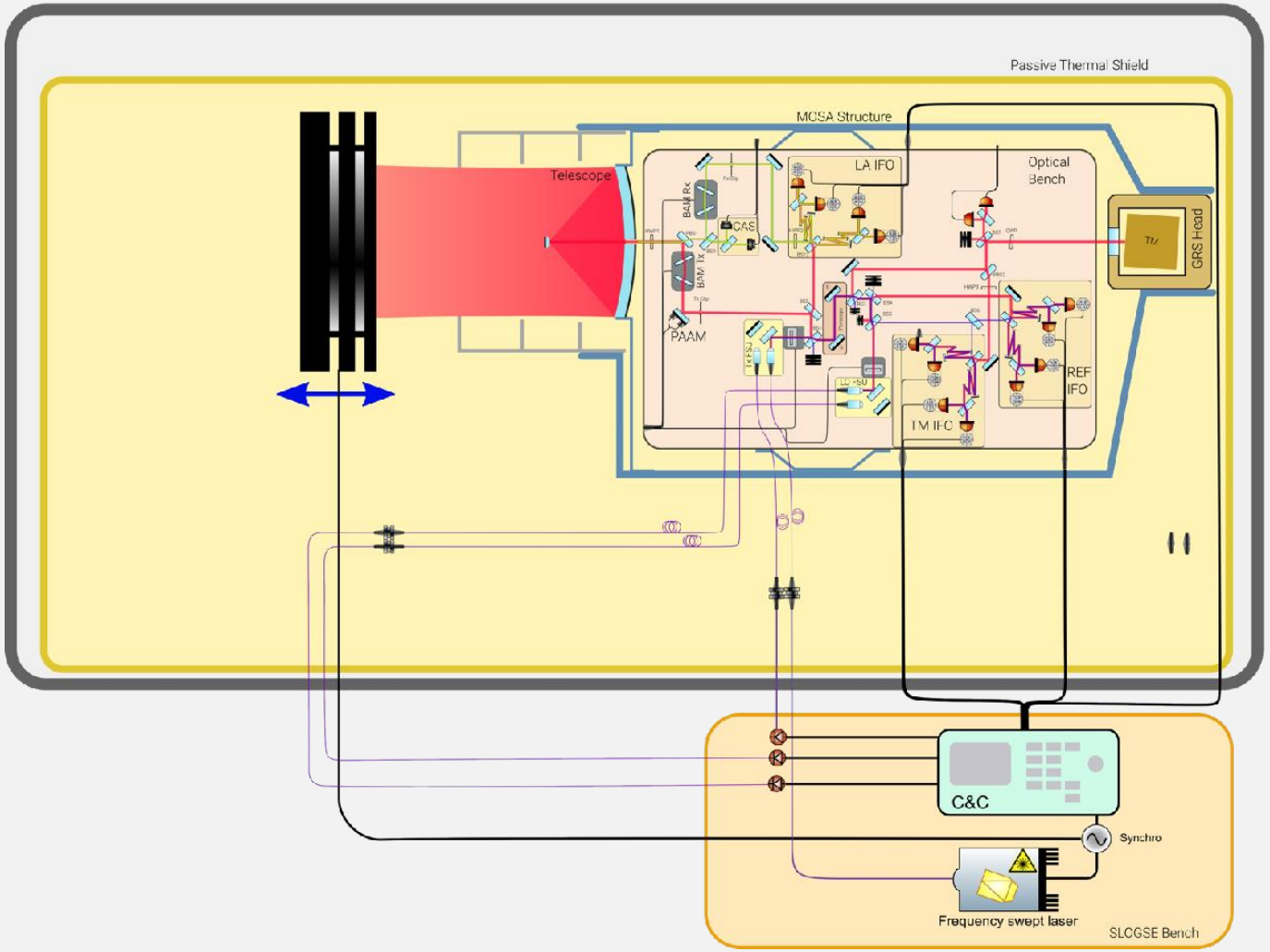


MOSA tests configurations

Stray light measurement

SL-OGSE (Stray Light OGSE)

- Based on deep frequency modulation of a laser
- The frequency of the disturbance depends on the distance of the straylight source

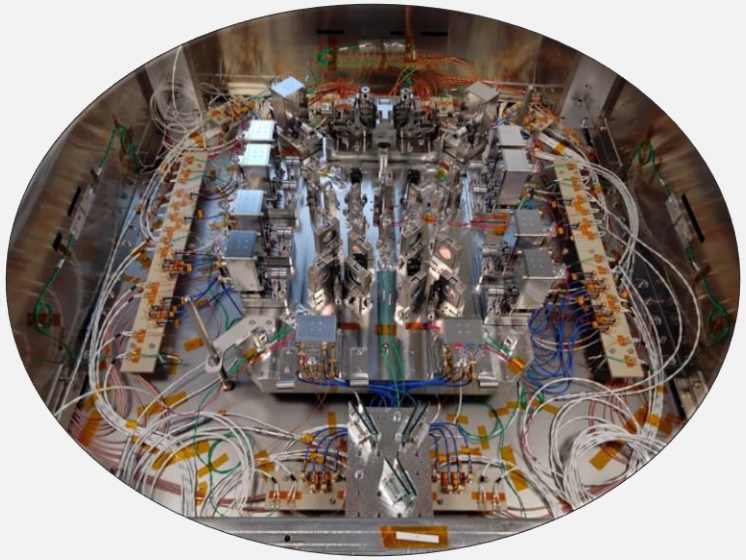


GSE Status

Ultra-stable Prototypes

Assess the achievable path length stability in representative conditions on ground

MIFO: Test campaign completed in March 2022 (data analysis on-going)
ZIFO: Test campaign starting now



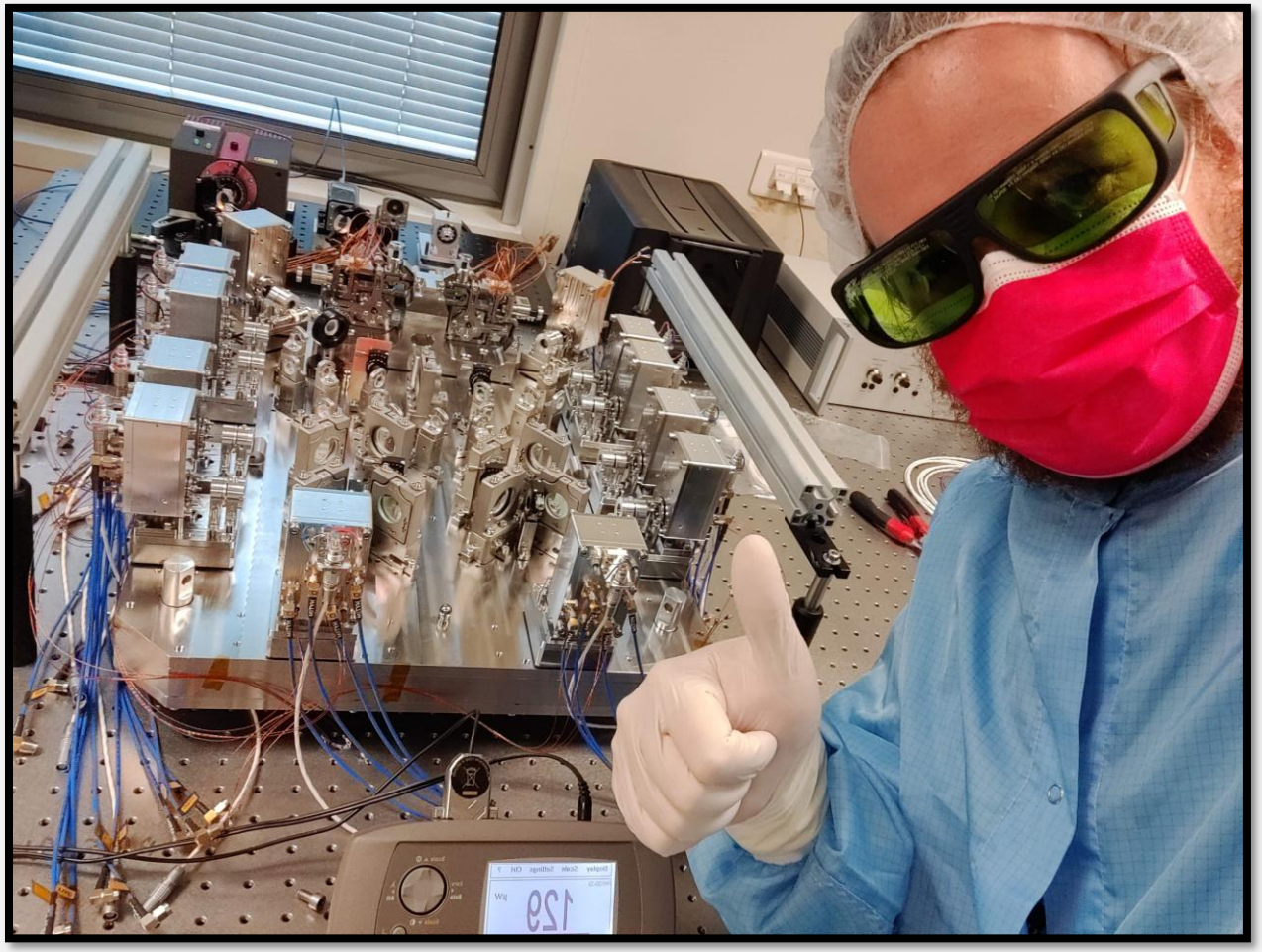
IDS test benches

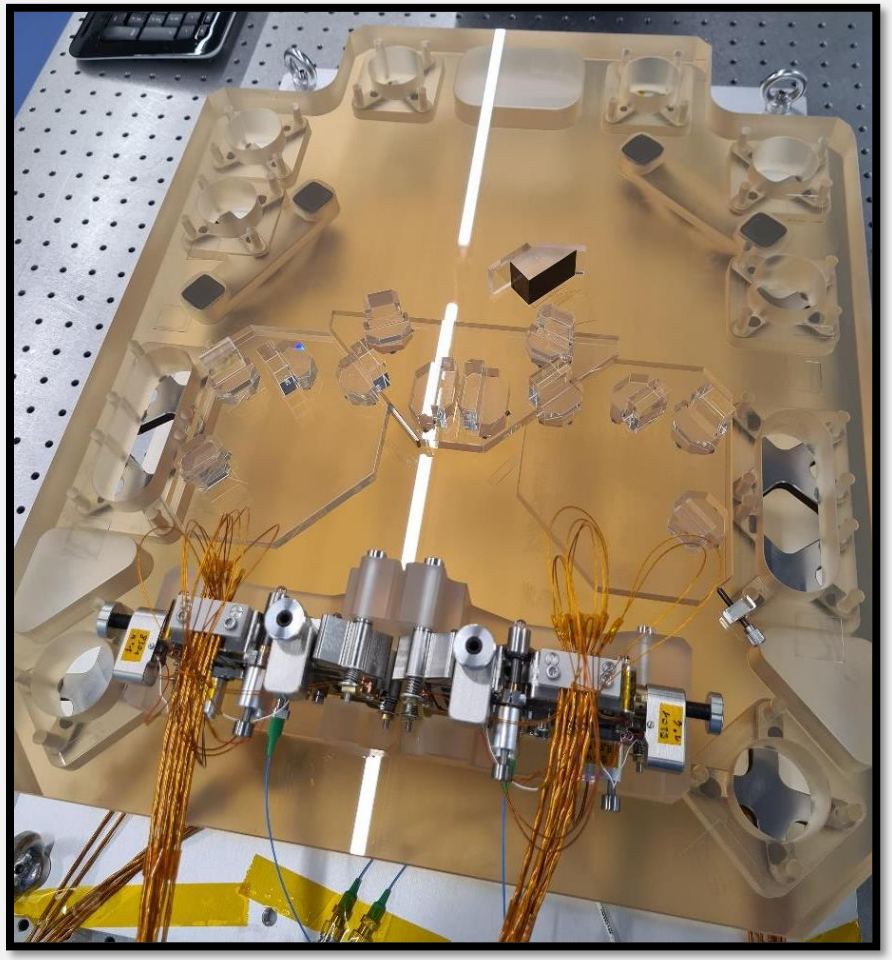
- Beams and TM simulator preliminary designs
- Photoreceptors improvements
- Mechanical and thermo-mechanical studies
- Infrastructures identification and sizing

MOSA test benches

- Consolidation of test plan with prime candidates
- On-going prototyping of critical techniques for FF-OGSE and SL-OGSE

Thank you!





PM3: FMT SCHEDULE