INAF ISTITUTO NAZIONALE DI ASTROFISICA
OSSERVATORIO ASTROFISICO DI ARCETRI

SPLATT

Contactless active mirrors

for next generation space telescopes

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on behalf of the SPLATT team
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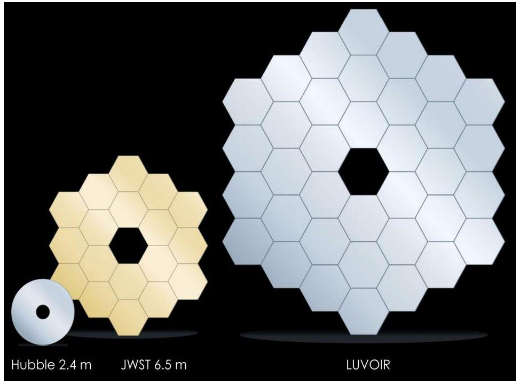
Context: next generation space telescope



Next generation of space telescopes will investigate cosmic structures, galaxies formation, exo-atmospheres,...

Science requirements include:

- High contrast
- high angular resolution
- exceptional optical quality and stability

Context: next generation space telescope

Next generation of sp
cosmic structures, ga

Science requirement
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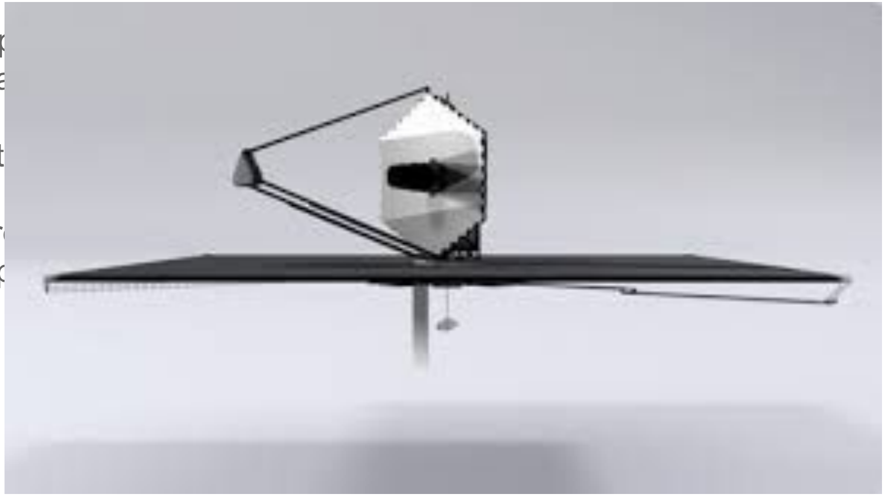
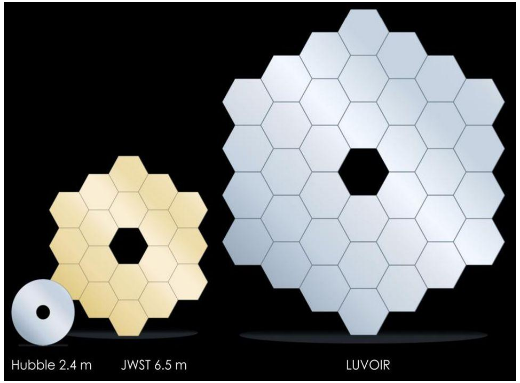




Active Optics:

crucial technology to meet REQ
and reduce mission cost.

BTW these values are beyond our current capacity →

Requirements for ExoEarth Imaging

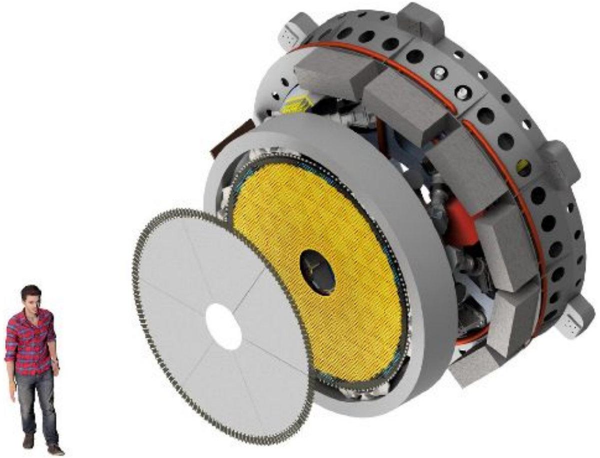
~10 m diam.
~10 nm surf err
~10 pm stability
~10^{-10} contrast

Open question:

How can ground base AO contribute to LUVOIR?

E-ELT adaptive M4

6 segments
2.5m diam.
5300+ actuators
10nm Surf Quality
incl. phasing



The LATT Project

A 2010 project on Space Active Optics:

Testing the **conversion** of the **Adaptive Secondary** into an **Active Space Primary**

Proven with a demonstrator:

17Kg/m^2, 55mW/act, 19 acts.

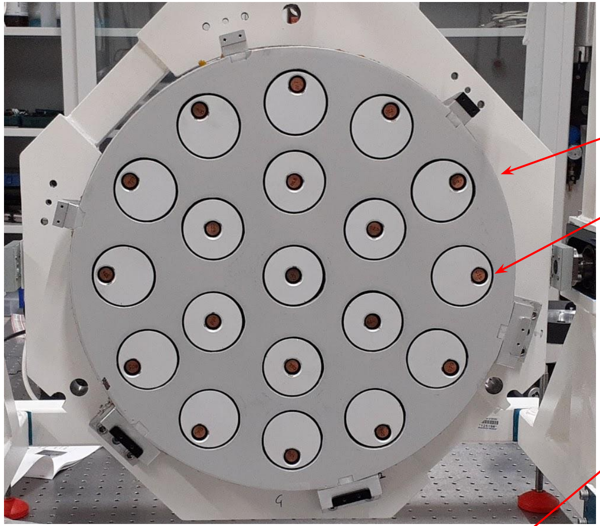
1 mm stroke, TRL 5

Laboratory tested.

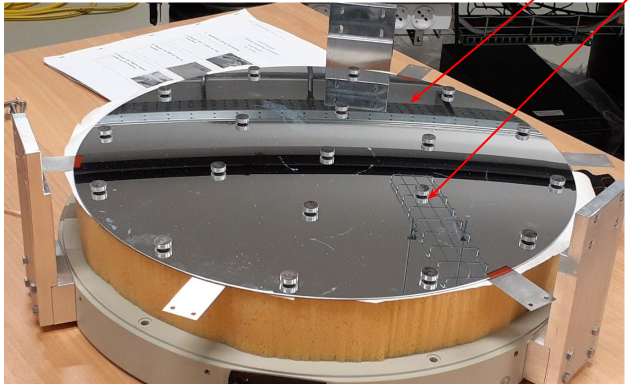
Project ended in 2015.

Prototype recovered in Arcetri under a loan agreement with ESA in 2021.

LATT - working principle



- Reference Body, Aluminum honeycomb
- Voice coil actuators
- Capacitive position sensors



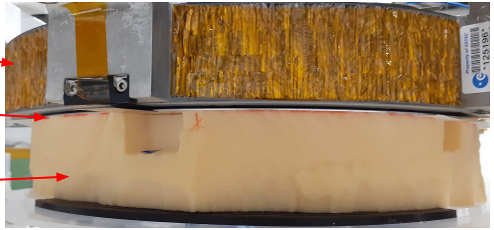
- Thin Zerodur glass shell as **optical surface**
- magnets on the shell back

The ThinShell "**floats**" at 100-800um from RefBody

RefBody

Floating ThinShell

safety foam
(5 mm below)



Contactless active mirror?

Voice-coil motors + capacitive sensors
provide a contactless actuation mechanism
(100-800 um gap from RefBody to optical surface)

A breakthrough in space optics?

- shape error of support have no impact on optical quality
- low freq. deformations are corrected with 0% fitting error
- optical surface is insulated from vibrations from payload

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- **mechanical decoupling → Requirements "separation":**
  - **ultra light-weight structures, simplified components, reduction of mass and cost**

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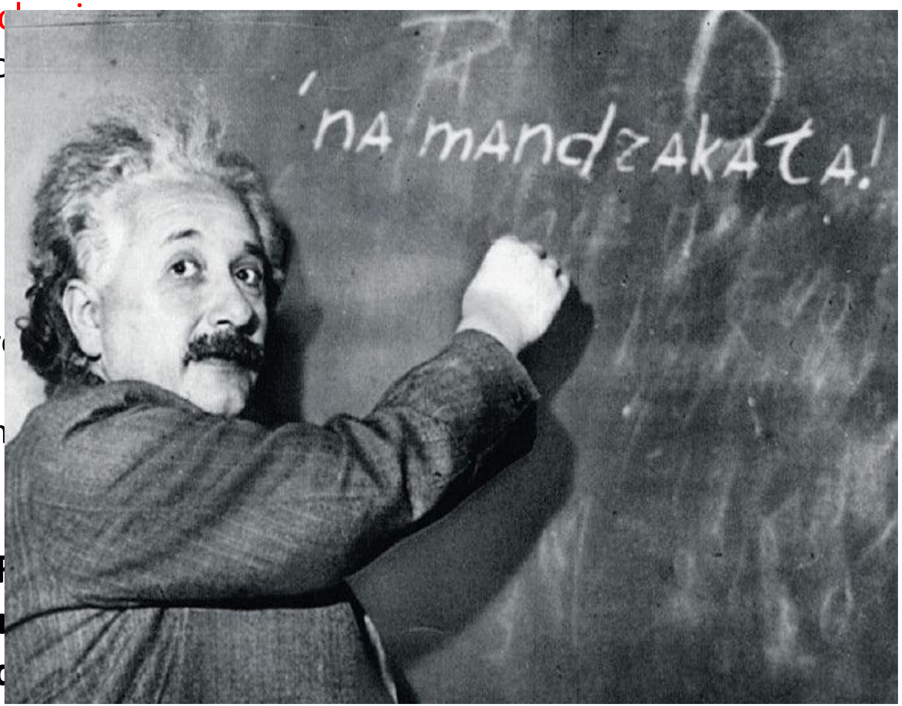


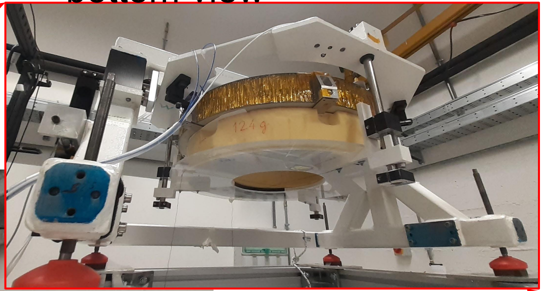
The SPLATT experiment

Goal:
demonstrate that the “floating” optical surface is insensitive to vibrations

Funded by PRIN INAF 2019 - funded in 2021
137 k€, to recover the prototype and set-up the test tower

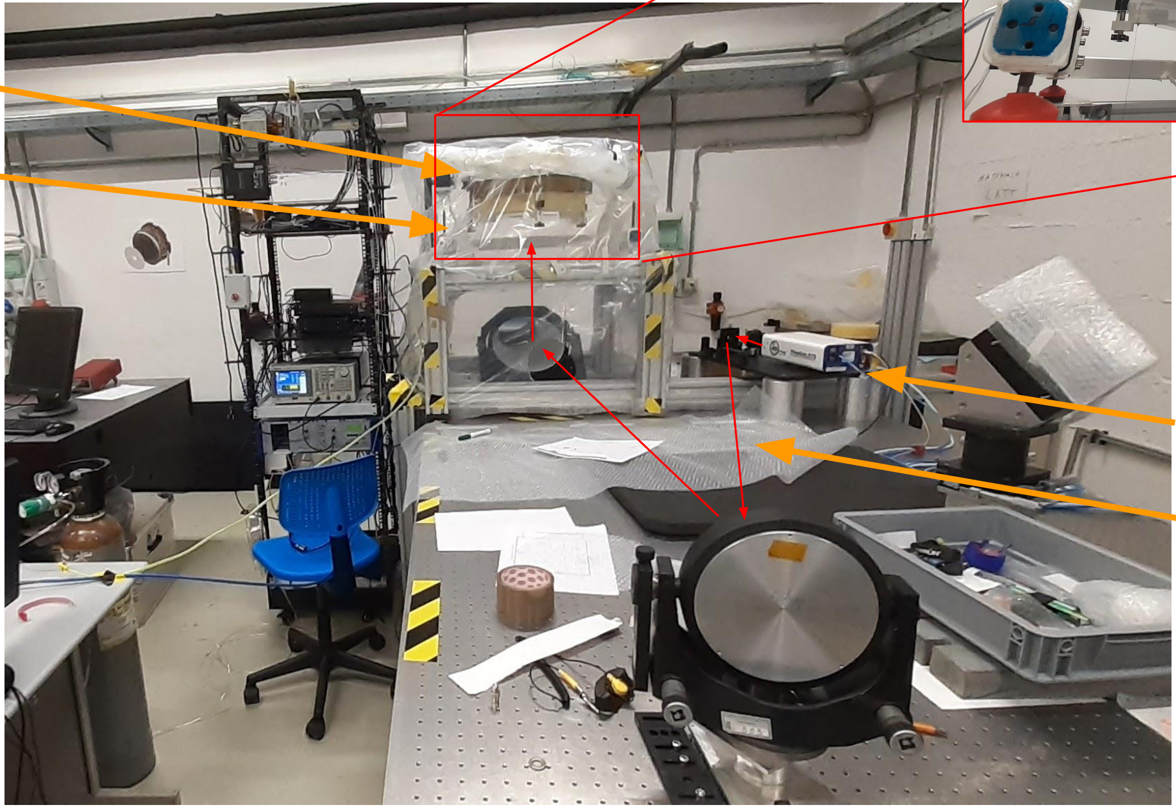
Laboratory setup (2022)

bottom view



LATT prototype

Helium chamber



Fast interferometer

optical path

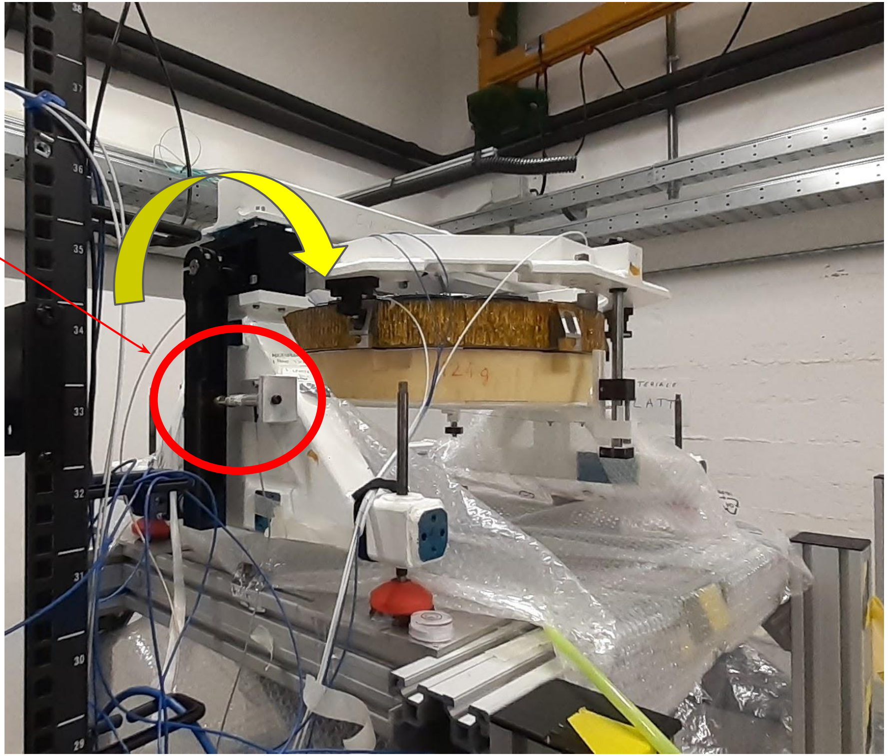
Vibrations injection

Piezo actuator on elevation arm,
to inject controlled vibration on the support.

Vibration signal from waveform generator.

Freq range:1 Hz to 120 Hz

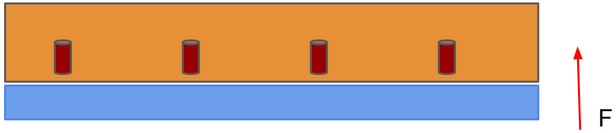
seismic accelerom. on the stand and RefBody



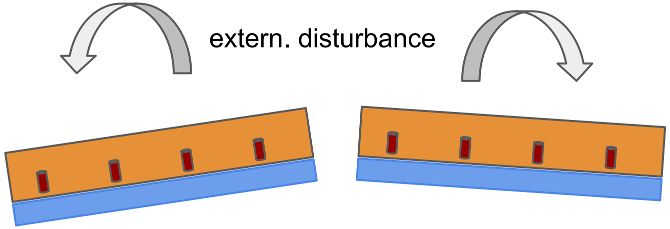
Vibration test procedure

We measure the TipTilt with a fast interferometer, when an external disturbance is applied

1. tilt TT_L when the ThinShell is pressed against the RefBody by the actuators



1. ThinShell lifted. lifting force F>shell weigth



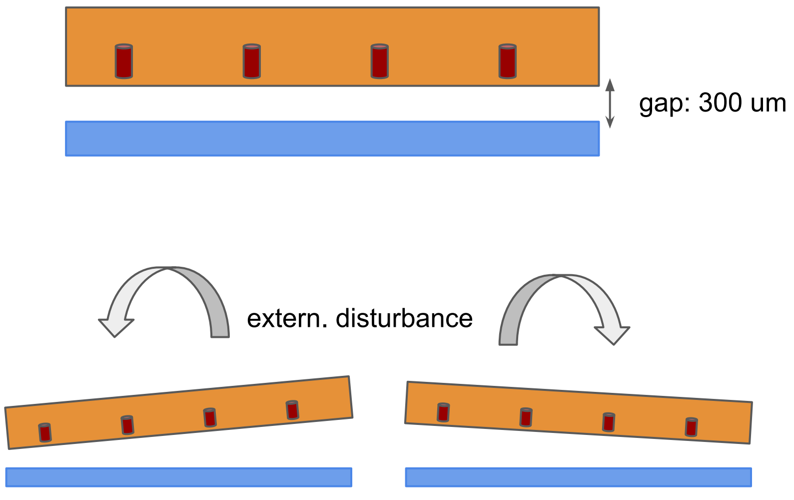
Vibration test procedure

We measure the TipTilt with a fast interferometer, when an external disturbance is applied

1. tilt TT_L when the ThinShell is pressed against the RefBody by the actuators

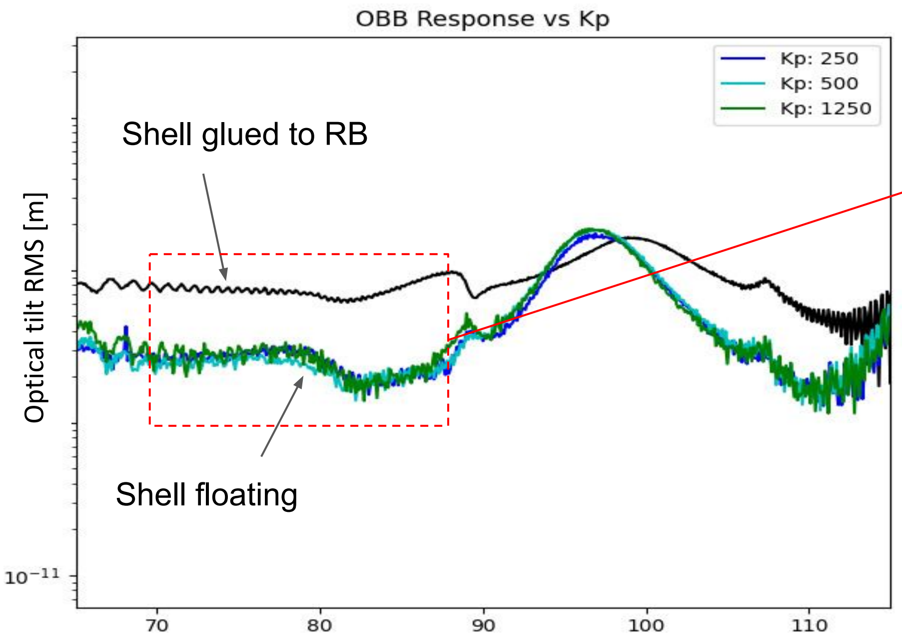
2. tilt TT_F when the ThinShell "floats" at the working gap (100 um, e.g.)

TT_F/TT_L is the vibration attenuation



2. ThinShell floating. Tot force =0

Results of the SPLATT experiment



Resonances @40, 60, 100 Hz
but

Vibration rejection > 70% @70-90 Hz

Shell-RefBody coupling mediated by air??

Tests to be repeated in vacuum chamber, next month…

Conclusion

Contactless, floating active mirrors:
could be breakthrough for next generation space telescopes

Physical **decoupling** between mech. support and optical surface:

→ improvement of scientific performances
  lower vibration foot-print
  lower thermal foot-print

→ reduction of system-wide requirements
  ultra light-weight structures, lower manufact. specs,
  simpler REQ., mass&cost reduction

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Project funded by INAF-PRIN Tecno
137k€ for setting up the ***facility*** *and demonstrate the concept*

Grant from INAF was "necessary" aid as startup:
- out of scope for ESA/ASI (TRL and uncertainties)

The team just participated in the ASI "TopicalTeams"

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Results presented at:
SPIE2022
ICSO2023

to be presented at
ESA-ESTEC nov23

Strong synergy within INAF / ADONI:
- Wavefront sensing
- Control strategy
- Scientific sampling for high contrast

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Active optics for space:

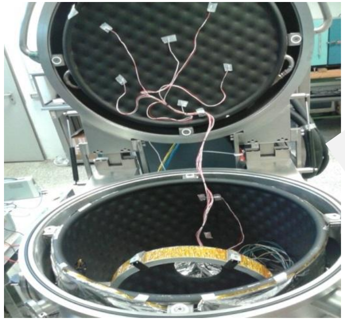
INAF can be a game changer.

What's our next move?

backup

Laboratory test campaign

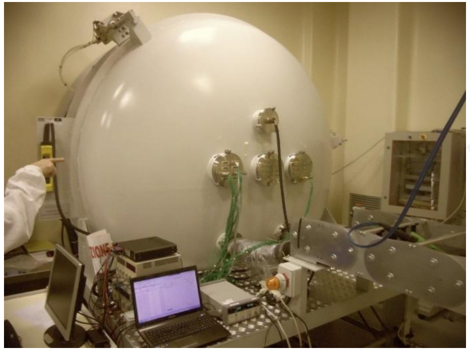
Thermal test



DONE

Temperature range: -25°C□55°C

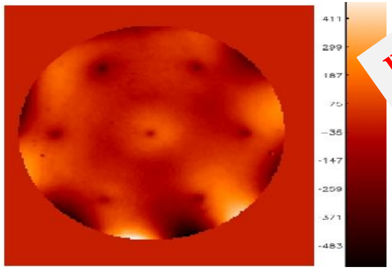
Thermo-vacuum test



DONE

Tested @ 1e-5mbar

Optical test



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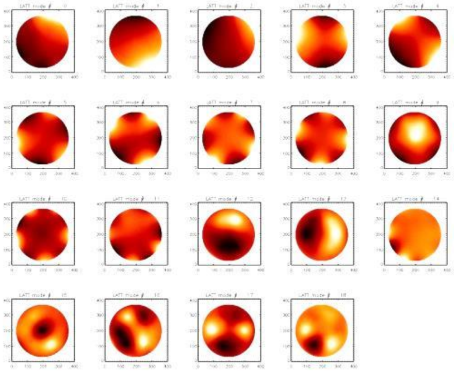
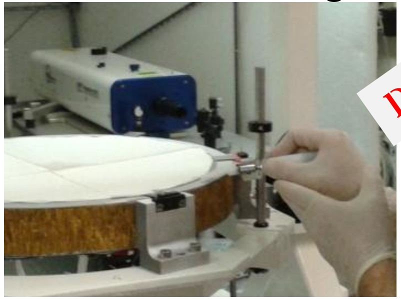


WFE comparable with AO DM

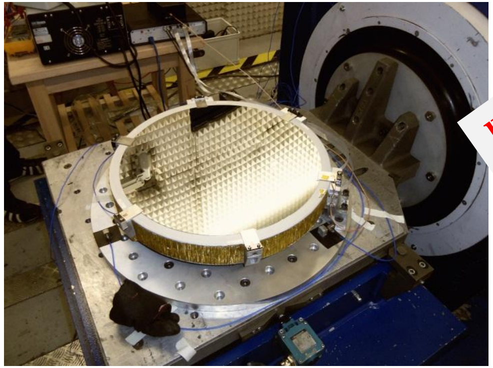
Electrostatic locking test



DONE

locking pressure: 600 N/m2

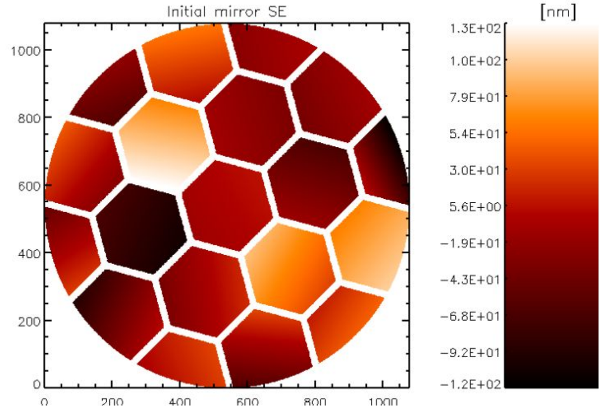
Vibration test

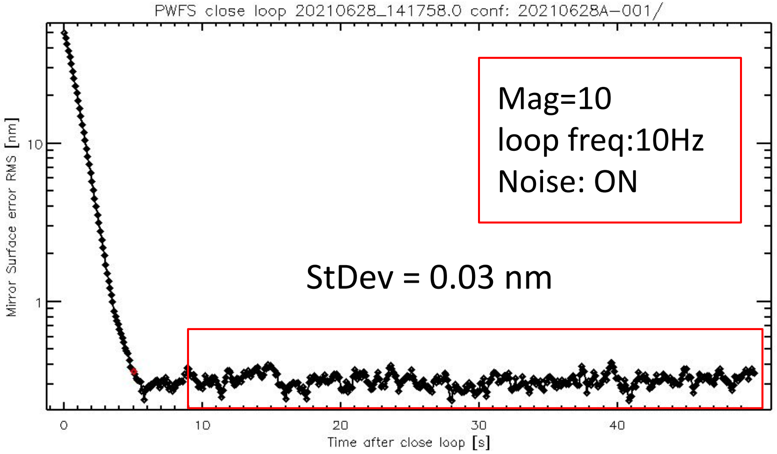


DONE

Max acceler.: 10g

Close loop result: sub-nm stability (and sensitivity)

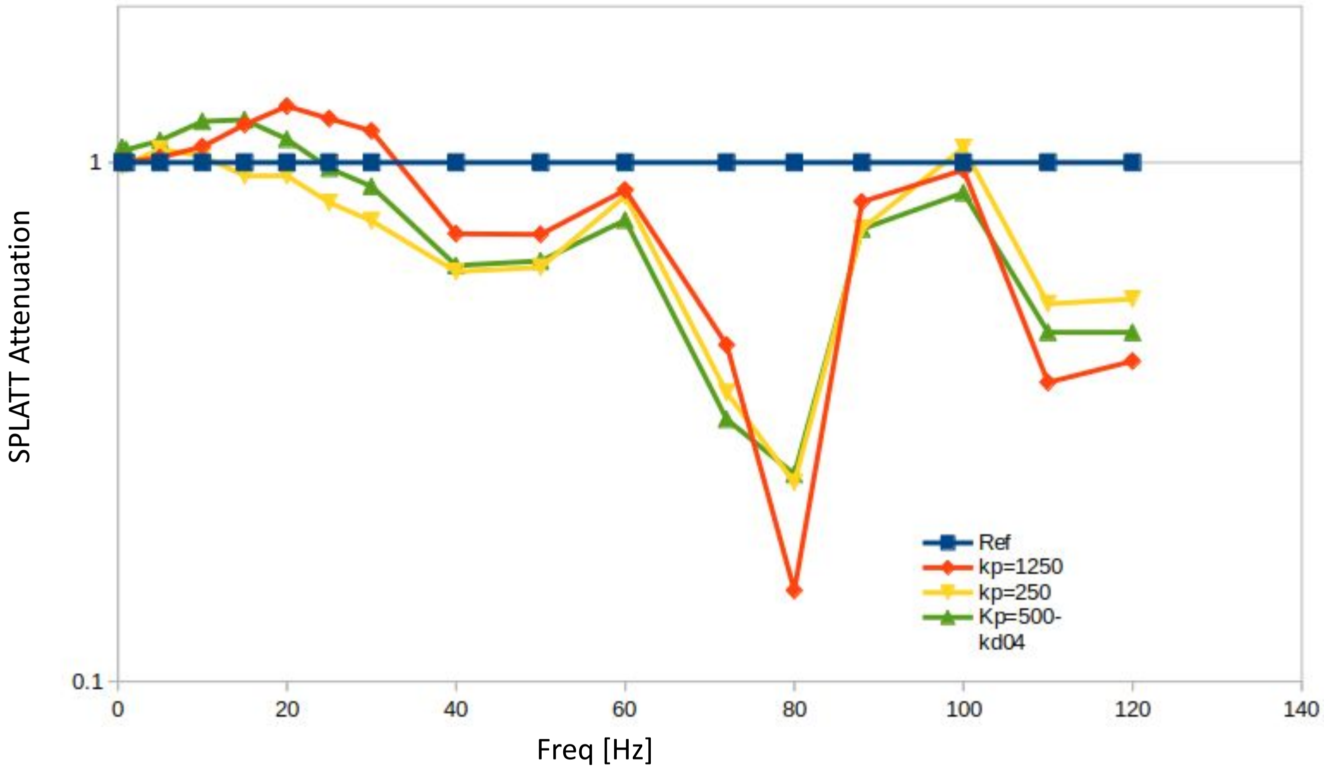




Comments in view of LUVOIR:

- value is consistent with LUVOIR REQ
- No GS V<5 needed
  - (no laser GS constellation)
- time scale: << 1 min (relaxed stability REQ system-wide)
- fast sampling → post-facto correction

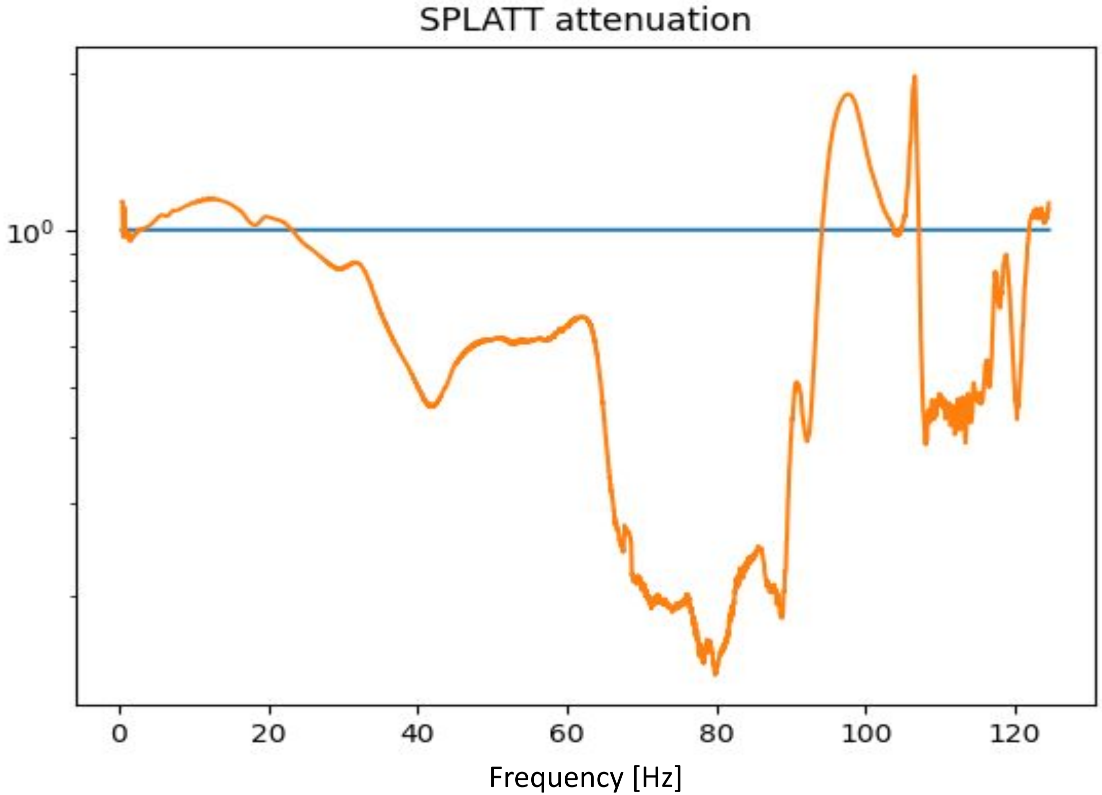
Frequency response, single frequency test



$T(freq) = T_F / T_L$

T_F : Tilt ampl. shell floating
T_L : Tilt ampl. shell lifted to RB

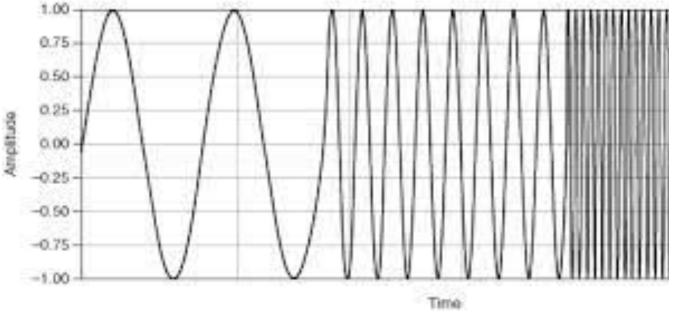
Frequency response, sweep test



Sweep measurement:

Excit.Freq variable in time
15 s to capture F range 1-120 Hz

Same processing



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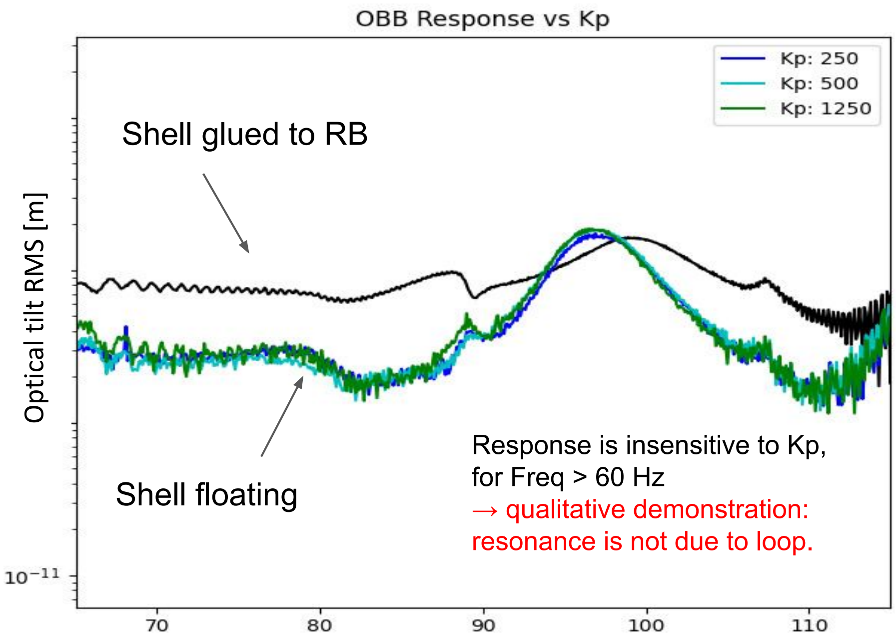
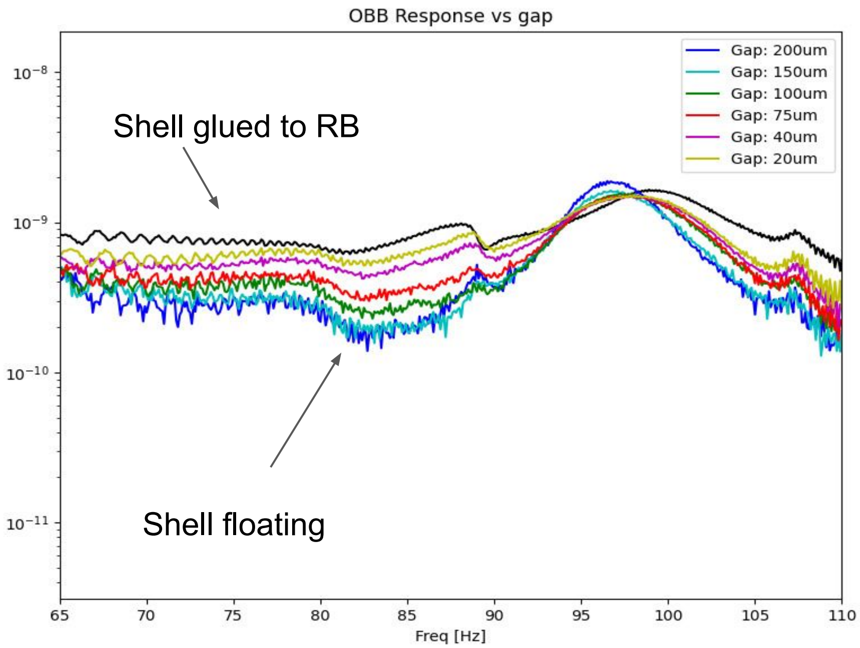
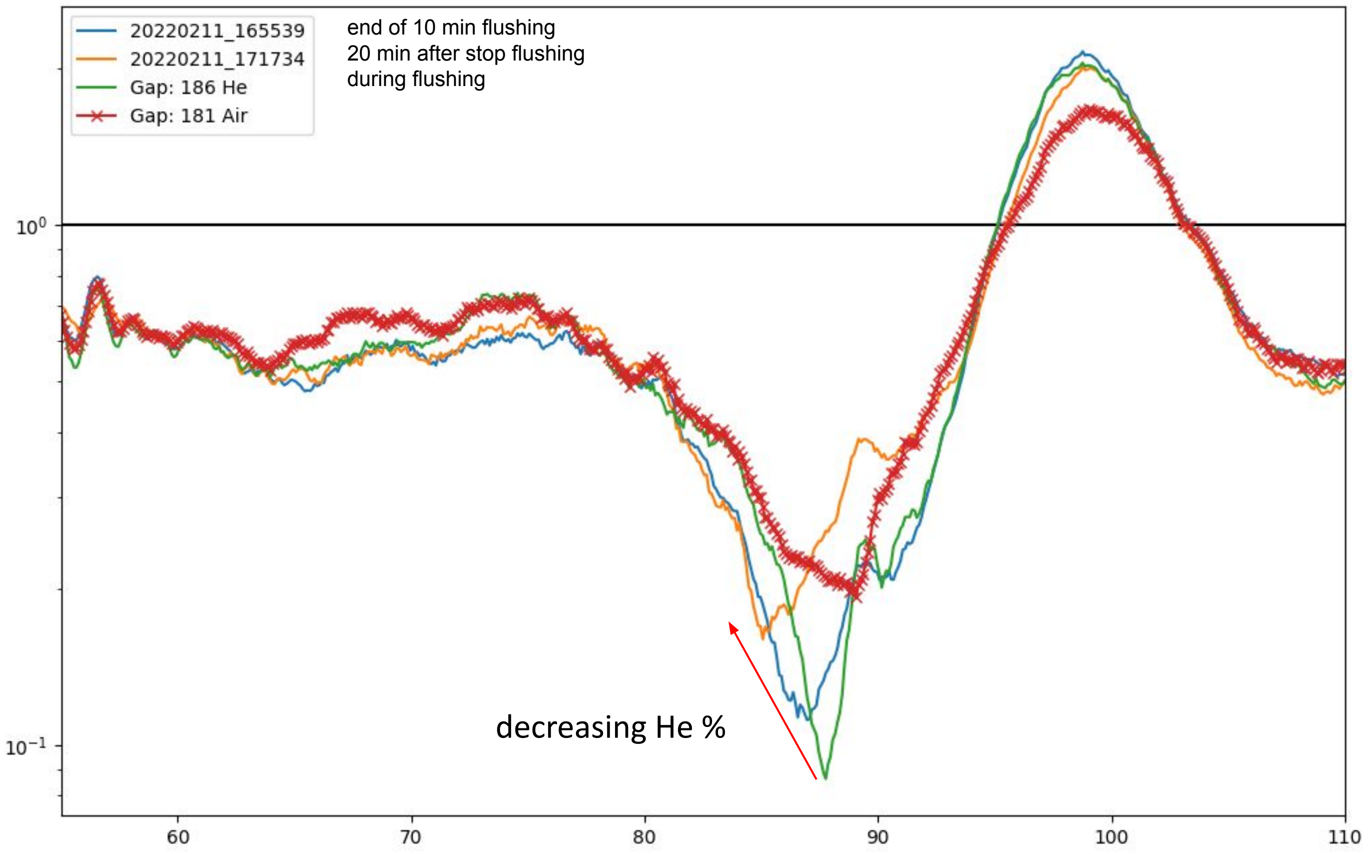


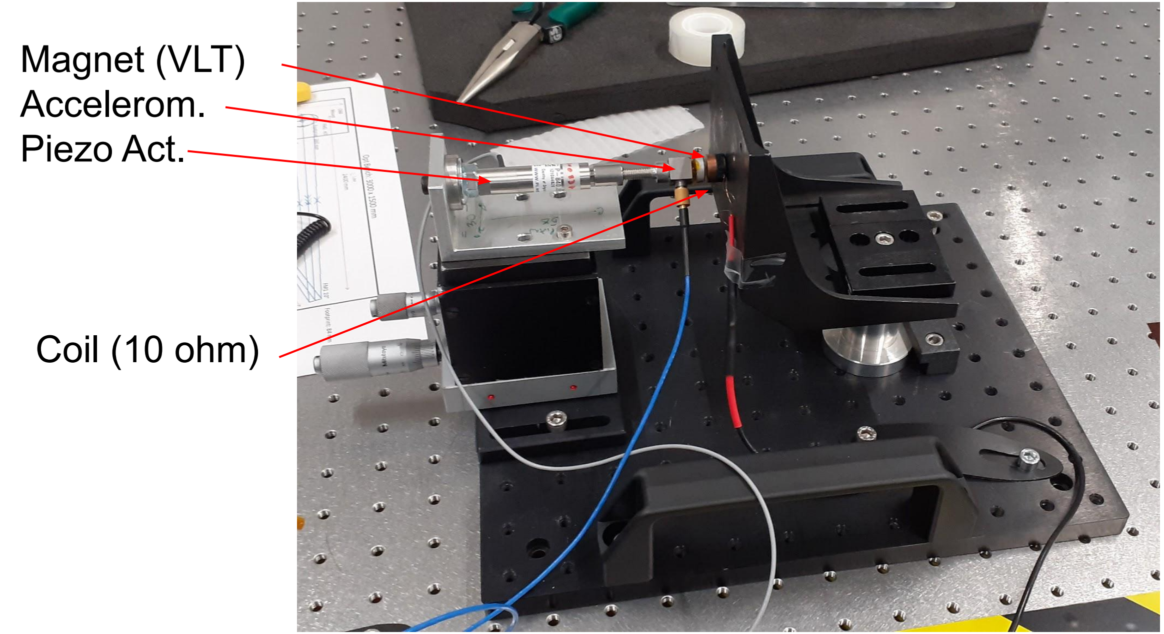


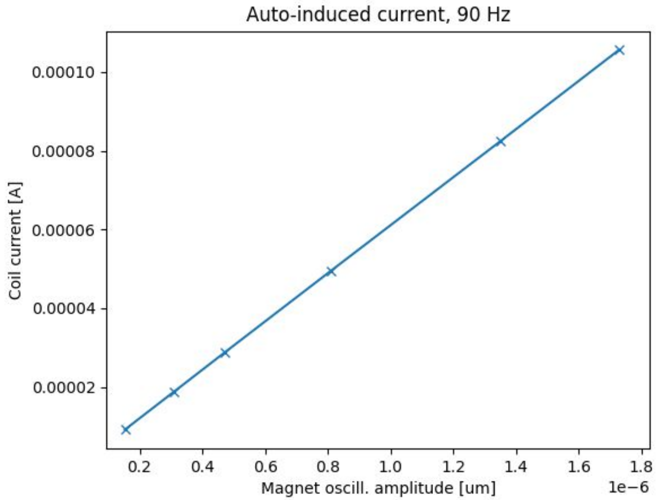
Vibration rejection vs Actuator PID parameters, vs gap, Air vs Helium…

Frequency response, Air vs Helium



Measurement of auto-induced current





Qualitative proof:

Auto-induced current is < command noise
driver noise could be larger