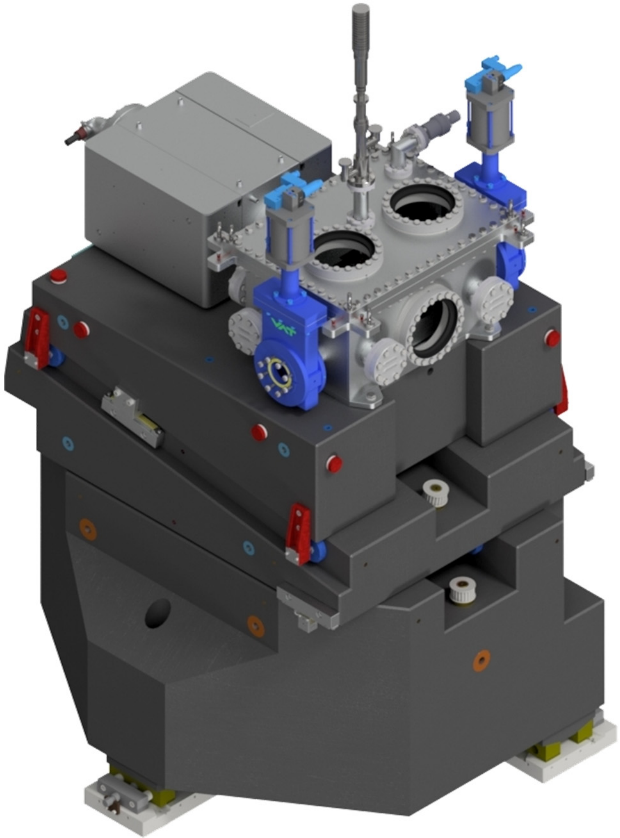
Brazilian Synchrotron Light Laboratory

MINISTRY OF SCIENCE, TECHNOLOGY INNOVATION AND COMMUNICATION

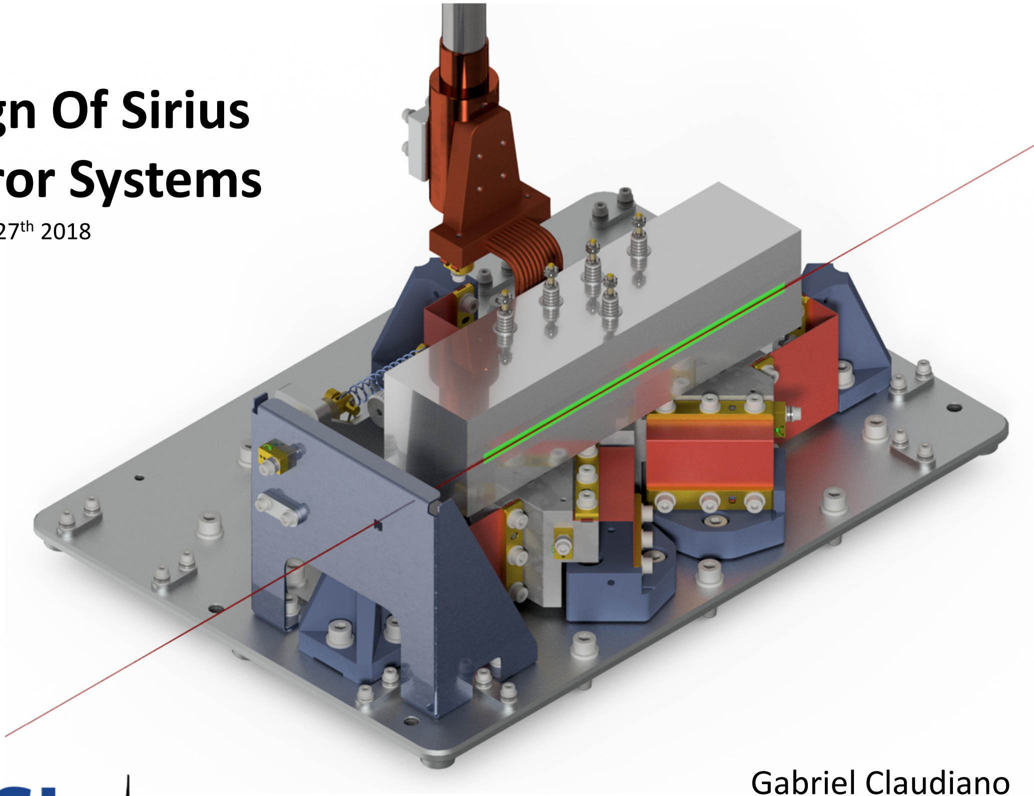
BRASIL BRAZILIAN GOVERNMENT

CNPEM Brazilian Center for Research in Energy and Materials



The Design Of Sirius X-ray Mirror Systems

June, 27th 2018



MEDSI MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

PARIS 2018

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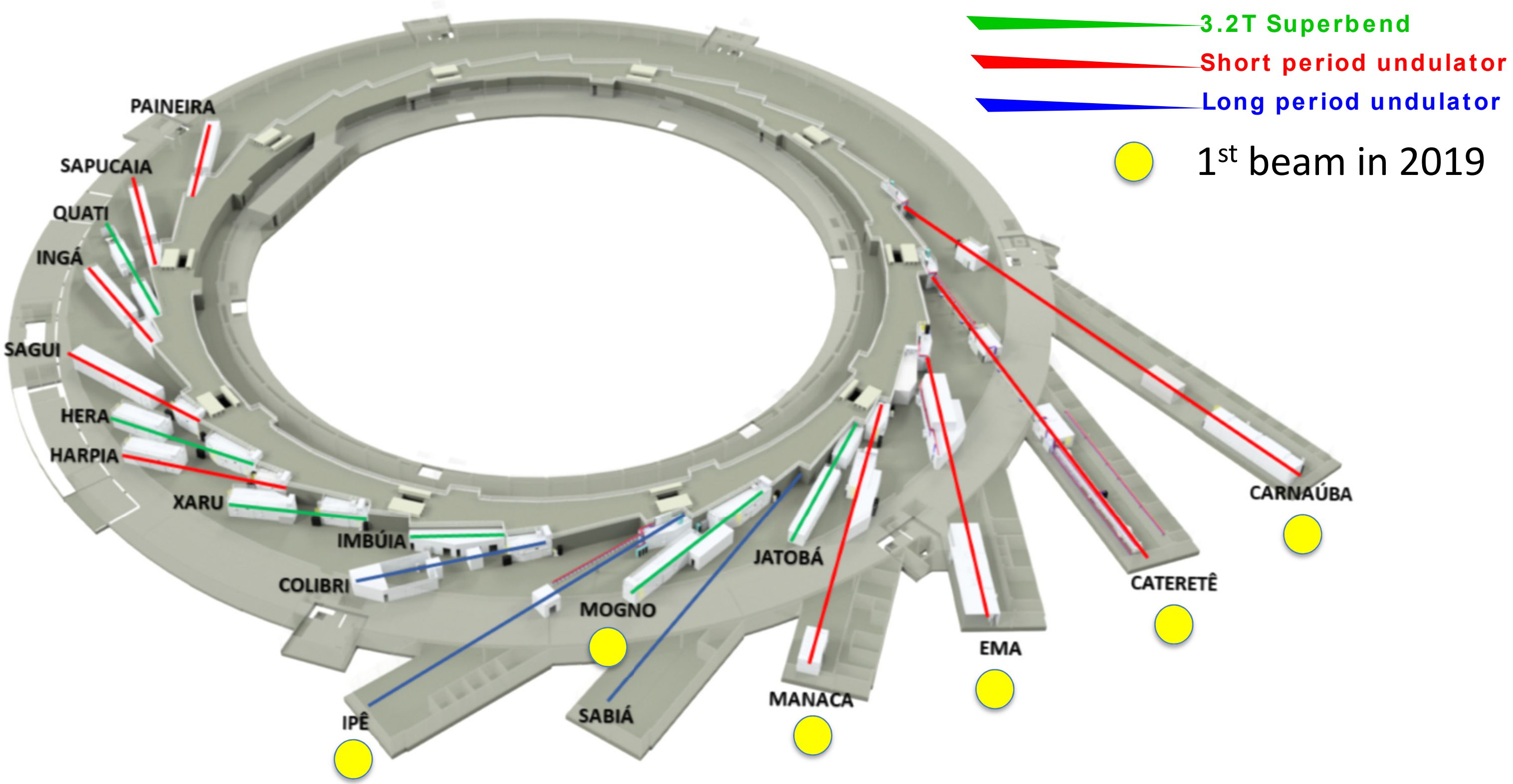
(On behalf of the Beamline Engineering Group of LNLS)

Outline

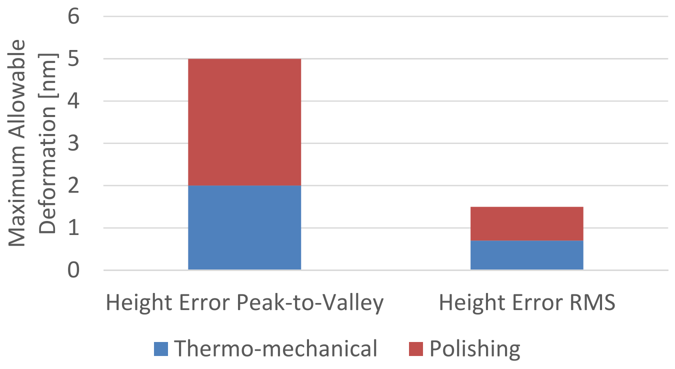
- Introduction
- Guidelines
- Concept
- Results
- Conclusions
- Next steps

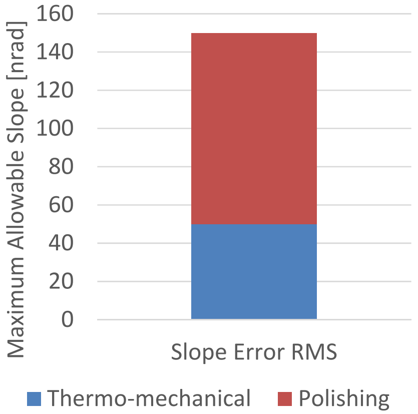
Introduction



Introduction

Description	Typical Specs
General Stability:	1 μm / 1 μrad
Pitch (Ry) stability:	0.1 ~ 0.5 μrad
Power load:	< 50 W
Peak-to-Valley Error:	5 ~ 30 nm
RMS Height Error:	1.5 ~ 10 nm
Slope Error:	150 ~ 300 nrad





Guidelines

Mirror:

- Fixed-shape
- Side-bounce

Positioning and Alignment:

- Minimum number of DoF
  - All DoF on mechanical bench
  - Fine-resolution in-vacuum DoF

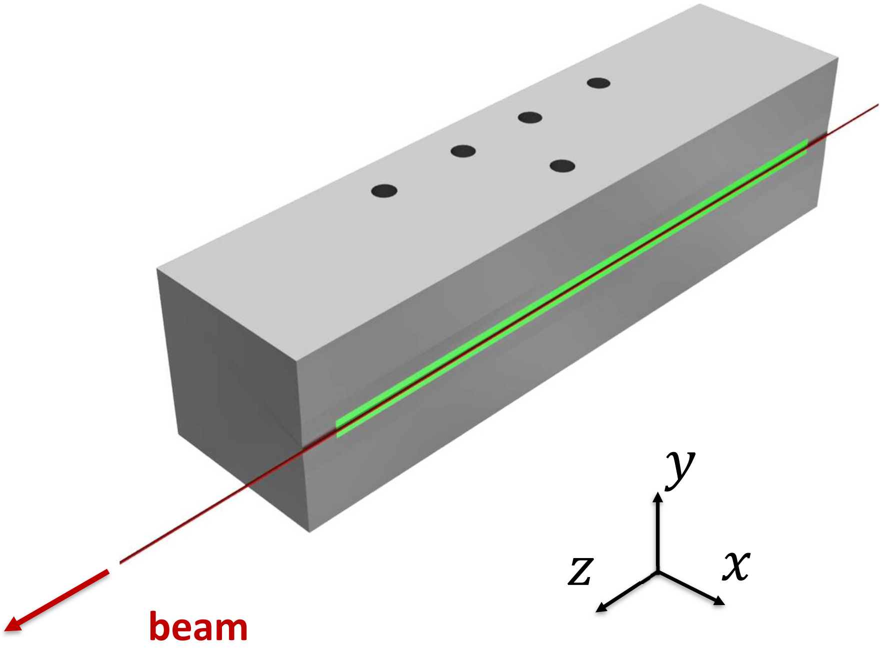
Designing for Stiffness:

- Simple and deterministic design
- Design for high eigenfrequencies
- Reduction of the number of interfaces

Cooling and Thermal Control:

- Avoiding complex mechanics
- Minimization of vibration sources

Introduction



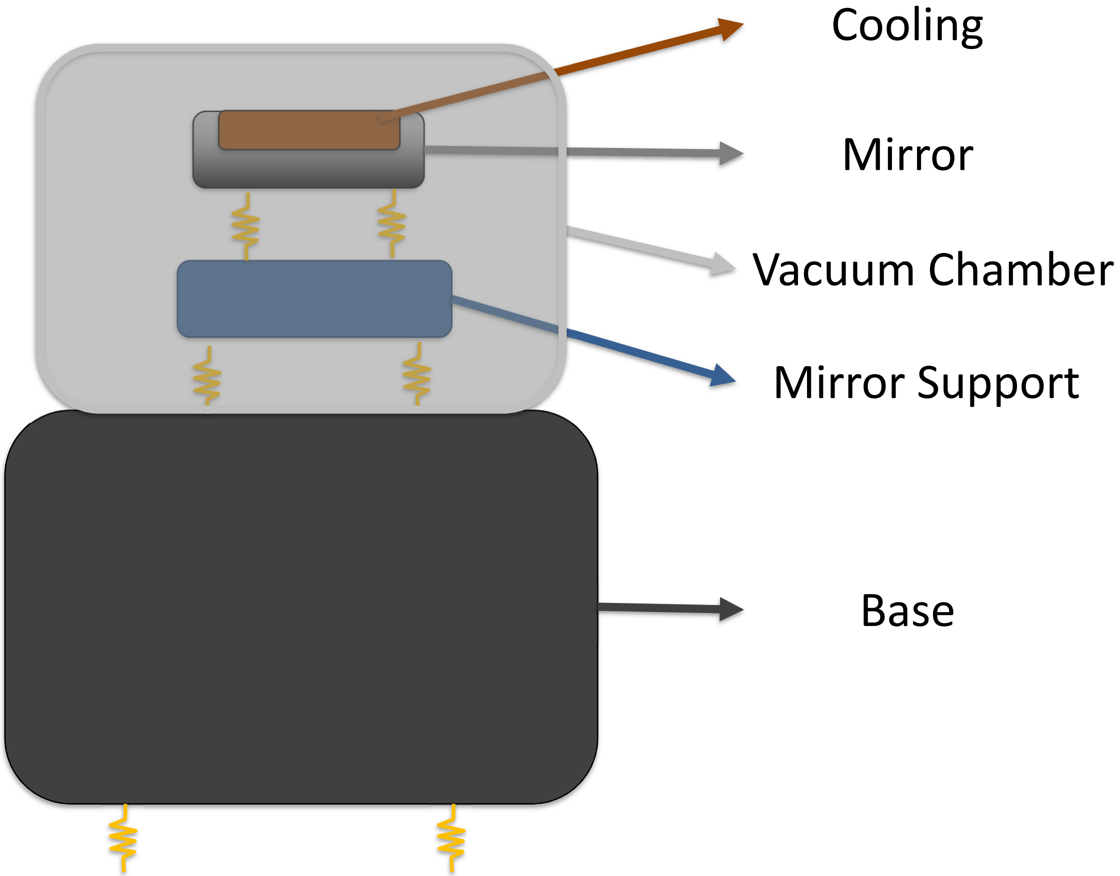
Coordinate System:

Z-axis: beam axis

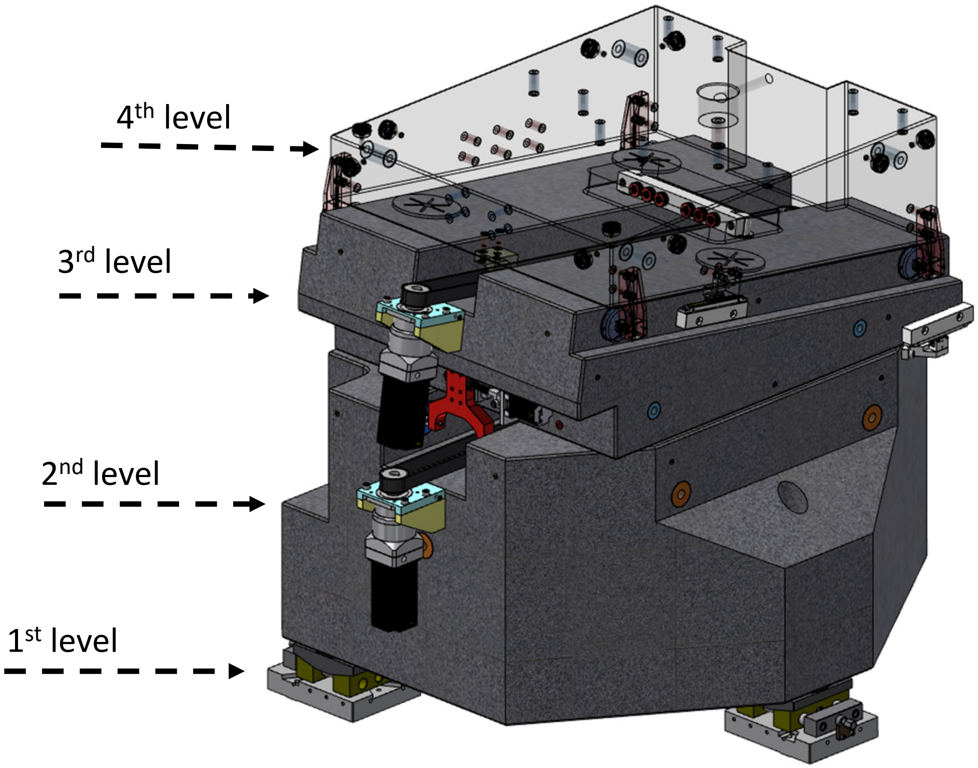
Y-axis: vertical axis

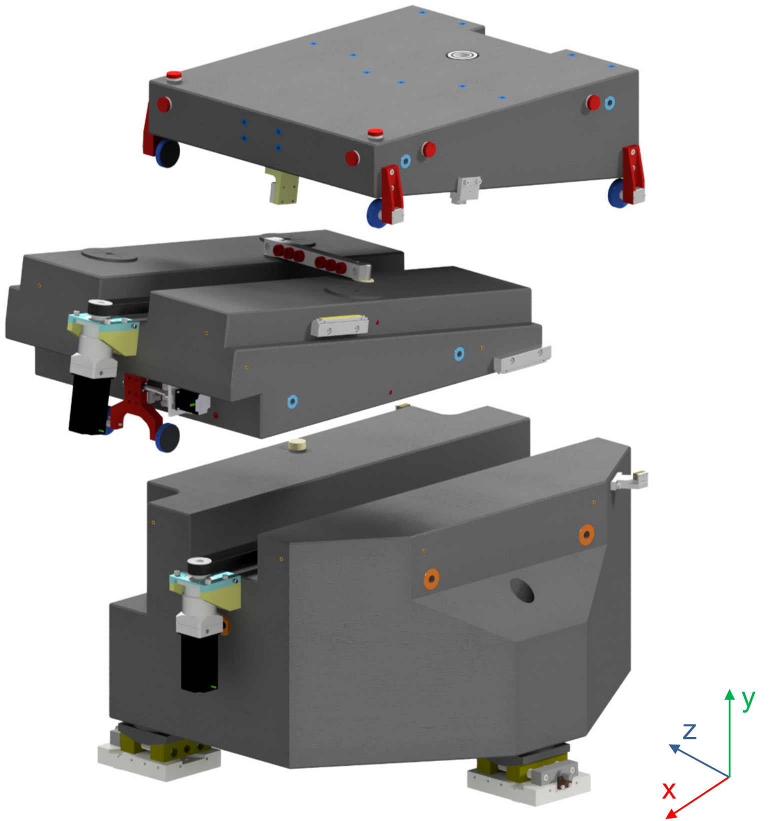
X-axis: transversal axis

Concept



Granite Benches

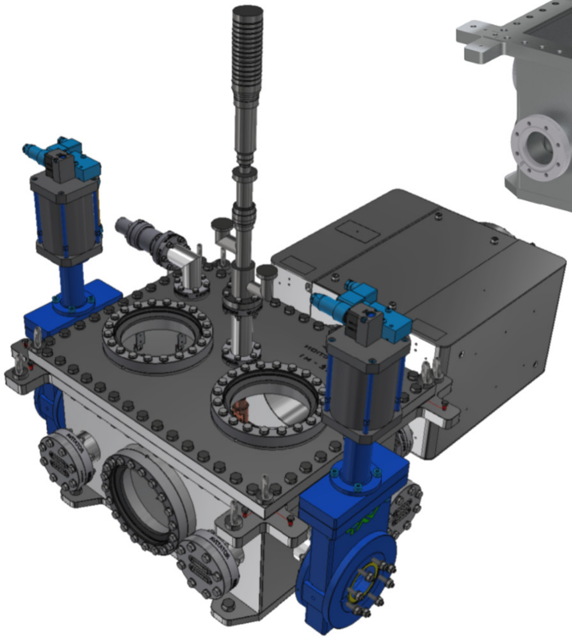


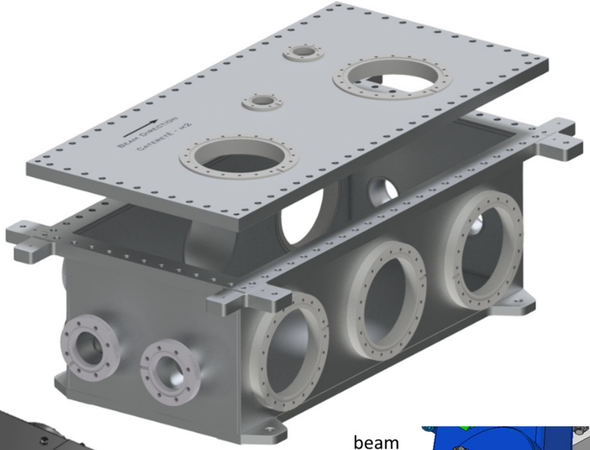


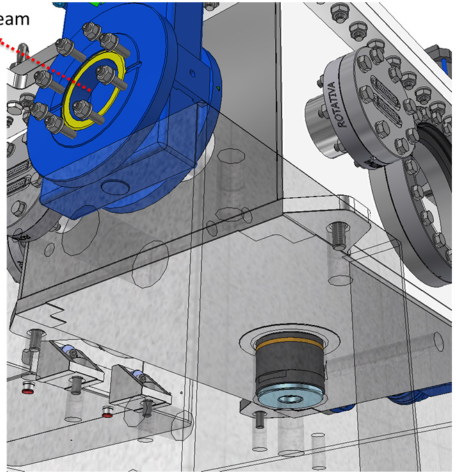
[Ref.: THPH12]

Vacuum Vessel

- Rectangular-shaped box
- Main vessel + top flange
- Deterministic contact pads
    - corners
    - center
- Pre-load
    - Bolts
    - Workpiece Positioning System (WPS)





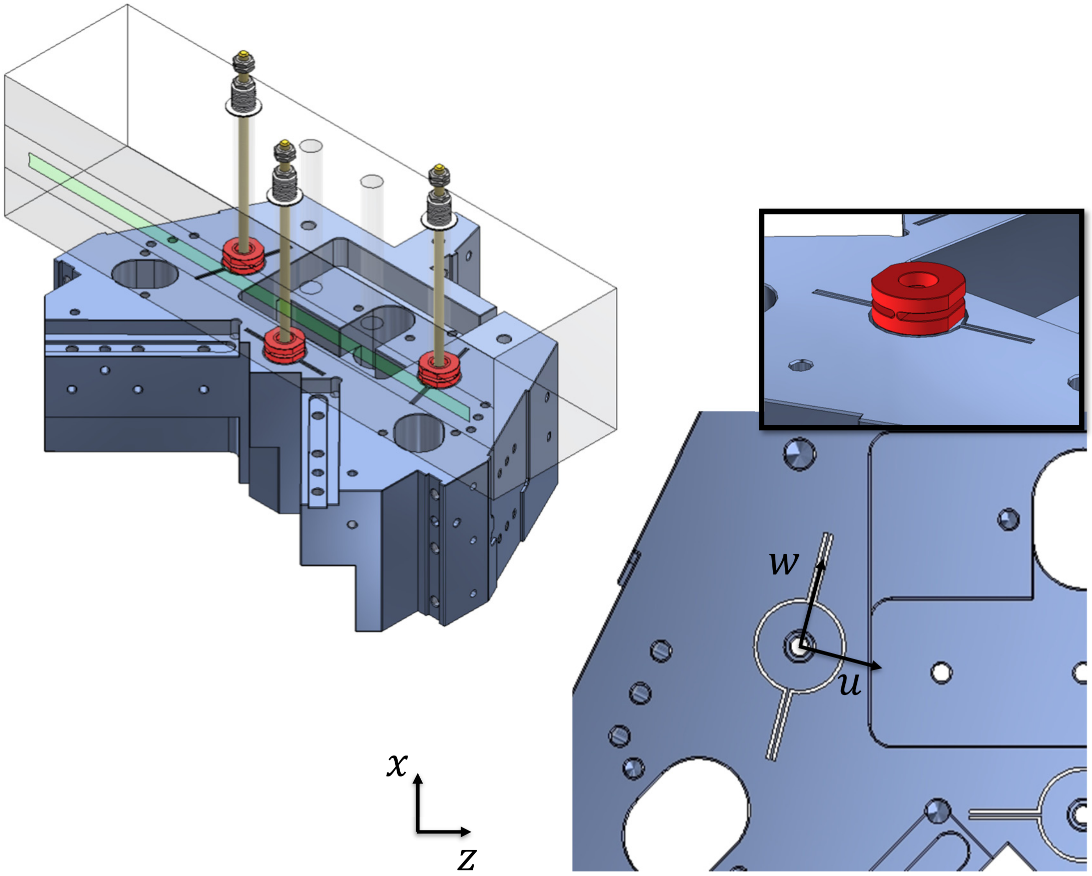


Mirror Fixation

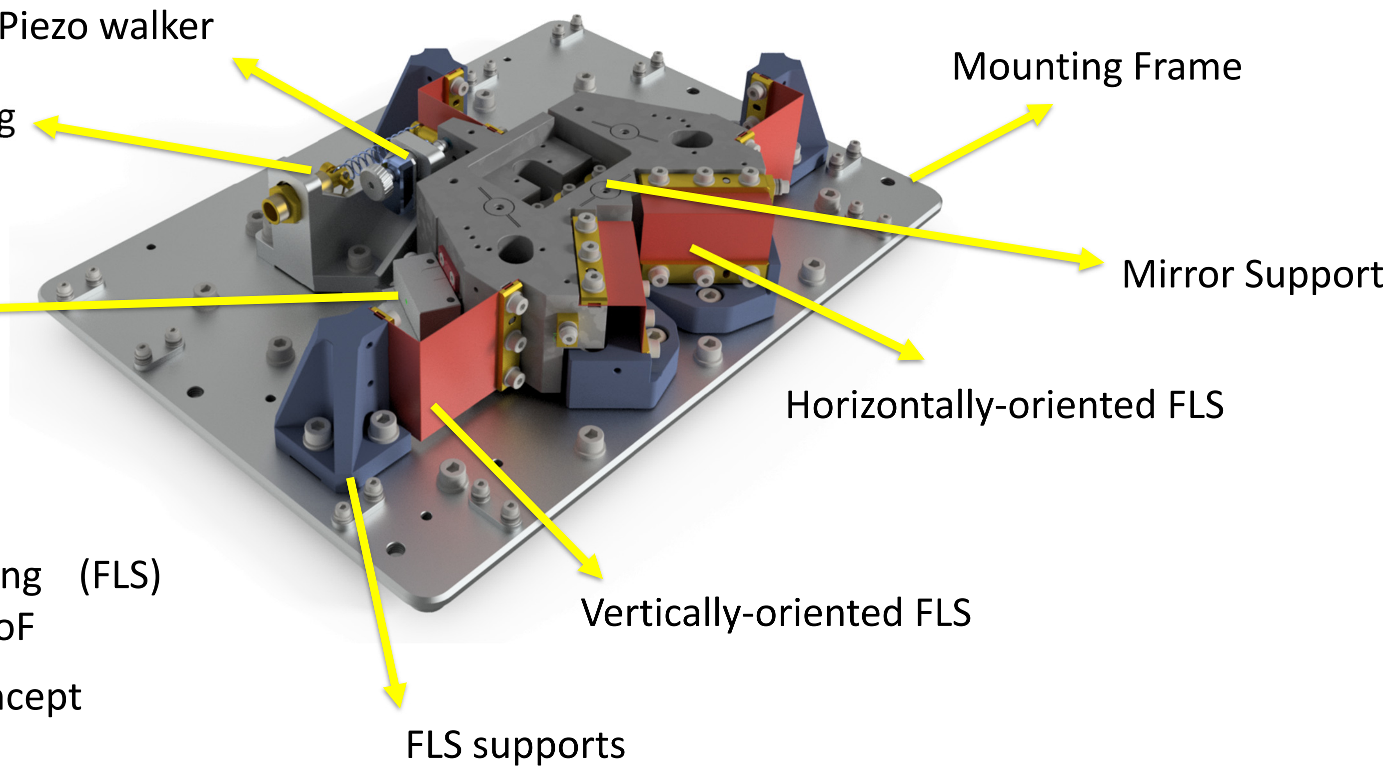
Flexures:
- Thermal expansion effects accommodation;
- Deterministic thermal center.

Hinges:
- Compliant rotation.

Flexures + Hinges:
- Deterministic quasi-kinematic mount, with emulated spherical joints;
- High-stiffness assembly with controlled thermal and mechanical deformations;
- Customized thermal resistance links.



Internal Mechanics



- Each folded leaspring (FLS) constrains only one DoF
- Nearly frictionless concept
- Repetitive behaviour

Internal Mechanics

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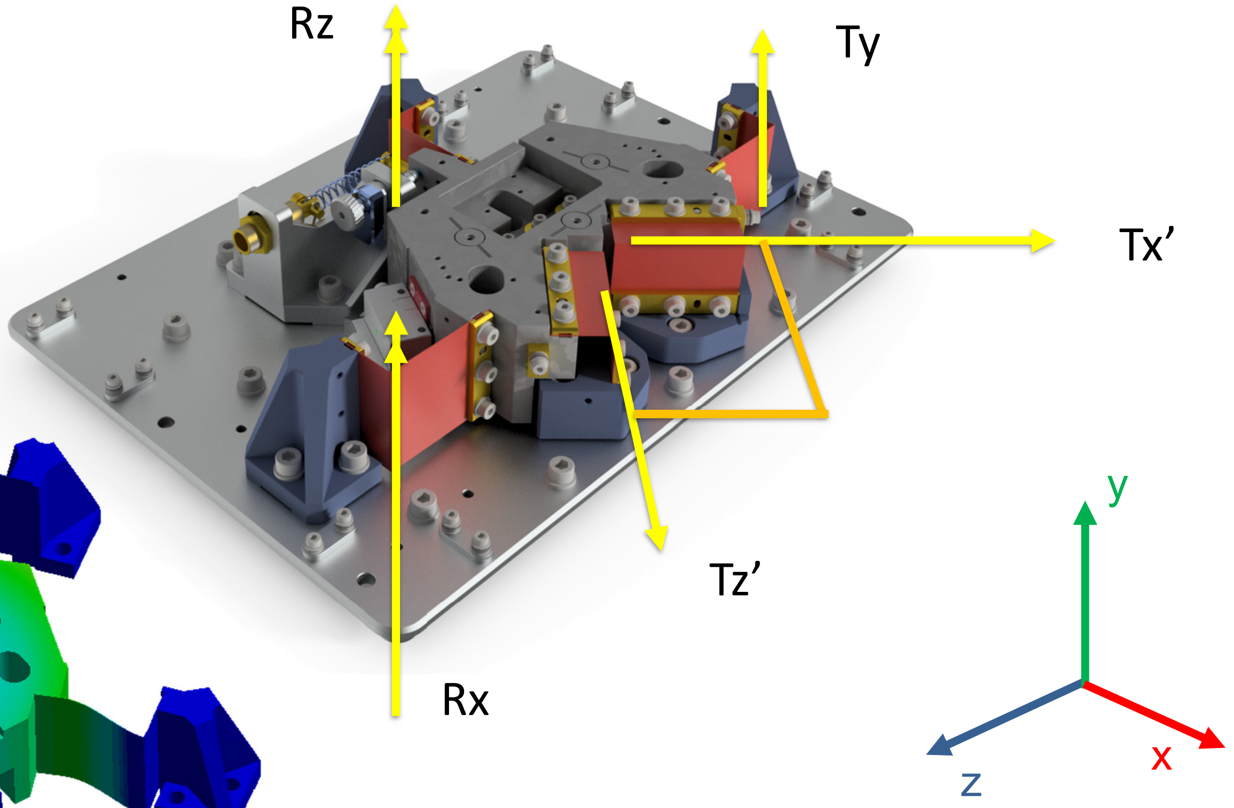
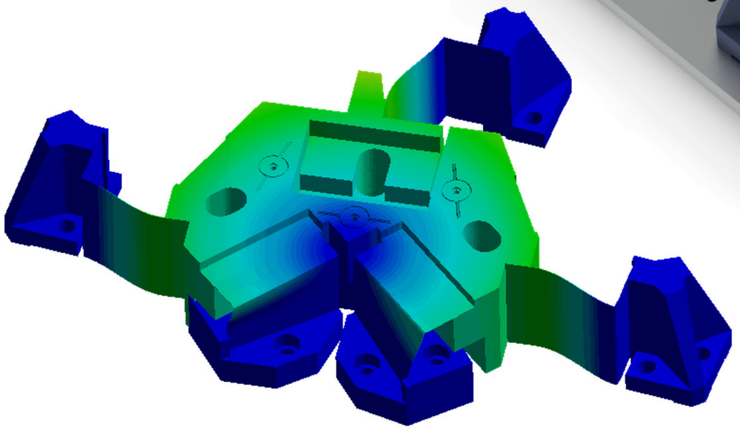
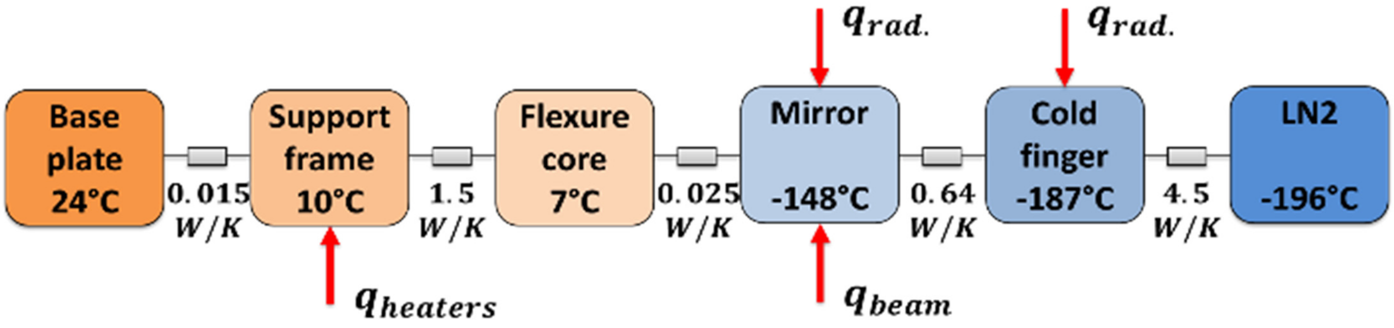
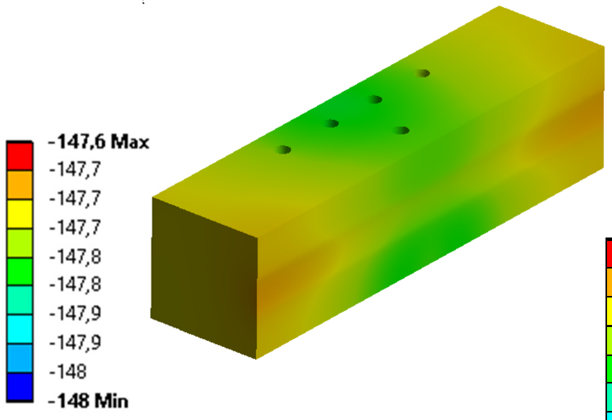
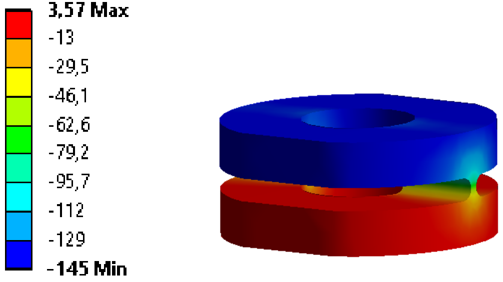


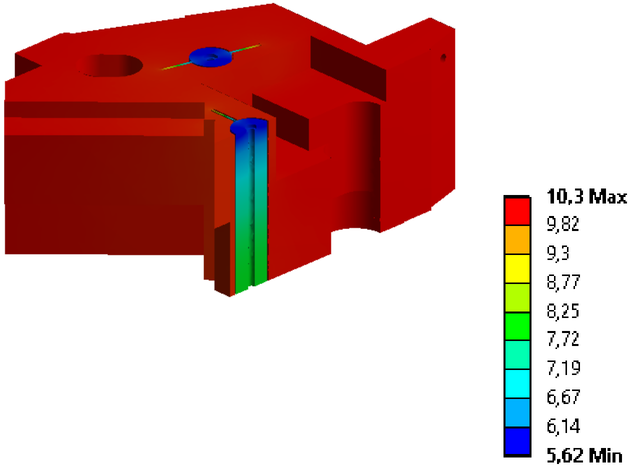


Thermal Management









Cooling

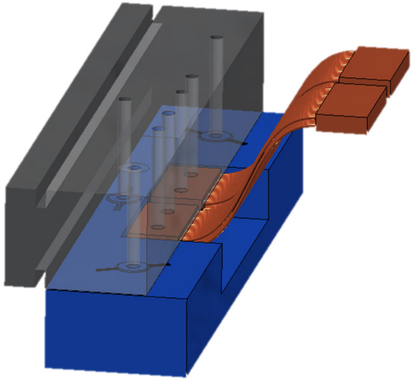
Cryostat + copper braid:

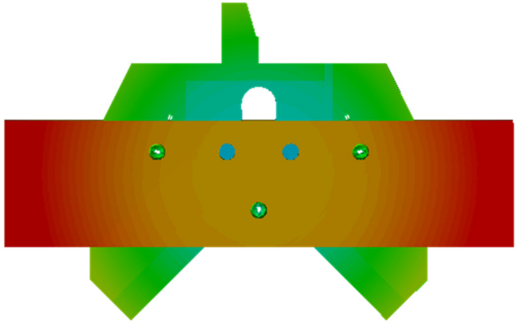
- Indirect cryogenic coolinng
- Decoupling from disturbance sources

Silicon @ 125K:

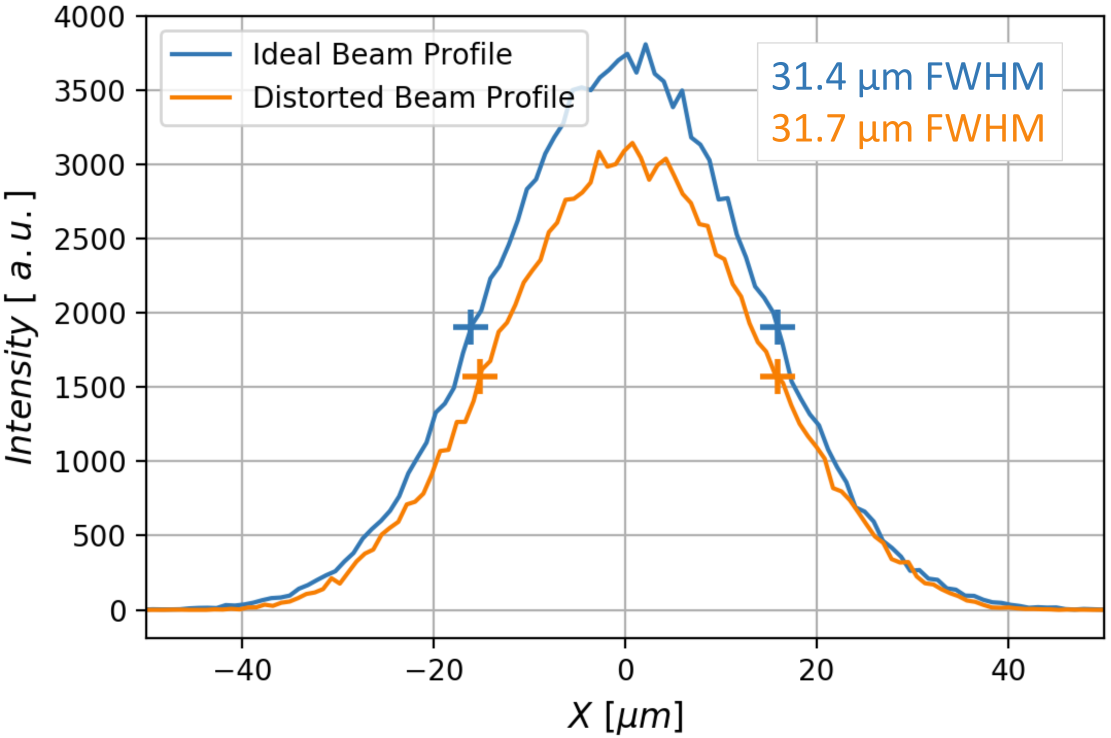
- High thermal conductance
  - Beam power dissipation
- Low coeficiente of thermal expansion
  - Reduced thermal bumps

Matching of secant thermal expansion coefficients:





Simulations: Figure Error



Combined effects from different sources:

- Gravity
- Thermal
- Bolt tightnening
- Mirror polishing
- Manufacturing limitations

[Ref.: WEPH31]

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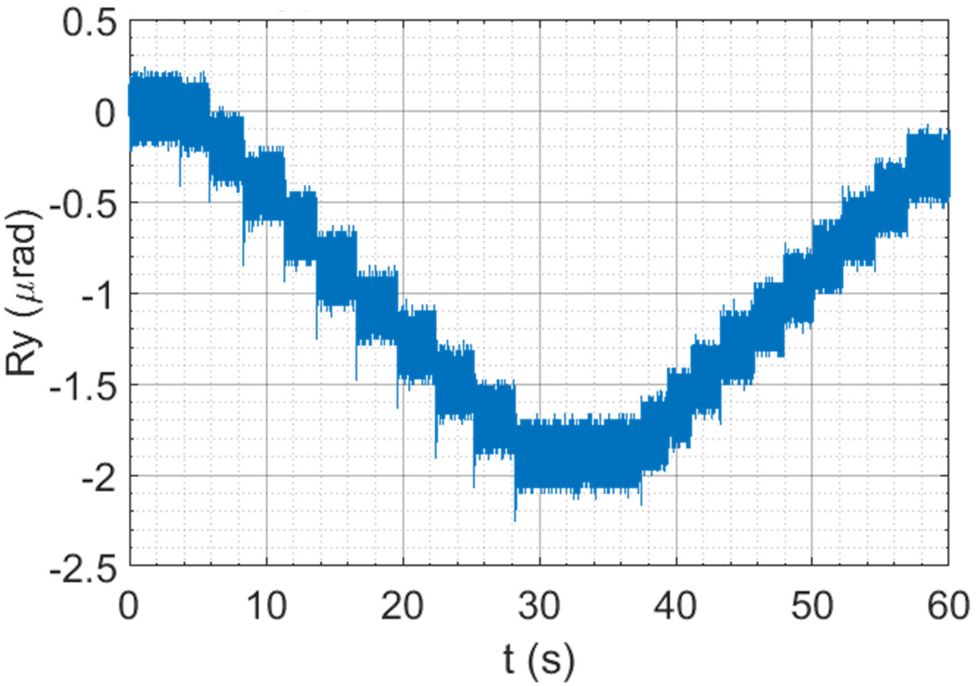
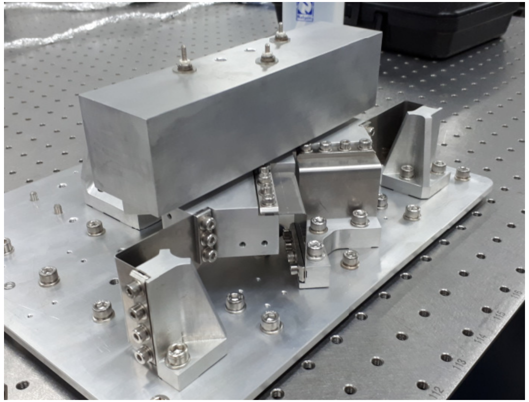
Results – Prototype

CNPEM

Open-loop Resolution:





Prototype:

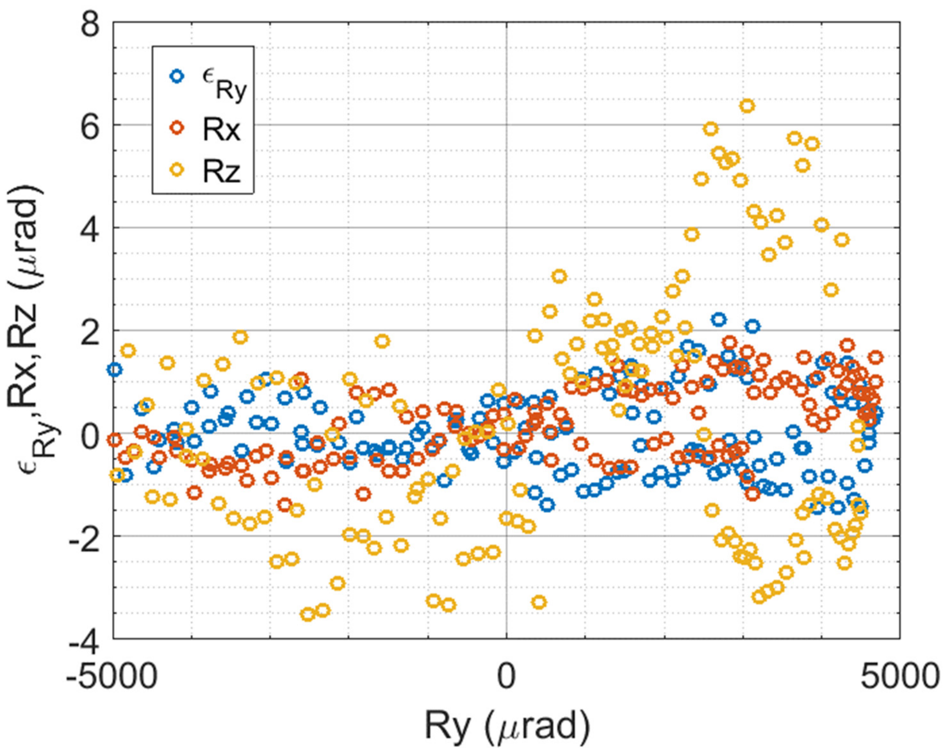
- Piezo walker with 22nm step resolution
  - 220 nrad Ry resolution
- Optical encoder with 5 nm resolution

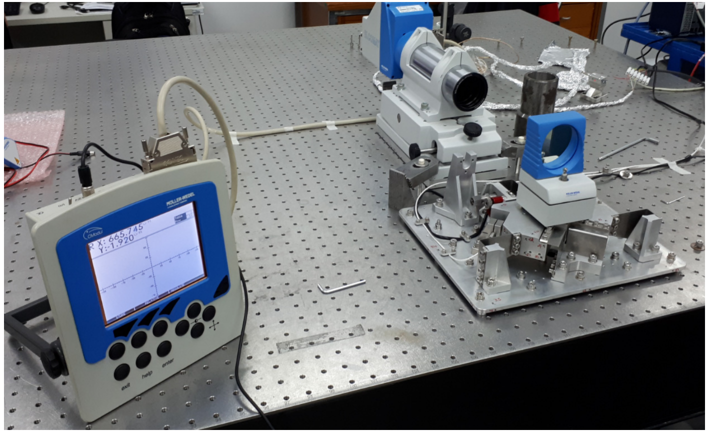
Final version:

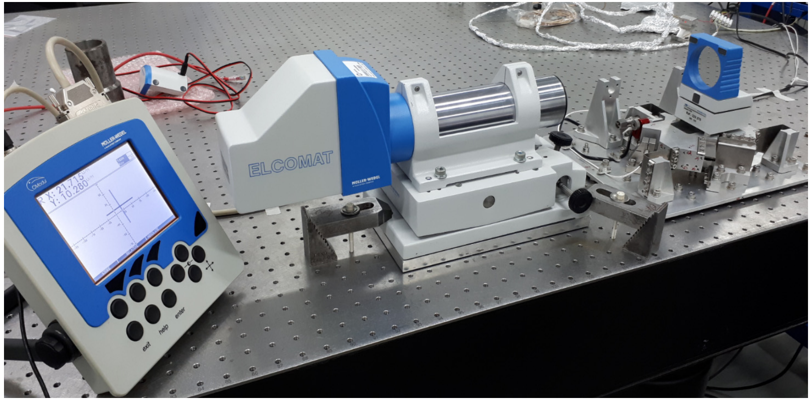
- Piezo walker with 8 nm step resolution
  - 100 nrad Ry resolution
- Optical encoder with 1 nm resolution

Results – Prototype

Linearity and Parasitic (Rx/Rz) Motion:



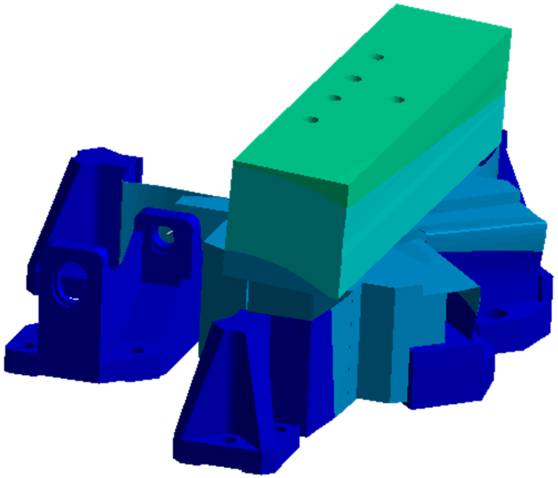


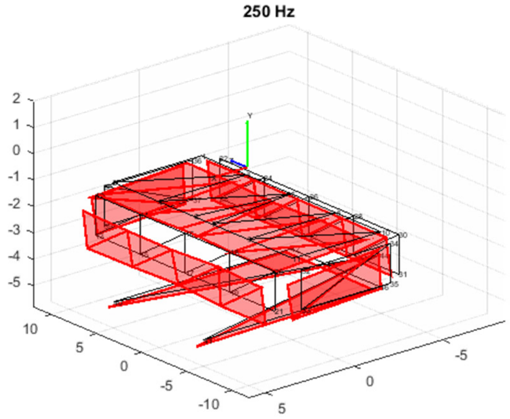


Results – Prototype

Modal Analysis:

Mode	FEA [Hz]	Experimental [Hz]
1 (T_x)	249,7	250
2 (R_y)	312,5	313
3 (T_z)	342,4	341
4 (T_y)	408,9	403
5 (R_z)	602,5	554
6 (R_x)	614,9	851





Results – Mirror Clamping

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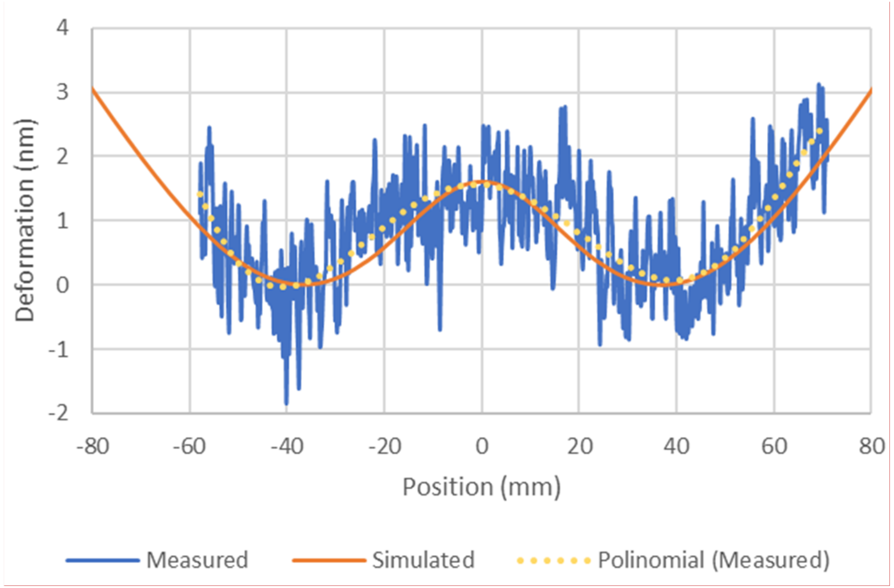
Fizeau Measurements

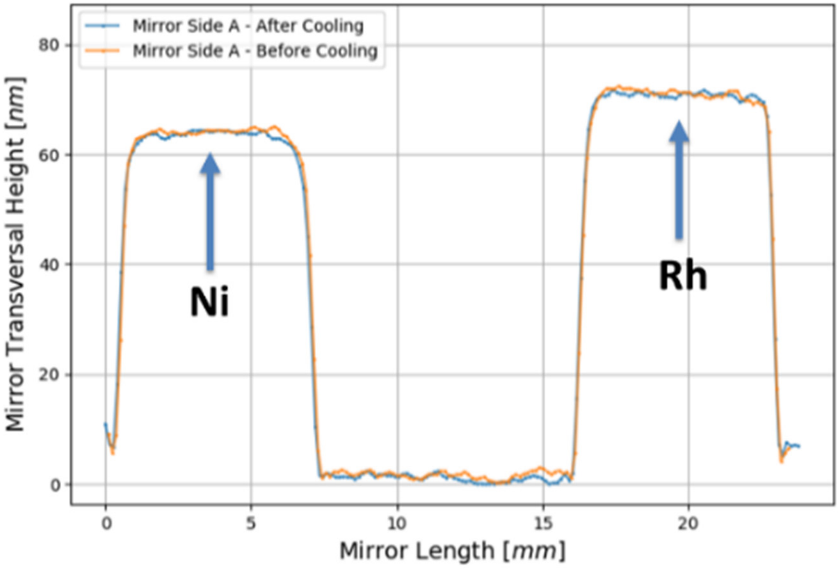
The graph representes the data for the mirror mounted on a support with flexures and hinges



The simulated and the measured data are in agreement

Results – Cooling Risks

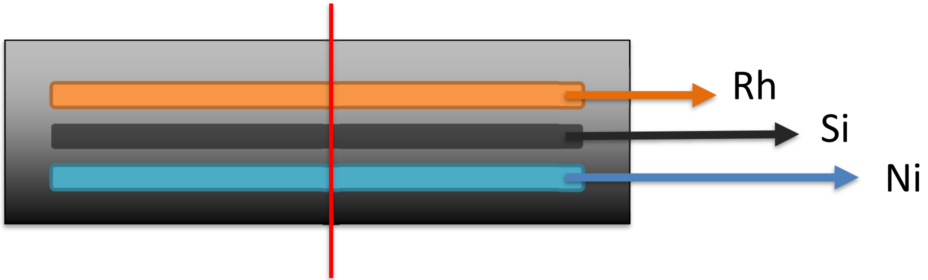
Fizeau Measurements



Thermal cycling test

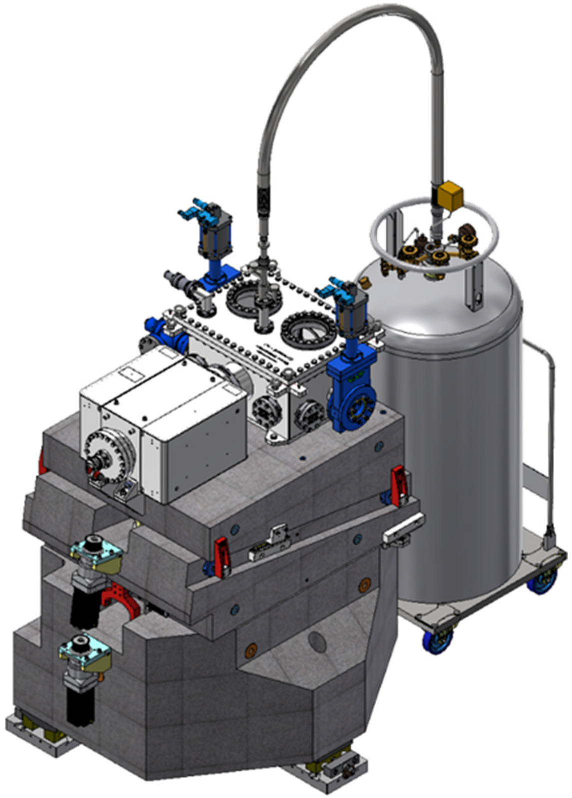
- From ambiente to cryogenic temperature
- Repeated a few times

There was no degradation of the interest region



Conclusions

It was possible to achieve the desired levels of stability, range, resolution and reliability on the proposed concept!



Next Steps

The manufacturing, assembly, commissioning and installation of the first set of mirrors.

Acknowledgements

The authors would like to gratefully thank:

- Brazilian Ministry of Science, Technology, Innovation and Communication;
- LNLS team;
- The community;
- The organizers;
- The audience.

Sirius (May 2018)