
# Exactly-Constrained KB Mirrors for Sirius Beamlines

Design and Comissioning of Tarumã Station Nanofocusing optics at Carnaúba Beamline

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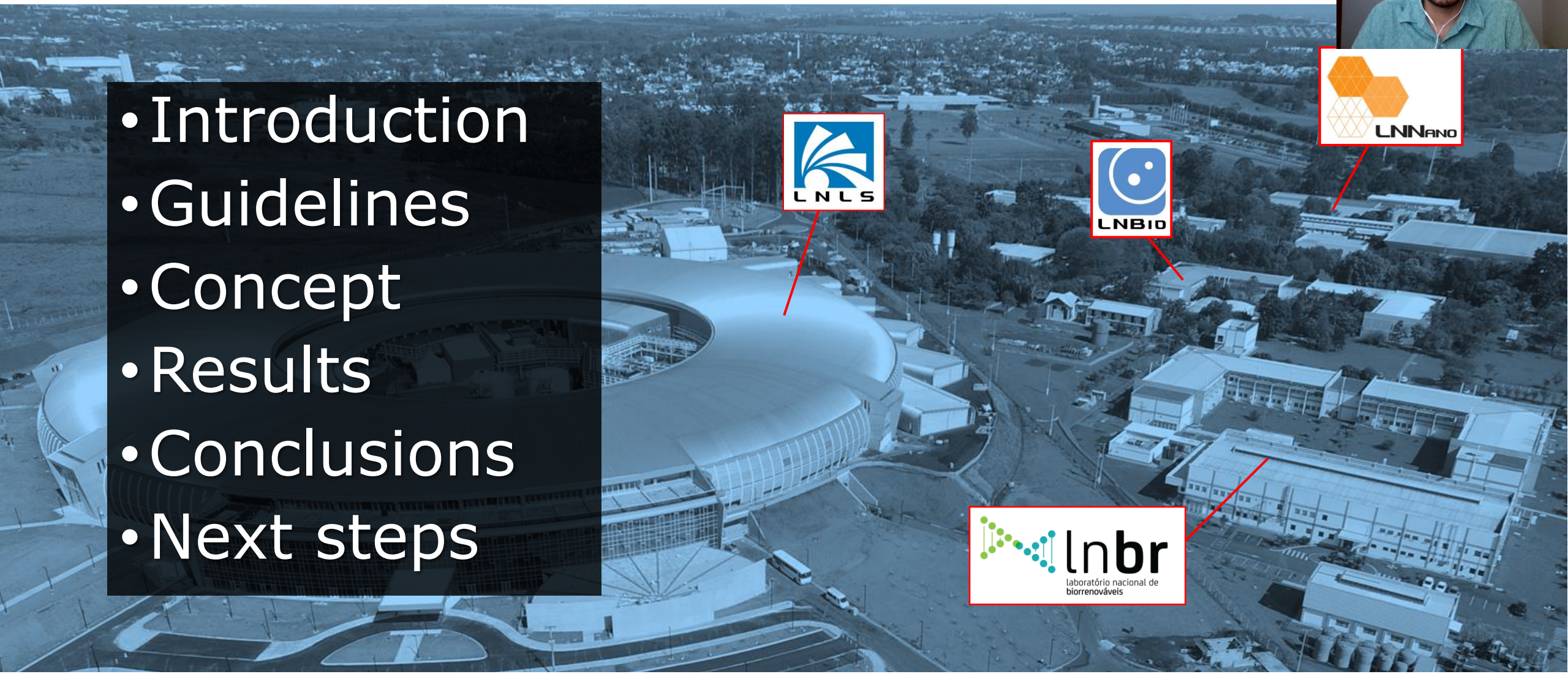
# Outline



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

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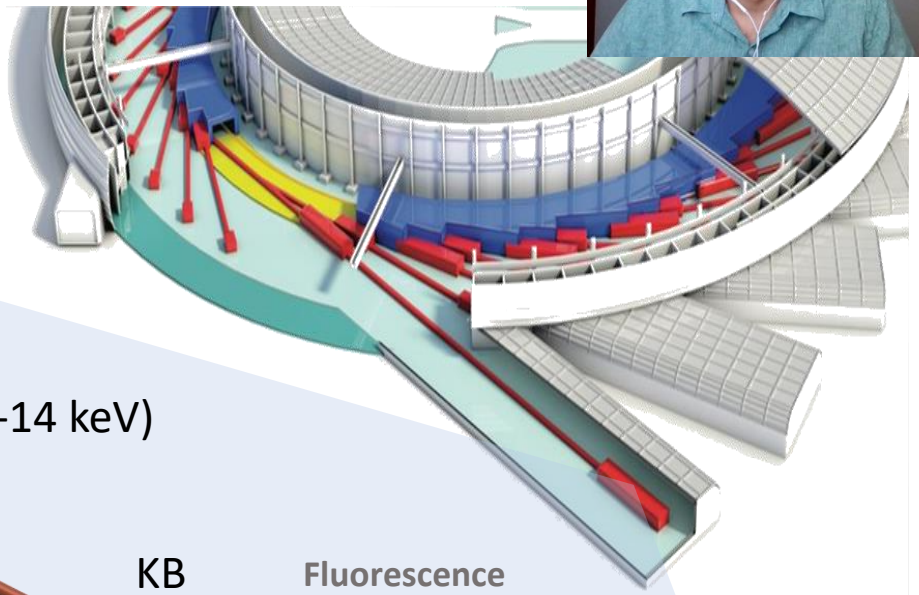
# CARNAÚBA Beamline

SIRIUS: 3GeV, 4th gen
Brazilian Synchrotron

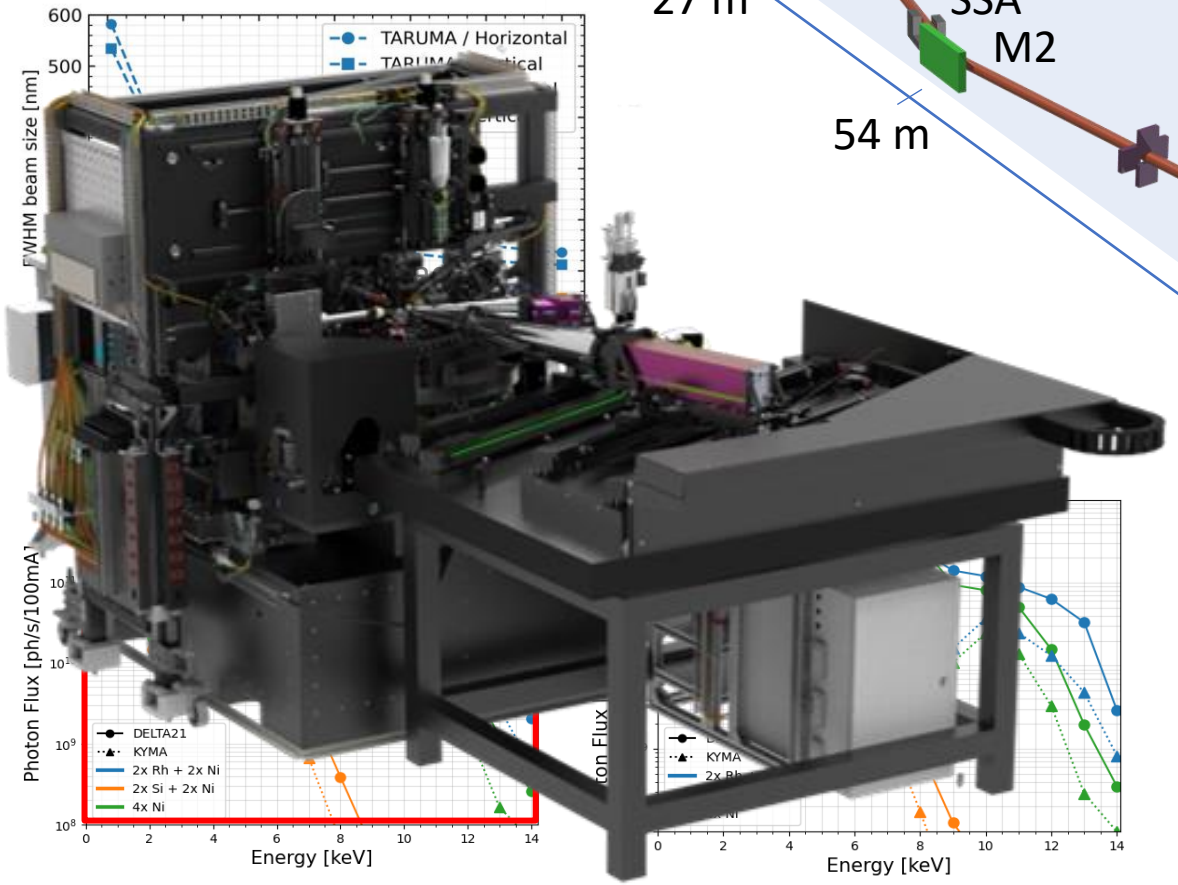


0 m
M1
27 m
SSA
M2
54 m
(E = 2-14 keV)
4CM
KB
130 m
Fluorescence
Luminescence
Transmitted
Scattered

**TARUMÃ: 135 m**
(σ = 500 to 120 nm$^2$)
(WD = 440 mm)

**SAPOTI: 143 m**
(σ = 140 to 35 nm$^2$)
(WD = 55 mm)

*Beam size at sample*




CNPEM
MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATIONS
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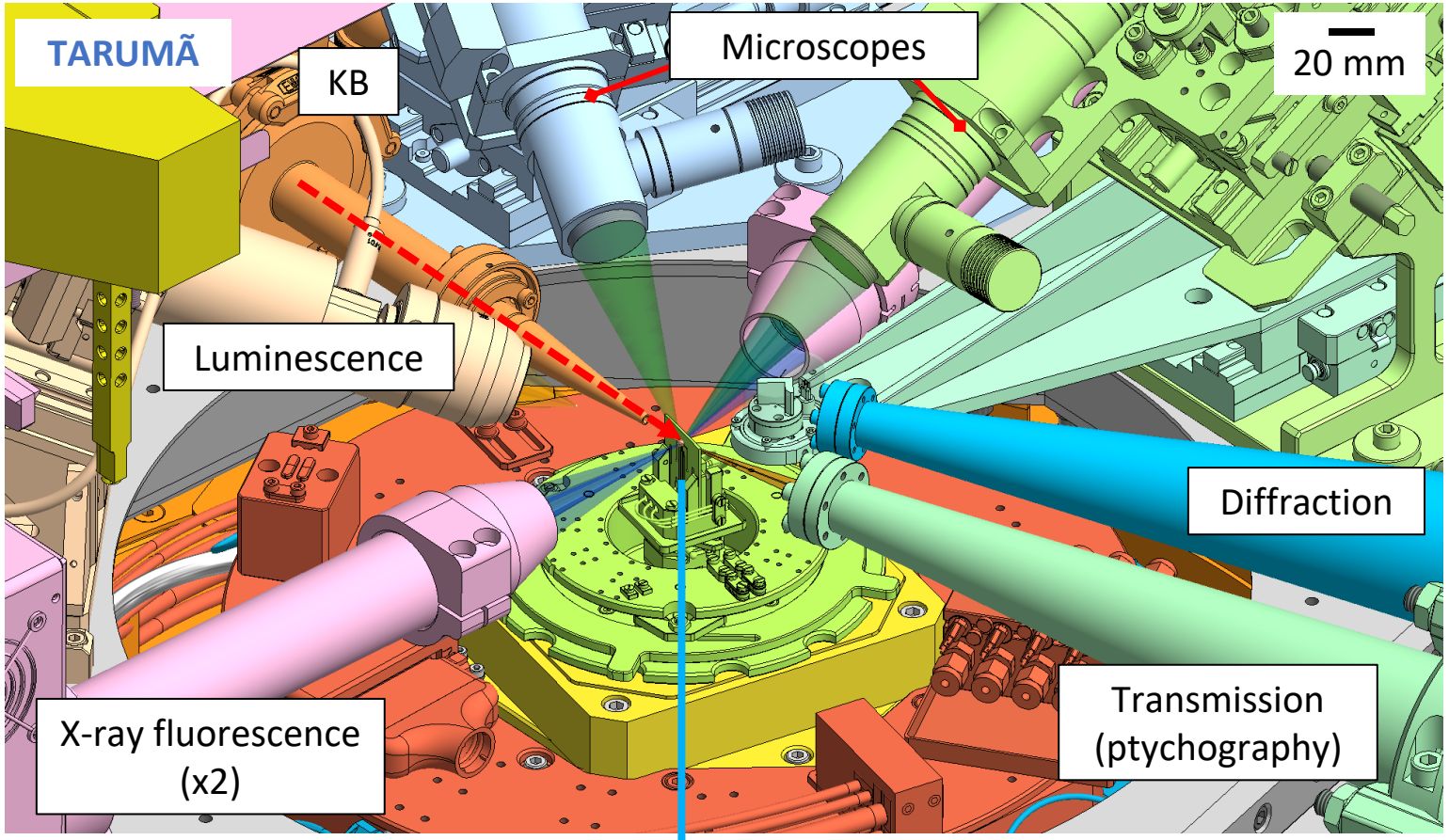
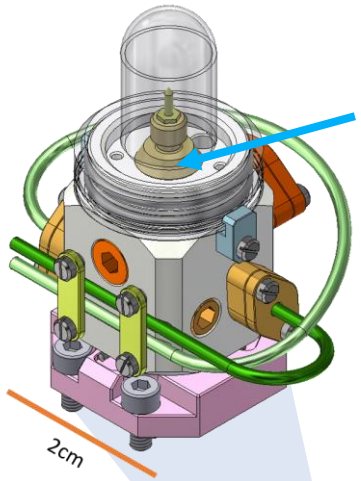
# TARUMÃ Station

- **Multitechnique** – *in situ*, *in operando*, *in vivo* experiments

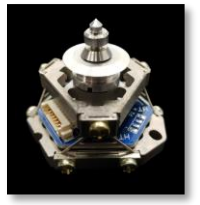


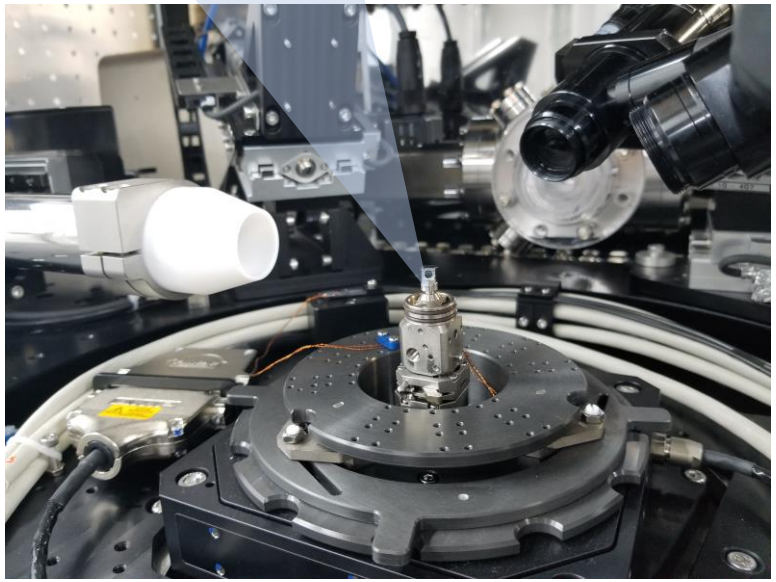

Samples

(biological, agro-environmental, energy, etc.)




Various sample environments and holders





**See WEPC02, WEPC03, and WEPB13 posters!**

# All-in-one Focusing System!

Spectroscopy

Achromatic focusing

Large Working Distance

*In situ* cells

Kirkpatrick-Baez (KB) mirrors

*In operando* studies

High Flux

Shared Alignment tolerances

Long Mirrors

Limited grazing angles

Tender to Hard x-rays

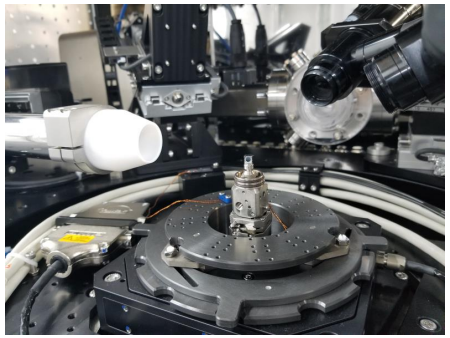
Exactly-constrained KB mirrors design

High stiffness (passive or active)

Ultra stability

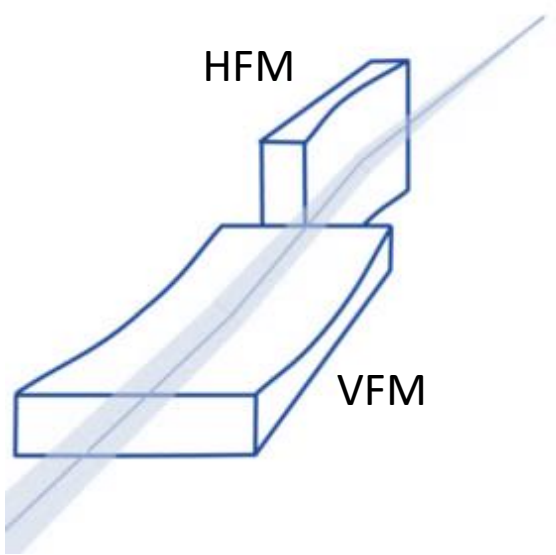
Small focus

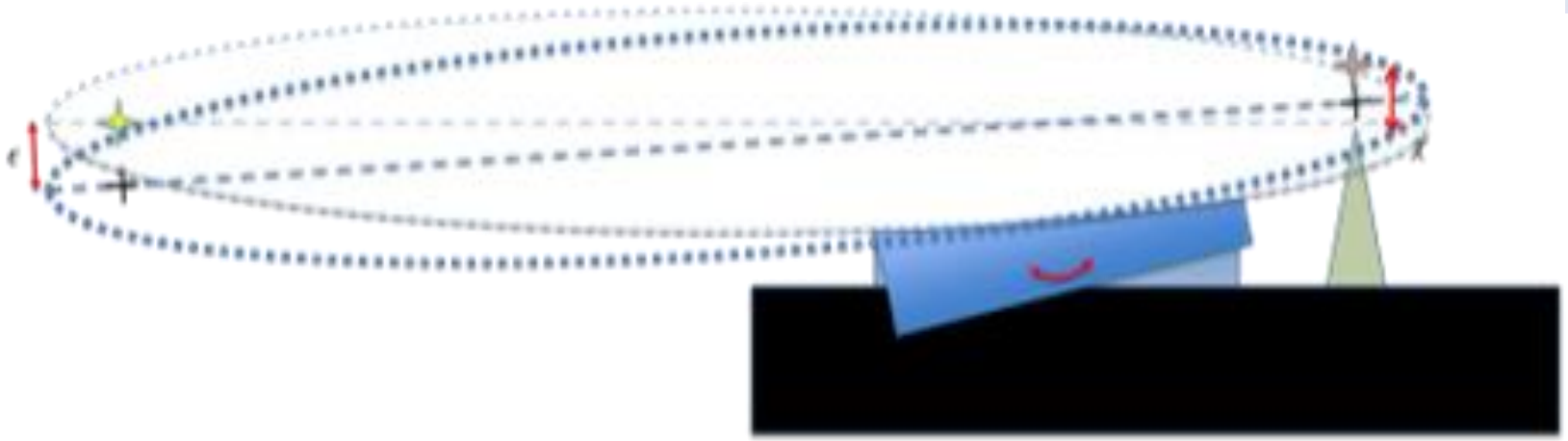
Nanometer resolution



# Kirkpatrick-Baez (KB) Mirrors

- Elliptical mirrors, placed orthogonally to focus x-rays
- To have a proper focus, the mirrors have to:
  - **Preserve its original design shape!!**
  - Have very good orthogonality (typically < 50 µrad)
  - Be properly aligned to source's virtual position (sub-µrad)
  - Be longitudinally placed within each other's depth-of-focus
- **Most sensitive DoF in one mirror is the least sensitive DoF in the Other!** (pitch chamber around VFM = yaw HFM [tol > 1mrad])

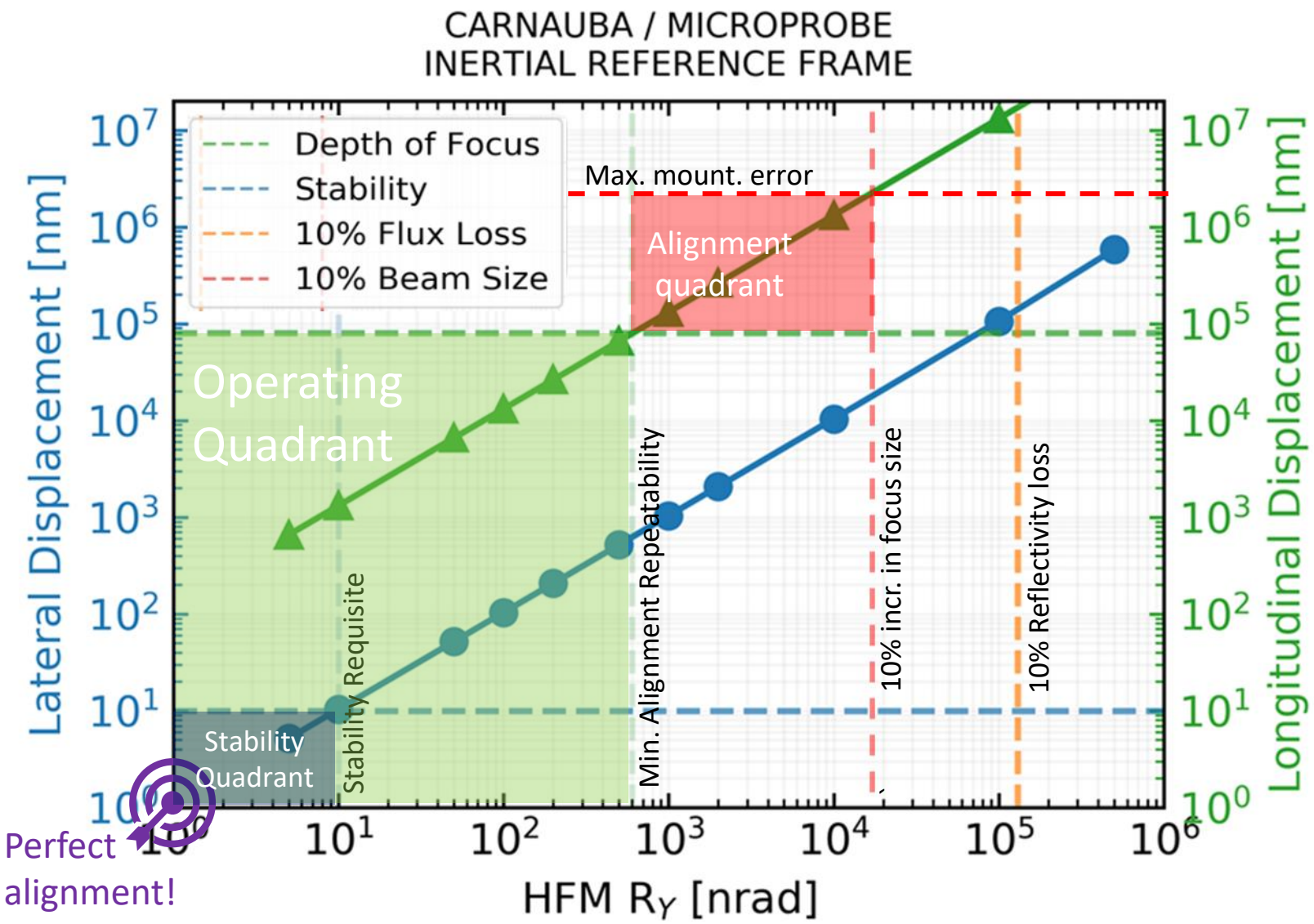


**TARUMÃ Mirrors (j-tec)**

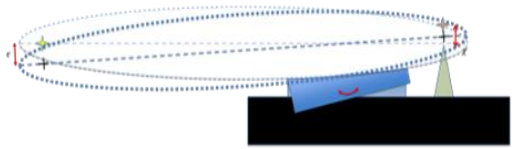
- Ni-coated Si surfaces
- Slope <50 nrad; PV <1 nm
- VFM: L=210 mm;
- HFM: L=130 mm
- **HFM: WD=450 mm**

# KB Mirror Sensitivity Model




Perfect alignment!

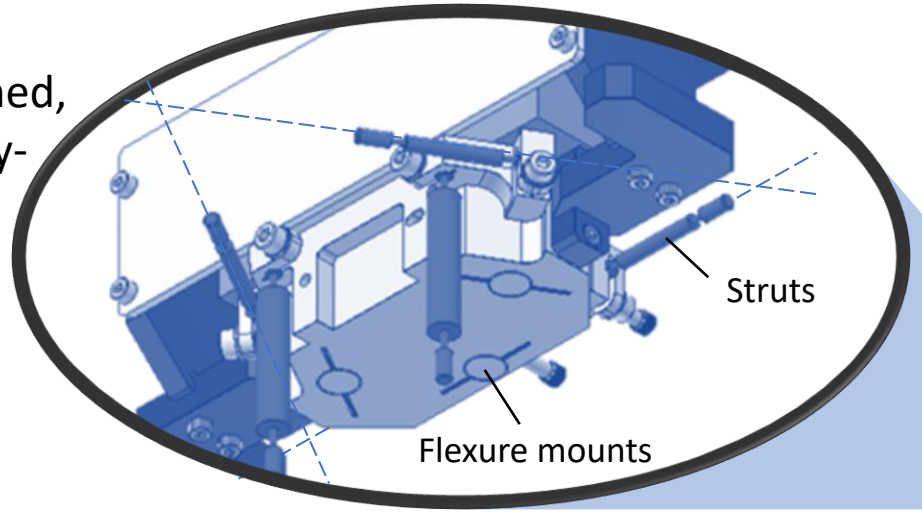
| Tarumã HFM specs (pitch Ry) | |
|---|---|
| **vibration RMS Stability** | **10 nrad** |
| Alignment (best focus) | 600 nrad |
| Tolerance (+10% size) | 15 µrad |
| Z axis correction range | 2 mm |



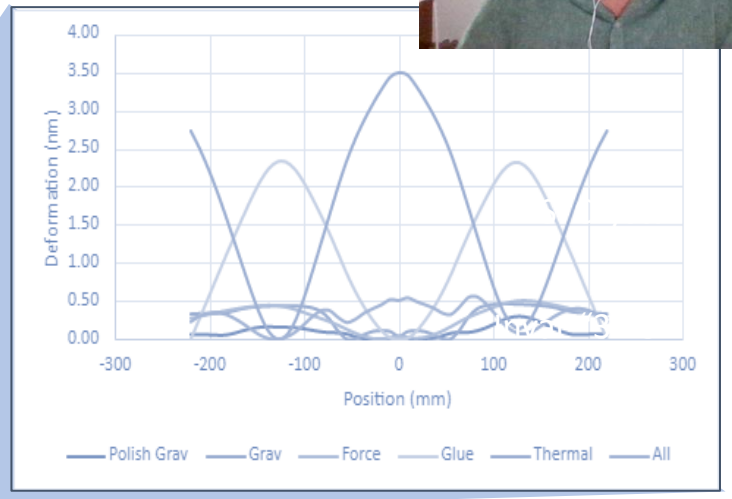
| Tarumã VFM specs (pitch Rx) | |
|---|---|
| **vibration RMS Stability** | **7 nrad** |
| **Alignment (best focus)** | **400 nrad** |
| Tolerance (+10% size) | 4 µrad |
| Z axis correction range | 1 mm |

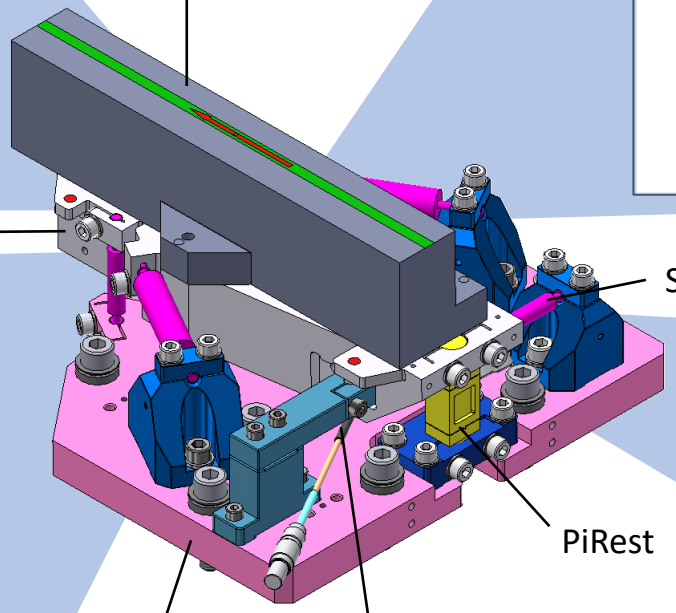
# Exactly-constrained KB Mirrors

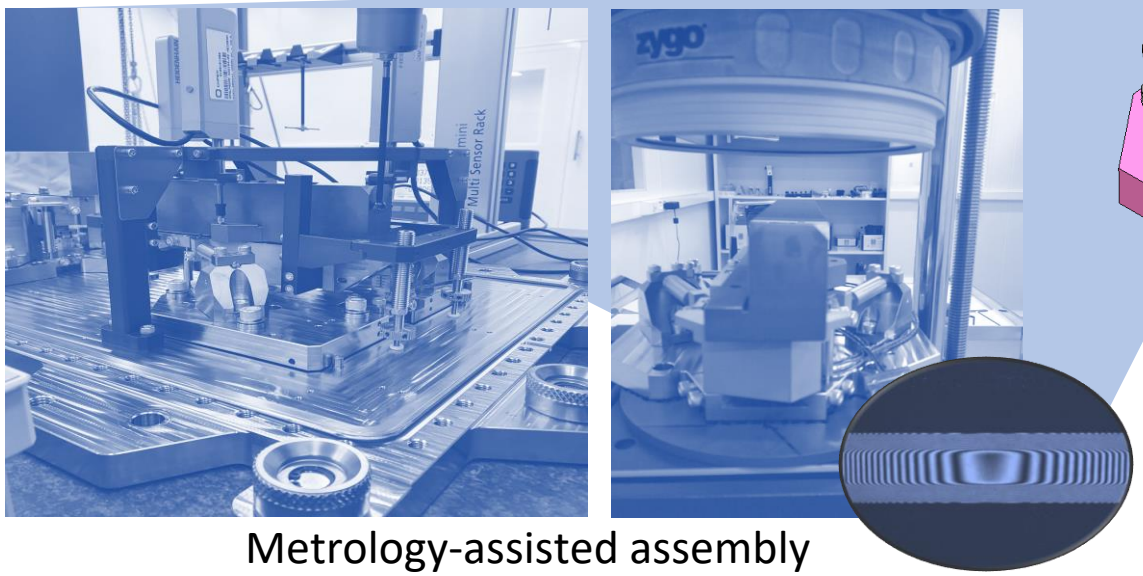
Exactly-constrained, thermally-centered Design



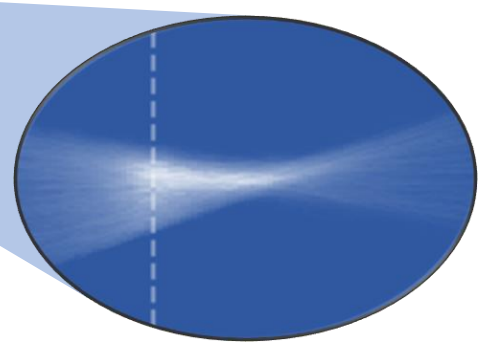

Glued mirrors to mitigate surface deformations



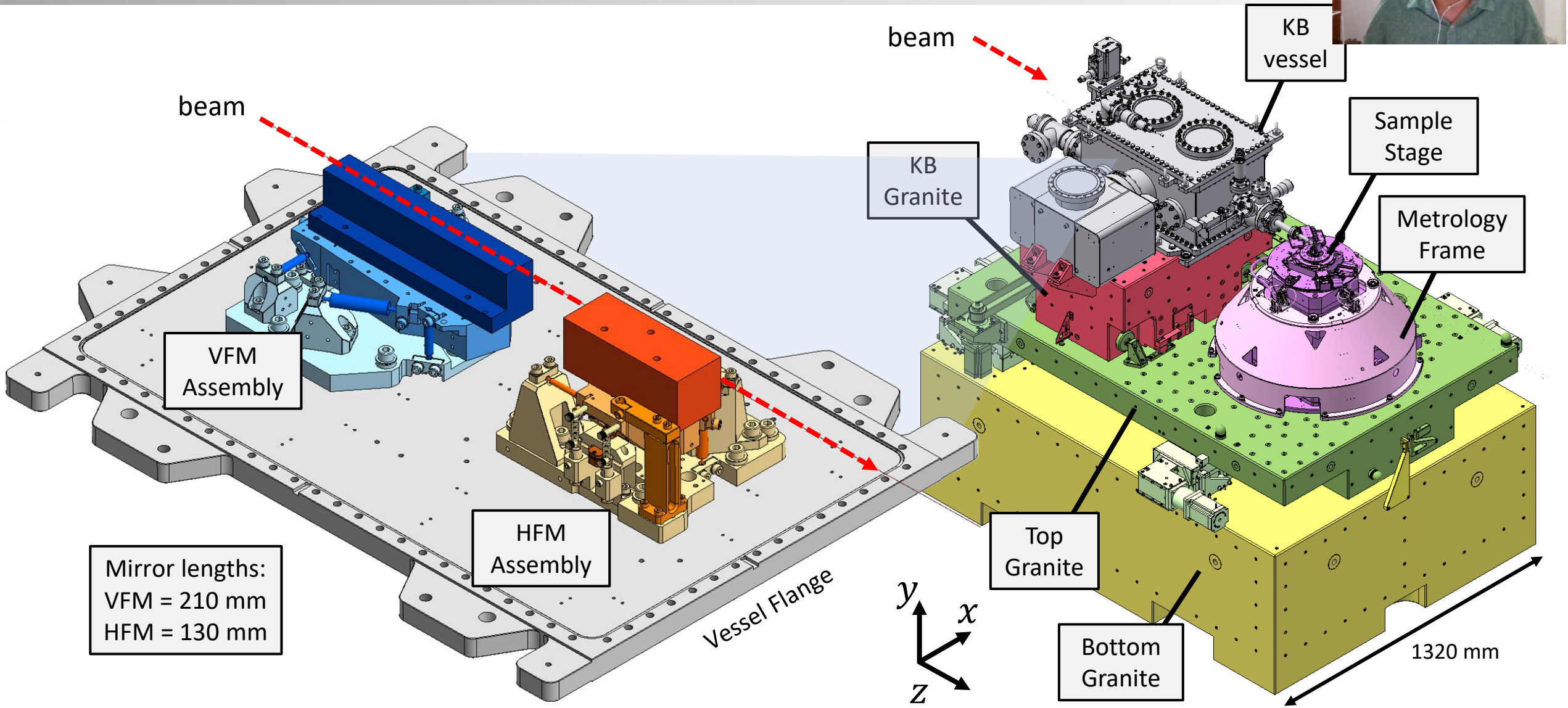




Metrology-assisted assembly



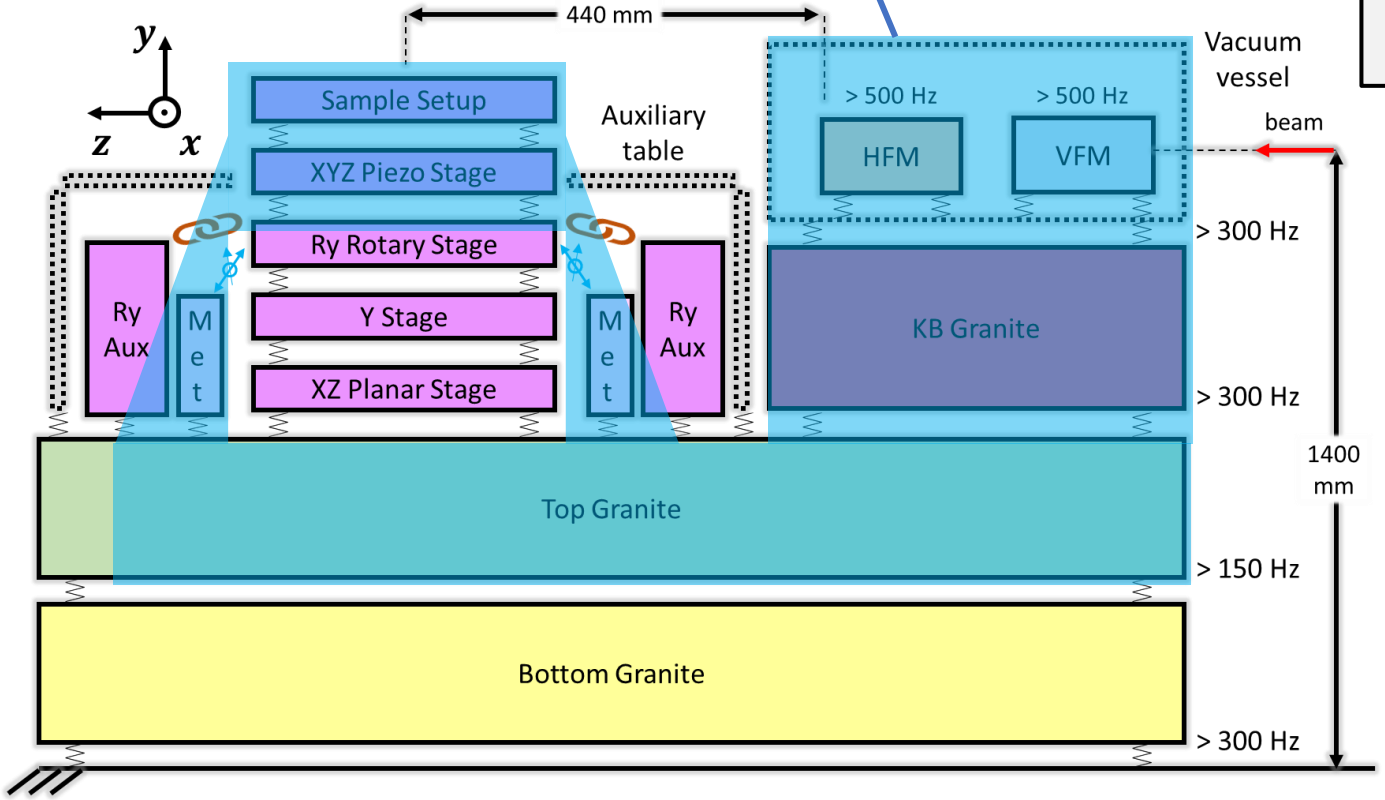
Essential-only DoFs for pitch and astigmatism corrections

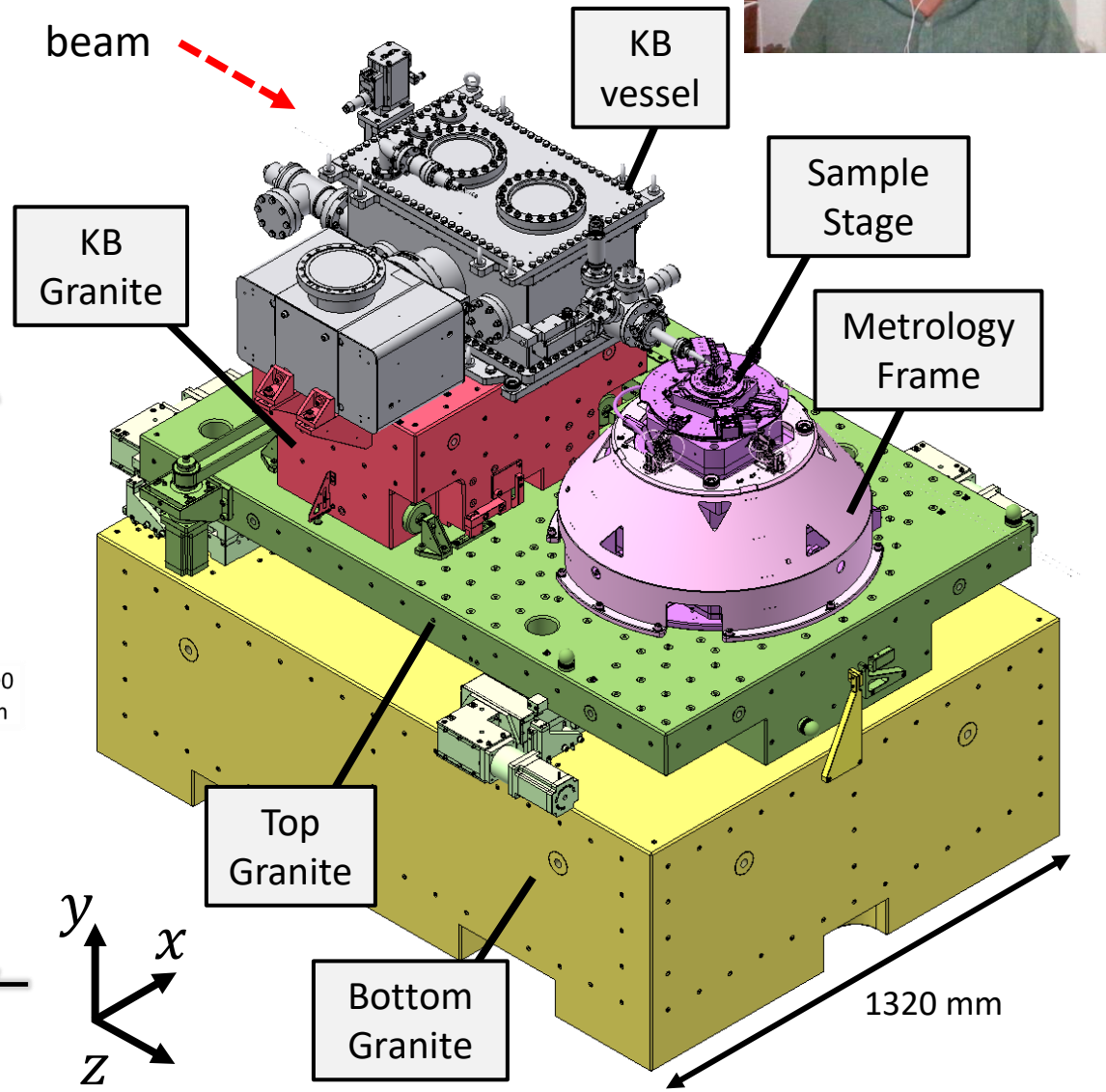
# Concept: Internal Mechanisms



# Concept: Base and Sample Stack

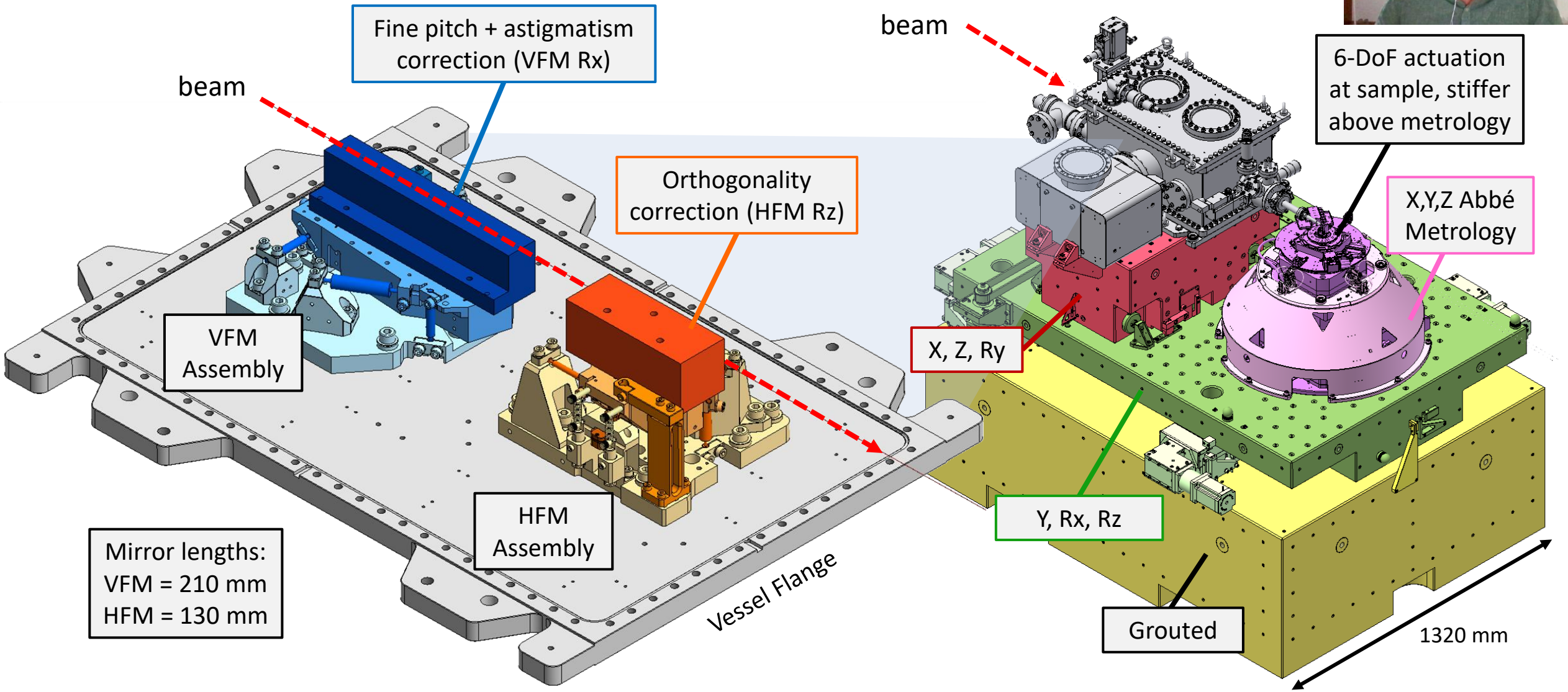
High-stiffness chain from sample to mirrors!



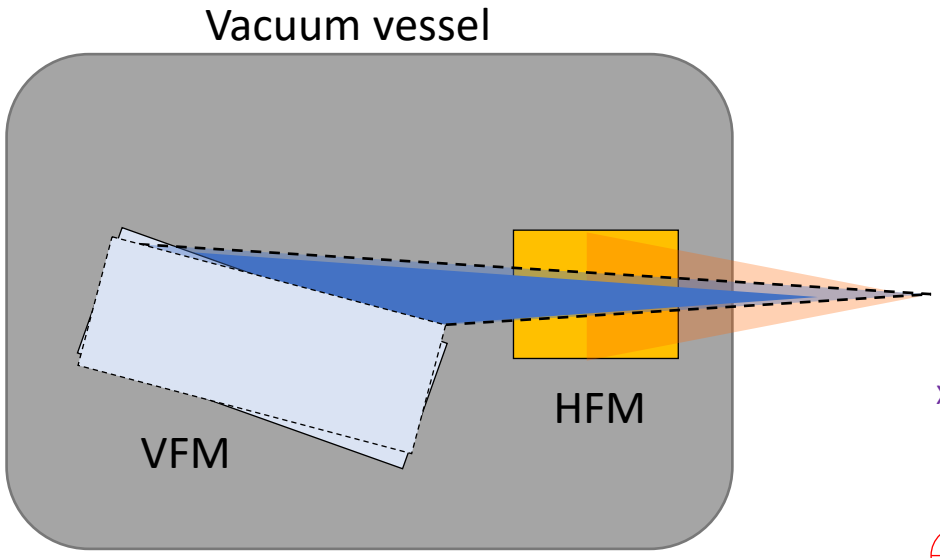




**See MOPB08 poster!**

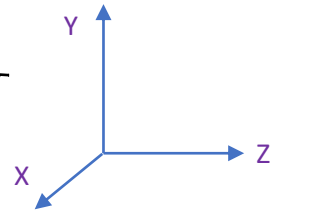
# Alignment DoFs



# Alignment DoFs

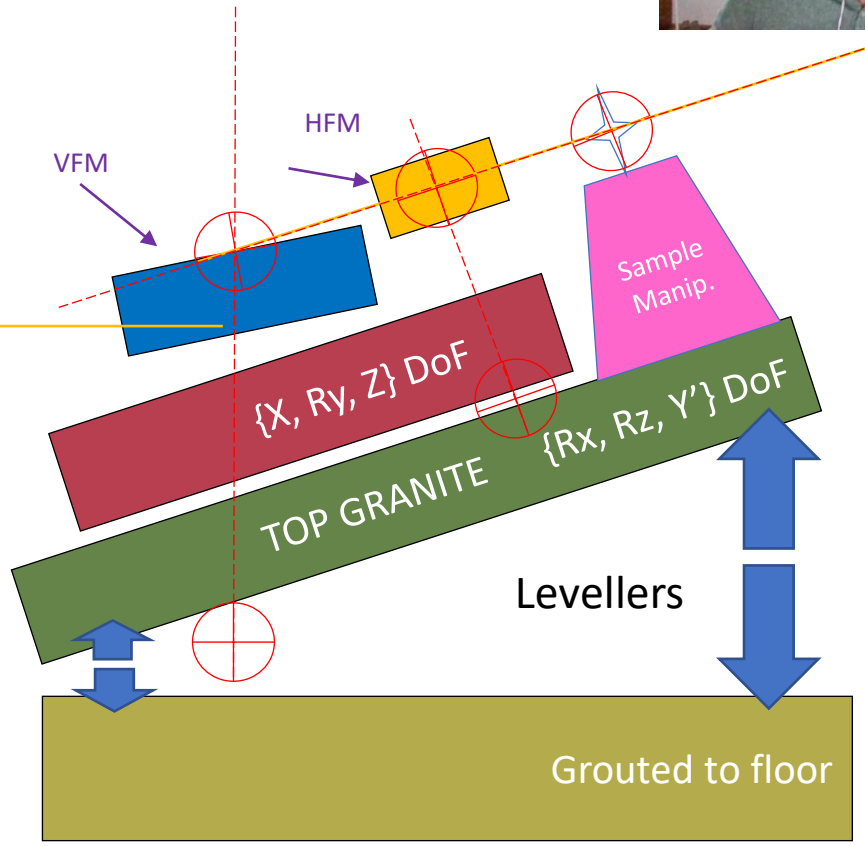



Fine pitch and astigmatism alignment (in-vacuum)



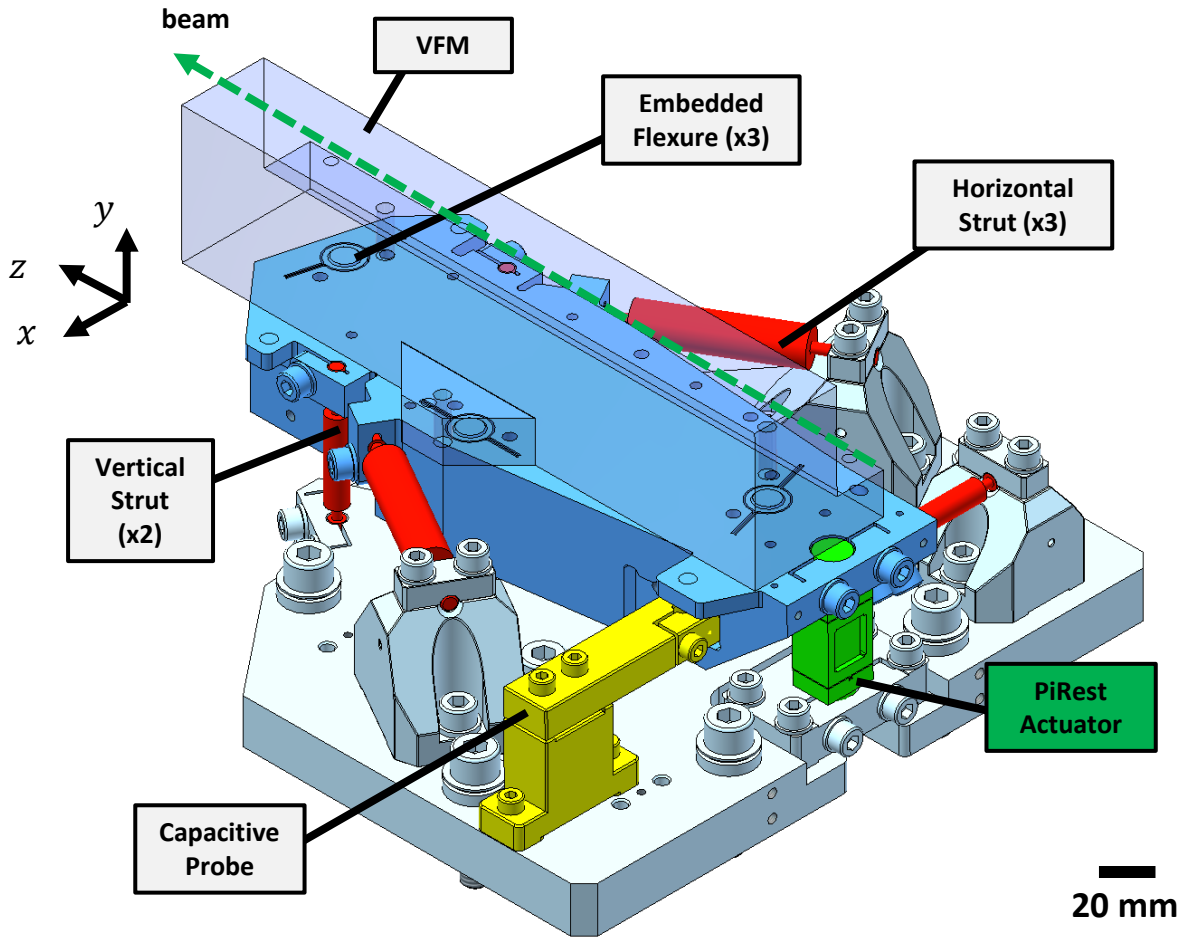

Coord. System

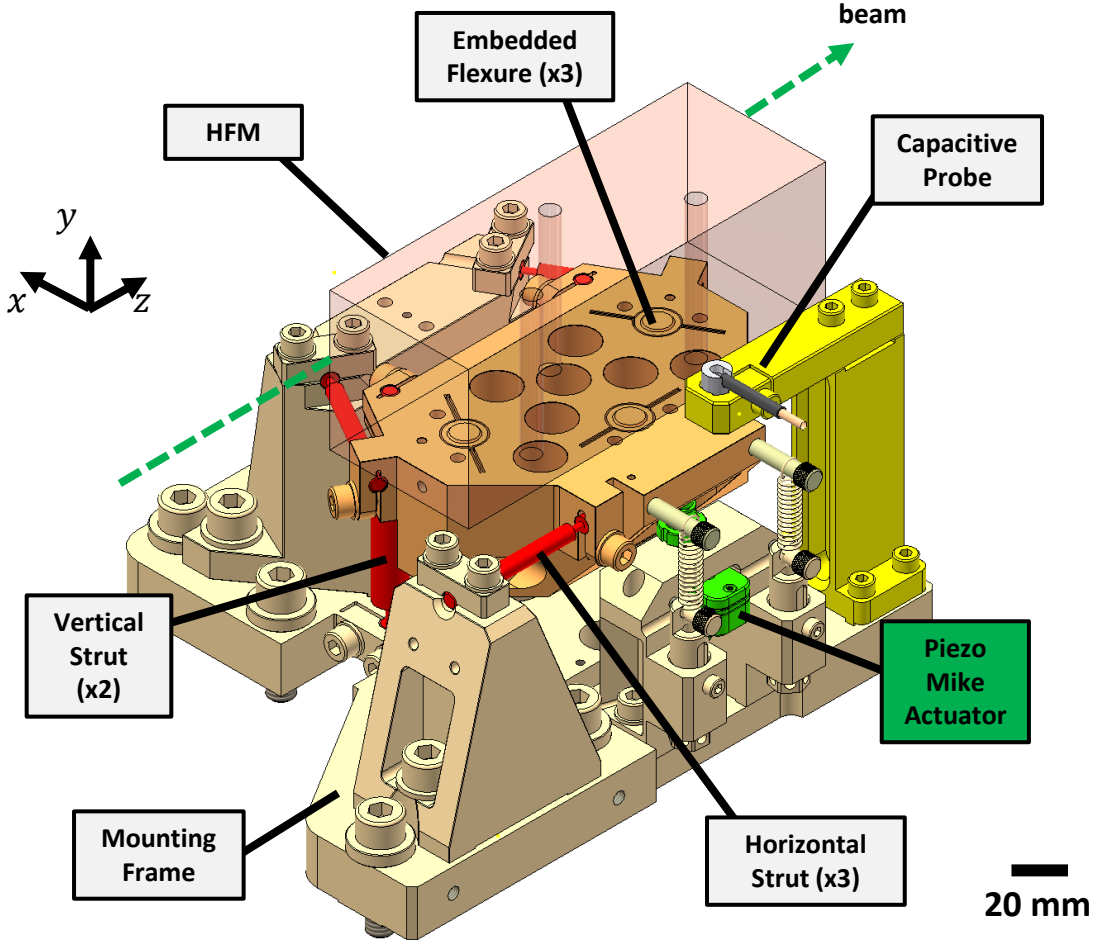
Alignment Req.




Coarse alignment – Base (6-DoF)

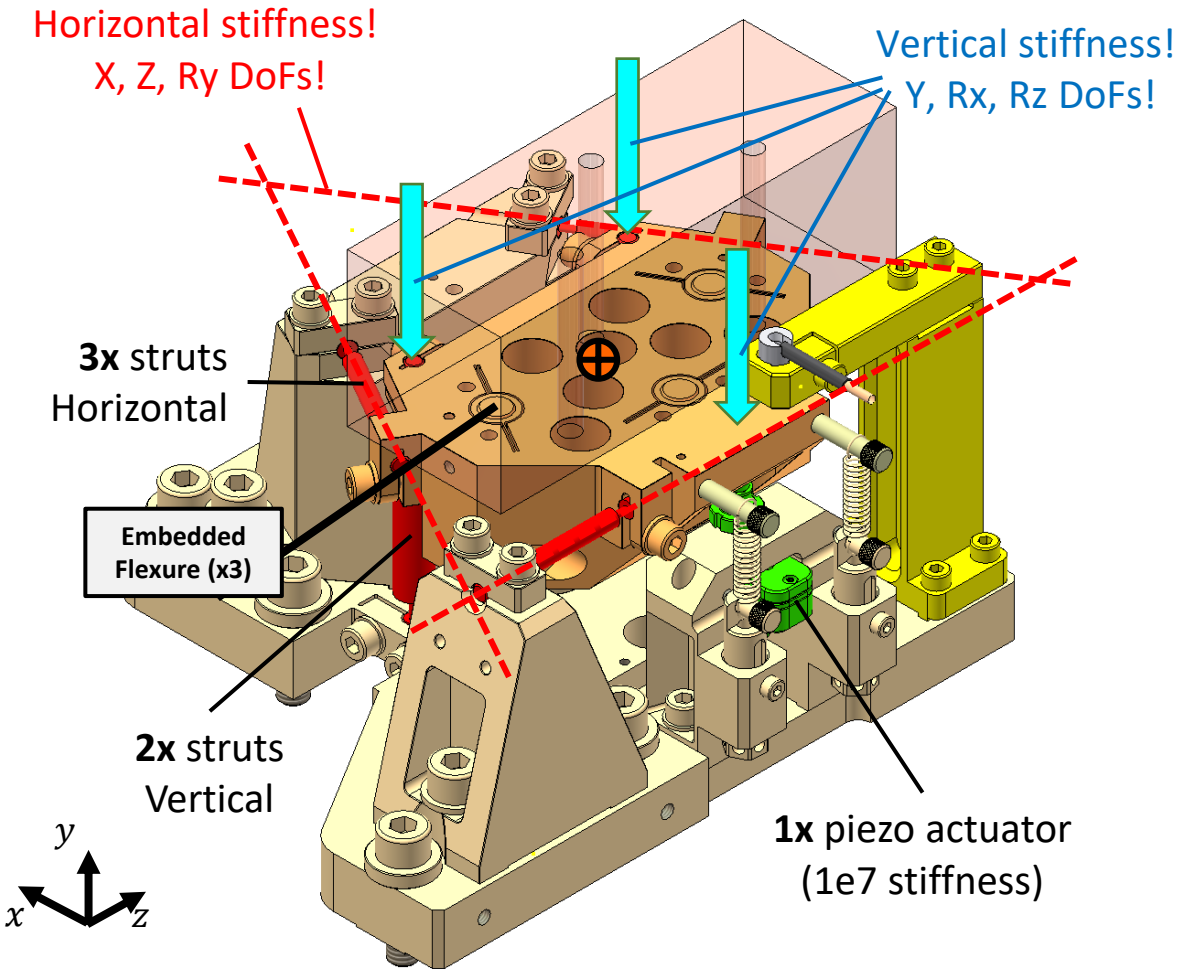
# VFM and HFM Assemblies



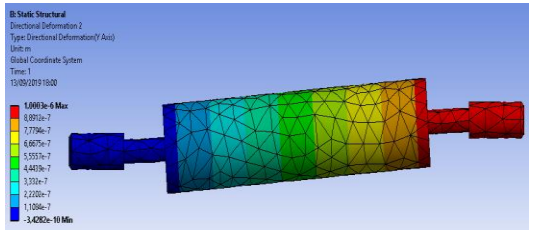



# Exactly-constrained Mechanics

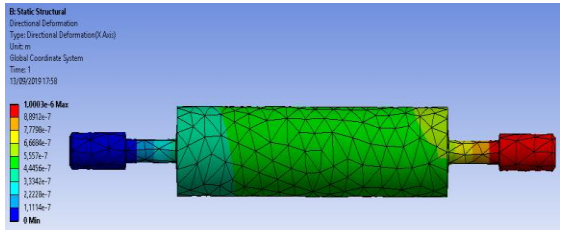
6 Degrees of Freedom (DoF) constrained




Reinforced struts: stiff in one direction

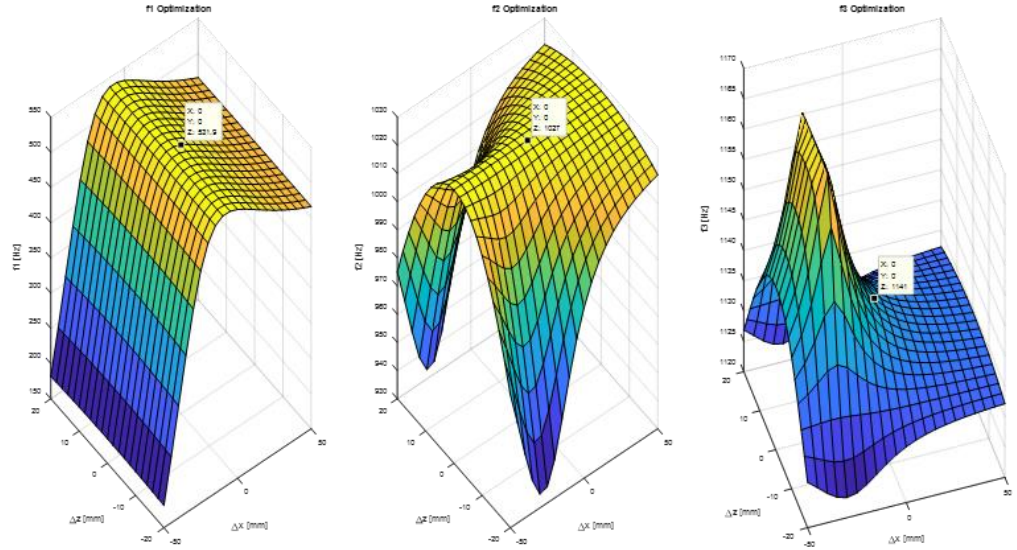


$k_t = 8.5e4\ N/m$

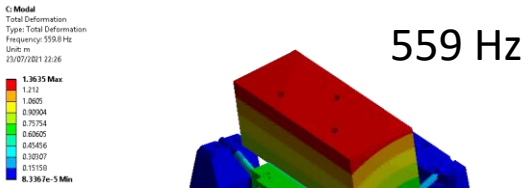


$k_l = 7.2e7\ N/m$

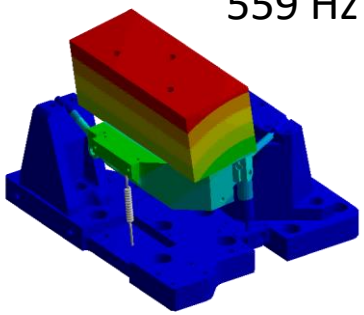
Modal optimization for strut positions

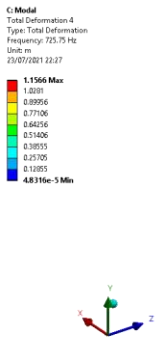


# Modal Simulations and Analyses

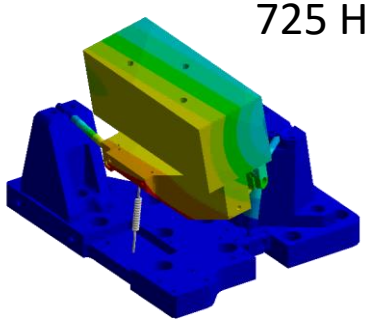


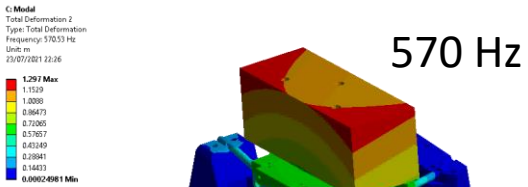
559 Hz



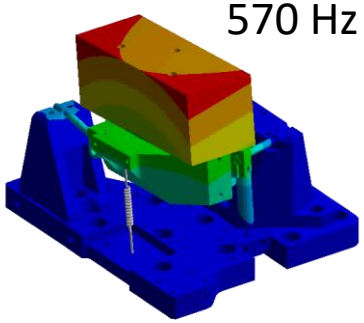


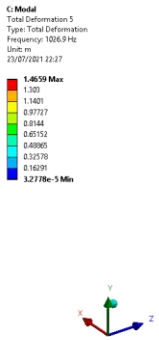
725 Hz



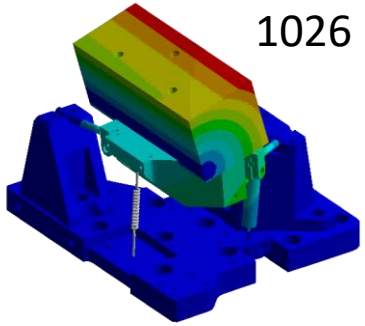


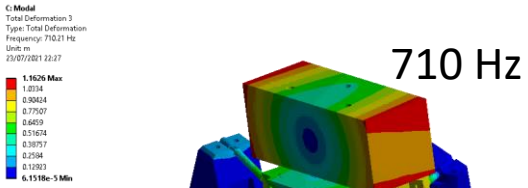
570 Hz



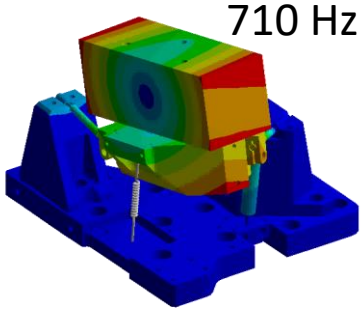


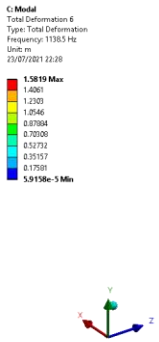
1026 Hz



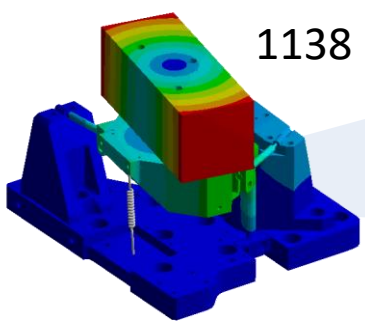


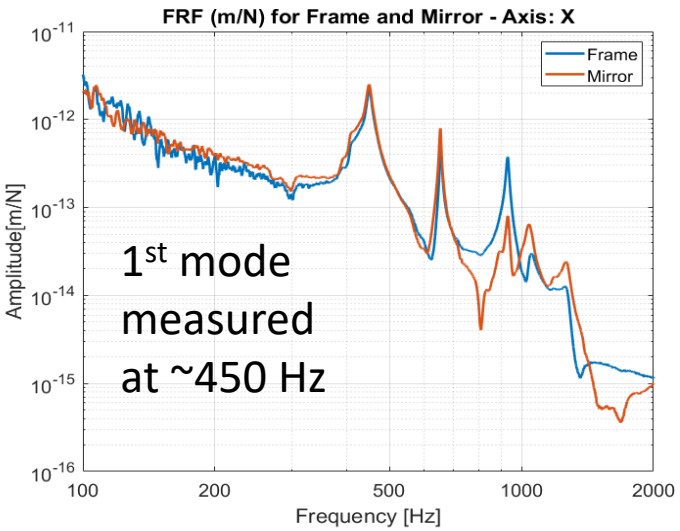
710 Hz

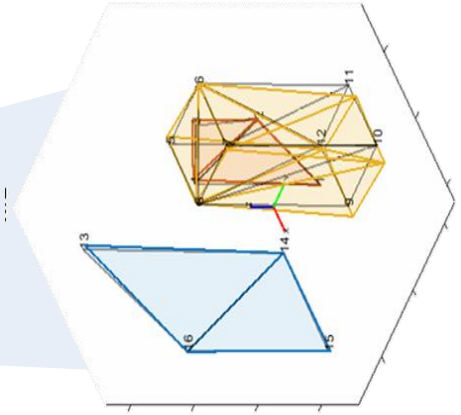




1138 Hz



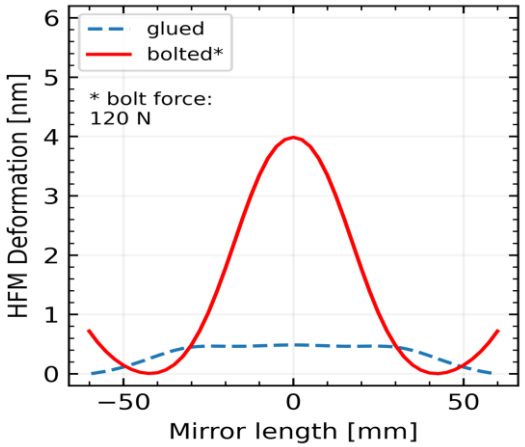


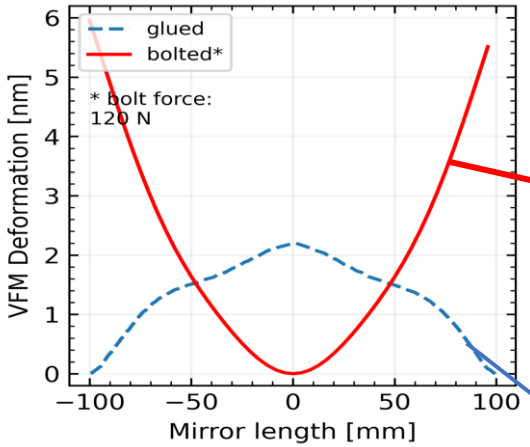



6th mode
measured
at 1037 Hz

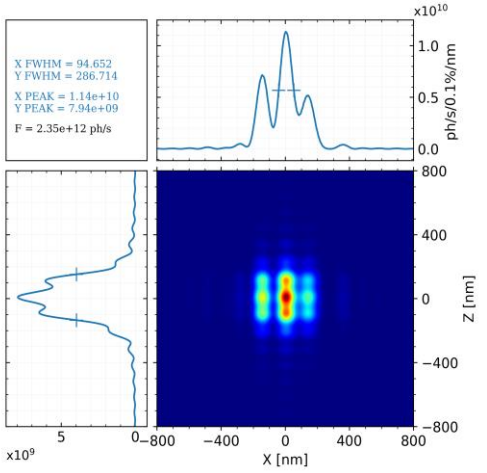
# Clamping deformations

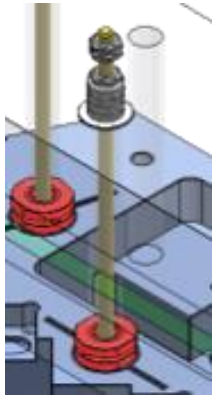
## Ansys Simulations



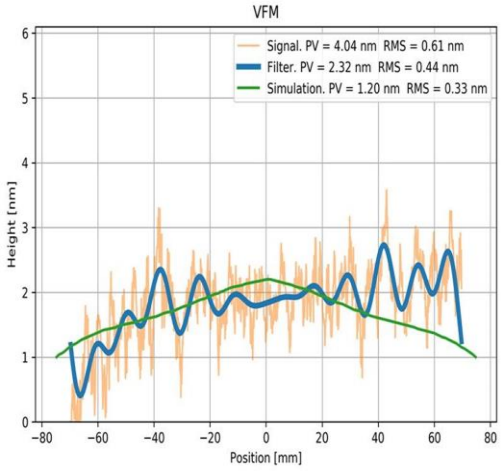

## SRW Simulations

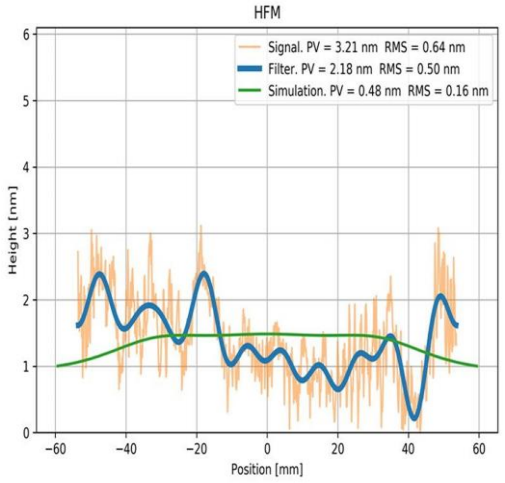


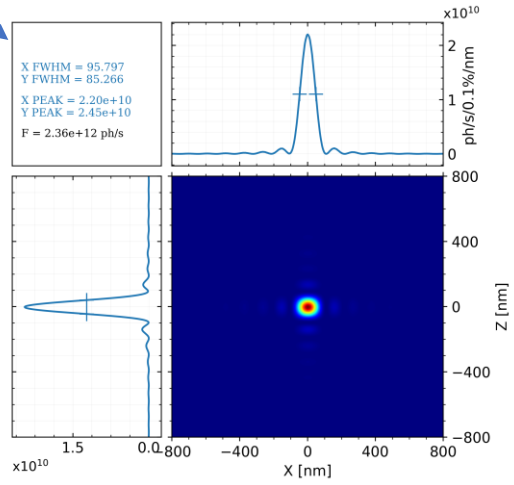



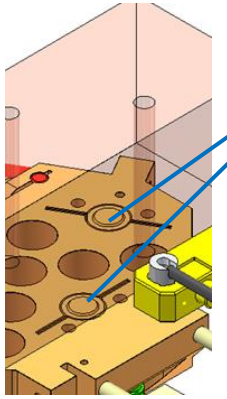
BOLTED

## Optical Metrology Mesurements (def. < 2nm noise!!)



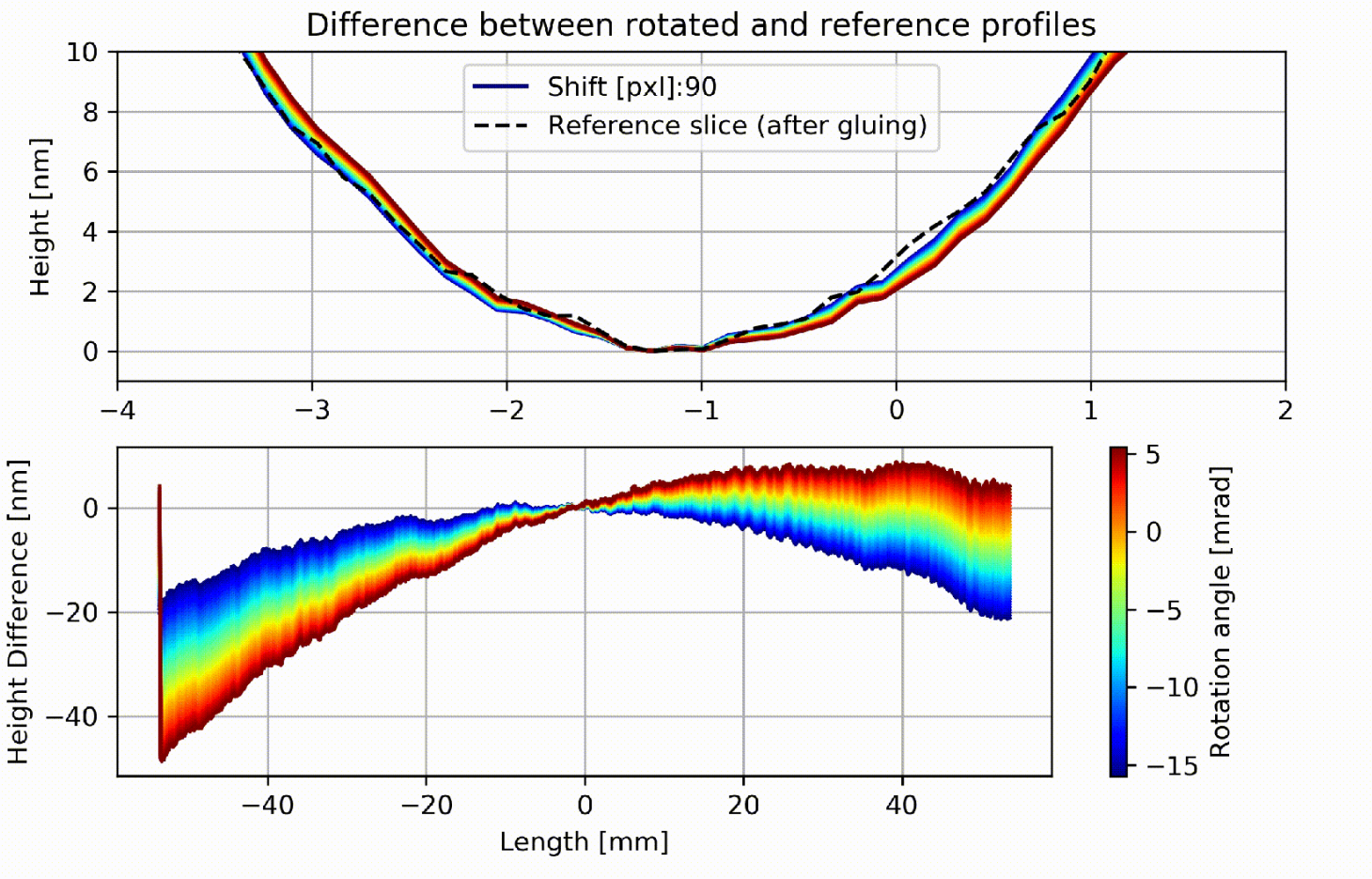



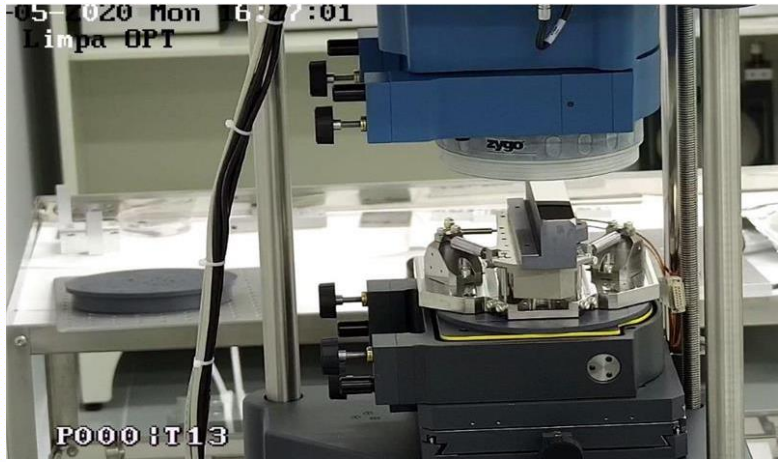
GLUED

Glue droplets

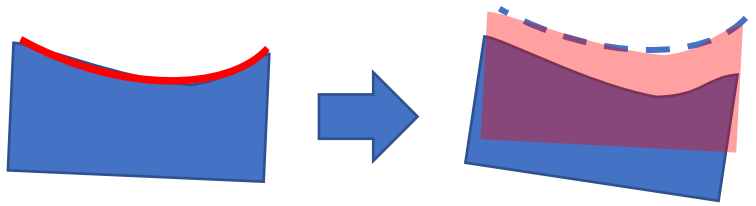
~10e9 N/m

# Ellipse Fitting in Fizeau

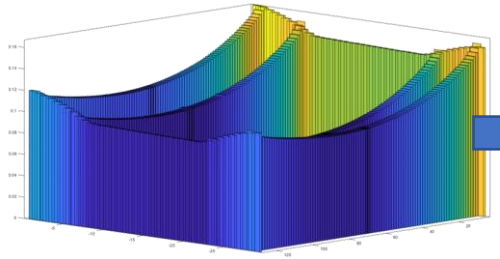


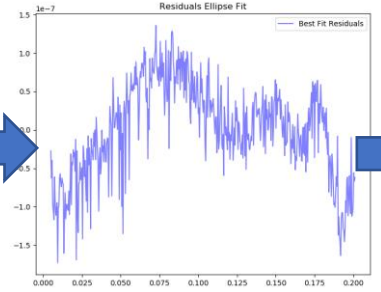

Pre and post gluing measure matching!



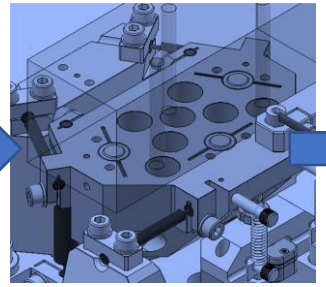
# Assembly and alignment



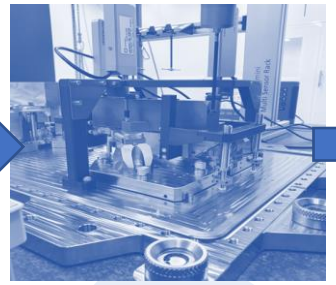
Measure ellipse figure around polished area




Fit focus position to mirror substrate

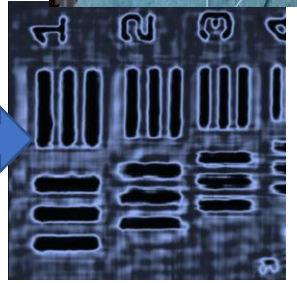


Clean-room gluing

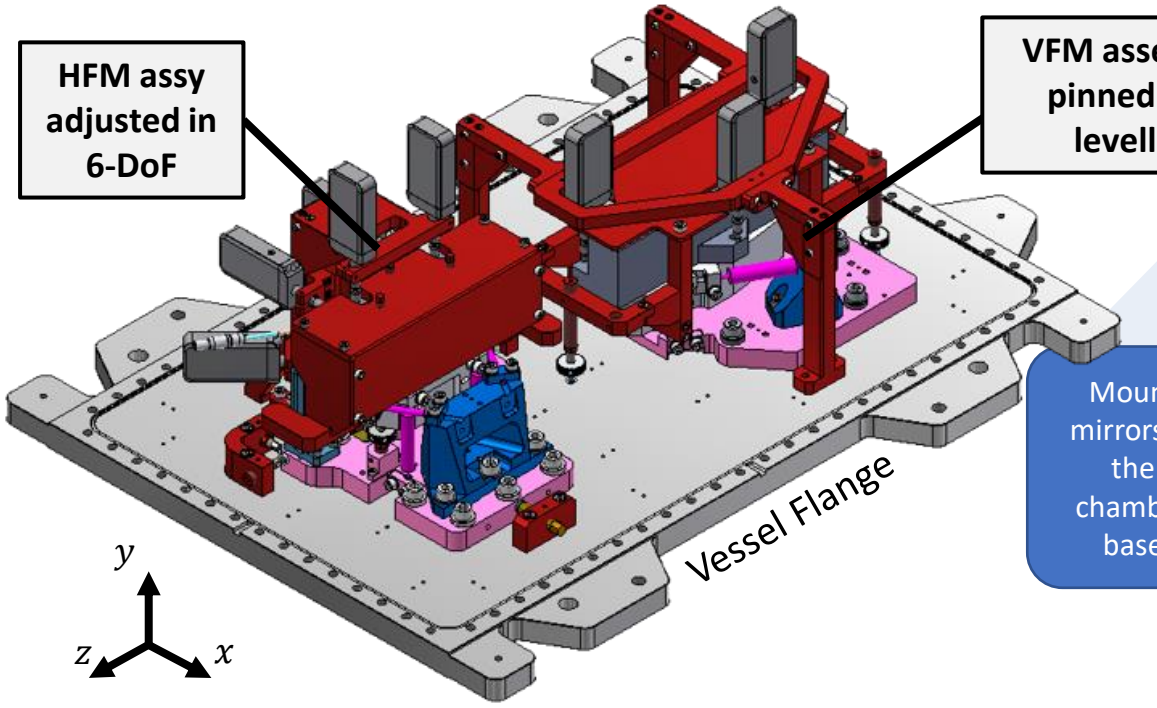


CMM assisted assembly

Beamline installation



Alignment with x-rays




Mount mirrors in the chamber base

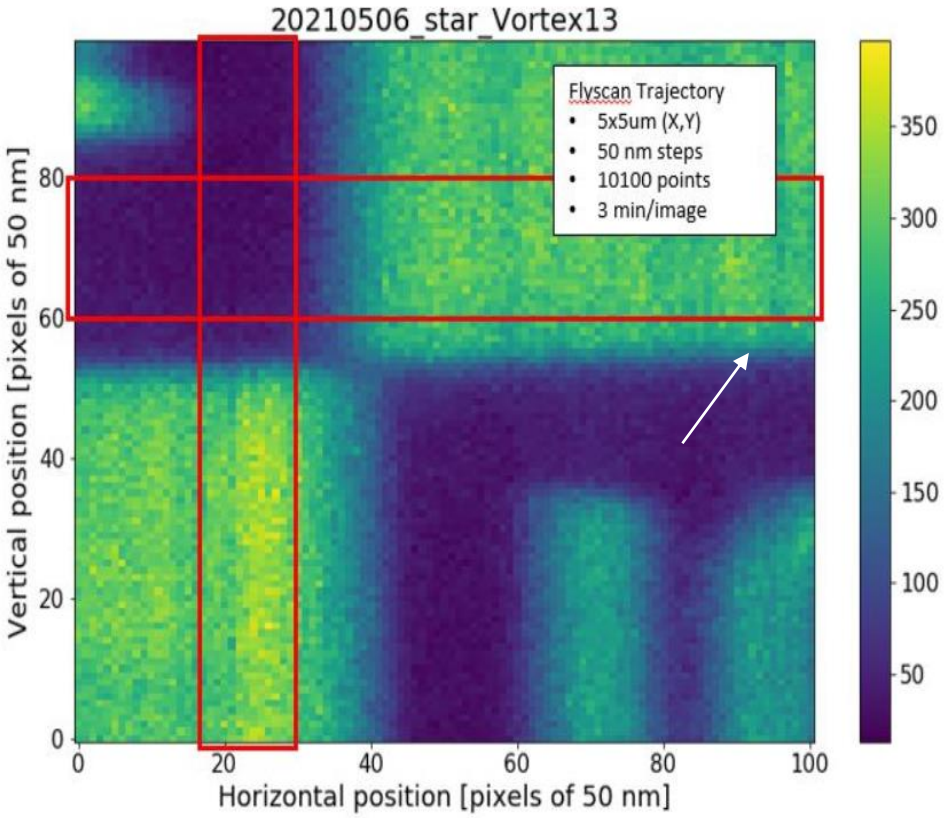
Reference VFM base with dowel pins

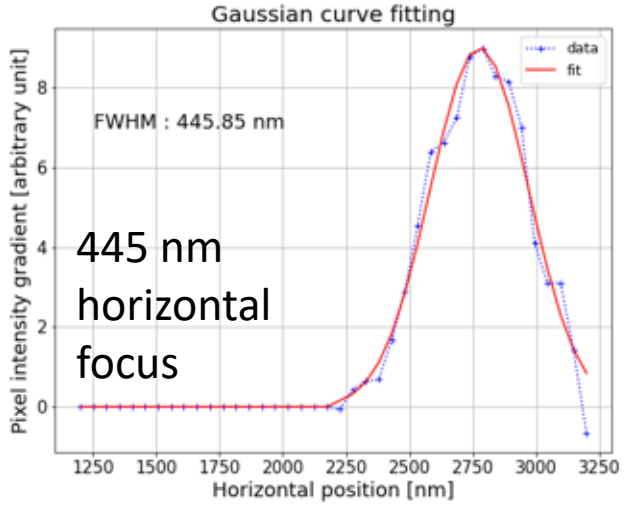
Adjust Rx, Rz and Y using the vessel flange as a reference

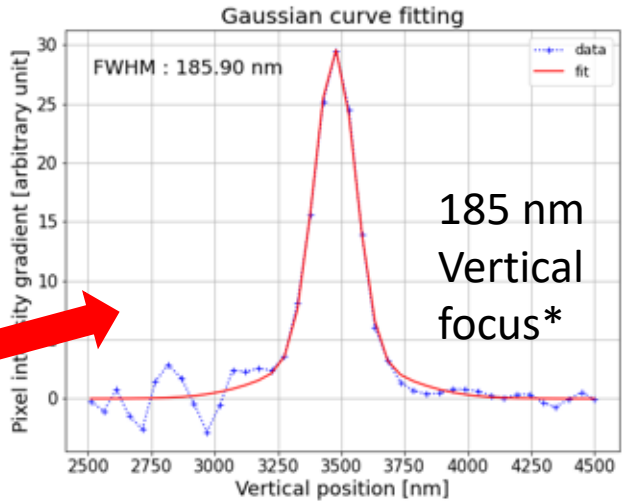
Align All 6 DoFs of HFM assembly using the VFM focus reference

Convert focus reference to laser tracker align. spheres

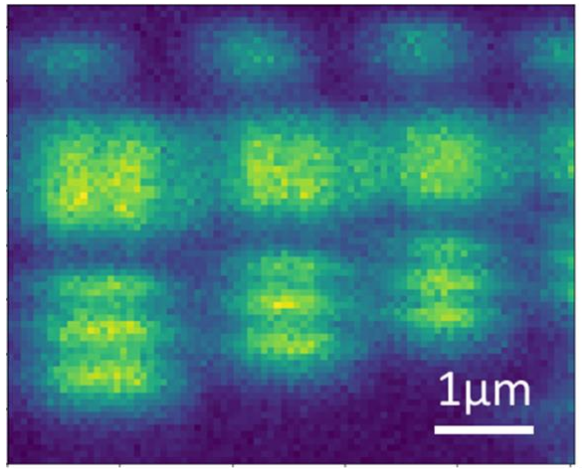
# Focus alignment (in progress)



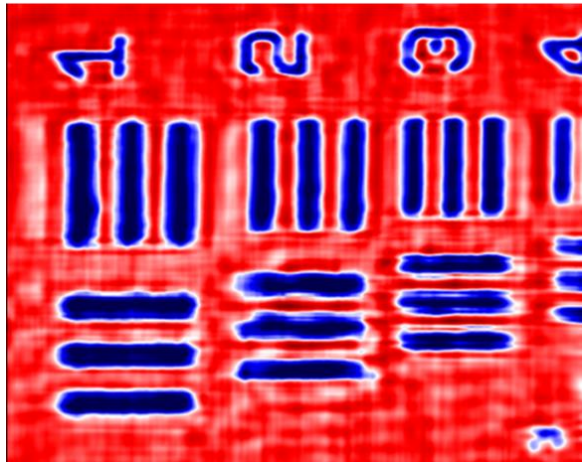




Includes 50 nm probe-dragging during fly-scans!!



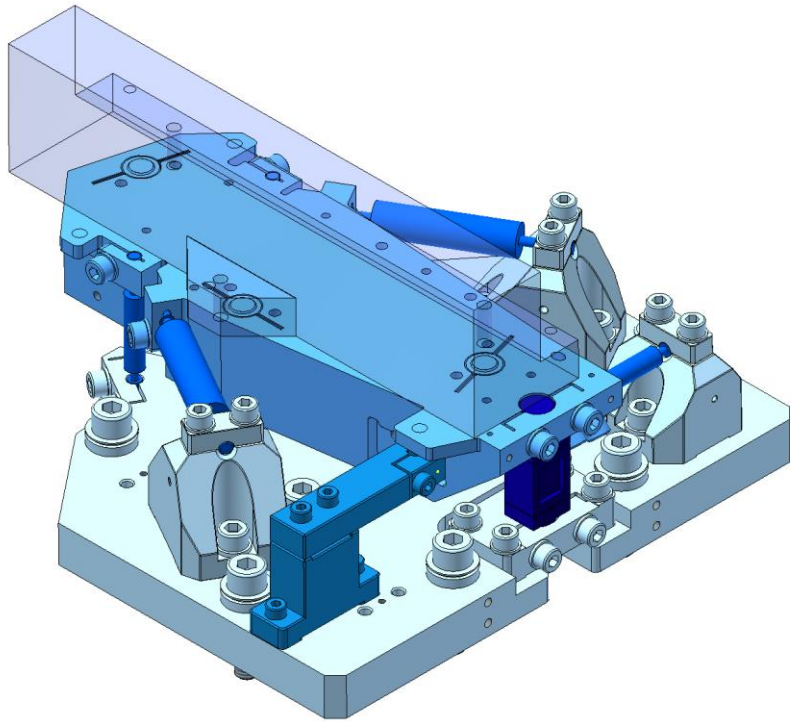

FLUORESCENCE



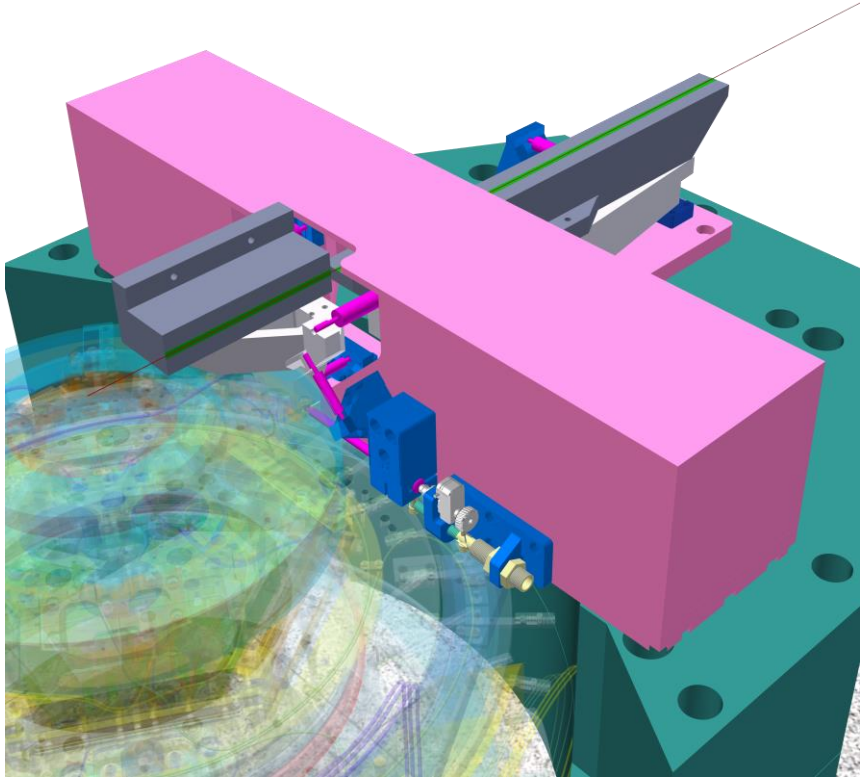
PTYCHOGRAPHY

# Conclusions

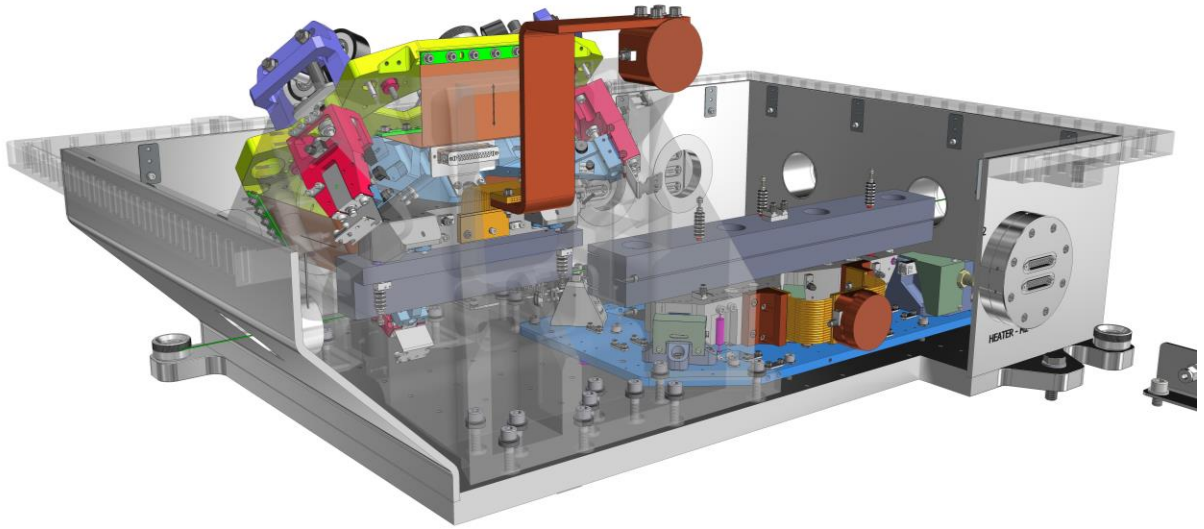
- Focus comissioning underway shows promising results already, giving enough information to optimize next KB system designs at Sirius
- The high stiffness concept was proven for high stability
- The current design also leaves way to adaptive optics and high dynamics realizations



# Next Steps



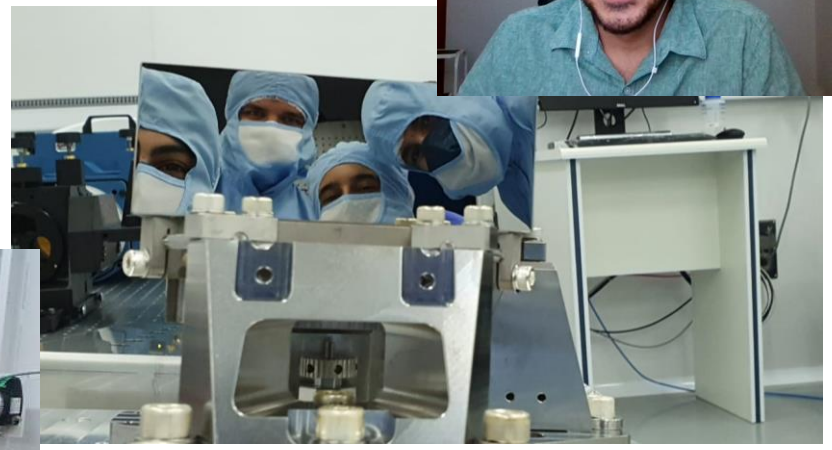
SAPOTI KB System

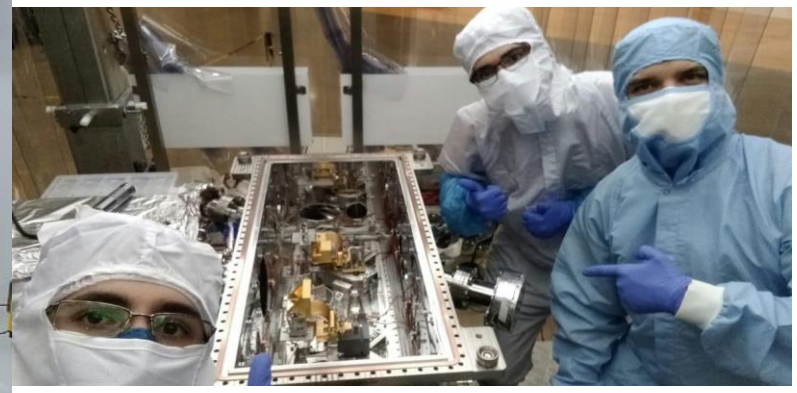


MOGNO KB System

# Acknowlegments

Experiment hall,
October 27, 2020





Control room, December 16, 2020


# Thank you!

On behalf of Sirius/LNLS Beamline Engineering Division (DEL)
and everyone that contributed to this project

Gabriel B. Z. L. Moreno
On behalf of Beamlines Design Group - PLL
gabriel.moreno@lnls.br

# New Comissioning results!!

- 2 weeks after MEDSI, the final resolution was finally achieved with pink beam, resolving ANT 100-nm features in fluorescence mapping!!