New Developments and Status of XAIRA, the New Microfocus MX Beamline at the ALBA Synchrotron

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TUOAM04

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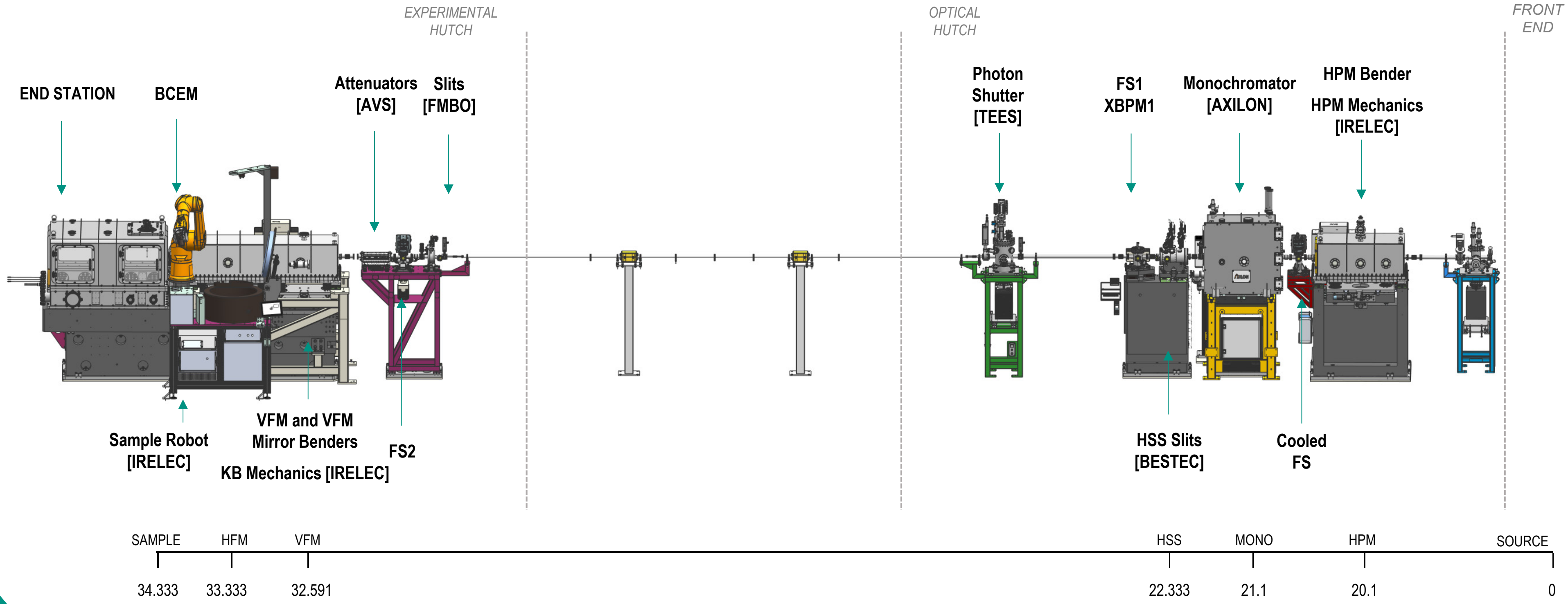
INTRODUCTION

- BL06-XAIRA is the first hard X-ray microfocus beamline at the ALBA Synchrotron.
- Macromolecular crystallography (MX) beamline designed to deliver high quality data from micron-sized and/or challenging crystal samples from oscillation and fixed-target serial MX experiments.
- Beamline characteristics:
  - Beam size at sample position: 3 x 1μm^2 (FWHM).
  - Energy Range: 3 – 15 keV (nominal 4 – 14 keV)
  - High flux (>10^{13} ph/s/250mA) at 1Å wavelength (12.4keV)
- Currently under comissioning, expecting first users in 2024.

BEAMLINE LAYOUT



- Windowless Optics
- Simple and stable optomechanical elements

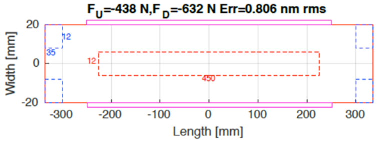
→

- Maximum Flux at sample (at low energy range).
- Maximum Beam Stability at sample position.

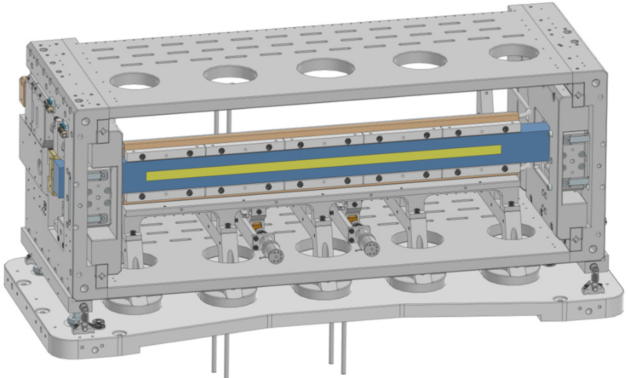
OPTICAL COMPONENTS

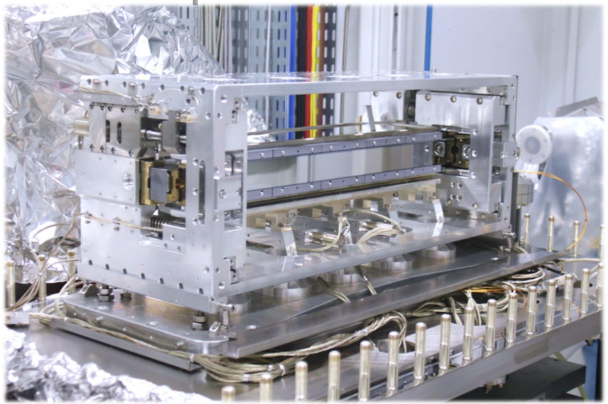
HPM – Horizontal Prefocusing Mirror

Mirror Parameters



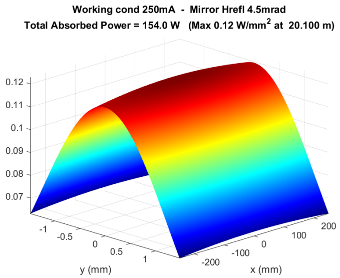
- Rectangular Mirror: 40x30x670mm (WxHxL)
- Horizontally deflecting mirror bender
- Bending Forces: Fu = 438N ; Fd = 632N
- Incident Angle: 4,5 mrad
- Footprint (full slits aperture 0.112x0.150 $mrad^2$): 2,8 x 500 mm^2
- 2 adaptive optics correctors to improve slope errors





Thermal Loads

	NOMINAL CASE (250mA) Slits closed to 0.099x0.150 mrad
Total Absorbed Power	**153.99 W**
Peak Power Density	**0.12 W/mm^2**

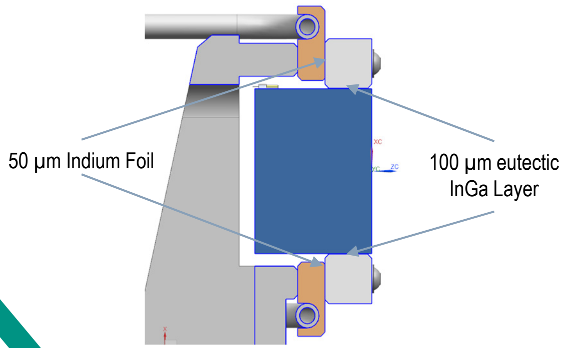


OPTICAL COMPONENTS

HPM – Horizontal Prefocusing Mirror

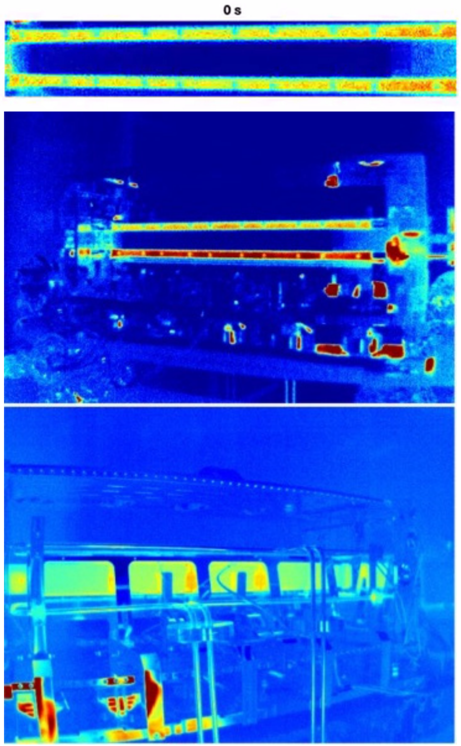
COOLING DESIGN

- Water cooling with InGa, following the procedure developed at SLAC.
- Disregarded options:
  - Internally Cooled Mirror – or Side Clamped Mirror: Mechanical interaction between cooling and mirror.
  - Trough cooling: Uncertainity in the deformation model, non-symmetric, gallinstan issues.



- Stainless Steel Tubes brazed to the long copper pads.

  Copper pads are nickel plated, to avoid copper-InGa issues
- Silicon Pads clamped to the copper pads, with Indium foils
- InGa layer between the mirror and the pads
- Thermal contact validated at the optics lab with a precision infrared camera (Optris PI640).

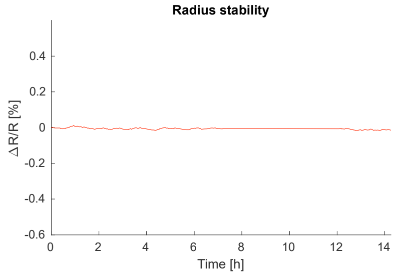


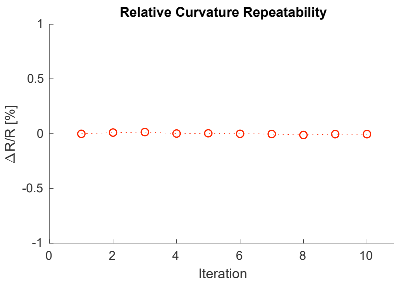
OPTICAL COMPONENTS

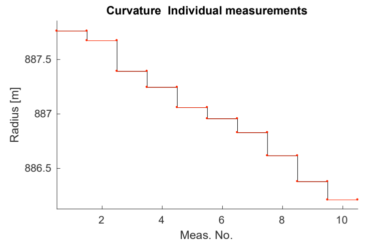
HPM – Horizontal Prefocusing Mirror

RESULTS

Metrology at the Optics lab



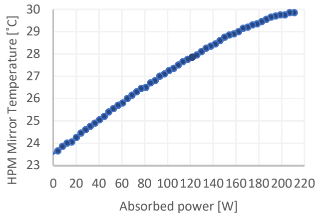


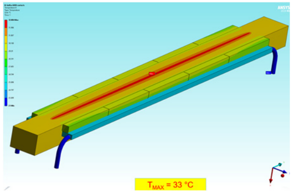


Bender Error	0,023urad rms
Radius repeatability ΔR/R	0,0076%
Radius Stability (14 h)	0,0054% rms
Radius resolution (400 halfsteps)	≤ 0.0371 %
Slope Error	0.258 µrad rms
Height Error	1.56 nm rms

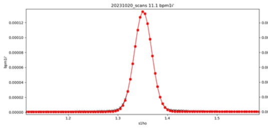
Bender performance was not affected by the InGa Cooling System

Comissioning at the Beamline

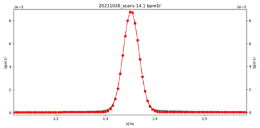




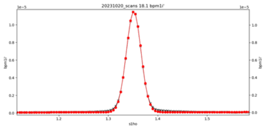
Temperature increase with the front-end vertical aperture, as calculated by FEA.



POSITION: 1,3510
FWHM: 41 µm
S0hg0.8



POSITION: 1,3519
FWHM: 37 µm
S0hg0.5



POSITION: 1,3514
FWHM: 35 µm
S0hg0.1

H beam size measurements (edge scans at HSS pos) at different H apertures
Theoretical value achieved at narrow aperture, optimization with correctors to be done.

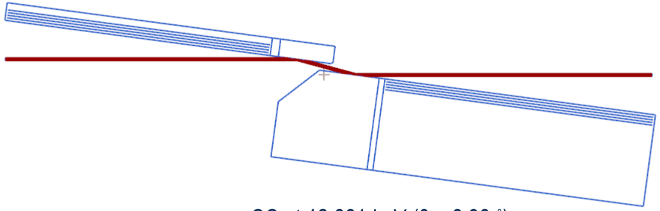
OPTICAL COMPONENTS

Monochromator

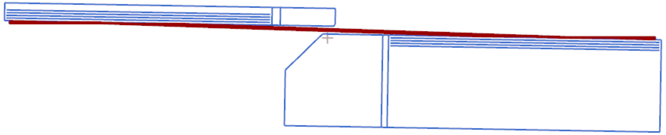
DESIGN CONCEPT

- Channel Cut Monochromator (CCM, Si(111)) and Double Multilayer Monochromator (DMM, Mo/B_4C) in a single mount.
- Bragg axis is 2,3mm underneath the first optical surface: the center of the beam travels along the crystals surface depending only on Bragg angle, θ.
- Due to the relatively small grazing incidence angle of the multilayers compared to the channel cut, the beam positions for the two diffracting surfaces do not overlap in the ranges:
  - 3-15 keV (θ: 41,2˚ - 7,2˚) for the CC
  - 6-14 keV (θ: 2,27˚ - 0,97˚) for a ML with a d spacing of 26 Å.
- Dimensions optimized to change from CC to ML just changing the Bragg rotation angle
- Minimized beam excursion (4,5mm gap – max. excursion: 2,2mm – 60µm at sample)

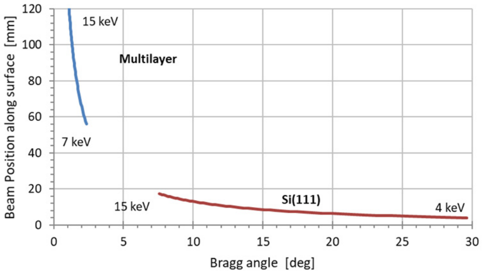
MINIMIMUM MECHANICS (NO TRANSLATIONS) SO AS TO MAXIMIZE BEAM STABILITY AT SAMPLE POSITION



CC at 12.661 keV (θ = 8,98 ˚)

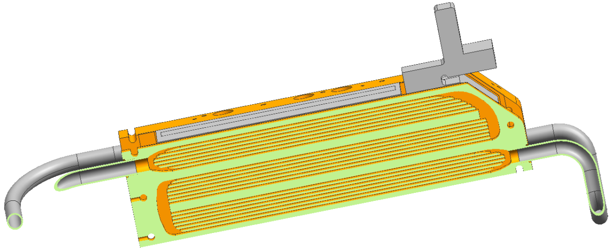


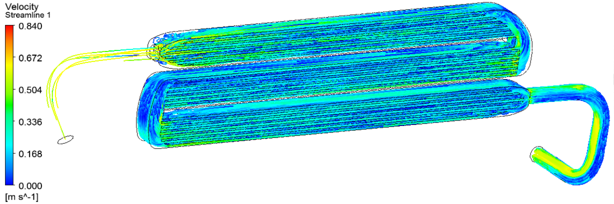
ML at 14 keV (θ = 0,97˚)

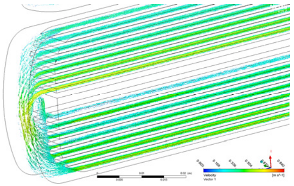


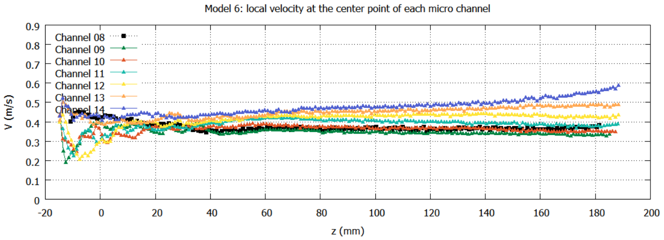
OPTICAL COMPONENTS

Monochromator









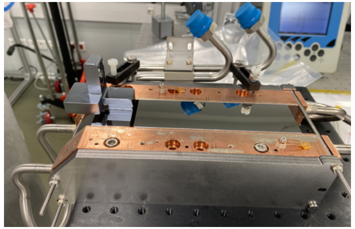
Almost constant velocity (rms) in each microchannel (~0,4m/s)

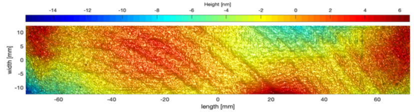
* *Marcos Quispe et al 2022 J. Phys.: Conf. Ser. 2380 012073; DOI 10.1088/1742-6596/2380/1/012073*

MONO COOLING

- In-depth internal geometry optimization (CFD and FEA simulations) to make the LN2 flow as uniform as possible and minimize turbulences while maximizing the cooling capacity.
- Multilayer cooling with LN_2 was a critical point.
  - Mo/B_4C was found to be the most suitable coating material for cryogenic temperatures
  - Cooling optimized to minimize thermal cycling on the ML substrate
- Clamping pressure was potentially an issue:
  - Essential in order to have a good thermal conductance at CC
  - It induced surface deformations on the ML optical surface

Step by step clampling procedure measuring surface deformations with Fizeau Interferomenter



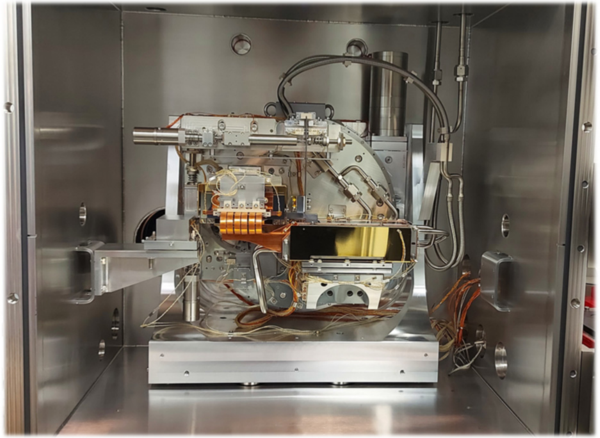


OPTICAL COMPONENTS

Monochromator

Concept validated by the first commissioning tests with beam

- Substrates changed in ~1min just rotating the Bragg axis (limited by the rotation speed)
- Horizontal beam position is almost constant (± 0,1mm).
- Measured flux 1.1 10^{14} ph/s at 7,29 keV after mono (ML).



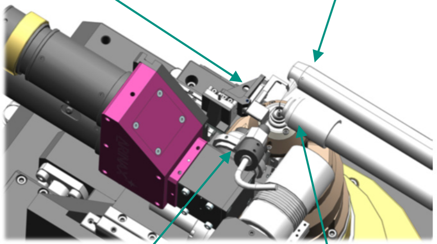
** Vertical Beam Excursion 0,34mm*

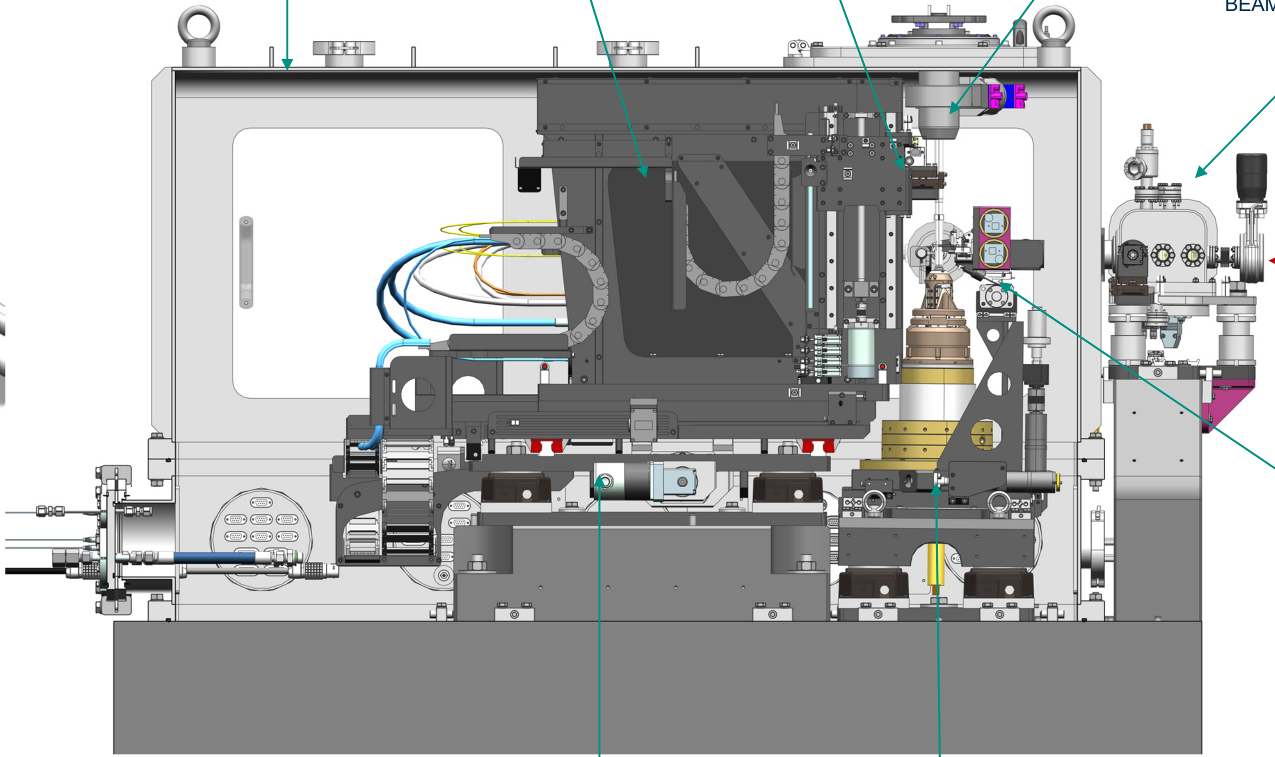
** Design and construction of the monochromator mechanics by AXILON.*

END STATION

Layout

Sample to detector distance **70** - 250mm

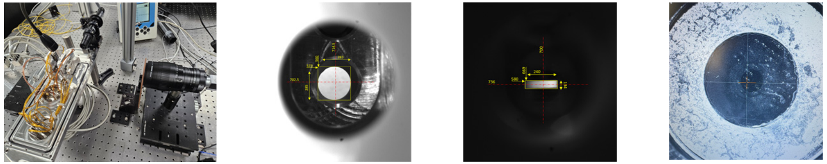


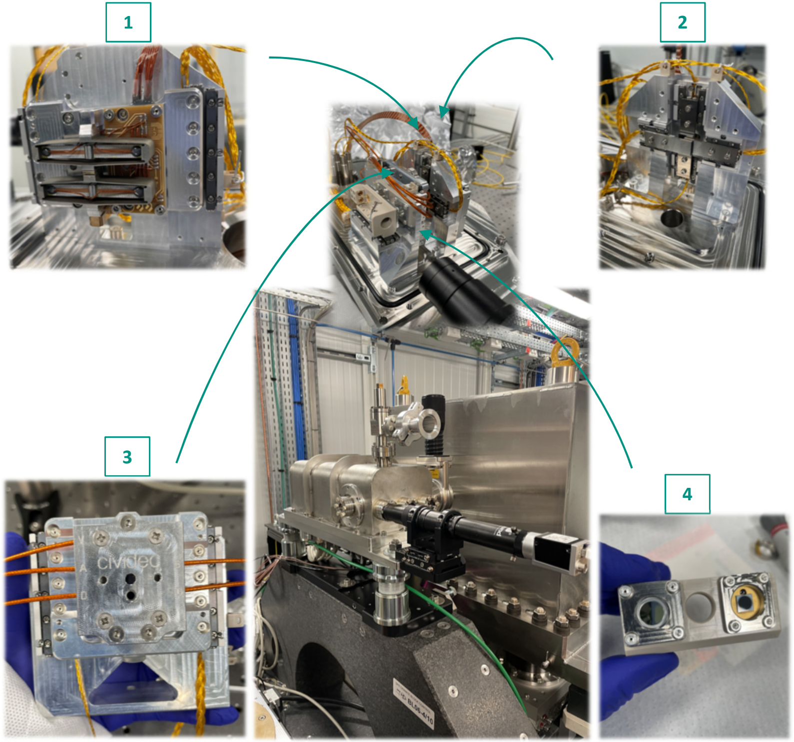


END STATION

Beam Conditioning Elements

- LOCATION: In between the KB System and the ES Helium Chamber [250mm]
- UHV Compatible, sealing with a CF16 Diamond Window (Ø2mm 10μm thickness).
- Independent actuation by SmarAct PiezoGuides of the following elements:
    1. Fast Shutter [CEDRAT]
    2. 4-Blade Slits
    3. XBPM [CIVIDEC]
    4. Beam Diagnostics: Diode and Fluorescence Screen (YAG:Ce)
- XBPM vertical position is monitorized by a interferometer [Qtools]
- The setup was pre-aligned at the optics lab using a telecentric lens





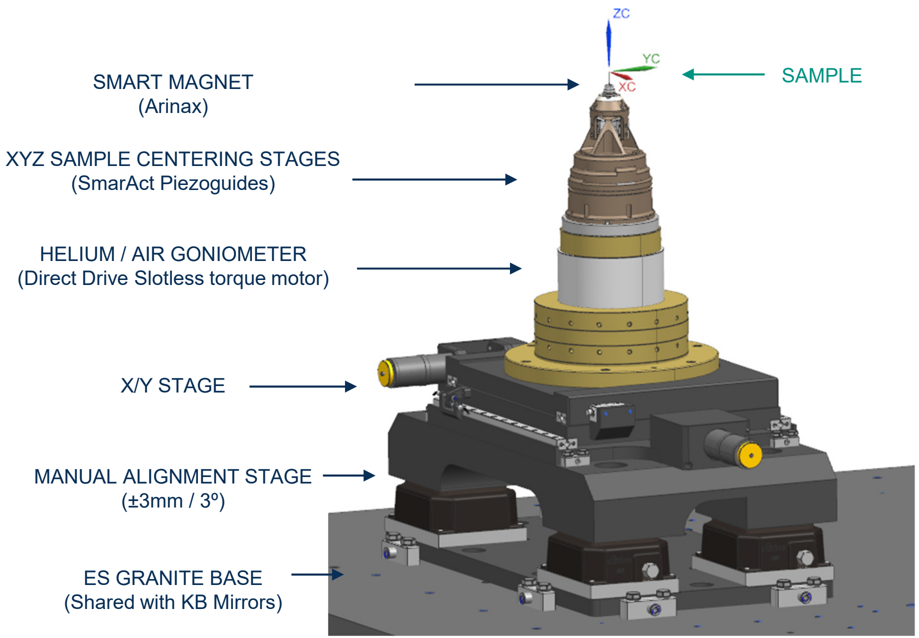
END STATION

Diffractometer

REQUIREMENTS

- To maximize sample position stability and minimize SoC (≤ 0,1 µm).
- To allow the positioning of the goniometer axis with respect to the beam.
- To allow the centering of the sample to rotation axis.
- To be compatible both with air and helium environments.
- To allow generating trajectories required for the experiments (i.e. helical scans, raster scans)

	Range [mm]	Resolution	Speed [mm/s]
Longitudinal (Y)	- 4 to 0,1 mm	100nm	0,5
Transversal (X)	± 5mm	100nm	*0,5*
Sample Centering (x&y)	± 2mm	10nm	*2,5*
Sample Centering (z)	± 5mm	10nm	*2,5*
Goniometer Rotation (Ω)	360˚	0,05 mdeg	*60 rpm*

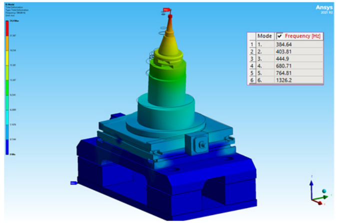


END STATION

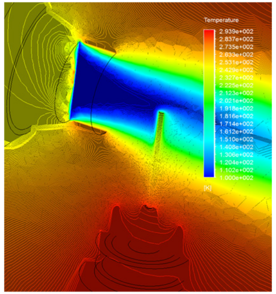
Diffractometer

GONIOMETER

- Direct Drive Torque Motor; Slotless (zero cogging) from Aerotech.
- 2 Encoder Heads (Analog Encoders).
- Precision Slip-Ring (Moog) with a vibration dampling coupling



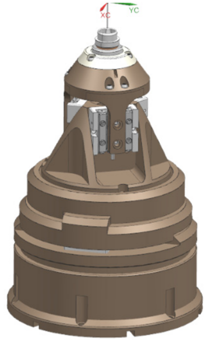
1st mode 384 Hz



Temp. at goniometer 293K

SAMPLE CENTERING SETUP

- SmarActs in parallel or 3 for the vertical motion.
- Frame made in Titanium
  - Low thermal expansion coeficient.
  - Not heavy.
  - Rigid.
- Total weight: 0,6kg Easily removable. It can be exchanged by a XZ fast scanning setup (for SSX experiments).



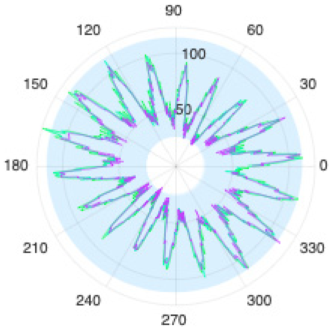
The whole system has been calculated and optimized by FEA and CFD.

END STATION

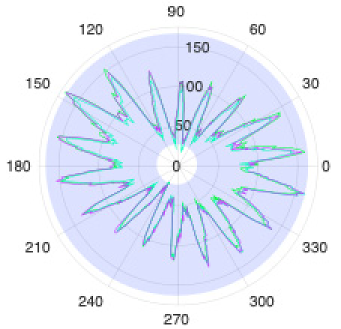
Diffractometer

RUNOUT MEASUREMENTS

- Run out measured with a high resolution microscope.
  - At different speeds (360deg/s ; 55 deg/s; 5,5 deg/s).
  - Both with compressed air and helium.
  - With and without the slip ring.
- Motor poles can be observed.
- Behavior is similar in air and helium: concept validated.
- Run out of full setup still being optimized.

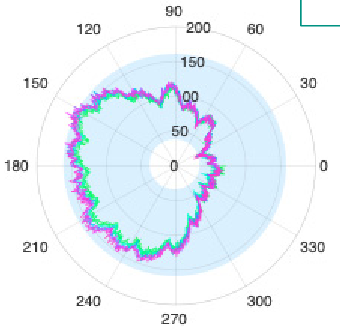


GONIO WITH AIR
50nm

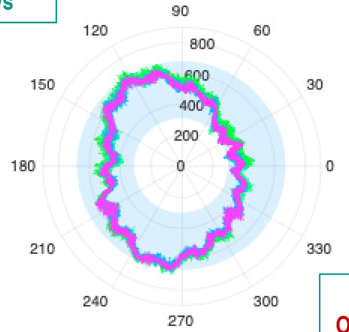


GONIO WITH HE
70nm

At 360deg/s



GONIO WITH SLIP RING
65nm



FULL SETUP
242nm

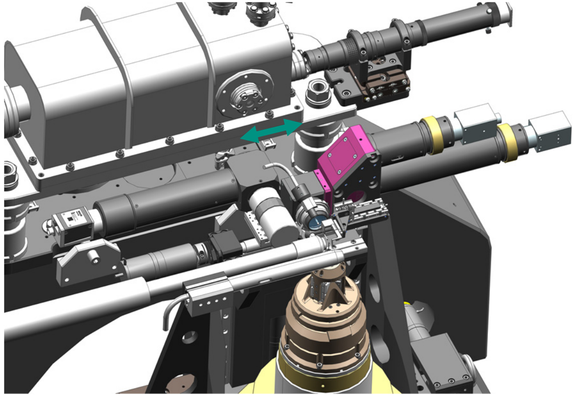
NOT YET OPTIMIZED

END STATION

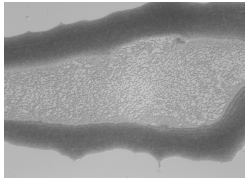
On Axis Viewing System

- Sample visualization is one of the key components of the BL.
- Based on two separate optics
- Fast exchange from one to another (< 4s)

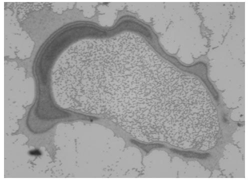
	Description	Resolution
High Magnification Branch	High Resolution Objective	0,7 µm (fixed)
Low/Medium Magnification Branch	Parallax-free comercial system [B-ZOOM ARINAX] Ø1mm drilled hole objective Splitter for 2 lens branches	1,2 µm > 1,2 µm



WHITE LIGHT ILLUMINATION



BLUE LIGHT ILLUMINATION



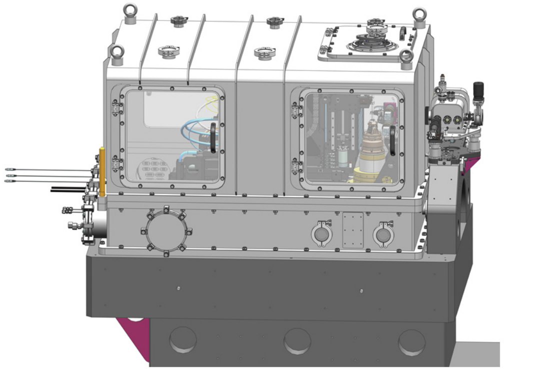
UNDER COMISSIONING

∅0.5µm polystyrene microspheres

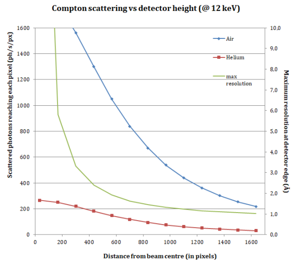
Scaled image showing whole FOV

END STATION

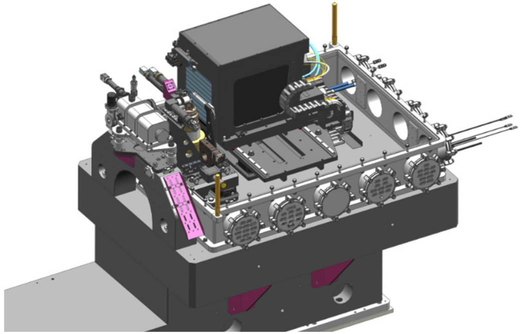
Helium Chamber

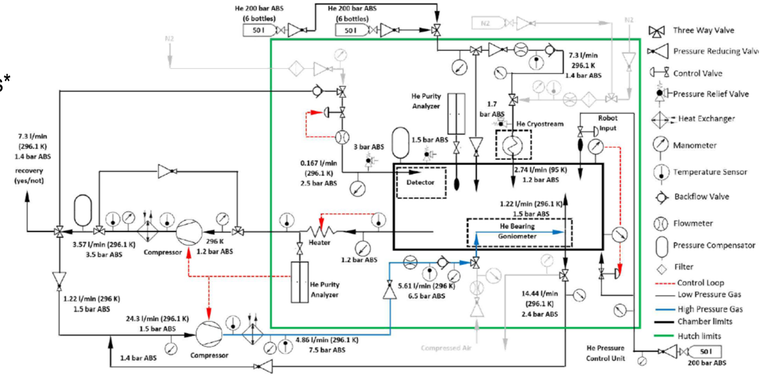


- End station to be fully compatible with standard MX operation using robot



- Compatible with air and helium atmospheres (Pmax. 1,2bar).
- The chamber is split in 2 parts:
  - Bottom Part: not removable; includes all the electrical and fluid interfaces.
  - Top Part: removable; includes:
    - Robot interfaces (sealing and gate valve)
    - Acces doors for maintenance.
    - Helium recovery system interfaces*

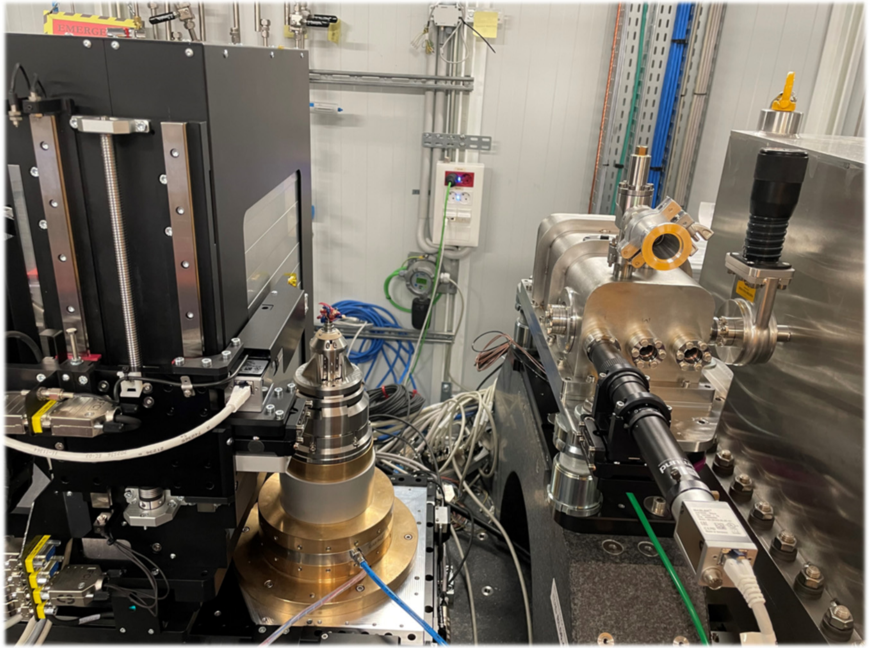




* *Marcos Quispe et al MEDSI 2023; WEPPP035*

CONCLUSIONS and NEXT STEPS

- Optimized performance compatible with standard MX BL operation.
- Novel solutions for the BL optics and End Station
  - HPM: improved stability and focus
  - Dual monochromator concept: Channel Cut and Multilayer on a single mount.
  - Helium/Air compatible sample environment.
- Integrated custom design of the whole End Station.



NEXT STEPS:

- Fine commissioning of the optics: mirror correctors, interferometry system.
- Complete the installation and commissioning of the end station.

Aknowledgements

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Juan Luis Frieiro
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Liudmila Nikitina
Alejandro Enrique
Jose Ferrer

THANK YOU

谢谢

Q&A?

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