BEATS

Work Package 6

Beamline assembly and commissioning

Commissioning of the beamline optical components

D 6.01

June 2023

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PROJECT DETAILS

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DISSEMINATION LEVEL		
x	P - Public	
☐	PP - Restricted to other programme participants & EC:	
☐	RE - Restricted to a group	
	CO - Confidential, only for members of the consortium	

REPORT DETAILS

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Contents

SUMMARY

The day-one operation of the BEATS beamline was defined in the beamline's technical design report (cf. BEATS deliverable 4.1) as operation with white / pink beam, i.e. at the beginning of operation in June 2023, the beamline will offer x-radiation from a 2.9 T wavelength shifter installed in a short straight section of the 2.5 GeV SESAME storage ring, the spectrum of which can be shaped by

- the magnetic gap of the insertion device and
- absorber foils of various materials and thicknesses.

Two major configurations were defined: "high energy" and "low energy", providing a spectrum of 60 keV and 20 keV mean energy, respectively (cf. BEATS deliverable 6.2).

Furthermore, the BEATS project comprises the design, procurement, and installation of a double multilayer monochromator (DMM) which shall, as the first beamline upgrade, be made available from the beginning of the official user operation of BEATS in February 2024. The design of the monochromator is detailed as well in the beamline technical design report.

This document describes the status of the procurement, installation, and the results obtained during the commissioning of the DMM.

DESIGN OF THE DMM

During the design phase of BEATS it was decided to limit the monochromatic operation range of BEATS to start at 8 keV and to go up to 50 keV. The monochromator will use multilayers as energy selective elements instead of monocrystals, trading in monochromaticity for flux. Two mirror elements are foreseen, one reflecting the incoming beam vertically upwards, the other reflecting the beam back into the original propagation direction leading in total to just a vertical offset. In case the beamline is operated in white / pink mode, the mirror elements can be moved out of the incoming beam. Each mirror will feature two stripes with different multilayer coatings (material and d-spacing) to optimise the performance to two different x-ray energy ranges:

BEATS DMM - overview

Distance from source (1st mirror)	15.165 [m]
Beamline aperture	1.8 mrad × 0.4 mrad (Hor. × Ver.)
Max. Beam size @ 1st mirror	29 mm × 6 mm (Hor. × Ver.)
Offset (variable)	Min. 4.0 – Max. 18.0 [mm]
Substrate dimension	500 mm × 70 mm × 60 mm
Distance between ML centers	510 mm
Theta (Bragg angle)	-0.5 – 2.5 [deg]
Bragg resolution	0.5 µrad
Energies	8 – 50 keV
Max. power on 1st mirror	133 W

General design characteristics of the double multilayer monochromator of BEATS

Multilayer coatings

Stripe 1

	$[W/B_4C]_{100}$ – d = 2.5 nm
d-spacing	2.5 nm
d-spacing gradient along Z (O.A. 500 mm)	3.41 % (0.00682 % / mm)
N. bilayers	100
Energies	20 – 50 keV
dE/E	1.8 %
Theta (Bragg angle)	0.292 – 0.728 [deg]
Filling factor Γ	0.5

Stripe 2

	$[Ru/B_4C]_{65}$ – d = 4.0 nm
d-spacing	4 nm
d-spacing gradient along Z (O.A. 360 mm)	3.52 % (0.00704 % / mm)
N. bilayers	65
Energies	8 – 22 keV
dE/E	2.4 %
Theta (Bragg angle)	0.42 – 1.159 [deg]
Filling factor Γ	0.5

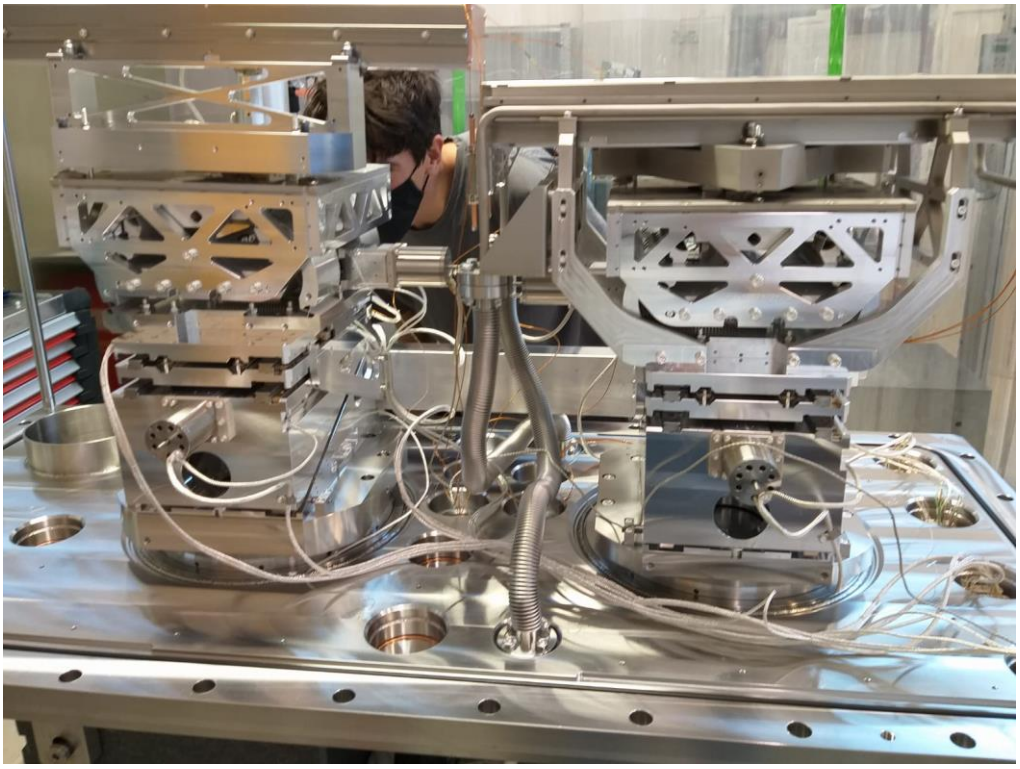
Design characteristics of the two multilayer stripes of BEATS' DMM

PROCUREMENT OF THE DMM

A Call for Tender process following SESAME's standard procurement procedures was carried out and in April 2021 the contract was awarded to the Italian company CINEL. The fabrication phase was hit by the CoViD19 pandemic. It was decided not to procure, as originally foreseen, the multilayer mirrors from the shelve, but to have them fabricated at the ESRF's new multilayer coating facility (i.e. ESRF would procure the substrates and coat the mirrors in-house). In this way, the design and coating of the multilayers was performed under full control of ESRF staff at the new, state-of-the-art ML coating facility of the ESRF. An amendment of the BEATS Grant Agreement was established and approved by the European Commission to cope with the corresponding transfer of funds (other direct cost, no direct personnel cost) from SEAME to ESRF.

In May 2022 the factory acceptance test of the mechanical DMM structure was carried out at CINEL.

The performance of all motorized axes was tested and found compliant with the specifications (with respect to resolution and range of motion) limit to limit. The vacuum performance of the assembly was tested over a period of 2.5 days, which was deemed sufficient, as the pressure decrease followed exactly the same curve as did a similar device produced by CINEL in parallel for another customer.



The DMM mechanical assembly (without vacuum vessel) during the FAT at CINEL. Clearly visible are the two towers holding the two multilayer mirrors.

It was concluded that the device was fulfilling the specifications and CINEL was authorised to pack and ship it to SESAME, where it arrived in July 2022.

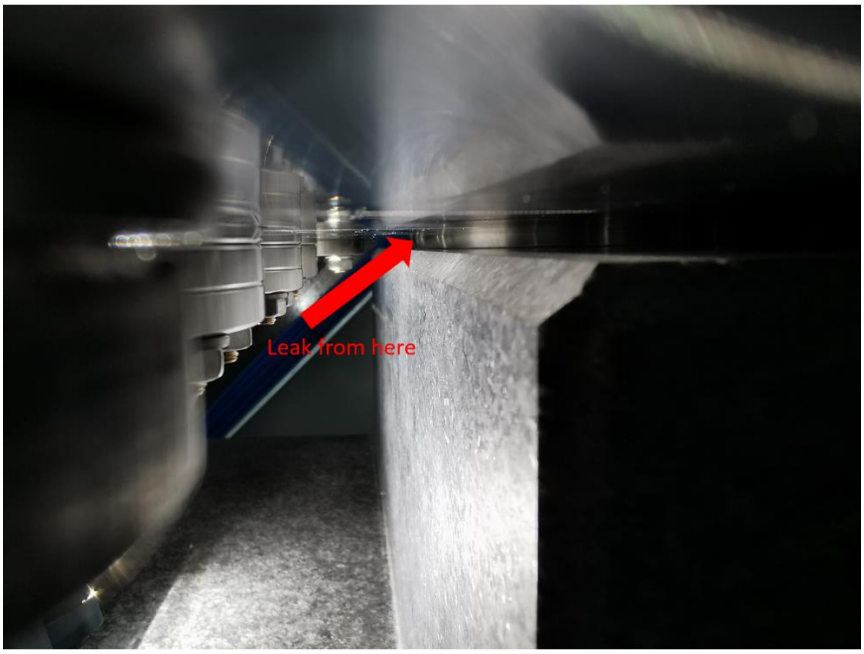
INSTALLATION OF THE DMM

The installation of the monochromator began in January 2023. Alignment of the device comprised of aligning the plane of the supporting granite and the vacuum vessel (entry, exit flange) with respect to the SESAME orbit coordinate system with 0.1 mm precision. Final alignment will concern the actual positioning of the multilayer mirrors within the assembly and will be carried out with the x-ray beam once the mirrors are available.

Following the installation, as part of the site acceptance test, again all motion axes were checked and found to be within specifications.

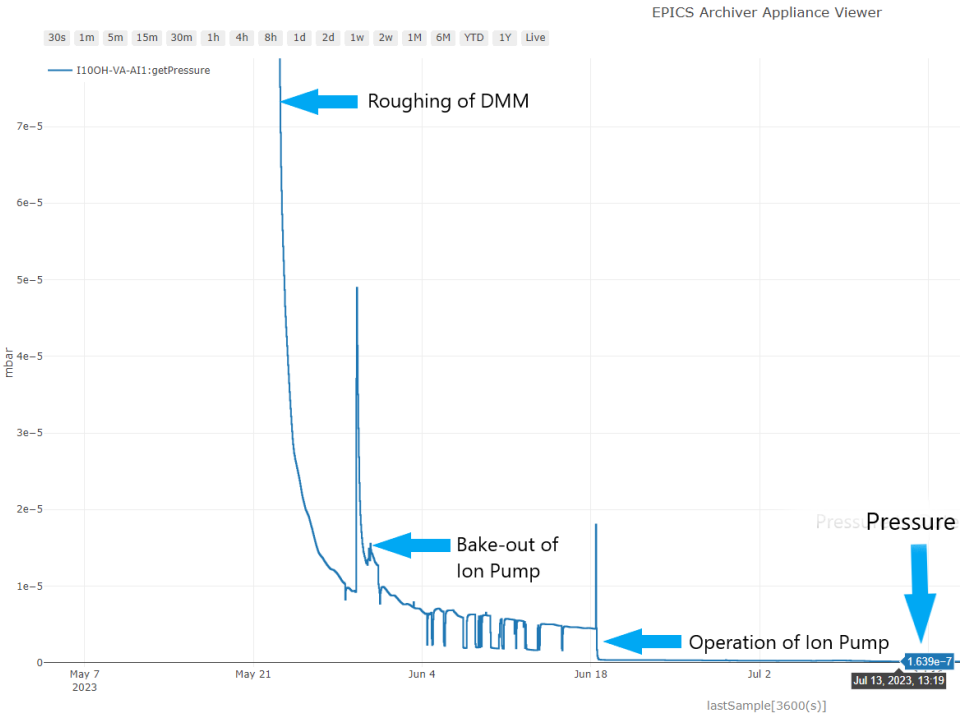
The DMM installed at the Optics Hutch of BEATS at SESAME during the motion axes test

However, when pumping down the device following the motion tests, a leak was detected, as the pressure inside the DMM vessel only reached the level of 10^{-3} mbar, very likely due to damage occurred during transport. A leak test showed, that the leak was at the lower side of the vacuum vessel at a position necessitating an intervention of the supplier.

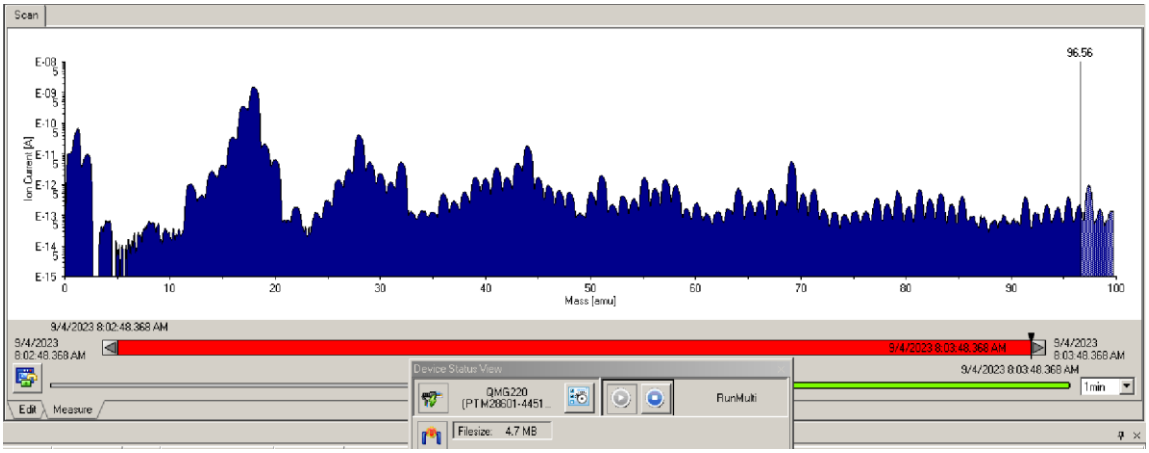


Position of the suspected vacuum leak

CINEL sent an engineer and a technician over to SESAME in May and successfully repaired the device.



Pressure inside the DMM vessel following the repair intervention of CINEL

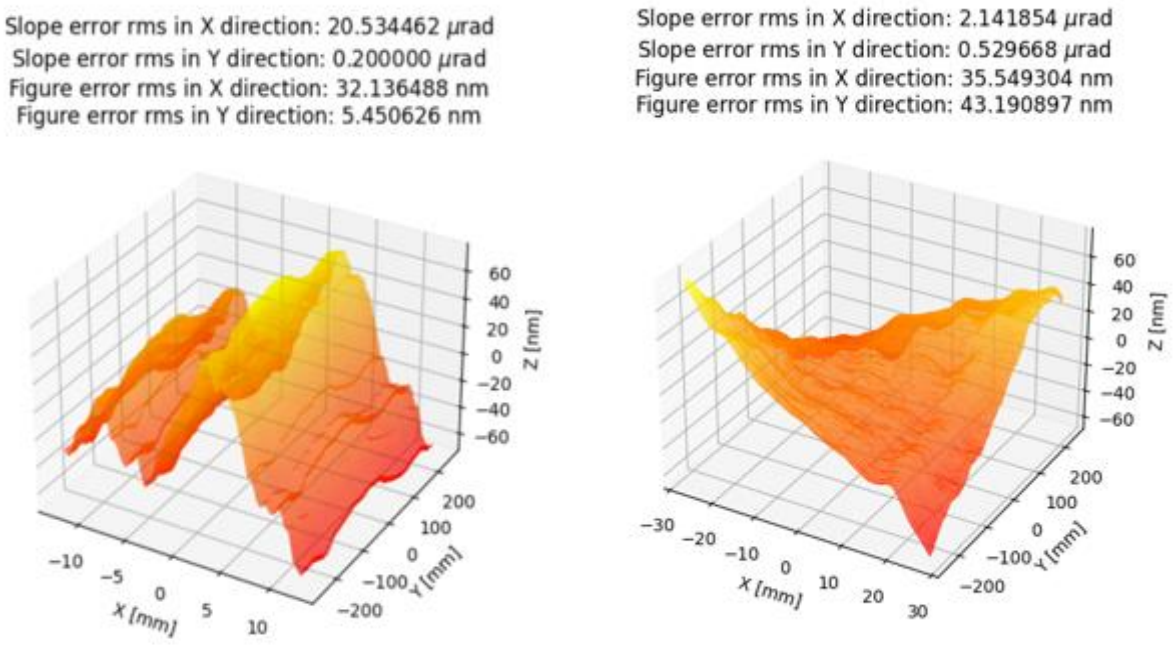


A Rest Gas Analysis (RGA) of the vacuum inside the DMM vessel shows no adverse findings.

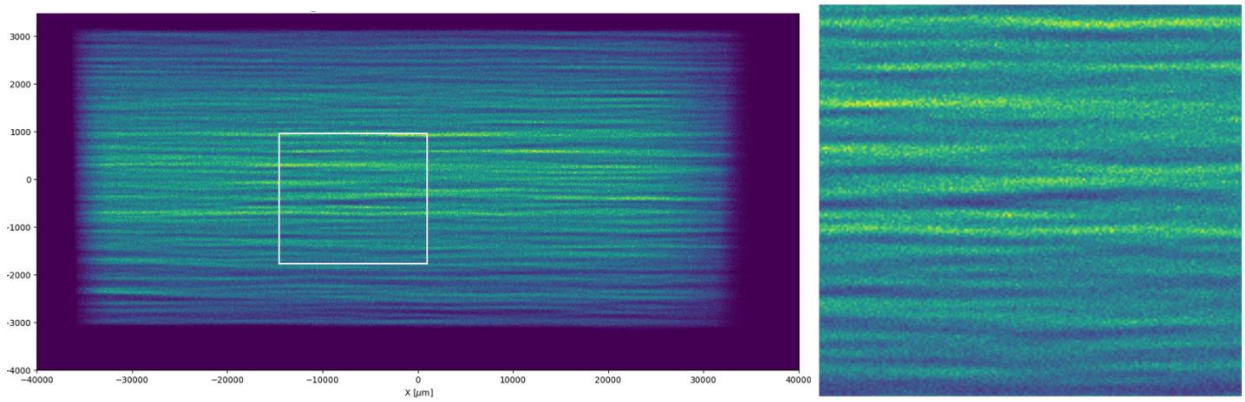
THE MULTILAYER MIRRORS

The substrates for the multilayer mirrors were ordered by the ESRF from the company SESO and delivered in autumn 2022. Measurements of the surface quality showed that the longitudinal slope error was outside specifications (0.25 – 0.29 µrad over the useful substrate area instead of 0.2 µrad; kink of the substrate surface towards the edges, leading to total surface error > 0.5 µrad). Nevertheless, it was decided to accept the substrates as *vis-à-vis* their surface roughness they showed values better than expected (below 14 nm RMS instead of 15 nm). Furthermore, Monte-Calo based raytracing calculations showed no degradation of the beam profile when comparing the

real surface of the substrates with a simulated one, which fulfils the original specifications. Following this decision, the substrates were coated end of June 2023 at the ESRF's multilayer coating facility and are currently under investigation of the x-ray optical properties. First measurements of the x-ray reflectivity indicate a successful coating process.



Comparision of a simulated surface profile (left) used during the design phase for ray-tracing simulations of the beamline performance with (right) the surface profile obtained by SESO.



Expected beam profile at the position of the sample, SHADOW raytracing calculation based on the measured substrate surface. Left: Overall profile, right: inset

NEXT STEPS

The beamline will operate from July 2023 onward in white / pink beam mode and with friendly users to

- continue the commissioning and further explore and optimize the overall operation parameters of BEATS, and
- to accustom and train potential users of the facility.

The multilayer mirrors will be transported to SESAME and installed in the DMM by end of September 2023, allowing for the commissioning of the monochromatic operation mode (first upgrade of BEATS) until the end of the year 2023.

BEATS will open for the submission of applications for beamtime in September 2023 (next proposal deadline of the SESAME facility). This will lead to the first experiments carried out by the official user programme of SESAME on the BEATS beamline in February 2024, for which the users can already benefit from both white / pink and monochromatic operation mode.