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# X-RAY FACILITY FOR THE CHARACTERIZATION OF THE ATHENA MIRROR MODULES AT THE ALBA SYNCHROTRON

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*Abstract*

MINERVA is a new X-ray facility under construction at the ALBA synchrotron specially designed to support the development of the ATHENA (Advanced Telescope for High Energy Astrophysics) mission [1]. The beamline design is originally based on the monochromatic pencil beam XPBF 2.0 from the Physikalisch-Technische Bundesanstalt (PTB), at BESSY II already in use at this effect [2]. MINERVA will host the necessary metrology equipment to integrate the stacks produced by the cosine company in a mirror module (MM) and characterize their optical performances. From the opto-mechanical point of view, the beamline is made up of three main subsystems. First of all, a water-cooled multilayer toroidal mirror based on a high precision mechanical goniometer, then a sample manipulator constituted by a combination of linear stages and in-vacuum hexapod and finally an X-ray detector which trajectory follows a cylinder of about 12 m radius away from the MM. MINERVA is funded by the European Space Agency (ESA) and the Spanish Ministry of Science and Innovation. MINERVA is today under construction and will be completed to operate in 2022.

## INTRODUCTION

The ATHENA telescope is a space observatory that will address fundamental questions about energetic objects (accretion disk around black holes, large-scale structure, etc...). One of the key elements of the telescope is the innovative modular architecture of its optics subdivided by 15 concentric rings and filed by about 600 sub-systems called mirror modules (MMs). The technology used to manufacture the MM is based on the Silicon Pore Optics technology developed at cosine. At XPBF 2.0, cosine is currently optimizing the method to produce MMs at large scale [3] and today MINERVA is built to strengthen and boost their production and characterization while preserving the interoperability with XPBF 2.0. The final angular resolution of ATHENA strongly depends on the alignment accuracy between the 4 stacks constituting a singular MM. It is why stability, accuracy and repeatability are crucial parameters for the opto-mechanical components specifications.

## GENERAL BEAMLINE DESCRIPTION

MINERVA takes port 25 at the ALBA experimental hall. This port is fed by a bending magnet source and provides optimal spatial distribution to allow future upgrades of the components. The beamline will operate under Ultra High Vacuum conditions (UHV) from the source to the exit of the photon shutter, where a vacuum window (Silicon Nitride) will separate them from the rest of the beamline. Downstream the vacuum window, the beamline will operate under High Vacuum conditions (HV, 10-5 mbar). The beamline will assess the absolute distance between the end detector and the MM origin with the adequate accuracy needed by the data analysis. This measurement is performed by the combination of laser tracking technology and high positioning repeatability of the mechanics. The whole beamline will be controlled using the Tango control system, standard at ALBA. MINERVA follows the optical layout sketched in Fig. 1. In there are presented the following components:

- A bending magnet of the ALBA storage ring as the X-ray source and the front-end elements.
- A toroidal mirror (M1) with a multilayer coating. The mirror deflects the beam inboard, with a total deflection angle of 14 degrees. It collimates the beam in both the horizontal and vertical planes. Its reflective surface selects a narrow bandwidth at the nominal energy of 1.0 keV. This element is enclosed in the optics hutch.
- A filter unit consisting of one $Si_3N_4$ membrane coated with a thin Al deposition. This filter removes the visible light reflected by the M1 mirror.
- A set of pinholes ranging from 10 µm to 500 µm in diameter.
- A photon beam shutter which includes a fluorescent screen beam diagnostic unit.
- A $Si_3N_4$ window, which separates the upstream UHV section from the downstream HV.
- A four-blade slit system that allow for apertures from fully closed to more than 10 mm in aperture.

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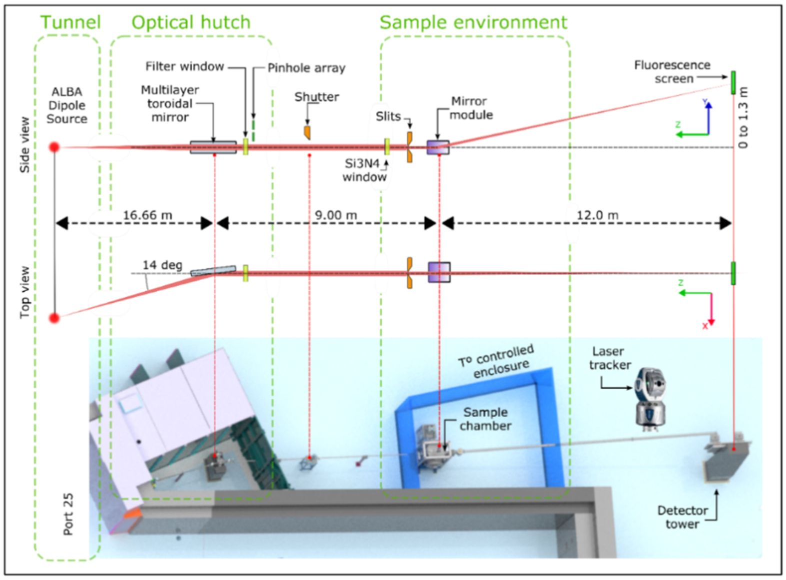


Figure 1: MINERVA layout presenting the main components of the beamline. Side view in a), top view in b) and 3D view in c).

- The sample station, which includes an in-vacuum hexapod and 2 linear stages for vertical and horizontal linear translations. The sample chamber seats inside a temperature-controlled enclosure.
- A flight-tube, which links the sample station to the detector. The flight-tube preserves the vacuum along the 12 meters long beam path between the MM and the detection system.
- The imaging detector, which consists on a fluorescent screen coated at a viewport at the downstream flange of the flight-tube, and imaged by a visible light 2D visible camera. The detector is mounted on a support tower that allows changing its height from 1.4 m from the floor to about 2.7 m. Also, for calibration purpose, the direct beam (not deflected by any MM) can be accessed.

## MECHANICAL SPECIFICATIONS

Minerva beamline three main mechanical components are now detailed as follow:

### *Monochromator*

The mirror substrate holder and surrounding elements are shown in Fig. 2. They are mounted on a single column as has been done before for MIRAS and LOREA beamline [4], with a proven outstanding resolution and stability, reaching up to 192 Hz for the first resonance mode. The column is decoupled from the vacuum chamber thanks to a large bellow and acts as a standalone insert that constitutes the base for the mirror holder, the cooling pipes and electrical feedthroughs. The column motion mechanics are based on a high precision goniometer that adjusts the angular X-ray beam incidence angle with a sub-micro-radian angular resolution and a horizontal translation stage that move the substrate perpendicular to its surface.

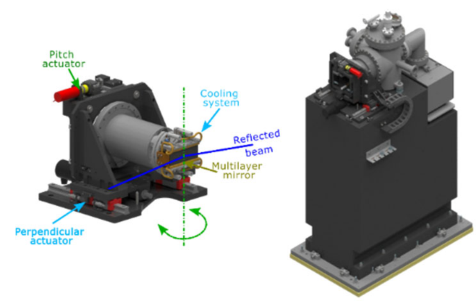


Figure 2: Monochromator mechanics description.

### *Sample Environment*

For the characterization of each MM, the four stacks are inserted into a jig. The MM optical entrance is scanned both vertically and horizontally in front of the fixed incident beam keeping its orientation within 1.0 arcsec. The main components used to fulfill those requirements are shown in Fig. 3. The jig is mounted on top of two high precision linear stages and an in vacuum hexapod. The vertical stage takes place in air and is particularly designed to keep constant the orientation of the MM during a vertical scan. It is based on the ALBA skin concept [5] that includes two precisions synchronized actuators mounted at both sides of the granite for better mechanical and thermal stability. Combination of ball spindles and ball linear guides accurately move a thick horizontal platform with two flexures joints on its sides. The displacement range of this motion is enough to scan the height of a complete MM. The horizontal linear stage work under vacuum and consists in a ball spindle and cross roller linear bearings actuated by a stepper motor. Both vertical and horizontal stages are provided by optical encoders.

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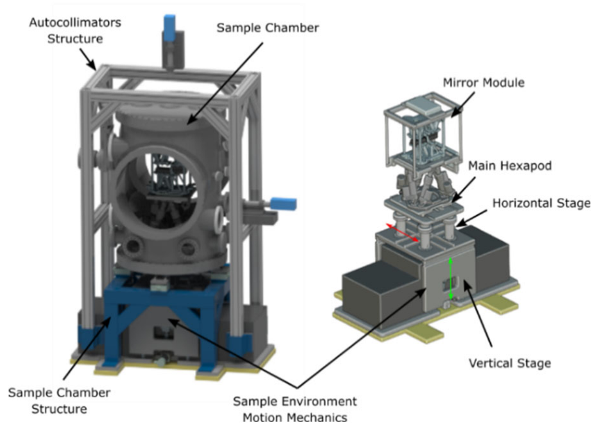

Figure 3: Sample environment.

The vacuum chamber is fully decoupled of the sample positioning stages by means welded bellows with robust columns holding the in-vacuum base plate. A metallic frame around the chamber includes two autocollimators that measure the 3 orientation angles MM respect of the incident beam which signal is re-used to act on the main hexapod for orientation correction.

### *Detector Tower*

The beam deflected by the MM is then sent to a 2- dimensional array detector. To fully characterize a MM, the detector has to move on the portion of a cylinder surface with radius between 11.5 and 12.5 m. This trajectory is performed by using a 4-axis positioning combination, as is shown in Fig. 4. The height and the orientation of the detector are achieved by a twin vertical linear stages placed side by side. The detector can also follow the line of sight of the deflected beam and be adjusted to find the focus of the optics. The mechanics of all the stages are based on precision ball spindles and ball linear guides, all actuated by stepper motors. Each stage position feedback is given by optical encoders. The position of the detector is accurately measured and related with the MM position by a permanent laser tracker.

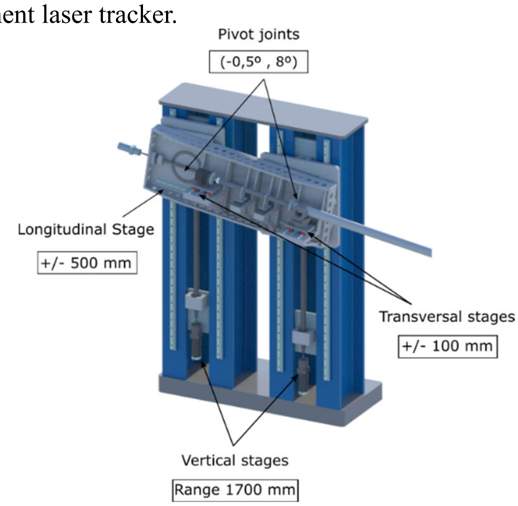

Figure 4: Detector tower.

## CONCLUSIONS

MINERVA, a new beamline under construction at the ALBA synchrotron, has been described. The optical layout is a replica of XPBF 2.0, however, MINERVA will bring some innovation by trying to reduce the MM characterization time with a different scanning scheme. Also, more stability and repeatability are expected with the innovative sample environment and detector tower design, bringing improved mechanical performances.

The beamline, which is currently finishing the detailed design phase, will move into the production phase during the following months until 1st semester 2022, aiming to receive first synchrotron light by the end of 2022.

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