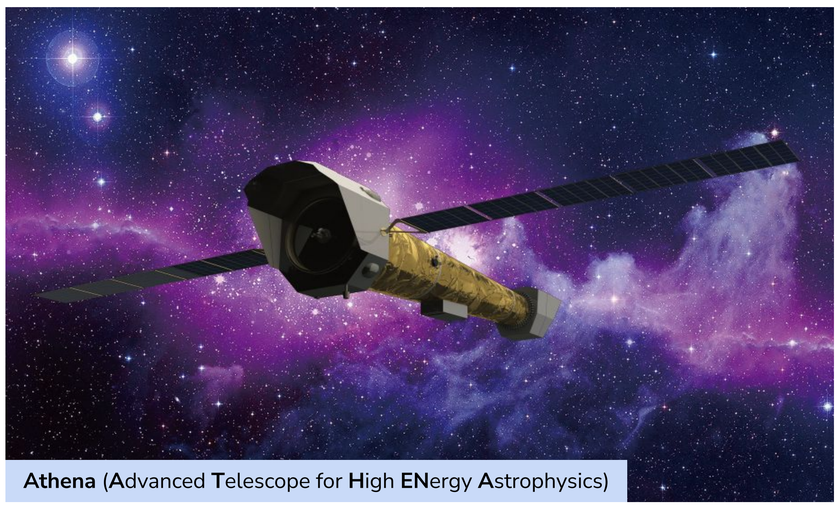
Athena, The Next Generation X-ray Observatory

Synchrotron radiation facilities for the assembly and characterization of Silicon Pore Optics

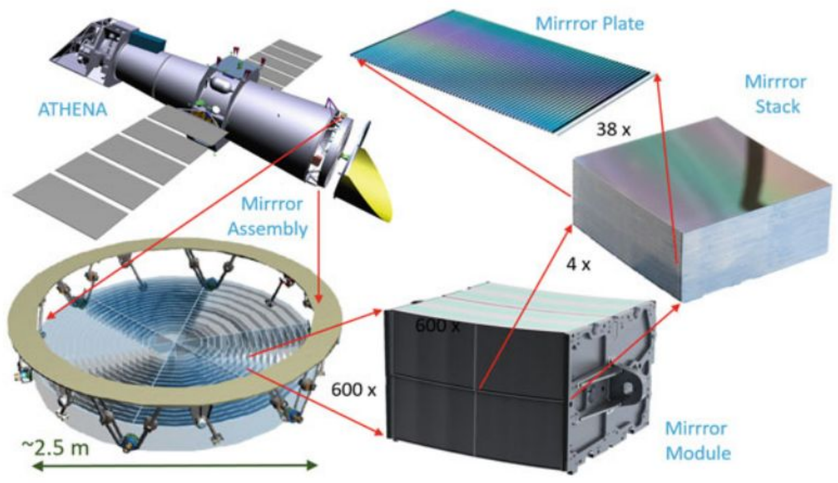
L. Abalo[1,2] *, N. M. Barrière[1], M. Beijersbergen[1,2], M. J. Collon[1], E. Hauser[1], G. Vacanti[1], S. Verhoeckx[1], M. Krumrey[3], L. Cibik[3], D. Skroblin[3], D. Heinis[4], A. Carballedo[4], M. Bavdaz[5], I. Ferreira[5], E. Wille[5]

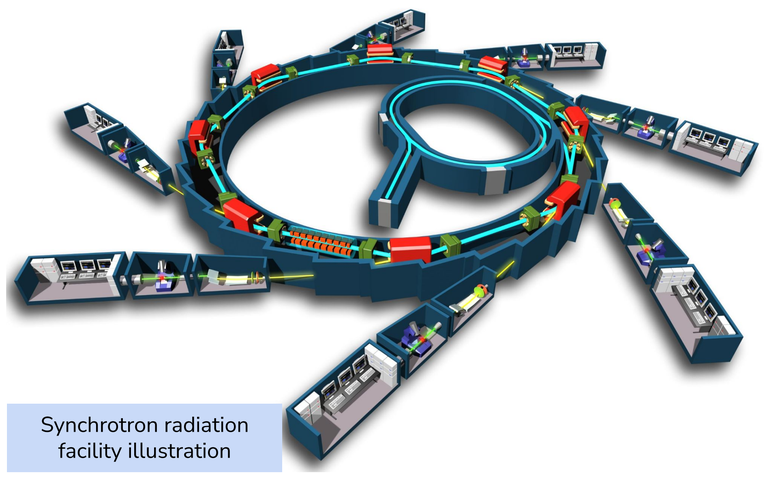
*l.abalo@cosine.nl

[1]cosine, Warmonderweg 14, 2171 AH, Sassenheim, The Netherlands
[2]Huygens-Kamerlingh Onnes Laboratory, Leiden University, 2300 RA Leiden, The Netherlands
[3]Physikalisch-Technische Bundesanstalt (PTB), Abbestr. 2-12, 10587 Berlin, Germany
[4]ALBA synchrotron, Carrer de la Llum, 2, 26, 08290 Cerdanyola del Vallès, Barcelona
[5]European Space Agency, ESTEC, Keplerlaan 1, 2200 AG Noordwijk, The Netherlands



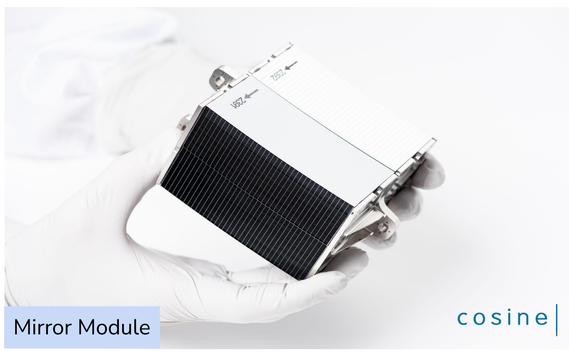
Athena (**A**dvanced **T**elescope for **H**igh **EN**ergy **A**strophysics)





Synchrotron radiation facility illustration

SPO Stack



Mirror Module

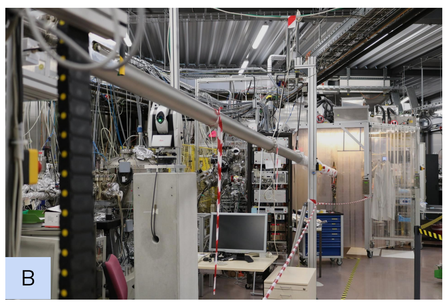
Silicon Pore Optics (SPO) uses commercially available monocrystalline double-sided super-polished silicon wafers as a basis to produce mirrors that form lightweight high-resolution X-ray optics. The technology has been **invented by cosine measurement systems and the European Space Agency (ESA)** and developed together with scientific and industrial partners by the semiconductor industry to handle, process, and clean silicon wafers and plates. SPO is an enabling technology for large spaceborne X-ray telescopes such Athena and ARCUS, operating in the 0.2–12 keV band. SPO has also shown to be a versatile technology that can be further developed for gamma-ray optics, medical applications and material research.

Reference: Barrière, N.M. et al. (2022). Silicon Pore Optics. Handbook of X-ray and Gamma-ray Astrophysics. Springer, Singapore.

PTB@BESSY II

XPBF2 beamline

Aerial perspective of BESSY II



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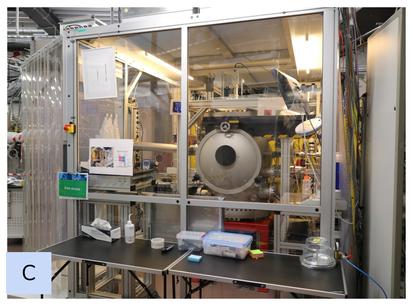

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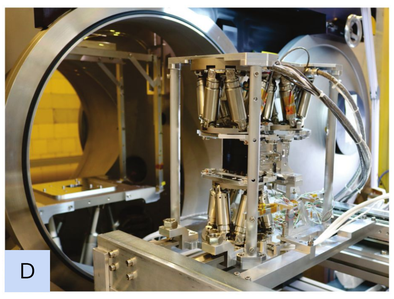

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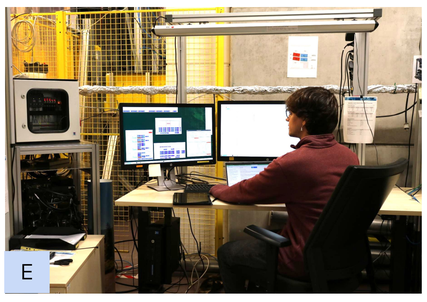

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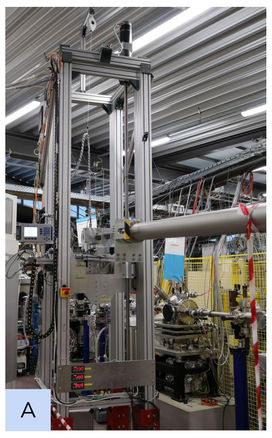


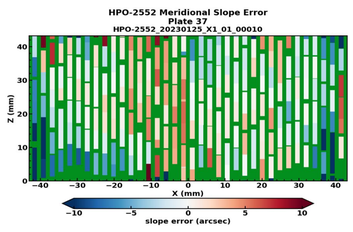
A

XPBF 2 and its different components are shown in the pictures: (A) detector tower, (B) flight tube, (C) clean tent, (D) vacuum chamber with Mirror Module (MM) assembly jig, and (E) control station.

- **Low-divergence X-ray pencil beam** characterization rather than full-flood illumination, enables high-resolution probing of the surface of each plate in a stack. This approach allows for the assessment of surface slope errors and millimeter-scale defects that contribute to beam widening.
- **XPBF 2 operates at 1 keV**. It provides nearly identical reflectivity between 0.8 and 0.9 deg incidence angle for SiO_2, and all the coatings currently considered (Cr, Ir, and C).
- We have measured a resolution of **8 arcsec HEW angular resolution**, in accordance with PANTER (Collon, M. et al, Proceedings of the SPIE, Volume 12181, id. 121810U 10 pp. 2022).
- The beamline has undergone **continuous upgrades to enhance performance**: a laser tracker to accurately measure the CCD detector position, a cooling unit maintaining 20 °C at the clean tent, etc.

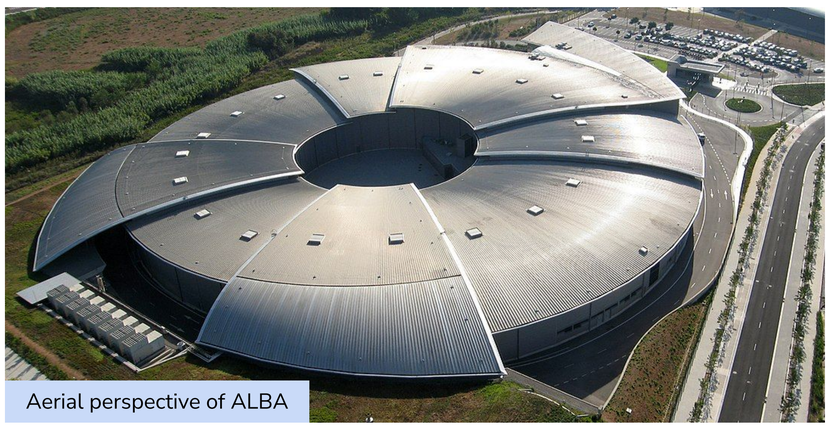
BESSY II is located in Berlin, Germany.
The **X-ray Parallel Beam Facility 2** (XPBF 2) installed in the laboratory of the Physikalisch-Technische Bundesanstalt (PTB) is used to assemble and characterize the optics of Athena (Handick et al. 2020). The detector is at 12 ± 0.5 m from the sample chamber, tailored for Athena.

(Right) The **meridional slope error map** of plate 37 of stack HPO-2552. The colour codes the slope error and each line's length shows the extent of the 100 µm square beam onto the plate due to the grazing incidence. It is obtained by fitting a model of stack such that the orientation of the stack with respect to the beam is determined. From there the model is used to predict where the beam spot should hit the detector. The difference between the measured position and the expected one allows determining the slope error at the location of the reflection.



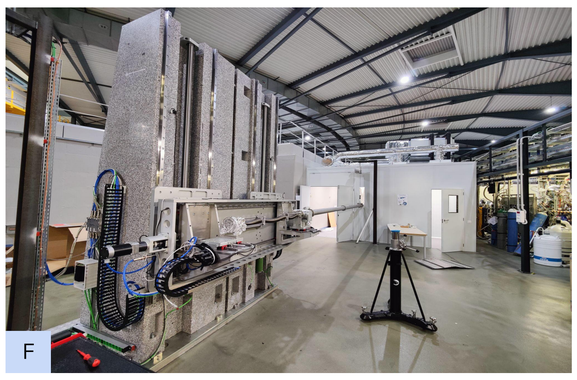
ALBA

MINERVA beamline



Aerial perspective of ALBA

MINERVA, General Overview



F

G

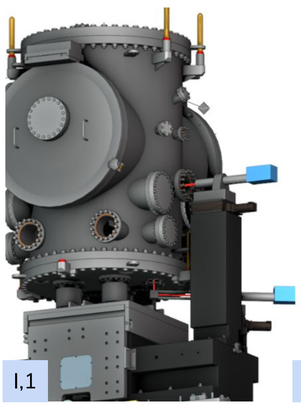
ALBA is located in Barcelona, Spain.

MINERVA is an X-ray beamline designed to contribute to the development of Athena. Its design is based on the monochromatic pencil beam XPBF 2. It had the first light one month ago (May 2023) and will soon be ready to be used at its maximum performance (Heinis et al. 2023).

The images depict MINERVA along with its different components: (F) the detector tower and the flight tube entering the clean room, (G) the interior of the clean room, (H) the vacuum chamber, (I,1) the design of the vacuum chamber and (I,2) the hexapod system.

- With MINERVA, the MM development and production is not dependant on one facility.
- The MM station is closely resembles the one at XPBF 2 for good interoperability.
- New tower concept provides increased stability and repeatability.

- Dedicated linear actuators reduce MM characterization time.



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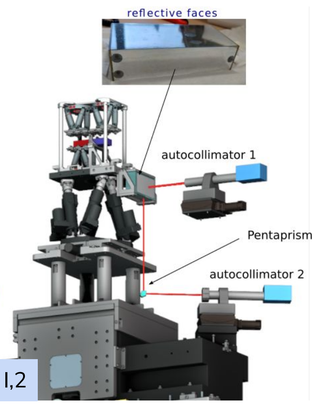

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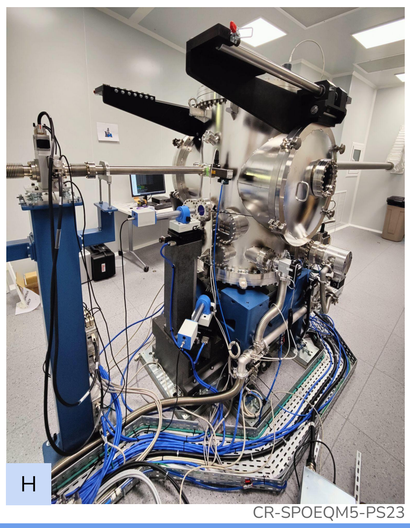

H

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