

X-ray optics testing for NewATHENA at PANTER

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ABSTRACT

X-ray mirror modules are currently being developed for the large mission of the European Space Agency (ESA): NewATHENA, which is scheduled for launch in 2039. These modules are based on Silicon Pore Optics (SPO) technology, developed by ESA and Cosine, and are assembled at BESSY. Throughout the development phase, tests and calibration measurements of these optics have been performed at the 130-metre X-ray test facility, PANTER, of the High Energy Group at the Max Planck Institute for Extraterrestrial Physics (MPE). The MPE's high-energy group is also providing the Wide-Field Imager (WFI) detector for NewATHENA.

This talk will present the current status of measurements of individual state-of-the-art SPO mirror modules. Furthermore, plans to perform opto-thermo-mechanical tests of mirror modules mounted in 1/6-mirror assembly petals under space-like thermal conditions will be presented. This work is being carried out as part of the NewATHENA mission adoption in 2027.

Keywords: ATHENA, NewATHENA, PANTER, X-ray Mirrors, X-ray Optics, X-ray Test Facilities, Calibration

1. INTRODUCTION

Currently, the European Space Agency's (ESA) “flagship” L-class mission, the NewATHENA project, is in the final stage of its phase A study, with a planned mission adoption in 2027. NewATHENA is designed to observe the hot and dynamic universe in X-rays [1]. To achieve its goals, it will require the largest X-ray mirror ever built, a 2.5 m diameter mirror assembly [2] with a focal length of 12 m that has an imaging Point Spread Function (PSF) half energy width (HEW) of ≤ 9 arcsecs and at 1 keV, an effective area of ≥ 1.1 m². On a Silicon Pore Optic (SPO) [3] mirror module level, the HEW requirement translates to ≤ 8.2 arcsec. These goals can be met by using the SPO technology developed by ESA and cosine.

The X-ray test facility PANTER (see Fig. 1, top) [4] of the Max-Planck-Institute for Extraterrestrial Physics in Neuried, southwest of Munich, Germany, has been involved in testing this SPO technology since the first prototypes were produced about 20 years ago. The measurements cover single High Performance Optical (HPO) units, SPO Mirror Modules (MMs), small MM assemblies, and even mirror modules mounted into a large mirror assembly petal that represents 1/6th of the NewATHENA mirror assembly for opto-thermo-mechanical tests. Also, tests and calibration of the optics that produce the parallel beams for the BEaTriX and VERT-X facilities are done at PANTER.

In the following, we describe the PANTER X-ray test facility, the campaigns conducted to date, and the upcoming campaigns planned as we move towards adopting NewATHENA as a new flight mission.

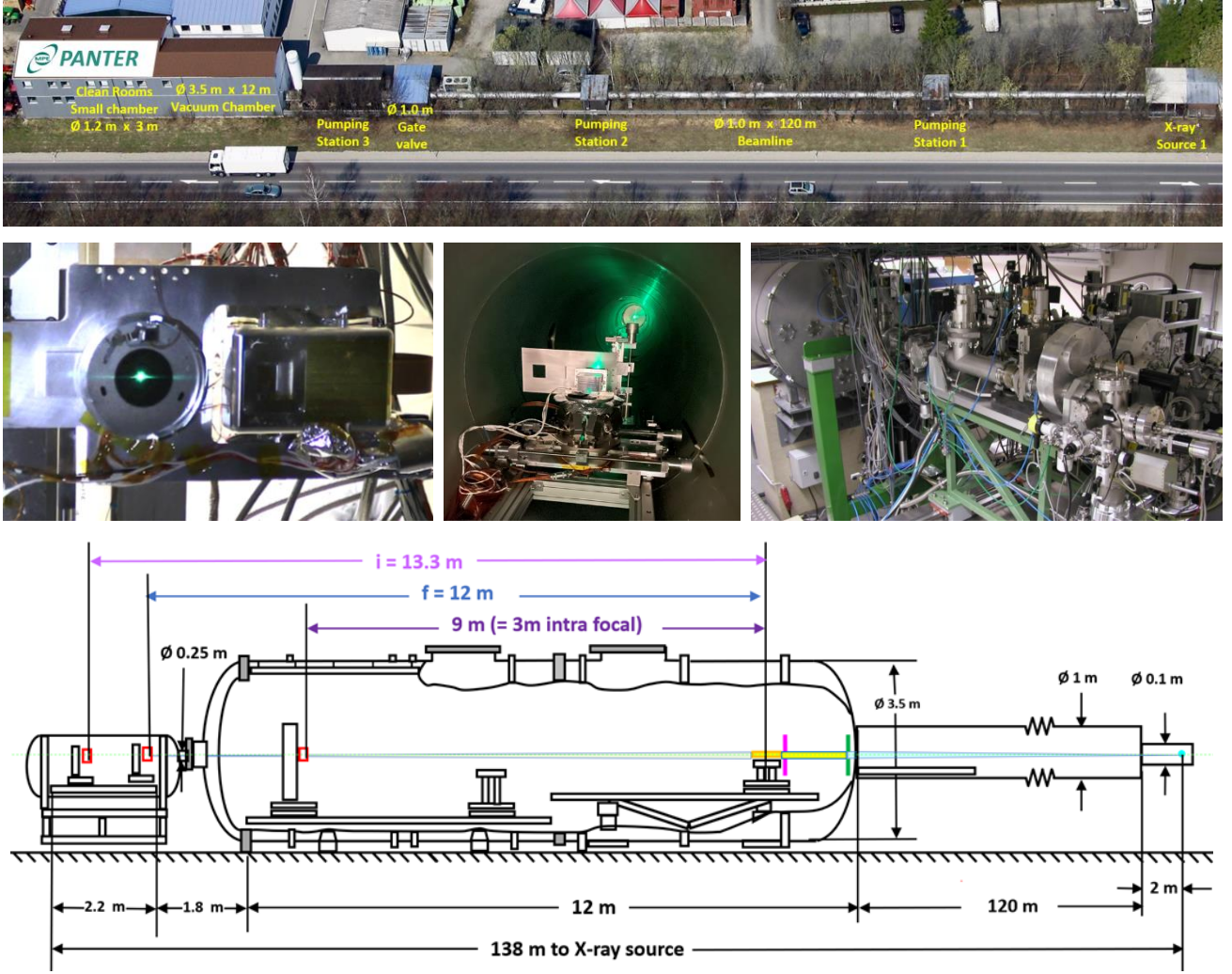


Figure 1 (Top) Photo of the PANTER X-ray test facility. (Center left) Photo of the X-ray detectors, left PIXI, right PIC02, mounted on their translation stage in the vacuum chamber. (Center middle) Photo showing an SPO mounted on a Hexapod behind a mask for selecting regions of the optic, on an optical bench setup inside the vacuum beamline. (Center right) Photo of the multitarget X-ray source. (Bottom) X-ray Test setup for SPOs in the PANTER X-ray test facility. On the right (cyan), the X-ray source is shown. The optic (yellow) mounted on a hexapod is located 120 meters from the source. To its right (magenta) is a mask. In (red), the locations of the detectors are indicated. The vacuum chamber with its 3 optical benches and the X-ray source (on the right side of the figure) are drawn to scale, while the 120 m tube is compacted. The location of a Fresnel zone plate (green) to produce a parallel 1.49 keV beam is shown.

2. NEWATHENA IN THE PANTER X-RAY TEST FACILITY

The PANTER X-ray test facility [5-9] of the Max-Planck-Institute for Extraterrestrial Physics has a 132 m X-ray beamline for optics with focal lengths of up to 12 m. The beamline can be extended to 147 m to test optics with up to 20 m focal length. The X-ray source allows testing at energies from 0.18 keV (B K α) to 11 keV (Ge K β), with the bulk of the measurements being performed at 1.49 keV (Al K α), which works well for uncoated glass and silicon optics. (see Fig. 1, Center right) To obtain images of the in-focus and extra-focal PSFs, we use two X-ray CCD cameras, PIXI and PIC02, at PANTER (see Fig. 1, Center left). PIXI is a commercial camera with a back-illuminated 1300 pixels $\times$ 1340 pixels CCD detector; the pixel dimensions are 20 μ m $\times$ 20 μ m. PIXI operates in an integrating mode with a typical integration time of 1 minute. The PIC02 camera is a custom-made camera designed and built at MPE; it features a pnCCD detector with 384 $\times$ 384 pixels, each 75 μ m $\times$ 75 μ m. PIC02 has a frame readout rate of 20 frames/sec, and the electronics

deliver photon events. The beam stability and spectrum are verified using a Silicon Drift Detector located 35 m downstream of the X-ray source. The Masks, optics and detectors are moved around in the vacuum using translation and rotary stages, as well as hexapods, where necessary (see Fig. 2 Top, Center left).

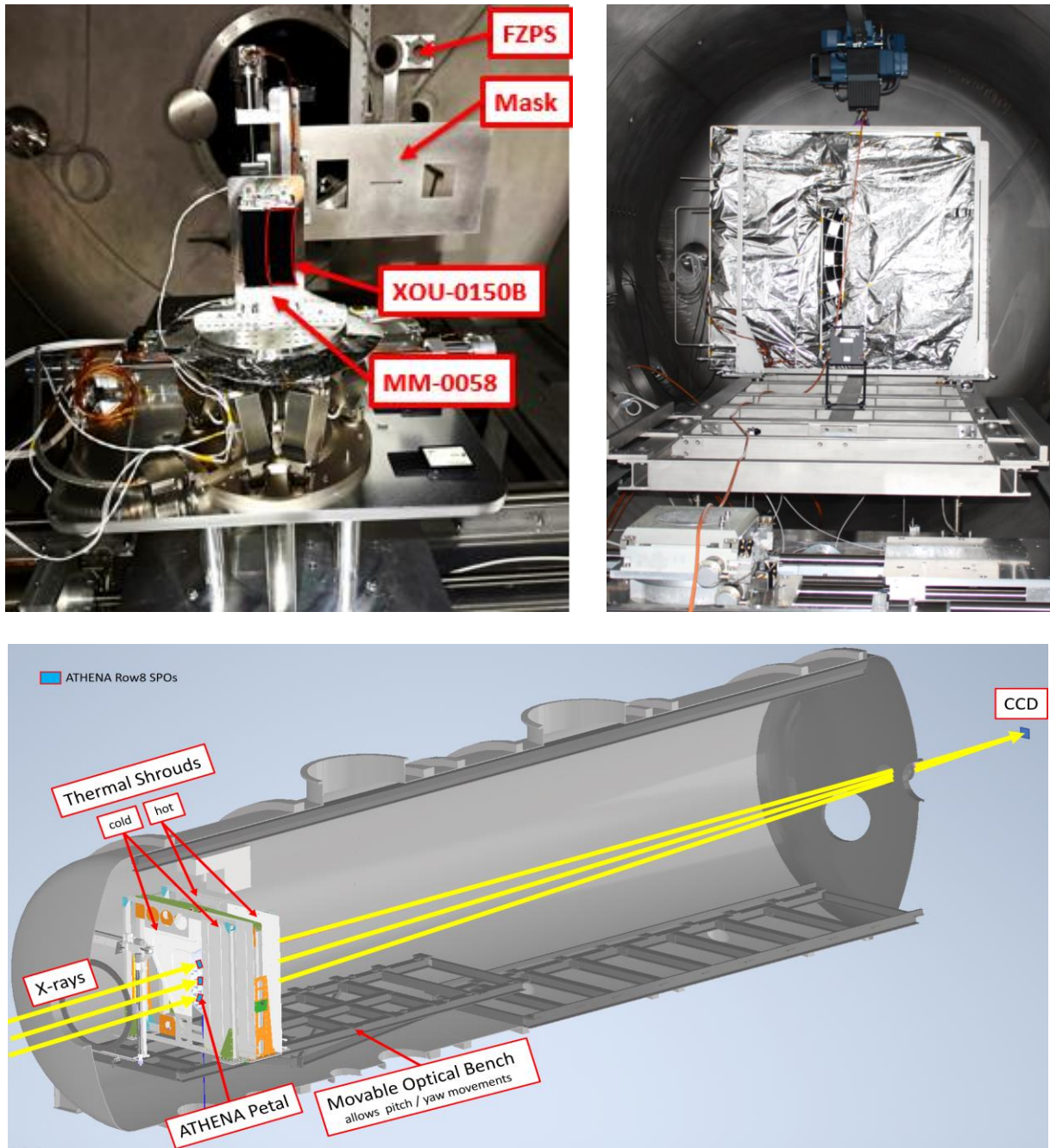


Figure 2 (Top left) shows a photo of SPO MM-0058 mounted on the Hexapod in the main chamber. X-ray Test setup opto-thermo-mechanical tests on a petal that represents 1/6th of the NewATHENA mirror assembly in the PANTER X-ray test facility: (Top right) shows a picture of the setup in the chamber, (Bottom) the X-rays from source 120 m away enter the test setup with its three NewATHENA SPOs from the right through the opening in the cooling shroud. The focusing X-rays exiting the setup for the heated side of the shroud become focused outside the large chamber in the extension chamber, as shown in Fig. 1 Bottom.

3. PREVIOUS ATHENA / NEW ATHENA MEASUREMENTS

Over the last 10 years at PANTER, we have been testing many different 12 m focal-length SPO mirror modules specifically developed for the ATHENA, now the NewATHENA project. PANTER has been supporting improvements in the development and tracking of the optical quality of the SPO MMs by conducting extensive measurement campaigns to accurately determine PSF properties (see Figure 3) and, more recently, the effective area of coated optics (see Figure 4). The co-alignment of X-ray modules has been tested in detail to verify the applicability of the UV alignment method for integrating the SPOs into the NewAthena Mirror assembly at Media Lario. At PANTER, a set of opto-thermo-mechanical tests on a petal that represents 1/6th of the NewATHENA mirror assembly were performed to verify the performance of the optics and petal when large artificial gradients were applied.

Other tests to support the verification and final calibration of the SPOS in BEaTriX and the complete NewATHENA mirror assembly in VERT-X have been conducted at PANTER. These tests entail measuring the critical, highly accurate optical components (parabolas for BEaTriX and a parabola and a Wolter optic for VERT-X) using the Fresnel zone plate, which produces a parallel beam at 1.49 keV. Also, a new low-energy X-ray source for BEaTriX is optimised and characterised at PANTER.

All round robin cross-calibration measurements between facilities (BESSY, PANTER, Minerva) are performed on a regular basis using a SPO mirror module MM-0037 made up of a pair of silicon mandrels. These tests have provided us with an upper limit to the contribution of each facility to the optic HEW.

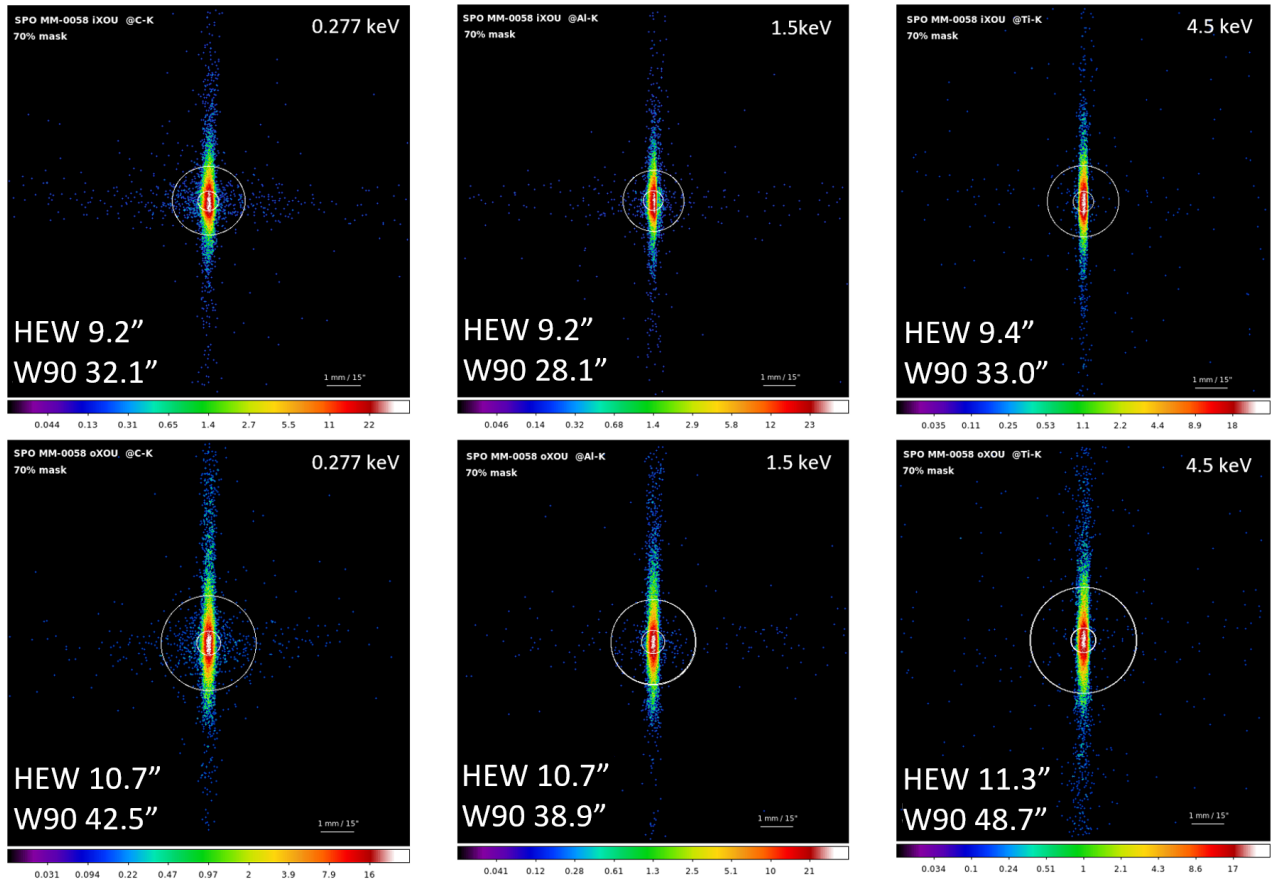


Figure 3 Typical X-ray PSF measurements performed at PANTER in this case for first coated SPO MM-0058 using a 70% Mask for the inner (top) and outer (bottom) XOUs, and (from left to right) at the energies 0.277 keV (C-K), 1.49 keV (Al-K) and 4.51 keV (Ti-K)

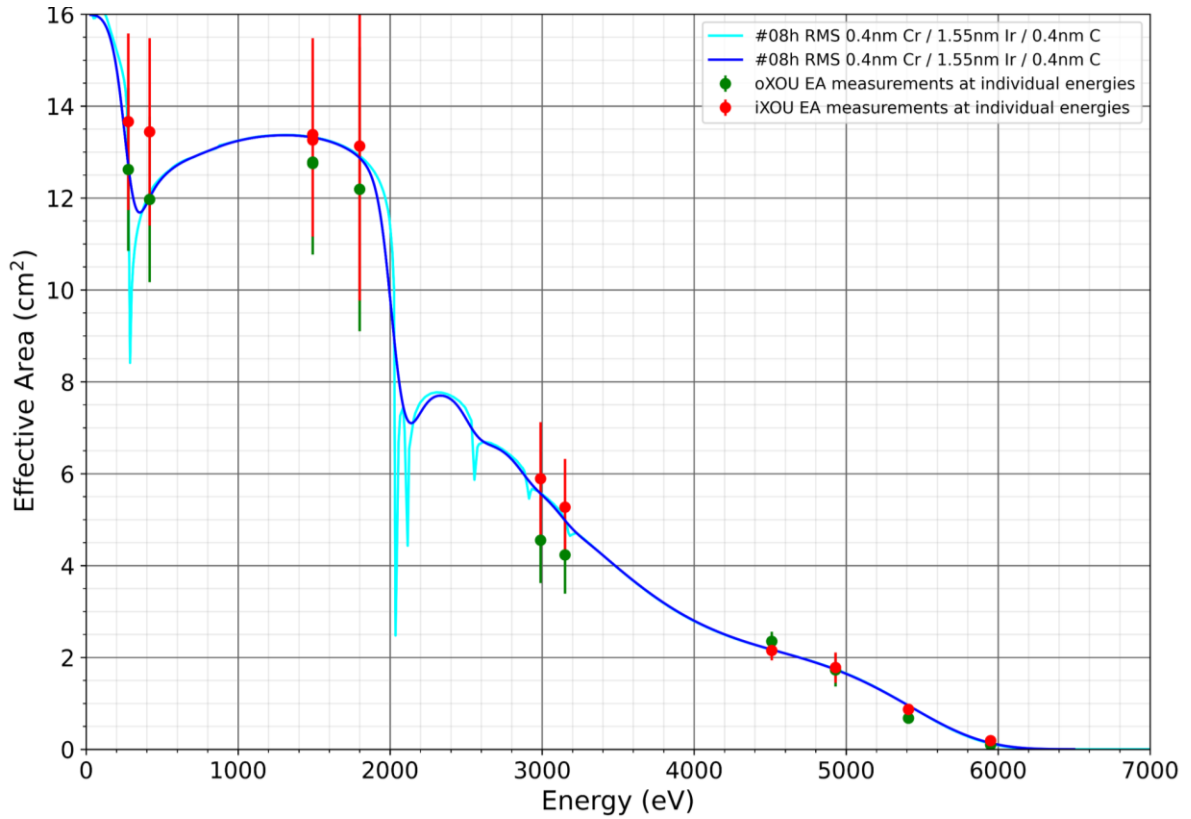


Figure 4 Typical X-ray effective area measurements performed at PANTER, in this case for first coated SPO MM-0058.

4. UPCOMING NEWATHENA MEASUREMENTS

In the upcoming months, we will be testing many new optics for the NewATHENA project. (1) The measurements start with the characterisation of the new round robin coated mandrel SPO that will be used to verify the contribution of each facility to the SPO HEW not only at 1.49 keV but also at 4.5 keV and higher energies. (2) Then a series of mass-produced Row-8 SPOs will become available for testing, some even with the final optimised just under 2 mm rib spacing. (3) Followed by tests of the flight-like mirror assembly thermal control system integrated into the petals produced by the primes Airbus and Thales Alenia. For these tests, it is planned to integrate the petals into the existing shroud setup at PANTER and to cool the space-facing side with LN2 while keeping the spacecraft side at room temperature. These tests are scheduled for early 2027. (4) Further tests of the Vert-X parallel beam generator optic are scheduled.

5. SUMMARY

Much progress has been made over the years to help improve the performance of the SPOs through measurements at PANTER. The PANTER measurements provide independent confirmation of performance predictions based on production non-X-ray metrology. The upcoming measurements will provide us with a good handle on the status of the optics prior to adoption and will help answer remaining questions on thermal requirements for the mirror assembly. And with the help of the new round robin mandrel SPO optic, we will improve our knowledge on the cross-calibration between the X-ray test facilities

REFERENCES

- [1] Cruise, M., et al., „The NewAthena mission concept in the context of the next decade of X-ray astronomy“, Nat. Astron. 9, 36–44 (2025) ; doi.org/10.1038/s41550-024-02416-3
- [2] Bavdaz; M. et al., „Optics developments for NewATHENA“, SPIE 13093, 1309318 (2024) ; doi.org/10.1117/12.3019059
- [3] Collon, M. J. et al., „Silicon pore x-ray optics for the NewAthena telescope“, SPIE 13093, 1309319 (2024) ; doi.org/10.1117/12.3019675
- [4] Burwitz, V. et al., „Testing and calibrating the ATHENA optics at PANTER“, SPIE 10399, 103990O (2017) ; doi.org/10.1117/12.2274237
- [5] Menz, B., et al., „Studying ATHENA optics with divergent and collimated x-ray beams“, SPIE 9144, 91445J (2014); doi.org/10.1117/12.2057463
- [6] Menz, B. et al., „Large area x-ray collimator—the zone plate approach“, Applied Optics 54, 26, 7851-7858 (2015) ; doi.org/10.1364/AO.54.007851
- [7] Burwitz, V., et al., „Testing x-ray optics at PANTER for the NewATHENA mission“, ICSO 2024, SPIE 13699, 136990M (2025) ; doi.org/10.1117/12.3075162
- [8] Burwitz, V., et al., „Testing silicon pore optics for NewATHENA at PANTER“, SPIE 13093, 130931B (2024) ; doi.org/10.1117/12.2023309
- [9] Hartner, G., et al., „Characterization of the x-ray beam at PANTER“, SPIE 12679 1267918-1 (2023) ; /doi.org/10.1117/12.2677498
- [10] Rukdee, S., et al., „NewATHENA x-ray optic: current status of post-thermal test performance at PANTER“, SPIE 13626, 1362606-1 (2025) ; doi.org/10.1117/12.3064381