

Novel X-ray optics developed within the AHEAD2020 project

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We present a summary of our contribution to the EU Horizon 2020 project AHEAD2020, with emphasis on the X-ray optics work package. The Czech Technical University – together with other collaborating institutes – studied innovative Lobster Eye and Kirkpatrick-Baez X-ray modules, based on the Multi Foil Optics technology. In addition, a student's workshop in December 2023 and a summer school in May 2024 were organized within the project.

1 Introduction: The AHEAD2020 project

The AHEAD2020 project (“Integrated Activities for High Energy Astrophysics”) has been funded under the Horizon 2020 Research Infrastructure Program [1] (Fig. 1).



Fig. 1 Logo of the AHEAD 2020 project.

The main goal was to integrate and open research infrastructures for high energy and multi-messenger astrophysics. It offered transnational access to European test and calibration facilities and access free of cost to selected European astronomical institutes and data centers [1]. Moreover, there was the possibility for scientists and engineers at all expertise levels to visit European institutes of their choice through a visitor program. The access costs for the selected facility are covered by AHEAD2020 as well as travel costs and daily allowances for the applicants [1]. In addition, a student's workshop in December 2023 and a summer school in May 2024 were organized (Fig. 2).



Fig. 2 Conference picture of the AHEAD summer school 2024 in Cheb (CZ).

2 Novel optics: Kirkpatrick-Baez modules

Here we present a summary of our contribution to the EU Horizon 2020 project AHEAD2020, with emphasis on the X-ray optics work package [2]. The Czech Technical University – together with other collaborating institutes – studied innovative Lobster Eye (LE) and Kirkpatrick-Baez (KB) X-ray modules, based on the Multi Foil Optics technology [3] [4]. The KB optics represents a promising and cost effective alternative for wide field imaging with moderate angular resolution with respect to the currently mainly used Wolter I telescopes (Fig. 3 and Fig. 4).



Fig. 3 Large Kirkpatrick-Baez X-ray optics array.

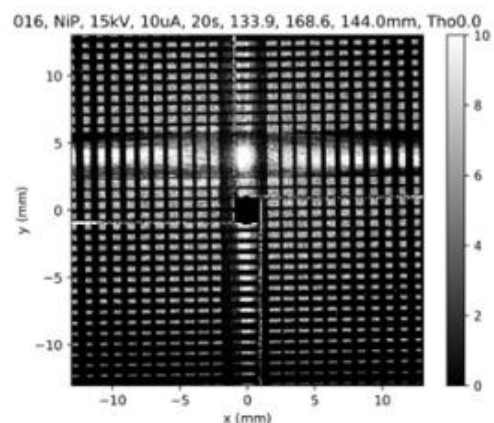


Fig. 4 Focal plane image of the Kirkpatrick-Baez Array during optical tests at the CTU laboratory in Prague.

3 Novel optics: Lobster-Eye X-ray modules

The LE X-ray optics, based on the Schmidt design, has a wide field of view (FOV) with a short focal length, making it suitable for CubeSat application. Thereby the 2D LE optics consist of two orthogonal sub-modules of flat smooth reflecting foils, each sub-module focuses in one direction. The advantage of such optics is that it preserves the angular resolution throughout the FOV even for large off-axis angles, as demonstrated by simulations and measurements (Fig. 5 and Fig. 6). There was a collaboration with Aschaffenburg University in design, development, and testing of the double LE module HORUS, comparing different reflecting coatings [5] [6].

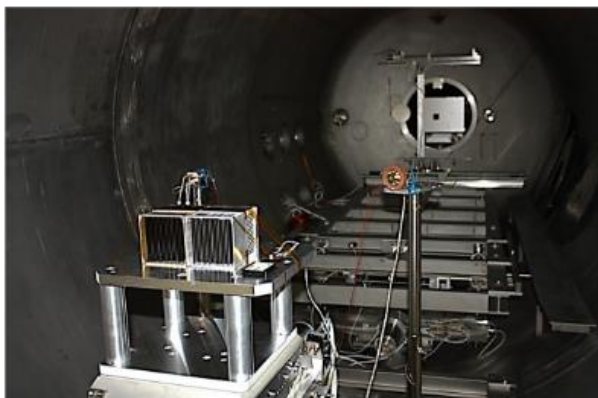


Fig. 5 Example of the X-ray modules developed within the project, here the LE system HORUS during the measurement campaign at the PANTER test facility.

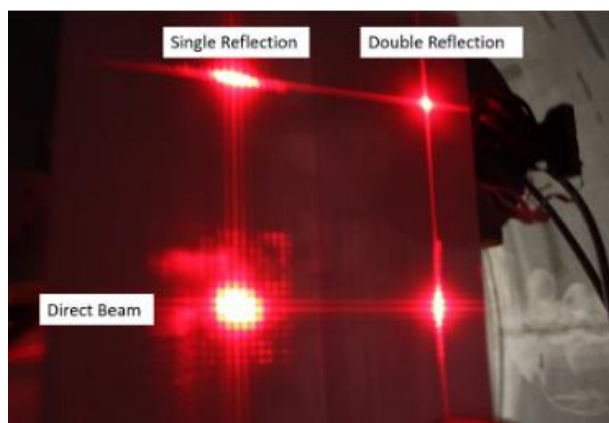


Fig. 6 Focal plane image during visual alignment showing the location of the direct beam through the LE optic, two single reflection on the top and to the right side of the image, and the double reflection on the top right side.

4 Summary

The AHEAD2020 project offered transnational access to European test and calibration facilities and access free of cost to selected European astronomical institutes and data centres. In addition, the

Czech team organized a student's workshop in December 2023 and a summer school in May 2024.

The Czech Technical University – together with its collaborating institutes – studied innovative Lobster Eye and Kirkpatrick-Baez X-ray modules, based on the Multi Foil Optics technology. Full aperture X-ray tests at the PANTER facility of the Max-Planck institute for extraterrestrial Physics (MPE) were performed in two runs, the first one in April 2021 and the second one in November/December 2022. The double LE HORUS X-ray test module was measured in the first run and the large KB module in the second.

The presented activities are integral parts of the AHEAD2020 project, funded by the European Union Horizon 2020 research and innovation program, which ended on December 1st, 2024. In conclusion, the activities are in line with the strategic goals of AHEAD2020 and resulted in a major step forward for the European X-ray optics community and its challenging astronomical projects.

Acknowledgement

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Literature

- [1] AHEAD website: <https://ahead.iaps.inaf.it/>
- [2] R. Hudec, P. Oberta, V. Marsikova, L. Pina, A. Inneman "Czech contribution to AHEAD2020: a summary", Proc. SPIE 13531, 1353103 (2025)
- [3] R. Hudec, V. Maršíková, A. Inneman, P. Oberta, L. Pina: "Czech contribution to AHEAD2020: Novel/alternative X-ray optics", Acta Polytechnica 65(1): 25–32 (2025)
- [4] V. Stieglitz, V. Burwitz, T. Döhring, et al.: "Design and testing of a Kirkpatrick-Baez optics variation", European Physical Journal- Web of Conferences 266:03021 (2022)
- [5] T. Döhring, V. Stieglitz, R. Hudec, et al.: "Characterization of a Lobster-Eye type X-ray telescope", European Physical Journal - Web of Conferences 266:13010 (2022)
- [6] T. Döhring, V. Stieglitz, P. Friedrich, V. Burwitz, M. Jelinek, R. Hudec: "Testing of lobster-eye type telescopes with X-rays and visible light", Proc. SPIE 12576, 1257606 (2023)