CROWN

A. Marcelli (Resp. Naz.), M. Coreno (Ass.), S. Dabagov, G. Della Ventura (Ass.), P. De Padova (Ass.), M. de Simone (Ass.), D. Hampai, Z. Ebrahimpour (Ass.), and S.J. Rezvani (Ass.)

I. SUMMARY

X ray imaging can be performed using both soft and hard X rays. The latter have greater penetrating power and greater energy but can induce damage on samples during the experiment. Soft X rays, which range from 1 to 10 nm, may also achieve high resolution with lower doses. In the last two decades we assisted to impressive progresses in the field of microscopy, both technically, through developments in radiation sources, optics, and imaging methodologies and scientifically by expanding the range of applications. The elemental specificity of soft X-rays and the tunability of SR together allow a variety of materials to be probed using spectro-microscopy. CROWN will demonstrate a new concept for soft x-ray/UV microscopy based on the development of a confocal microscope using two low-cost compact meta-lenses, i.e., two Micro-Channel Plates (MCPs) and a full field transmission layout. The main interest of INFN in this project is the development of instruments and expertise required for a successful evolution of the ESFRI EUPRAXIA project, as well as of the EuAPS PNRR project. On one side the development of novel X-ray imaging optics will certainly assist in improving single shot photon diagnostics, which are fundamental for stable and reliable operations of plasma-based accelerator sources. FEL and betatron radiation production as foreseen within the EUPRAXIA project can be used to gather information on biological samples with imaging, one of the main topics of FEL and betatron research. [1, 2]

II. ACTIVITY

In the first year we used the available experimental high vacuum (HV) chamber (see Fig. 1) assembled to test VUV soft x-ray optics for 3rd and 4th generation radiation sources and commissioned at the Circular Polarization (CiPo) beamline at ELETTRA. The project is managed within the LNF unit of the INFN with the support of associated personnel working at Elettra and at the University of Camerino. The experiments are performed in collaboration also with additional personnel associated to ISM-CNR premises at Elettra, Trieste, namely 2 PhD students, M.Sc. Gabriele Bonano from University of Modena and M.Sc. Awad Mohamed from University of Camerino and Fabio Zuccaro, senior technician at CNR ISM, whom we particularly acknowledge for assistance in the design, realization and installation of mechanical parts for our set-up, as well as for taking part into its assembly. In November thanks to an ICTP TRIL grant funded by CNR-ISM Melaku Teklehawariyat, graduate student from Adama University (Ethiopia) joined our project, who will further contribute to the activities of the second year as a PhD student in Nanotechnology at University of Trieste, with a specific research plan on "XUV Metalenses for Spectroscopic and Morphological Characterization of C-Based Quantum Dots ".

The main activities of the project performed in 2024 have been:

- design and construction of the top cover of the HV chamber;
- design and construction of the lifter of the top cover of the HV chamber;
- acquisition of new meta-lenses;
- maintenance of the hexapods;
- the developments of a common SW for the hexapods to be used for the microscope;
- assembling of all mechanical and electrical components;
- first tests of the mechanical systems.

To install the two hexapod manipulators that will allow the alignment of the meta-lenses in the HV chamber we had to redesign and manufacture the top flange of the chamber. The present status is visible in the two photographs in Fig. 1 The top flange has been realized and tested and now loads the robot (Hexant design) in the upside-down position. We have also designed and realized the lifting system of the top flange. The order of this mechanical components has been completed and the lifter delivered and installed (visible in the image in the left panel in Fig.1). According to the layout of the confocal system with the two hexapods we identified the radius of curvature of the meta-lenses (50

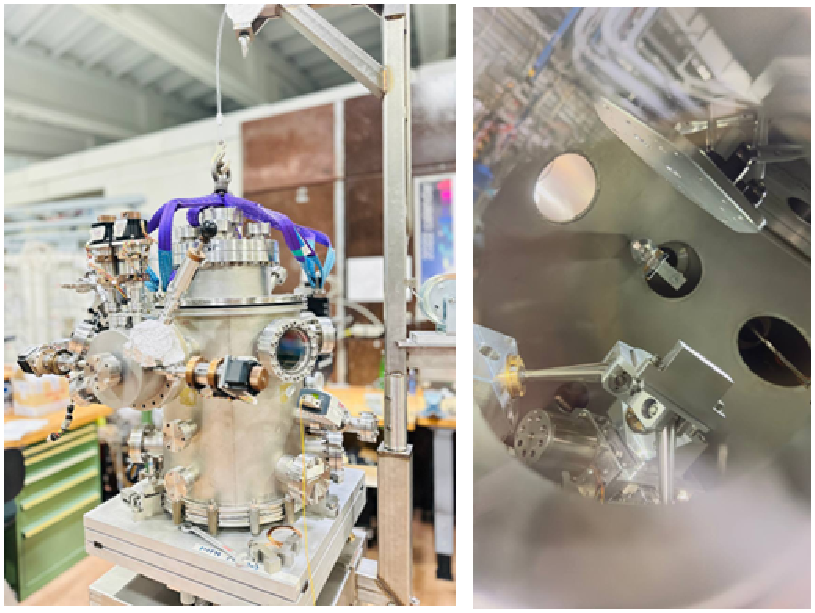

FIG. 1. (left) Side view of the HV chamber that will be used to test the confocal microscope with two meta-lenses; (right) photograph showing the interior of the HV chamber where are visible the two hexapod manipulators.

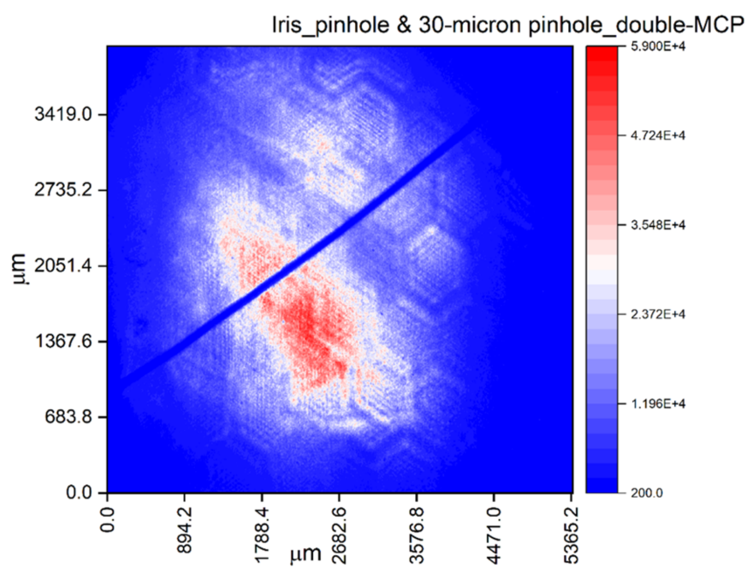

FIG. 2. Image taken with the blue laser going through the 30 μm pinhole and the iris diaphragm after two coupled MCPs.

mm and 30 mm +/- 2 mm). We investigated the availability of these optics and emitted the orders. All new optics including two 2 flat MCPs will be available in early 2025. In the first year we also worked on the maintenance of both hexapods after their arrival in Trieste. Both robots have been tested also with the new SW to be ready for the next beamtime with the new controller firmware ordered and delivered in the early September.

All necessary connectors have been ordered and delivered. The cabling has been performed for the runs with light planned in the period October/November 2024. First opto-mechanical tests were planned from October 3 to 8 and from November 14 to 18. Unfortunately, a late delivery of one robot first, and a major vacuum fault of the accelerator after, made it impossible to perform the tests with synchrotron radiation with the hexapods. Nonetheless, we have performed tests offline, and all activity is summarized in a report now in progress. We exploited more control and software tests, successfully, in two users experiments at Elettra on the GasPhase beamline: for the alignment of a high-pressure gas cell (beamtime Zitnik 20240183) and for tests of microcapillary VUV lenses (beamtime Martinez Vasquez 20240034).

III. TESTS

With the dedicated experimental layout, we performed tests of the new and the old hexapod. Several images have been collected using single and double flat meta lenses, i.e., microchannel plates (MCP) using a pinhole with 30 μm or 100 μm diameter. As the source, we employed both red and blue lasers (632.8 nm and 450 nm, respectively) and to minimize the scattered light, a diaphragm was positioned in front of the laser to define a better beam profile. Images after the lenses were collected using the CCD camera. For all tests, both red and blue laser were used to evaluate the performance of both hexapod devices. The assessment involved the alignment of the pinhole on the old hexapod and of the MCP (MicroChannel Plate) mounted on the new hexapod (Hexant) device. Both devices were moved to align all optical components and to collect diffraction patterns generated on the YAG crystal by both single and double flat microchannel plates (MCPs). The setup featured a laser-to-pinhole distance of 36 cm, a laser-to-MCP distance of 60 cm, and a YAG crystal sets 4 cm downstream the MCP. The reproducibility was checked using the translation of the pinholes of 30-micron and 100-micron. Figure 2 shows a typical image collected after the double flat MCP with the iris and in this case the 30-micron pinhole, using the blue laser. A special thanks for the tests is also due to Gianluca Bortoletto and Roberta Totani of the XUV optics of Elettra Sincrotrone Trieste ScpA for support during the measurements of users from Ljubliana and Milan.

IV. PUBLICATIONS

- Z. Ebrahimpour, M. Coreno, S. Dabagov, M. de Simone, M. Mazuritskiy, A.E. A. Mohamed, J. Rezvani, F. Zuccaro, and A. Marcelli, Advancing Soft X-ray Microscopy with Diffractive Metalenses: Experimental Design and Initial Results, submit. to Nucl. Instr. & Method. A Proceedings (2024)

V. ORAL CONTRIBUTIONS

- Z. Ebrahimpour, Microchannel Plate (MCP) Optical Device Characterization Using Synchrotron Radiation in the Soft X-Ray Domain, 10th International Conference, Charged & Neutral Particles Channeling Phenomena, 8-13 September 2024 Riccione (Rimini), Italy; https://www.lnf.infn.it/conference/channeling2024/.

[1] D. Oberthur, Inter. Union Cr. Journal 5, 663 (2018).
[2] J. Wenz, et al., Nature Commun. 6, 7568 (2015).