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CROWN@ELETTRA

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Abstract

X-ray imaging can be performed with both hard and soft x-rays, but the latter offer several advantages, e.g., a lower dose, elemental specificity and spectral tunability around the water window, in particular using brilliant synchrotron radiation sources. Over the years, microscopy has seen major advancements in sources and optics, expanding the already large number of applications. The CROWN project introduces a novel soft X-ray/UV confocal layout using two low-cost, compact meta-lenses, i.e., microchannel plates (MCPs) suitable also to perform single-shot photon diagnostics, an important issue for stable plasma-based accelerator operations. This document describes the preliminary tests of the CROWN instrumentation performed at Elettra.

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1 Introduction

X-ray imaging performed with soft X-rays (i.e., in the 1–10 nm range) using brilliant synchrotron radiation sources offers several advantages over hard X-rays, including lower radiation doses, elemental specificity, and spectral tunability around the water window. Over the years, microscopy has seen major advancements in sources and optics, expanding the already existing wide range applications. The CROWN project introduces a full-field transmission setup with the confocal layout for soft X-ray/UV confocal microscope using two low-cost, compact meta-lenses, i.e., microchannel plates (MCPs). Advancements in X-ray optics will enhance single-shot photon diagnostics, important for stable plasma-based accelerator operations. These developments also support FEL and betatron-based imaging of biological samples, a key research area in both projects. The development of this instrumentation and the expertise are strategic to support the ESFRI EUPRAXIA and EuAPS PNRR projects[1-3]. This document describes the results of the preliminary tests of the instrumentation of the CROWN project.

2 Tests of the two hexapods

We performed several tests by means of single and double flat microchannel plates (MCP) [4] with an experimental layout shown in Fig.1, that combine the old six axes hexapod, a pinhole with 30 μm or 100 μm diameter and the new six axes manipulator (Hexant), where single and double flat MCPs can be mounted also in the upside-down geometry.

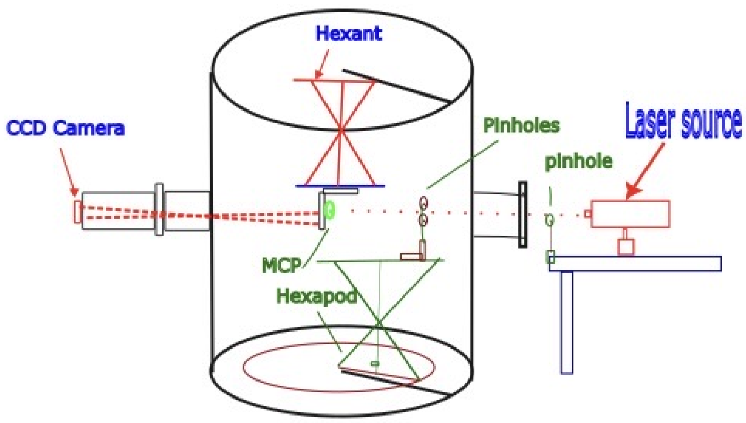

Figure 1: The main components of the optical set up: the laser source, the hexapod with the pinhole (located between the MCP and the laser source) and the Hexant device hosting the MCP and the CCD camera.

As sources, we employed for these tests both red and blue lasers (632.8 nm and 450 nm). To minimize the scattered light, a diaphragm was positioned in front of the laser source, to define a precise beam profile. Images after the MCPs were collected using the CCD camera.

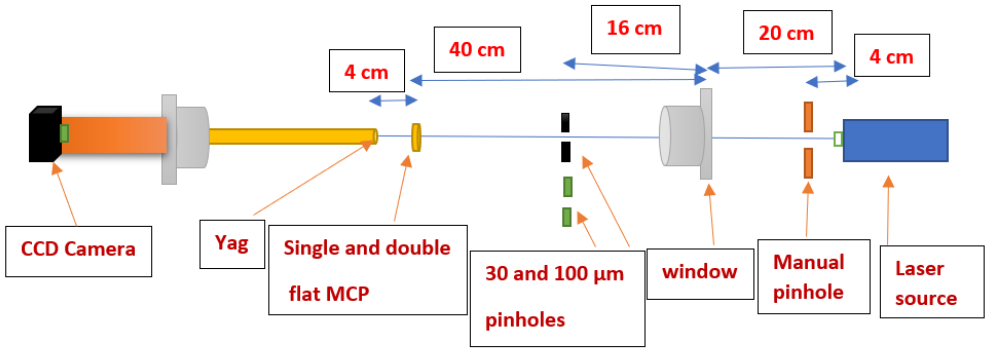

Figure 2: The layout used for the tests showing the position and the distances of the different components: laser source, iris, pinhole, MCPs, YAG, and CCD camera.

The experimental layout used for the tests is displayed in Fig.2. For these tests, both red and blue laser were used to evaluate the performance of the devices. The assessment involved the alignment of the pinhole on the Hexapod and of the MCP (MicroChannel Plate) mounted on the Hexant device. Both devices were moved to align the 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 $\sim 60\,cm$, and a YAG crystal sets 4 cm downstream the MCP. The reproducibility was checked during the tests translating the pinholes with apertures of 30 μm and 100 μm.

3 The MCP optics

The first device we tested is an assembly of two MCPs made by a silicon-lead glass with a composition of 70% PbO and 30% SiO_2 by mass. It consists of 10^4 to 10^7 uniformly spaced and systematically arranged hollow microchannels, within a hexagonal symmetry in the transverse cross-section. Each microchannel has an inner diameter of 10 μm and a pitch of 12 μm between adjacent channels. In the longitudinal cross-section, the MCP reveals an elongated channel structures with a length-to-diameter ratio of ~ 120. When we irradiated the device in the center only one MCP is illuminated, while shifting it by side by few mm the radiation went through both MCPs within the assembled device.

4 Results

With the dedicated experimental layout, we performed tests of both hexapods. Several images have been collected using single and double flat meta lenses, i.e., microchannel

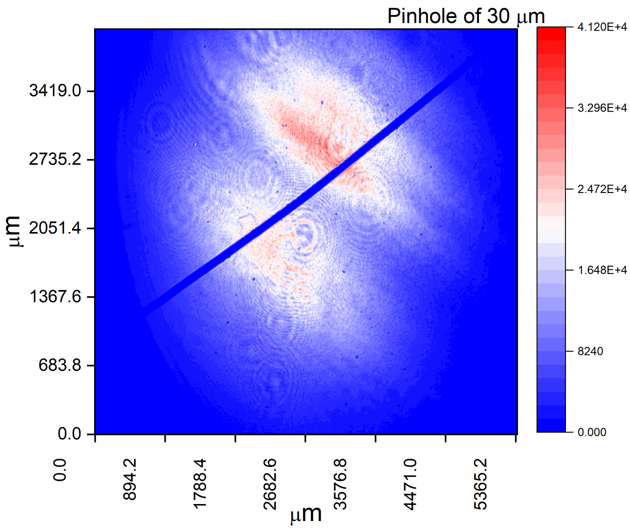

Figure 3: This image was taken without the MCP after a 30 μm pinhole, with an exposure time of 10^4 miliseconds, using the camera set at a gain of 54.

plates (MCP) using both pinholes (30 μm and 100 μm diameter). The assessment involved the alignment of the pinhole on the first hexapod and of the MCP (MicroChannel Plate) mounted on the Hexant device. Both manipulators were moved to align the optical components and to collect diffraction patterns generated on the YAG crystal by both single and double flat microchannel plates (MCPs).

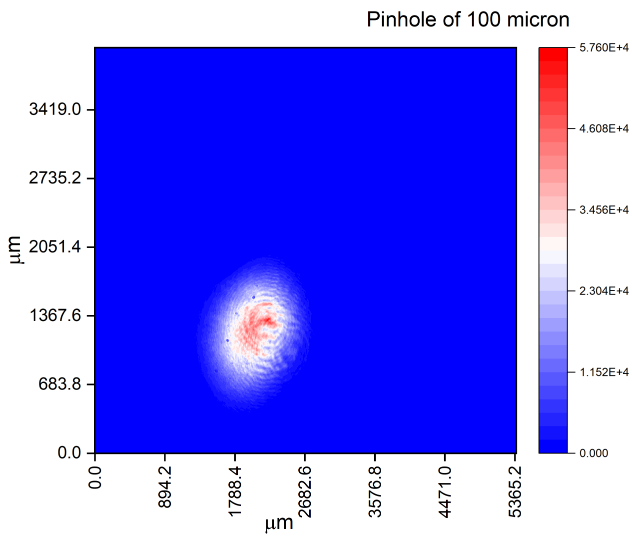

Figure 4: The image is taken without the MCP with the 1 mm iris after the laser and the pinhole of 100 μm

The setup showed in Fig.1 and Fig. 2 allows the visualization of the single flat microchannel plate (MCP) hole array. As showed in Fig. 3 the blue laser beam going through the 1 mm iris and then through the 30 μm pinhole inside the HV chamber generates a pattern on the YAG screen that is stored with the CCD camera (sCMOS digital camera Basler Ace acA2040-35 gm). The wire in front of the YAG has a size of 100 μm. From the measure of the pixel numbers of its diameter (38) we obtained the conversion coefficient from pixels to μm for the images. The exposure time and the gain were 10^4 miliseconds and 54, respectively. These parameters slightly changed for the next images to achieve best result and contrast. Fig. 4 is the image collected after a 100 μm pinhole with a blue laser beam passing through the 1 mm iris diaphragm, without any MCP.

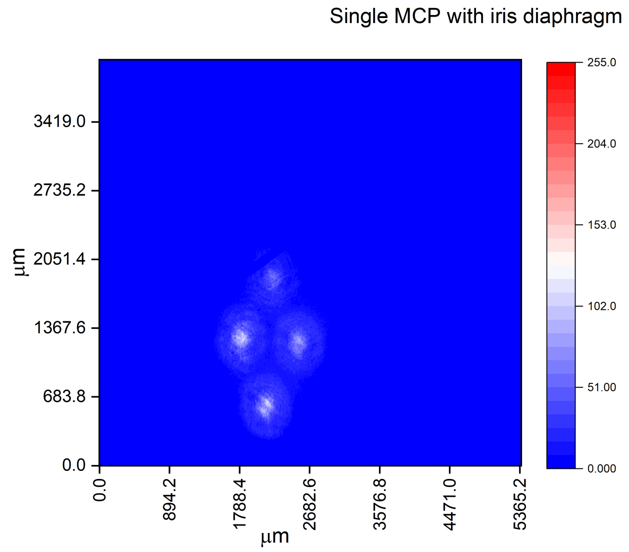

Figure 5: The diffraction pattern obtained with the flat MCP with the 1 mm iris sets after the blue laser and the pinhole of 100 μm.

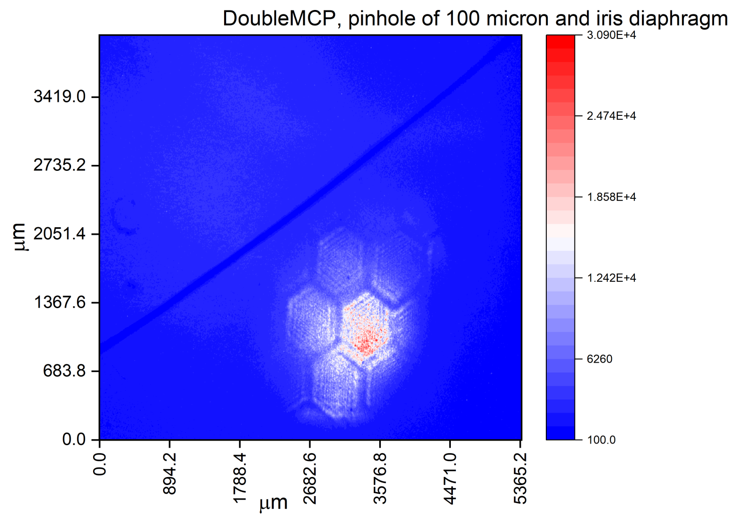

Figure 6: The diffraction pattern generated by the double MCP with the blue laser source going through the 100 μm pinhole and the 1 mm iris diaphragm.

The next image (Fig. 5) illustrates the diffraction pattern observed after the single flat MCP optic by the blue laser collimated by the 1 mm iris diaphragm and a pinhole. The pattern obtained after the double flat microchannel plate device is showed in Fig. 6. For this image the blue laser was collimated by the iris and after went through the 100 μm pinhole. The pattern is observed on the YAG screen and stored with the CCD camera.

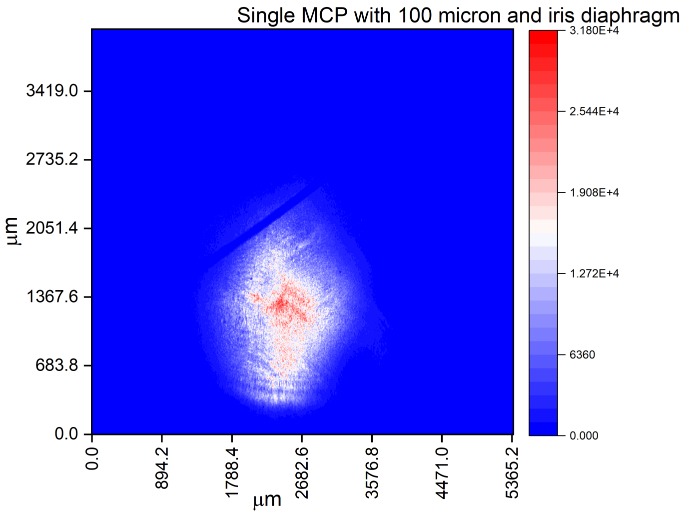

Figure 7: The diffraction pattern generated by the single flat MCP with the blue laser source going through the 100 μm pinhole and the 1 mm iris diaphragm.

The occurrence of a partial diffraction pattern obtained after the single flat MCP is showed in Fig. 7. The latter has been collected with the blue laser, after the iris of 1 mm diameter positioned in front of the laser and the 100 μm pinhole set before the MCP. Finally, Fig. 8) shows the complex pattern collected with the blue laser after the double flat MCP device, the iris and the 30μm pinhole.

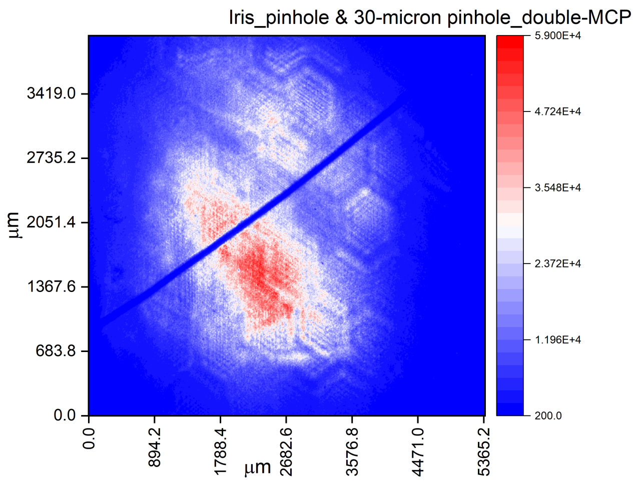

Figure 8: Image taken after the double MCP device with the blue laser source going through the 30 μm pinhole and the 1 mm iris.

4.1 Test with synchrotron radiation

The instrumentation was recently used also for a user experiment at Elettra looking at the waveguide properties of fused silica channels. The experiment was carried out testing several guides, each containing seven channels. The goal was to study the impact of channel size on waveguide behavior, beam propagation, and coupling efficiency. The experiment was performed at 95 eV using the SGM4 monochromator (40 to 140 eV) at the CiPo beamline. The beam passed through the 30 μm or the 100 μm pinhole available inside the chamber, allowing for vertical and axial adjustments. Samples were aligned with the Hexapod controlled by the HexAnt SpaceFAB controller system to illuminate the guide with the monochromatic beam. Detection was performed using the YAG screen, collimating lenses and the Basler camera, capturing 50 averaged frames, each with a 10 second acquisition time. Throughout the experiment, the HV chamber pressure was maintained between 1.1 and 5.5×10^{-6} mbar.

Images were taken with the valve closed to capture the background. Then, with the valve open, images (see Fig. 9) were stored to detect the transmitted signal. The background was subtracted using MATLAB to distinguish the XUV signal followed by Gaussian filtering to smooth the image. The image below shows the weak guided XUV beam in the center of the frame.

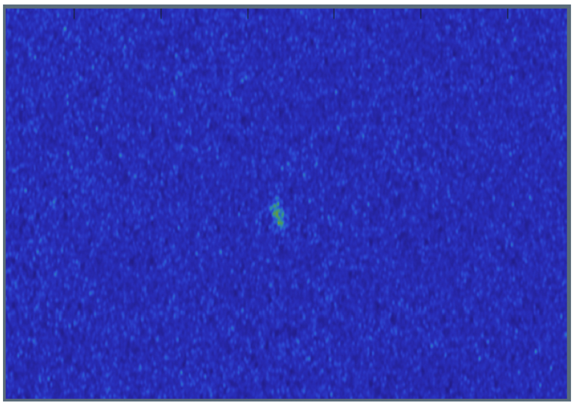

Figure 9: Image showing the XUV beam (95 eV) passing through a partially obstructed 40 μm reference channel after the alignment (courtesy by users).

5 Evaluation of the mechanical lifting system

During the tests we also verified the lifting system of the top flange of the HV chamber of the CROWN project. The system efficiently lifts the upper flange where the Hexant is mounted up-side-down. The system may safely load up to 1200 kg reducing manual effort and ensuring the required precise alignment between flanges. It enhanced the stability, and even more important, it reduces the risks of the manipulation of the hexapod. The system operates smoothly and reliably and it is now regularly used during the experimental operations.

Figure 10: Pully System Test images

6 Acknowledgements

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