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Focusing properties of X-ray radiation channeling at the exit of a MCP

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Capillary optics is a basic X-ray technology capable of delivering a high flux density within a sub-micrometer spot. This compact optics could be easily used both to guide and to shape an intense X-ray beam within a small spot, a low divergence and with a high homogeneity. Arrays of curved tapered capillaries (polycapillary optics) can be used to focus, collimate, and filter x-ray radiation [1]. In addition to the established use of capillary optics to shape radiation in x-ray lithography, x-ray astronomy, crystal diffraction, x-ray fluorescence, neutron prompt gamma analysis, etc., the mode propagation of x-rays in capillaries allows other unique applications, e.g., x-ray microscopy and focusing of coherent x-ray sources.

We present here synchrotron radiation soft X-ray experiments performed in transmission with different values of curvature radius of thin Microchannel plates (MCPs), the optics formed by hollow microcapillaries [2]. MCPs, we characterized, are the arrays of 104-107 miniature hole microchannels oriented parallel to one another and characterized by spatial regular channels with hexagonal symmetry in the transverse cross-section. The channel matrix of MCPs is fabricated from silicon-lead glass and axes are normal to the MCP surface. In this study we measured both angular and energy distributions of X-ray radiation for two types of MCPs: one with diameter 3.4 μm , a pitch size of 4.2 μm and a thickness of ~ 0.27 mm and a second with a diameter of 10 μm and pitch size of 12 μm . The length to diameter ratio is about 80 for both.

The Reflectometer, the end-station for XUV-Optics beamline recently made available at the BESSY synchrotron radiation facility, has a four circles goniometer: two for sample scans and two for the detector. A layout of this UHV-Reflectometer is shown in Ref. [3].

We measured the primary monochromatic radiation transmitted by MCPs, propagating through the microchannels of these devices. The monochromatic radiation travelling inside the microchannels of the MCPs was detected by a pinhole photodiode with a circular window of 0.5 mm diameter, located at the distance of 310 mm from a sample, inside the Reflectometer. In particular, we have measured the soft X-ray transmission in the energy range around Si L and K edges (from ~ 100 to 1800 eV) to characterize the fine structures of angular distributions of the radiation at the exit of MCPs.

We also calculated the transmission efficiency of MCPs (both flat and spherically-bent) at the fixed energy of the primary radiation ($E=100, 450, 900, 1800$ eV). Data at 1800 eV point out an efficiency of $\sim 60\%$ for the MCP with a microchannel diameter of 3.4 μm . Actually, the same value corresponds to the light transmission efficiency of a flat MCP.

To focus a x-ray parallel beam a MCP device has to be bent with a spherical shape. We characterized a spherically-bent MCP with the radius of 50 mm and microchannel diameters of 10 μm . The spherical shape has been achieved by thermally bending these plates with a special metallic mandrel. Experimental data pointed out an optimal focus distance from the window of the detector to the surface of the spherical bended device of ~ 27.5 mm, roughly half of its spherical radius. According to these measurements the transmission efficiencies of a MCP at 100 eV ranges from 57% to 22% working with a slit from 100 μm to 1 mm, respectively. The transmission efficiencies of such spherically-bent MCPs are roughly the same also at 450, 900 and 1800 eV.

References

1. C.A. MacDonald, Focusing polycapillary optics and their applications, X-Ray Optics Instrum. (2010) 867049
2. M.I. Mazuritskiy, S.B. Dabagov, A. Marcelli, A.M. Lerer and K. Dziedzic-Kocurek, J. Synchr. Rad. 23 (2016) 274-280

Summary

We measured the primary monochromatic radiation propagating through microchannels of Multi Channel Plates (MCP). The monochromatic radiation traveling inside these devices was detected by a pinhole photodiode inside the Reflectometer station at BESSY. We have measured the soft X-ray transmission in the energy range around Si L and K edges to characterize the fine structures of angular distributions of the radiation at the exit of MCPs. We also calculated their transmission efficiency at different fixed energy of the primary radiation. Data at 1800 eV point out an efficiency of ~60% for MCPs with a microchannel diameter of 3.4 μm for both flat and bent devices.

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