Testing of Refractive X-Ray Optics for Focusing and Imaging at the Pohang Light Source

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The article represents results of focusing and imaging of X-rays at the beamline 6D – XMI of Pohang Light Source with use of the X-ray optics designed in Belarus.

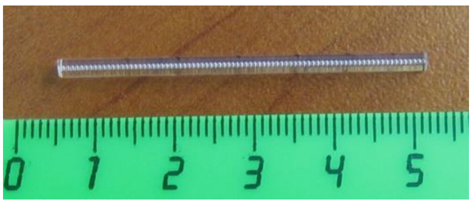
More than 40 centers of synchrotron radiation operate today, including and so-called synchrotrons of the third generation (ESRF (France), APS (USA), SPring-8 (Japan), etc.) which allow to receive intensive x-ray beams with a cross size about 100 microns and the energy of photons 5-20 keV. Such X-ray beams can be focused into micron sized spots with the use of a number of the optical elements one of which is the compound refractive X-ray lens.

The third generation Pohang Light Source of synchrotron radiation was put into operation in May, 2012 as a result of modernization of existing earlier synchrotron of the second generation. As a result of the modernization the current of electrons in the synchrotron ring increased considerably and the cross section of the electron beam was reduced up to the size of 100-200 microns.

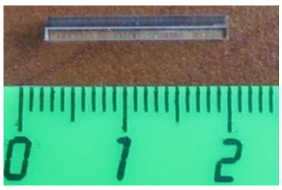
The used for experiments compound refractive X-ray lenses were produced in the A.N. Sevchenko Institute of Applied Physics Problems of Belarus State University [1]. The lens is designed in the form of a glass capillary filled by a given number of epoxy microlenses. Radius of curvature of a separate microlens is equal to the radius of the capillary channel and due to this it become possible to create lenses with the surface curvature radius equals to 10-50 microns that is difficult to realize with other known methods. The number of microlenses may be from 50 to 200. The lens focal length is about 100 mm for 8 keV X-rays.

Refractive X-ray lens works as ordinary lens for visual light. In the case of synchrotron radiation the distance between the source and the lens is high enough and equals, as a rule, to 10-50 m; the size of the source is also, as a rule, less than 1000 microns. When refractive lens with a focal length equal to approximately 10 cm is used, expected size of source image may be equal to some microns. This is a way for obtaining micro and nano-sized X-ray beams.

Two compound refractive X-ray lenses were developed and made for experiments. Lens # 1 consists of 81 biconcave microlenses, with 250 microns surface curvature radius. The calculated focal length of the lens for 8-keV photons is equal to 408 mm. Lens # 2 consists of 126 microlenses. Radius of curvature of the surface for a separate lens is equal to 50 microns. The calculated focal length of the lens for photons with energy 8 keV is equal to 52,5 mm. Fig.1 shows images of the lens #1 and lens #2.



(a)



(b)

Fig. 2 – Photo of the lens #1 (a) and the lens #2 (b)

Fig. 2 shows photo of experimental setup for measuring lens focal length. 8-keV X-rays from synchrotron source were directed through the X-ray lens on a scintillating crystal. Visual light from the scintillating crystal was collected by objective lens and the lens forms image at the digital CCD- camera. 12-bit CCD camera of 1376 X 1040 pixels format was used. The size of the synchrotron's source at beamline 6D - XMI was equal to 148 microns x 71 microns. The X-ray lens was placed at the distance 31,4 m from the source.

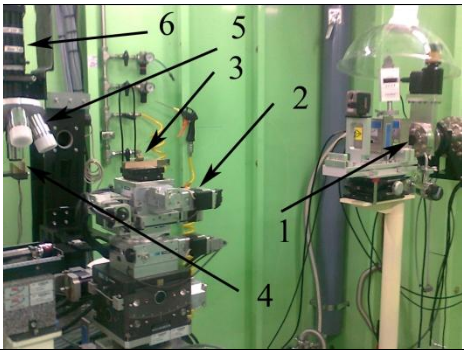
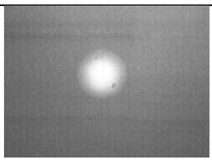
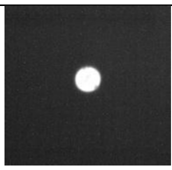


Fig. 2 – Setup for measuring X-ray lens focal length.
1- X-ray beam output system; 2- goniometer; 3- X-ray lens in a holder; 4-scintillater, 5-microscope objective lens; 6- CCD- camera.

Fig.3 shows images of the X-ray beam cross section formed by the lens # 1 at various distances to the lens.


(a)


(b)

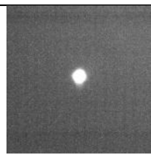

(c)

Fig.3- Image of the X-ray beam formed by the lens # 1 at various distances *d* to the lens.
a) *d*= 20 cm; b) *d*= 30 cm; c) *d*=41 cm.

From Fig.3 it is seen that the smallest cross section of beam is observed when the camera is placed at distance *d*= 41 cm to the lens. This distance coincides with the calculated focal length of the

lens # 1 equals to 40,8 cm. It was established that the beam size in horizontal direction is equal to 4,5 microns, and in the vertical - 5,5 microns. It was impossible to establish the beam size more precisely, because the spatial resolution of this method for the used CCD-camera was in the range of 2-3 microns.

The lens # 2 with focal length of 52,5 mm was used as an objective lens of a simple X-ray microscope which was realized at the station 6D X-ray microimaging of the Pohang Light Source.

The gold mesh # 1500 with a number of cells on one inch equals to 1500 was used as an object; thickness of a wire was equal to 6 microns. The mesh was placed at the doubled focal length to the lens. The scintilater plate was placed at the same distance to the lens: that allows receiving the object image in the ratio 1:1. Fig. 3 shows the image of the grid # 1500 obtained with the use of the lens # 3 with magnification equals to 1.

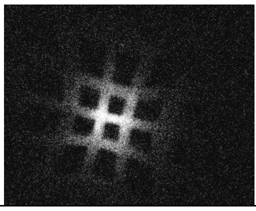


Fig. 3- The image of the grid # 1500 obtained with the use of the lens # 3 with magnification equals 1.

The analysis of the image of a grid No. 1500 showed that spatial resolution of a microscope makes about 2-3 microns. Better resolution may be obtained after optimization of the used X-ray CCD-camera.

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References

1. *Dudchik, Yury. Design and Application of X-Ray Lens in the Form of Glass Capillary Filled by a Set of Concave Epoxy Microlenses // Optical Fiber Communications and Devices. Edited by: Moh. Yasin, Sulaiman W. Harun and Hamzah Arof (Ed.), ISBN: 978-953-307-954-7, Publisher:InTech, February 2012.- P.77-94.*