| ESRF | **Experiment title:** ULTRA SHORT-FOCUS HARD X-RAY REFRACTIVE LENS MATRIX | **Experiment number:** MI 371 |
|---|---|---|
| **Beamline:** BM-5 | **Date of experiment:** from: 05.10.99 to: 09.10.99 | **Date of report:** 17.02.00 |
| **Shifts:** 5 | **Local contact(s):** A. Souvorov | *Received at ESRF:* 29 FEV. 2000 |


**Names and affiliations of applicants** (* indicates experimentalists):

Kuznetsov Serguei — Institute of Microelectronics Technology (IMT) RAS, 142432 Chernogolovka, Russia, Moscow district

Shabel'nikov Leonid — Institute of Microelectronics Technology (IMT) RAS, 142432 Chernogolovka, Russia, Moscow district

Snigirev Anatoly — ESRF, BP 220, F-38043 Grenoble Cedex, France


**Report:**

During the beamline allocated within the proposals MI-371 we have tested ultra short-focus X-ray refractive lenses. The short-focus parabolic lenses with extremely small curvature radius were realized by a method of deep photoanodic etching of silicon. These lenses have aperture A=5 μm each and are grouped in a square matrix combined from single lenses with the period d=8 μm in horizontal and vertical directions. The lens matrices were preliminary investigated on a laboratory source (RU-200 rotating anode generator) using $MoK_\alpha$ radiation. We will concentrate in this report on the results obtained on the synchrotron radiation in the energy range 12 - 30 keV using high-resolution CCD-camera (pixel size 0.6 μm). The experiments with the ultra short-focus lenses were successful and results can be summarized as folows:

Images from matrix consisting from the square array of focal points with period 8 μm were recorded in the full energy range from 12 to 30 keV. It was found, that the FWHM of focal spots is diffraction limited by an aperture and not by demagnification of the source size.

Some focusing parameters of individual lenses are summarized in Table 1.

| | | | |
|---|---|---|---|
| Energy E, keV | 12 | 17 | 30 |
| Focal length, cm | 3.9 | 7.2 | 25.2 |
| Gain G, arb.units | 4 | 3.5 | 2.3 |

| | | | |
|---|---|---|---|
| Intensity profile FWHM, μm | 1.1 | 1.2 | 1.7 |
| Focal depth, cm | 0.26 | 0.82 | 4.8 |
| Transmission, % | 98.9 | 99.3 | 99.9 |

The calculations of gain G and FWHM of intensity profiles were fulfilled with the help of computer simulation methods developed earlier. The transmission of lenses is estimated on the basis of general considerations of properties of parabolic lenses.

The ultra short-focus lenses have high values of transmission and are close analogues of the visual range lenses. It seems quite interesting to observe classical interference effects in the hard X-ray range. We illuminated at energy 12 keV two adjacent rows of lenses in a matrix, as in the experiment with the Billet's split lens. The interference fringes with a period of 10 μm were observed at distance 80 cm. The intensity of the interfernce fringes descends from center to peripherals and is modulated by an envelope function defined by the lens FWHM. The visibility of the interference fringes was used to estimate quantitatively degree of coherence of the incident radiation and source parameters.

The experiment with the image self-reconstruction (Talbot effect) was carried out with two values of energy $E_1$=17 keV and $E_2$=12 keV and a fully illuminated matrix. The most clearly observed images were obtained at $E_2$. Registered series of images have demonstrated the self-reconstruction of the focal spots array of the two dimensional phase-contrast object. The Talbot distance and spatial coherence length determined an estimated resolution of 0.65 μm in the Talbot image.

In the conclusion we can note, that interference scattering effects were firstly observed for the two-dimensional phase-contrast periodic object. As a new element of refractive optics the lens matrix provides a real approach to construct Talbot imaging schemes and bifocal nondestructive techniques. A new technique for experimental determination of coherence properties of the synchrotron source can be developed on the basis of carried out experiments.

**References.**

V.Aristov, L.Shabel'nikov, S.Kuznetsov, V.Starkov, A.Snigirev, I.Snigireva "Interference effects of the coherent hard X-ray radiation on the refractive lens matrix made of silicon" (submitted to J.Synchrotron Radiation)