# IMAGE TRANSMISSION BY A BRAGG-FRESNEL X-RAY LENS

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A periodic grid image transmission by a Bragg–Fresnel lens (BFL) in a twice reduced scaled scheme has been carried out. The experiments have been performed in white synchrotron radiation in a hard spectral region ($\lambda \approx 1$ Å).

Weak interaction of hard X-radiation with a substance – the refractive index close to unity – illuminates fabrication of refractive X-ray elements analogous to visible light optics. Along with a number of theoretical and experimental works it has been shown that it is possible to use X-ray diffraction on a crystal lattice for coherent focusing of X-rays [1–4]. The property of dynamical Laue diffraction, when a refractive index near the exact value of the Bragg angle undergoes great dispersion, was taken into account when investigating perfect crystals.

In refs. [5,6] attempts to transmit an image in X-radiation using the effect of dynamic focusing were made. Practical applications of the schemes suggested is limited by the small angle aperture ($\Delta\theta \sim 10^{-4}$–$10^{-5}$) of the lenses, low light grasp of the schemes, and besides large chromatic aberrations require the preliminary use of a monochromatic beam [6].

In this connection the idea of X-ray optical element fabrication as a synthesis of X-ray Bragg diffraction on a crystal lattice and Fresnel diffraction on an artificial structure is likely to be of much interest [7–9]. In this case there exists the possibility to create effective focusing X-ray elements with three-dimensional Fresnel zone structures (Bragg-Fresnel lenses).

The first simple step for experimental realization of a BFL is the fabrication of a profile on a silicon single crystal according to the law of one-dimensional Fresnel zones, the dimensions of which, $r_n$, can be expressed as follows

$$r_n = (1/\sin\theta_B)\,(f\lambda N)^{1/2}\,,$$

where $N$ is the zone number, $f$ is the focal distance, $\theta_B$ is the Bragg angle, $\lambda$ is the radiation wavelength. An angular aperture of this lens can significantly exceed the rocking curve of a perfect crystal. The resolution of the BFL is determined by the size of the outermost zone. The chief advantage of the BFL as compared with both the focusing elements based on Laue dynamic diffraction and conventional Fresnel optics lies in the fact that this lens is completely free from chromatic aberrations.

The aim of the present work is to demonstrate the possibility of image transmission by means of a BFL in polychromatic radiation.

The image transmission experiments were performed using a synchrotron radiation beam emitted by a superconducting wiggler installed on the electron-positron storage ring VEPP-2M (Novosibirsk, Institute of Nuclear Physics, Siberian Division of the USSR Academy of Sciences).

Under ordinary experimental conditions the energy of electrons in the storage ring $=630$ MeV, the maximum magnetic field on the axis of the wiggler $=71$ kG, electric current in the storage ring $=30$ mA. The lateral dimensions of the electron beam in the wiggler (dimensions of the source of radiation) were $60\times800$ 5μm. A synchrotron radiation beam came

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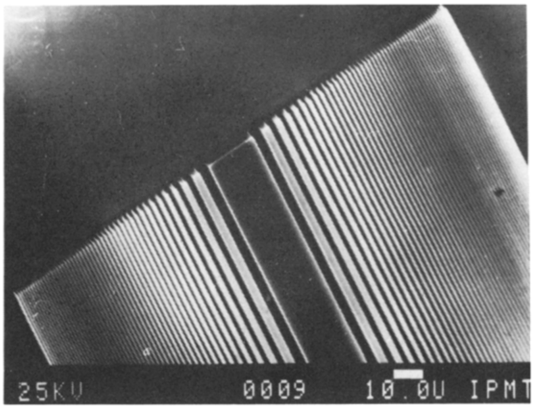


Fig. 1. Bragg–Fresnel lens.

from a vacuum chamber of the storage ring through beryllium windows (total thickness of Be was 200 μm) which prevent transmission of the longwave part of the spectrum.

A rectilinear Fresnel zone plate fabricated in the form of a profile on a surface (111) of a perfect silicon crystal was used as a BFL (fig. 1). The main geometrical parameters of the Bragg–Fresnel lens are: innermost zone width =20 μm, outermost zone width =0.5 μm; total lens width =200 μm, length =1 mm; zone height =3 μm. The experiment on image transmission is given schematically in fig. 2. The distance from the radiation point to the zone plate was 5 m.

Reflection Si(111) was used for a wavelength of 1.7 Å. In this case the focal distance of the lens, $f$, was equal to 5 cm [#]. A nickel grid 7 μm thick with a period of 20 μm was used as an object. The grid was positioned at a distance $L_1=15$ cm from the lens,

[#] The lens fabricated by us permits obtaining a resolution of the order of 0.5 μm and it has a diffraction efficiency of 2%.

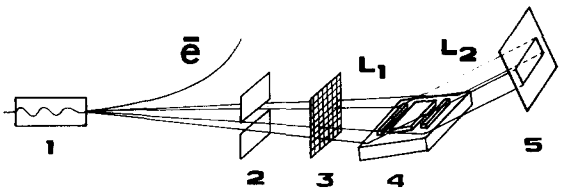


Fig. 2. Scheme of the image transmission experiment: 1 – superconducting wiggler; 2 – slit; 3 – nickel grid; 4 – BFL; 5 – observation plane.

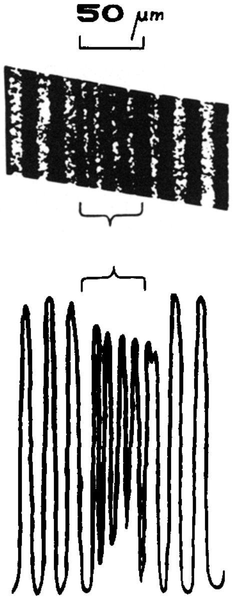


Fig. 3. Experimental topogram and densitogram of the grid image.

and the image was recorded on a photoplate located at a distance $L_2=7.5$ cm behind the lens. Thus according to the lens formula $(1/L_1)+(1/L_2)=(1/f)$, this experimental geometry provided twice a reduction of the object image.

Fig. 3 shows a topogram of the grid image transmitted by the BFL and a densitogram corresponding to the topogram. It is well observed that in the single crystal region where a zone profile is absent, the grid image is transmitted as 1 : 1. In the region of the zone plate (the projection of its aperture is 70 μm and is shown in the figure by a bracket) the grid image doubled.

Thus, in this work the first experiments on image transmission by a BFL in hard X-radiation were carried out. These experiments open up the possibilities for developing X-ray microscopy on the basis of the elements of Bragg-Fresnel optics.

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