

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

<http://193.49.43.2:8080/smis/servlet/UserUtils?start>

Reports supporting requests for additional beam time

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

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All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.



	Experiment title: Sagittal focusing of synchrotron radiation by means of round holes drilled into perfect crystals.	Experiment number: MI-446
Beamline:	Date of experiment: from: 26.10.2000. to: 31.10.2000.	Date of report: 26.02.2001.
Shifts: 9	Local contact(s): R Tucoulou.	<i>Received at ESRF:</i>
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Report:

A very simple method of sagittal focusing of synchrotron radiation is presented. It is demonstrated both by the ray tracing simulations and by the experiment that a reasonably good sagittal concentration of 8 keV synchrotron radiation by the diffraction on the walls of the cylindrical hole drilled into Si crystal may be achieved. The hole was drilled parallel with (111) planes and its diameter, 1 mm, was chosen such that the focusing distance fits the geometrical arrangement of BM5 beamline in ESRF. In our case the maximal focusing distance was 2 m. We have used two such crystals in the dispersive and nondispersive arrangement. The better result was achieved with the dispersive arrangement. The intensity in the center of the focus is increased 5 times with respect to unfocused radiation. The coincidence between ray tracing simulations and experiment is excellent.

1. Introduction

The utilization of refraction phenomena for focusing of x-ray synchrotron radiation (SR) is now well established. Compound Refractive Lens (CRL) (Snigirev et al., 1996) is an analogue to the classical refractive lens in visible optics. It is relatively simple device, which works well for hard radiation. For longer wavelengths, however, the absorption in the material of the lens may deteriorate the intensity gain due to the focusing. To avoid this drawback rather sophisticated schemes were suggested (Lengler et al., 1999; Piestrup et al., 2000), which substantially reduce the absorption but the manufacturing of such lenses is arduous. The alternative way of the SR focusing based on the refraction was proposed by Hrdý (Hrdý J., 1998). In his idea the refraction phenomena occurring during Bragg diffraction is utilized. It was shown that the radiation diffracted on the longitudinal groove with parabolic profile machined into a single crystal monochromator is sagittally concentrated (focused). Here the grooved crystal plays the roles of both x-ray monochromator and sagittally focusing lens. There are no losses due to the absorption as in the case of CRL. At the same time it was shown that the best results are achieved when using the dispersive arrangement of such grooved crystals.

The sagittal focusing based on this idea was first experimentally demonstrated in National Synchrotron Light Source (NSLS) in the Brookhaven National Laboratory (Hrdý & Siddons, 1999) where 15 keV radiation was successfully focused at the focal distance 5 m after successive diffraction on four grooved crystal surfaces arranged in (-,+,+,-) position.

A grooved single crystal is relatively simple device but the production of the parabolic groove of given parameters needs to order a specially profiled tool (as we did) which is expensive and this tool could be used probably only once (or several times at the best case). In this work we show that in some cases a relatively good sagittal concentration of SR may be achieved by using the cylindrical shape of the groove instead of the parabolic one and that such a sagittaly focusing monochromator may be realized by the cylindrical hole drilled into a single crystal parallel with diffraction planes. In other words a hole plays a role of a channel with inclined walls.

In order to check the focusing ability of such optical elements, which utilize refraction phenomena occurring during Bragg diffraction, the special ray-tracing program was created.

2. Experiment description.

In order to utilize the small vertical source size (about 80 μ) and to achieve maximal flexibility in arrangements and adjustment of BM5 equipment the crystals were oriented in such a way that a beam was focused in vertical direction.

Unfortunately, we couldn't use the standard double crystal monochromator of BM5 because of dispersion in vertical direction. So, in order to decrease heat load on the first sample crystal and to avoid fast damage of detectors a primary channel-cut Si(111) was installed on the first goniometer head in such a way that its dispersion plane was horizontal.

Fine slits were installed on the same goniometer head in 20.5 centimeters downstream the primary channel-cut.

The first sample crystal with hole was mounted on the second the most versatile goniometer head, which has all degrees of freedom. The second sample crystal and the detector were mounted on the third goniometer head. The distance between the sample crystals was 46 cm, which is the minimal distance between axes of the second and the third goniometer heads.

3. Results and discussions.

The experimental snap shots of the focal spots, their processed plots and corresponding ray-tracing pictures for antiparallel and parallel arrangements of the sample crystals are shown on Fig. 1 and Fig. 2 correspondingly.

The upper pairs of pictures on Fig. 1 and Fig. 2 represent the experimental images of the focal spots and corresponding ray-tracing scatter plots posted in the same scale as the experimental images. Under these figures corresponding the 3D plots of the intensity distribution and the contours plots are depicted. In comparison with intensity in these focuses, intensity of not focused beam is shown in far distant corners of the 3D plots and on the upper parts of corresponding contour plots.

It is perfectly seen that aberrations are much larger in the case of parallel (non-dispersive) arrangement of the crystals. First of all it is connected with the shape of working surfaces of the crystals and corresponding optical paths of geometrical rays through this optical system. Then, for parallel arrangement the smearing effect accompanying inclined Bragg diffraction (Artemiev N., 2000) is increased with the factor which is equal to the number of reflections while in the case of antiparallel (dispersive) arrangement this effect is practically canceled, or at least not so noticeable.

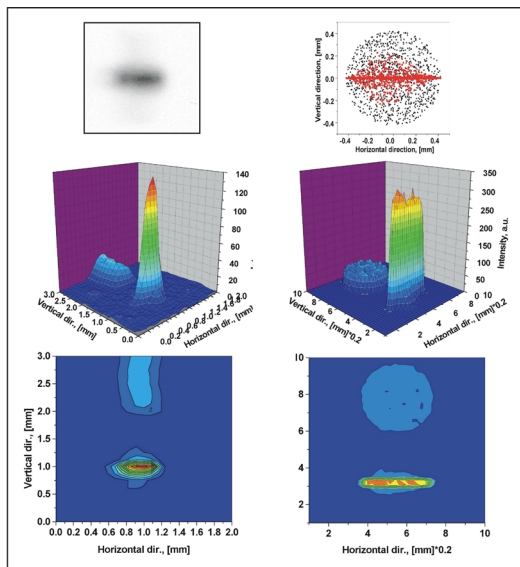


Fig. 1

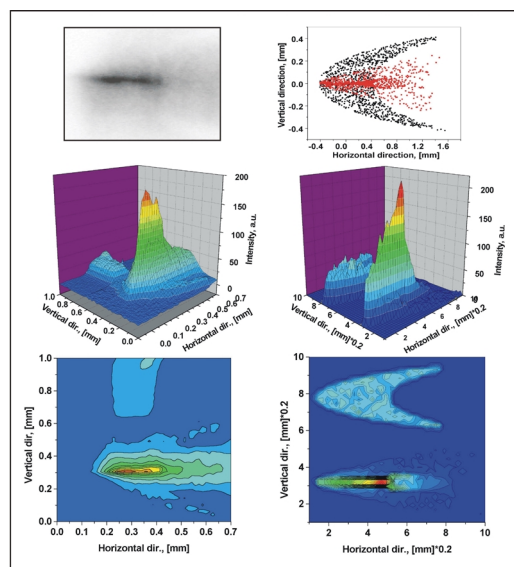


Fig. 2.

Fig.1. Antiparallel (dispersive) crystals arrangement. Left column: the experimental image of the focal spot, the 3D plot of intensity and the contour plot; Right column: the scatter plot of the ray tracing simulation of the exact parameters of the experimental layout, the 3D plot of intensity and the contour plot.

Fig. 2. Parallel (non dispersive) crystals arrangement. Left column: the experimental image of the focal spot, the 3D plot of intensity and the contour plot; Right column: the scatter plot of the ray tracing simulation of the exact parameters of the experimental layout, the 3D plot of intensity and the contour plot.

4. Conclusions.

The experimental results show that intensity in the focal spot is 4 - 5 times higher than in a spot without focusing. Surely, five is not so high a factor. However, this is not so bad if one would take into account the large aberration of such a scheme when a hole is filled with light completely. Moreover, holes were simply drilled and etched without any polishing and their cross sections aren't perfect circles. The maximal gain, which could be achieved in this case, is about 7.

The advantage of this scheme is obvious: focusing and monochromatizing of synchrotron radiation is performed (during its monochromatizing) by the same optical elements.

So, we conclude that the experiment results are quite successful.

ACKNOWLEDGEMENTS.

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