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Report:

Bent crystals can be employed for several applications. As an example, due to the strong electrical field generated between atomic planes and axes, it is possible to manipulate charged particle trajectories via coherent effects, such as channeling and volume reflection. Radiation emission due to curved trajectories of charged particles in bent crystals has been studied in order to obtain photon production through bremsstrahlung, channeling radiation, PXR, and undulators. Bent crystals can also be used in synchrotrons as high-efficiency monochromators for high-energy X-ray beam lines, and to control neutron diffraction over a wide angular range.

Among bent crystals, self-standing bent samples are useful if used as optical elements for focusing hard X- and γ-rays with high efficiency and resolution. Such bent crystals can represent the solution that the astrophysics community has been seeking for in order to make the experiments based on Laue lenses achievable. Their diffraction efficiency is not limited to 50% because the continuous change of the incidence angle on bent crystalline planes prevents re-diffraction of a diffracted beam. The energy passband of the photons diffracted by these crystals can be very well controlled, featuring a uniform transfer function provided that the crystal curvature is homogeneous.

In three previous experiments at ESRF (MA-717, MI-1021, and MA-1744) self-standing bent crystals proved to work to diffract hard X-rays with an encouraging diffraction efficiency [1,2,3].

In this experiment, we measured new self-standing silicon and germanium curved samples. We were interested in checking the quality of the curvature and the diffraction efficiency of the samples. In fact, these two factors are the key parameters needed for the concrete realization of a Laue lens based on bent crystals.

The measurements were performed using a pencil beam 50x50 μm^2 wide and with energy of 150 keV. The monochromator was composed of three crystals in Laue geometry. The first two crystals were a fixed exit double bent Si(111) Laue monochromator with a typical resolution of $\Delta E/E = 2x10^{-3}$. The last crystal was mounted on the first tower in the laboratory. It was an unbent Si(220), which provided a high monochromaticity of the beam. The sample holder was set on the second tower.

The measurements consisted in rocking curves (RC) in Laue geometry. Both diffracted and transmitted beams were alternatively recorded by moving back and forth a germanium detector.

We measured the samples produced within the LOGOS project, which is a project financed by the National Institute of Nuclear Physics (INFN).

In the first part of the experiment, we measured the curvature of a sample bent by ion implantation. Indeed, we checked the possibility to produce thick bent crystals by implantating a certain dose of ions on one sample surface. We tried with He^+, Ar^+ and Kr^+ implantated with energy of 50, 100, and 150 keV on silicon samples. The samples were 10x10x0.2 mm^3. To test the deformation of the samples, we performed rocking curves on the planes perpendicular to the samples major surfaces, and studied the shifting of the rocking curve peaks as a function of the position. We found that the deformations obtained were of the order of 10 meters.

In the second part of the experiment, we measured the curvature of a sample bent through a carbon fiber film. Due to its high Young modulus, carbon fiber can represent a good method to bend rigid materials as silicon and germanium. A silicon sample 5 millimeters thick has been bent to 20 meters radius of curvature. The sample was (111) oriented and presented a QM curvature on internal (422) planes. The QM planes are crystallographic planes perpendicular to the sample major surfaces, which result bent due to an anisotropic response of a sample subjected to a bending [4]. Such internal planes resulted bent to a radius of curvature of about 70 meters. A rocking curve of such QM planes is shown in Fig. 1.

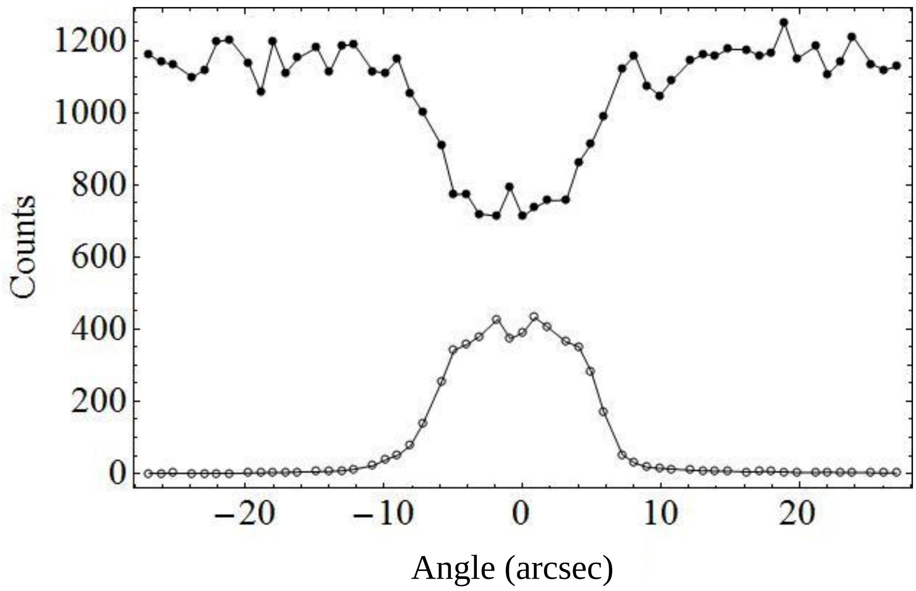

Fig.1 Rocking curve of QM planes in a 5 mm thick silicon crystal

As can be noticed, the QM (422) planes resulted curved, subtending an angle of about 15 arcsec with a diffraction efficiency of 38%. These data fit very well with the theoretical expectations. Since for these crystallographic orientations the ratio between the primary curvature and the QM curvature is 3.542 [5], the primary radius of curvature resulted to be about 20 meters. This result represents a very high curvature for a 5 mm Si sample, which was near to its breaking point.

Reference:

[1] N. Barrière, V. Guidi, V. Bellucci, R. Camattari, T. Buslaps, J. Rousselle, G. Roudil, F.-X. Arnaud, P. Bastie, and L. Natalucci, J. Appl. Cryst. **43**, 15191521 (2010), 10.1107/S0021889810038343.

[2] V. Bellucci, R. Camattari, V. Guidi, I. Neri, and N. Barrière, Exp Astron **31**, 4558 (2011), 10.1007/s10686-011-9226-5.

[3] R. Camattari, E. Dolcini, V. Bellucci, A. Mazzolari and V. Guidi, J. Appl. Cryst., in press (2014).

[4] O. I. Sumbaev, Soviet Phys. JETP, **27**, 1042-1044 (1957)

[5] R. Camattari, V. Bellucci, V. Guidi, Astron. and Astrophys., **560**, 1-8 (2013), 10.1051/0004-6361/201322053