ESRF	**Experiment title:** Study of crystals elastically bent by periodical microscratches (grooves), application to the realisation of high-diffraction efficiency crystals	**Experiment number**: MI-1021
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Report:

The main goal of this experiment was to study crystals bent by superficial indentations. The measurements were performed using a pencil beam of 50µm x 50µm of monochromatic energy varrying from 150 keV to 700 keV. The monchromator was composed of 2 unbent Si-111 crystals in Laue geometry, insuring a monochromatic beam position independent of the energy (fixed exit setup). The sample holder was set on the first tower (the closest from the optical hutch) in order to have enough distance between the crystal samples and the detector to separate properly the diffracted and the transmitted beams at 700 keV. 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.

In the first part of the experiment, we measured several samples of pure silicon and pure germanium wafers of various thicknesses and sizes, with various indentation parameters (pitch, depth, width, and saw roughness). Grooving a silicon wafer by a semiconductor dicer has been proven to be a good method to bend crystals [1], and to induce a uniform curvature within the crystal [2]. The grooves manufactured on the surface of the crystal by a diamond saw act as a tensile film, which bends permanently the entire sample with no need for an external device.

The motivation to develop this crystal bending technique is twofold. The first aspect is to develop crystals yielding a high reflectivity in a controled bandpass at soft gamma energy. This aspect is related to the development of a Laue lens, a focusing optic to realize an astronomical telescope that work over selected energy bands within the ~100 keV - ~1.5 MeV domain. A Laue lens relies on Bragg diffraction (in Laue geometry) to deviate the gamma rays in a large number of accurately oriented crystals (typically of 1x1cm of cross section), which requires highly reproducible crystals having the highest reflectivity possible [3]. The second aspect is the development of compact ondulator and particle extractor. Both applications rely on particle channeling in a deformed crystals. The crystal lattice has to be as perfect as possible, while being ondulated or curved over marcoscopic scale. Ondulations can be obtained by indentations made on both sides of the crystal shifted of half the pitch on one face with respect to the other, whereas banding requires indentation only on me side, as it was the case in the present experiment.

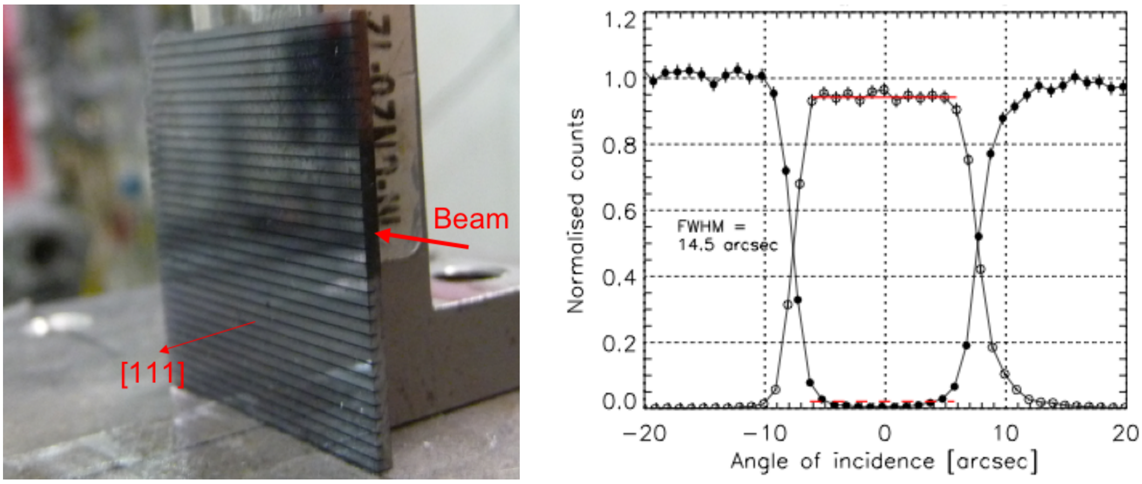

Figure 1: *Left:* Picture of a sample (Si, 1 mm thick) measured along the indentations. The beam enters by the edge as sketched by the arrow and is diffracted by the (111) plans parallel to the indented face. *Right:* Example of a rocking curve obtained with an indented Si crystal. The rocking curve width (equal to the total curvature of the diffracting plans) is 14.5 arcsec and the diffraction efficiency is nearly 100%, which indicates a very proper curvature.

The bending is eliptical, being more pronounced perpendicular to the indentations. These measurements performed at different depth from the indented face allowed us to access three information :

- The total curvature of the crystalline planes, via the RC width
- The homogeneity of the curvature over the crystal thickness, via the RC shape recorded at many different location in the crystals.
- The quality of the curvature and of the crystal (perfect elastic curvature of the diffracting planes, or mosaic-like dislocation-rich crystal), via the diffraction efficiency.

The several RC recorded on 9 different samples, either parallel or perpendicular -or both- to the grooves will allow to constrain efficiently the model of indented crystal which is being developped at the University of Ferrara. A preliminary conclusion of this first part of the experiment is that this technique allows a very reproducible and predictable curvature to be obtained, even in wafers as thick as 5 mm.

In the second part of the experiment, we took advantage of the beamline setup to study the diffraction properties of the best of our bent crystals versus energy on the 150 keV – 700 keV range. We also measured other candidate crystals (mosaic crystals) for the realization of a high energy Laue lens: Low mosaicity copper crystals produced by the monochromator group of the Institute Laue Langevin (ILL, Grenoble, France), as well as lead, tantallum, irridium and silver produced by Mateck GmbH (Juelich, germany). These mosaic crystals showed execlent quality, with mosaicity in the 15-60 arcsec, which is perfectly suited for the realization of a Laue lens. We noticed during these measurements that the mosaicity of a given reflection is very different if the crystal is rotated about the normal of the plans. We noticed mosaicity variation of up to a factor of 10 while rotating the crystal of 90º. It wasn't possible however to relate the 'good' and 'bad' orientations with for instance the cut direction. This is a very important aspect that will have to be taken into account in the future for the cutting of the pieces used for the realization of a Laue lens.

The experiment was a full success, thanks especially to the competences of our local contact Thomas Buslaps. Based on the data acquired during this experiment and the previous one (MA-717), several papers are being written or have been submitted for publication.

References:

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