ESRF	**Experiment title:** Study of mosaic single crystals for MAX gamma ray lens telescope	**Experiment number**: ME-1203
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Report:

In 2001, the CLAIRE project demonstrated the feasibility of a gamma-ray lens for nuclear astrophysics with the detection of photons from the Crab nebula during its 5-hour balloon flight [1]. CLAIRE, which was built by an international collaboration and flown by the French Space Agency CNES, features a Laue diffraction lens composed of 556 germanium-silicon mosaic crystals mounted on eight concentric rings. This success opens the way for a new generation of nuclear astrophysics instruments: focusing, which seemed impossible in this energy range, allows to combine a large photon collecting area with a small detection volume, thus improving dramatically the detection efficiency (background noise in a detector being roughly proportional to its volume).

MAX is the next step towards the nuclear astrophysics of tomorrow; it is a space borne gamma ray lens, using the latest developments in satellite formation flying to achieve an 86 m focal length. MAX is still in a design phase, mainly due to the ongoing evolution in diffracting materials. In the current design baseline, MAX lens is composed of about 13700 copper and germanium crystals of 30 arcsec mosaicity distributed on 36 rings whose radii vary from 57 to 128 cm [2]. Such a mosaicity is required for the lens performance but represents a challenge for crystal growth.

Mosaic crystals constitutes the simplest way to realize a Laue lens. In parallel, we are also investigating more “exotic” diffracting materials such as curved or composite crystals. The aim is to obtain a crystal that diffracts a defined and reproducible energy bandpass without having a Gaussian intensity profile of the diffracted beam as are doing mosaic crystals. A Gaussian profile of the diffracted beam is responsible of a defocusing effect on the focal plane, which decrease the overall sensitivity of the instrument.

The aim of our experiment was to measure accurately the diffraction efficiency and the bandpass of various diffracting materials at energies of interest to MAX. We planned to measure Rocking curves of each sample at 300 keV, 500 keV and 850 keV. However, because of technical problems on the beamline, two full days have been lost, consequently only 300 keV measurements have been achieved.

For this experiment, our samples available were 2 copper crystals whose mosaicity was around 1 arcmin, a composite crystal made by our self composed of a stack of 15 germanium single crystal wafers of 500 µm thickness, a Si_xGe_{1-x} gradient crystal (relative concentration of Ge is varying along the growth axis [3]), and one of the best Ge_xSi_{1-x} mosaic crystal from the lens CLAIRE, to be used as a reference.

Despite good preliminary measurements performed on the X-ray diffractometer in ILL, the stack of Ge wafers has exhibited an unexpected rocking curve: the misorientation between wafers was greater than their intrinsic angular width, resulting in a rocking curve composed of every single contribution of each wafer (Figure 1). This experiment highlights the importance of performing high-resolution measurements. The interest of building such composite crystal is to reproduce a mosaic crystal whose crystallite thickness is homogeneous and optimized for a given energy throw the value of the extinction length. Moreover, since the number of wafers is relatively small, the probability to have many wafers with exactly the same orientation is low, that comes down to have a curved perfect crystal. We have effectively observed in this experiment that every wafer had a singular orientation, in spite of the too big spread.

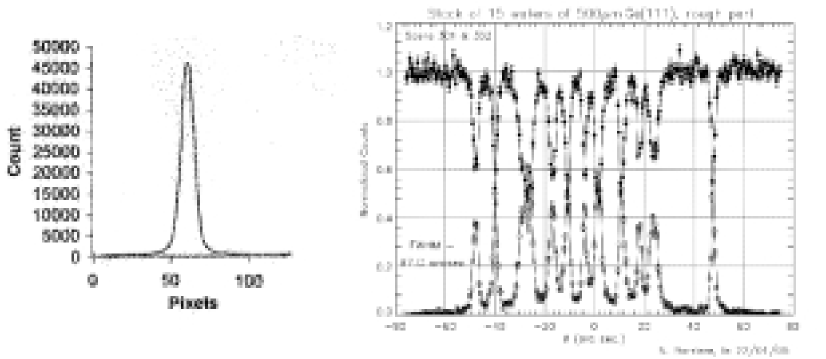

Figure 1. Stack of 15 single crystal Ge wafers measured (on the left) on the X-ray diffractometer at ILL, medium resolution beamline, and (on the right) in ESRF. The top curve was measured in transmission; the bottom curve was obtained in diffraction. The reference for the normalisation of both curves is the transmitted beam when no diffraction occurs. In these conditions, mosaic crystals are expected to reach 0.5, and perfect or bent crystals can go up to 1.

Another way to combine a controlled bandpass width and a diffraction efficiency as good as that one obtained with a single crystal is to use curved crystals [4]. The rocking curve of the Si – Ge gradient crystal featured a square shape (Figure 2) that renders the curvature of the Bragg planes. This result is very encouraging, nevertheless, the peak efficiency was “only” in the range of 0.4 (the value 1 is taken as the transmitted beam when no diffraction occurs), due to the fact that the curvature would have been more optimized for an higher energy.

Finally rocking curves obtained with copper crystals confirm the expected 1 arcmin mosaicity. These results will be used as input for numerical simulations to deduce key parameters, as crystallite size, that have to be known to simulate accurately low mosaicity copper crystals.

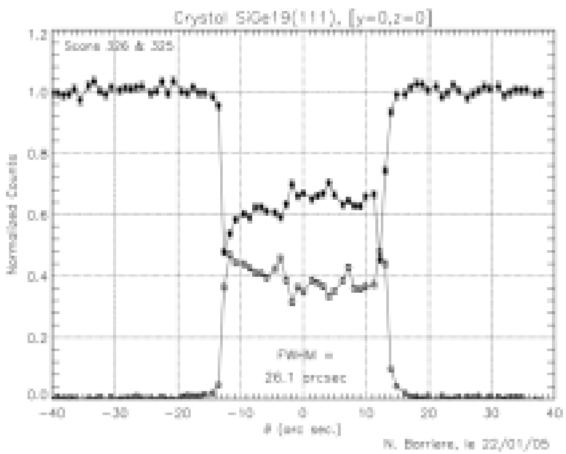

Figure 2. Rocking curves of the gradient crystal

This experiment has opened the way for the understanding of new diffracting materials, but other session will be necessary to go further in their development and characterization. Furthermore, tests at higher energies are mandatory.

References :

[1] Halloin, H., von Ballmoos, P., et al., NIM A504, 120-125, (2003)
[2] Barriere, N., von Ballmoos, P., et al., 2006, Exp. Astronomy (to be published)
[3] Abrosimov, N., et al., 2006, Exp. Astronomy (to be published)
[4] Smither, R., and al., 2005, RSI 76, 123107