Experimental report

11/12/2016

Proposal: **3-03-767**

Council: 4/2015

Title: Diffraction effficiency of self standing bent crystals for x-ray astronomy and medical imaging

Research area: Physics

This proposal is a resubmission of 3-03-765

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Samples: GaAs
silicon
germanium

Instrument	Requested days	Allocated days	From	To
PN3 - GAMS 6 DIGRA	7	10	01/12/2015	07/12/2015

Abstract:

Gamma ray focussing is a central topic in the X- and gamma-ray astronomy and in medical imaging. A great advance in sensitivity and resolution can be obtained by focusing systems based on Laue lenses obtained by assembling a large number of single crystals in the Laue diffraction configuration.

Self-standing bent crystals obtained by a method based on the surface damaging may permit to enhance the diffraction efficiency and to obtain a spontaneous and permanent lattice curvature, fundamental when assembling a large number of crystals. To date the only measurements of diffraction efficiency in these crystals were obtained at low x-ray energies showing an unexpected high value of the integrated intensity.

For gamma ray focussing it is important to measure the diffraction profiles of surface damaged bent crystals at high gamma ray energies and to confirm that the presence of a few micron thick heavily damaged layer has minor effects on the diffraction efficiency.

The aim of the present proposal is the measurement of diffraction profiles of curved GaAs, Si and Ge crystals, produced by the method of surface damage, at high x-ray energies (184, 517 and 788 keV) for lattice planes

Experimental report of the experiment n. 73778 "Diffraction efficiency of self standing bent crystals for x-ray astronomy and medical imaging"

Gamma ray focussing is a central topic in the X- and gamma-ray astronomy and in medical imaging. A great advance in sensitivity and resolution can be obtained by focusing systems based on Laue lenses obtained by assembling a large number of single crystals in the Laue diffraction configuration [1-2].
Self-standing bent crystals obtained by a method based on the surface damaging may permit to enhance the diffraction efficiency and to obtain a spontaneous and permanent lattice curvature, fundamental when assembling a large number of crystals [3].
In the experiment (220), (111) and (004) Laue diffractions of bent silicon and GaAs crystals have been measured at the energy of 184.517 KeV radiation coming from a 168 Er source. According to dynamical theory an increase of the diffraction efficiency with curvature 1/R occurs [4], corresponding to the integrated intensity of diffraction profiles.

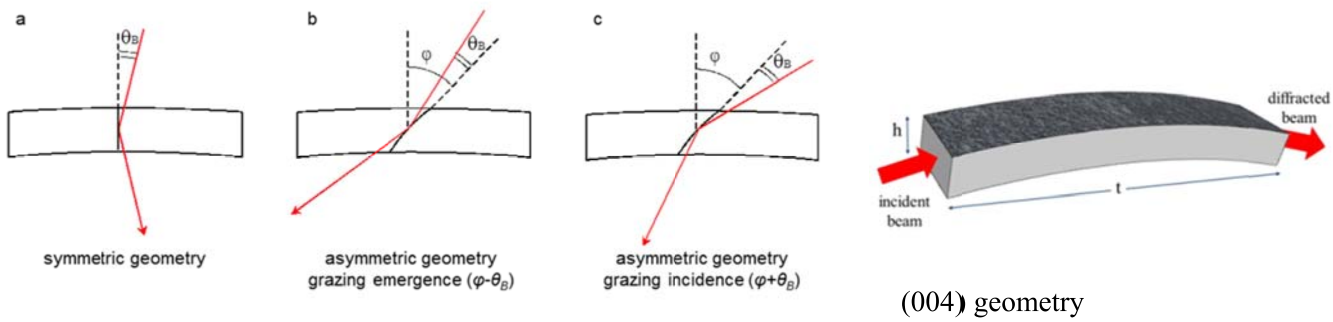

Fig. 1: setting of the measurements. In the experiment the (220) symmetric, the (111) grazing incidence and the (004) geometry have been used.

Results:

Silicon sample.

The Si sample was a monocrystal 60 m bent along the (001) surface, 2 mm thick, 10 mm long. The normalized integrated intensity passes form a 0.50 arcseconds to 7.3 arcseconds , with an increase of more than 14 times. The reflectivity profile for the (004) diffraction is that expected for a regularly bent crystal, with a flat and uniform reflectivity profile and a full width at half maximum corresponding to the total bending Δθ of the crystal along the (001) plane.

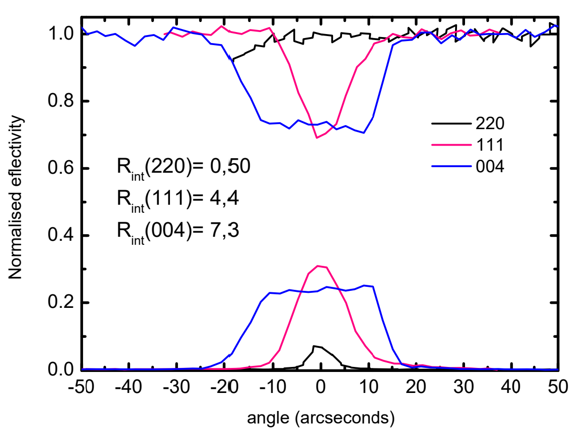

Fig. 2: reflectivity and transmissivity normalized profiles of 60m bent silicon crystal

GaAs samples

Reflectivity and transmissivity (220), (111) and (004) profiles of GaAs bent samples 2mm thick, 30 mm long with curvatures R= ∞ (ftat), 54m, 20m and 9 m have been measured for gamma rays energy E=184 keV. The section of gamma ray beam has been reduced by slits to ensure that both the incident and the diffracted beams cross the crystal. It is observed that:

- No relevant increase of the integrates intensity is observed for flat crystals or intermediate curvatures such as for the (111) diffraction.
- An increase of a factor of 8 of the normalized integrated intensities is observed when the curvature is increase from flat (R=∞) to the R=9m curved crystal.
- The (004) reflectivity profile is not that expected form the theory, reporting several peaks with varying intensity.

The data need to be carefully compared with the results of dynamical theory for uniformly bent perfect crystals. Preliminary evaluation confirms that silicon behaves as a bent perfect crystal. Silicon is confirmed as the best crystals for focussing hard x-rays up to an energy of 120 keV. Thank to the higher density and higher diffraction efficiency GaAs should be preferred for x- ay energies up to 200 KeV, with respect to Cu, Ag, Au or other heavy crystals thank to the lower x-ray extinction length [5]. Preliminary results show the presence of non uniform reflectivity profiles with the presence of several peaks in the reflectivity profile.

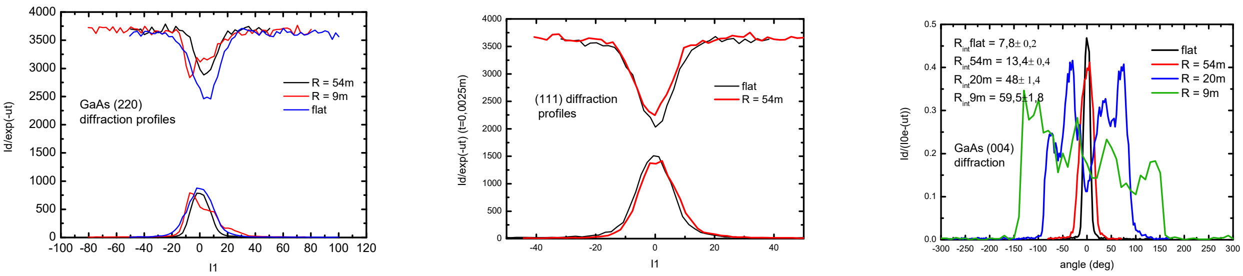

Fig. 3: reflectivity profiles of GaAs (220), (111) and (004) diffraction of crystals with different bending.

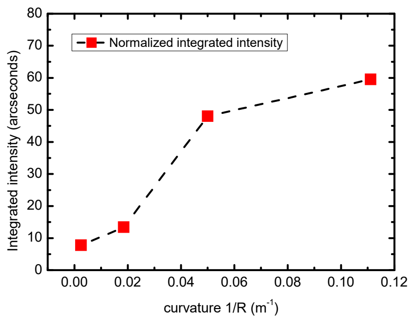

Fig.4: normalised integrated intensity of reflectivity (004) profiles of GaAS crystals with different curvatures.

This is an indication of a mosaic structure of the crystal, containing relatively big grains as the origin of the multiple peaks.

The comparison with theory will determine if this mosaic structure, always observed in GaAs crystals, is compatible with application in the field of gamma ray focussing. As an alternative materials bent perfect crystals of germanium can be considered.

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[4] C. Malgrange, Cryst. Res. Technol. 37, 654 (2002).
[5] E Bonnini, E Buffagni, A Zappettini, S Doyle, C Ferrari, J. of Appl. Cryst. 48 (3), 666-671 (2015)