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Abstract

Drawbacks of white beam topography with synchrotron radiation like intense fluorescence background, thermal strain and radiation damage can be avoided by filtering the beam with an oscillating perfect crystal monochromator. The advantage of the white beam technique namely the imaging of a sample of poor quality is maintained. The image contrast is even improved due the surpression of higher harmonics. Topographs of a *LiF* crystal demonstrate the feasibility of the method.

1 Introduction

It is well known that white beam topography is a simple and very useful X-ray imaging method especially when crystals of poor quality are studied. On the other hand, the sample is hit by the white spectrum of synchrotron radiation that has passed the beryllium or aluminium windows at the end of the beamline which often leads to experimental problems. Sample crystals containing heavy elements produce a strong fluorescence background. If the crystal has a low heat conductivity the heat load causes unwanted strains or certain crystals cannot withstand the radiation damage caused by the intense white beam /1/. Therefore in these cases a smaller spectral range than obtained by the simple low energy filtering by the beam pipe window is very desirable. In a first attempt we tried to use a totally reflecting mirror to cut off unwanted higher energies. But although the quality of the plane mirror was at the state of the art it produced a strong pattern of horizontal fringes and spoiled the topographs.

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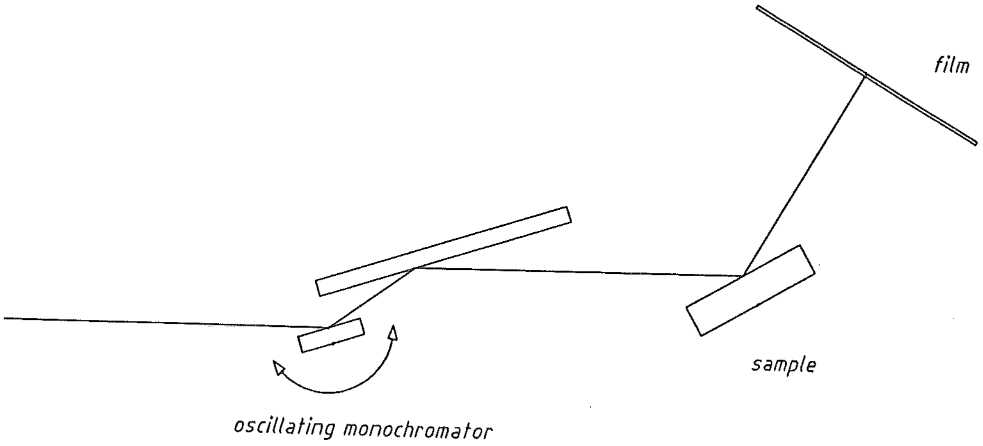


Figure 1: Schematic diagram of the experimental arrangement.

In this paper we propose as a possible solution a compromise between monochromatic and white beam topography by using an oscillating monolithic monochromator crystal.

2 Experimental Setup

The scheme of the experiment is shown in Fig. 1. A channel-cut monochromator reflects a small part of the white spectrum into a direction parallel to the incident white beam. The reflection angle is set to the energy needed for the selected reflection of the sample. The monochromator is oscillating about this angle thereby passing the full spectrum that is required for producing a "white beam" reflection by the sample.

For this purpose a channel-cut monochromator was prepared from a Si (111) crystal of $100mm$ diameter. This size was sufficient to allow for a $2mm$ high X-ray beam within the energy range from $2keV$ to $20keV$. One of the reflecting walls had a "weak link" to enable a detuning of the two reflections for the rejection of higher harmonics /2/. This was accomplished by a piezoelectric translator.

The crystal was mounted in a rigid frame which was held by two pivots made from torsional springs with negligible friction. The angular position of this frame with respect to the incident beam defines the transmitted energy. It is controlled by a loudspeaker coil where the DC part of the input to the coil determines the central energy and the AC component

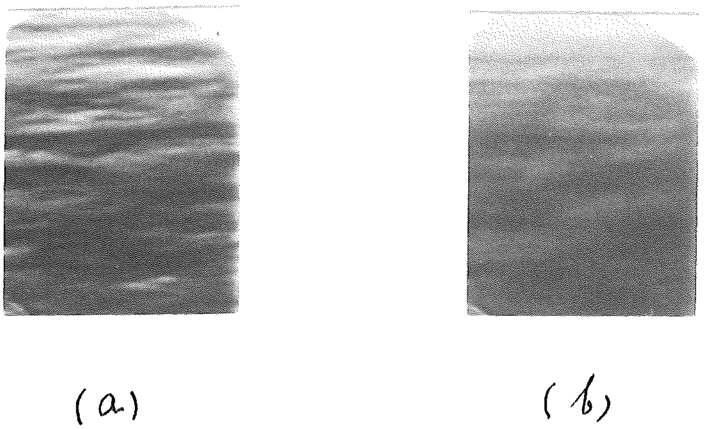


Figure 2: Structure of the monochromatic beam (a) without vibration (b) with vibration

the energy range. The mechanical part of the monochromator was already developed for a fast switching monochromator for angiography /3/.

As a sample a *LiF* crystal with a (100) cleaved surface was used. The (100) reflection is forbidden and the (200) reflection is the lowest order for the reflection of X-rays. It was set to an angle $\Theta = 30^o$ with respect to the incoming beam in Bragg geometry. This corresponds to a reflected wavelength of $\lambda = 201pm$ and a Bragg angle for Si (111) of 18.7^o. The monochromator oscillated with a frequency of $1Hz$ whereas the exposure of the topographs took several seconds.

From Bragg's law it follows

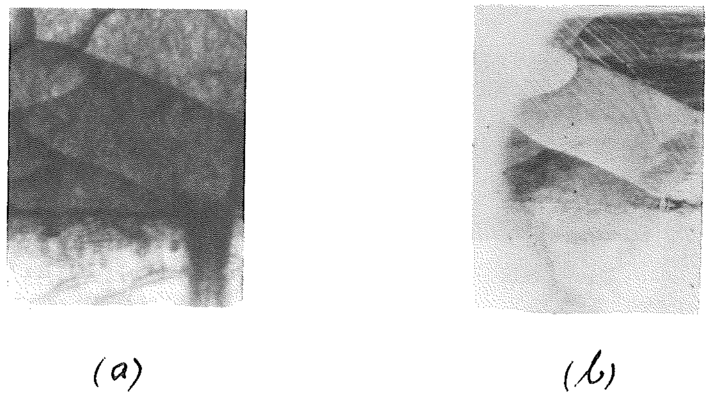
$$\frac{\Delta\lambda}{\lambda} = \cot\Theta_{Si}\,\Delta\Theta_{Si} = \cot\Theta_{LiF}\,\Delta\Theta_{LiF}. \qquad (1)$$

In our case we have

$$\Delta\Theta_{Si} = 0.58\Delta\Theta_{LiF} \qquad (2)$$

The monochromator angle was modulated by the loudspeaker coil in such a way that $\Delta\Theta_{Si} = 0.3^o$. Hence the Bragg angle change at the sample was $\Delta\Theta_{LiF} = 0.5^o$.

In Fig. 2(a) the beam directly after the monochromator is shown for a fixed Bragg angle. Obviously the crystal quality was not good enough for a uniform illumination of the sample. However, the principle of our approach could be demonstrated clearly. After switching on the vibration some of the



(a) (b)

Figure 3: (a) white beam topograph, (b) oscillating monochromator topograph

structures are blurred because different parts of the two reflecting surfaces of the monochromator contribute to the same spot in the image (Fig 2(b)). In our special geometry the beam moves by $0.5mm$ along the surface but by $30\mu m$ in its exit position, only. The sample cannot accept all of the beam. Hence the effective illumination of the sample lies somewhere in between.

Fig. 3 presents a comparison between a white beam topograph and a topograph of the same crystal region taken with the oscillating monochromator. Except at the lower part of the picture all blocks of the crystal participate in the reflection. In the wide bandwidth topograph more details are seen than in the white beam topograph. For instance, the cleavage steps (white lines) at the surface are only seen in Fig. 3(b). The invisibility in the white beam topograph is caused by the presence of higher harmonics. During our experiments the higher harmonic rejection was not used but through the dispersive setting between monochromator and sample the total reflectivity of the system is strongly in favour of the lowest order reflection. In addition for the LiF (400) reflection the corresponding Si (222) reflection is forbidden. Another feature of the wide bandwidth topography is the strong surpression of flares caused by regions of large strain. An example is seen in the lower right corner of the image.

The horizontal structures seen in Fig. 3(b) are caused by the poor quality of the monochromator.

The topographs of Fig. 4 were taken with the monochromator at rest

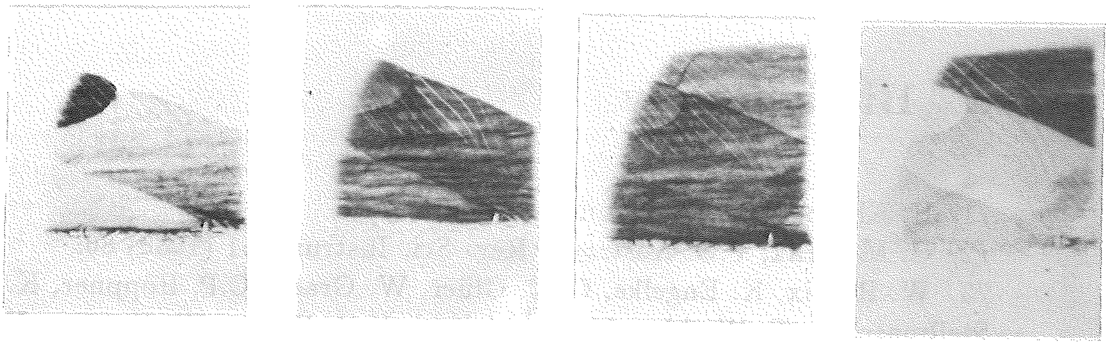


Figure 4: Monochromatic beam topographs taken at different angular positions. Compare to Fig. 3

but at different angular positions. Between each topograph the sample was rotated by $\Delta\Theta = 0.004^o$. The mosaicity of the sample is clearly visible.

3 Discussion

We have demonstrated that by the use of a perfect crystal monochromator oscillating about a certain energy quasi-”white beam topographs” can be obtained without the drawbacks of the white beam. These wide bandwidth topographs can even be more instructive as many more details are visible due to a strong surpression of higher harmonics and the absence of flares caused by regions of large strain.

The use of this technique certainly is more complicated than the white beam topography technique. However, in many cases the latter technique is not applicable if the sample is immediately destroyed by the white beam. On the other hand, monochromatic topography is sometimes too sensitive to sample perfection to give a useful topograph.

4 Acknowledgement

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