ESRF

Experiment title:
Imaging of the energy flow in the three-beam case of interference

Experiment number: HS 722

Beamline: ID 22

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Report:

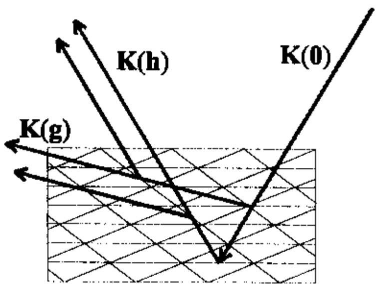

Fig. 1: three-beam case in the direct space (crystal)

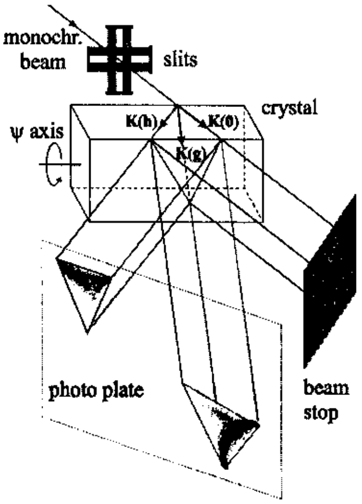

Fig. 2: experimental setup

The purpose of this experiment was the systematical investigation of the energy flow in the three-beam case of x-ray diffraction. In this case, two Bragg reflections **h** and **g** are simultaneously excited and three strong wave fields **K(0)**, **K(h)**, **K(g)** exist inside the crystal. The intensity diffracted into the direction of **K(h)** can then be depicted as an interference between the wave diffracted at the lattice planes of **h** (direct wave) and a wave which is diffracted at **g** and afterwards at **h-g** (Umweg wave). /3/ For the systematical investigation of such a case, a Ψ-rotation (a rotation around the primary diffraction vector **h**) was used. Thus, the distance of the reciprocal lattice point G to the Ewald sphere can be changed independently of H.

In the two-beam case the energy flow is limited inside the Borrmann triangle formed by the direction of **K(0)** and **K(h)**. For three strong waves in a plane-parallel crystal plate the corresponding figure is a pyramid. Its top is given by the incidence point of radiation on the crystal and a triangular base on the exit surface. The sides of the pyramid are limited by **K(0)**, **K(h)** and **K(g)**, respectively. All directions inside this pyramid which start from the top are possible directions of energy flow. For the imaging of the intensity distribution in the triangular basis we used a kind of pinhole topography with a cross section of the incidence beam reduced by slits in both dimensions to a 'point' of 30x30 μm² (see Fig. 2).

With this experimental setup we could take several systematical series of topographs in different three-beam interferences. The ψ - position of the crystal was the control parameter. Because of the precise and fast six-circle diffractometer at ID22 we could reach a better relation between the topograph and the ψ - position compared with our first attempt at the end of HS-401. /1/
The results of our experiment show that the topographs image the dispersion surface. This is confirmed by the investigation of a three-beam case with a forbidden coupling reflection **h-g**. Although there is no direct energy transfer between the **h** and **g** reflection we found an intensity spread over the complete triangular basis of the pyramid in the exact three-beam position (see Fig. 3 left). The contrast change in our topographic series in dependence on ψ describes clearly the intensity transfer between the reflections **h** and **g** when G passes the Ewald sphere. A special characteristic feature in all of our pinhole topographs is the visibility of the inflection point on the dispersion surface (see Fig. 3 right). As an another important point in our results we could observe a systematics in the relation between the shape of the diffraction pattern and the triplett-phase of the reflections.
In a last step before the end of our beam time we had the opportunity to change the experimental setup into a 90° reflection position. In spite of the polarisation obliteration we observed intensity.

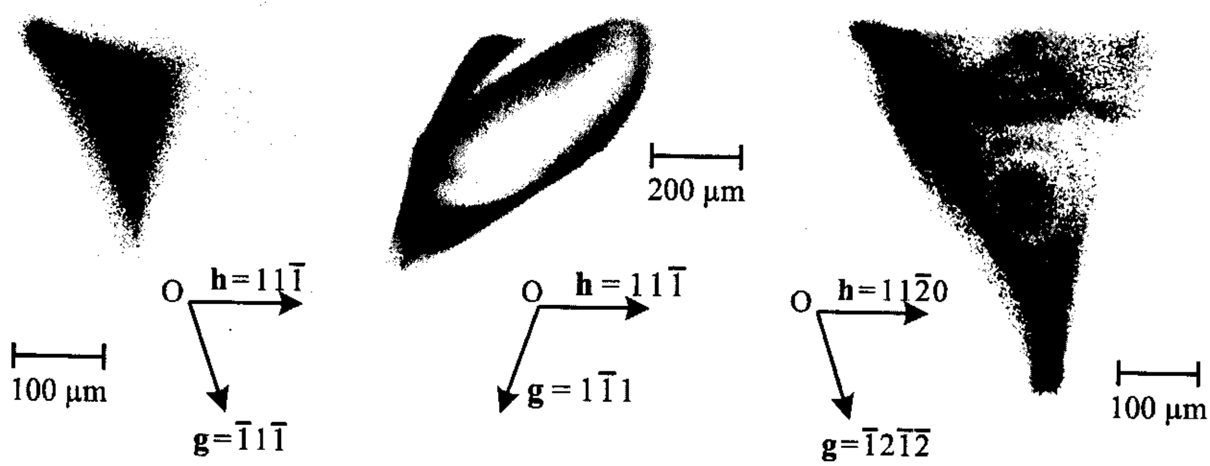

Fig. 3: Examples for pinhole topographs which show the change in the energy distribution for different three-beam cases. The excited three-beam cases are put a inscriptions in the figures. Each of the pictures shows the respective **g** reflection.

left: A 1 mm thick silicon crystal plate with a (111) surface is shown. In this case the structure factor of the coupling reflection **h-g** = (200) is zero.

center: This picture presents a 2 mm thick silicon crystal plate with a (111) surface taken on nuclear plates with a strong coupling reflection **h-g**=$(02\bar{2})$. The triplett phase in the centrosymmetric silicon is zero.

right: A 1 mm thick quartz crystal with a $(\bar{1}100)$ surface and a incident beam with the wavelength of $\lambda \approx 0.749$Å was used. Here the triplett phase has a value of about 30°.

references

/1/ F. Heyroth, H.-R. Höche and C. Eisenschmidt „Imaging of the energy flow in the three-beam case of X-ray diffraction" J. Phys. D: Appl. Phys. 32 (1999), A133 - A138

/2/ F. Heyroth, H.-R. Höche and C. Eisenschmidt „Contrast in X-ray section topographs of perfect silicon crystals using the Laue-Laue three-beam case of diffraction" J. Appl. Cryst. 32 (1999), 489 - 496

/3/ Weckert, E. & Hümmer, K. (1997) „Multiple-Beam X-ray Diffraction for Physical Determination of Reflection Phases and its Applications" Acta Cryst. **A53**, 108-143.