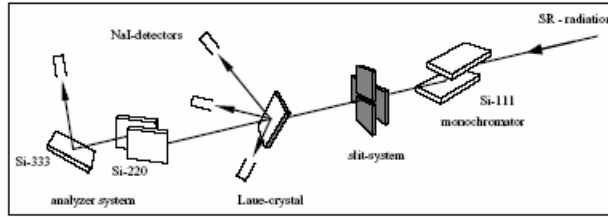


X-ray collimation by multiple beam diffraction

Reinhard Pahl
Humboldt Fellow, CHESS

A unique method for the collimation of X-rays has been tested at CHESS. Employing multiple beam diffraction in thick Laue-crystals, a very narrow angular divergence in the forward diffracted beam has been obtained.

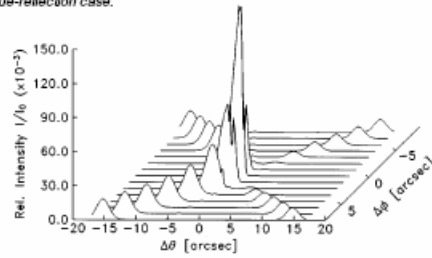
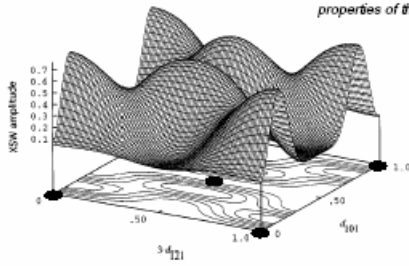
Simultaneous reflections from different sets of reciprocal lattice planes are a very well known diffraction process.^{1,2} In Bragg geometry, this is commonly used for solving the so-called phase problem. In Laue geometry, the multi-beam reflection in some cases yields an enhanced trans-



(Above) Experimental setup at CHESS beamline D1.

(Below, left) Calculated amplitude for the x-ray standing wavefield in the (111)-plane of the Si lattice at the exact setting of the six-beam Laue diffraction case. Note that the wavefield has nodes at the locations of the Si atoms (black ovals), so that the attenuation is greatly diminished.

(Below, right) Calculated intensity distribution of the 0-beam for the Si-044, 220, 202, 242, 224 reflection. The narrow angular spread in both directions $\Delta\theta$ and $\Delta\phi$ shows the excellent collimation properties of this Laue-reflection case.



mitted or reflected intensity compared to the normal two-beam diffraction. This enhanced Borrmann effect is caused by a minimized absorption when interference of the wavefields inside the crystal results in a reduced amplitude in the vicinity of the lattice-atoms as shown in the figure. As the enhancement is limited to a narrow angular range the transmitted beam shows very good collimation in any direction normal to the propagation vector.

A computational analysis of multi-beam diffraction in Laue and Bragg geometries based on the dynamical theory of X-rays was carried out to study these effects for several crystal orientations. Significant effects were found for a germanium four-beam and a silicon six-beam Laue-reflection. In both cases the forward diffracted beam is expected to have a significantly higher transmission than in the two-beam cases combined with a very narrow angular width. The absorption coefficients at 8 keV have been calculated to be $\mu_{\text{Ge}} = 21 \text{ cm}^{-1}$ and $\mu_{\text{Si}} = 3.9 \text{ cm}^{-1}$ compared to $\mu_{\text{Ge}(40)} = 32.5 \text{ cm}^{-1}$ and $\mu_{\text{Si}(044)} = 21.5 \text{ cm}^{-1}$ for the corresponding 2-beam values of the main reflections respectively.

The experiments were performed at the CHESS beamline D1 using ger-

manium and silicon Laue-crystals with monochromatic X-rays at 8 keV. The angular intensity distribution $I(\theta, \phi)$ of the 0-beam, i.e. the forward diffracted beam, was analyzed by a high resolution double-crystal system. For both multi-beam cases the observed divergence of the anomalous transmission is less than 1.6×10^8 rad. In particular, the Si-044, 220, 202, 242, 224 diffraction resulted in point-like collimation: the FWHM was measured to be appr. 9 mrad parallel and vertical to the main diffraction plane (see photo). The experimental data are in good agreement with theory.

The point-like collimation is of particular interest in small-angle scattering at high scattering vectors q . Because the enhanced Borrmann effect reduces the absorption coefficient drastically, the transmitted beam still has sufficient intensity. A crystal-camera featuring two consecutive multi-beam diffractions has been designed and is currently under development.³ Besides its very high angular resolution, this design is also characterized by an excellent monochromaticity. With these characteristic, the necessity of

desmeared recorded data can be avoided.

- [1] Borrmann, G. and Hartwig, W., *Z. Krist.* 121, 401-409 (1966).
- [2] Colella, R., *Acta Cryst.* A30, 413-423 (1974).
- [3] Pahl, R., Presented at the 8th Nat. Conf. Synchr. Rad. Instrum., August 23-27 (1993).

(Below) A schematic of the 4-beam diffraction process. All diffraction vectors that intersect the Ewald Sphere will be simultaneously excited.

(Right) A film record of the 6-beam Laue diffraction from a Si(111) crystal. The indices of the corresponding diffraction spots are shown.

