ESRF	**Experiment title:** High resolution topography on ultrasonically excited crystals	**Experiment number:** HS-65
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Report:

The response of Bragg diffracted X-ray or neutron beams to longitudinal ultrasonic excitations in perfect silicon crystals has been investigated by a series of experiments [1][2][3][4]. In particular high energy X-rays have been used to investigate the broadening and the form of the rocking curves, the intensity gains, a reciprocal space ma ping and recently phase resolved experiments with a 20 ns time resolution. Besides the major physical and technical aspects, like confirmations of the diffraction theory for vibrating crystals, the measurement of atomic amplitude distributions, the potential use of vibrating crystals as X-ray optical elements and fast beam choppers in the MHz range, we learned from these experiments a lot about pure mode excitations of silicon crystals by bonded $LiNbO_3$ transducers.

The present experiment was intended to look at the development of the Borrman fan as a function of the ultrasound excitation. In a perfect crystal the intensity distribution across the fan is given by the dynamical theory of diffraction and shows a very typical pattern of fringes stemming from the interference of two wave fields belonging to two branches of the dispersion surface inside the crystal. This interference is very sensitive to lattice distortions and is one of the first diffraction effects which changes with the application of an internal strain.

Topographies were taken in the white beam section setup. A horizontally narrow, typically 20 µm wide white beam impinges onto a 5 mm thick FZ silicon crystal with a 111 surface normal and excites a Laue pattern in transmission. The examined Laue spot is brought into the horizontal scattering plane. The energy of the reflected beam is given by the scattering vector of the observed reflection and therefore known from the scattering angle. Reflections in an energy range from 30 keV to 150 keV were investigated. A photographic film perpendicular to the reflected beam axis serves as a two dimensional detector.

Typical topographies taken at the -351 reflection at 58 keV are shown in the figure (1). In this geometry the fan widens the beam by 1.17 mm. Figure (la) shows the intensity distribution in the undisturbed crystal. Large fringes in the center become rapidly narrower towards the borders of the Borrman fan. Note that the maximum intensity is scattered to the margins. The measured intensity distribution agrees quantitatively with the expected values from the dynamical scattering theory. Horizontal intensity streaks arise from dust particles on the slits and the diagonal line in the top right corner is a shadow from the transducer connector.

As soon as one applies an ultrasonic wave with a tiny amplitude the fringes blur to a uniform gray and with increasing, but still weak dynamic strain most of the scattered intensity is diffracted to the center of the fan in figure (lb). This is known as the channeling effect by ultrasound, which is caused by adiabatic refraction from localized lattice gradients of the beams inside the crystal [5][6]. Here the rays oscillate from forward diffracted to Bragg diffracted directions in maximal gradient positions defined by the period of the sound wave.

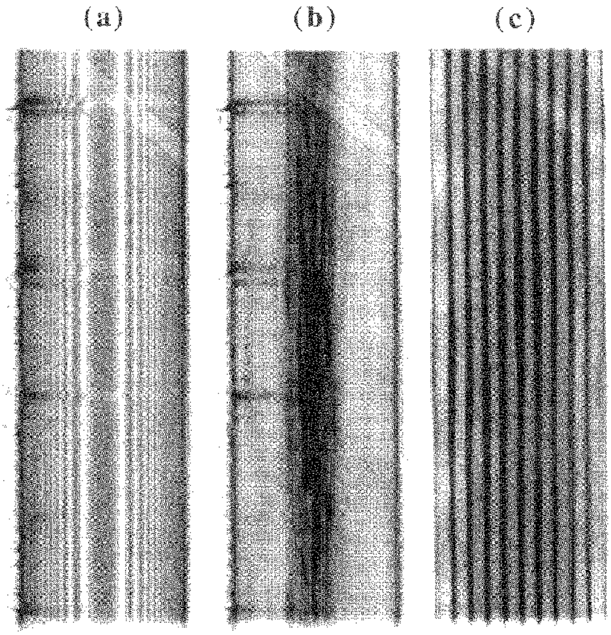

Figure 1: Borrman fans at the Si -351 reflection for the unexcited ideal crystal (a), weak excitation (b) and strong ultrasonic amplitudes (c). The gray levels range from zero intensity, white to a maximum value, black.

A blurred fine structure can be seen in the topography (1 b). With increasing sound amplitude this fine structure develops into a very regular spaced underlying stripe pattern, the main intensity still diffracted in the central region. Finally, at the highest excitation the intensity is uniformly distributed among the stripes as shown in figure **(1c)**. At the resonance frequency of 5.038 MHz roughly 2.5 wavelengths fit into the silicon crystal. Thus the sample volume is divided into 5 regions separated by the wave nodes. The stripe pattern shows 9 dark stripes splitting 10 light regions. This pattern did neither depend on the X-ray energy nor on the investigated reflection, but only on the resonance frequency. Actually the mechanism of the formation of the stripe pattern is still discussed. Angular dispersive and time resolved measurements of the individual stripes could clarify the situation relating to the earlier experiment HS-63.

References:

[1] K-D. Liss, A. Magerl, A. Remhof, R Hock, “Ultrasound induced gradient crystals observed by high energy X-rays” Acta Crystallographica, (1997). A(53): p. 181.186.

[2] K-D. Liss, A. Magerl, R Hock, A. Remhof, ‘The evolution of an ultrasonic strain field followed by diffraction with a 20 ns time resolution”, in “ESRF highlights”. (1996), p. 46-47.

[3] A. Remhof, K-D. Liss, A. Magerl, “Neutron diffraction from sound excited crystals” Nuclear Instruments and Methods, (1997). (A): in press.

[4] ESRF experimental reports for HC-290 (1996), HC-476 (1996) and HS-63 (1997).

[5] R. G. Gabrielyan, A. R. Mkrtchyan, H. A. Aslanyan, K V. Kotandyan, “On the theory of X-ray diffraction in oscillating piezocrystals” Physica Stati Solidi, (1985). A(92): p. 361-368.

[6] Y. Zheng, A. Zarka, B. Capelle, J. Detaint, J. Schwartzel, “Pendellosung fringes in stroboscopic X-ray section topography of weakly excited quartz resonators” Acta Crystallographica, (1989). A(45): p. 275.285.