ESRF

Experiment title:
Diffraction in sound-excited crystals

Experiment number:
HS-63

Beamline:
ID15A

Date of experiment:
from: 6. Aug. 96 15:00 to: 15. Aug. 96 7:00

Date of report:
26. Feb. 1996

Shifts:
18

Local contact(s):
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Received at ESRF:
04 MAR 1997

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Report:

X ray diffraction on perfect single crystals subjected to ultrasound has been studied previously in both a time integrated and a time resolved experiment, HC-290 (1995) [1] and HC-476 (1996) [2], respectively. In the former an investigation of the broadening of the rocking curve, a two dimensional reciprocal space mapping and the intensity gain reveal the atomic amplitudes. The latter experiment was a first attempt for a time resolved study within a 20 ns time resolution. It has been found that it is not evident to excite the silicon crystal by a pure standing wave. Instead, the rocking angle - time spectra reveal in most cases higher harmonics and a superposition of different eigenstates. A pure excitation, however, can be found by a careful search in the frequency domain away from the transducer resonance. Although the transducer amplitude is low the resonance condition of the silicon gives nevertheless highest atomic amplitudes. Meanwhile the amplitude

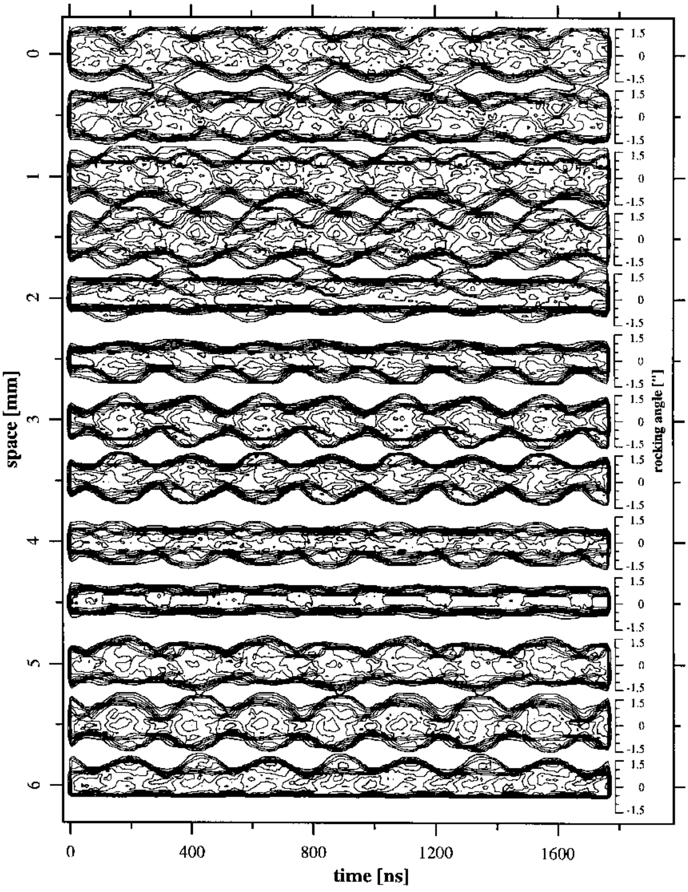

Figure I: Space time rocking angle distribution of a sound excited Si 555 *reflection*. The top scans are closer to the $LiNbO_3$ transducer where the wave field is more disturbed.

distributions of the pure excitation have been modeled revealing an inverse circle function for a snapshot in time and an elliptic integral of type K in the time average.

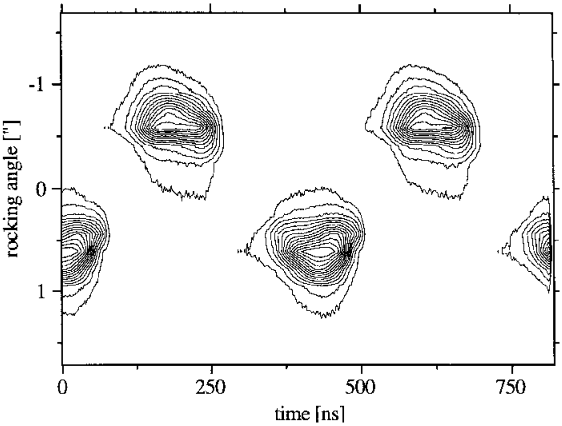

Figure 2: A rocking angle time scan at the border of the Borrman fan. Intensity hops from one angular position to another.

The present experiment, an extension of HC-476, was aimed to study the ultrasonic standing wave characteristics in space and time. A 11 mm thick silicon crystal has been prepared in a geometry allowing to have both the sound propagation vectors and the scattering vector parallel to the 111 direction. In a perpendicular direction the crystal had a thickness of 10 mm. At 500 keV the scattering angle is 2.26° which gives a beam broadening through this thickness of 0.4 mm. Entrance and exit slits, each about 200 µm wide were used to limit the scattering volume and thus to probe for the local sound amplitudes as a function of space. An overview scan is shown in figure (1) which is assembled from 13 rocking angle time scans. A broad rocking curve at given times reflects a maximum sound amplitude, while a narrow one relates to the strain free zero transition. Neighboring scans are taken with a 0.5 mm translation of the sample along the sound vector. The ultrasound frequency is 2.2399 MHz and the corresponding acoustic wavelength is λ = 4.17 mm. Nodes in space are expected with a periodicity of $\lambda/2$ and indeed they are observed by the lower amplitudes around 2.4 mm and 5.5 mm. The ordinate position 0 is roughly 1 mm below the surface carrying the transducer, and positive space coordinates are further away from the exciting surface. Note, that no nice wave pattern is formed up to the ordinate 2 mm, neither in space nor in time: In particular no well defined phases of the strain amplitude can be identified in the ordinate range of say up to 2 mm. In contrast, for higher values a clean wave pattern with distinguished areas of maximum amplitudes and for nodes is seen in both space and time. Another indication for an evolution of a highly disturbed wave near the transducer towards a plane wave in the volume is the contribution of harmonics? reveal t from the asymmetry of the rocking angle - time scans. Although the wave becomes locally plane the individual time scans show an average over compressed and expanded crystal regions. This may be a hint that the crystal macroscopically shows sound figures as we observed them in a neutron topography [3].

Furthermore a 10 mm thick Si 111 crystal extending 30.30 mm2 towards the other dimensions has been studied in a similar setup. Here the beam travels through its whole length and the Borrman fan opens to 2.54 mm using the 333 reflection at 140 keV. Instead of the sample translation the exit slits were scanned along the cross section of the reflected beam. Figure (2) shows a contour plot of a rocking angle - time scan at 2.2510 MHz at the border of the Borrman fan. Clearly intensity hops by about 1.2" from one angular position towards another related to a compressed or expanded lattice, resppectively. The intensity in between drops to the background level the beam going different paths through the fan depending on the momentary sound amplitude. These states mix when scanning further through the Borrman fan and multiple scattering processes have to be considered. This relates to the experiment HS-65 where we studied in a white beam section topography the development of the intensity pattern in the Borrman fan as a function of the excitation amplitude.

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, "Neutronen- und Rontgenstreuung an Idealkristallen im Ultraschallfeld". Diplomarbeit, Ruhr Universitat Bochum, (Februar 1996)