Diffuse Scattering of X-Rays from Piezoelectrically Oscillating Quartz

G. E. M. JAUNCEY AND W. A. BRUCE
Wayman Crow Hall of Physics, Washington University, St. Louis, Missouri
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Bertsch's investigation of the effect of the different modes and types of piezoelectric oscillations of quartz on the intensity of Laue spots and Bragg reflections necessitates a similar investigation of the effect of the different modes and types of vibration on diffuse scattering. Extending the result found by Jauncey and Deming we find that in all cases the piezoelectric oscillations have no effect on the intensity of the diffuse scattering. Since the diffuse scattering cannot be affected by secondary extinction, it is concluded that the change of intensity of the Laue spots is due to a decrease of secondary extinction in the body of the crystal.

INTRODUCTION

FOX and Carr[1] were the first to show that the intensity of the Laue spots from a thin quartz plate is increased when the plate is set into piezoelectric oscillation. The Laue spots produced by a nonoscillating quartz plate are double due to very little reflection from the interior of the crystal where the extinction coefficient is high. When the crystal is oscillating the space between the two parts of each Laue spot becomes black indicating that the interior of the crystal loses its high extinction coefficient. Further work by Barrett and Howe[2] shows that piezoelectric oscillations introduce a fine structure into the Laue spots. The effects of etching found by Colby and Harris[3] indicate that the increased intensity of the Laue spots is not due to increased reflection from the layers near the two surfaces of the crystal. This together with the fine structure found by Barrett and Howe supports the view that the increased intensity produced by the oscillations is due to increased reflection from the interior of the crystal. Barrett and Howe ascribe the increased reflection from the interior of the crystal to a reduction of primary extinction while Colby and Harris ascribe it to a reduction of secondary extinction. Bertsch[4] has found that the intensity of the Laue spots and Bragg reflections is variously affected by the different modes and types of vibrations. From his results it is concluded that increased reflection occurs from those parts of the crystal which are at a node of motion or antinode of stress.

Diffuse scattering of x-rays as measured by the transmission method[5] is a volume and not a surface phenomenon and so it seemed worth while to examine the effect of piezoelectric oscillations on the intensity of diffuse scattering. This was first done by Jauncey and Deming,[6] who found that the oscillations have no effect. However, Jauncey and Deming only used a Y cut crystal and one mode of oscillation. In view of the work of Bertsch it is necessary to study the effect of different types and modes of vibration upon the intensity of diffuse scattering.

EXPERIMENTAL METHOD

We did most of the work with a $15\times15\times0.823$ mm^3 X cut crystal and a $15\times15\times1.05$ mm^3 Y cut crystal. Both crystals were unetched and unpolished. A crystal under test was mounted in a holder consisting of two brass plates each with a 5 mm hole. Between each brass plate and the crystal was placed a 0.15 mm sheet of aluminum which covered the whole area of the crystal plate. The x-ray beam passed through the crystal and the two thicknesses of aluminum. The aluminum was kept pressed against the crystal with light brass springs which were adjusted so that the crystal was free to oscillate. Electric oscillations were produced by coupling to the tank circuit of an oscillator embodying one WE212D tube. This

[1] G. W. Fox and P. H. Carr, Phys. Rev. **37**, 1622 (1931).
[2] C. S. Barrett and C. E. Howe, Phys. Rev. **39**, 889 (1932).
[3] M. Y. Colby and S. Harris, Phys. Rev. **43**, 562 (1933).
[4] C. V. Bertsch, Phys. Rev. **49**, 128 (1936). For further information concerning the modes and types of oscillations of quartz, reference is made to H. Osterberg, Phys. Rev. **43**, 819 (1933), and R. S. I. **5**, 183 (1933).
[5] G. E. M. Jauncey and W. D. Claus, Phys. Rev. **46**, 941 (1934).
[6] G. E. M. Jauncey and J. H. Deming, Phys. Rev. **48**, 462 (1935).

delivered a peak voltage of 1500 v. Resonance was checked in two ways—first, by an electric light bulb in series with the crystal and pick-up coil and, second, by the increased intensity of the Laue spot as measured by the ionization chamber and electrometer. The usual diffuse scattering transmission method was used in these experiments.[5] A collimated beam of x-rays from a tungsten target tube operating at a peak voltage of 37 kv was allowed to fall upon the quartz plate. The ionization chamber was set up at an angle ϕ and the normal to the crystal plate at an angle θ with respect to the direction of the primary beam. In an X or Y cut crystal the plate is parallel to the optic axis. We have found it convenient to introduce α, which is the angle between the optic axis and the plane of scattering.

Results

A typical result is shown in Fig. 1, where it is seen that although the oscillations cause an increase in the intensity of the Laue spot they have no effect on the diffuse scattering. In order to show more certainly the zero effect of the vibrations a typical set of observations is shown in Table I. The average deflection time for the non-oscillating crystal was 62.88 sec., while that for the oscillating crystal was 62.87 sec. The average deflection time for the leak was 105 sec. We may

TABLE I. *Y cut crystal*, $\phi=30°$, $\alpha=0°$.

θ	Deflection Time			
	Not Oscillating sec.		Oscillating sec.	
10°	63.8	61.8	63.6	63.7
	66.0	65.2	64.0	64.0
10.5°	66.0	60.2	64.9	63.5
	63.9	63.2	63.5	61.6
11°	63.0	64.0	63.0	62.4
	63.5	63.0	63.7	59.4
	Laue Spot			
16.0	63.3	59.6	62.4	61.6
	61.0	61.4	64.2	59.9
16.5	62.0	65.4	60.0	63.5
	62.7	60.2	64.2	61.6
17.0	62.0	63.5	63.4	61.7
	65.0	59.4	63.7	65.4

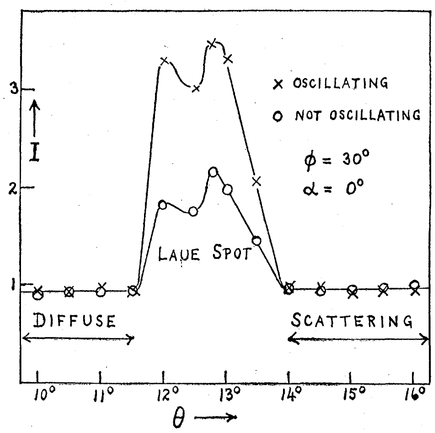

FIG. 1. Diffuse scattering from a Y cut quartz crystal.

conclude therefore that Table I confirms Jauncey and Deming's conclusion that the oscillations produce no change in the diffuse scattering. Similar results for various values of α and for the X cut crystal were obtained. Thickness vibrations up to the second harmonic and width vibrations to the third harmonic also had no effect on the diffuse scattering. We therefore conclude that the piezoelectric oscillations in no case affect the diffuse scattering from quartz.

Discussion

Since the effect of piezoelectric oscillations on the intensity of Laue spots is due to a reduction of extinction and since these oscillations have no effect on diffuse scattering we conclude that extinction has no effect on diffuse scattering. As between primary and secondary extinction we can see no reason why secondary extinction should affect diffuse scattering. It is possible that primary extinction would affect diffuse scattering. It is therefore our opinion that it is a reduction of secondary extinction which gives rise to the increase of intensity of the Laue spots when the crystal oscillates.

Fox and Frederick[7] have recently discussed the division of the total x-ray energy which enters the quartz plate. Since there is no reason to expect a change of the photoelectric absorption due to oscillations and since there is no change in the diffuse scattering, they feel that the only

[7] G. W. Fox and J. R. Frederick, Phys. Rev. **53**, 135 (1938).

place for the necessary complementary change is in the transmitted beam. However, both they and Jauncey and Jacques[8] were unable to find any noticeable change in the transmitted beam. We suggest that the conservation of energy merely requires that dL, the increase in intensity of all the Laue spots, equal $-dT$, the decrease of the intensity of the transmitted beam. The conservation of energy does not require that $dL/L = -dT/T$ since $L \neq T$. The transmitted intensity, T, is of the order of $1000L$ as is shown by the relative exposure times for producing equal photographic blackness in the Laue spots and the transmitted beam. Although the ratio $(L+dL)/L$ is measurably different from unity, the ratio $(T-dT)/T$ is not.

[8] G. E. M. Jauncey and A. T. Jacques, Phys. Rev. **50**, 672 (1936).

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The Yield of Alpha-Particles from Beryllium Bombarded by Protons

GRAHAM T. HATCH
University of Chicago, Chicago, Illinois

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Experiments to determine the excitation function of the reaction $_4Be^9(p, \alpha)_3Li^6$ for proton energies up to 400 kv are reported. It is shown that the yield is very large, *ca.* 4×10^{-6} alpha-particle per proton at 400 kv, but the derived thin target curve shows a marked flattening from the exponential form observed at lower voltages. The cross section is nearly constant above 300 kv, and has a value of about 2.3×10^{-25} cm^2.

INTRODUCTION

THE reactions

$$Be^9+H^1\rightarrow Li^6+He^4 \quad (1)$$

$$\rightarrow Be^8+H^2 \quad (2)$$

were first studied by Oliphant, Kempton, and Rutherford[1] who used electric counting methods. They were particularly interested in determining the end products and establishing the reactions. Allen[2] studied the yield of the two reactions at voltages below 125 kv and determined the ratio of the two yields. Williams, Haxby and Shepherd[3] continued the yield curve for the two reactions to 238 kv. Because of the very high efficiency of the process, it has been thought worth while to continue the study of the yield to still higher voltages. To this end, reaction (1) was particularly studied, while the ratio of the yields of reactions (1) and (2) was determined whenever conditions of measurement were sufficiently favorable.

[1] Oliphant, Kempton, and Rutherford, Proc. Roy. Soc. **150**, 241 (1935).
[2] J. S. Allen, Phys. Rev. **51**, 182 (1937).
[3] Williams, Haxby and Shepherd, Phys. Rev. **52**, 1031 (1937).

APPARATUS

Proton source

The proton source was a low voltage arc of the probeless type, similar to that described by Lamar, Samson, and Compton.[4] Ions from this were subjected to an initial small acceleration to collimate the beam, and introduced into the main acceleration tube. The acceleration took place in a horizontal tube in four gaps, across which the potential was distributed by means of variable corona points. The tube was evacuated by two 6″ oil diffusion pumps in parallel working into a two stage 3″ oil diffusion pump.

The accelerating voltage was supplied by a voltage quadrupling circuit of the Cockcroft and Walton type. This was operated from a 60-cycle transformer which could give a 165 kv wave above ground. Because of insulation difficulties this transformer was operated with the case and center of the primary connected to the center of the secondary. It was mounted on an insulating stand, and the primary fed through a 1 : 1 high voltage insulation transformer.

[4] Lamar, Samson and Compton, Phys. Rev. **48**. 886 (1935).