Investigation of the diffraction of Mössbauer radiation by the weakly ferromagnetic single crystal $^{57}FeBO_3$

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Investigations were made of the diffraction of Mössbauer radiation by a synthetically grown weakly ferromagnetic single crystal of iron borate enriched with ^{57}Fe to 85%. The dependence of the intensity of the diffracted resonant radiation on the direction of the magnetic field at the scattering nuclei was obtained experimentally for the first time.

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We investigated experimentally, for the first time, the dependence of the intensity of diffracted resonant radiation on the direction of magnetic field at the scattering iron nuclei in the weakly ferromagnetic single crystal $^{57}FeBO_3$.

Diffraction of Mössbauer radiation has uncovered new possibilities of studying the nature of the interaction of resonant radiation with matter and gives grounds for hoping that this method is effective in the investigation of the physical properties of crystals. In this study we have investigated experimentally the dependence of the nuclear scattering amplitude on the orientation of the magnetic field at the scattering nuclei. In the kinematic approximation, the differential cross section for the scattering is determined for the magnetic maxima, in the case of an antiferromagnet, in the symmetric Bragg case, by the expression[1]:

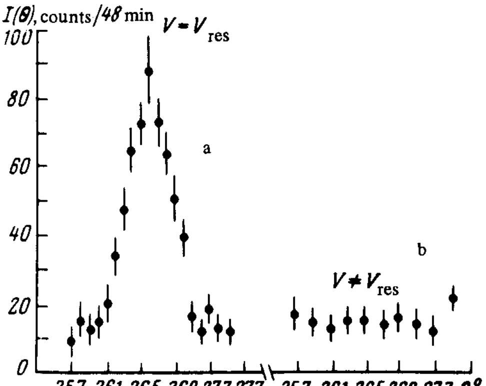

FIG. 1. Angular dependence of the diffracted radiation for the reflection (555) of the single crystal $^{57}FeBO_3$: a) $V=V_{res}$, b) $V-V_{res} > 50\ \Gamma_{nat}$.

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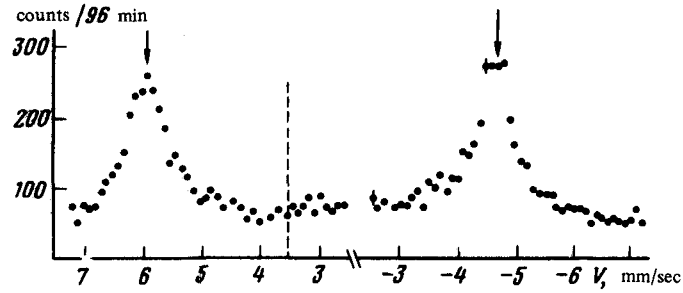

FIG. 2. Energy dependence of the diffracted radiation for the (555) reflection of single-crystal $^{57}FeBO_3$.

$$\sigma_\gamma \sim \sin^2\theta_B + 2\cos 2\theta_B \cos^2\theta_B \cos^2\phi, \tag{1}$$

where θ_B is the Bragg angle, and ϕ is the angle between the scattering plane and the antiferromagnetic axis of the crystal.

The object chosen for the investigation was a single crystal of iron borate ($^{57}FeBO_3$) synthesized by us; this substance has a number of properties of applied interest and is extensively used in scientific experiments.[2,3] The iron borate was crystallized by cooling the melted solution of the reagents in a platinum crucible from 1150 to 750°C. The initial reagents were Fe_2O_3 (enriched with ^{57}Fe to 85%), B_2O_3, PbO and PbF_2. The crystals were obtained in the form of well shaped hexagonal plates up to 4 mm in diameter and up to 0.1 mm thick. The plane emerging to the surface was (111).

The investigations were made with a Mössbauer diffractometer similar to that used in[4]. The diffracted radiation was registered with an Si(Li) detection block having a resolution ~700 eV for the 14.4 keV line and an intrinsic background of ~1 count in three hours. The divergence of the beam from the ^{57}Co source in a chromium matrix, with activity ~70 μCi, was 1.7°. All the measurements

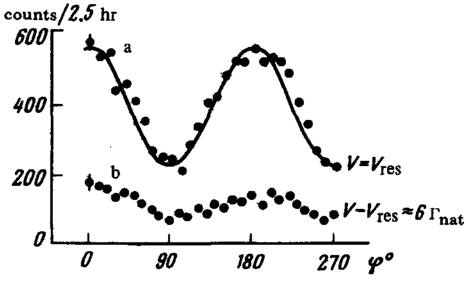

FIG. 3. Dependence of the intensity of the diffracted radiation for the (555) reflection of single-crystal $^{57}FeBO_3$ on the direction of the magnetic field at the ^{57}Fe nuclei (ϕ is the angle between the antiferromagnetic axis and the scattering plane).

were made at constant velocities. The crystal was mounted in a symmetrical Bragg position. The investigations were made at the magnetic maximum (555), $\theta_B = 26.6°$.

The angular dependence of the scattering, shown in Fig. 1, indicates that the reflection is pure nuclear, since this dependence appears only when the resonance condition is satisfied (Fig. 1a).

Figure 2 shows the energy dependence of the diffracted beam. We can note here the characteristic features of the magnetic maxima, namely the absence of scattering through the nuclear transition $\Delta m = 0$ (shown dashed), while the transitions $\Delta m = \pm 1$ (the outermost peaks in the absorption spectra, marked by arrows) take the form of maxima.

The dependence of the intensity of the diffracted radiation on the orientation of the antiferromagnetic axis was obtained by rotating a magnetic field of intensity $H \sim 400$ Oe in the (111) plane. It is seen from Fig. 3 that the experimental results agree well with the curve calculated on the basis of the kinematic theory.

A certain discrepancy can be attributed to the fact that the crystal does not satisfy completely the conditions of the kinematic approximation. This circumstance can be used to estimate the degree of perfection of the magnetic and crystal structure of single crystals.

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[1]V. A. Belyakov, Usp. Fiz. Nauk **115**, 553 (1975) [Sov. Phys. Usp. 18, 267 (1975)].
[2]J. Bernal, C. W. Struck, and J. G. White, Acta Crystallogr. 16, 849 (1963).
[3]M. Eibschütz and M. E. Lines, Phys. Rev. B 7, 11, 4907 (1973).
[4]A. N. Artem'ev, K. P. Aleshin, R. M. Mirzabaev, V. V. Sklyarevskiĭ, and E. P. Stepanov, Prib. Tekh. Éksp. No. 6, 64 (1971).