Anomalies in the angular distributions of radiation from channeled electrons

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A two-peak structure has been detected in the angular distribution of γ rays with an energy $E_\gamma \approx 315$ MeV emitted by 4.4-GeV electrons which move in the (011) plane of diamond single crystal. This angular distribution also exhibits an azimuthal asymmetry of the incoherent part of the spectrum at an energy $E_\gamma \approx 3$ GeV.

At small entry angles of high-energy electrons with respect to the crystal planes and axes, a huge number of atoms can, as we know, be drawn simultaneously into the interaction, giving rise to specific phenomena: intense radiation in the low-energy part of the γ-ray spectrum and an acute directivity[5] and polarization[6] of this radiation. At higher γ-ray energies and especially in the incoherent part of the spectrum, i.e., when the coherent interaction length is reduced, there are no theoretical grounds for expecting the manifestation of new effects. The results of experimental studies presented in this letter show, however, that this is not so.

The experiment was carried out using an internal electron beam of the Erevan synchrotron with a beam divergence of $\sim 5 \times 10^{-5}$ rad. At electron energy of 4.4 GeV this divergence is smaller than the Lindhard critical channeling angle for the (011) plane of diamond single crystal ($\theta_{\rm crit} \approx 10^{-4}$ rad), which was chosen as the internal target of the synchrotron, with a thickness of 72 μm in the direction of the electron trajectory.

The angular distributions of γ rays and their energy were measured using a double magnetic spectrometer[5] with a narrow movable target, allowing the γ-ray beam to be scanned only in the horizontal projection. The angular distributions could nonetheless be measured in two mutually perpendicular directions when one of the two mutually perpendicular equivalent planes, (011) or $(01\bar{1})$, was alternately oriented parallel

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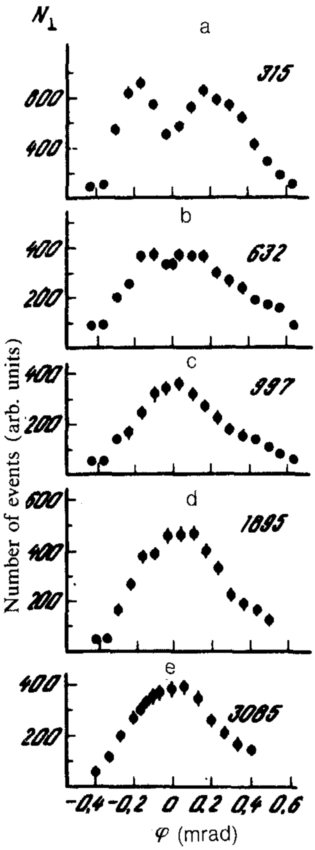

FIG. 1. Angular distribution of the γ rays over the entry angles φ from the crystal in the direction perpendicular to the (011) plane. The entry angle of the electrons is $\theta = 0°$. The γ-ray energies, in MeV, are shown in the upper right-hand corner of each figure.

to the direction of motion of the primary electrons. These experimental conditions excluded, moreover, the effect of asymmetry of the beam and of the geometric shape of the diamond target.

The distributions obtained by us are shown in Figs. 1 and 2. At an energy $E_\gamma = 315$ MeV we see a clear splitting into two peaks. At lower energies,[5] just as at higher energies, there is no splitting (Fig. 1, c–e). A change in the average entry angle of electrons to $\theta = 0.7 \times 10^{-4}$ rad caused one of the peaks to vanish at the same energy $E_\gamma = 315$ MeV and the distribution to become asymmetric (Fig. 3). Studies of the spectral dependence of the radiation of channeled electrons with an energy $E_e = 4.3$ GeV have previously shown[7] that at $E_\gamma \approx 315$ MeV the coherent intensification of radiation is barely discernible. Figure 1a therefore is a total distribution of coherent and incoherent production of γ rays. We have subtracted the incoherent γ-ray background on the basis of the distribution in Fig. 2a. The spacing between the peaks in the distribution which we obtained then turned out to be $\Delta\varphi = 5 \times 10^{-4}$ mrad. Consequently, the average angle of emission of γ rays relative to the primary electron is $\frac{1}{2}\Delta\varphi = 2.5 \times 10^{-4}$ mrad. This value is much higher than the critical electron channel-

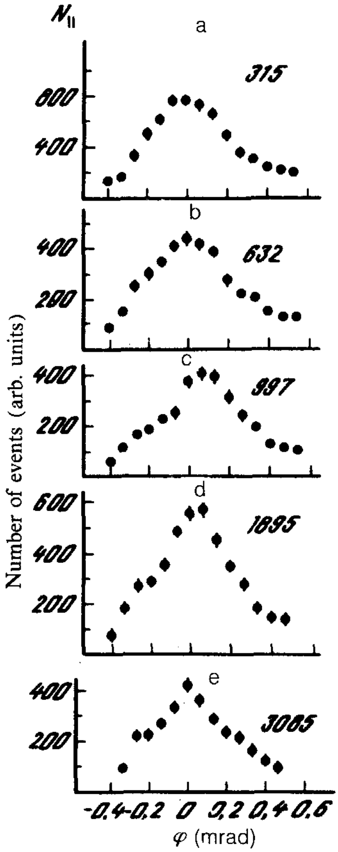

FIG. 2. The same as in Fig. 1, but in the direction parallel to the (011) plane.

ing angle. The splitting thus cannot be explained in terms of the particular features of the trajectory of the channeled electrons.

As can be seen from Figs. 1 and 2, the distribution widths are not the same in the two mutually perpendicular directions. In other words, we see an azimuthal asymme-

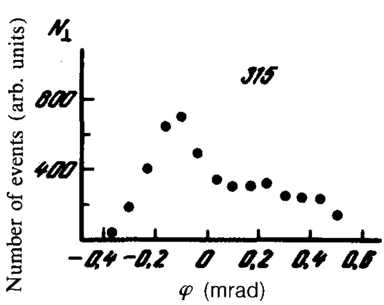

FIG. 3. The same as in Fig. 1, but for $\theta = 0.7 \times 10^{-4}$ rad.

TABLE I.

E_γ, GeV	1	1.9	3.1
A	0.09 ± 0.02	0.09 ± 0.02	0.12 ± 0.03

try in the angle distributions up to the measured maximum energy, $E_\gamma = 3$ GeV.

Table I gives the asymmetries $A = S_\perp - S_\| / S_\perp + S_\|$ for the three values of E_γ, where $S_{\perp(\|)} = \int N_{\perp(\|)}(\varphi) d\varphi$ was evaluated in the angular interval determined by the condition $N_{\perp(\|)}(\varphi) \geqslant \frac{1}{2} N_{\max}$.

The azimuthal asymmetry at $E_\gamma \sim 3$ GeV, i.e., in the incoherent part of the spectrum, is at variance with the present theory. The observed asymmetry, in our view, indicates that the γ-ray beam is linearly polarized. This circumstance is of considerable interest in light of its possible practical application in experimental high-energy and elementary-particle physics.

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