Behavior of the hard part of γ radiation of 4.4-GeV electrons in an oriented diamond crystal

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As electrons pass near the axis of a crystal, they emit radiation. Despite the predictions, the radiation yield near the upper boundary of the spectrum does not exceed the radiation yield of the disoriented crystal either at the axis or on the plane.

The radiation of high-energy electrons, as they pass through various single crystals parallel to their plane and axis, was studied experimentally, principally in the low-energy region of the photon spectra, i.e., at $\hbar\omega/E_0 = x < 0.1$, where $\hbar\omega$ is the photon energy, and E_0 is the initial electron energy. The study of the harder part of the spectrum at $E_0 \gtrsim 4$ GeV is of interest for two reasons.[1,2] Kimball and Cue[1] and Shul'ga *et al.*[2] have focused their attention on the following important circumstances.

1. They assumed that in the case of axial channeling of high-energy electrons, in addition to the known intense low-frequency radiation,[3,4] there must also occur a strong high-frequency radiation, which they refer to as the electric synchrotron radiation. The synchrotron approximation used in the calculations of Kimball and Cue[1] becomes valid for diamond, beginning at 3.7 GeV, and the experimental results up to $x = 0.05$, which were previously obtained by us (see Ref. 1) and at CERN (Ref. 5), are in Kimball and Cue's[1] view consistent with their theory. The results with electrons, however, are now incomplete. Measurements must be carried out for values of x higher than those that have so far been used.

2. The radiation near the upper boundary of the bremsstrahlung spectrum in an oriented crystal stems from the interaction with small impact parameters, rather than with coherent phenomena. This circumstance is the underlying principle upon which the study of Shul'ga *et al.*[2] is based. Since the axially[2] and planar[2,6] channeled electrons approach the crystal nuclei more closely, the integral yield of nuclear reactions and of radiation with x approximately equal to unity increase appreciably in comparison with a corresponding amorphous substance of equivalent radiation thickness. The contribution from above-the-barrier electrons is no greater than that of the amorphous level,[2] so that the particular features of the interaction mentioned above can be used to identify the conditions under which the electrons pass near the crystal axes and planes. Without the knowledge of these conditions, the total picture of the interaction cannot be obtained.

The planning of the experiment was inspired by the circumstances and possibilities that were described in Secs. 1 and 2.

The photon spectra were measured over a broad range of values of $x, 0 < x \lesssim 1$, for various orientations of a 100-μm-thick diamond single crystal. The measurements were carried out in an internal beam of the Erevan synchrotron with an electron energy $E_0 = 4.4$ GeV and monochromaticity of $\sim 0.6\%$. The beam divergence, determined from the characteristics of synchrotron radiation, was no worse than 5×10^{-5} rad, which is smaller than the critical angle of Lindhard channeling in the plane ($\theta_c \approx 10^{-4}$ rad) and along the axis ($\theta_c \approx 2 \times 10^{-4}$ rad) of the diamond single crystal.

The relative number of times the electrons pass through the target under study was determined from the synchrotron radiation of electrons with use of a secondary-emission monitor, which was placed in the vacuum tube of the accelerator.

The γ-ray energy was measured by a pair magnetic spectrometer to $x < 0.05$ within 10% and for $x > 0.05$ within 5–3%.

The necessary orientation of the axes and planes was established within 4.5×10^{-5} rad with a goniometric device.

Figure 1 shows the measured spectra which are normalized to the corresponding yield of the disoriented crystal. The upper part of the figure shows the results obtained when the radiation is collimated in an angle $\pm 1.5 \times 10^{-4}$ rad and the lower part of the figure shows the results obtained when the radiation is collimated in an angle $\pm 3 \times 10^{-4}$ rad, which is equivalent to the absence of collimation, since under these conditions essentially all of the radiation is detected in the crystal.

We see in Fig. 1 that, in addition to an intense photon emission at small values of x, in the case of the [100] axis, there is an appreciable increase in radiation up to $x \approx 0.3$–0.4. At $x \geqslant 0.15$ the relative yields are nearly independent of the beam collimation and remain constant even at an entrance angle $\theta = 3 \times 10^{-4}$ rad, which is greater than the critical Lindhard angle, with respect to the axis. This behavior was not predicted by Kimball and Cue.[1]

The intensification of radiation from positrons of roughly the same energy as those in our case and the same orientation of the diamond crystal is less pronounced, as is evident from a recent experimental study of Cue *et al.*,[7] than that of electrons and ceases at lower values of x.

We also see from Fig. 1 that in the extremely hard part of the spectrum at $x > 0.5$ the radiation yield resulting from the passage of electrons parallel to the (110) plane differs only slightly from the case in which the crystal is disoriented. At entrance angles $\theta = 0$ and $\theta = 3 \times 10^{-4}$ rad relative to the [100] axis, the corresponding radiation yield is strongly suppressed in comparison with that of a disoriented crystal even at a collimation angle $\pm 3 \times 10^{-4}$ rad. Note that this collimation angle is nearly three

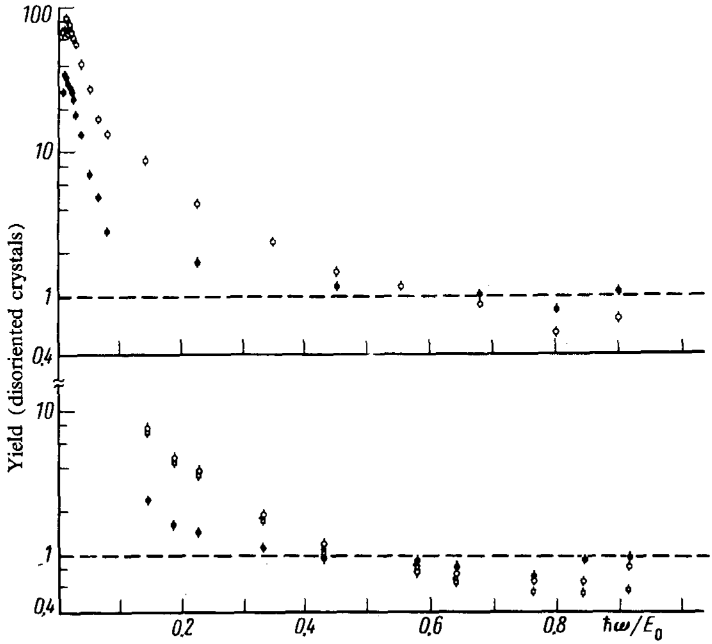

FIG. 1. Spectra of the emission of electrons from a 100-μm-thick diamond single crystal at entrance angles: ●—($\theta = 0$) relative to the (110) plane; ○—($\theta = 0$) and □—($\theta = 3\times 10^{-4}$ rad) relative to the [100] axis. The upper part of the curve corresponds to the collimation $\pm 1.5\times 10^{-4}$ rad and the lower part corresponds to $\pm 3\times 10^{-4}$ rad.

times as large as a typical emission angle $1/\gamma$, where γ is the Lorentz factor of the primary electron.

In summary, the radiation yield[2,6] of the extremely hard part of the spectrum is not found to be greater than that of a disoriented crystal either on the plane or along the axis, irrespective of collimation. The radiation yield would be greater if the channeled electrons would comprise a significant part of the transmitted beam.

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