Narrowing of the cone of the emission of relativistic electrons in an oriented diamond crystal

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The widths of the angular distributions of ~100-MeV γ rays decrease by a factor of 2–3 in comparison with a disoriented diamond crystal at crystal thicknesses of 100 μm and 470 μm.

Agan'yants *et al.*[1] and Avakyan *et al.*[2] were first to show that electrons which interact with the field of the crystal planes and with the field of the axes exhibit properties of strong forward emission. This particular feature of the emission was observed in the collimation of a γ-ray beam through one-half of the emission angle characteristic of the relativistic electrons m/E (m and E are the mass and energy of the electron). Under these conditions the detected yield of low-energy emission is two orders of magnitude greater than that of disoriented diamond crystals of thickness to 500 μm.

Kumakhov and Trikalinos[3] showed that in the case of channeling, the angular distribution of the emission of electrons is not related to the multiple scattering, so that the distribution width decreases in comparison with bremsstrahlung. In this letter we show, however, that channeling motion is not the only case in which a strongly directed emission is observed.

The direct measurements of the γ-ray distributions based on the angles of emission from the crystal which have so far been carried out have yielded a limited amount of information obtained essentially in experiments with channeled positrons.[4] Measurements of the angular distributions of γ rays had to be carried out at various energies over a broad range of electron-emission angles relative to the planes and axes of single crystals of various thicknesses.

The experiment was carried out in the internal electron beam of the Erevan synchroton, whose divergence was 5×10^{-5} rad. At electron energy of 4.4 GeV, this

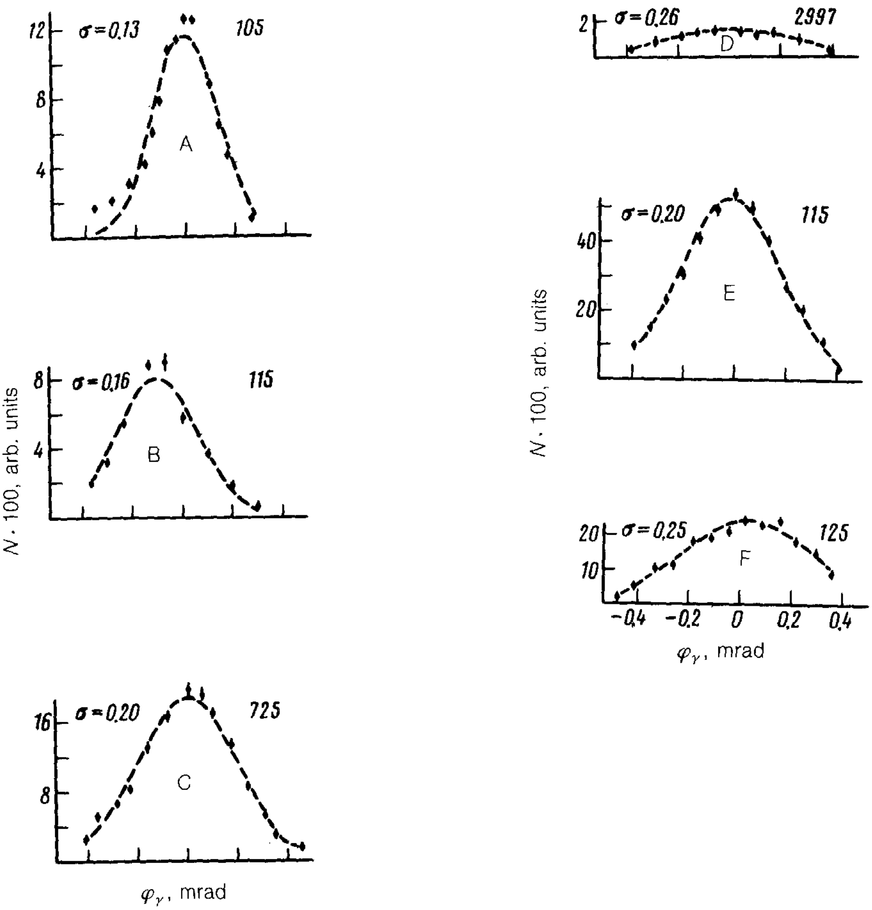

FIG. 1. Distributions of γ rays according to angles of emission from the crystal in the direction perpendicular to the (110) plane. The diamond thickness is 100 μm. Dashed curves—Approximations of experimental data by a Gaussian distribution. The standard deviations for the curves are shown in the left corner of each figure and the γ-ray energies (in MeV) are shown in the right corner. Figures A, B, C, and D correspond to the (110) plane and Figs. E and F correspond to the [100] axis. Each figure corresponds to a different angle at which electrons enter the crystal: A—0; B—1.3×10^{-4}; C—8.6×10^{-4}; D—0; E—0; F—3×10^{-4} rad. For a disoriented crystal $\sigma = 0.24 \pm 0.02$ mrad.

beam divergence is smaller than the Lindhard critical channeling angle for the (110) plane, $\theta_c \approx 10^{-4}$ rad, and for the [110] axis, $\theta_c \approx 2\times10^{-4}$ rad. The γ-ray energy was measured with a double magnetic spectrometer[5] whose lower energy-detection limit in our experiment was $E_\gamma \sim 90$ MeV, which was only 30 MeV higher than the peak energy in the planar channeling spectrum.[2]

The angular distribution was studied by scanning the profile of the γ-ray beam in

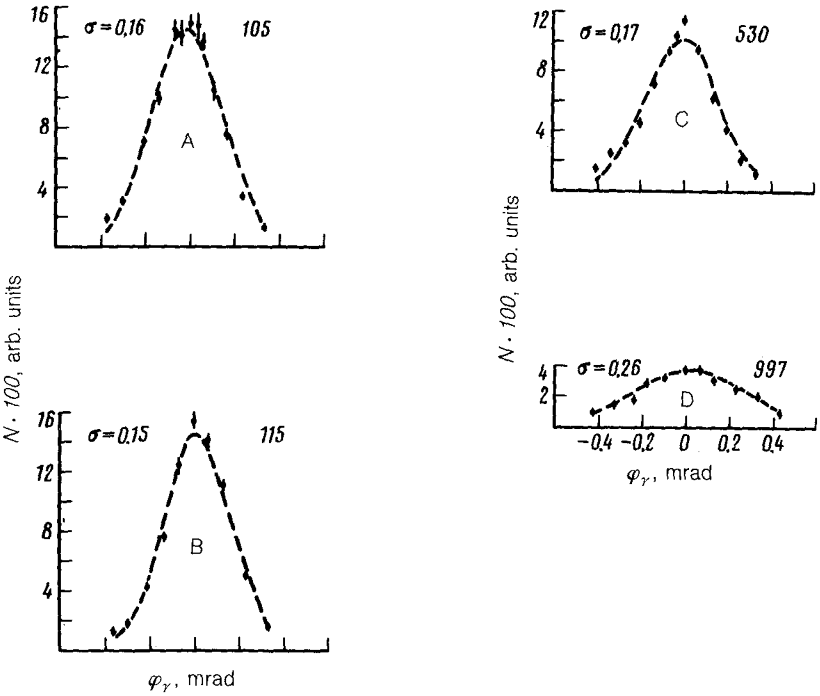

FIG. 2. The same as in Fig. 1, but in the direction parallel to the (110) plane. The diamond thickness is 470 μm. The angles at which electrons enter the crystal relative to the (110) plane are: A—0; B—1.3×10^{-4}; C—9.3×10^{-4} rad; D—0. For a disoriented crystal $\sigma=0.45\pm0.04$ mrad.

the horizontal projection. We used for this purpose a narrow mobile target of the double magnetic spectrometer which was placed 30 meters from the diamond crystal. The beam profile formed at this distance measured 9 mm vertically and 25 mm horizontally. The resolution of the apparatus with respect to the γ-ray emission angle, which was determined by the diamond size and the size of the target of the double magnetic spectrometer in the horizontal projection, was 0.027 mrad.

Figures 1 and 2 show the distributions of γ rays according to the angles of emission from the crystals. The standard deviations indicated in the figures were determined within $\pm$ (3–6)%. As can be seen from Fig. 1, the width of the angular distributions in the direction perpendicular to the (110) plane decreases, in contrast with a disoriented crystal, both in the case of channeling (curve A) and in its absence (curve B), as well as in coherent bremsstrahlung (curve C). In contrast, the distributions in Fig. 2 were detected in the direction parallel to the (110) plane. According to Refs. 6 and 7, the uncorrelated multiple scattering of electrons, and hence the angular distribution of emission, remain the same as in the amorphous medium because of random distribution of atoms in the plane of the crystal. The results in Fig. 2 (A, B, and C) demonstrate, however, that the distribution decreases appreciably in width in comparison with the disoriented crystal. The widths of the angular distributions are virtually unaffected by the difference in the widths of the diamond in the directions in which the γ rays of a given energy are emitted. This behavior occurs because of the decrease in the multiple scattering in the oriented crystal. A decrease in the width of the γ-ray distribution in the direction parallel to the (110) plane at a thickness of 470 μm is evidence that the suppression of scattering is nontrivial in nature.

The distribution width also decreases in the channeling of electrons near the [100] axis (Fig. 1E).

In our experiment we have also measured the angular distributions of γ rays from the hard part of the spectrum (Figs. 1D and 2D). These distributions are wider than those represented by the curves in Figs. 1A and 2A. They are, however, independent of the crystal width and direction of the γ-ray emission.

Other features of electron emission indicate that the distribution peaks are displaced from the direction of motion of the primary electrons (Figs. 1B and 1F). The displacement is in the direction opposite to the direction of rotation of the plane and the axis, respectively.

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