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PRODUCTION OF A QUASI-MONOCHROMATIC γ-RAY BEAM FROM MULTI-Gev ELECTRON ACCELERATORS

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Experimental results concerning electron pair production and bremsstrahlung from high-energy photons and electrons in a silicon single crystal have been reported in two previous Letters.[1,2] These results appeared to be in qualitative agreement with Überall's calculation.[3]

After these experiments were reported, we carried out a set of measurements with better angular resolution. The most important result of these measurements was the discovery of a "fine structure" in the coherent bremsstrahlung from the crystal. We then proceeded to calculate the bremsstrahlung cross section taking into account the actual structure of the crystal lattice planes, which were assumed as continuous planes by Überall. Our calculation shows a "fine structure" in good agreement with our experimental results. This will be shown in detail in a future paper to be published.

We want to indicate in this Letter a consequence of this result which may be of importance for some new possibilities in experiments with multi-Gev electron accelerators.

In effect it is possible to obtain, by the use of a suitably oriented single crystal as a radiator, a bremsstrahlung γ-ray beam which reveals a "line" for a certain value k of the photon energy, the value k being in the low-energy region relative to the maximum energy. The most suitable crystal for this effect is diamond because of its small lattice spacing and high Debye temperature.

Figure 1 shows the quantity $I(k, \theta)$ which is proportional to the bremsstrahlung intensity and has been defined in a previous Letter.[2] We have calculated this quantity for an electron beam with $E_0 = 6$ Gev striking a single diamond crystal at room temperature. We have chosen the angle θ between the momentum $\vec{p}_0$ of the primary electron and the $\vec{a}_1$ crystal axis [110] equal to 0.29 mrad. We have also assumed the plane $(\vec{p}_0, \vec{a}_1)$ coincident with the plane $(\vec{a}_1, \vec{a}_2)$, where $\vec{a}_2$ is a crystal axis perpendicular to $\vec{a}_1$.

The spectrum of Fig. 1 effectively shows a set of discontinuities; one may see that the first discontinuity dominates the others.

The angle $\theta = 0.29$ mrad has been chosen in such a way that this maximum discontinuity falls at $k = 1$ Gev. At the value $I(k, \theta)$ which is half the maximum, the relative width of the "line" associated with this discontinuity is $\Delta k/k = 0.25$. This

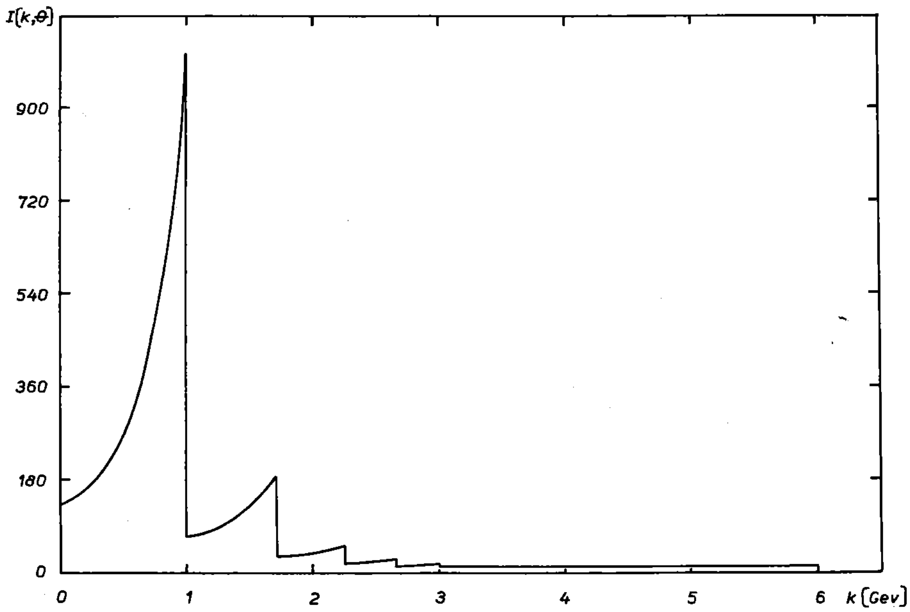

FIG. 1. Plot of the quantity $I(k,\theta)$, which is proportional to the intensity of the bremsstrahlung produced in a diamond single crystal ($T = 293°K$), versus the energy k of the photons. The angle θ between the momentum of the 6-Gev incoming electrons and the crystal axis [110] is 0.29 mrad.

value, for a fixed k/E_0 and the same single crystal, is roughly independent of E_0. The ratio between the peak value of the "line" and the value of the spectrum near $k = 6$ Gev is approximately 80. In general the value of this ratio increases with increasing E_0 and decreasing k/E_0.

The curve of Fig. 1 was obtained assuming that the electron beam had no angular divergence and that there was no multiple scattering in the target before the electrons radiated.

The photons contained in the region of the "line" are partially polarized.[4] Calculations and measurements of this effect at lower energies are in progress and will be reported at a later date.

As far as the experimental situation is concerned, we may say that the natural emission angle of the bremsstrahlung is $mc^2/E_0 \simeq 10^{-4}$ rad. It is therefore possible to discriminate photons emitted from electrons at angles $\approx 10^{-4}$ rad with the γ-ray beam axis by means of a suitable collimation. The reduction in intensity is dependent on the angular divergence of the accelerated electrons and on the radiator thickness. This will be partly compensated by the "line" height with respect to a spectrum from a normal radiator.

If we take $\theta = 0$ or $\theta \gg 0.29$ mrad, all the discontinuities vanish and the spectrum degenerates into a normal bremsstrahlung spectrum. This may be useful in single photoproduction experiments to subtract out the background due to multiple photoproductions.

We have reported these results in a preliminary manner in view of the possible applications in the multi-Gev electron accelerators under construction (Cambridge, DESY, Stanford University).

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