Emission of channeled 4.7-GeV electrons in diamond

A. O. Agan'yants,[1)] Yu. A. Vartanov,[1)] G. A. Vartapetyan,[1)] M. A. Kumakhov, Kh. Trikalinos, and V. Ya. Yaralov

Institute of Nuclear Physics, M. V. Lomonosov Moscow State University

(Submitted 5 March 1979)

Pis'ma Zh. Eksp. Teor. Fiz. **29**, No. 9, 554–556 (5 May 1979)

An increased γ-ray yield was observed in a comparatively narrow spectral region which is two orders of magnitude higher than the bremsstrahlung radiation in a disordered target.

PACS numbers: 61.80.Mk, 61.80.Ed, 61.80.Fe

1. The possibility of existence of a new physical effect—spontaneous γ-emission of relativistic channeled particles—was recently proposed.[1] An indication of existence of this effect for electrons was first obtained in Ref. 2.

In this work we obtained quantitative experiemental results which formally confirm the existence of a spontaneous γ-emission effect for both axial and planar channeling of electrons. These results are interpreted on the basis of theory in Ref. 1 with allowance for the real beam characteristics (divergence, probability of capture into channeling mode, distribution of channeled particles with respect to oscillation amplitude, etc.) which substantially affect the experimental results.

2. Experiments were carried out by means of the internal beam of Erevan synchrotron with 4.7-GeV electron energy and $\sim 2\times 10^{-4}$-rad beam divergence. A 100-μm thick diamond single crystal was used as target. Crystal orientation was carried out in a goniometer with accuracy to 4.5×10^{-5} rad. Measurements were made for both axial channeling along the $\langle 100\rangle$ direction and planar channel (110). The γ-beam was formed by a 1.2×1.2 mm^2 collimator placed at 10 m from a diamond target.

Photon energy measurements were carried out by means of a double magnetic gamma-spectrometer. Two scintillation counters connected to register coincidences were used as a detection system in the latter. Spectrometer resolution was 20% and the level of background random coincidences was below 15% for the maximum spectrometer counting rate. Relative monitoring of the electron flux through the diamond was carried out using the high-energy portion of the bremsstrahlung spectrum with respect

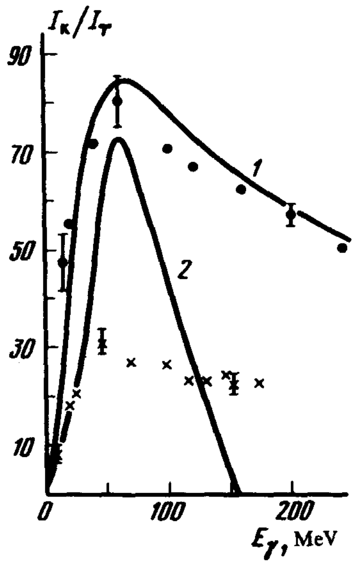

FIG. 1. Ratio of γ-ray yield for channeling to γ-ray yield in an unoriented target: ●●●—experiment (⟨100⟩ axis); xxx—experiment ((110) plane); curve 1—theory (⟨100⟩ axis); curve 2—theory ((110)plane).

to the secondary γ-rays with $E_g \gtrsim 1$ GeV by means of a Cerenkov total absorption counter.

Figure 1 shows the gamma-ray spectrum in the case of axial and planar channeling. In addition to this, measurements were made of the orientation-dependent γ-ray yield with a fixed energy for both axial and planar channeling (Fig. 2).

We also obtained integral γ-ray yield functions in the γ-ray interval 4 MeV$\leqslant E_\gamma \leqslant$4.7 GeV. We found that in the case of axial channeling the integral yield is $\sim$7.5 times higher than the yield in an unoriented target. The same ratio for a planar channeling is $\sim$2.7, i.e., it is comparable to results in Ref. 2.

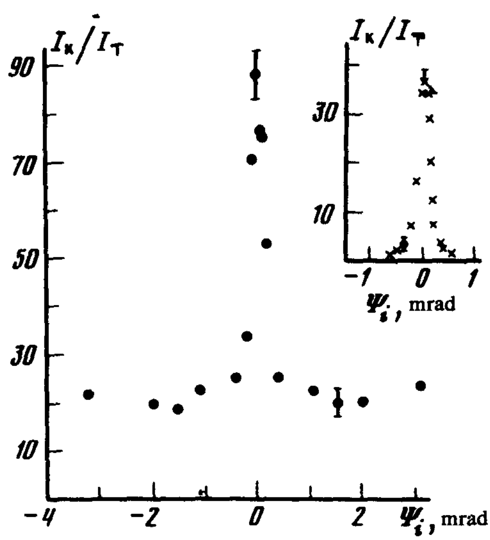

FIG. 2. Orientation dependence of γ-ray yield at fixed energy on yield for an unoriented target: ●●●—experiment (100 axis); $E_\gamma = 90$ MeV; xxx—experiment ((100) plane); $E_\gamma = 45$ MeV.

3. The experimental results were interpreted on the basis of theory in Ref. 1. For a beam divergence of $\Delta\bar{\theta}\sim 2\times 10^{-4}$ rad, approximately 13% of the beam is captured in the axial channel ⟨100⟩ and approximately 30% in the planar channeling mode.[2)] Non-dipolarity of radiation and the effect of higher harmonics were taken into consideration for the axial spectrum. The continuous Lindhardt potential was used in calculations. Figure 1 (curve 1) shows the results of calculations for axial channeling. Since de-channeling for the given experiment is immaterial, it was not taken into consideration.

As can be seen from the figure, satisfactory agreement exists between experimental results and the theory in terms of both amplification of the γ-ray yield in the course of channeling, and the spectral shape and location of its maximum.

Figure 1 (curve 2) shows the theoretical spectrum for the planar case calculated in the dipole approximation. Evidently, the position of the calculated maximum differs from the experimental. When non-dipolarity is taken into consideration, displacement of the calculated maximum in the direction of lower energies is expected (corresponding calculations are being done). It should necessarily be also noted that the theoretical calculation of yield enhancements exceeds the experimental values approximately twofold. This, apparently may be explained as follows.

To obtain the experimental results, we monitored, as indicated above, the hard portion of the bremmstrahlung radiation, not the primary electrons. This requires that we take into consideration the fact that as a result of spatial regrouping of the particle flow in the planar channel, the hard particle yield may increase due to scattering of electrons on nuclei when the atomic plane is intersected. Preliminary estimates show that when this factor is taken into consideration, experimental data points lie approximately twice higher than in Fig. 1, i.e., agreement between theory and experiment will be improved.

The experimental results obtained and the comparison of these with theory provide evidence for the existence of spontaneous gamma-emission effect during channeling. However, further experimental and theoretical investigation of this effect is desirable.

[1)]Erevan Physical Institute.
[2)]This indicates that at low beam divergence for which the percentage of particles captured in the channeling mode increases, considerably greater enhancement of γ-ray yield during channeling than shown in Figs. 1 and 2 may be expected.

[1]M.A. Kumakhov, Phys. Lett. **57A**, 17 (1976); Phys. Stat. Sol. (b) **84**, 41 (1977); Dokl. Akad. Nauk SSSR **230**, 1077 (1976) [Sov. Phys. Dokl. **21**, 581 (1976)]; Zh. Eksp. Teor. Fiz. **72**, 1489 (1977) [Sov. Phys. JETP **45**, 781 (1977)].
[2]A.O. Agan'yants, N.Z. Akopov, Yu.A. Vartanov and G.A. Vartapetyan, Preprint EFI-312 (37)-78; A.O. Agan'yants, Preprint EFI-313 (38)-78. Erevan, 1978.