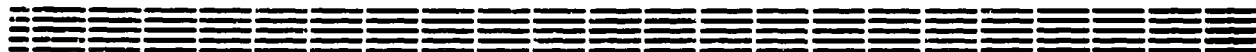


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ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ  
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**ORIENTATIONAL DEPENDENCE OF HIGH ENERGY  
ELECTRON MULTIPLE SCATTERING AT SMALL  
ANGLES OF INCIDENCE TO CRYSTAL**

Նախնատիպ EՓՄ-1024(74)-87

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կախման փորձառական հետազոտություն 4,5 ԳԷՎ էներգիայով էլեկտրոն-  
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ORIENTATIONAL DEPENDENCE OF HIGH ENERGY  
ELECTRON MULTIPLE SCATTERING AT SMALL  
ANGLES OF INCIDENCE TO CRYSTAL

Experimental investigation is carried out for the orientational dependence of the mean square of the multiple scattering angle at small incidence angles of 4.5 GeV electrons relative to crystallographic (110) planes of diamond. A theoretical discussion of the experiment is reported.

Yerevan Physics Institute

Yerevan 1987

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ОРИЕНТАЦИОННАЯ ЗАВИСИМОСТЬ МНОГОКРАТНОГО РАССЕЯНИЯ  
ЭЛЕКТРОНОВ ВЫСОКИХ ЭНЕРГИЙ ПРИ МАЛЫХ УГЛАХ ВЛЕТА  
В КРИСТАЛЛ

Проведено экспериментальное исследование ориентационной зависимости среднего квадрата угла многократного рассеяния при малых углах влета электронов с энергией 4,5 ГэВ относительно кристаллографических плоскостей (110) алмаза. Дано теоретическое обсуждение эксперимента.

Ереванский физический институт

Ереван 1967

At small incidence angles of the relativistic charged particles to a crystal relative to the crystallographic axis or plane, the particles simultaneously interact with large number of atoms of the axis or plane (coherent scattering). Such interaction may be described by continuous potential of the axes or planes [1]. At the same time the particles multiply scatter on thermal oscillations of individual atoms (incoherent scattering), this finally leading to an increase in the mean square angle of particle motion relative to the initial direction and respectively in monotonous broadening of the beam as the latter penetrates into the crystal. Earlier [2,3], it was theoretically shown a possibility of suppression of the incoherent multiple scattering of electrons at planar channeling and quasi-channeling in crystals compared to the amorphous matter case.

In the present work we report the results of experimental study of the dependence of mean square angle of multiple scattering of 4.5 GeV electrons in a diamond crystal with a

thickness  $\ell = 200 \mu\text{m}$  on the incidence angle relative to crystallographic (110) planes. The layout of the experimental setup is shown in Fig.1. When measuring the multiple scattering angle, the deflecting magnet DM was switched off, the electrons having passed through the crystal target were detected by the array of gas proportional counters (GPC) and multiwire proportional chambers (MPC). The trigger signal was formed by coincidence of signals from the gas proportional counters GPC-1 and GPC-3, and particle coordinates were detected with the proportional chambers MPC-1 + MPC-5. Note, that the MPC-1 practically detected a coordinate of electron interaction with the target (T), and the electron trajectory after the interaction was restored with the MPC-2 + MPC-5.

On the basis of the electron trajectories, the particle distribution with respect to the emission angle was constructed as well as the mean square scattering angle  $\langle \theta^2 \rangle_c$  was calculated. The divergence of the primary electron beam was nearly 0.1 mrad, i.e. of the order of the Lindhard critical angle  $\theta_L$ .

The experiment revealed a notable dependence of  $\langle \theta^2 \rangle_c$  upon the crystal orientation (Fig.2) which has a minimum at incidence angles  $\theta_0$  of the order of  $\theta_L$ . In our case (diamond,  $\ell = 200 \mu\text{m}$ ) the value of  $\langle \theta^2 \rangle_c$  for all  $\theta_0$  turned out to be less than the analogous quantity  $\langle \theta^2 \rangle_a$  in the case of amorphous matter. Such orientational dependence earlier was revealed in the investigation of photon angular distribution [4].

The orientational dependence we have found apparently has a simple explanation. The multiple incoherent scattering of the relativistic electron moving under a small angle relative

to the crystallographic planes essentially depends on energy  $\epsilon_{\perp}$  of its transverse motion. The proportionality factor between the mean square scattering angles  $\langle \theta^2 \rangle_c$  and  $\langle \theta^2 \rangle_a$  referring to a sufficiently small interval of path also depends essentially on  $\epsilon_{\perp}$  :

$$\eta(\epsilon_{\perp}) = \langle \theta^2 \rangle_c / \langle \theta^2 \rangle_a . \quad (1)$$

The quantity  $\eta(\epsilon_{\perp})$  approximately is determined by the formula [2] :

$$\eta(\epsilon_{\perp}) = \frac{2}{(\epsilon_{\perp}/U_0)^{1/2} \ln |(1+(\epsilon_{\perp}/U_0)^{1/2}) / (1-(\epsilon_{\perp}/U_0)^{1/2})|} , \quad (2)$$

where  $U_0$  is the potential well depth.

The quantity  $\eta(\epsilon_{\perp})$  may be calculated more precisely only numerically [2] . It is appreciably less than unity for the particle moving at the top of the barrier (  $\epsilon_{\perp} \approx U_0$  ).

The ratio  $\eta_B(\ell)$  of mean squares  $\langle \theta^2 \rangle_c / \langle \theta^2 \rangle_a$  for the particle beam and for the crystal of finite thickness  $\ell$  one can obtain by integration:

$$\eta_B(\ell) = \frac{1}{\ell} \int_0^{\ell} d\ell \int_0^{\infty} d\epsilon_{\perp} F(\epsilon_{\perp}, \ell) \eta(\epsilon_{\perp}), \quad (3)$$

where  $F(\epsilon_{\perp}, \ell)$  is the particle distribution function over transverse energy at penetration depth  $\ell$  .

The calculation of quantity  $\eta_B(\ell)$  without account of evolution of  $F(\epsilon_{\perp}, \ell)$  with depth shows its essential orientational dependence (Fig.2, curves 1, 2). This is connected with the fact that at incidence angles  $\theta_0 \gtrsim \theta_L$  the portion of particles with  $\epsilon_{\perp} \ll U_0$  that undergo strong incoherent

scattering is negligible. With the depth of penetration into a crystal the particle redistribution over transverse energy must bring to an increase of the portion of particles with  $\epsilon_{\perp} \approx U_0$ , compared to that with  $\epsilon_{\perp} < U_0$ . This implies that a more correct calculation of  $\eta_g(\ell)$  with account of the  $F(\epsilon_{\perp}, \ell)$  evolution with depth must yield smaller values of  $\eta_g(\ell)$ , preserving qualitatively orientational dependence. The calculation based on the solution of the Fokker-Planck equation for  $F(\epsilon_{\perp}, \ell)$  in the case of 4.5 GeV electrons incoming parallel to the diamond (110) planes have shown that the quantity  $\eta_g(\ell)$  indeed decreases with penetration depth. At  $\ell = 200 \mu\text{m}$  this quantity decreases approximately by a factor of 1.7 [3], this giving a better agreement of theory with experiment.

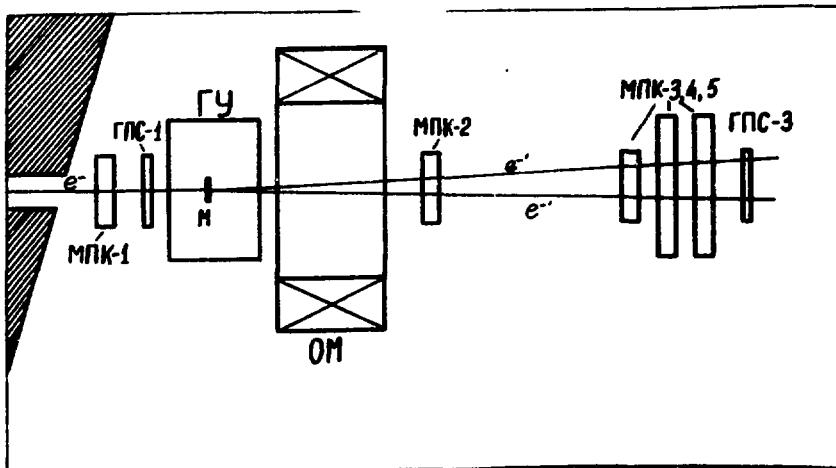


Fig.1. Experimental set-up.

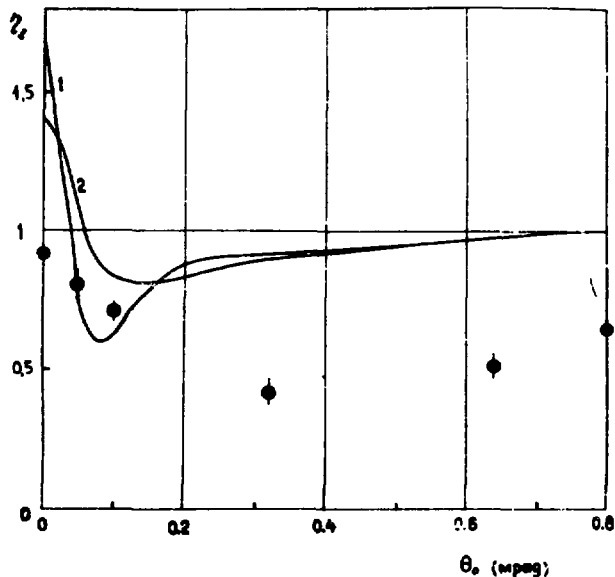


Fig.2. Dependence of mean square multiple scattering angle normalized by the mean square angle of multiple scattering in disoriented crystal on electron incidence angle relative to crystallographic, (110) planes of diamond. Full circles - the experiment; curve 1 - the calculation by formula (3) without account of the beam initial divergence; curve 2 - initial divergence was  $\theta_L$ .

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ВЫСОКИХ ЭНЕРГИЙ ПРИ МАЛЫХ УГЛАХ ВЛЕТА В КРИСТАЛЛ

(на английском языке, перевод З.Н.Асланян)

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