

508800119

Preprint ЕФИ-908(59)-86

**ԵՐԵՎԱՆԻ ՖԻԶԻԿԱՅԻ ԻՆՍՏԻՏՈՒՏ**  
**ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ**

H.H. AKOPIAN, P.I. GALUMIAN, V.H. GRABSKI,  
V.V. KARAPETIAN, G.V. KARAPETIAN

AN EFFECTIVE METHOD FOR ELECTRONS COHERENT  
BREMSSTRAHLUNG POLARIZATION CALCULATION  
BASED ON INTENSITY SPECTRA

**ЦНИИатоминформ**

**ЕРЕВАН-1986**

**Հ.Գ.ՀԱԿՈՔՅԱՆ, Պ.Ի.ՂԱԼՈՒԽՅԱՆ, Վ.Հ.ԳՐԱԲԱԿԻ  
Վ.Վ.ԿԱՎԱՊԵՏՅԱՆ, Գ.Վ.ԿԱՐԱՊԵՏՅԱՆ**

**ԲՅՈՒՐԵՂՆԵՐՈՒՄ ԷԼԵԿՏՐՈՆՆԵՐԻՆԻՐԱՏ ԱՊԵԿՏՐԻ ԽՏՏՆՍԻ-  
ՎՈՒԹՅԱՆ ԿՈՀԵՐԵՆՏ-ԱՐԳԵԼԱԿԱՅԻՆ ԺԱՌԱԳԱՅԹՄԱՆ ԲԵՎԵՌԱՑ-  
ՄԱՆ ՀԱՇՎԱՐԿԻ ԱՐԴՅՈՒՆԱՎԵՏ ԵՂԱՆԱԿ**

Առաջարկված է Բյուրեղներում էլեկտրոնների կոհերենտ-արգելակա-  
յին ճառագայթման Բևեռացման հաշվարկի արդյունավետ եղանակ՝ ըստ էներ-  
գետիկ սպեկտրերի ինտենսիվության, Ֆուրյե-ձևափոխության կիրառությամբ  
Բևեռացման հաշվարկի հարաբերական ճշտության ավանդական մեթոդների  
արդյունքների համեմատ 1-ին կոհերենտ առավելագույն արժեքի տիրույ-  
թում ոչ վատ քան 2-3 % է: Հաշվարկի ծրագրի Բարձր արագունակույթ-  
յունը թույլ է տալիս այն օգտագործել ԿԱՃ-սպեկտրերի "օր - ըլոս"  
եղանակով մշակման համար:

Երևանի Ֆիզիկայի ինստիտուտ

Երևան 1986

Препринт ЕФИ-906(59)-86

Г.Г.АКОЛЯН, П.И.ГАЛУМЯН, В.О.ГРАВСКИЙ,  
В.В.КАРАПЕТЯН, Г.В.КАРАПЕТЯН

ЭФФЕКТИВНЫЙ МЕТОД РАСЧЕТА ПОЛЯРИЗАЦИИ  
КОГЕРЕНТНО-ТОРМОЗНОГО ИЗЛУЧЕНИЯ ЭЛЕКТРОНОВ В  
КРИСТАЛЛАХ ПО СПЕКТРАМ ИНТЕНСИВНОСТИ

Представлен эффективный метод расчета поляризации по энергетическим спектрам интенсивности когерентного тормозного излучения электронов в кристалле с использованием быстрого Фурье-преобразования. Относительная точность расчета поляризации в сравнении с результатами традиционных методов расчета не хуже 2-3 % в области I когерентного максимума. В то же время высокое быстродействие программы расчета позволяет использовать её для обработки спектров КТИ в режиме "on - line".

Ереванский физический институт

Ереван 1986

H.H. AKOPIAN, P.I. GALUMIAN, V.H. GRABSKI,  
V.V. KARAPETIAN, G.V. KARAPETIAN

AN EFFECTIVE METHOD FOR ELECTRONS COHERENT  
BREMSSTRAHLUNG POLARIZATION CALCULATION  
BASED ON INTENSITY SPECTRA

An effective method is presented for polarization calculation of electrons coherent bremsstrahlung spectra in monocrystals, using fast Fourier transformation. The relative accuracy of the calculation compared with the results of conventional methods is about 2 - 3% in the working region of the first coherent maximum. At the same time, the method provides a high-speed calculation, which permits it to be used for on-line processing of coherent bremsstrahlung spectra.

Yerevan Physics Institute

Yerevan 1986

## 1. Introduction

Polarization calculations of electrons coherent bremsstrahlung in monocrystals by the experimental spectra of intensity in the framework of the available methods (e.g., [1,2]) are rather time-consuming. The conventional calculation technique is based on the well known Timm formulae [3] :

$$I^{EX}(x) = \frac{\iint I^T(x, \theta, \alpha) W(\theta, \alpha) d\theta d\alpha}{\iint W(\theta, \alpha) d\theta d\alpha} \quad (1)$$

$$P^{EX}(x) = \frac{\iint P^T(x, \theta, \alpha) I^T(x, \theta, \alpha) W(\theta, \alpha) d\theta d\alpha}{\iint I^T(x, \theta, \alpha) W(\theta, \alpha) d\theta d\alpha} \quad (2)$$

Here  $I^{EX}(x)$  and  $P^{EX}(x)$  are the experimental intensity and polarization of photons, respectively;  $I^T(x, \theta, \alpha)$  and  $P^T(x, \theta, \alpha)$  are the corresponding theoretical expressions [4] (see Fig.1);  $x = \frac{k}{E_e}$ , where  $k$  is the energy of  $\gamma$ -quantum and  $E_e$  - the energy of electron,  $\theta$  and  $\alpha$  are the crystal orientation angles relative to the electron momentum,  $W(\theta, \alpha)$  is the probability density.

The right hand side of the expression (1) is integrated either numerically [1], or by Monte Carlo method [2], certain assumptions being made about the beam parameters, multiple scattering of electrons in crystal, angular distribution of

radiation and its effective collimation, etc. The unknown free parameters are determined by fitting the calculated intensity spectra to the experimental ones. In all, at correct parametrization of the function  $W(\theta, \alpha)$ , these methods allow to have  $\sim 1-2\%$  absolute accuracy in polarization value.

In the present work a method is presented for the coherent bremsstrahlung (CB) polarization calculation based on the solution of the integral equation of the type (1) using fast Fourier transformation.

## 2. The CB polarization Calculation Scheme

It is supposed that all the experimental factors distorting the theoretical spectra, can formally be described by the unified perturbation function which has acted only in the scale of the energy variable. Then, the Eq.(1) can be rewritten as:

$$I^{EX}(x) = \int_{-\infty}^{\infty} I^T(x')_{x_0} W(x'-x)_{x_0} dx' \quad (3)$$

Here  $I^T(x')_{x_0} \equiv I^T(x', \theta_0, \alpha_0)$  is the theoretical spectrum of CB for the fixed values of  $\theta_0, \alpha_0$  (or  $x_0$  - the energy of coherent maximum),  $W(x'-x)_{x_0}$  is the perturbation function. In analogy with the Eq.(2)

$$P^{EX}(x) = \frac{\int_{-\infty}^{\infty} P^T(x')_{x_0} \cdot I^T(x')_{x_0} W(x'-x)_{x_0} dx}{I^{EX}(x)} \quad (4)$$

where  $P^T(x')_{x_0} \equiv P^T(x', \theta_0, \alpha_0)$ .

It should be noted that the presentation of polarization in the form of the Eq.(4) as well as in the form of the Eq.(2) is based on approximation of radiation angular and energy dis-

tributions and their correlation [1,3] in conditions of collimation. The fixing of the parameter  $x_0$  in the expressions (3,4) is also an approximation which considers the weak distortion of the form of intensity spectra and CB polarization at variation of  $x_0$  in the range of the effective width of the perturbation function  $W(x'-x)_{x_0}$ . The integral equation is a Fredholm one of the first kind with nucleus dependent of the difference of arguments, which can be solved by the method of integral Fourier transformation [5]. It can be shown that the Fourier image of perturbation function has the following form:

$$W(k) = \frac{1}{\sqrt{2\pi}} \frac{I^{EX}(k)}{I^T(k)} \quad (5)$$

where  $I^{EX,T}(k) = F(I^{EX,T}(x))$  are the Fourier images of  $I^{EX}(x)$  and  $I^T(x)$ . Using the inverse Fourier transformation, one can resume the perturbation function energy spectrum:

$$W(x) = F^{-1} [W(k)] \quad (6)$$

Substituting the expression for  $W(x)$  into (4), one might obtain the following expression for polarization:

$$P^{EX}(x'_0) = F^{-1} \left[ \frac{PI(k) I^{EX}(k)}{I^T(k)} \right] / I^{EX}(x_0) \quad (7)$$

where  $PI(k) = F[P^T(x) I^T(x)]$  is the Fourier image of the product of theoretical intensity and polarization. The expression (7) has been used in calculations of the CB polarization experimental spectra.

### 3. The Calculation Procedure

The calculation procedure has the following stages:

1) the mean angles of  $(\theta_0, \alpha_0)$  have been determined and theoretical spectra of intensity and polarization calculated [4]. For this the energy of the 'fall-off centre of the first coherent maximum  $x_{f.c.}$  has been used as an initial parameter, assuming that  $x_{f.c.} \approx x_0$ .

2) the "amorphous" part of the CB spectrum has been deduced on the basis of well-known relations between the integral intensity of different parts of the CB energy spectrum. It has been also assumed that the corresponding choice of these regions provides the same relations for integral intensities as in case of nonperturbed theoretical spectra. In calculations presented below, the region of the first four maxima and the region of plateau ( $0.6 < x < 0.8$ ) have been used. Deduction of the "amorphous" part has been carried out by the iteration method.

3) there have been determined the limits of the region for Fourier analysis within which statistical smoothing of the experimental spectrum is carried out. Usually the region of the first three coherent maxima being chosen. In calculations the method of fast Fourier transformation has been used on the basis of standard algorithm FFT [6], which supposed a discrete presentation of initial functions as a succession of  $2^m$  points. The discretization step was chosen in accordance with the energy step of multichannel pair spectrometer of about 2-3% [7].

### 3. Results and Discussion

The presented method of calculation has been checked in comparison with the methods [1,2] in the range of  $0.2 < X_0 < 0.5$  using the CB spectra for diamond monocrystal, obtained in the framework of these methods. In Figs.2-6 are presented the parts of CB spectra characteristic of the Bonn Synchrotron (Figs.2,3) and the Yerevan Synchrotron (Figs.4,5,6), together with calculated values of polarization and spectra of the perturbation function. The initial data in Figs.2,3 are extracted from figures of Ref.[1] and, as it is seen, in the limits of their accuracy (2-3%) the method of fast Fourier transformation describes the results of the Ref.[1]. Intensity and polarization spectra in Figs.4-6 are obtained by the Monte Carlo method with a good statistical accuracy. As seen from the figures, the method of fast Fourier transformation of an absolute accuracy of  $\leq 1\%$  describes the results of Ref.[2] in the working region of the first coherent maximum ( $\Delta x/x \approx 0.15-0.2$ ) and the relative error in the value of polarization does not exceed 2% on the average. In the whole mentioned region of the first and second coherent maxima the results of fast Fourier method and those of Ref.[2] agree with an accuracy of 2-3%. Deterioration of the fast Fourier method towards the edges of regions weakly distorted by perturbation, is due to its ideology and makes its use impossible in the plateau region, which has small weight according to the criterion  $P^2 I$ . The influence of different factors on the accuracy of polarization calculation by the fast Fourier transformation method has been investigated. The following results are obtained:

- 1) the statistical error of  $\sim 5\%$  of the spectra measurement is connected with  $0.5\%$  error in the absolute value of polarization in the working region of photon spectrum;
- 2) the error of  $x_0$  determination in the limits of  $\Delta x_0/x_0 = \pm(5-10)\%$  practically does not influence on the accuracy of calculations, it only manifests itself in the sign-compensating shift of the perturbation function spectrum in the energy scale. The mentioned feature comes from the structure of the formula (3) and is based on the absence of noticeable distortion in the CB spectra at small shifts of  $x_0$ .
- 3) the choice of the width of regions and the degrees of their discretization in the calculation procedure manifest themselves on the level of  $\leq 0.5\%$  in the absolute value of polarization.

The polarization calculation program has been adapted on minicomputer CM-4-MERA CAMAC, the characteristic time of processing per spectrum being less than 10-20 seconds.

We are indebted to thank A.P. Karapetian for help in calculations, G.P. Taroyan and A.A. Armaghanian for helpful discussions, prof. H.A. Vartapetian for support and interest in this work.

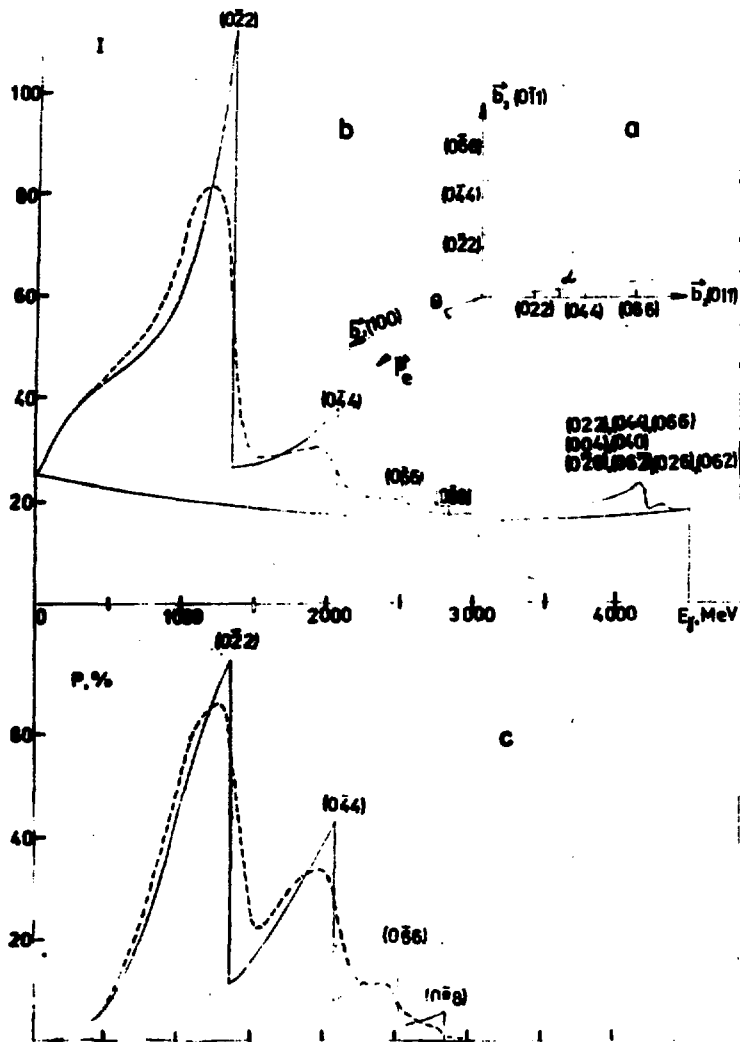


Fig.1 a) The spatial orientation of the incident electron momentum  $\vec{p}_e$  relative to diamond lattice axes  $\vec{b}_1, \vec{b}_2, \vec{b}_3$ . b,c) theoretical spectra of intensity and polarization (solid line), calculated spectra [2] (dashed line) which illustrate the effect of experimental factors.

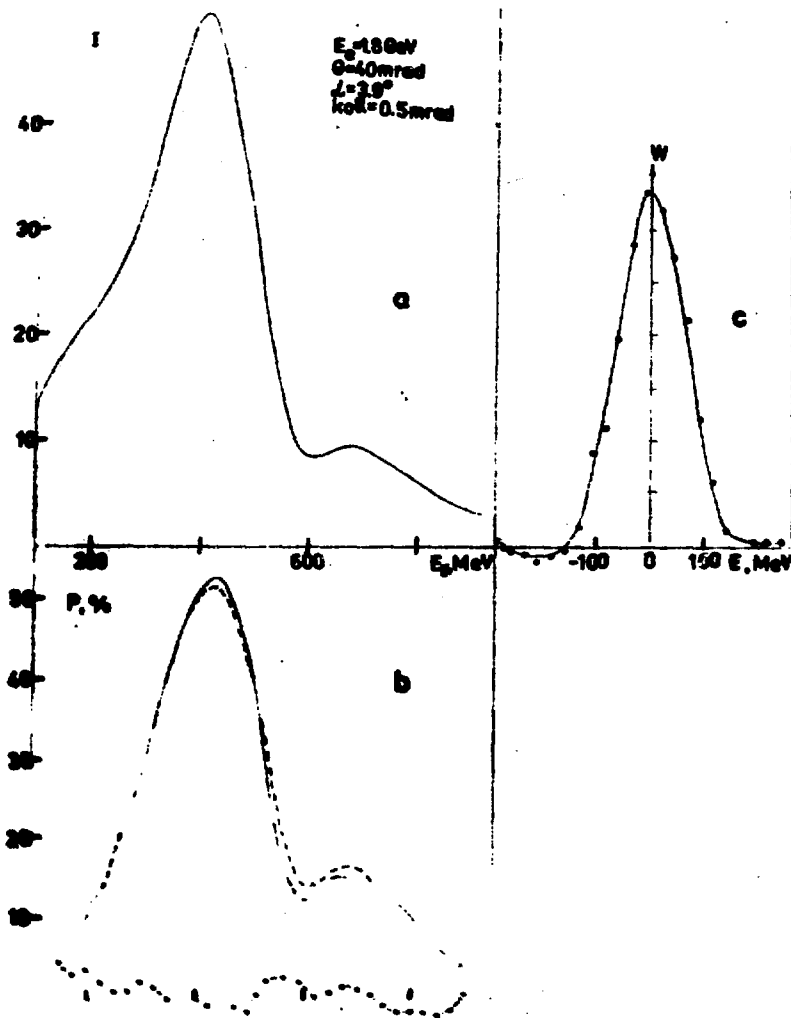


Fig.2 a) A part of the intensity spectrum from Ref. 1 with the "amorphous" constituent subtracted at  $x(\overline{022}) = 0.27$ .  
 b) Polarizations calculated by the FFT method (dashed line), the method from Ref. [1] (solid line), and their difference (dash-and-dot line); c) the energy spectrum of the perturbation function.

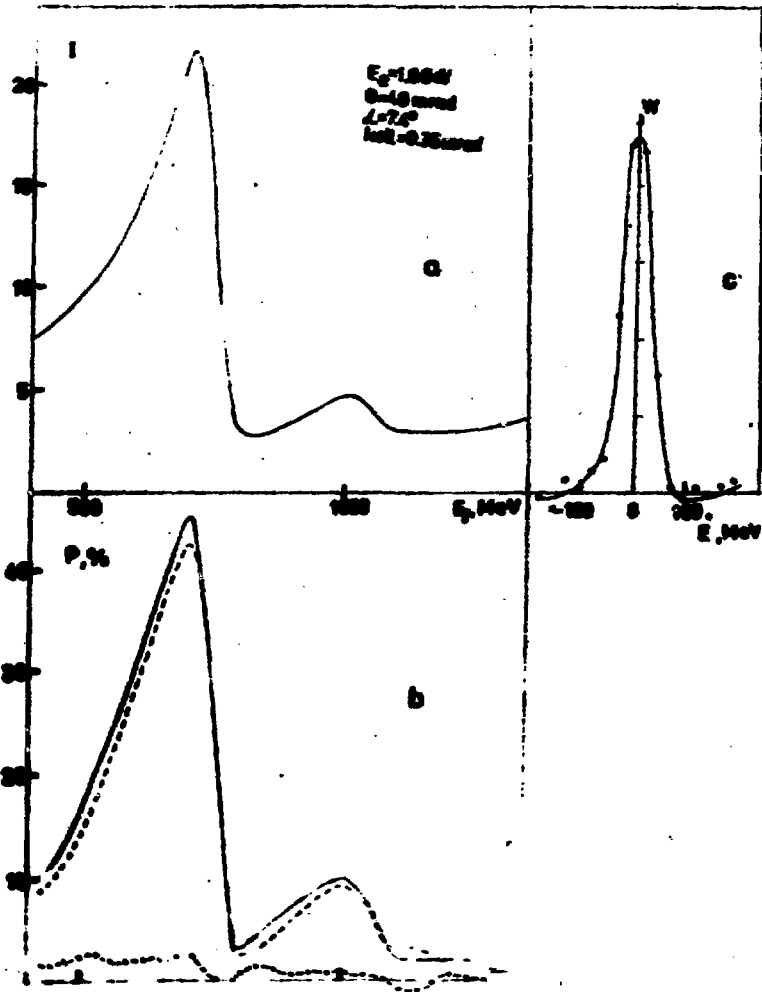


Fig.3 The same as in Fig.2 at  $x = 0.41$ .

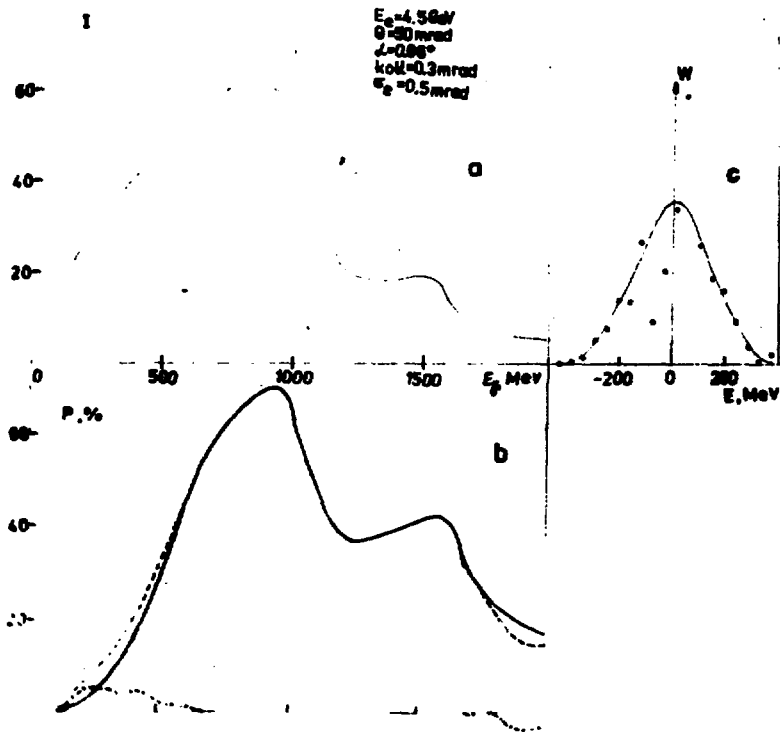


Fig.4 a) A part of the intensity spectrum with the "amorphous" constituent subtracted, obtained by the method from Ref. [2] at  $x_{(0\bar{2}2)} = 0.22$ . b) Polarizations calculated by the FFT method (dashed line), the method from Ref.[2] (solid line), and their difference (dash-and-dot line). c) The energy spectrum of the perturbation function.

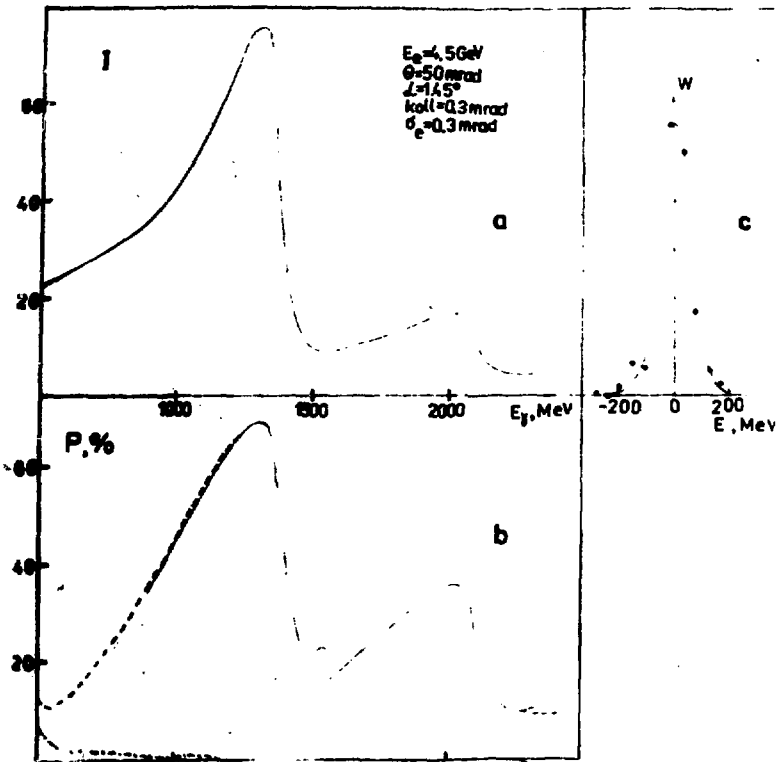


Fig.5 The same as in Fig.4 at  $x_{(022)} = 0.3$ .

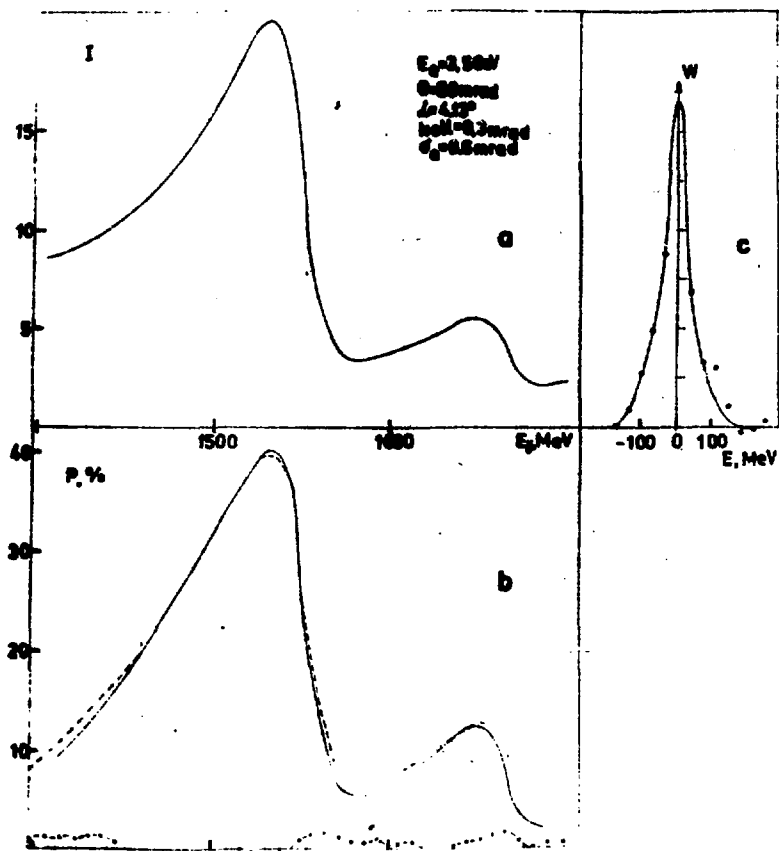


Fig. 6 The same as in Fig. 5 at  $x_{(0\bar{2}2)} = 0.5$ .

## REFERENCES

1. Dahl E.A. Experimentelle Bestimmung der Asymmetric  $\Sigma$  des differentiatellen Wirkungsquerschnitts fur die Deuteronspaltung  $\gamma d \rightarrow pn$  mit linear polarisierten Photonen im Energiebereich 230-820 MeV. Preprint Bonn-IR-82-26, p.140, 1982.
2. Авакян Р.О., Акопов Н.З., Бевзержая А.П., Дарбонян С.М.  
Вычисление поляризации тормозного пучка фотонов. Препринт ЕФМ-265(56)-77, Ереван, 1977.
3. Timm U. Coherent Bremsstrahlung of Electrons in Crystals. Fortschritt der Physik 1969, vol.17, p.765-808.
4. Тер-Микаэлян М.Л. Влияние среды на электромагнитные процессы при высоких энергиях. Изд-во АН АрмССР, 1969.
5. Свешников А.Г., Тихонов А.Н., Теория функций комплексной переменной. М.: Наука, 1974, с.273.
6. Рабинер Л., Гоулд Б. Теория и применение цифровой обработки сигналов. М.: Мир, 1978.
7. Агабабян К.Ш., Адамян Ф.В., Акопян Г.Г. и др. Экспериментальная методика для исследования реакции фоторасщепления  $\gamma d \rightarrow pn$  на пучке линейно-поляризованных фотонов ЕФМ. Препринт ЕФМ-790(7)-85, Ереван, 1985.

The manuscript was received 30 June 1986

Г.Г.АКОУЯН, П.И.ГАЛУМЯН, В.О.ГРАБСКИЙ, В.В.КАРАПЕТЯН,  
Г.В.КАРАПЕТЯН

**ЭФФЕКТИВНЫЙ МЕТОД РАСЧЕТА ПОЛЯРИЗАЦИИ КОГЕРЕНТНО-ТОРМОЗНОГО  
ИЗЛУЧЕНИЯ ЭЛЕКТРОНОВ В КРИСТАЛЛАХ ПО СПЕКТРАМ ИНТЕНСИВНОСТИ**

(на английском языке, перевод Г.А.Папаян)

Редактор Л.П.Мукалян

Технический редактор А.С.Абрамян

---

Подписано в печать 28/ХІ-86 ВФ-06875 Формат 60х84

Офсетная печать. Уч. изд. л. 1,0

Тираж 299 экз. Ц. 15 к.

Зак. тип. № 626

Индекс 3624

---

Отпечатано в Ереванском физическом институте  
Ереван 36, Маржарана 2

индекс 3624



**ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ**