PRODUCTION OF LINEARLY POLARIZED PHOTON BEAM AT MAX-LAB

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Spectra of coherent bremsstrahlung from the diamond crystal in the laboratory MAX-lab on the accelerator MAX-I are measured at the energy of the electronic beam 144 MeV. First in the laboratory MAX-lab a source of the polarized photon radiation was created. Photon spectra were compared with theoretical calculations, that allow to estimate a magnitude of photon polarization, which is sufficient, for performing the nuclear experiments in the intermediate energy range.

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1. INTRODUCTION

The principled possibility to produce a linearly polarized photon beam for photonuclear researches at the MAX-lab facility (for electron energies about two hundred MeV) using the coherent bremsstrahlung (CB) of electrons in diamond crystals was considered some years ago [1]. The proposition on production the CB polarized beam at the MAX-lab was supported by Program Committee of the laboratory in the 2002. Since that time the necessary practical steps have been accepted for necessary equipment and methods development for the project realization. The first test experiment on the CB polarized beam production was performed in the 2007 of September [2]. The goal of the experiment was to perform the crystal orientation and obtain the CB spectrum. In this article the results of this experiment are presented.

2. EXPECTED PARAMETERS OF THE COHERENT BREMSSTRAHLUNG AT MAX-LAB CONDITIONS

As it is known, the coherent bremsstrahlung appears as a result of interference effects at interaction of the relativistic electrons with periodic structure of a crystal [3-5]. As follows from the low of momentum-energy conservation for the bremsstrahlung, the interference appears under condition, that the recoil momentum which transferred to the crystal as whole, coincides with the vector of the crystal reciprocal lattice:

$$\vec{q} = \vec{g}. \qquad (1)$$

This condition can be realized at definite crystal orientation respectively to the electron beam. Due to interference the intensity of the electron radiation in a crystal sufficiently increases and exceeds the radiation intensity of electrons in amorphous matter. The interference is revealed itself in experiment, as wide peaks over the ordinary bremsstrahlung. In accordance with [3-5] the CB cross section can be presented as a sum of two parts, coherent $d\sigma_{coh}$ and incoherent $d\sigma_{in}$,

$$d\sigma(\vec{q}) = d\sigma_{coh} + d\sigma_{in} \, . \qquad (2)$$

The coherent part of the cross section is a sum of the terms, each of which according to the condition (1) related to one vector of the reciprocal crystal lattice. Thus, from all continuum of the recoil momenta permitted by the conservation law, only discrete group of the vectors, which coincides with the vectors of the reciprocal lattice, gives contribution to the $d\sigma_{coh}$. Therefore, $d\sigma_{coh}$ depends on the crystal orientation relatively to the electron beam. It is possible to increase the coherent cross section by crystal rotation, i.e. by shifting the reciprocal lattice vectors in the region of the permitted recoil momenta, where the cross section $d\sigma(\vec{q})$ is large. It is possible to select orientation, when many or only one vector of the reciprocal lattice gives contribution to the $d\sigma_{coh}$. In the last case the maximal CB polarization is achieved. The crystal orientation is determined by two angles, θ and α, where θ is the angle between electron beam momentum $\vec{P}_0$ and one crystal axis, for example $\vec{b}_1$, α is the angle between planes ($\vec{P}_0$, $\vec{b}_1$) and ($\vec{b}_1$, $\vec{b}_2$).

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The calculations of the CB expected parameters for diamond crystal presented in ref. [1] have been made on the base of Born approximation with using formulas from [3-5]. It was chosen the orientation when the point $(0, 2, \overline{2})$ of the crystal reciprocal lattice gave main contribution to the CB cross section which provides maximal value of the CB beam polarization. There were also taken into account the other experimental factors which had influence on the CB characteristics: the electron beam divergence and multiply scattering in crystal, collimation of the gamma radiation.

In Fig.1 it is shown the calculated spectra of the CB intensity and polarization for electrons with energy $E_0 = 250\,MeV$ in the diamond crystal $0.1\,mm$ thick for some collimation angles $\theta_s/\theta_\gamma =$ (0.25, 0.5, 1) ($\theta_\gamma = mc^2/E_0$, m is the electron mass). The coherent peak energy is $E_{\gamma,p} = 60\,MeV (x_d = E_{\gamma,p}/E_0 = 0.24)$. The intensity is presented in the form of ratio

$$\beta = (d\sigma_{coh} + d\sigma_{in})/d\sigma_{in} = (I_{coh} + I_{in})/I_{in}\,, \quad (3)$$

where I_{coh} and I_{in} are intensities of the coherent and incoherent parts of the CB. For estimation possibilities of the CB beam applying in the experimental researches there are important two main characteristics: intensity of the coherent part of the radiation I_{coh}, which is estimated by magnitude of the coherent effect β_{max} (the value of (3) in the point of the CB maximum), and radiation polarization $P_{\gamma,max}$ in the coherent maximum. Our estimations show that for MAX-lab experimental conditions these parameters must have magnitudes:

$$\beta_{max} \geq 1.4 \; and \; P_{\gamma,max} \geq 20\%\,. \quad (4)$$

Fig.1 show that for selected conditions of the CB beam generation the requirements (4) are satisfied: the coherent effect and polarization are changed from $\beta_{max} \sim 2$ to ~ 4.5 $P_{\gamma,max}$ 35% to $P_{\gamma,max}$ 65% with reducing the collimation angle from $\theta_s = 1\theta_\gamma$ to $0.25\theta_\gamma$.

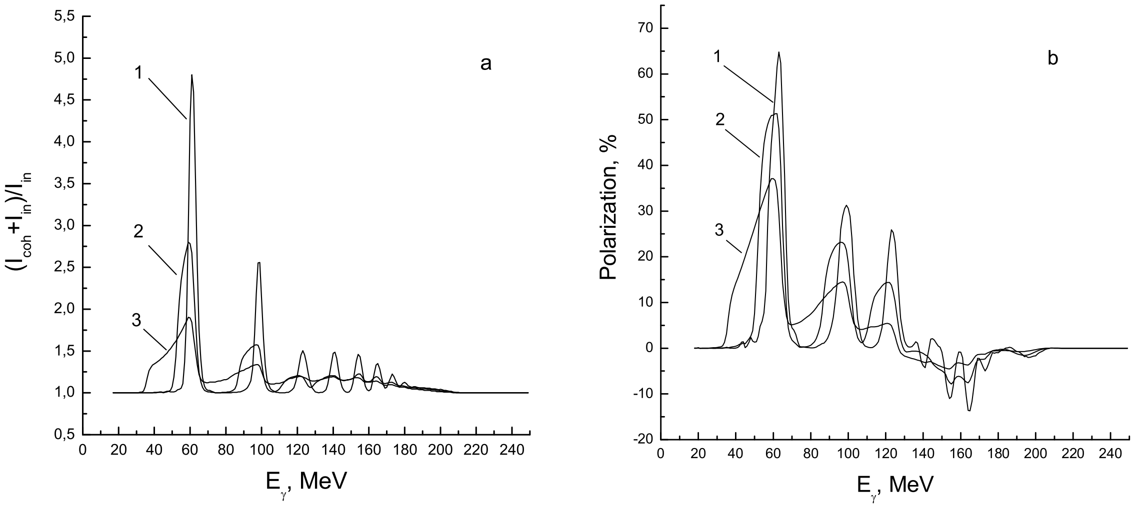

Fig.1. *Intensity (a) and polarization (b) of the CB of electrons in diamond crystal* $0.1mm$ *thick (from [1]). Energy of the electrons and CB peak are* $E_0 = 250\,MeV$ *and* $E_{\gamma,p} = 60\,MeV$*, the collimation angles* $\theta_s/\theta_\gamma = 0.25(1),\ 0.5(2),\ 1(3)$

Collimation has significant influence on the CB beam parameters [3-5], and therefore it was studied more detail. In Fig.2 it is shown the calculated functions of the coherent effect and polarization at the CB peak from the collimation angle for initial electron energies $E_0 = 150$ and $250\,MeV$ and peak energy $x_d = 0.2$. Fig.2 demonstrates the similar behavior these functions β_{max} and $P_{\gamma,max}$ from electron energies and crystal thickness: increasing their values with the collimation angle decreasing, which occur especially rapidly fast at the angles $\theta_c < \theta_\gamma$. The collimation $\theta_c \sim 0.5\theta_\gamma$ provides most suitable CB beam parameters for photonuclear experiments even for $E_0 = 150\,MeV$.

Recently the new code was developed by P.Grabmayr with colleges [6]. In this code the experimental factors were taken into account more accurately. Thus, it was taken into account the size of the electron beam sport on the target and the beam density distribution. So, the calculations of the CB characteristics were repeated [7,8] with using this code which as a whole, confirmed the results of the previous ones [1]. In Fig.2 there are shown the results of new computation of CB for diamond crystal $0.1\,mm$ thick, initial electron energies $E_0 = 200$ and $250\,MeV$ for some higher peak energies, $x_d = E_{\gamma,d}/E_0 = 0.3$ and 0.32, respectively. They demonstrate the same dependence on the collimation angle, as it was discussed above.

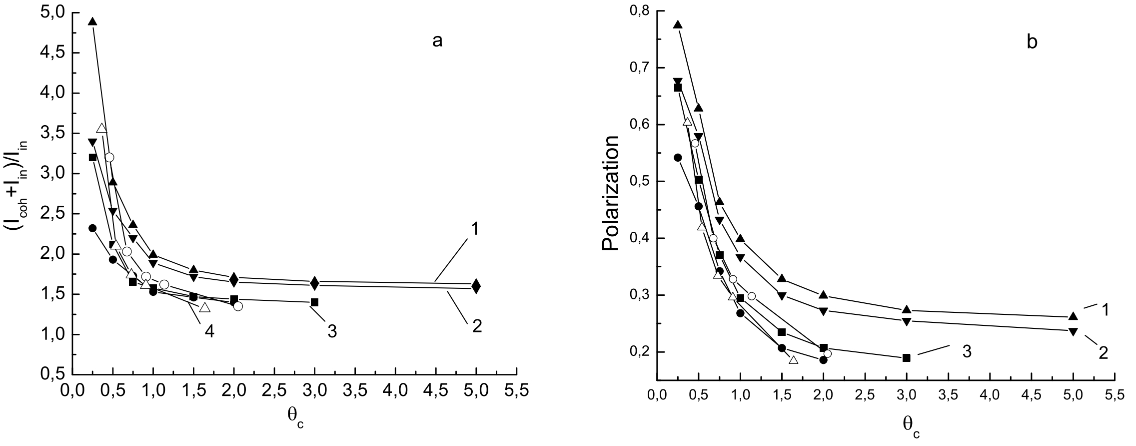

Fig.2.*Dependence of the coherent effect (a) and polarization (b) at the CB maximum energy* $x_d = 0.2$ *vs. collimation of the* γ *radiation. (1)- electron energy is* $E_0 = 250\,MeV$*, crystal thickness is* $0.1\,mm$*; (2)-* $E_0 = 250\,MeV$*,* $0.3\,mm$*; (3)-* $E_0 = 150\,MeV$*,* $0.1\,mm$*; (4)-* $E_0 = 150\,MeV$*,* $0.3\,mm$ *[1]. Calculations for diamond* $0.1\,mm$ *thick from [7]: empty triangles -* $E_0 = 200\,MeV$*,* $x_d = 0.3$*;empty circles* $E_0 = 250\,MeV$*,* $x_d = 0.32$

Both coherent effect and polarization are decreased, when the coherent peak moves to higher energies. The range, in which the coherent effect and polarization are still sufficient for nuclear physics experiments (4), was estimated and calculations of these dependences from the CB peak energy were executed for some values of the collimation angle and electron energies $E_0 = 150$ and $250\,MeV$. They were shown in the Fig.3,4, which allow to make some important conclusions.

At small CB peak energies, $E_{\gamma,p} = 20\ldots30\,MeV$ ($x_d \sim 0.1\ldots0.2$) the coherent effect and polarization can achieve the high values even for $E_0 = 150\,MeV$ at the condition of strong collimation, especially θ_c $0.25\theta_\gamma$. In the case of more real and often applied collimation $\theta_c \sim \theta_\gamma$ their magnitude falls to $\beta_{max} \approx 2$ and $P_{\gamma,max} \approx 40\%$ even for $E_{\gamma,p} = 20\,MeV$ ($x_d \sim 0.12$). Therefore, for the initial energy $E_0 = 150\,MeV$ at the collimation $\theta_c \sim \theta_\gamma$ the upper boundary, where polarization and coherent effect still have magnitude sufficient for photonuclear experiments, is about $40\,MeV$. It can be increased up to 60 or $80\,MeV$ with increasing the electron energy up to $200\,MeV$ or $E_0 = 250\,MeV$, respectively.

If we use the collimation angle $\theta_c \sim 0.5\theta_\gamma$, then the expected range for photonuclear experiments could be increased up to 60, 80 and 100 for $E_0 = 150$, 200 and $250\,MeV$, respectively. So, increasing of the electron beam energy to $E_0 = 250\,MeV$ it is desirable to extend effective energy range practically to the threshold of the pion photo-production, improving parameters of the CB beam in all energy range. Increasing of crystal thickness to $0.3\,mm$ at the collimation $\theta_c \sim 0.5\theta_\gamma$ practically doesn't change characteristics of the CB beam, therefore, it is partly possible to compensate some losses intensity at strong collimation, using more thick crystals.

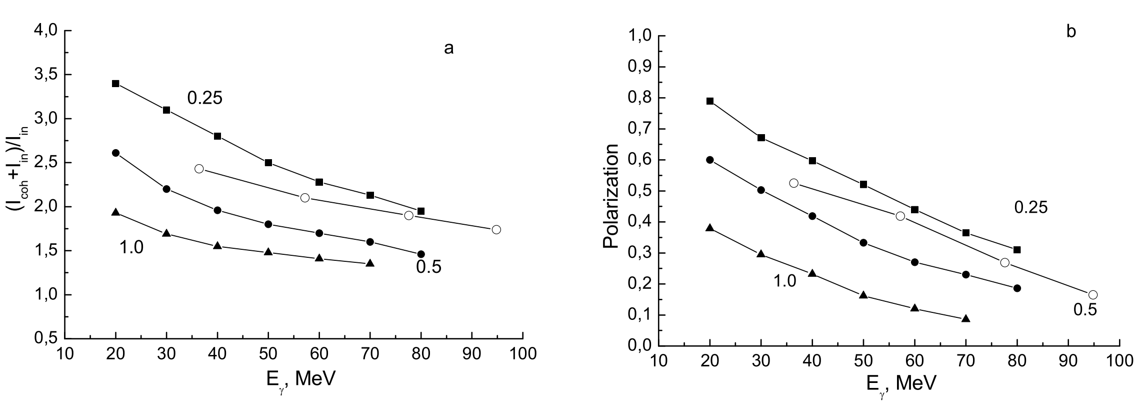

Fig.3. *Dependence of the coherent effect (a) and the polarization (b) in the CB maximum vs. photon energy for electron energy* $E_0 = 150\,MeV$ *and diamond crystal* $0.1\,mm$ *thick. Collimation angles are* $\theta_c/\theta_\gamma = 0.25, 0.5, 1$

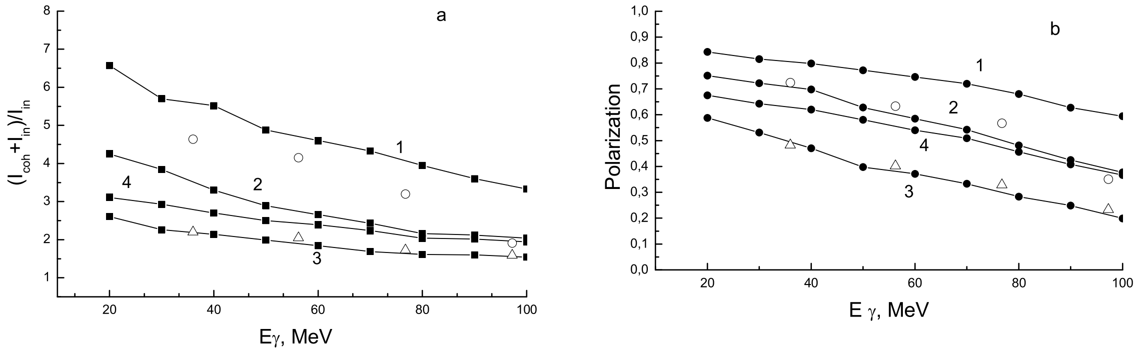

Fig.4. *Dependence of the coherent effect (a) and the polarization (b) in the CB maximum vs. photon energy for initial electron energy* $E_0 = 250\,MeV$*. The crystal thickness* $0.1\,mm$ *and collimation angles of* $\theta_c/\theta_\gamma = 0.25$ *(1),* 0.5 *(2),* 1 *(3) and a crystal with the thickness* $0.3\,mm$ *and* $\theta_c = 0.5\theta_{gamma}$*(4)(from [4]). Results from ref. [5]: full squares - collimation angle* $\theta_c = 0.46\theta_\gamma$*, empty -* $\theta_c = 0.91\theta_\gamma$

3. EXPERIMENTAL METHODS AND TECHNIQUE

3.1. Electron and photon beams forming

The electron beam for photonuclear researches in MAX-lab is taken from the storage ring MAX-I, which in this case works in a stretcher mode and can operate only with electron energy no more than $250\,MeV$. Injection of electrons into the ring is carried out by the double-section linear accelerator - recirculator. Duration of the electron injected impulse in MAX-I is usually $200\,ns$, frequency of the impulses is $10\,Hz$. The injected electron beam impulse left the MAX-I ring during $100\,ms$ and by the beam transportation system delivered into the experimental hall. A scheme of the beam line and experimental equipment placing in the hall is shown in Fig. 1.

At the hall entrance the dipole magnet (1) was placed. It turns the electron beam on angle 50° and directs along the beam line to photon targets, one of which is before the magnet (4) of end-point tagger (ET) and the other is before the magnet (6) of main tagger (MT). The ET system can tag photons in the range $E_\gamma \sim 91 - 225\,MeV$, the MT can tag photons in the interval $E_\gamma \sim 18 - 163\,MeV$ [1].

After passing the photon targets the electron beam with the help of the MT magnet and additional magnet (7) directs to the Faraday cup which measures the beam current and absorbs it.

For production the CB polarized beam the diamond crystal was used which was fixed in a 3-axes goniometer. The goniometer was placed in a vacuum chamber between magnets of the ET and MT tagging systems instead of MT amorphous photon target. The goniometer consists of three rotation stages providing the orientation of the crystal and two translation stages providing the vertical adjustment of the target and the movement perpendicular to the electron beam direction. The control of the goniometer is provided by MM4006 motion controller connected with RS-232 port of the PC. The main characteristics of the moving stages are presented in [9].

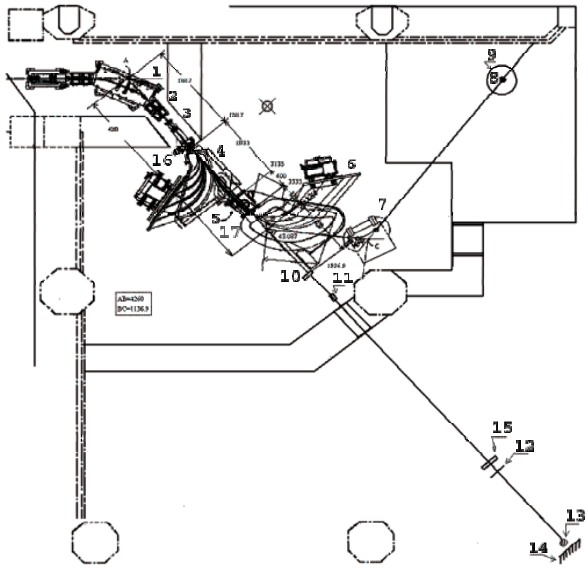

Fig.5. *Scheme of the MAX-lab nuclear physics beam line. 1- bending magnet (*$50°$*); 2- quadrupole lenses; 3- vertical and horizontal correctors of the beam; 4- end-point tagger (ET); 5- goniometer; 6- main tagger (MT); 7- additional turning magnet (*$60°$*); 8- Faraday cup; 9- radiation shielding; 10- exit photon window of the MT magnet chamber; 11- photon collimator; 12-nuclear target; 13- quantometer; 14- photon beam-dump*

The rotating goniometer target holder has five positions for radiators. At the center of the holder a $100\,\mu m$ thick diamond radiator was fixed. In the four other locations on the circumference of the target holder the $300\,\mu m$ Si crystal, the $50\,\mu m$ Al radiator, the viewing screen and an empty slot were positioned.

The CB beam, produced at interaction of the electron beam with the diamond crystal was cleaned by the MT magnet from charged particles and formed by the photon collimator (10), which was placed before the shielding wall near exit window of the MT magnet on distance $\sim 2.14\,m$ from the crystal. The collimator was made from a heavy metal and had $40\,cm$ in length. The collimator holes diameter can be changed from 19 to 12 and $4\,mm$. The hole's diameter $19\,mm$ corresponds to the collimation angle θ_c $1.9\theta_\gamma$ for electron energy $E_0 \sim 250\,MeV$ (and point-like beam).

The number of emitted photons in the energy interval of the tagging system was determined by means of the measured number of the scattered electrons with the tagging system detectors. Intensity of the photon beam that passed the collimator was controlled by gamma beam monitor. The final control of the beam position was produced by photographing of the photon beam after collimator and estimation of the photon density distribution on the slide. On the whole, the system of the beams diagnostic and forming allows after a few corrections to get almost symmetrical distribution of the photon beam density at the exit from the photon collimator, that corresponded to passing of the beams along the geometrical axis of the beam line.

Stability of the beam parameters in the course of experiment was controlled by means of stability of the tagging system detectors and the Faraday cup counting rate. That is the control was carried out non-directly but through the control of beam intensity stability, as deviation from the beam parameters obtained and fixed at primary beam forming, as a rule, causes changes of the beam intensity. The existing system of the beam forming and control allows one to produce the polarized CB beam.

3.2. Method of crystals orientation

A crystal initial orientation concludes in finding the angles of goniometer rotations, $\Phi_{v0}, \Phi_{h0}, \Phi_{a0}$, along vertical, horizontal and azimuthal axes at which one of the crystal axes, for example $\overrightarrow{b_1}$, is directed along the axis of electron beam (along the impulse of electrons $\overrightarrow{P_0}$), and other two axes $\overrightarrow{b_2}$ and $\overrightarrow{b_3}$ are directed along the axes of goniometer rotations f_v and f_h.

There are many methods of the orientation realization, and they all are based on using any effects dependent on crystal orientation. At present experiment two methods were used, which are based on measuring of the orientation dependence of gamma radiation intensity of electrons in crystal. In one method (so called the "Stonehenge" method) developed by Livingstone [10] and adapted for facilities with photon tagging systems (for example, Mainz, Bonn, Jefferson Lab) used the orientation dependence of gamma radiation registered by the tagging system detectors.

In the second method the orientation dependencies of the total radiated photon flux is used which is usually measured with any photon beam monitor, e.g. ionization chamber or quantometer [11,12]. In this experiment the scintillation gamma monitor was applied, that consisted of scintillation counter $0.8\,cm$ thick, in front of which a metal converter was placed for increasing of the secondary charged particles yield a $2\ldots6\,mm$ thick. The monitor worked in the counting rate mode and the measured particle yield was normalized on electron beam current that was measured by the Faraday cup.

Possibility of the above second method using for determining initial crystal orientation resulted from effect of the electron radiation intensity increasing when they crossover the crystal planes. As a result, appear the interference maxima in the orientation dependence. More intensive maxima are produced by main crystal planes. Position and height of the maxima allow one to identify the planes of the crystal and their position relatively to the axes of goniometer rotation [11,12]. In the coordinates system related to the reciprocal lattice of the crystal position of the maxima are determined by the formula [3-5],

$$\delta = \theta(g_2 cos(\alpha) + g_3 sin(\alpha))\,, \tag{5}$$

where θ and α are the angles of crystal orientation. g_2 and g_3 are the components of the vector of the reciprocal lattice. δ is the minimal recoil momentum which is equal to

$$\delta = \frac{1}{2E_0}\frac{x}{1-x}\,. \tag{6}$$

One can link orientation angles and with the angles of the goniometer rotation Φ_v, Φ_h, Φ_a by the relations

$$\Phi_v = \Phi_{v_0} + \theta cos(\alpha + \Phi_{a_0})\Phi_h = \Phi_{h_0} + \theta sin(\alpha + \Phi_{a_0})\,, \tag{7}$$

where Φ_{v_0}, Φ_{h_0}, Φ_{a_0} are the angles of goniometer rotation at which the orientation angles θ and α are equal zero, that is, these are the needed angles of initial orientation. From relations (5) and (7) follows

$$\delta = g_2(\Phi_v - \Phi_{v_0}) + g_3(\Phi_h - \Phi_{h_0})\,. \tag{8}$$

So, for fixed values of g_2 and g_3 position of the coherent maximum in the coordinate system of Φ_v and Φ_h is depicted by the straight line. A number of these lines for different vectors of reciprocal lattice produce "map of the crystal". In the case of photons of low energies, $x \to 0$ and $\delta \to 0$, all these lines for different vectors of reciprocal lattice have only one intersection, coordinates of which are Φ_{v_0}, Φ_{h_0}. From this follows, that for realization of successful orientation it is necessary the gamma radiation detectors sensible to low energy part of photon spectrum.

The measurement of gamma radiation intensity was carried out as a function of the crystal rotation round one of the axes, for example, f_h (angle of rotation Φ_h) and fixed second angle (Φ_v). Then the measurements of orientation dependencies are repeated at a few fixed angles Φ_v and values of the peak position coordinates are determined. The angles of initial orientation are obtained as a result of the system of equation decision that describes the lines which pass through the coordinates of discrete peaks with the same Miller's indexes. These lines cross of in the point, coordinates of which correspond to the angles of initial orientation Φ_{v_0}, Φ_{h_0}.

The crystals to be placed in the goniometer were cut in such a way that axis $\langle 001\rangle$ was perpendicular to the diamond crystal plate and axis $\langle 111\rangle$ to the silicon plate. The proper map of the diamond crystal planes is shown in Fig.6. One can see that at implementation of the orientation procedure, which was described above, such maxima must be observed: central, corresponding to strong plane (022), and less lateral peaks corresponding to the planes (026), (062), (004), (040).

The estimations of the monitor counting rate and its possibility to measure the radiation orientation dependence were done by simulation with using the GEANT-3 package. It was simulated the charged particles yield that has to be detected by gamma monitor with tungsten converter $0.2X_0 - 2X_0$ thick (for tungsten $X_0 = 0.41\,cm$) for coherent and incoherent spectra, normalized on equal number of electrons.

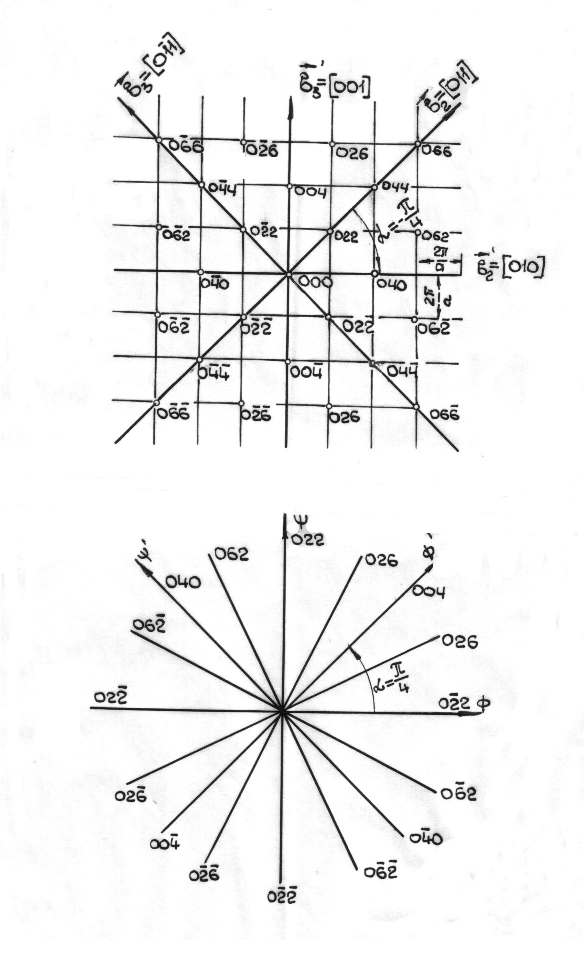

Fig.6. *Map of the crystal plane for diamond cut along the plane* (100)

As the coherent spectrum was used the theoretically calculated spectrum of the radiation when electrons with energy $200\,MeV$ move near axis $\langle 110\rangle$ of diamond crystal $0.3\,mm$ thick. This calculation has shown strong increasing of radiation intensity at low photon energies. Thus, at $\sim 3\,MeV$ it almost 10 times exceeds intensity of electron radiation in the amorphous matter of the same thickness.

Expected relation of intensities of electron gamma radiation in oriented and disorientated crystal that will be registered by the gamma monitor, is $\sim 2-2.5$ and it does not depend on the converter thickness. For this ratio increasing, that it is very importantly for orientation procedure, the monitor must be more sensible to the low energy part of the photon spectrum, $\leq 20\,MeV$, that is to the region of the coherent spectrum maximum.

At total photon beam intensity $\sim 10^7\gamma/sec$ even at the thin converter ($\sim 0.1X_0$) with efficiency of converting 0.01 expected counting rate of the monitor will be $10^4 - 10^5 counts/sec$, that is enough for the rapid measuring of the orientation dependence.

4. EXPERIMENTAL RESULTS

At first the test experiment was carried out with the electron beam energy $E_0 = 193.72\,MeV$, then it was decreased to $143.87\,MeV$. The beam current was $10\,nA$. The orientation dependencies for diamond and silicon were measured follow the above procedure and clear maxima were observed. The radiation intensity in the maxima is increased at approaching to the angles of initial orientation Φ_{v_0}, Φ_{h_0}. In Fig.7 the orientation dependence with large maximum is shown, which corresponds to the goniometer rotation angles coincide with crystal axis $\langle 001\rangle$ with direction of the electron beam. The intensity of the maximum is ~ 5 times more the intensity in disoriented crystal. Such large intensity observed, because for electron beam moving along the crystal axis, the conditions of channeling or above barrier types of electron motion are realized, and as a result intense photon radiation with low energies is produced.

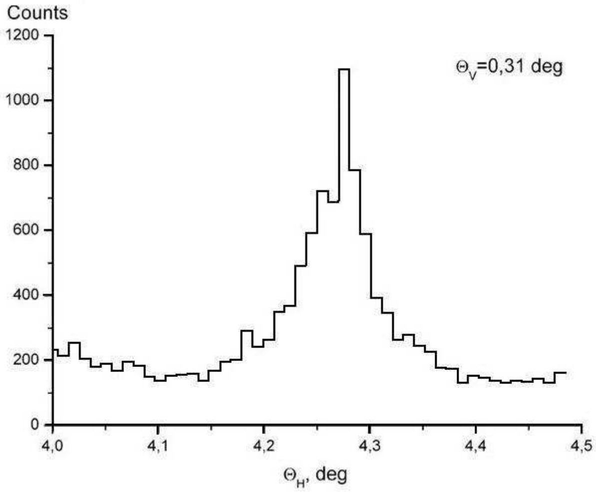

Fig.7. *Orientation dependence of the intensity of the radiation from the diamond crystal at the electron energy* $E_0 = 193.72\,MeV$

The silicon crystal was orientated by the same way. Verification of the crystals initial orientation for less electron energy $E_0 = 143.87\,MeV$ showed that the founded angles of initial orientation did not change within limits of the measurement accuracy. This indicates on repeatability of the electron beam parameters and passing it along beam line. The experimental results demonstrate on the intensive radiation that is generated by electrons at their motion near the crystalline axis, when the conditions of channeling and above-barrier electron motion are realized, even for these not large energies.

4.1. Measurement of the CB spectra

After finding of the crystals initial orientation, the CB radiations spectra measurements were performed. In this paper the results obtained with with NaI detector are presented. The measurements were carried out at electron energy $E_0 = 143.87\,MeV$ and decreased the beam current. The NaI detector with sizes $25 \times 25 \times 25\,cm^3$ was placed in the experimental hall. The photon collimator hole diameter was $12\,mm$ that corresponds to collimation angle $\theta_c \sim 0.73\theta_\gamma$.

Measurements were performed at a few crystal orientations that answered positions of the CB maximum in the range of energies $10-40\,MeV$. Results of the measurements when the energy of CB maximum was $E_{\gamma,p} \sim 18$ and $28\,MeV$ ($x_d = E_{\gamma,p}/E_0 \sim 0.1$ and 0.2) are shown in Fig.8. The spectra are normalized on the bremsstrahlung spectrum of electrons in amorphous Al target.

5. CONCLUSIONS

Measured spectrum (Fig.8.) has all characteristics of the CB spectrum: maximum with sharp upper side and smooth reduction toward the low energies. Value of the coherent effect β_{max} is enough large and grows from $\beta_{max} \sim 1.9$ to ~ 2.2 at changing the peak energy from 28 to $18\,MeV$. These values are in agreement with results of previous [1,7,8] calculations and corresponds to polarization of radiation in the CB maximum 30%. The calculation of the CB spectrum with code [6] and our experimental results are in good agreement.

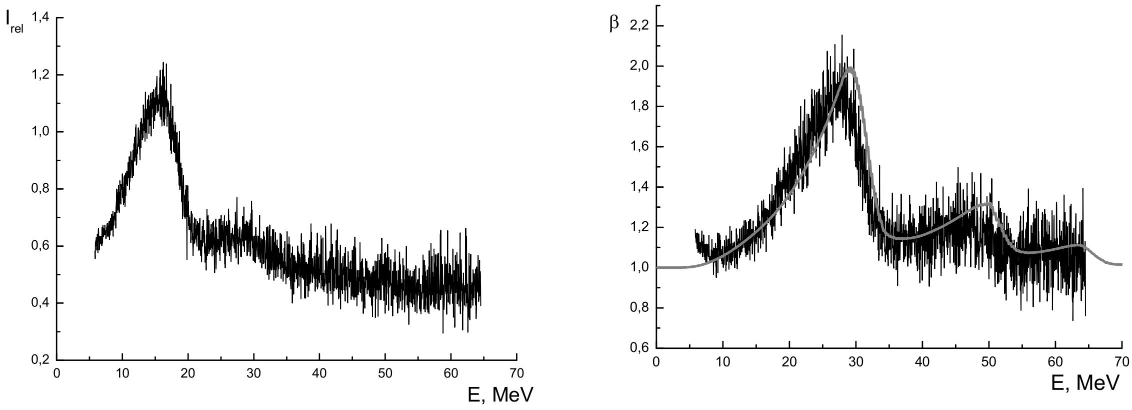

Fig.8. *Spectra of the CB from diamond crystal by thickness* $0.1\,mm$. *Collimation angle* $\theta_c \sim 0.73\theta_\gamma$. *Electron energy is* $143.9\,MeV$. *The curve is calculated with code [6]*

It is possible to expect substantial increasing of the polarization and coherent effect at stronger collimation of gamma radiation, $\theta_c \sim 0.5\theta_\gamma$ and increasing the energy of electron beam up to $250\,MeV$. This will allow one to get the CB beam parameters which are needed for using it for nuclear physics experiments in energy range from 10 and up to $100\,MeV$. Thus, the proposed method of the crystal orientation proved well itself and showed its possibility of using at the MAX-lab conditions. The test measurements have shown that the CB beam at MAX-lab was produced and the previous computations were confirmed experimentally.

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СОЗДАНИЕ ЛИНЕЙНО ПОЛЯРИЗОВАННОГО ПУЧКА ФОТОНОВ В ЛАБОРАТОРИИ MAX-LAB

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Измерены спектры когерентного тормозного излучения с кристалла алмаза в лаборатории MAX-lab на ускорителе MAX-I при энергии электронного пучка 144 *МэВ*. Впервые в лаборатории MAX-lab был создан источник поляризованного фотонного излучения. Полученные спектры были сравнены с теоретически рассчитанными, что позволяет оценить величину поляризации фотонов как достаточную для проведения ядерных экспериментов в области промежуточных энергий.

СТВОРЕННЯ ЛІНІЙНО ПОЛЯРИЗОВАНОГО ПУЧКА ФОТОНІВ В ЛАБОРАТОРІЇ MAX-LAB

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Виміряні спектри когерентного гальмівного випромінювання з кристала алмаза в лабораторії MAX-lab на прискорювачі MAX-I при енергії електронного пучка 144 *МеВ*. Вперше в лабораторії MAX-lab було створено джерело поляризованого фотонного випромінювання. Отримані спектри були порівняні з теоретично розрахованими, що дозволяє оцінити величину поляризації фотонів як достатню для проведення ядерних експериментів в області проміжних енергій.