# EXPECTED COHERENT BREMSSTRAHLUNG PHOTON BEAM PARAMETERS AT THE S-DALINAC

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Expected spectra and polarization of the coherent bremsstrahlung photon beam that can be created at S-DALINAC was calculated using the Uberall-Diambrini theory. Photon beam parameters are convenient for carrying out experiments on photon scattering and nuclear photodisintegration in the giant resonance region with polarized photons.

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## 1. INTRODUCTION

Coherent bremsstrahlung radiation (CB) generated by relativistic electrons in monocrystal photon targets made from diamond crystals, having a high Debay temperature, perfect crystal lattice and small atomic number, offer the most high operating parameters, and due to this they findwide use in experiments of nuclear physics and elementary particles [1]. In consequence of the periodicity of atom location in the crystal lattice, when relativistic electrons fall onto the crystal at a small angle $\psi$ relative to the crystal axes, (but exceeding substantially a critical angle of axial channeling, $\psi >> \psi_c$,) in the CB spectra the interference maxima appear. The radiation intensity in these maxima substantially exceeds the electron radiation intensity in an amorphous material and the radiation in the maximum possesses a significant linear polarization.

The spectrum and polarization of CB are well described by the theory based on the Born approximation [2-4]. According to [2-4] the CB cross section can be presented in the form of a sum:

$$d\sigma_{kti} = d\sigma_{int} + d\sigma_{am},$$

where $d\sigma_{int}$ is the interference part of CB cross section depending on the crystal orientation relatively to the electron beam; $d\sigma_{am}$ is the non-coherent part of cross section, which does not depend on the crystal orientation and presents itself a cross section of usual bremsstrahlung in the amorphous substance. Thus CB spectrum consists of two parts: coherent part with interference maximuma and usual bremsstrahlung. The interference peak has a sharp upper border and is reduced slowly in the low-energy area. The radiation intensity in the interference peak falls with increasing angle $\psi$, and the peak itself is displaced in the higher energy range and at larger $\psi$ it is not observed.

CB beams on the base of diamond crystal were obtained practically at all electron accelerators with a beam energy of $E_0$~1 GeV and higher [1]. However, there are sufficient number of accelerators at which is conducted studies of nuclear structure and mechanisms of photonuclear reactions in the low-energy range (before the threshold of pion production) and with the significantly lower energy, $E_0$~100 MeV. Photonuclear studies on such setups, as a rule, are conducted on nonpolarized beams of bremsstrahlung or tagged photons, while the presence of radiation polarization often opens more possibilities for investigations. Great advantages of accelerators of such a class are unique electron beam parameters, first of all the high intensity that allows conducting precise experiments.

We have studied a possibility of making the beam of linear polarized photons on the base of CB electrons in the diamond crystal at the accelerator with the initial electron energy $E_0$=100 MeV suitable for investigations in the area of giant dipole resonance. As an example considered the beam parameters, which can be get at the accelerator S-DALINAC [5], which have such main electron beam parameters:

- electron energy $E_0$=20-100 MeV;
- maximal intensity of the electron beam –20 μA;
- duty factor –100%.

## 2. RESULTS

For evaluation of the CB beam quality and possibility to use it in experimental studies, of deciding importance are two main characteristics: intensity of coherent part of the beam and value of polarization in the radiation maximum $P_\gamma$. Usually, the intensity of coherent part $I_{int}$ is evaluated by the excess of radiation intensity in the CB maximum over the intensity of non-coherent part of radiation $I_{am}$(coherent effect β):

$$\beta = (d\sigma_{int} + d\sigma_{am})/d\sigma_{am} = (I_{int} + I_{am})/I_{am}.$$

For getting a beam suited to experimental investigations it is necessary to provide values of coherent effect and polarization not less than ~1.4 and ~20%, respectively. Concrete values of these parameters substantially depend on real conditions of getting and forming the CB beam.

We have performed calculations of CB spectra and polarization for the initial electron energy $E_0$=100 MeV and diamond crystals of a thickness 0.01 and 0.03 cm with taking into account real experimental conditions: angle of multiple scattering and divergence of electron beam, collimation of gamma radiation. Crystals of such thickness are most optimal for obtaining high beam polarization. The calculations were performed for the crystal orientation, when a main contribution to the CB cross section is given only from one point of the reciprocal lattice (2,2,0). The given orientation ensures the highest value of polarization.

Fig. 1 presents the calculation results for spectrum and polarization of CB electrons of the initial energy


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$E_0$=100 MeV in the diamond crystal of the thickness 0.01 cm at the energy of interference maximum $E_\gamma^p$=20 MeV (relative energy $X=E_\gamma/E_0=0.2$) for values of radiation collimation angle in the interval $\theta_c=0.25\text{-}2\theta_\gamma$ ($\theta_\gamma=mc^2/E_0$, m-electron mass). It is seen that for the initial electron energy $E_0$=100 MeV the spectrum and polarization keep yet all particularities inherent to CB, observed under the higher energy $E_0 \geq 1$ GeV. Results of the calculation show that both a coherent effect and polarization in the CB maximum substantially depend on the angle of radiation collimation and can reach sufficiently high values.

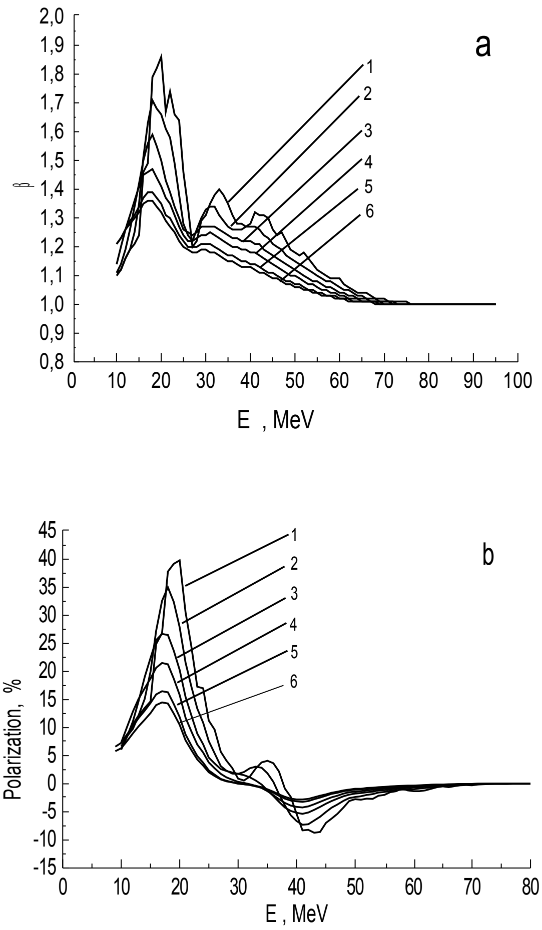


***Fig. 1**. Spectra (a) and polarization (b) of CB electrons with $E_0$=100 MeV in the crystal of the thickness 0.01 cm at energy interference maximum $E_\gamma^p$=20 MeV and radiation angles collimation (1)-0.25, (2)-0.5, (3)-0.75, (4)-1, (5)-1.5, (6)- 2$\theta_\gamma$.*

In Fig. 2 the value of coherent effect and polarization in the CB maximum is shown as a function of radiation collimation for crystals of the thickness 0.01 and 0.03 cm. The value of coherent effect decreases from $\beta\approx$ 1.85 to $\beta\approx1.34$ at collimation angle changing from $\theta_c=0.25\theta_\gamma$ to $2\theta_\gamma$, the polarization at that decreases from $P_\gamma\approx40\%$ to 14%. During further increasing the collimation angle the coherent effect and polarization practically do not change. For the crystal of the thickness 0.03 cm the values of coherent effect and polarization decrease within 2-10%. The calculations results allow to conclude that for getting a CB beam suitable for use in experimental investigations at accelerators with the initial energy $E_0$~100 MeV, a very strong radiation collimation within $\theta_c\approx0.25\text{-}0.5\theta_\gamma$ is required. Decreasing of intensity of the gamma beam may be in some cases compensated by increasing the photon target thickness.

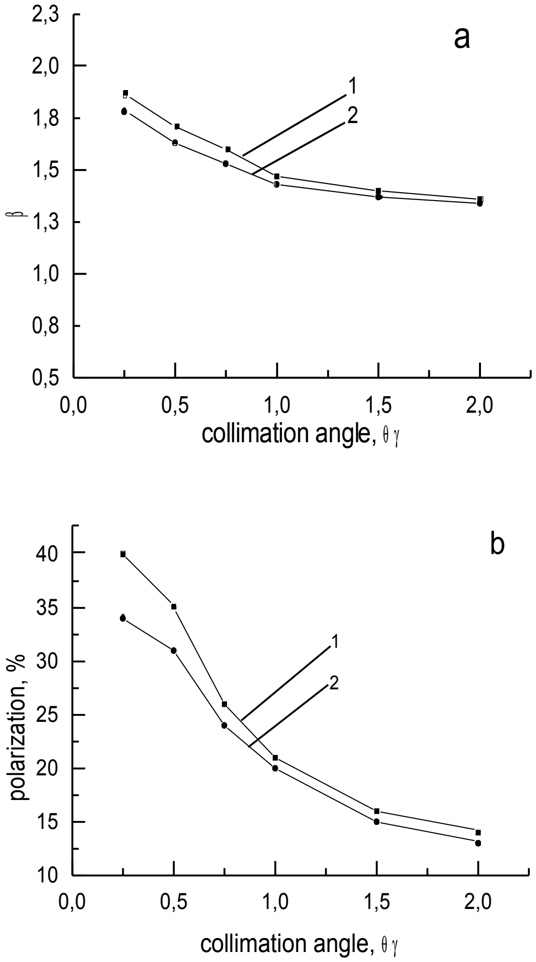


***Fig. 2**. The value of coherent effect (a) and polarization (b) versus radiation collimation for $E_\gamma^p$=20 MeV and crystals thickness 0.01 cm (1) and 0.03 cm (2).*

In Fig. 3 the results of calculation of the energy dependence of coherent effect and polarization are given at collimation angles $\theta_c=0.5\theta_\gamma$ for the crystal of thickness 0.01 cm. It is seen that the values of coherent effect and polarization increase to $\beta\approx2.2$ and $P_\gamma\approx45\%$ at $E_\gamma$=10 MeV and decrease to $\beta\approx1.4$ and $P_\gamma\approx20\%$ at $E_\gamma$=35 MeV so the collimation provides acceptable parameters of CB beam for photonuclear investigations within the photon energy range from 5 to 35 MeV. At the collimation angle $\theta_c\approx\theta_\gamma$ this range decreases to 20 MeV.

To evaluate the intensity of CB radiation at the given collimation we calculated the intensity of a usual bremsstrahlung under these conditions (electron energy $E_0$=100 MeV, thickness of diamond 0.01 cm, collimation angle $\theta_c=0.5\theta_\gamma$), which practically is equivalent to non-coherent part of CB. At the electron current of 1 μA the expected flux of bremsstrahlung gamma-quanta of the energy $E_\gamma$=20 MeV is about $dN/dE_\gamma \approx 8.9\cdot10^7$ γ/MeV/s. Taking into account the coherent effect ($\beta\approx1.7$) the CB intensity of the given energy and current increase up to $dN/dE_\gamma\approx1.5\cdot10^8$ γ/MeV/s. If the electron current at the accelerator S-DALIINAC reach value 20 μA thus, it is hoped for getting intensive beams of linear polarized CB photons up to $dN/dE_\gamma\approx3\cdot10^9$ γ/MeV/s at $E_\gamma$=20 MeV with which one can carry out investigations of widespread

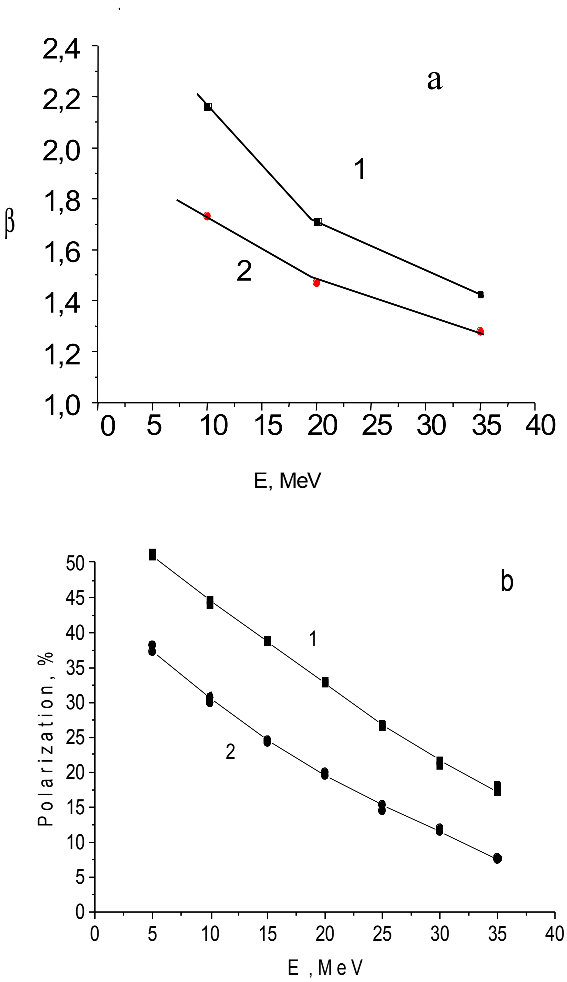


***Fig. 3**. Energy dependence of coherent effect (a) and polarization (b) of CB for the crystal of the thickness 0.01 cm at radiation collimation angles $\theta_c=0.5\theta_\gamma$ (1) and $\theta_c=\underline{\theta_\gamma}$ (2).*

photonuclear reactions in the range of the giant dipole resonance (GDR), in particular on the elastic and non-elastic photon scattering on nuclei. Cross sections of these processes in the GDR region are sufficiently great. So, the cross section of the elastic scattering on $^{28}$Si for the scattering angle $135^0$ in the interval $E_\gamma$=18-22 MeV is ~14 μb so tagged photon beam may be used [6,7]. With the increase of atomic number an elastic scattering cross section increases and, for example, for $^{208}$Pb at $E_\gamma$=20 MeV and at the scattering angle $120^0$ is already 200 μb [8]. The great cross sections do such investigations quite real. The expected reaction yield for experimental conditions provided in works [7,8] with the use of polarized CB photons at the electron current 10 μA equals ~27 count/s for [6] and ~9 count/s for [7]. More precise estimations should be made for each concrete experiment.

## REFERENCES

1. G.D. Kovalenko, L.Ya. Kolesnikov, A.L. Rubashkin. Topics in Current Physics 38. *Coherent Radiation Sources. Coherent Bremsstrachlung-Experiment. P. 33-60.* Springer-Verlag Berlin Heidelerg, 1985.
2. G. Diamrini. High-energy bremsstrachlung and electron pair production thin crystals // *Rev. Mod. Phys*. 1968, v. 40, p. 611-623.
3. U. Timm. *Coherent bremsstrahlung of electrons in crystals*. Preprint DESY, 69/14, 1969.
4. M.L Ter-Mickaelyan. *Influence of a medium on electromagnetic processes at high energies*. Yerevan: Izd. AS Arm. SSR. 1969, 457 p. (in Russian).
5. H. Genz, H.-D. Graf, J. Horn, K.D. Hummel, M. Knirsch, C. Luttge, A. Richter, T. Rietdorf, K. Ruhl, P. Schardt, E. Spamer, A. Stiller, F. Thomas, O. Titze, J. Topper, H. Weise. *Operational experience and results from the S-DALINAC.* Proceedings of the third European particle accelerator conference, EPAC 92, Berlin, 24-28 March, 1992, v. 1, p. 49-51.
6. S.F. LeBrun, A. M.Nathan,, S.D. Hoblit. *Photon scattering in giant dipole resonance region of $^{16}$O.* University of Illinois at Urbana champaing nuclear physics laboratory department of physics. Preprint P/87/2/28.
7. R. Alarkon, A. M.Nathan, S.F. LeBrun, S.D. Hoblit. *Photon scattering in giant resonance region of $^{24}$Mg, $^{28}$Si and $^{32}$S.* University of Illinois at Urbana champaing nuclear physics laboratory department of physics. Preprint P/88/9/130.
8. K.P. Schelhaas, J.M. Henneberg, M. Sanzone-Arenhover, N. Wieloch-Laufenberg, U. Zurmuhl, B. Ziegler, M. Schumacher and F. Wolf Nuclear photon scattering by $^{208}$Pb // *Nucl. Phys.* 1988, v. A489, p. 189-224.