Polarization Radiation in a Teflon Target

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Abstract. Contribution of Cherenkov radiation and Diffraction radiation when electrons are moving close to a dielectric prism for different angles of the prism face in respect to the electron beam direction was experimentally investigated. The comparison of experimental results with calculations using the known theoretical model shows the significant discrepancy in angular dependence for different orientation angles. The experimental analysis of the causes of discrepancy was performed. The experiment was performed on the relativistic electron beam with energy 6.2 MeV in Tomsk Polytechnic University.

1. Introduction
In [1] the characteristics of Cherenkov radiation (ChR) from the Teflon triangular prism surface, which is in parallel to the relativistic electron beam, and diffraction radiation (DR) from the upstream surface of prism, when electrons are moving close to the prism were experimentally investigated. In this paper we present recent investigations on the nature of these types of radiation, focusing on the radiation from the prism surface nearest to the electron beam. Namely, have studied the angular distribution of the radiation for different values of the angle $\psi$ (see figure 1) by rotating the prism around the vertical axis. As it will be shown later, the structure of this radiation is rather complicated. To exclude the DR contribution from the upstream surface of the target (see [1]), the surface was covered by an absorber.

![Figure 1. Principle of the measurement.](image_url)

This configuration allows us to investigate the radiation emitted only from the surface nearest to the electron beam.
2. Experimental set-up and procedure

The experiment was carried out in the extracted electron beam of the Physical and Technical Institute of Tomsk Polytechnic University microtron with beam parameters presented in Table 1. The beam is extracted from the vacuum chamber through a 50 $\mu$m thick beryllium foil.

| Table 1. Electron beam parameters. |
|-------------------------------------|
| Electron energy               | 6.1 MeV ($\gamma = 12$) |
| Train duration                | $\tau \approx 4 \mu$sec |
| Bunches in a train            | $n_b \approx 1.6 \cdot 10^4$ |
| Bunch period                  | 380 psec |
| Bunch population             | $N_e = 6 \cdot 10^8$ |
| Bunch length                  | $\sigma \approx 1.9\sim 2.4$ mm |

The radiation was measured using a room-temperature detector based on the antenna with low-threshold diode, produced by Tomsk Semi-conductive Devices Institute (Russia). The high frequency limit of the wavelength interval is limited both by the spectral efficiency of the detector and by the bunch form-factor due to the coherency of radiation ($\lambda_{\text{min}} \approx 9$ mm for $\sigma \approx 2.2$ mm). In figure 2 is shown the instrumental electron bunch pseudo-photon spectrum measured using this detector in circuit of the interferometer, which is placed directly on the electron beam.

![Figure 2. The instrumental electron bunch pseudo-photon spectrum.](image)

To exclude the prewave zone effect [2] a parabolic telescope (see figure 4) was used for the angular distribution measurement. This method was suggested and tested in [3] and gives the same angular distribution as in the far field zone ($R \gg \gamma^2 \lambda$). The layout of experimental set-up is shown in figure 3. The target used in the experiment is a triangular prism made out of Teflon with dimensions of 175x175x74 mm. The target was placed at a distance of 220 mm from the extraction window; the distance from the target to the electron beam (impact parameter) was 20 mm. The refractive index of Teflon target was $n = 1.41 \pm 0.1$ in the wavelength range from 10 to 30 mm. To keep the same impact-parameter the target was rotated around the point a for the positive angle $\psi$ (see figure 3), and around the point b for negative values of $\psi$ (see insertion in figure 3).
3. Measurements
The intensity of the Coherent radiation was measured by displacing the detector along the angle $\theta$ for different values of angle $\psi$. The angular distribution obtained for $\psi = 0$ is shown in figure 4.

In the next paragraph we will consider the position and the intensity of the peak of the radiation angular distribution for each value of angle $\psi$. 

Figure 3. Experimental layout including the radiation monitor for the negative angle $\psi$.

Figure 4. Angular distribution of the coherent radiation for $\psi = 0$. 
In figure 5 the measured coherent radiation intensity is shown as red circles for different values of angle $\psi$.

ChR is defined as the result of interference of radiation, induced by the electron field in target, from different points of electron trajectory. So, if the electron trajectory is screened, like it is shown in figure 6, the contribution of the ChR in the total radiation should be excluded. The absorber on the copper screen was used to avoid multiple reflections of radiation from screen and target surface.

**Figure 5.** Peak intensity for different values of angle $\psi$.

**Figure 6.** Experimental layout showing the screening of the Cherenkov radiation.
The result of the measurements taken in these conditions is shown in figure 5 by square points (DR). The filled area depicts the part of DR intensity in the total radiation assuming the simple approach of sum of radiation intensities.

4. Discussion
In order to compare the measurements with theory, let's use the polarization currents method, developed in [4]. The calculations for these experimental conditions, normalized to the experimental radiation intensity acquired for \( \psi = 0 \) are depicted in figure 5 by solid line (Theory). We see a good agreement of the theoretical calculations with experimental data for \( \psi < 0 \). However, in the case of \( \psi > 0 \) a large discrepancy is observed. A possible cause of the discrepancy can be proposed by considering in more detail the second part of experiment, where ChR is screened by copper screen. We will use the pseudo-photons viewpoint for analyses of an interaction of the relativistic electron electromagnetic field with matter. The "pseudo-photon" method proposed by Fermi [5] and developed by Williams [6] is widely used for theoretical studies of electromagnetic processes (see for instance [7] and [8]). According to this approach, the field of a charged particle may be replaced by a field of photons, which in this case are called pseudo-photons (in [9] is used the term "virtual quanta"; this term should differ from the term "virtual quanta" in quantum mechanics). This approach provides a good accuracy for the ultra-relativistic particles when the particle velocity is close to the light velocity \( (v_p \approx c) \) (see [7]) and when the longitudinal electric field component of the particle is negligible. In this case the particle field has the same properties as the field of real photons. According to the pseudo-photons viewpoint, the electron field, cutted by the copper screen, will continue to propagate as real photons. It corresponds to the DR in traditional notion. Further this DR will be refracted on the target surface and propagate as a usual radiation. So, the total radiation consist from ChR and DR. Unfortunately we can not use the simple subtraction of DR from total radiation due to interference between these types of radiation, but we see that qualitatively this difference may be close to the theoretical curve.

Finally we can conclude, that in calculations using the model of polarization currents, DR is not taken into account.

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