TRANSITION RADIATION DETECTOR WHICH USED DIHEDRAL ANGLE AS RADIATOR

A.V.Koltsov and A.V.Serov. P.N.Lebedev Physical Institute RAS

Abstract

The spatial distribution of the field of transition radiation generated by a relativistic particle flying into a dihedral angle formed by perfectly conducting plane surfaces is determined. The angular distributions of radiation intensity in dihedral angles of different values are calculated. It has been shown that the dependence of the angular distributions of radiation intensity in a dihedral angle on the energy and on the direction of motion of particles is stronger than a similar dependence in the case of transition radiation on a plane interface.

Transition radiation possesses certain properties that make this radiation useful for solving various problems [1]. One of the simplest and important particular cases in the theory of transition radiation is the radiation generated when a particle is incident on a perfectly conducting plane. This problem was considered in the first paper by Ginzburg and Frank on the theory of transition radiation [2]. They pointed out that the transition radiation on a perfectly conducting plane can be considered as radiation from two particles: a real particle with charge q and its image with charge $-q$.

The study of radiation on dihedral angle has shown that the spectral-angular distributions of radiation in this case exhibit new features that enhance the applicability of transition radiation. The properties of transition radiation generated when a particle passes through a dihedral angle have been investigated both theoretically [3-5] and experimentally [6].

In the present paper, we consider the specific features of transition radiation in a dihedral angle that enhance the applicability of this transition radiation to the measurement of the parameters of charged particles.

The geometry of the problem is shown in Fig.1. Let us introduce a cylindrical system of coordinates (ρ,φ,z).

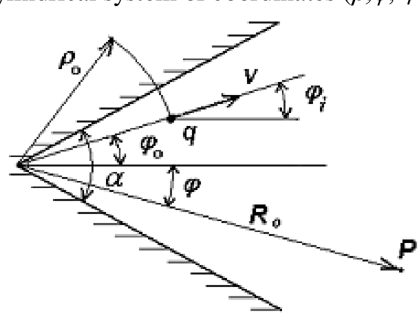

Figure1: Geometry of the problem.

The value of the dihedral angle is α. The z-axis is directed along the edge of the dihedral angle, and the planes that form the dihedral angle coincide with the planes $\varphi = \alpha/2$. The charged particle with charge q flies out from a point (ρ_0,φ_0) on the edge of dihedral angle and moves at constant velocity v. The velocity vector of the particle lies in the plane z=0 and is directed at an angle φ_t.

In this paper the method of images is used to describe transition radiation. Fig.2 illustrates the dispositions and velocity vectors of real and additional charges in dihedral angles of $\alpha = \pi/2$ and $\alpha = \pi/3$. The dihedral angles are shown in Fig.2 by solid lines, while the complementary angles are shown by dashed lines. The original charge q_1 moves on dihedral angle and additional image charges move on complementary angles.

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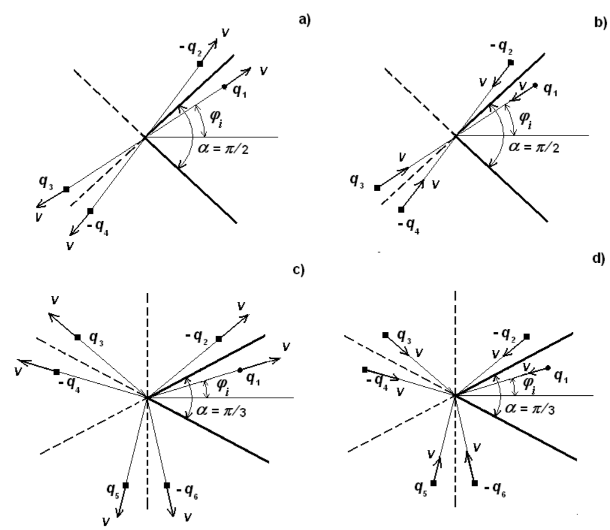

Figure2: The disposition and the velocity vector of the given and additional charges in dihedral angles of $\alpha = \pi/2$ and $\alpha = \pi/3$.

In the case of a dihedral angle of $\alpha = \pi/n$, where $n=0,1,2..$, Fourier component of the field of transition radiation can be expressed as

$$E_\omega = \frac{q\,v}{2\pi}\,\frac{\exp(-ikR_o)}{R_o}\sum_{i=0}^{n-1}\Big[\frac{\sin(\varphi-\varphi_t-2j\alpha)}{1-\beta\cos(\varphi-\varphi_t-2j\alpha)}\times \exp(ik\rho_o\cos(\varphi-\varphi_t-2j\alpha)) - \frac{\sin(\varphi+\varphi_t-(2j-1)\alpha)}{1-\beta\cos(\varphi+\varphi_t-(2j-1)\alpha)}\times \exp(ik\rho_o\cos(\varphi+\varphi_t-(2j-1)\alpha))\Big] \qquad (1)$$

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where $k=2\pi/\lambda$, λ - wave length.

The angular distribution of the radiation intensity in the plane $z=0$ has been considered. Fig.3 shows the distributions of intensity for various values of the dihedral angle. Particles are injected along the bisector of the dihedral angle. One can see that decrease of α up to value $\alpha=\pi/\gamma$ leads to increase of maximum of the intensity. Further decrease of α causes intensity reduces.

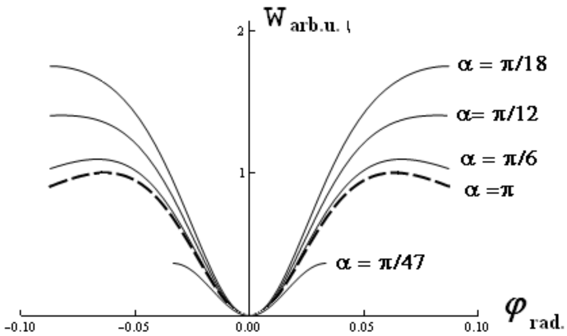

Figure3: Angular distribution of radiation intensity for various α. Particles with energy $\gamma=15$ are injected along the bisector of dihedral angle.

The impact of shifting the injection point along one of the conducting plane surfaces and change of angle of injection on angular distribution of radiation intensity has been investigated. The results of calculations are presented in Fig.4. Distributions have been calculated for different α. For all pictures dashed lines are used for distributions for $\alpha=\pi$, thin lines – for $\alpha=\pi/3$ and thick lines – for $\alpha=\pi/6$.

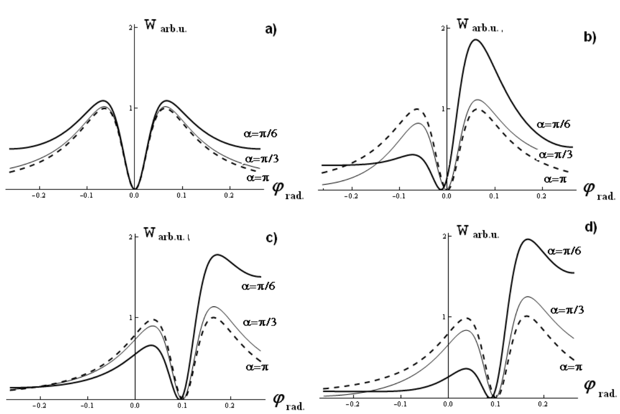

Figure4: Angular distribution of radiation intensity as function of φ for various directions of injection, injection points and α. $\rho_0=0$; a) $d=0$, $\varphi_i=0$; b) $d/\lambda=0.5$, $\varphi_i=0$; c) $d=0$, $\varphi_i=0.1$; d)) $d/\lambda=0.5$, $\varphi_i=0.1$.

It can be seen that shifting the injection point leads to asymmetry of angular distribution. Increase of sensibility caused by using of dihedral angle is explained by field in the dihedral angle is formed as a result of interference of radiation fields of many particles (real particle and its images).

To determine particles parameters pickup where transition radiation intensity is measured in two directions can be used. Pickup scheme is shown in the upper left corner of the Fig.5. Indicators D_1 and D_2 measure radiation lengthwise both sides of the dihedral angle. Difference between D_1 and D_2 values characterises shifting of injection point. In Fig.5 dependence of $\Delta W=W_1 - W_2$ on shifting value d for different α is presented.

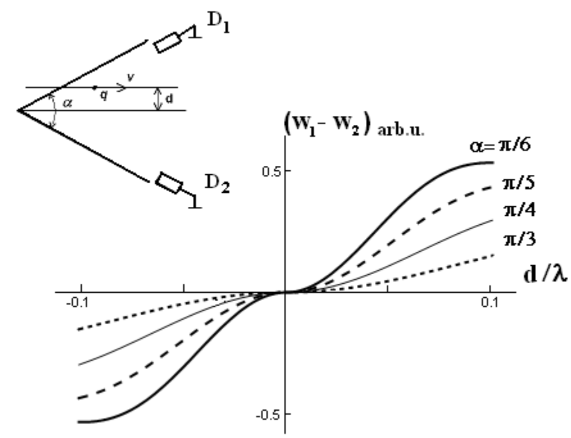

Figure5: Dependence of radiation intensities difference along sides of the dihedral angle W_1-W_2 on shifting d of injection point.

Let us mention one more property of transition radiation in a dihedral angle. For this purpose angular distributions of radiation for two cases should be compared: when the particle injects out of dihedral angle and when the particle falls on the dihedral angle. Let's particle trajectory is directed under angle $\varphi_i\neq 0$. In Fig.6 dependence $W=f(\varphi)$ for angles $\alpha=\pi, \pi/2, \pi/3, \pi/4$ is presented. In Fig.6a distributions of radiation intensities when the particle injects out of dihedral angle and in Fig. 6b - when it falls on the dihedral angle are demonstrated.

In both cases particles move under $\varphi_i=0.3$. It can be seen in the figures that change of angle α impacts to the angular distribution of radiation intensity differently.

When a particle injects out of the boundary surface of the dihedral angle, decrease of the angle increases asymmetry of distribution relatively to particle movement direction (Fig. 6a), but for any α radiation is concentrated under angles close to a trajectory of the particle.

Change of the dihedral angle has qualitatively other influence on angular distribution in a case when the particle falls on the boundary surface. For angles $\alpha=\pi/n$, corresponding to even n, distributions of radiation when the particle injects out of the boundary surface and when the particle falls on this surface coincide (dependences for $\alpha=\pi/2$ and for $\alpha=\pi/4$ are in Fig. 6a and Fig. 6b). For odd n - angular distributions of injecting out and falling particles are symmetric relatively to a bisector of the dihedral angle $\varphi=0$ (curves for $\alpha=\pi$ and $\alpha=\pi/3$ are in Fig. 6a and Fig. 6b).

To explain such feature of angular distribution of intensity of the transition radiation of the particle calculation schemes using a method of images should be considered (Fig. 2).

Remember that the relativistic particle at start and at stop radiates mainly in a direction its movement in an interval of angles $\Delta\varphi=\pm\gamma^{-1}$. Therefore when particle starts main contribution to a field of radiation of the dihedral angle is given by the real charge q_1 (Fig. 2a and Fig. 2c), and when the particle falls – by the image charge. For $\alpha=\pi/2$ the image charge is q_3 (Fig.2b), and for $\alpha=\pi/3$ the image charge is $-q_4$ (Fig.2d).

It can be seen in figures that for $\alpha=\pi/2$, i.e. when n is even, trajectories of the real charge q_1 and of the image charge q_3 are situated on one straight line, even when $\varphi_t\neq 0$. Therefore both at a start and at stop radiation is concentrated under angles close to a trajectory of the real charge.

For odd n, when $\varphi_t\neq 0$, value of the angle between trajectories of the real charge and the image charge is $2\varphi_t$. Therefore radiation is concentrated under angles $\varphi\approx-\varphi_t$, i.e. close to the trajectory of the image charge. Angular distribution of radiation of the particle injecting out of the dihedral angle and the particle falling on the dihedral angle will be mirror - symmetric.

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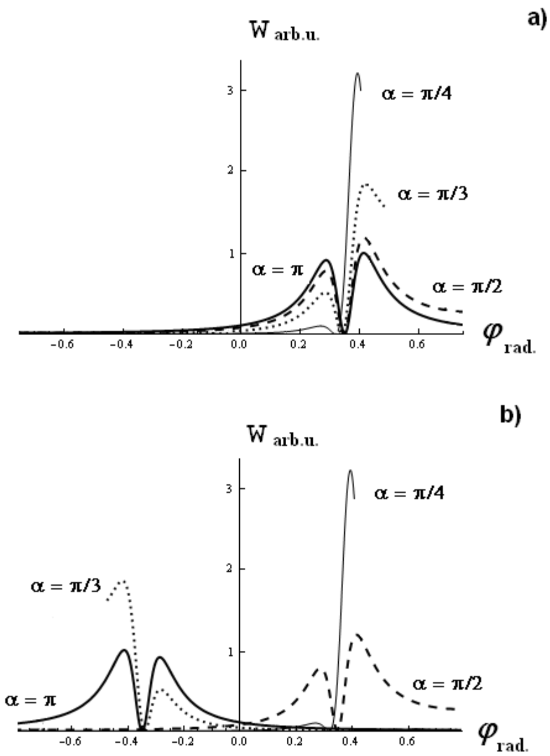

Figure6: Angular distributions of radiation intensities for particles injecting out of (a) and falling to (b) the dihedral angle.