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V.N.Strel'tsov

THE CHERENKOV BREMSSTRAHLUNG

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Introduction. The opinion that the Cherenkov radiation, the transition radiation, and the radiation in gas below Cherenkov threshold are varieties of one phenomenon has been expressed earlier [1]. This non-bremsstrahlung is conditioned by the «velocity part» of the electromagnetic field of a relativistic charge. The forward direction of the radiation reflects the corresponding direction of the «accompaniment field» (see, e.g., [2]). Remind that the expressions for the electromagnetic field strengths of a moving charge consist of two parts. The first («velocity») part depends only on velocity and does not depend on acceleration; the second («acceleration») part that is proportional to acceleration describes the bremsstrahlung.

The Poynting vector of the «velocity part» of the electromagnetic field of a charge moving with speed takes the form [1]

$$S_v(\theta) = \frac{e^2\beta c}{4\pi n^4 R^4} \frac{\sin\theta(1-\beta n\cos\theta-\beta^2 n^2)^{1/2}}{\gamma_n^4(1-\beta n\cos\theta)^6}. \qquad (1)$$

Here θ is the angle between the directions of charge e motion and the radius-vector $\mathbf{R}$ of retarded distance, n is the refractive index of medium, $\gamma_n = (1-\beta^2 n^2)^{-1/2}$. Remark that the initial formulae for the Lienard-Wiechert potentials in medium

$$\varphi = \frac{e}{n^2 R(1-\beta n\cos\theta)}, \quad \mathbf{A} = \frac{e\beta}{nR(1-\beta n\cos\theta)} \qquad (2)$$

define in fact the behaviour of the formation length of radiation (see, e.g., [3]). Based on (1) at large velocities for radiation intensity to a solid angle element, we have

$$W_v \cong \frac{e^2 c}{4\pi n^4 R^2} \frac{\sin\theta\,(1-n+n^2)^{1/2}}{\gamma_n^4(1-\beta n\cos\theta)^6}. \qquad (3)$$

In general, the «velocity radiation» is considerably weaker than the bremsstrahlug due to the field «acceleration part». Their ratio is proportional to

$$a_a^v \sim \frac{c^4\gamma_n^{-4}}{n^3(Rw)^2\sin\theta}, \qquad (4)$$

where w is the charge acceleration. As is seen, the energy flux of the field «velocity part» substantially diminished with distance and with Lorentz-factor growth. However, when the «Cherenkov radiation condition»

$$\sec\theta = \beta n \tag{5}$$

is fulfilled, the retardation factor $\kappa = 1 - \beta n \cos\theta$ and at the same time the denominators in the previous formulae vanish. As a result, the radiation intensity that was named Cherenkov one increases very strongly. One can say, in other words, that the Cherenkov radiation is the consequence of the extreme increase of the energy density of the electromagnetic field «velocity part».

The «Cherenkov bremsstrahlung». On the other hand, the bremsstrahlung intensity to an element of solid angle, when the velocity and acceleration are parallel, is described by the formula

$$W_b = \frac{e^2}{4\pi n c^3} \frac{w^2 \sin^2\theta}{(1 - \beta n \cos\theta)^6} \,. \tag{6}$$

When the condition (5) is fulfilled, this term also increases sharply. One can say that we have its way of the Cherenkov bremsstrahlung (CB) here. As far as one can judge, this phenomenon has been observed in the experiment [4] recently. In the very general case we have another («mixed») term side by side with (3) and (6).

At the same time the energy loss for Cherenkov radiation by a uniformly moving charge is evidently accompanied by its braking that leads to the appearance of the field «acceleration part» and consequently to the «induced» CB.

Besides that, note that the own parameters of a light wave should change as the light velocity in medium decreases* and equals $c_n = c/n$; e.g., its period increases and is $T_n = nT$, i.e., a shift to the red side of the spectrum occurs. This reminds of the known gravitational red shift. For this eq . (3) can be obtained on the besis of the Lorentz-like transformation

$$x^0 = (x^0_* + \beta n x^1_*)\gamma_n \,, \quad x^1 = (x^1_* + \beta n x^0_*)\gamma_n \,, \tag{7}$$

where $x^0 = cnt$, of the Coulomb potential $\varphi^* = e/n^2 R^*$ to a moving system.

Conclusion. The fulfilment of «Cherenkov condition» (5) leads to the vanishing of the retardation factor, and therefore to an extreme growth of the field «velocity part» of a moving charge. It is the Cherenkow radiation «itself».

* Due to electromagnetic interaction.

For the same reason the term answering the field «acceleration part» should increase. In other words, in its way the Cherenkov bremsstrahlung takes place.

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Стрельцов В.Н. Д2-95-75
Тормозное излучение Черенкова

Обращение в нуль «фактора запаздывания» ведет к значительному росту интенсивности «скоростной части» электромагнитного поля движущегося заряда, физическим следствием чего является черенковское излучение. Та же причина обуславливает рост и другого слагаемого: «ускорительной части» поля, что вызывает «тормозное излучение Черенкова».

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 1995

Strel'tsov V.N. D2-95-75
The Cherenkov Bremsstrahlung

The vanishing of the «retardation factor» leads to a significant growth of the intensity of the electromagnetic field «velocity part» of the moving charge. The Cherenkov radiation is its physical consequence. The same reason also conditions the growth of another term: the «acceleration part» of the field which gives rise to the «Cherenkov bremsstrahlung».

The investigation has been performed at the Laboratory of High Energies, JINR.

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