BREMSSTRANLUNG EMISSION OF A BUNCH OF ULTRARELATIVISTIC CHARGED PARTICLES MOVING THROUGH A THICK TARGET.

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Abstract: The theory of radiation emission a bunch of non-interacting classical-fast charged particles which are scattered elastically by atoms of the amorphous matter is developed for the first time. The spectral distribution of the energy of bremsstrahlung of this particles is obtained in the case when the particles fly into the medium along the same direction. It is shown that the presence more than a one irradiating particle leads to the essential changes of the spectrum of bremsstrahlung in the matter. In particular there is at least one maximum of the spectral distribution of the bremsstrahlung energy in contradiction to the situation of an individual irradiating particle [1-3].

Problem: At the time moment $t=0$ a bunch of non-interacting between themselves classical-fast ($E \gg \omega$ -radiation frequency) ultrarelativistic ($E \gg m$) charged particles (E, m, e are the energy, the mass and the value of the charge of the particle, $\hbar = c = 1$) is flying into the semi-infinite homogeneous scattering matter with the velocity $\vec{\vartheta}_0$. The particles are situated on the plane which is perpendicular to the $\vec{\vartheta}_0$ direction (the direction of Z axis) at this moment. Their coordinates are equal to $\vec{R}_1, \vec{R}_2, \dots, \vec{R}_N$; N is the quantity of the irradiating particles; T is a target thickness. We consider that the characteristic longitudinal size of the bunch is a small as compered with the thickness of a target.

To obtain the spectral density of the energy of bremsstrahlung $d\varepsilon_\omega/d\omega$ in the matter which may be observed experimentally it is necessary to average well known expression for the emission energy $dE_\omega/d\omega$ [1-3] over all trajectories of the particles in the scattering medium. As it is shown in the paper [4] the averaging is reduced to the calculation of the, Fourier component over coordinates $\vec{r}_\alpha$, $\vec{r}_\beta$ of the particles of two-time distribution function $F_{\vec{k}}(\vec{\vartheta}_\mu, \vec{\vartheta}_\nu, t, \tau)$ [4] ($\vec{\vartheta}_\mu$, $\vec{\vartheta}_\nu$ are the particles velocities) in the case when the multiple elastic collisions of the ultrarelativistic charged particles with the chaotic situated atoms of the matter take place. On averaging $dE_\omega/d\omega$ with the $F_{\vec{k}}(\vec{\vartheta}_\mu, \vec{\vartheta}_\nu, t, \tau)$ and integrating obtained expression after that over all emission angles we get the spectral distribution of the bremsstrahlung emission of the set of the classical-fast charged particles in the scattering matter.

Results: If the longitudinal size of the bunch of the particles is such that the inequality $\min |(\vec{d}_{\alpha\beta})_z| \gg \max\{\omega^{-1}; \tau\}$ (τ is the characteristic time of the formation of the emission quantum in the scattering medium; $|\vec{d}_{\alpha\beta}| = |\vec{R}_\alpha - \vec{R}_\beta|$ is the distance between two particles at the initial time moment) takes place then the spectral distribution of bremsstrahlung is the oscillation function of the radiation frequency. But the oscillation amplitude is differed from the value of the emission energy of N independent irradiating particles [3] very small.

In the another extreme case $\tau^{-1} \cdot \min\{|(\vec{d}_{\alpha\beta})_z|\} \ll \xi^2 = (m/E)^2 \ll 1$ the spectral distribution of bremsstrahlung has a maximum. Moreover one is a single. The physical reason of its existence is following. The particles of the bunch irradiate more coherent than the frequency ω is smaller. On the other hand the value of the $d\varepsilon_\omega/d\omega$ of the individual irradiating particle decreases with decreasing of the ω [3]. The presence of the two contrary tendencies at the $d\varepsilon_\omega/d\omega$ dependence on the frequency ω leads to the appearance of the maximum of the spectral distribution of bremsstrahlung of the set of the non-interacting particles in the matter as compared with the case of the individual irradiating particle [1-3], when the $d\varepsilon_\omega/d\omega$ is the monotonous function of the radiation frequency.

The analysis of the situation $\tau^{-1} \cdot \min|(\vec{d}_{\alpha\beta})_z| \ll \xi^2 \ll 1$ gives. The maximum of the bremsstrahlung spectrum is always situated at the $\omega \geq q\xi^{-4}$ (q is the average square of a multiple scattering angle along the path unit) . If $q\xi^{-3} \cdot |\vec{d}_{\alpha\beta}|_{min} \gg 1$ then $\omega_{max} \cong q\xi^{-4}$ but $d\varepsilon_\omega/d\omega \cong (d\varepsilon_\omega/d\omega)_{B.-H.}$ ($(d\varepsilon_\omega/d\omega)_{B.-H.}$ is the emission energy of an ultrarelativistic particle which is scattered by the isolated centre of the matter [1-3]).

At the $q\xi^{-3}|\vec{d}_{\alpha\beta}|_{max} \leq \xi(qT)^{-1/2} \ll 1$ the frequency ω_{max} is equal to the $q\cdot\xi^{-4}$ as before and quotient $(d\varepsilon_\omega/d\omega)_{max} : (d\varepsilon_\omega/d\omega)_{B.-H.}$ is N (the particles quantity).

In the case $q\xi^{-3}\cdot|\vec{d}_{\alpha\beta}|_{max} \ll \xi(qT)^{-1/2}$ the maximum of the spectral distribution has a form of the plate with the width is equal to $\Gamma \cong (qT)^{-1/2} / |\vec{d}_{\alpha\beta}|_{min}$. The quotient $(d\varepsilon_\omega/d\omega)_{max} : (d\varepsilon_\omega/d\omega)_{B.-H.}$ is approximately N.

References.

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