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G.M. GARIBIAN, L.A. VARDANYAN, C. YANG

THE INFLUENCE OF MULTIPLE SCATTERING  
ON RADIATION PRODUCED IN METALLIC  
GRANULES

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ВЛИЯНИЕ МНОГОКРАТНОГО РАССЕЙЯНИЯ НА ОБРАЗОВАНИЕ  
ИЗЛУЧЕНИЯ В МЕТАЛЛИЧЕСКИХ ГРАНУЛАХ

А Н Н О Т А Ц И Я

Согласно работе [1] при прохождении заряженной частицы через малые оловянные гранулы наблюдается квадратичная зависимость интенсивности рентгеновского переходного излучения от лоренц-фактора заряда. Это явление авторы указанной работы объясняют влиянием многократного рассеяния заряда. В настоящей работе вычислена интенсивность рентгеновского переходного излучения с учетом многократного рассеяния и показано, что в условиях эксперимента [1] влияние многократного рассеяния не может привести к квадратичной зависимости.

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For consideration of high energy elementary particle detectors Drukier et al.<sup>1)</sup> recently have performed an experiment realizing the interesting idea of using superheated superconducting tin granules for generation and detection of X-ray transition radiation (XTR). For this purpose a wax cylinder 3 mm in diameter and 10 mm long was uniformly filled by spherical granules of radii  $r \approx 2.5 \mu\text{m}$  (in another sample  $r \approx 1.7 \mu\text{m}$ ). The filling factor of the granules was  $\sim 10\%$ .

One may show that there were about  $10^8$  granules in the sample with a distance between the centers of the granules  $\sim 9 \mu\text{m}$  and a particle passing through the cylinder in direction parallel to its axis was intersecting in average  $\sim 300$  granules. Therefore, instead of granules one can consider the passage of the particle through 300 tin plates with  $\sim 30 \mu\text{m}$  distance between each other.

However, it is necessary to take into account that the passage of a charged particle through a sphere is equivalent to the passage through a plate only in the case<sup>2)</sup> when  $c\gamma/\omega \ll r$  ( $\gamma$  is the Lorentz-factor). This condition means that the dimension of the field Fourier component with frequency  $\omega$  must be much less than the sphere radius. For  $\omega$  equal to 10 keV one obtains  $\gamma \ll 10^5$ . Let us also note that from the point of view

of XTR production as well as absorption it is quite all the same are tin granules in normal or superconducting state.

Taking into account the wax and tin absorption coefficients one may show that the photons with energies  $\approx 10$  keV will be absorbed in tin while the photons with energies  $\approx 100$  keV will escape from cylinder without being absorbed. Therefore one may roughly assume that XTR photons in the energy interval from 10 to 100 keV will be absorbed in tin granules.

A change in the resonance frequency of an LC-circuit in which the cylinder was placed has been observed in Ref. <sup>1)</sup> when a fast electron passed through the sample. This frequency change may be conditioned by the XTR absorption in the granules as a result of which some granules turn to normal state. According to <sup>1)</sup> at  $\gamma \approx 4 \cdot 10^3$  this resonance frequency change depends on  $\gamma$  linearly while in the region  $\gamma \sim 10^4$  this dependence is quadratic. The authors of the work <sup>1)</sup> assume that such a quadratic  $\gamma$  dependence is conditioned by the multiple scattering effect on XTR production.

In order to verify this assumption let us calculate the radiation spectrum produced by a fast particle in a tin plate with a thickness, for instance,  $3 \mu\text{m}$ . Let the plate is in vacuum. In comparison with the real condition we does not take into account the wax medium and assume that the radiation in various plates (granules) takes place independently each from other. As the estimates of the formation zone length in wax show this last assumption is reasonable while the former one results in the fact that the number of quanta as well as their

$\gamma$  dependence will be somewhat overestimated.

One can take into account the multiple scattering effect using the method of Migdal's kinetic equation<sup>3,4)</sup>. For the case of semiinfinite medium this is done in the work<sup>5)</sup> (see also<sup>6)</sup>). The formula for the frequency spectrum of the total radiation produced by an ultra-relativistic charge in a plate averaged over all the possible trajectories is derived in Ref.<sup>7)</sup> (formula (30)). With the help on this formula we have carried out numerical calculation.

In Fig. 1 the thin solid curves present the total radiation. The dashed curves correspond to bremsstrahlung produced on  $3 \mu\text{m}$  length in infinite medium<sup>3)</sup>. The thick solid curves are the difference of these curves, i.e. the total boundary effect of radiation consisting of transition radiation and boundary effect of bremsstrahlung. The dotted curves correspond to the usual transition radiation (without taking into account the multiple scattering effect) produced in a plate<sup>3)</sup>. In the frequency region  $\omega \approx 40$  keV the thin and thick solid curves as well as dotted curves coincide, i.e. the total radiation in a plate coincides with the transition radiation and the latter gives the total boundary effect of radiation.

The curve 1 in Fig.2 is obtained by numerical integration of the total radiation spectra (see Fig.1) in the frequency region  $10 \div 100$  keV. The  $\gamma$  dependence of this curve can be approximated as  $\gamma^{0.48}$  (in the region  $\gamma = 10^3 \div 10^4$ ). Since in the work<sup>1)</sup> it is measured just the total radiation produced and absorbed in granules one cannot explain the observed  $\gamma$

dependence by the multiple scattering effect on XTR production.

For illustration of the properties of the total boundary effect in Fig. 2 it is also given the curve 2 obtained by numerical integration of the spectra of Fig.1 for the total boundary effect of radiation in a significantly much larger frequency interval, namely from 10 to  $10^5$  keV. It is seen that in the region  $\gamma = 10^3 \pm 10^4$  this curve has a linear dependence while in the region of larger  $\gamma$  this dependence gradually becomes quadratic.

#### Figure Captions

- Fig. 1. Computed differential spectra of radiation produced in a tin plate with a thickness of  $3 \mu\text{m}$  for various of  $\gamma$ -factor (the numbers on the curves).
- Fig. 2. Dependence of the total energy of radiation in the region  $10 \pm 100$  keV produced in a tin plate with a thickness of  $3 \mu\text{m}$  on  $\gamma$ -factor (curve 1). The same dependence for the total boundary effect of radiation (curve 2).

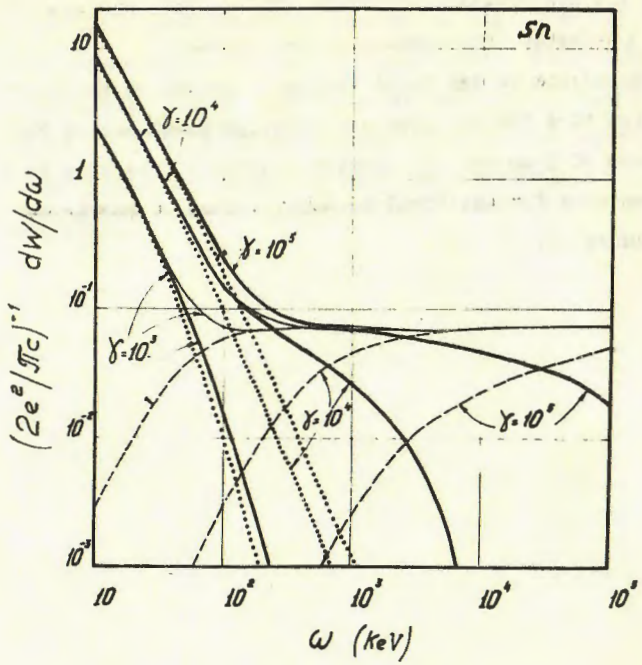


Fig.1

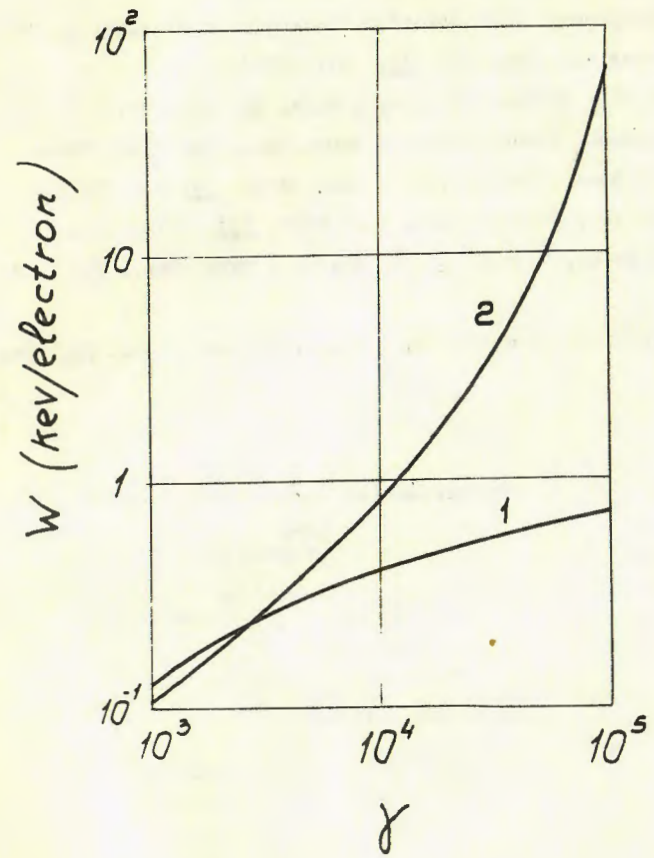


Fig.2

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ИЗЛУЧЕНИЯ В МЕТАЛЛИЧЕСКИХ ГРАНУЛАХ  
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