Alpic R. Mkrtchyan

Levon Sh. Grigoryan

Hrant F. Khachatryan

Institute of Applied Problems in Physics Yerevan

Radiation

from varying velocity charge

in flight through a plate

Table of contents

1. Introduction

2. Formulation of the problem

3. Numerical results and comments

4. Conclusions

1.

In the presence of matter a charged particle emits electromagnetic waves even when it moves **uniformly and rectilinearly**: CR, TR, etc.

This phenomenon is widely used in practice..

That is why

2.

when one studies the influence of matter on radiation from the charged particle

the motion of a particle is usually assumed to be uniform and rectilinear.

Furthermore,

the results obtained in this approximation are **in good agreement with the experimental data.**

The purpose of our report is to investigate the cases when such approximation is incorrect, and therefore one has take into account the non-uniformity of particle motion.
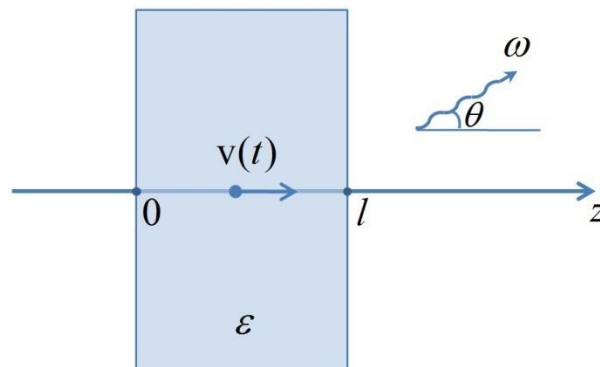
In 1951 there were derived general expressions for the electromagnetic field of a charged particle moving in an arbitrary way in a continuous and homogeneous medium.

In the 60's a similar problem has been solved in the presence of two plane-parallel interfaces between three media with different dielectric constants.

However, the impact of the non-uniformity of particle motion on Cherenkov radiation from a particle hadn't been studied in these investigations. **Our report is intended to fill this gap**.
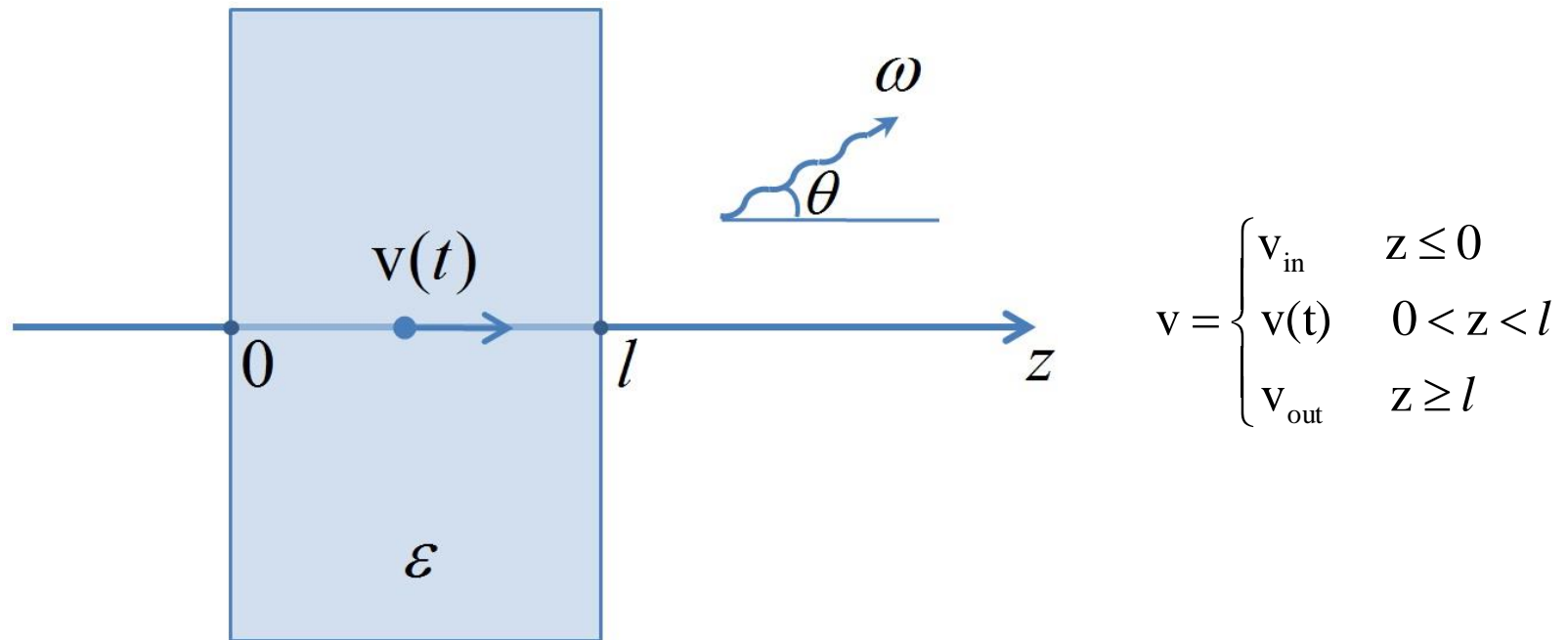
The purpose of our work is:

to investigate the impact of non-uniformity of a particle motion on radiation generated by the particle inside the plate.
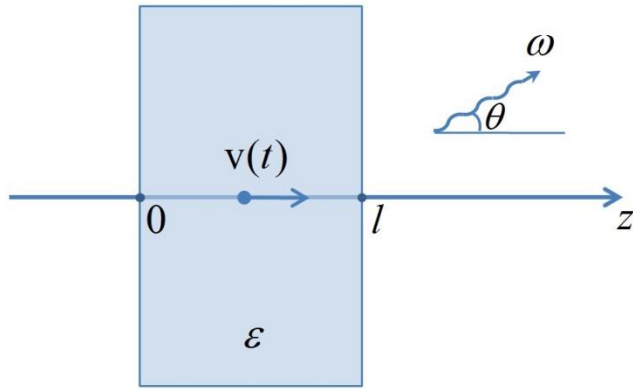
$$v = \begin{cases} v_{in} & z \leq 0 \\ v(t) & 0 < z < l \\ v_{out} & z \geq l \end{cases}$$

Consider a charged particle rectilinearly traversing a plate at variable velocity and normal to the surface.

$$v = \begin{cases} v_{in} & z \leq 0 \\ v(t) & 0 < z < l \\ v_{out} & z \geq l \end{cases}$$

A charged particle rectilinearly traversing a plate at variable velocity.

We'll assume that the dielectric permittivities of mediums on both sides of plate may be different.

Let us
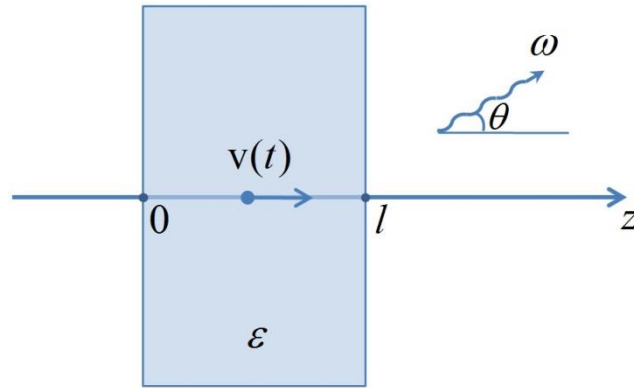a) consider the radiation from a particle in flight through a plate.
and
b) investigate the features of spectral-angular distribution of the energy

$$I_{\pm}(\omega, \theta_{\pm})$$

$$W_{\pm} = \int I_{\pm}(\omega, \theta_{\pm}) \, d\omega \, d\theta_{\pm}$$

of radiation

radiation propagating in vacuum in the forward (+) and backward (-) directions (with respect to the direction of particle motion) during the whole time of particle motion.

The formulas required for calculation of $I_{\pm}(\omega, \theta_{\pm})$

are well-known for the case uniform motion of a particle.

In our report a more realistic problem of non-uniform motion is solved with no limitations on how the velocity of particle is varying inside the plate.

The obtained **results are based on exact solutions of the corresponding Maxwell equations.**

I shall omit the final formulas for brevity.

In the case of uniform motion of particle, they lead to the well-known result which one can find, e.g., in the monograph of Gharibyan G.M.

1.

Below we shall confine ourselves to the consideration of radiation with wavelength of the order of the thickness l of plate assuming that l ranges from a fraction of a micron to millimeter and

2.

We shall consider a simplest case when the substance of plate slows down the motion of particle with a constant force:

$$F = \frac{d}{dt} \frac{m\mathrm{v}}{\sqrt{1 - \mathrm{v}^2/c^2}} = const$$

We shall also assume

a)
that the plate is made of quartz

$$\mu = 1$$

$$\varepsilon = 3.78 \cdot (1 + 0.0001i)$$

b) that the Lorentz factor of the particle at entrance into the plate is equal to 2:

$$\gamma_{in} = 2$$

$$\gamma_{out} = 1.5$$

c) that at the exit from the plate the Lorentz factor of the particle is reduced to 1.5 due to deceleration of the particle.

With this choice of parameters of the problem Cherenkov condition is satisfied:

$$\frac{c}{v(t)\sqrt{\varepsilon\mu}} < 1$$

and therefore **CR is generated during the all time of particle motion inside the plate**.

The spectral-angular distribution of the energy of total radiation from a particle passing through a such plate.
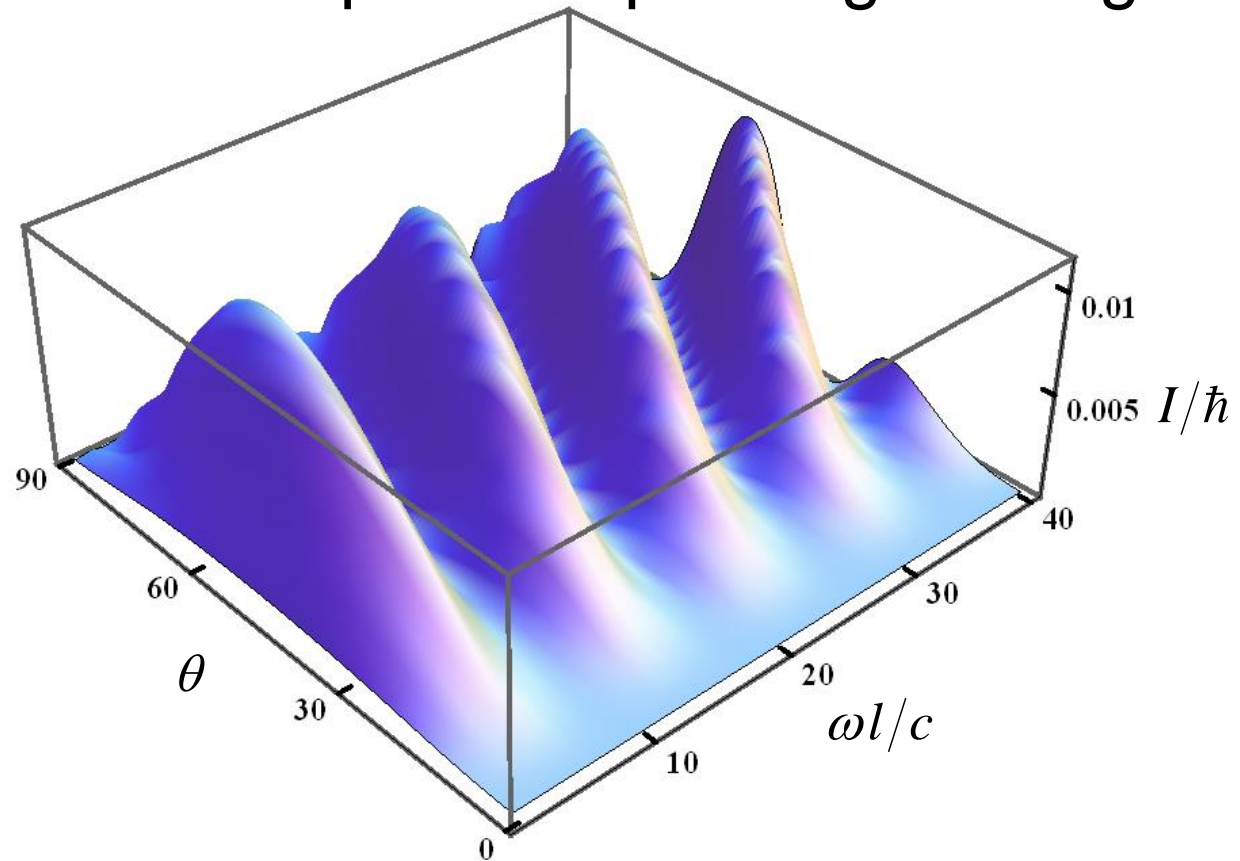
Fig. 2

It consists of CR and TR (it is generated by the particle at entrance into the plate and exit from it). In our case the contribution of TR is small.
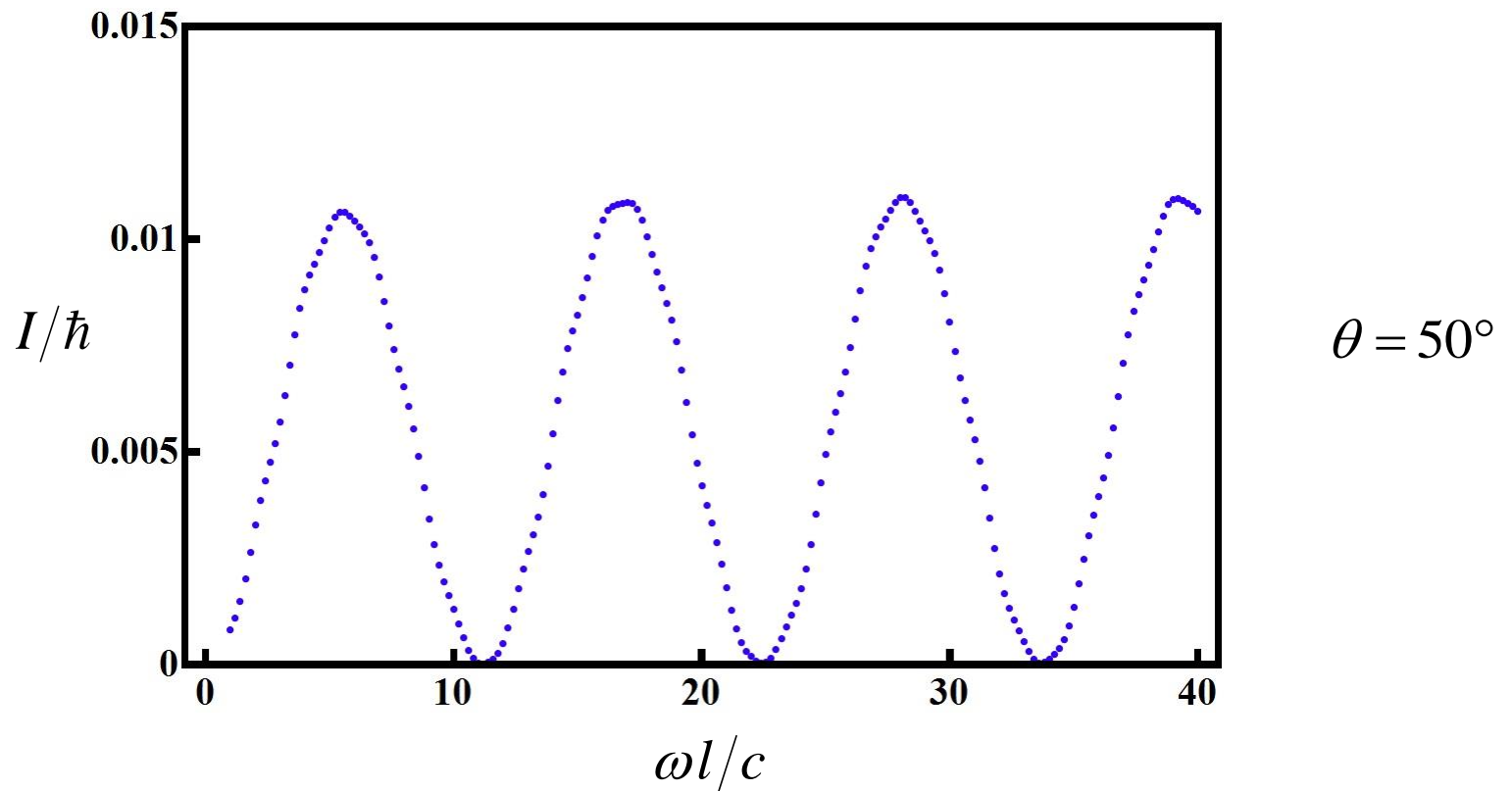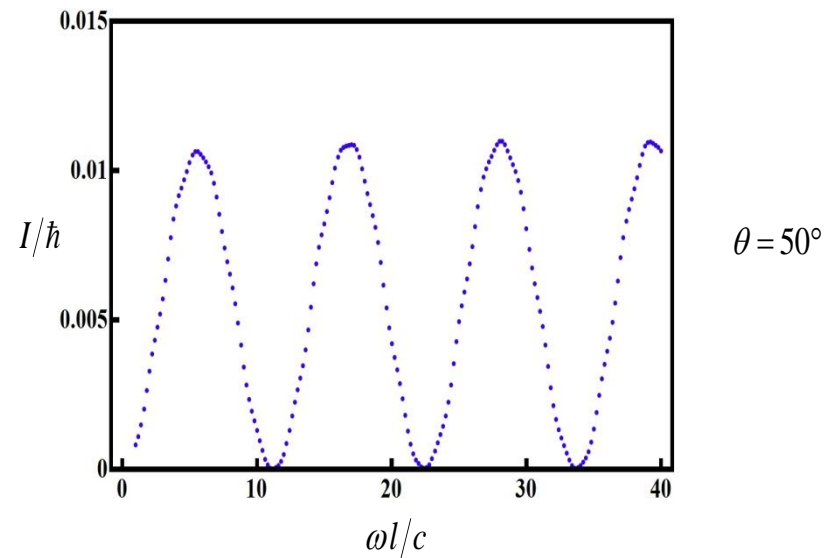
Fig. 3. The spectral distribution of the energy of radiation emitted in a given direction at the passage of an electron through the plate made of fused quartz.

$I/\hbar$ $\theta = 50°$

$\omega l/c$

Oscillations in the emission spectrum are due to the interference of electromagnetic waves. They are associated with the fact that the plate has a final thickness. For the first peak

$$\omega l/c = 5$$

Having the value of the frequency at the maximum of radiation **one can calculate the thickness of the plate** l by means of that simple formula.
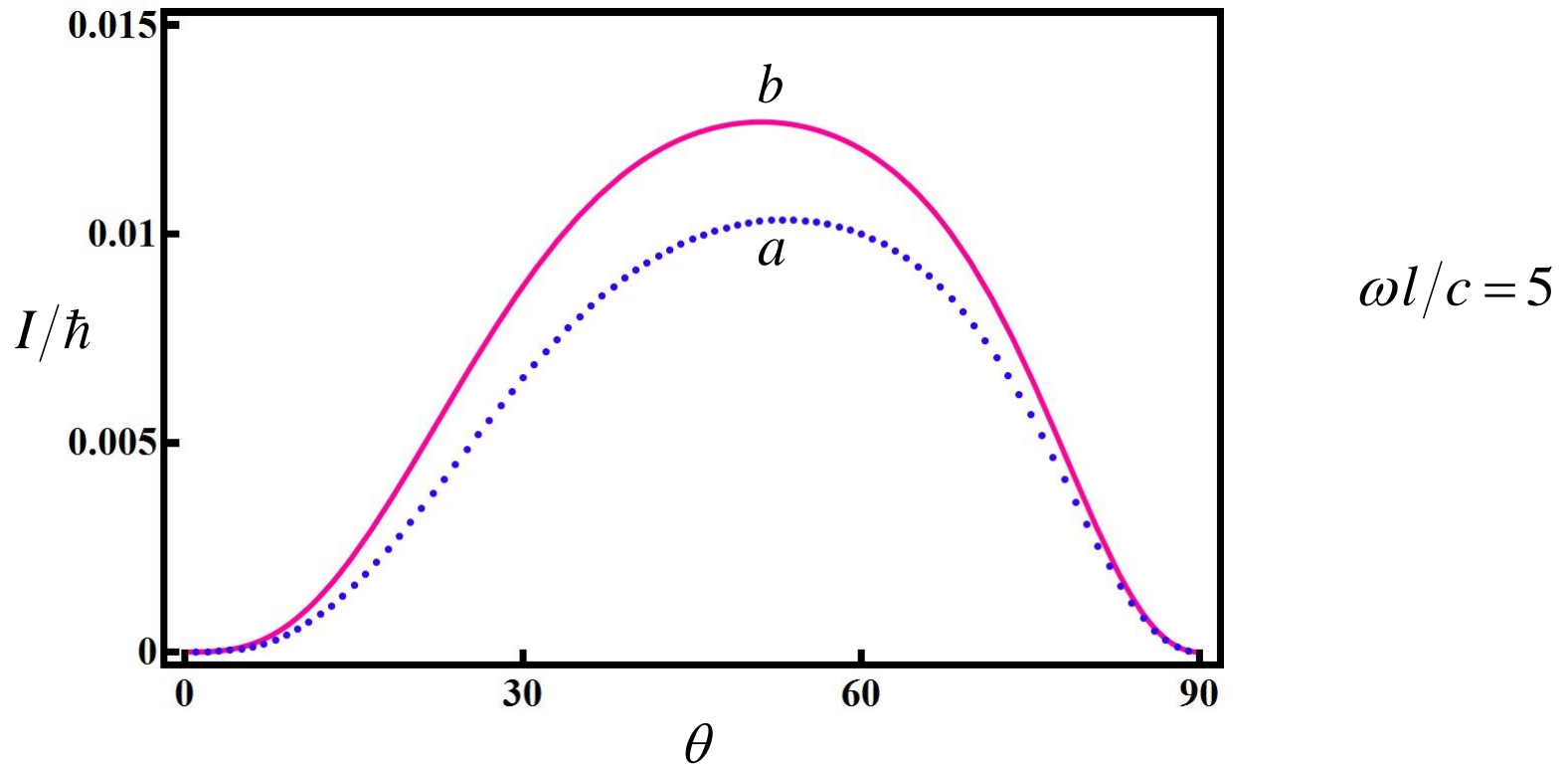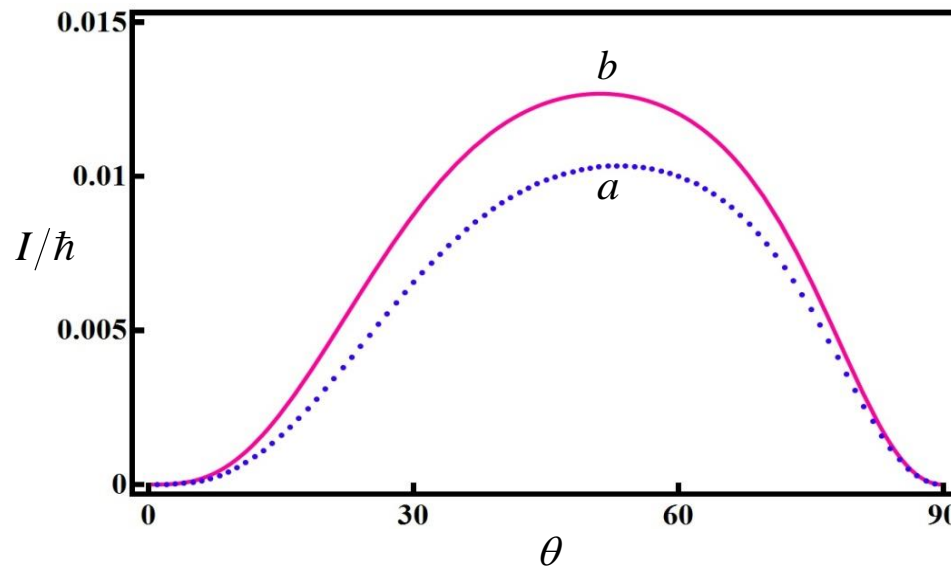
Fig. 4. The angular distribution of radiated energy emitted at given frequency during a passage of an electron through the plate with (curve *a*) and without (curve b) slowing down of the particle.

Fig.4

$I/\hbar$

$\omega l/c = 5$

θ

The energy of particle will be constant if the particle is not slowing down inside the plate:
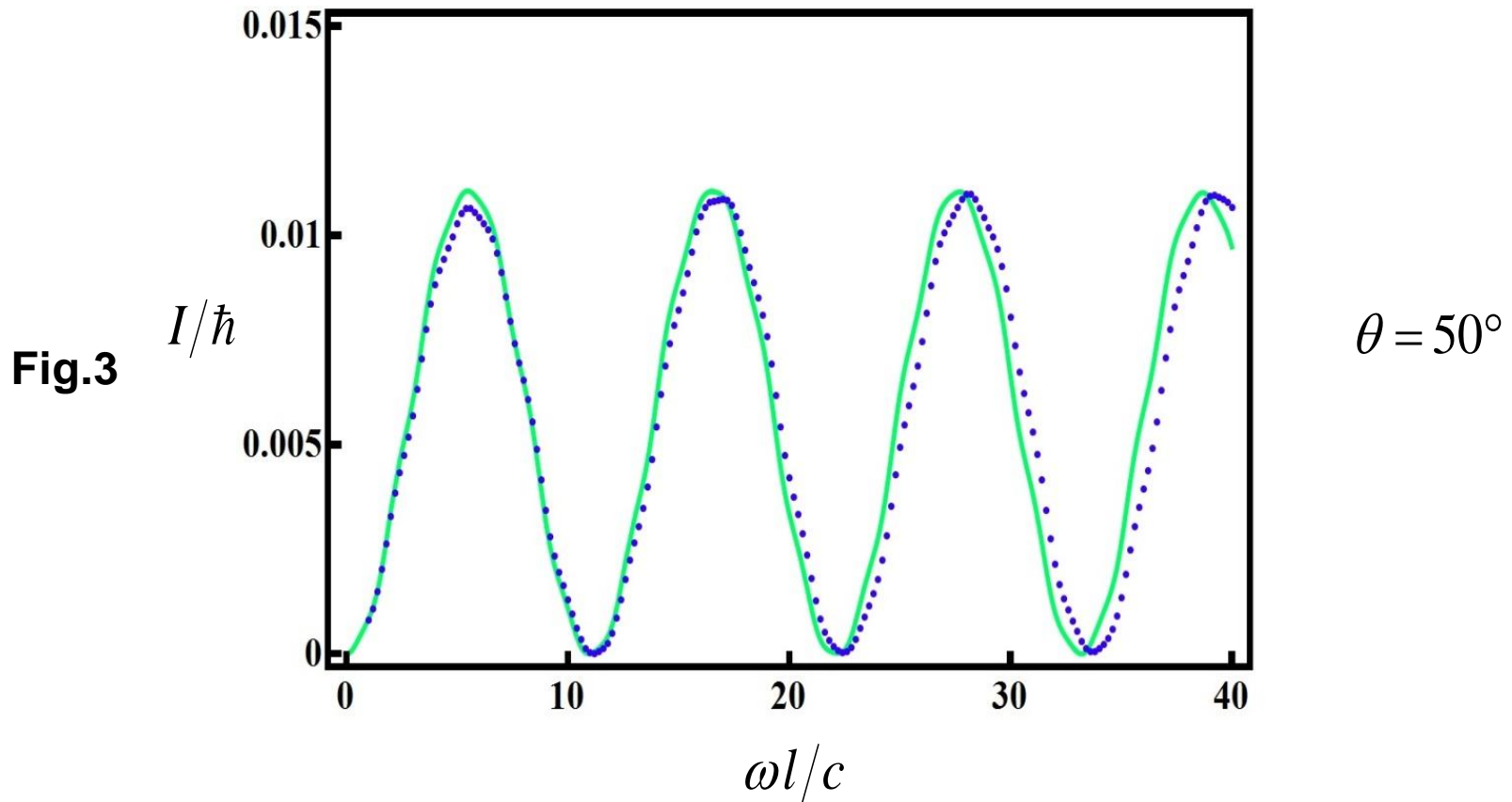
$$\gamma = const = \gamma_{in}$$

The upper curve in Fig. 4 corresponds to the that case.

Comparing curves a and b one sees that **deceleration significantly reduces the energy of radiation.**

17

Having the emission spectrum it is not difficult to determine such effective value of the energy of particle E_*

Fig.3

$I/\hbar$

$\theta = 50°$

$\omega l/c$

For which the spectrum of CR from uniformly moving particle well approximates the actual emission spectrum, in which deceleration of the particle is taken into account.

Our numerical results lead to the following natural conclusion.

The efficient value of energy is equal to the average value of the particle's energy:

$$E_* \cong (E_{in} + E_{out})/2 \qquad (1)$$

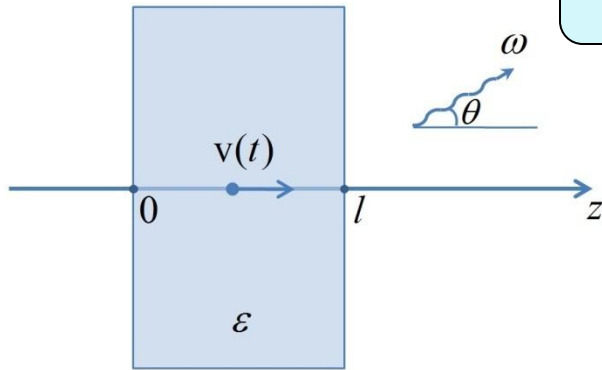Using the value of E_{in} and (1)

one can determine the energy loss of the particle conditioned by the deceleration inside the plate

$$E_{in} - E_{out}$$

and, hence,

the force braking the movement of the particle inside the plate.

$v(t)$
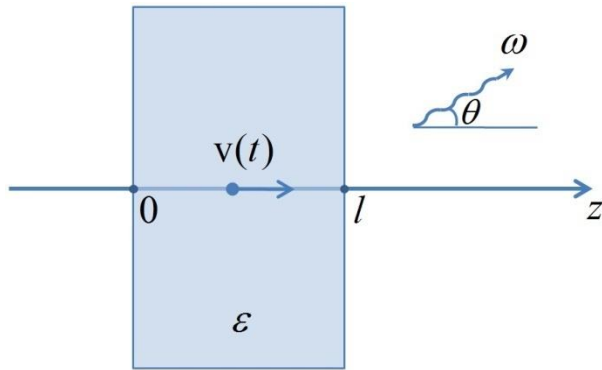
ω

θ

0 l z

ε

1.

We have determined the electromagnetic field of a particle rectilinearly traversing a plate at variable velocity and normal to the surface

with no limitations on the variation of the particle velocity inside the plate.

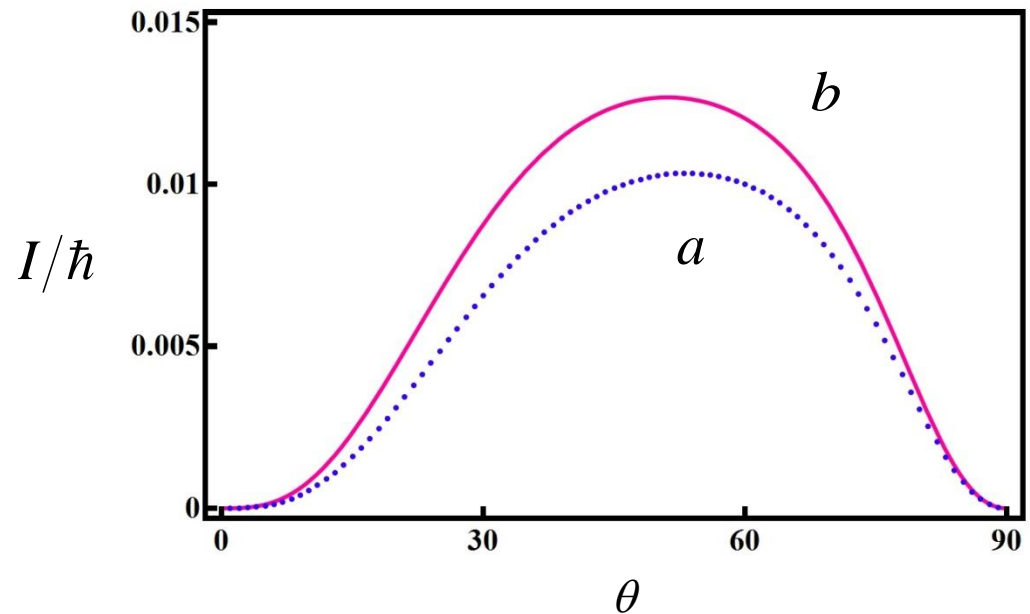$$v = \begin{cases} v_{in} & z \leq 0 \\ v(t) & 0 < z < l \\ v_{out} & z \geq l \end{cases}$$

20

$$v = \begin{cases} v_{in} & z \le 0 \\ v(t) & 0 < z < l \\ v_{out} & z \ge l \end{cases}$$

1.

Our study is based on
exact solutions of Maxwell's equations.

The expressions obtained are substantially simpler
than those following from general formulas
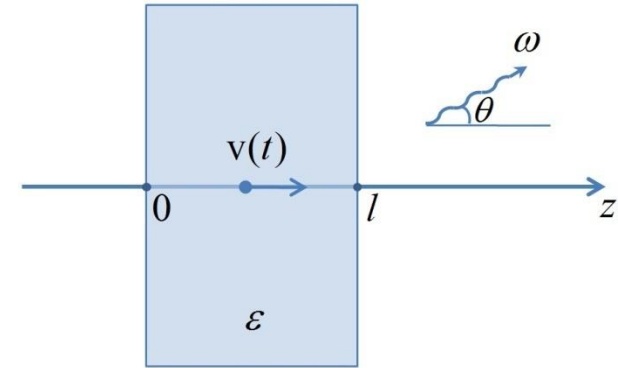well-known in scientific literature.

2.

It is shown that **the slowing-down of particles inside the plate may essentially influence** the spectral and angular distribution of radiation from the particle.
This phenomenon can be used
for **practical applications.**

For instance, one can measure
three parameters simultaneously:

a) **The force retarding the motion of particle inside a microscopic plate**

$$F = \frac{d}{dt}\frac{m\mathrm{v}}{\sqrt{1-\mathrm{v}^2/c^2}}$$

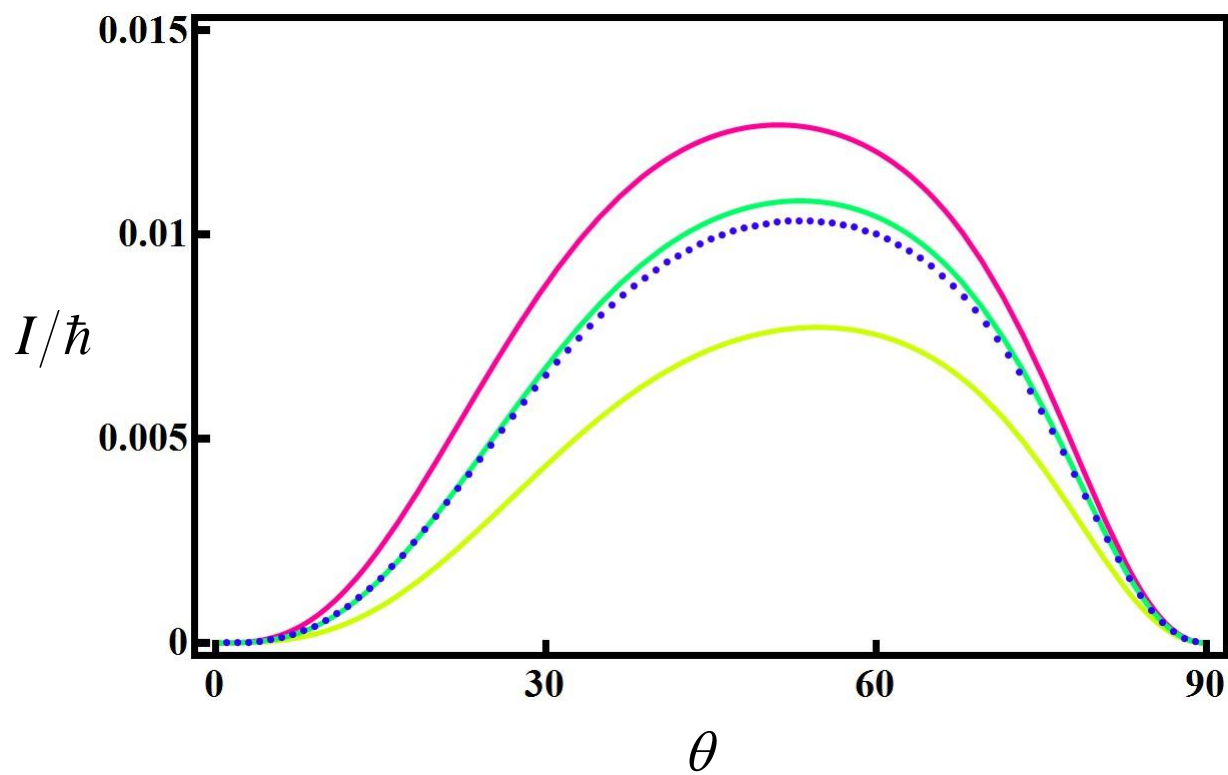b) **The thickness of microscopic plate:** l

and

c) **The refractive index of the substance of plate:**

$$\sqrt{\varepsilon\mu}$$

Thank you indeed for your attention

Levon Grigoryan

levonshg@mail.ru

$\omega l/c = 5$

$I/\hbar$

θ

25

θ

$\omega l/c$

$I/\hbar$

0.01

0.005

90

60

30

0

40

30

20

10

26