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Features of Radiation from a Charged Particle Flying Through a Ball of a Dispersive Material

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International collaboration

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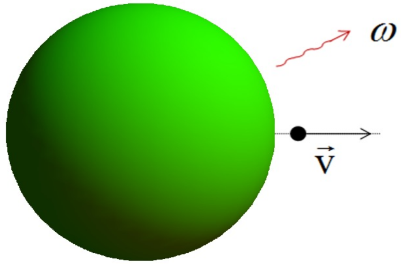
Outline



I. Introduction and motivation

II. Problem statement and basic formulas

III. The case of non dispersive dielectric ball

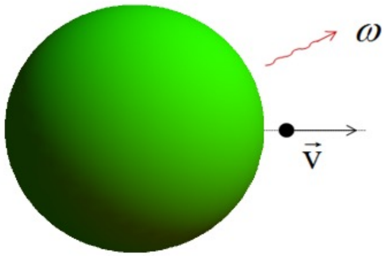
IV. Effects conditioned by dispersion

V. Conclusions

I. Introduction and motivation

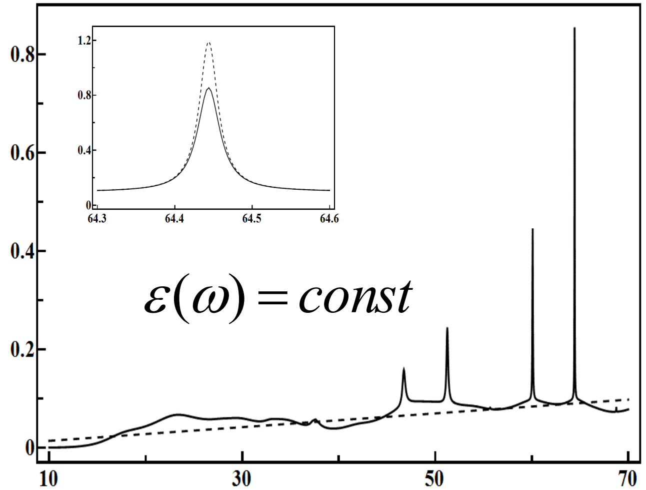
The influence of matter on electromagnetic processes covers a wide range of phenomena that have found a number of important practical applications. Our work is devoted to this topic.

The radiation from a charged particle flying through a ball of a dispersive material is studied.



$\varepsilon(\omega) \neq const$

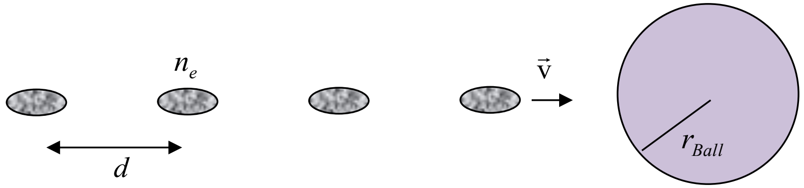
In 2012 [1], the radiation of a single electron was studied, which, with constant velocity, passes through the center of a non dispersive dielectric ball.



[1] S.R. Arzumanyan, J. Phys.: Conf. Series, **357**, (2012)

I. Introduction and motivation

In 2020 [2] the **powerful quasi coherent radiation** generated by a **train of bunches** of charged particles passing through the center of a ball had been studied.



$$\varepsilon(\omega) = const$$

In 2024 [3] the spectral **angular** distribution of that radiation has been studied.

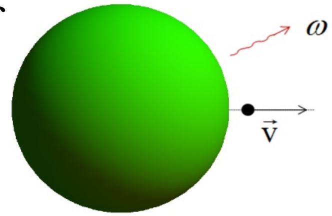
The purpose of this report is to show that the presence of dispersion can not only significantly change the spectral-angular distribution of radiation, but also significantly increase the total energy emitted in a fairly wide frequency range.

[2] A.R. Mkrtchyan, P.A. Aleksandrov, L.S. Grigoryan, A.H. Mkrtchyan, H.F. Khachatryan, M.V. Kovalchuk, Features of radiation generated by bunches of charged particles passing through the centre of a ball, Arm. J. Phys. 13 (2020) 95–104.

[3] L.S. Grigoryan, et all., Spectral-angular distribution of radiation generated by a train of electron bunches passing through the center of a ball, NIM A 1059 (2024) 168991.

II. Problem statement and basic formulas

Charged particle with constant velocity passes through the center of a dielectric ball with the radius r_b and dielectric permittivity $\varepsilon(\omega)$. The magnetic permeability of the material of the ball is taken to be one and it will be assumed that the ball is immersed in the vacuum.



The energy radiated during the entire time of the particle motion in the angular range (θ, $\theta+d\theta$) and in the frequency range (ω, $\omega+d\omega$) is presented as

$$dE_1(\omega,\theta) = J_1(\omega,\theta)d\omega d\theta$$

Spectral-angular density ⟹ $$J_1(\omega,\theta) = 2\pi c \sin\theta \left|\sum_l a_2^l \vec{X}_{l0}^{(2)}\right|^2 \quad (1)$$

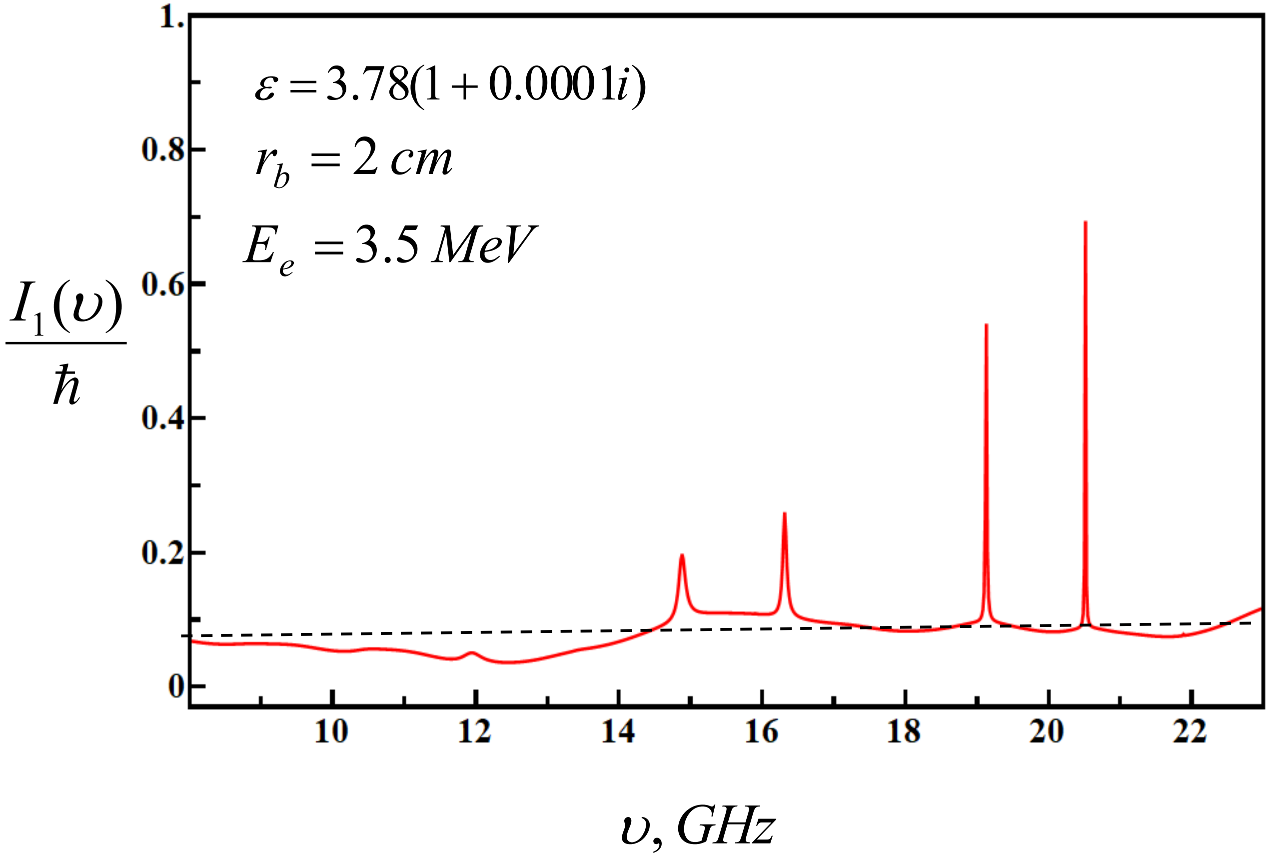
$\vec{X}_{l0}^{(2)}$ ⟸ vector spherical harmonics of electric type,

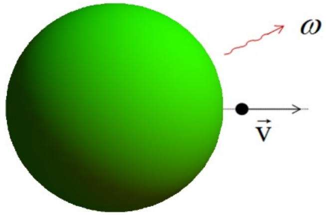
a_2^l ⟸ expressed in terms of the spherical Bessel and Hankel functions, see [1,2].

Corresponding spectral density

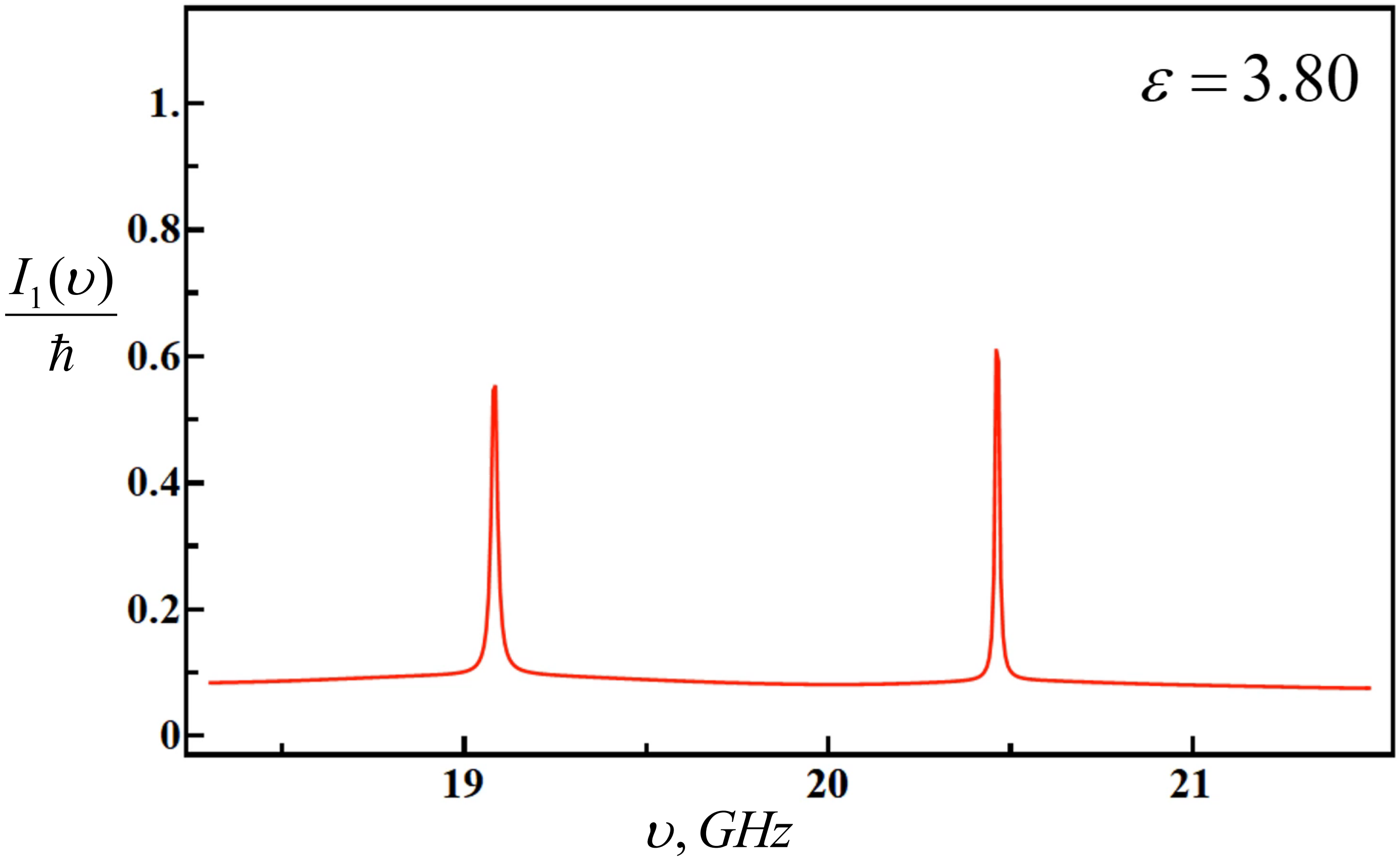
$$I_1(\omega) = \int_0^{\pi} J_1(\omega,\theta)d\theta = c\sum_l \left|a_2^l\right|^2. \quad (2)$$

III. The case of non dispersive dielectric ball

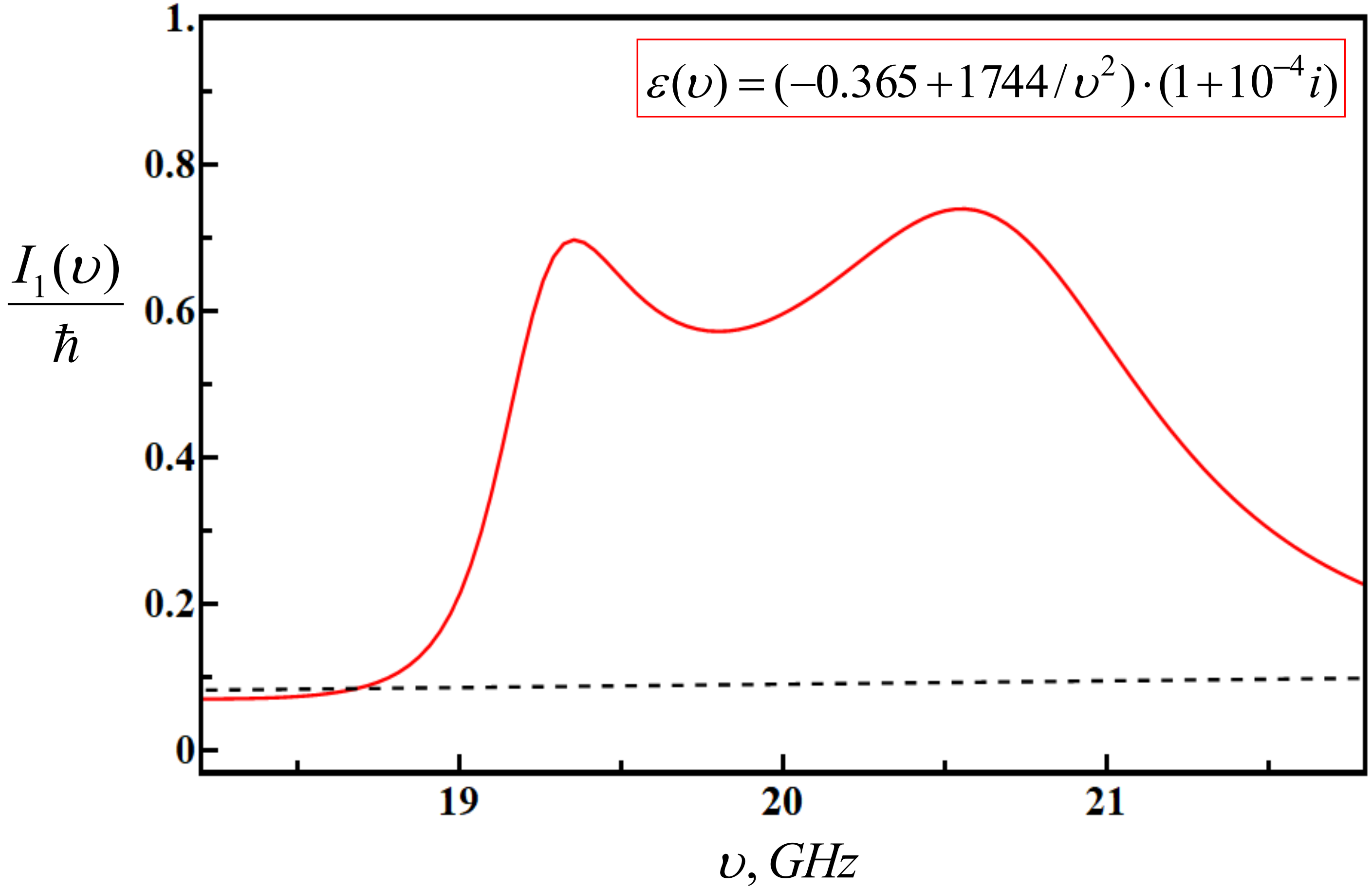




IV. Effects conditioned by dispersion

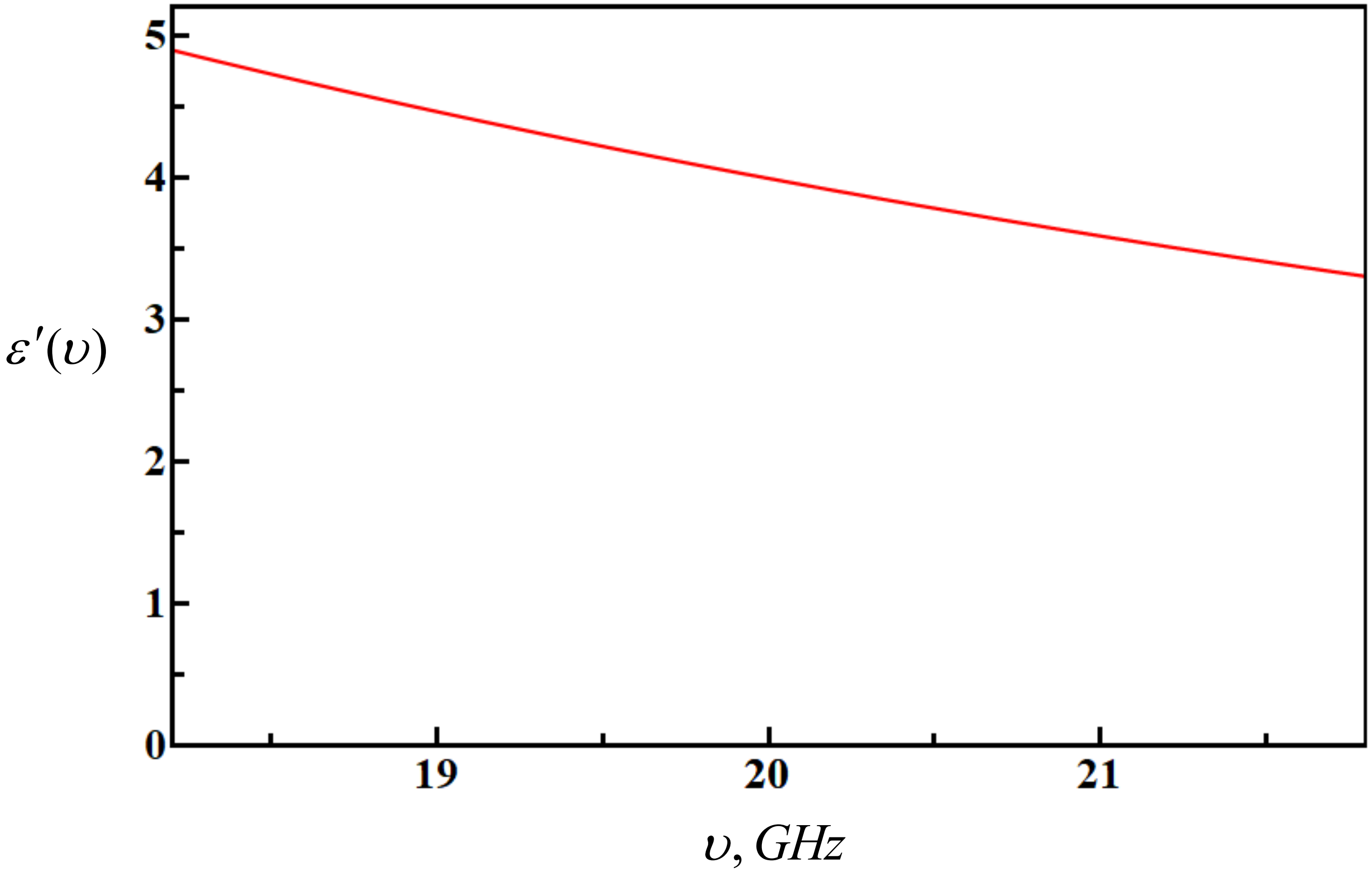


IV. Effects conditioned by dispersion



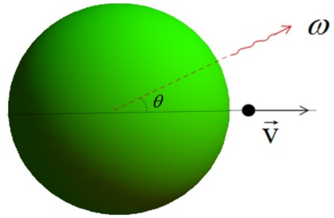
IV. Effects conditioned by dispersion

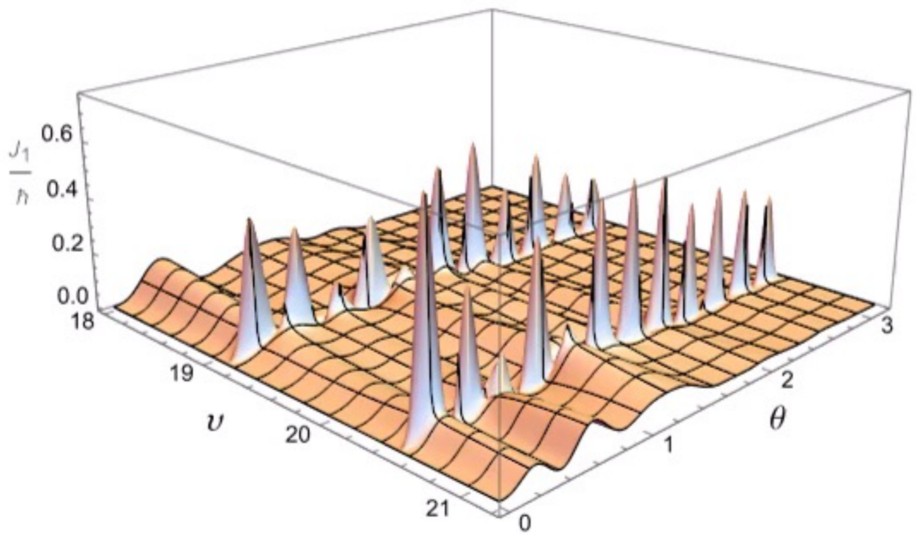
$$\varepsilon(\upsilon) = (-0.365 + 1744/\upsilon^2)\cdot(1+10^{-4}i)$$



V. Spectral-angular distribution of radiation

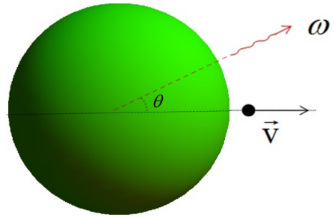
$$\varepsilon(\upsilon) = \text{Constant} = 3.78 \cdot (1 + 10^{-4} i)$$

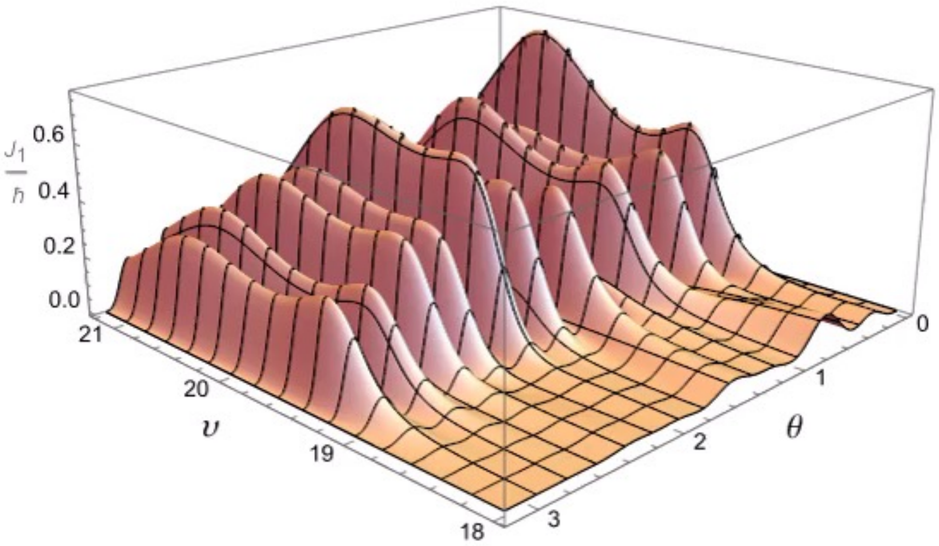




V. Spectral-angular distribution of radiation

$$\varepsilon(\upsilon) = (-0.365 + 1744/\upsilon^2)\cdot(1+10^{-4}i)$$





V. Conclusions

- **The results of theoretical observation of spectral-angular distribution of the radiation from a charged particle flying through a ball of a dispersive material are presented.**
- **It is shown that the presence of dispersion can not only significantly change the spectral-angular distribution of radiation, but also significantly increase the total energy emitted in a fairly wide frequency range.**
- **This effect can be used to develop powerful radiation sources in GHz-THz frequency range.**

References

[1] S.R. Arzumanyan, Radiation from a charged particle flying through a dielectric ball, J. Phys.: Conf. Series, **357**, (2012) 012008.

[2] A.R. Mkrtchyan, P.A. Aleksandrov, L.S. Grigoryan, A.H. Mkrtchyan, H.F. Khachatryan, M.V. Kovalchuk, Features of radiation generated by bunches of charged particles passing through the centre of a ball, Arm. J. Phys. 13 (2020) 95–104.

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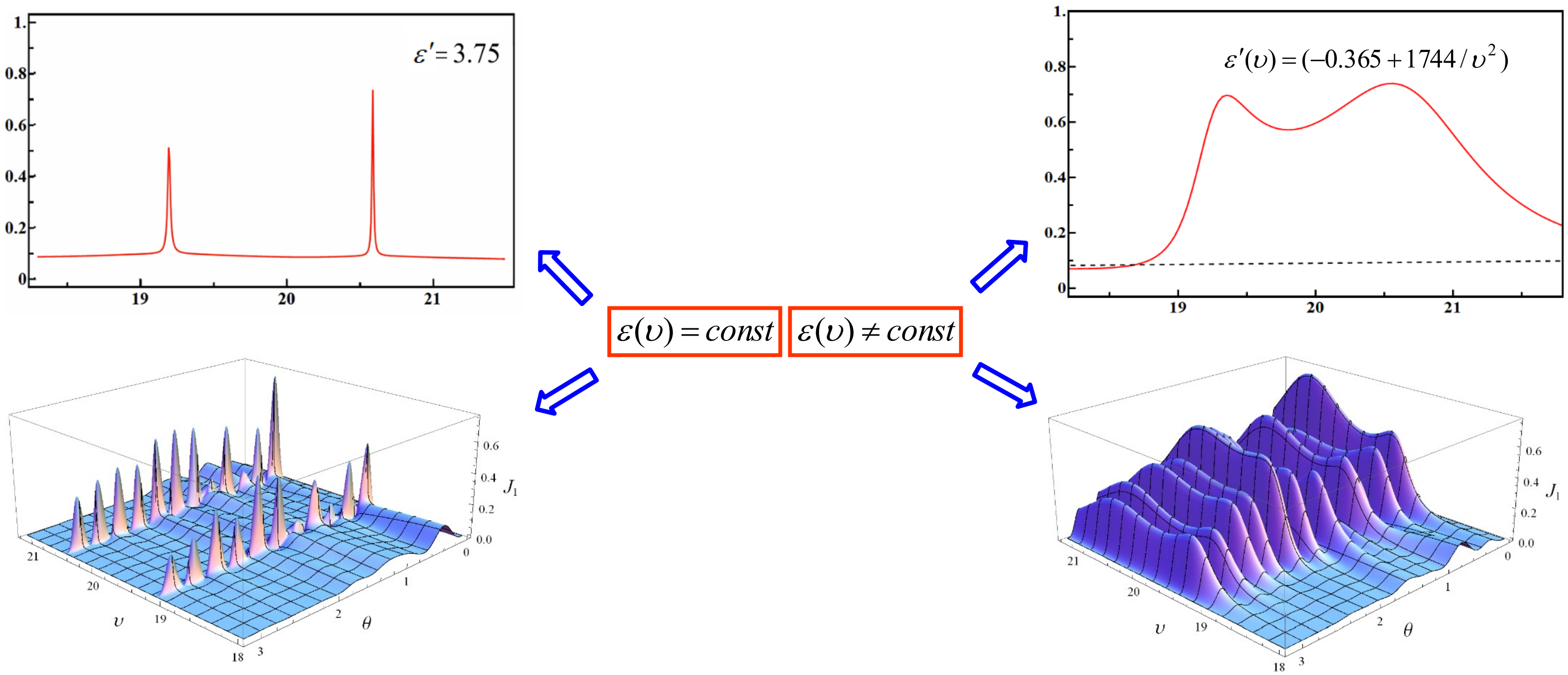

Thank you for attention

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$$\lambda_{res} = \frac{c}{\sqrt{\varepsilon(\upsilon) \cdot \upsilon}} \cong r_b \cdot const \Rightarrow \varepsilon(\upsilon) \sim \frac{const}{\upsilon^2}$$