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Radiation from a Charged Particle Rotating Around a Ball of a Dispersive Matter

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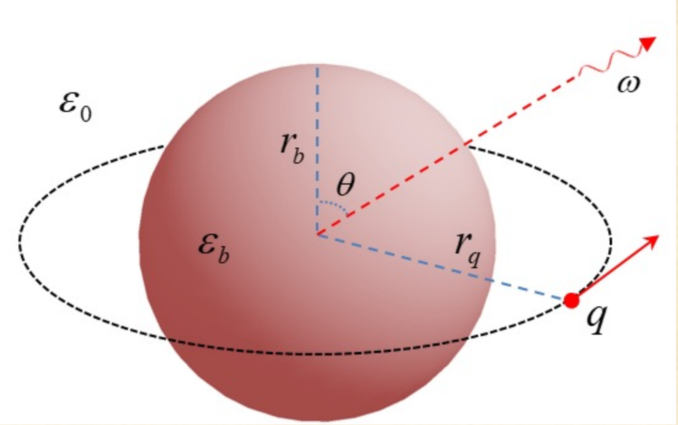
Outline



I. Introduction

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

- In ***L.Sh.Grigoryan,*** *H.F. Khachatryan, S.R. Arzumanyan, M.L. Grigoryan*, Nucl. Instr. & Meth. B **252**, 50 (2006) it has been shown that a relativistic electron rotating around a dielectric ball may generate **high power ("resonant") radiation on a given harmonic**.

- In *A.H. Mkrtchyan,* ***L.Sh.Grigoryan,*** *at al,* "REFFIT", **3,** p.1–6, (2018). Futures of the electromagnetic field oscillations of a charged particle rotating around a **conductive** ball has been investigated.

- Peculiarities of the **angular distribution** of the radiation have been studied in ***L.Sh.Grigoryan****,* et al, JINST **15**, C04035 (2020).

Novelty of our approach

In the present talk we consider

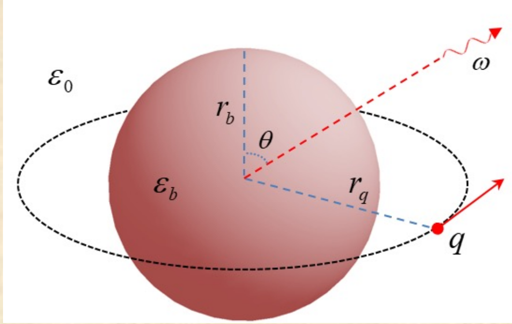
radiation from a charged particle
rotating around a ball of a **dispersive dielectric**

The purpose of this report is to show that by choosing the **dispersion law** it is possible to achieve the generation of "resonant" radiation simultaneously at **several neighboring harmonics**.

The results presented in our talk may be used to develop powerful sources of electromagnetic radiation in the GHz-THz frequency range.

II. Problem statement and basic formulas

The radiation intensity from a single particle is determined by the formula



Polar angle of the radiation

$$I_1(k,\theta)=\frac{16\pi^2 q^2 \omega_{rot}^2}{c\sqrt{\varepsilon_0}}\sin\theta\cdot\left|\sum_{s=0}^{\infty}(-1)^s[a_{kE}(s)\vec{X}^{(2)}_{k+2s,k}(\theta,0)+i\cdot a_{kH}(s)\vec{X}^{(3)}_{k+2s+1,k}(\theta,0)]\right|^2$$

$\vec{X}^{(\mu)}_{l,m}(\theta,\varphi)$ ⇦ vector spherical harmonics of electric ($\mu=2$) and magnetic ($\mu=3$) types

The expressions for amplitudes a_{kE} and a_{kH} are given in

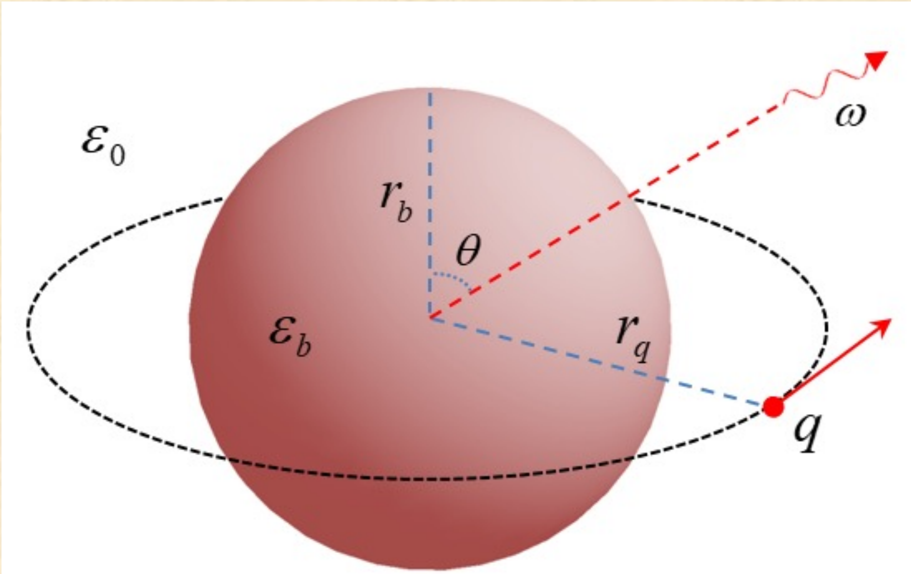
L.Sh.Grigoryan, H.F. Khachatryan, S.R. Arzumanyan, M.L. Grigoryan, Nucl. Instr. & Meth. B **252**, 50 (2006).

III. The case of non dispersive dielectric ball

It is suitable to introduce the number of quanta emitted on per period of rotation:

$$I_1(k,\theta) \quad \rightarrow \quad \frac{I_1(k,\theta)\cdot T_{rot}}{\hbar\omega_k} \equiv n_1(k,\theta) \qquad N = \sum_k \int_0^{\pi} n_1(k,\theta)$$

Consider an electron with $E_e = 2MeV$ and balls made of quartz or teflon.



III. The case of non dispersive dielectric ball

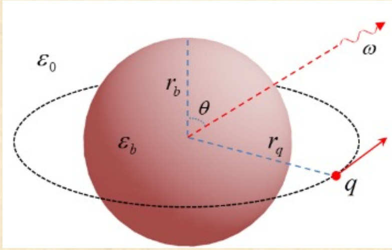
a) Ball made of quartz

$$\varepsilon_b = 3.78(1 + 0.0001i), \quad \varepsilon_0 = 1$$

$$r_q = 1cm$$

$$r_b / r_q = 0.9815$$

$$\frac{\omega_{k_0}}{2\pi} = 36.9 \cdot 10^9 \; Hz$$



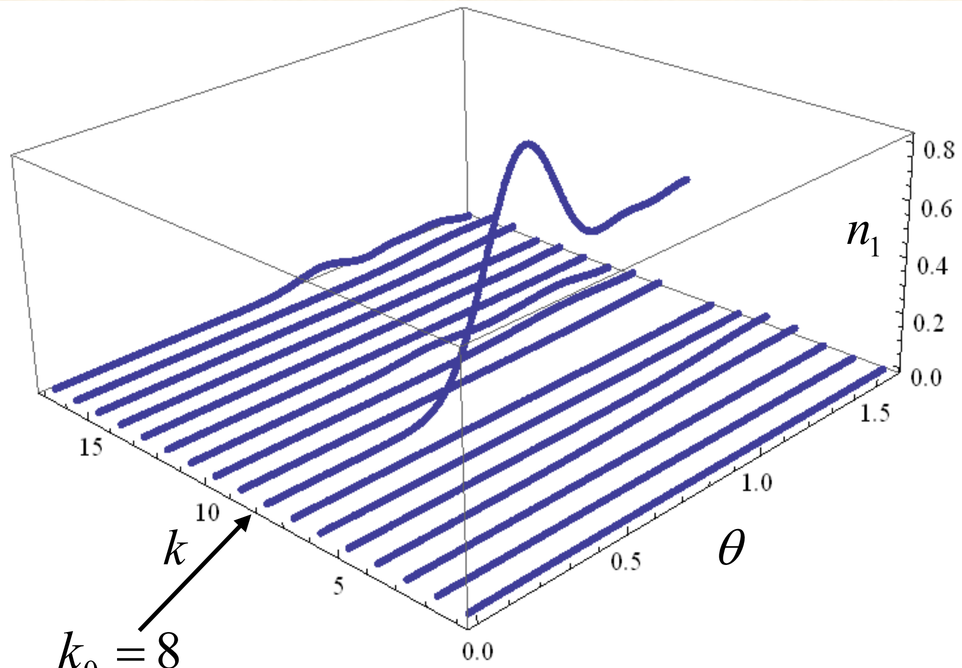
b) Ball made of teflon

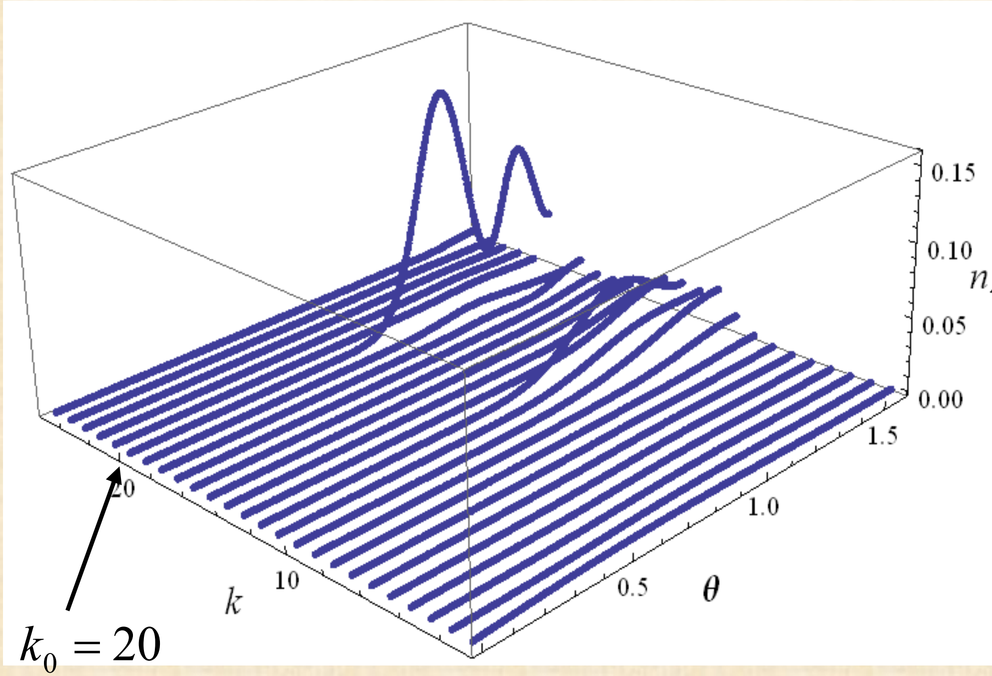
$$\varepsilon_b = 2.2(1 + 0.0002\,i), \quad \varepsilon_0 = 1$$

$$r_q = 0.15cm$$

$$r_b / r_q = 0.9616$$

$$\frac{\omega_{k_0}}{2\pi} = 6.15 \cdot 10^{11} \; Hz$$



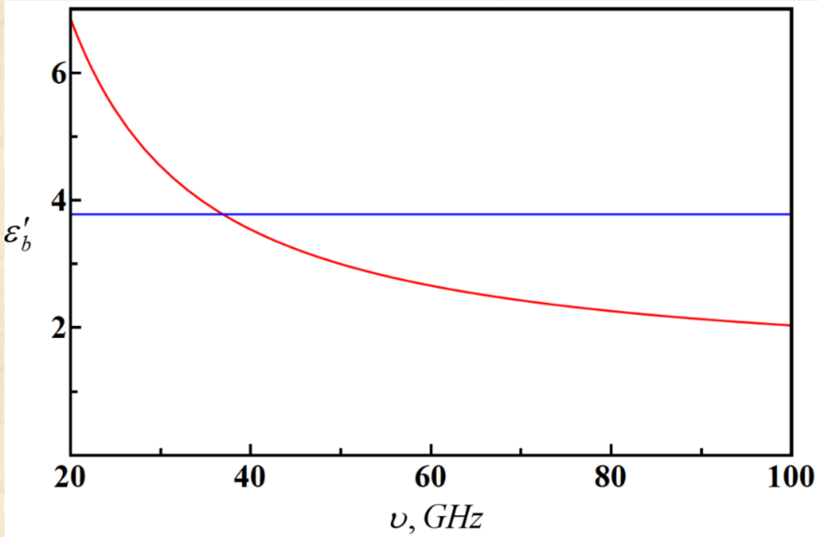


IV. Effects conditioned by dispersion

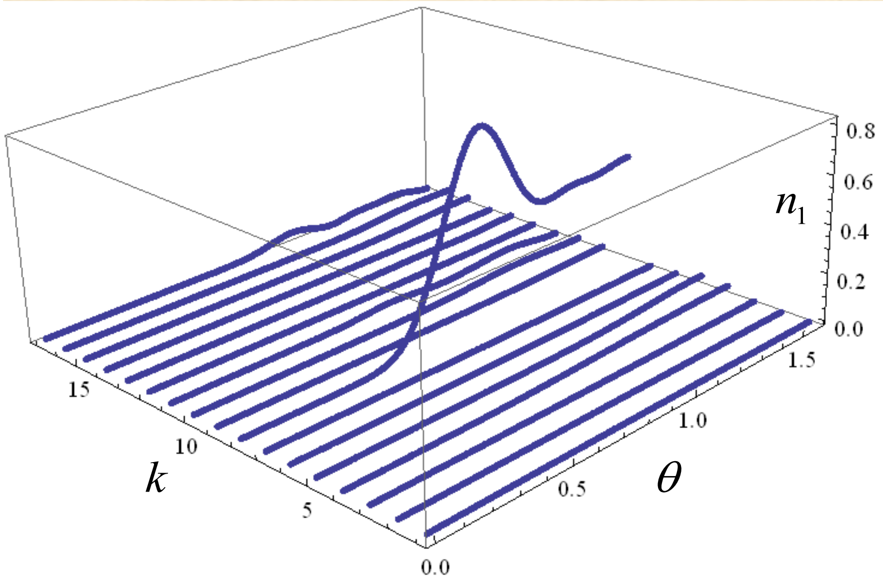
Ball made of quartz

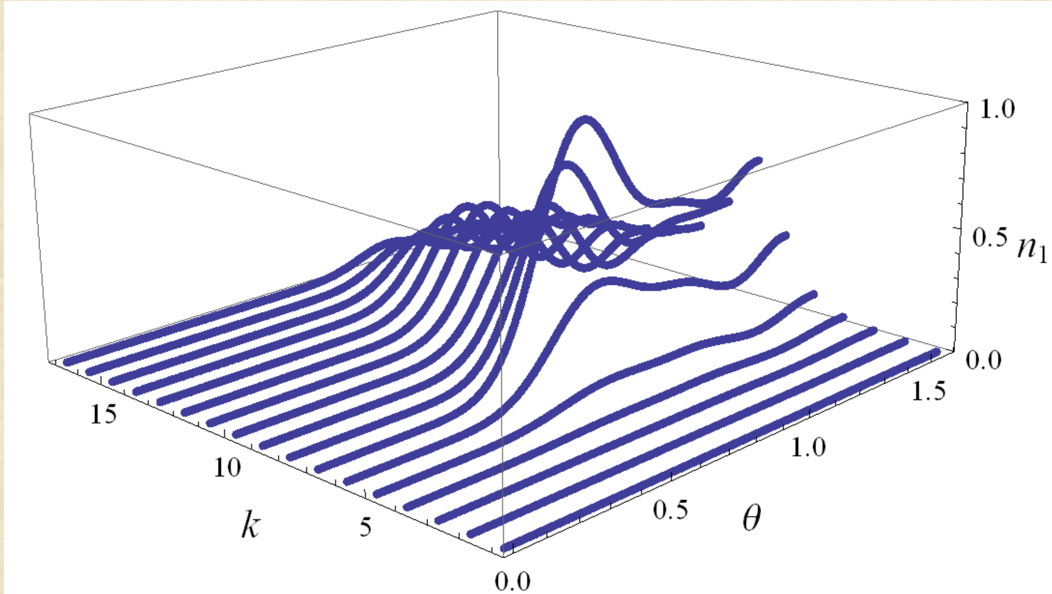
Ball made of dispersive dielectric

$$\varepsilon_b' = 3.78$$



$$\varepsilon_b'(\upsilon) = 1.235 + \frac{802.24}{\upsilon^2} + \frac{72.15}{\upsilon}$$





$$N = \sum_k \int_0^{\pi} n_1(k,\theta)d\theta = 1.16$$

$$\upsilon_1 = 4.61 \cdot 10^9 \, Hz$$

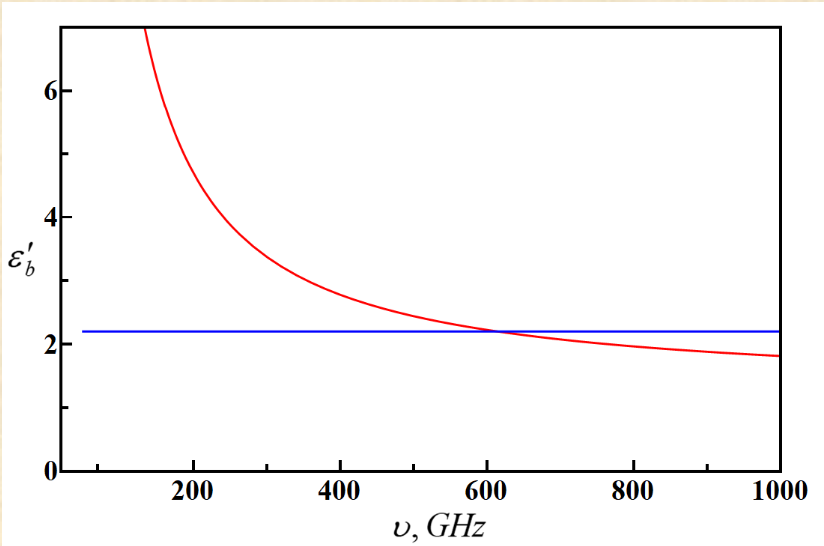
$$N = 5.78$$

IV. Effects conditioned by dispersion

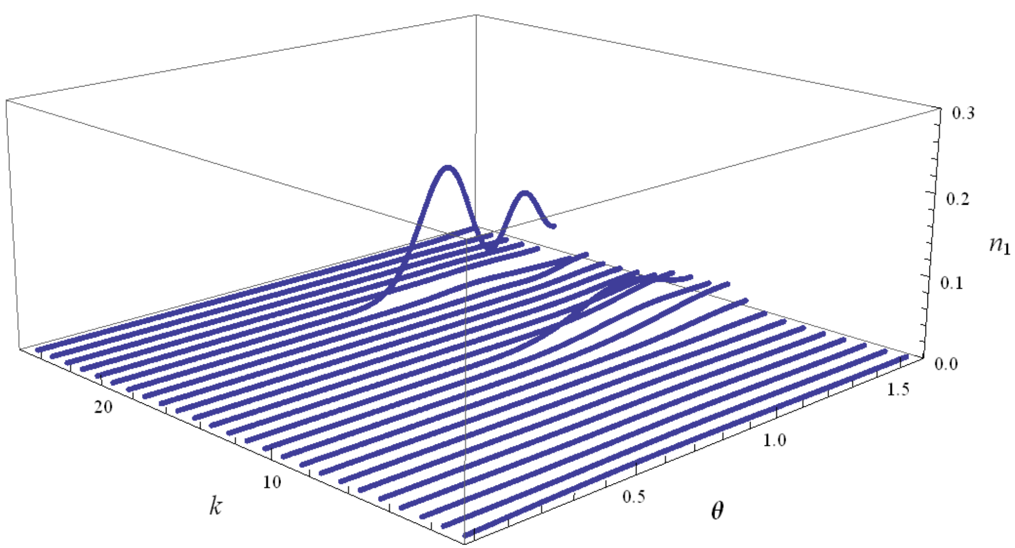
Ball made of teflon

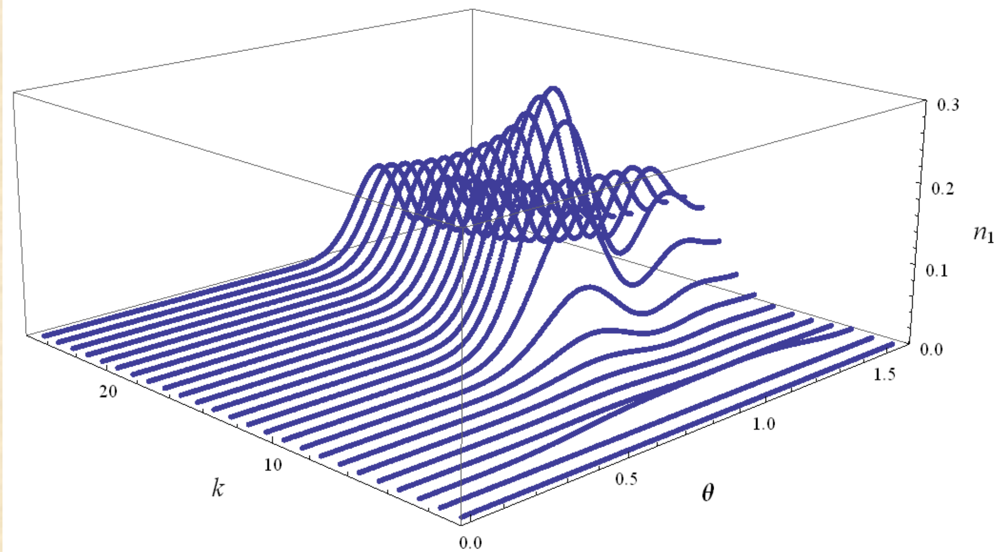
Ball made of dispersive dielectric

$$\varepsilon_b' = 2.2$$



$$\varepsilon_b'(\upsilon) = 1.235 + \frac{32418}{\upsilon^2} + \frac{533}{\upsilon}$$





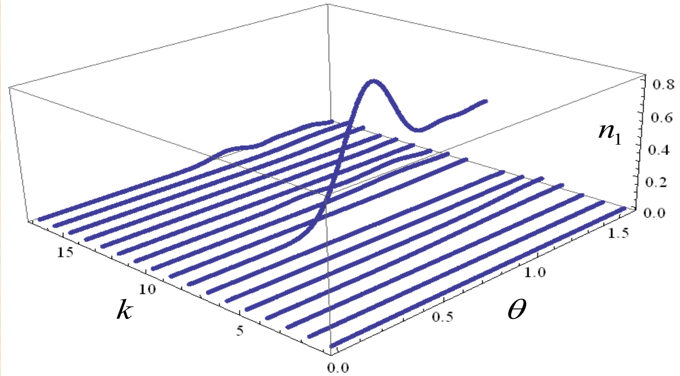
$N = 0.26$

$\upsilon_1 = 3.07 \cdot 10^{10}\ Hz$

$N = 2.6$

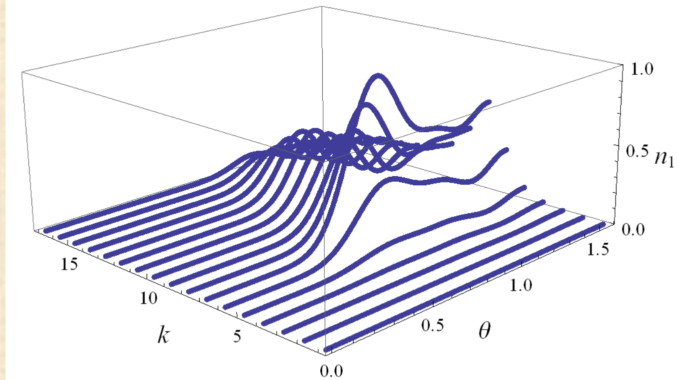
V. Conclusions

- **The results of theoretical observation of spectral-angular distribution of the radiation from a charged particle rotating around a ball of a dispersive dielectric are presented.**
- **It is shown that by choosing the dispersion law it is possible to achieve the generation of "resonant" radiation simultaneously at several neighboring harmonics.**
- **This effect can be used to develop powerful radiation sources in GHz-THz frequency range.**

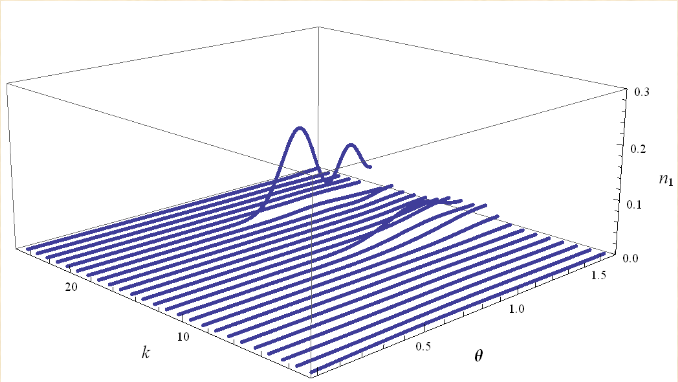


$\varepsilon_b' = 3.78$

$\varepsilon_b'(\upsilon) = 1.235 + \dfrac{802.24}{\upsilon^2} + \dfrac{72.15}{\upsilon}$

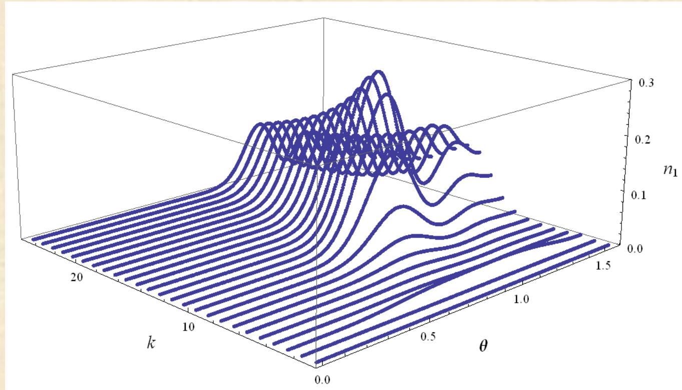


$\varepsilon(\omega) = const$ | $\varepsilon(\omega) \neq const$



$\varepsilon_b' = 2.2$

$\varepsilon_b'(\upsilon) = 1.235 + \dfrac{32418}{\upsilon^2} + \dfrac{533}{\upsilon}$



Thank you for attention

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