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In the Institute of the Applied Problems of Physics we investigate the influence of acoustic waves on physical process in crystals

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Contributions to this conference from IAPP

- Quantum Uncertainties in the Energy of Transverse Oscillations of Planar Channeled Particle
  L.Sh. Grigoryan, W. Wagner, H.F. Khachatryan, and B. Azadegan
- The Induction of Coherent X-Ray Bremsstrahlung In Crystals Under The Influence Of Acoustic Waves, A.R. Mktrtchyan, and V. V. Parazian
- COHERENT BREMSSTRAHLUNG FROM RELATIVISTIC ELECTRONS MOVING IN A GAS OF PERIODICALLY DEFORMED ATOMIC STRINGS, A. Aslanyan, G.K. Khachaturyan, A.G. Mkrtchyan, A.R. Mkrtchyan, N.N. Nasonov, and P.N.Zhukova
- The General Theory of Bremsstrahlung By High Energy Electrons In Periodically Deformed (By Acoustic Wave) Single Crystal , V.V. Parazian, A.R. Mktrtchyan, and A.A. Saharian
- The Possibility of Acceleration of the Charged Particles in Low Temperature Acoustoplasma, A.S. Abrahamyan, A.R. Mkrtchyan, and R.B. Kostanyan

Contributions to this conference from IAPP

- Formation of relativistic positron systems and their decay to gamma-rays by the axial channelling of positrons in ionic crystals, A.S. Gevorkyan, and A.R. Mkrtchyan
- Observation of Dynamical Maxima of Parametric X-Ray Radiation For 20 MeV Electron Energy Beam, G.K. Khachaturyan, A.R. Mkrtchyan, and A.H. Mkrtchyan
- Transition Radiation of Relativistic Electrons on Acoustic Superlattice in Amorphous Media, A. Mktrtchyan, V. Kocharyan, Z. Amirkhanyan, G. Khachaturyan, and A. Movsisyan
- Synchrotron Radiation from a Charge Moving Along Helical Orbit Around a Dielectric Cylinder, A.A. Saharian, A.S. Kotanjyan
- Coherent Pair Production in Crystals in Presence of Acoustic Waves A.R. Mkrtchyan, A.A. Saharian, and V.V. Parazian

COHERENT BREMSSTRAHLUNG IN PERIODICALLY DEFORMED CRYSTALS WITH COMPLEX BASE

A.R. Mkrtchyan, A.A. Saharian, V.V. Parazian

Institute of Applied Problems of Physics

Based on:

1. A.R. Mkrtchyan, A.A. Saharian, L.Sh.Grigoryan, B.V. Khachatryan, *Mod. Phys. Lett.* **A19**, 99 (2002);
2. A.R. Mkrtchyan, A.A. Saharian, V.V. Parazian, A.H. Mkrtchyan, H.A. Vardapetyan, A.M. Sirunyan, G.G. Hakobyan, J.V. Manukyan, *J. Contemp. Phys.*, **41**, 29 (2006).
3. A.R. Mkrtchyan, V.V. Parazian, A.A. Saharian, Coherent bremsstrahlung in periodically deformed crystals with a complex base, arXiv:0810.0615 .

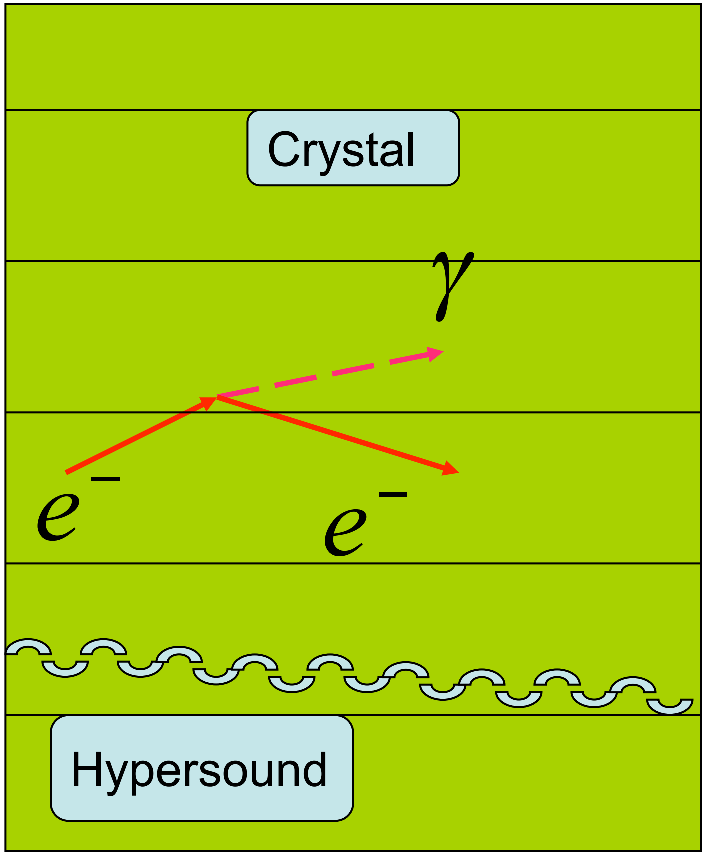
Outline

- Analysis of conditions under which the influence of hypersound is essential
- Cross-section of the bremsstrahlung in crystals in presence of hypersonic vibrations
- Numerical results and discussion

Motivation

- In crystals the cross-sections of the high-energy electromagnetic processes can change essentially compared with the corresponding quantities for a single atom
- From the point of view of controlling the parameters of the high-energy electromagnetic processes in a medium it is of interest to investigate the influence of external fields (acoustic waves, temperature gradient) on the corresponding characteristics
- Investigation of bremsstrahlung by high-energy electrons is of interest from the viewpoint of the underlying physics and from the viewpoint of practical applications for generation of intense photon beams

Problem setting and notations



Photon energy ω

Photon momentum $\vec{k}$

Initial energy of electron E_1

Initial momentum of electron $\vec{p}_1$

Final energy of electron E_2

Final momentum of electron $\vec{p}_2$

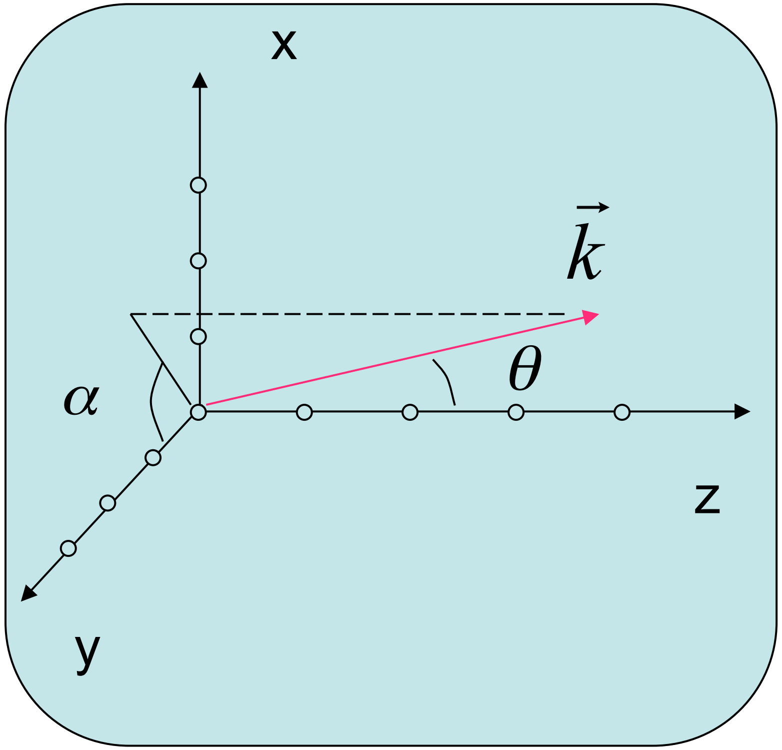
Hypersound wave vector $\vec{k}_s$

Displacements of atoms due to the hypersound

$$\vec{u} = \vec{u}_0 f(\vec{k}_s \vec{r})$$

Visual description 1

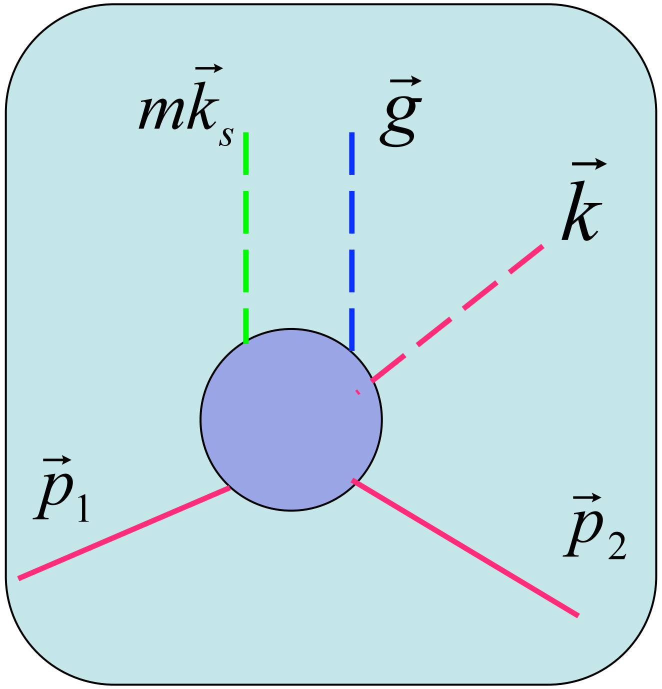
Coherence effects are essential if the electron enters into the crystal at small angle with respect to the crystallographic axis (angle θ below)



$$l_c = 2E_1E_2/\omega m_e^2$$ formation length

$$\delta = 1/l_c$$

Visual description 2



Momentum conservation

$$\vec{p}_1 = \vec{p}_2 + \vec{k} + \vec{g} - m\vec{k}_s$$

Condition under which the influence of the hypersound is essential

$$\frac{u_0}{a} > \frac{\lambda_s}{(2\pi)^2 l_c}$$

Interatomic distance

Hypersound wavelength

Cross-section

- Coherent part of the cross-section

$$\frac{d\sigma_c}{d\omega} = \frac{e^2 N}{N_0 E_1^2 \Delta} \sum_{m,\vec{g}} \frac{g_{m\perp}^2}{g_{m||}^2} \left|F_m\left(\vec{g}_m \vec{u}_0\right)\right|^2 \left|S\left(\vec{g}_m, \vec{g}\right)\right|^2 \times$$
$$\left[1 + \frac{\omega^2}{2E_1E_2} - 2\frac{\delta}{g_{m||}}\left(1 - \frac{\delta}{g_{m||}}\right)\right]$$

N_0 number of atoms

N number of cells

Δ unit cell volume

$$\vec{g}_m = \vec{g} - m\vec{k}_s$$

$$m = 0, \pm 1, \pm 2, \ldots$$

Summation goes under the constraint $g_{m||} \geq \delta$

$\vec{g}$ reciprocal lattice vector, $\delta = 1/l_c$,

$g_{m||}$ and $g_{m\perp}$ are the parallel and perpendicular components of $\vec{g}$ with respect to the initial electron momentum

Cross-section

$$F_m(x) = \frac{1}{2\pi}\int_{-\pi}^{\pi} dt\, e^{ixf(t)-imt},$$ $S(\vec{g})$ structure factor of the crystal

For $u_0 = 0$ one has $F_m = \delta_m^0$ and from the general formula given above the cross-section for the pair creation in an undeformed crystal is obtained

For the sinusoidal deformation field, $f(z) = \sin(z + \varphi_0)$ **, one has**

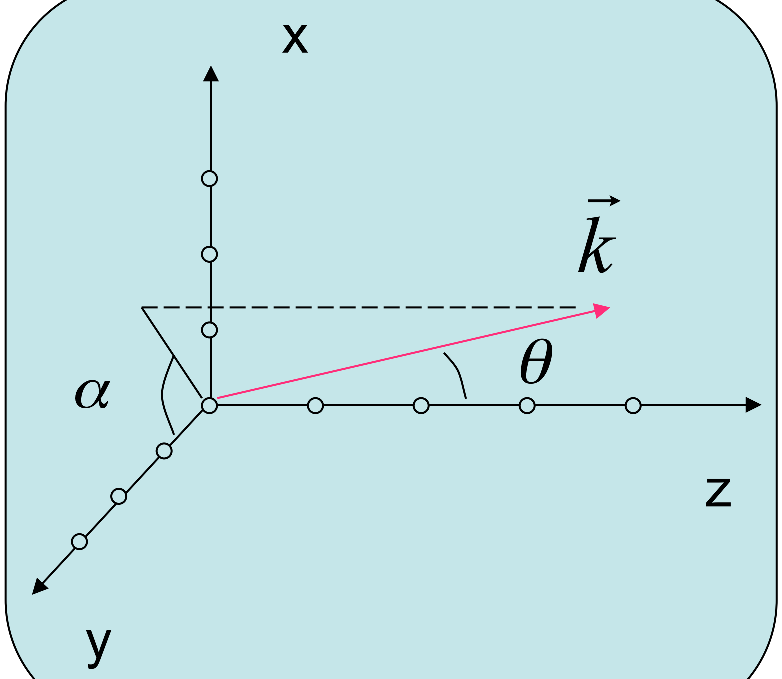
$$F_m(z) = e^{im\varphi_0} J_m(z)$$

Bessel function

In the case of the presence of the hypersound the corresponding formula for the cross-section differs from the formula for an undeformed crystal by the replacement $\vec{g} \rightarrow \vec{g}_m$ **, and additional summation over m with weights** $\left|F_m(\vec{g}_m \vec{u}_0)\right|^2$**.**

Numerical calculations

Numerical calculations are carried out for diamond and quartz crystals for the electron energies 70 Mev



Qualitatively different cases

a) Angles α and $\pi/2-\alpha$ are not small

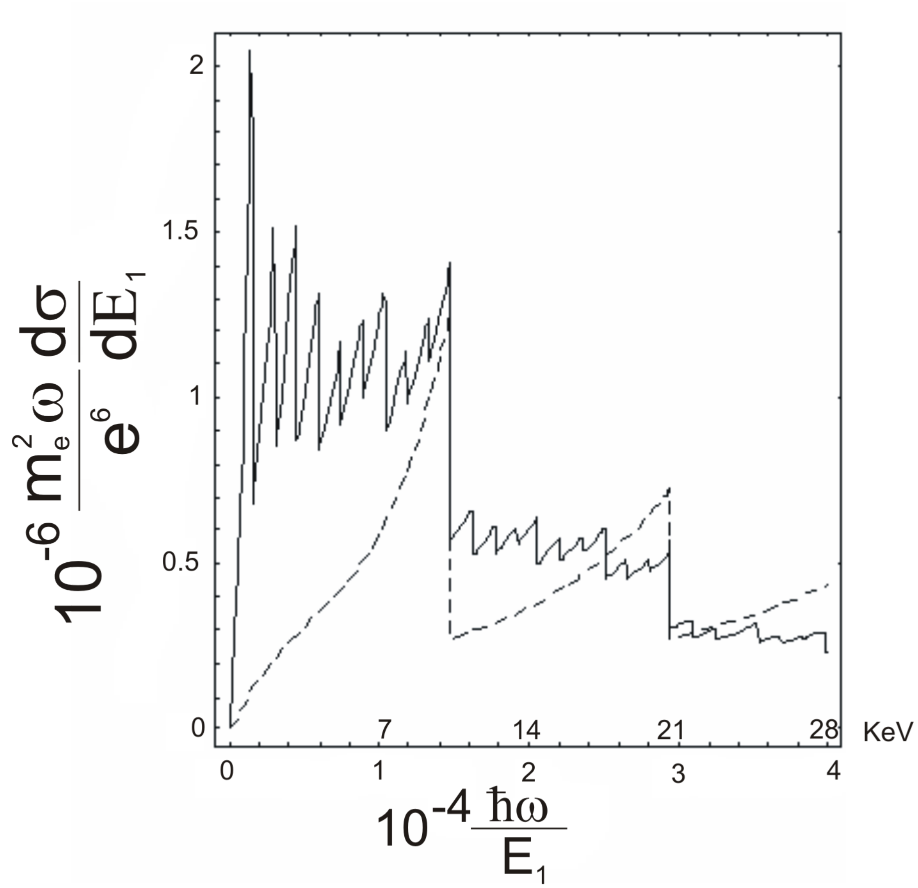
c) Angle α is small and $\delta \sim 2\pi\theta/a_2$

e) Angle α is small and $\delta \sim 2\pi\theta\alpha/a_1$

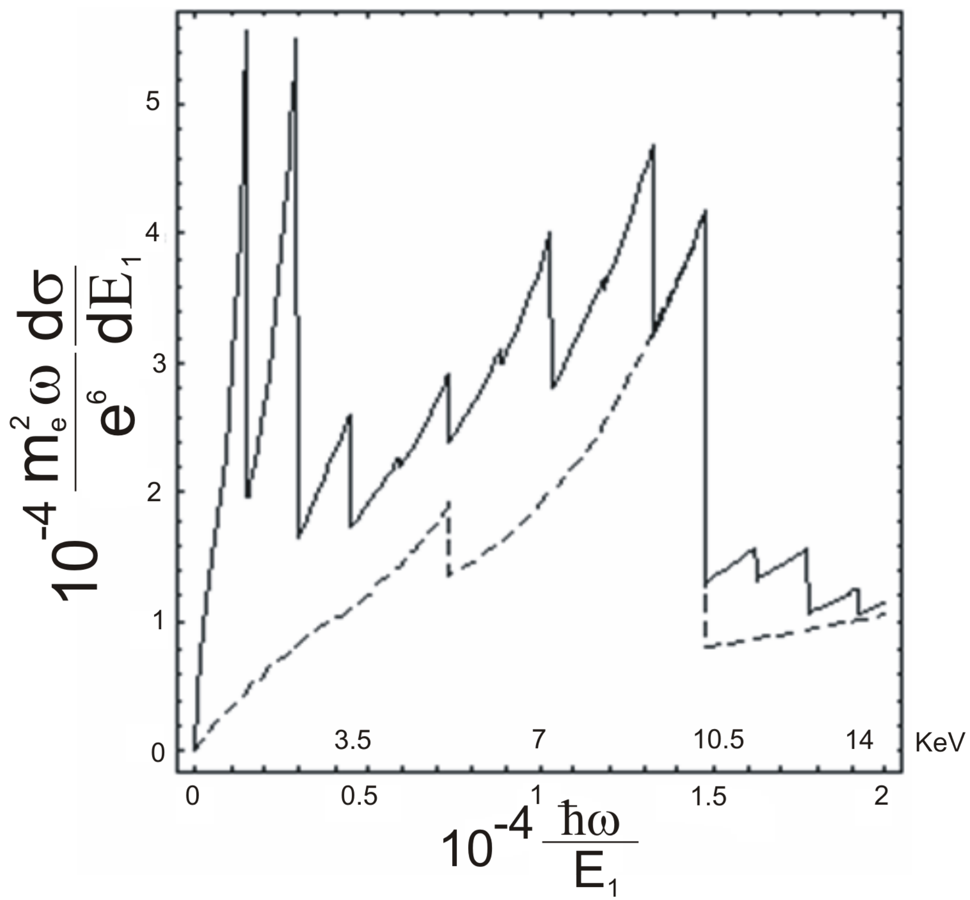
$\delta = 1/l_c$ Minimum transferred momentum

Coherent part of the cross-section (quartz crystal)

$$E_1 = 70\,\text{MeV}, \nu_s = 2.5\,\text{GHz}$$



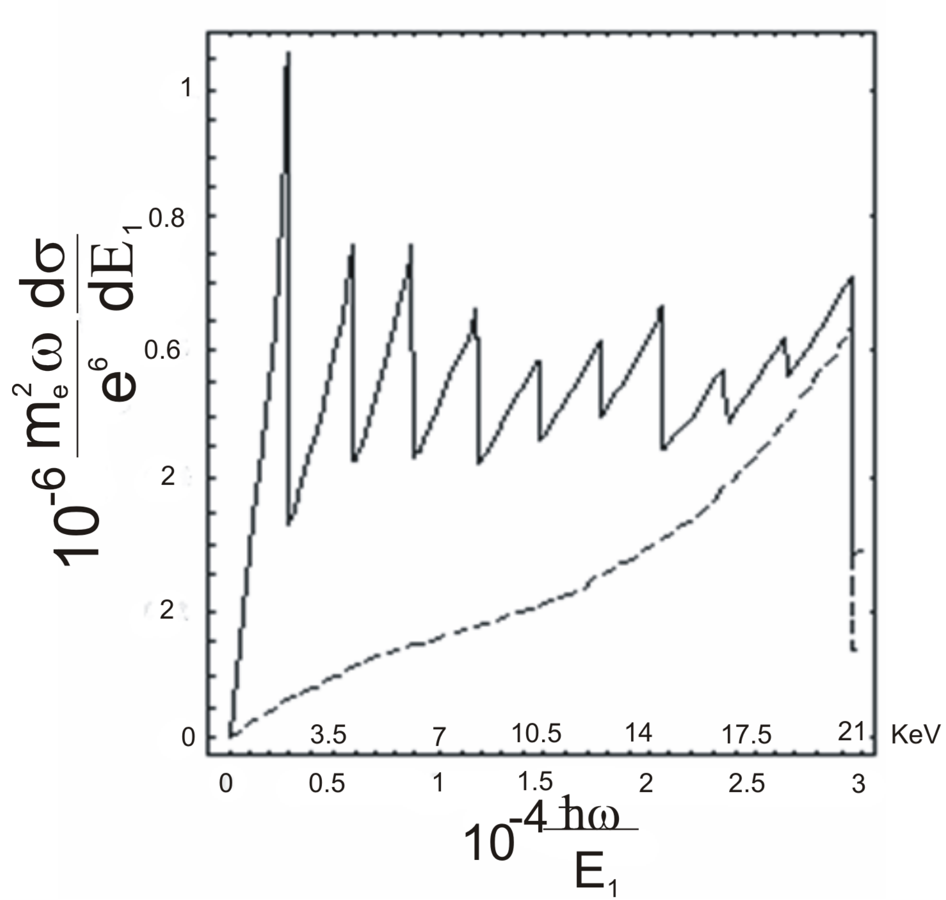
$$2\pi u_0 / a_2 = 0.55,\ \theta = 0.00012$$

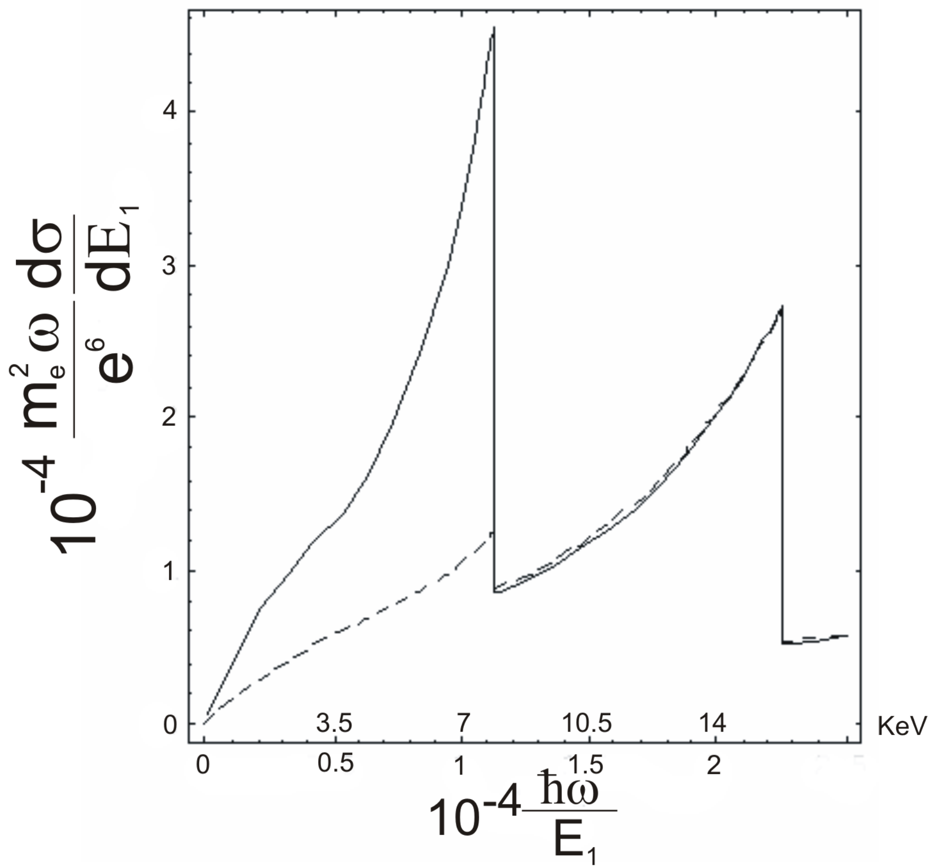


$$2\pi u_0 / a_1 = 0.28,\ \psi = \alpha\theta = 0.00006$$

Coherent part of the cross-section (quartz crystal)

$$E_1 = 70\,\text{MeV}, \nu_s = 5\,\text{GHz}$$



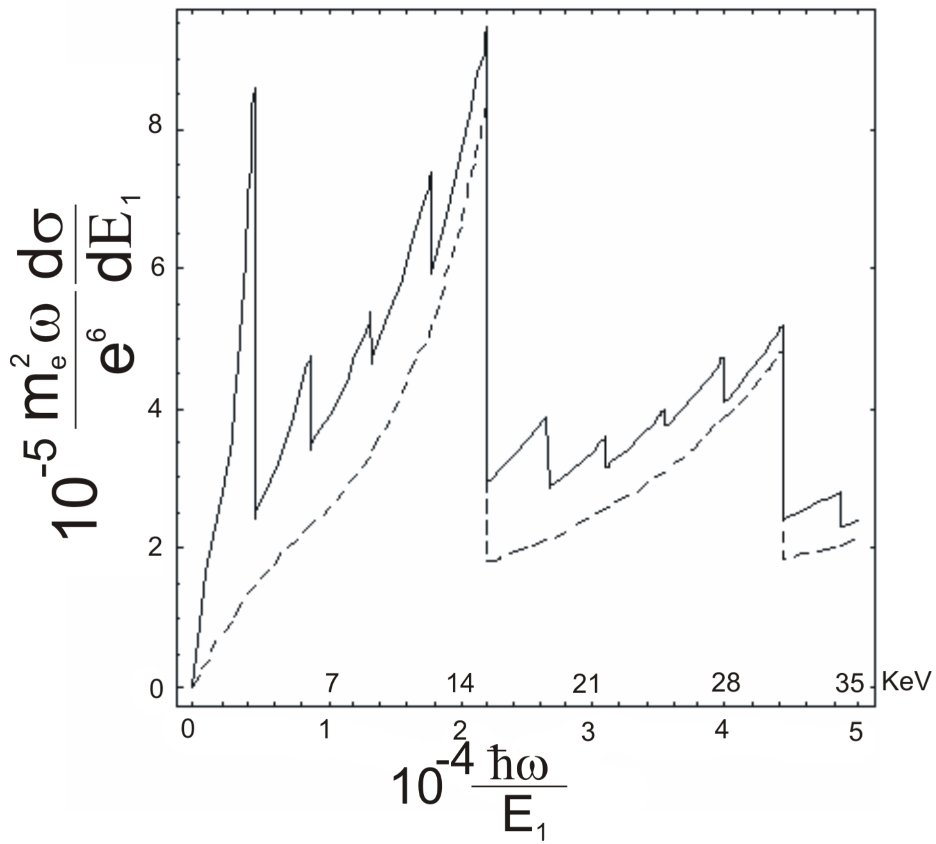


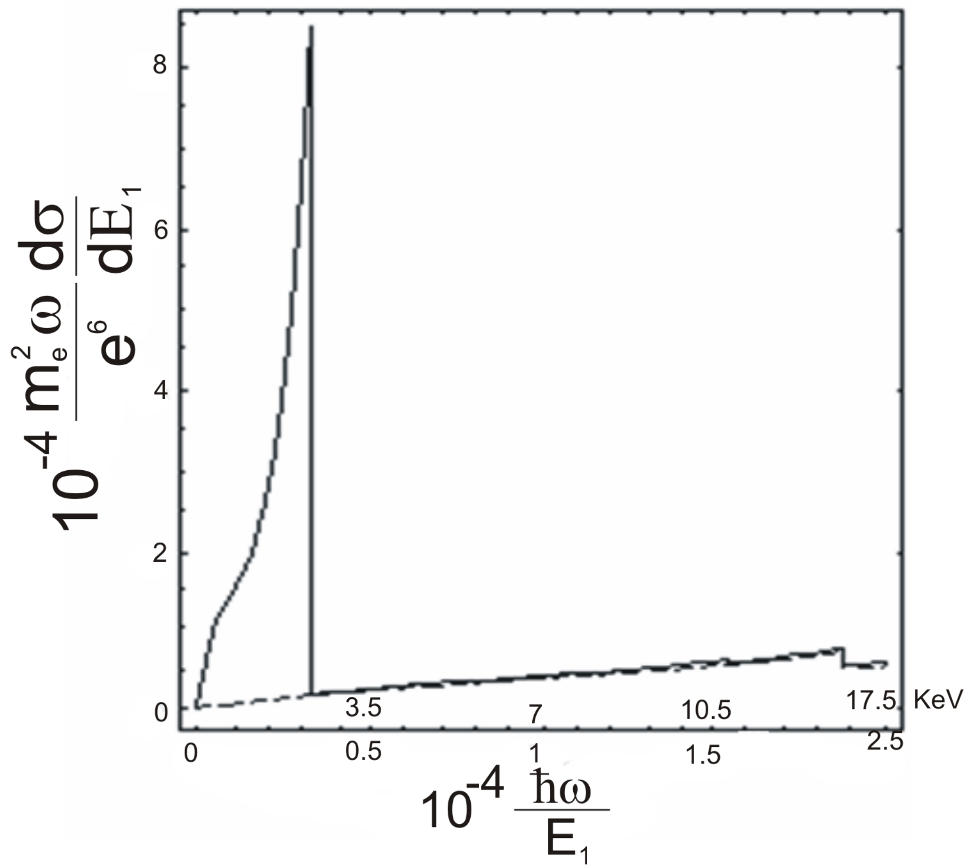
$$2\pi u_0 / a_2 = 0.55,\ \theta = 0.00024$$

$$2\pi u_0 / a_1 = 0.25,\ \psi = \alpha\theta = 0.00092$$

Coherent part of the cross-section (quartz crystal)

$E_1 = 70\ \mathrm{MeV}, \nu_s = 15\ \mathrm{GHz}$





$2\pi u_0 / a_2 = 0.18,\ \theta = 0.00018$

$2\pi u_0 / a_1 = 0.165,\ \psi = \alpha\theta = 0.000146$

Parameters for the left peaks

(GHz)		(KeV)	$\Delta\omega/\omega$	CROSS SECTION $10^{-4}\frac{m_e^2\omega}{e^6}\frac{d\sigma}{dE_1}$
2.5	b)	0.99	0.118	210
	c)	0.94	0.235	5.6
5	b)	2	0.2	1.3
	c)	7.2	0.15	4.6
15	b)	2.8	0.25	82
	c)	2.22	0.105	8.5

b) $\delta \sim 2\pi\theta / a_2$ c) $\delta \sim 2\pi\theta\alpha / a_1$

Conclusions

- Formula is derived for the coherent part of the differential cross-section for the bremsstrahlung by high-energy electrons in crystals in the presence of hyperacoustic vibrations
- Conditions are specified under which the influence of the hypersound is essential
- In dependence of the parameters, the hypersonic waves can either enhance or reduce the cross-section

Coherent pair production in crystals in presence of acoustic waves

1. A. R. Mkrtchyan, A. A. Saharian, L. Sh. Grigoryan and B. V. Khachatryan, *Mod. Phys. Lett.* A17, 2571 (2002).
2. A. R. Mkrtchyan, A. A. Saharian and V. V. Parazian, *Mod. Phys. Lett.* B20, 1617 (2006).
3. A. R. Mkrtchyan, A. A. Saharian, V. V. Parazian, A. H. Mkrtchyan, H. A. Vardapetyan, A. M. Sirunyan, G. G. Hakobyan and J. V. Manukyan, *J. Contemp. Phys.* 41, 29 (2006).