Combined Effect in the Coherent Bremsstrahlung

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Coherent Bremsstrahlung

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Channeling Radiation

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Combined Effect

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Photon scattering by channeled electron

(in reference frame moving with longitudinal channeled electron velocity)

$$d\sigma_{fi} = \frac{2\pi}{\hbar}\left|M_{fi}\right|^2 \delta\left(E_i - E_f - \hbar\omega\right)\frac{1}{J} d^3\mathbf{p}_{\parallel f}\, d\rho, \;\; d\rho = \frac{d^3\mathbf{k}}{(2\pi)^3};$$

$$\Psi_{ph}(\mathbf{r}) = \sqrt{\frac{2\pi\hbar c}{\hbar\omega}}\exp[-i\mathbf{k}\mathbf{r}]$$

Photon wave function

$$M_{fi} = \sum_n \left\{ \frac{(\mathbf{e}_2\mathbf{R}_{fn})(\mathbf{e}_1\mathbf{A}_{ni})}{(E_i + \hbar\omega_1) - E_n} + \frac{(\mathbf{e}_1\mathbf{A}_{fn})(\mathbf{e}_2\mathbf{R}_{ni})}{E_i - E_n - \hbar\omega} \right\}$$

$$\mathbf{R}_{kl} = -\frac{e}{mc}\int \Psi_k^*(\mathbf{r})\hat{\mathbf{p}}\sqrt{\frac{2\pi\hbar c}{\hbar\omega_2}}\exp[-i\mathbf{k}_2\mathbf{r}]\Psi_l(\mathbf{r})d\mathbf{r}$$

$$\mathbf{A}_{kl} = -\frac{e}{mc}\int \Psi_k^*(\mathbf{r})\hat{\mathbf{p}}\sqrt{\frac{2\pi\hbar c}{\hbar\omega_1}}\exp[= +\mathbf{k}_1\mathbf{r}]\Psi_l(\mathbf{r})d\mathbf{r}$$

$\mathbf{k}_1$ $\mathbf{e}_1$ ω_1 wave vector, polarization vector and frequency of the incident photon while

$\mathbf{k}_2$, $\mathbf{e}_2$ ω_2 wave vector, polarization vector and frequency of the scattered photon

$\hat{\mathbf{p}}$ momentum operator $\Psi_l(\mathbf{r})$ channeled electron wave function.

$$\Psi_{i(f)}(\mathbf{r}) = \varphi_{i(f)}(\boldsymbol{\rho}) \exp\left(i\mathbf{k}_{\parallel i(f)}\mathbf{r}_{\parallel}\right)$$ Channeled electron wave function

$$V(\rho) = -\frac{V_0}{\rho}$$ - axis continuous potential

$$\varphi_{i(f)}(\boldsymbol{\rho}) = e^{im\varphi}U_{nm}(\rho)$$ transverse wave function

$$U_{nm}(\rho) = \sqrt{\rho}\,\frac{1}{\Gamma(2m+1)}\left(\frac{\Gamma\left(n+m+\frac{1}{2}\right)}{\Gamma\left(n-m+\frac{1}{2}\right)2m}\right)^{1/2}(2\alpha_n)^{3/2}e^{-\alpha_n\rho}(2\alpha_n\rho)^{m-\frac{1}{2}}F\left(-n+m+\frac{1}{2};2m;\alpha_n\rho\right);$$

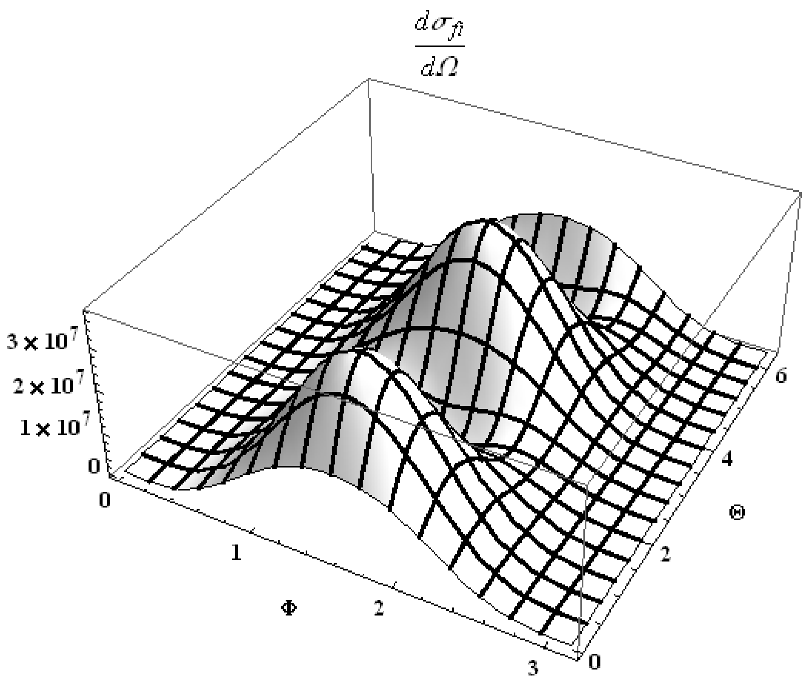
$$\alpha_n = \sqrt{-2\varepsilon_n E}\Big/(\hbar c)^2;$$

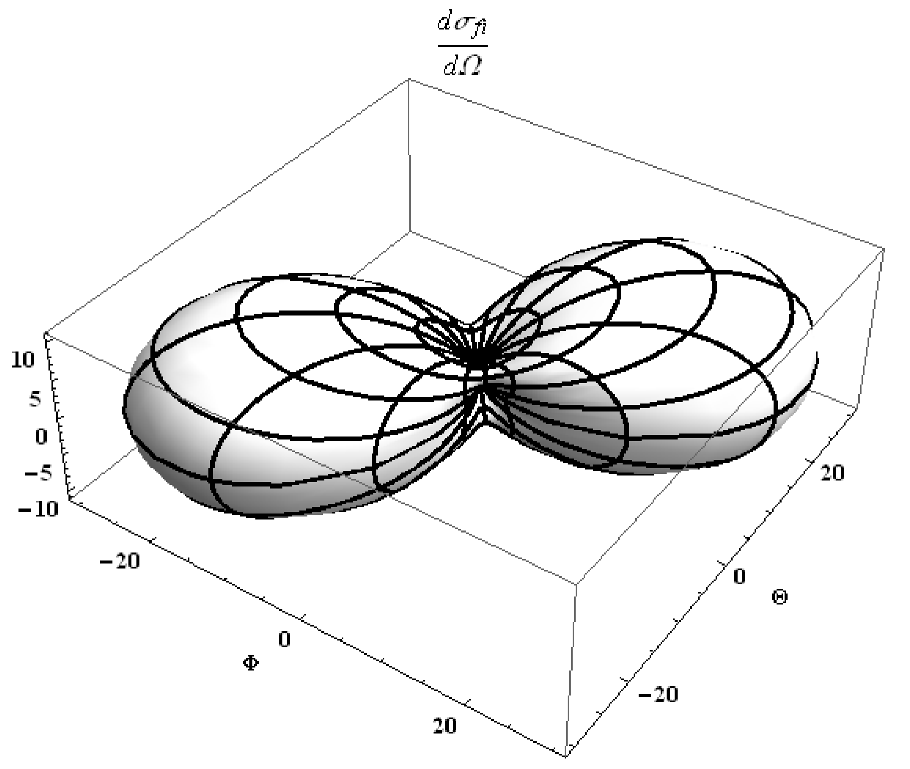
$$\varepsilon_n = -\frac{V^2E}{2\left(n+m+\frac{1}{2}\right)}. \qquad -\mathit{transverse}\quad \mathit{energy}$$

$$F\left(-n+m+\frac{1}{2};2m;\alpha_n\rho\right);$$ confluent hypergeometric function (Kummer function)

Photon scattering by channeled electron

Crystal W<100>, electron relativistic factor γ=10, transition *(n=1,m=1)* $\rightarrow$ *(n=0,m=0)*

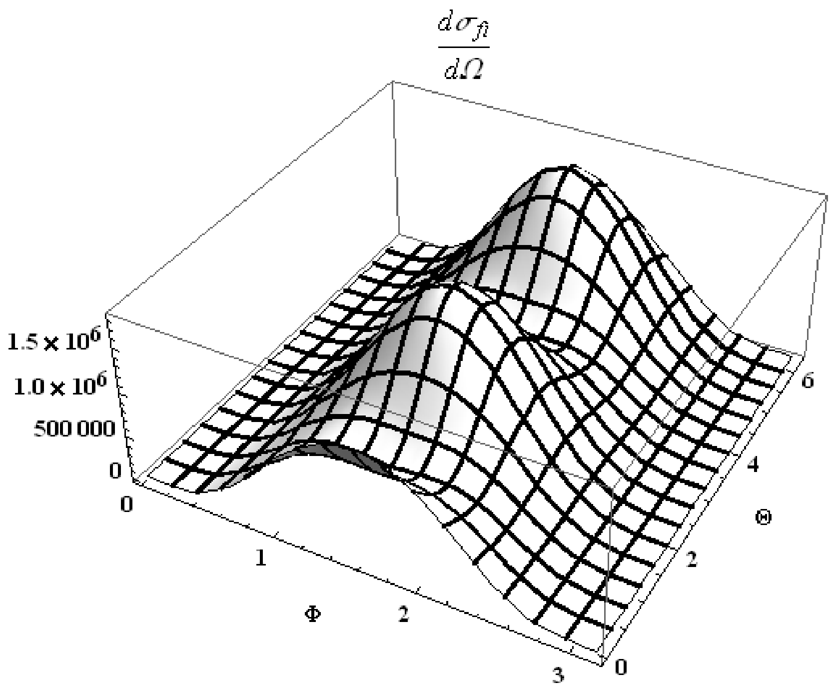


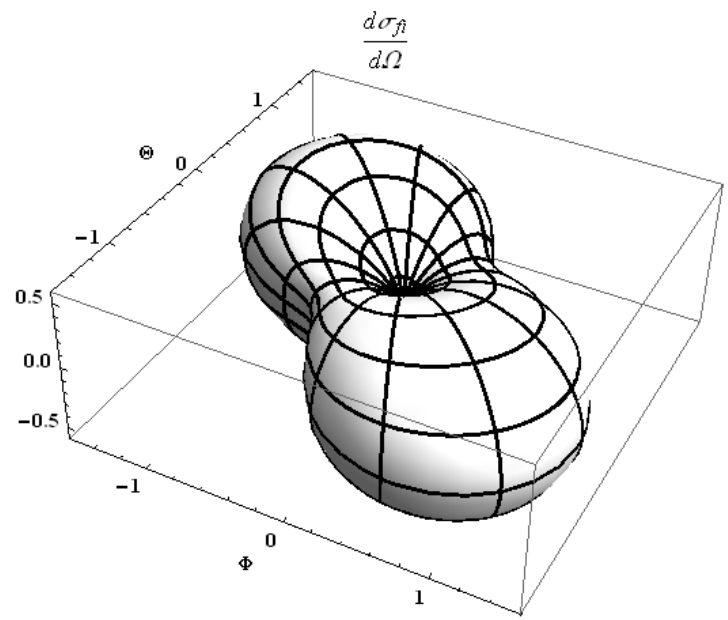


Angular distribution of scattered photon in reference frame moving with longitudinal channeled electron velocity

Photon scattering by channeled electron

Crystal W<100>, electron relativistic factor γ=10, transition *(n=3,m=2)* → *(n=0,m=0)*





Angular distribution of scattered photon in reference frame moving with longitudinal channeled electron velocity

The cross section of coherent bremsstrahlung

$$V(\vec{r}) = \sum_{i=1}^{N} V_1(|\vec{r} - \vec{r}_i|), \quad V_1(r) = \frac{Ze}{r}\exp\left(-\frac{r}{R}\right).$$ electrostatic potential of the crystal axis

Here V_1 is the potential of a single atom, *R* is the screening radius, *N* is the number of atoms in the axis, *Z* is atomic number.

The spectrum of virtual photons of crystal axis

$$n(\omega)d\omega = \frac{Z^2 e^2}{\pi^2} N \times$$

$$\left\{\left[L - B\exp\left[-\left(\frac{\hbar\omega}{\gamma\hbar c}\bar{u}\right)^2\right]\right] + \frac{2\pi}{d}\sum_{g_n} B\exp\left[-\left(\frac{\hbar\omega}{\gamma\hbar c}\bar{u}\right)^2\right]\delta(k_1 - g_n)|S|^2\right\}\frac{d\omega}{\omega}$$

$$L = \pi \ln\left[\frac{a\lambda^{-2}}{(\hbar\omega/\gamma\hbar c)^2 + R^{-2}}\right], \quad a \approx 1$$

d - the lattice constant, ω - the frequency of virtual photon, λ - Compton wave length of electron

$\bar{u}^2$ - mean–square displacement of the crystal atom from equilibrium position

Ei(-x) - exponential integral function

$g_n = 2\pi n/d$ - 1D reciprocal lattice vector

$|S|$ - structure factor of a crystal axis

γ - electron relativistic factor

In accordance with the virtual photons method, the cross–section of CB by channeled positron is:

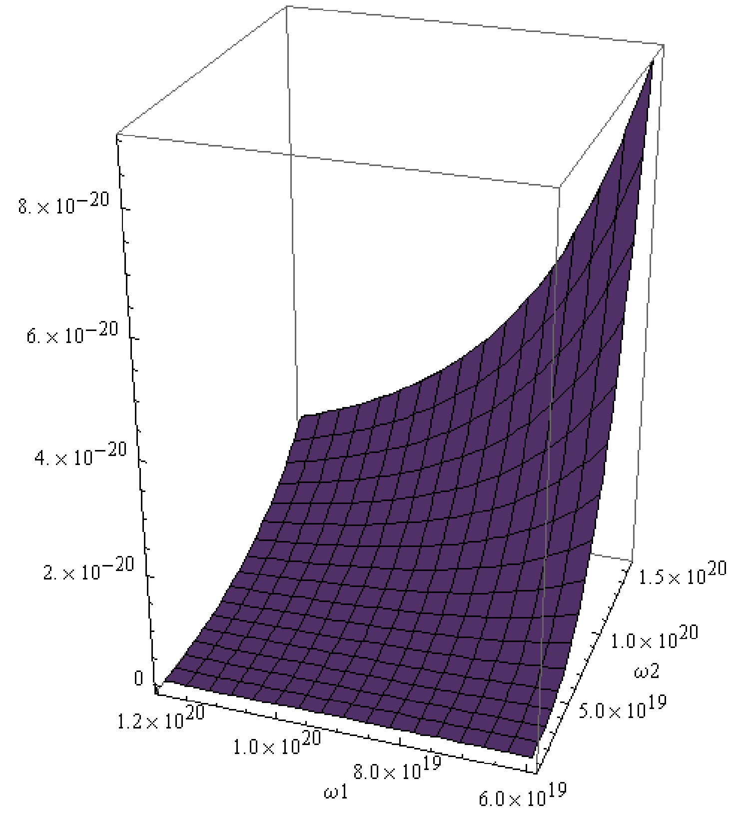
$$\frac{\sigma^{CR}(\omega_r)}{d\omega_r} = \int_{\omega_{MIN}}^{\omega_{MAX}} \frac{\sigma(\omega_r, \omega)}{d\omega_r d\omega} n(\omega) d\omega$$

$$\hbar\omega_r = \gamma\, \hbar\omega'(1 - \beta\cos\Theta')$$

the Lorentz transformation
for the photon energy (the Dopp

$$\beta = v/c$$

v the longitudinal velocity of
channeled electron in the laboratory coordinate syst



The limits of integration are determined by the condition

:

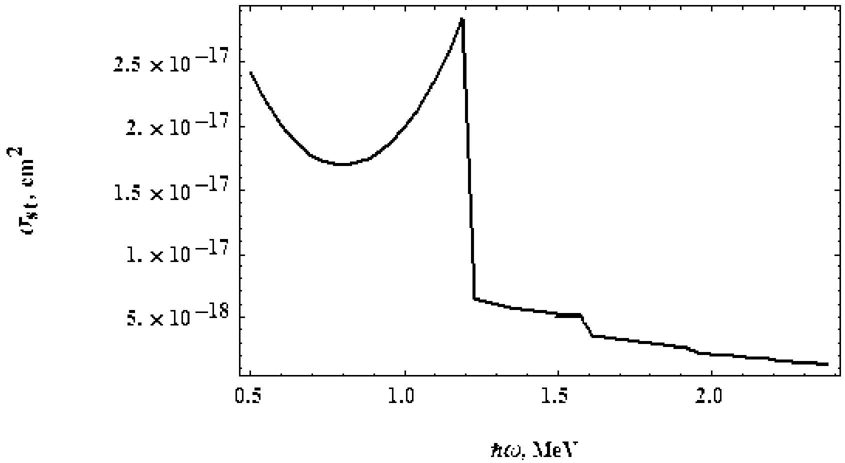
$$\left.\begin{array}{l} (\mathbf{k}_{||i} + \mathbf{k}_{||1}) = (\mathbf{k}_{||f} + \mathbf{k}_{||}) \\ (E_i + \hbar\omega_1) = (E_f + \hbar\omega_2) \end{array}\right\}$$

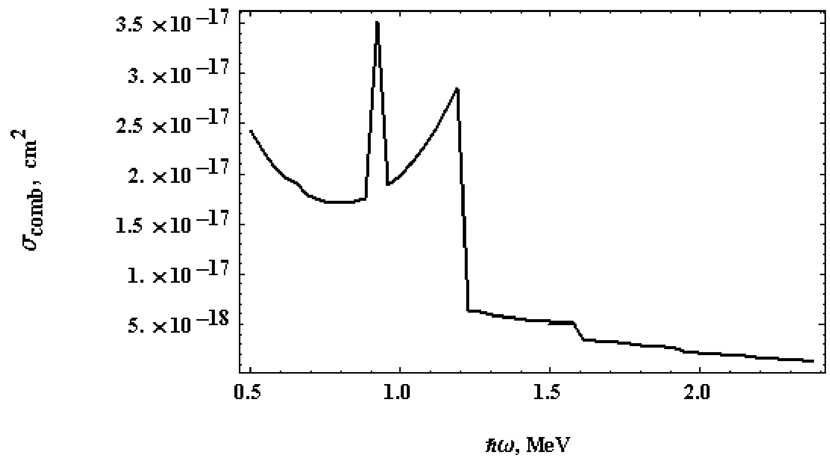
$$\omega_{MIN} = \frac{\hbar\omega + \gamma(1+\beta)(\varepsilon_{\perp f} - \varepsilon_{\perp i})}{\gamma(1+\beta)\hbar}$$

$$\omega_{MAX} = \frac{\hbar\omega + \gamma(1-\beta)(\varepsilon_{\perp f} - \varepsilon_{\perp i})}{\gamma(1-\beta)\hbar}$$

Result of calculation

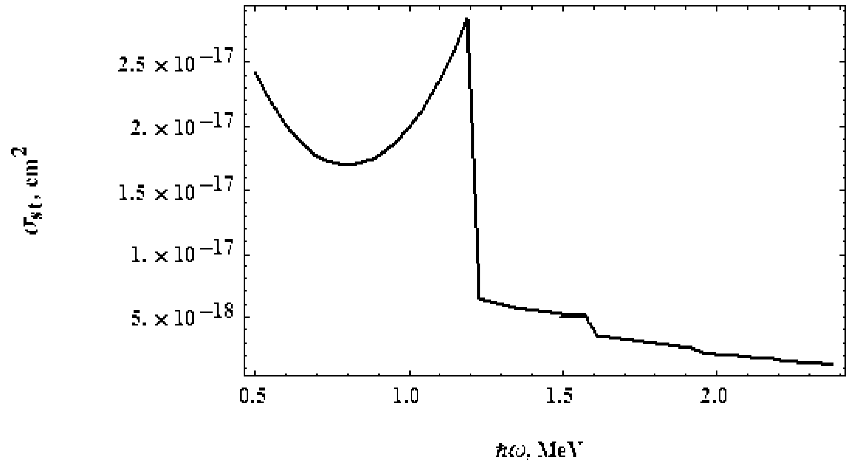
Crystal W<100>, electron relativistic factor $\gamma=10$, transition $(n=2,m=1) \rightarrow (n=0,m=0)$

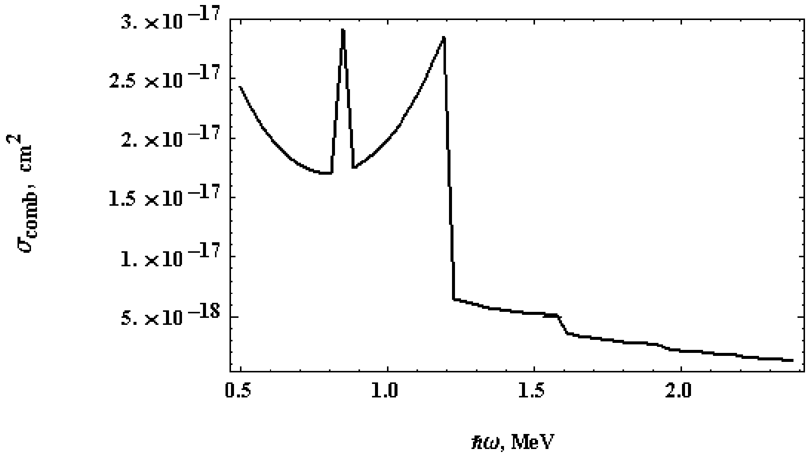




Result of calculation

Crystal W<100>, electron relativistic factor γ=10, transition *(n=3,m=1)* $\rightarrow$ *(n=0,m=0)*





We obtain that combined effect result in appearance of additional sharp peak in coherent bremsstrahlung cross-section. This result is not agree with the experiment. The reason is as follows:

1. It was used very simple approximation for continuous crystal potential.
2. It was used one string approximation.
3. It is necessary to take into account the resolution of detector.

Tank you for your attention