Channeling radiation on single crystals

S. Dabagov, W. Wagner, and B. Azadegan

Cooperation from Italy-Russia, Germany, and Iran

Publications

1. Azadegan, B., S. B. Dabagov, and W. Wagner. "Simulation of axial channeling radiation on a thin Ge single crystal. Nuovo Cimento-C 34, no. 4 (2011): 149.

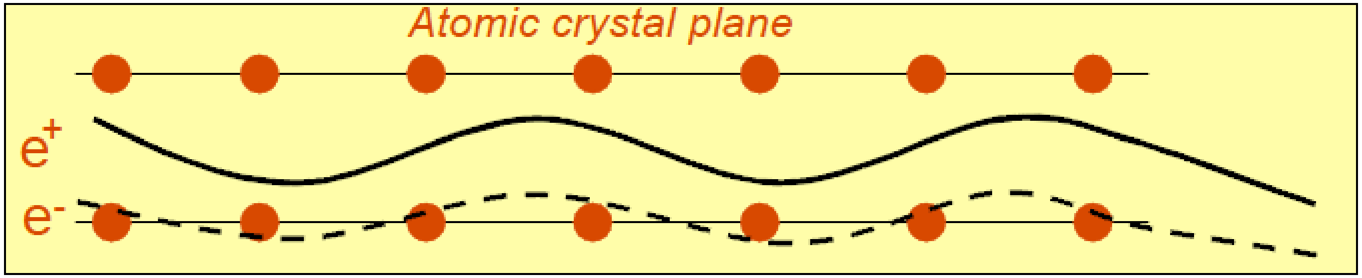
2. Azadegan, B., and S. B. Dabagov. "Planar channeling radiation by 20-800 MeV electrons in a thin silicon carbide." The European Physical Journal Plus126, no. 6 (2011): 58.

3. Azadegan, B., S. B. Dabagov, and W. Wagner. "Computer simulation of the radiation of electrons axially channeled in a thin Ge single crystal." Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 269, no. 19 (2011): 2098-2106.

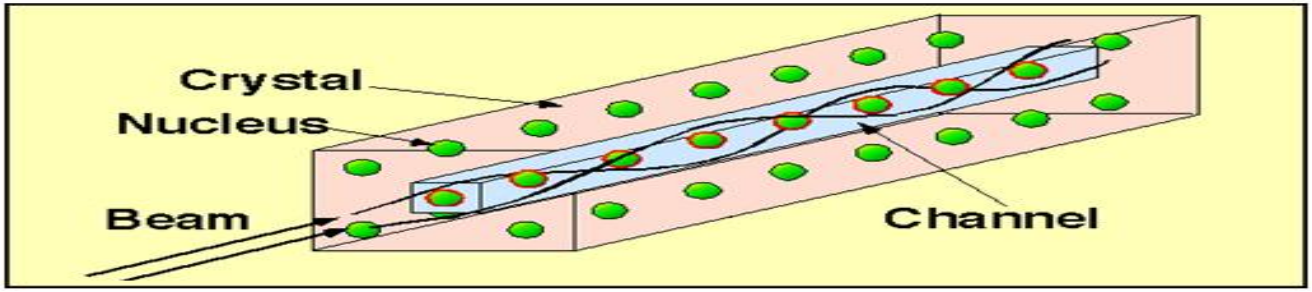
4. Azadegan, B., S. B. Dabagov, and W. Wagner. "Planar channeling radiation by relativistic electrons in different structures of silicon carbide." Journal of Physics: Conference Series, vol. 357, no. 1, p. 012027. IOP Publishing, 2012.

5. Azadegan, B., A. Mahdipour, S. B. Dabagov, and W. Wagner. "Positron energy distributions from a hybrid positron source based on channeling radiation." Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 309 (2013): 56-58.

Planar channeling: One dimensional problem



Axial channeling: two dimensional problem



2. Theory of planar channeling radiation

Planar channeling

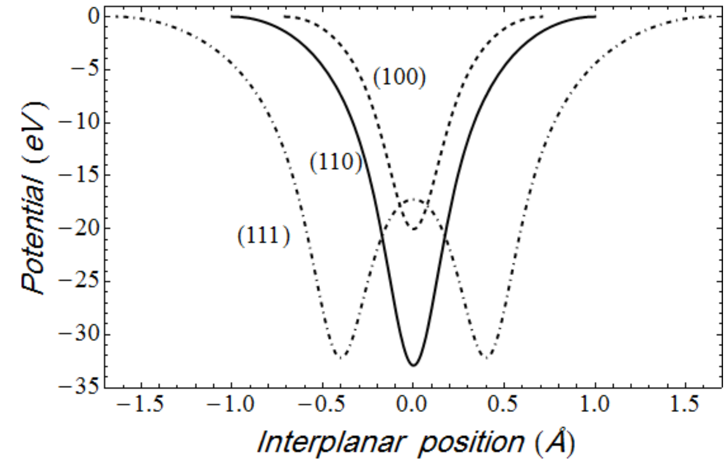
$$V(x) = \sum_n v_n e^{ingx}$$

$$v_n = -\frac{2\pi}{V_c} a_0^2 (e^2 / a_0) \sum_j e^{-M_j(\vec{g})} e^{-i\vec{g}.\vec{r}_j} \sum_{i=1}^{4} a_i e^{\left(-\frac{1}{4}\left(\frac{b_i}{4\pi^2}\right)(ng)^2\right)}$$

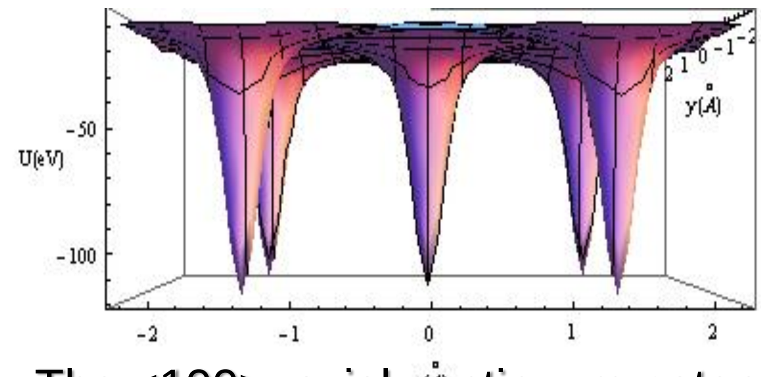
Axial channeling

$$V(x,y) = \sum_{\vec{g}_m} v_{\vec{g}_m} e^{i\vec{g}_m.\vec{r}_\perp}$$

$$v_{\vec{g}_m} = -\frac{2\pi}{V_c} a_0^2 (e^2 / a_0) \sum_j e^{-i\vec{g}.\vec{r}_j} \sum_{i=1}^{4} a_i e^{\left(-\frac{1}{4}\left(\frac{b_i}{4\pi^2} + 2 < u_j^2 >\right)|\vec{g}_m|^2\right)}$$



The planar continuum potentials of diamond for electrons



The <100> axial continuum potential of germanium for electrons

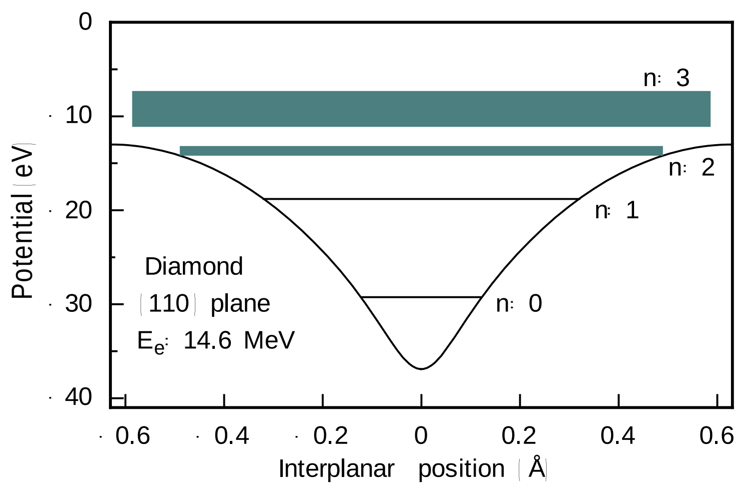
3. Theory of planar channeling radiation (Quantum)

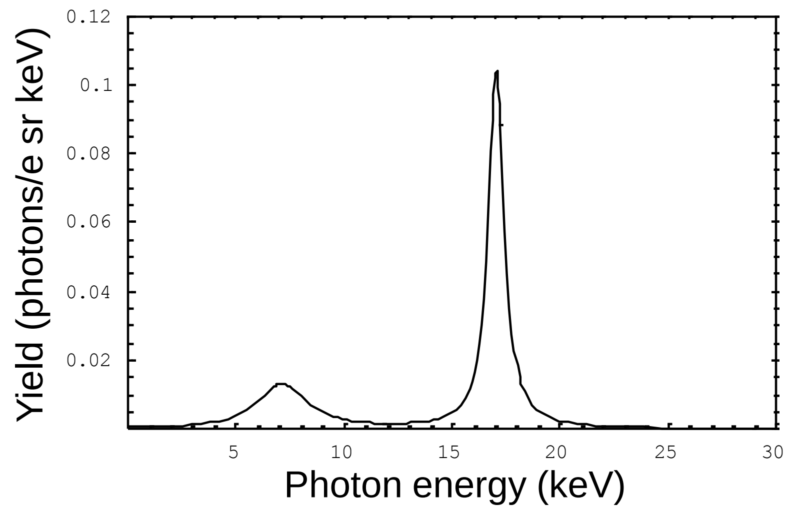
Quantum mechanical model $E_e < 100 MeV$

$$-\frac{\hbar^2}{2m_e\gamma}\frac{d^2\psi(x)}{dx^2} + V(x)\psi(x) = E\psi(x) \Longrightarrow$$ Wave functions $\psi_i(x)$ and eigenvalues E_i

$$E_0 = 2\gamma^2(E_i - E_f)$$

$$\frac{d^2N_{CR}(i\to f)}{d\Omega_\gamma dE_\gamma} = \frac{\alpha\lambda_c^2}{\pi\hbar c}2\gamma^2(E_i - E_f)\left|\left\langle\psi_f(x)\left|\frac{d}{dx}\right|\psi_i(x)\right\rangle\right|^2\int_0^z dzP_i(z)\times\frac{\Gamma_{\text{tot}}/2}{(E_\gamma - E_0)^2 + 0.25\Gamma_{\text{tot}}^2}$$





A Mathematica package for calculation of planar channeling radiation spectra of relativistic electrons channeled in a diamond-structure single crystal (quantum approach)

Computer Physics Communications 184 (2013) 1064-1069

4. Theory of planar channeling radiation (classical)

Classical model $E_e > 100 MeV$

Planar :

$$\gamma m\ddot{x}(t) = F = -\frac{\partial V(x)}{\partial x}$$

Axial :

$$\gamma m\ddot{x} = -\frac{\partial V(x,y)}{\partial x}$$

$$\gamma m\ddot{y} = -\frac{\partial V(x,y)}{\partial y}$$

$$\gamma m\ddot{z} = 0$$

Angular energy distribution:

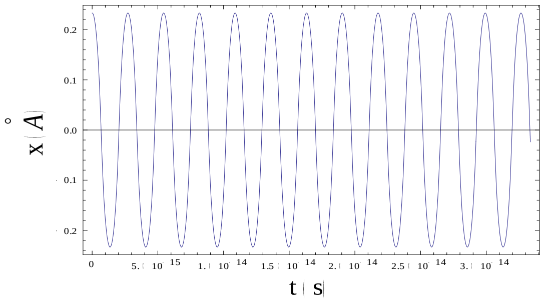
$$\frac{d^2E}{d\omega d\Omega} = \frac{e^2}{4\pi^2 c}\left|\int_0^{\tau} e^{i(\omega t - \vec{k}.\vec{r})}\frac{\vec{n}\times((\vec{n}-\vec{\beta})\times\dot{\vec{\beta}})}{(1-\vec{\beta}.\vec{n})^2}dt\right|^2$$

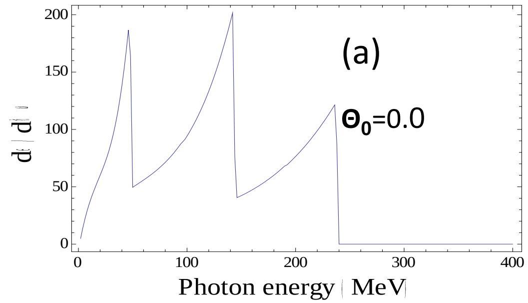
Total radiated energy in thick crystal:

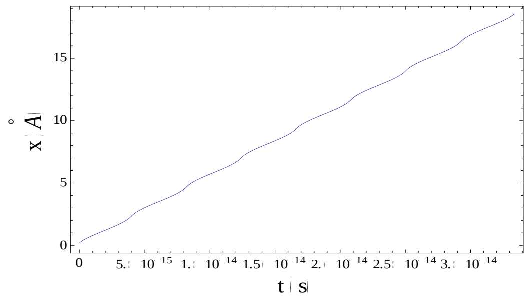
$$\frac{dE}{d\omega\Delta z} = \frac{e^2}{c^4T^2}\sum_{n=1}^{\infty}\Theta[1-\eta_n](\eta_n^2 - \eta_n + \frac{1}{2})\cdot\left|\dot{x}_{\tilde{\omega}}\right|^2$$

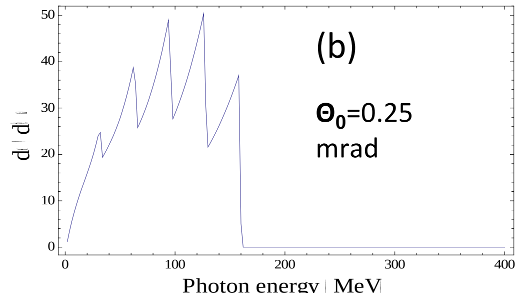
$$\eta_n = \frac{T\omega}{4\pi\gamma^2 n};\ \tilde{\omega} = \frac{2\pi n}{T};\ \dot{x}_{\tilde{\omega}} = \int_0^T \dot{x}e^{i\tilde{\omega}t}$$

Planar:



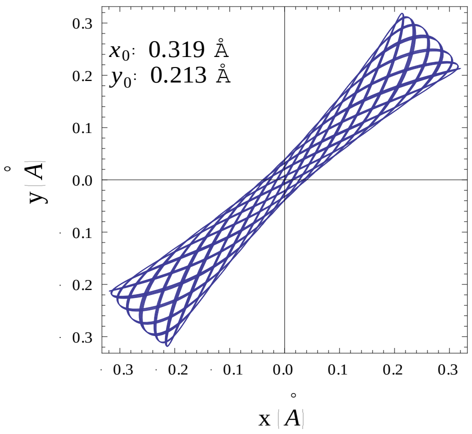


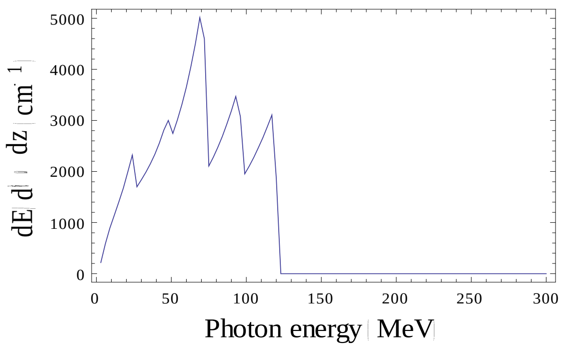




Trajectories and CR spectra for one incident point with a) zero b) 0.25 mrad incidence angles for 2 GeV electron channeled along the (110) plane of a tungsten single crystal.

Axial:





Trajectory (rosette motion) and CR spectra for one incident point for 1 GeV electron channeled along the <100> axis of W single crystal.

Simulation of axial channeling radiation on a thin Ge single crystal

Azadegan, B. and Dabagov, S. B. and Wagner, W. (2011) nuovo cimento C, 34 (4). pp. 149-156. ISSN 1826-9885
Official URL: https://www.sif.it/riviste/sif/ncc/econtents/2011/...

Abstract

Based on classical electrodynamics the radiation emitted by axially channeled electrons has been investigated by means of computer simulations. Using the Doyle-Turner approximation for the atomic scattering factor and taking thermal vibrations of atoms into account, we calculated the two-dimensional continuum potential of the 110 crystallographic axis of a thin Ge single crystal. The trajectories, velocities and accelerations of electrons are obtained by solving the equations of motion in three dimensions, and the spectral-angular distribution of radiation has been calculated within classical approach.

Instruments and Methods in Physics Research Section B

Nuclear Instruments and Methods in Physics Research B 309 (2013) 56–58

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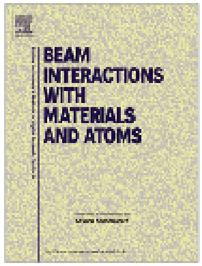

Positron energy distributions from a hybrid positron source based on channeling radiation

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Regular Article

Planar channeling radiation by 20–800 MeV electrons in a thin silicon carbide

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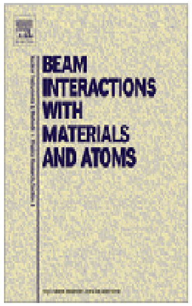

Computer simulation of the radiation of electrons axially channeled in a thin Ge single crystal

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Thank you