HANDLING OF PLANAR CHANNELING OF PARTICLE IN CRYSTALS DEPENDING ON THEIR PARAMETERS

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By means of channeling effect – the most known direction in physics of orientation phenomena, it is possible to study the thermal fluctuations and displacements of atoms in a lattice, the distribution of electron density in the interatomic space in crystals, as well as the possibility to use channeling for creation the efficient control systems for beams of high energy particles.

The channeling of light particles, such as electrons and positrons, is attractive, especially, in connection with an opportunity for using the appeared during the channeling monochromatic hard radiation, which presents a practical interest [1].

Consideration of moving of the fast charged particle in crystals within the classical theory framework is possible for protons, ions and other heavy particles of a specific range of energies, whereas for positrons and especially for electrons it is necessary the quantum description – due to the presence of diffraction effects [2].

Redistribution of density of electrons and positrons during their moving and penetration deep into the crystal is considered in presented work in the regime of planar channeling, within the framework of quantum-mechanical theory.

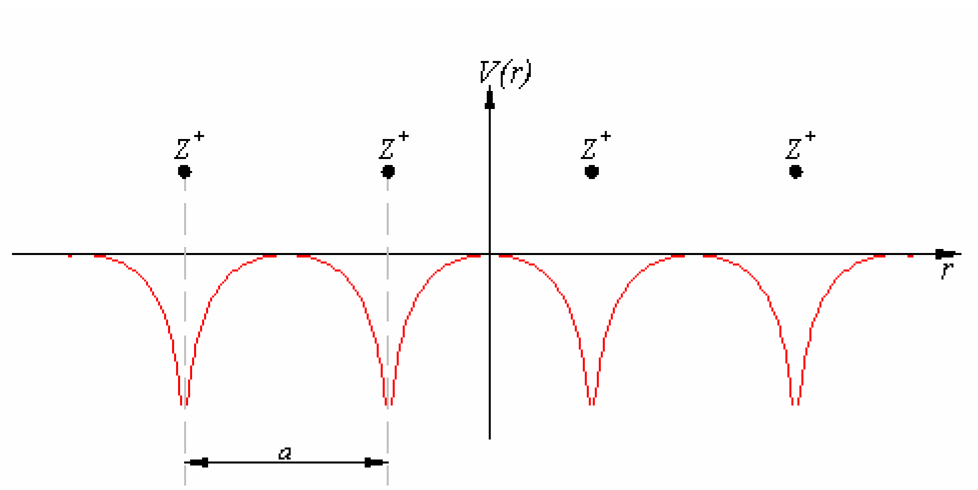

Fig. 1. The general form of one-dimensional periodic potential

The consequent quantum theory of channeling effect based on the usage of the density matrix formalism is developed in a series of works of Yu.M. Kagan and Yu.V. Kononets [3,4]. This method allows taking into account the coherent nature of diffraction in the regular medium and inelastic processes accompanying the motion of fast particle in the crystal. As part of this formalism all the observed phenomena can be explained in a unified way.

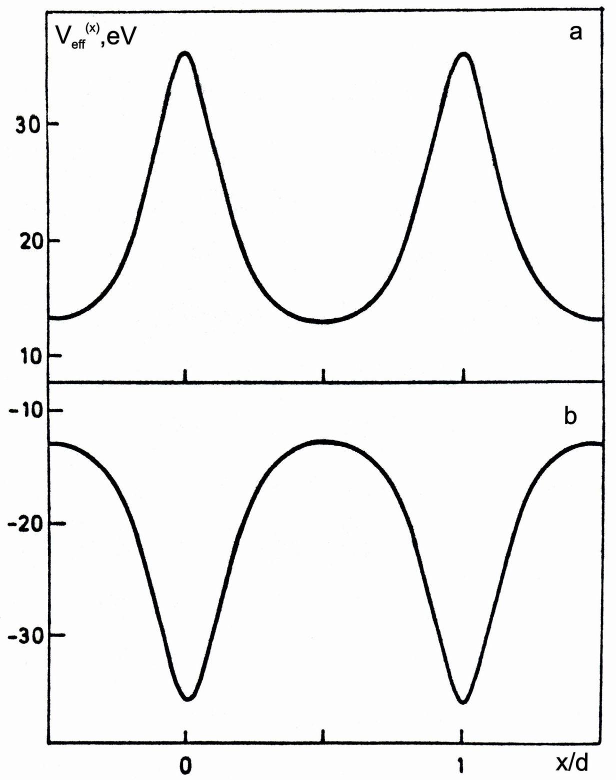

Fig. 2. The effective periodic potential for {110}-planar channeling in silicon:
a – for positrons, b – for electrons.

The behaviour of reflection coefficient both for rectangular potential barriers and potential holes [5] is investigated for the nearest above-barrier and below-barrier states, as well as the influence of this behaviour on the different physical phenomena arising at planar channeling of electrons and positrons with energies in the MeV-region has been studied [6]. The passage of MeV-energy electrons through monocrystals is discussed by S.B. Dabagov and L.I. Ognev [7].

In the channeling effect of electrons we have established a special role of the above-barrier states, which are placed in close proximity to a potential barrier that, by the way, has allowed explaining the anomalous passage of the above-barrier electrons in crystals (Fig. 3), which experimentally was observed at the Nuclear Physics SRI of Tomsk Polytechnic Institute [8] (Fig. 4).

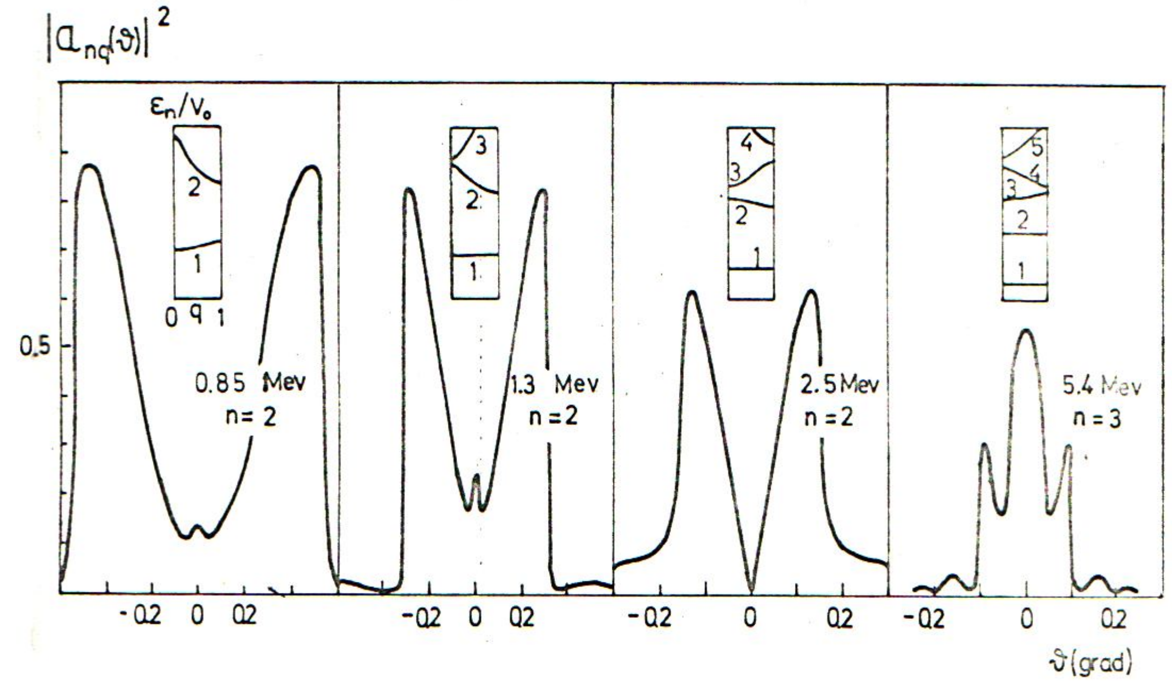

Fig. 3. Energy band structure of the transverse motion and angular distributions of electrons in low-lying above-barrier zones in the Krönig-Penney type potential model

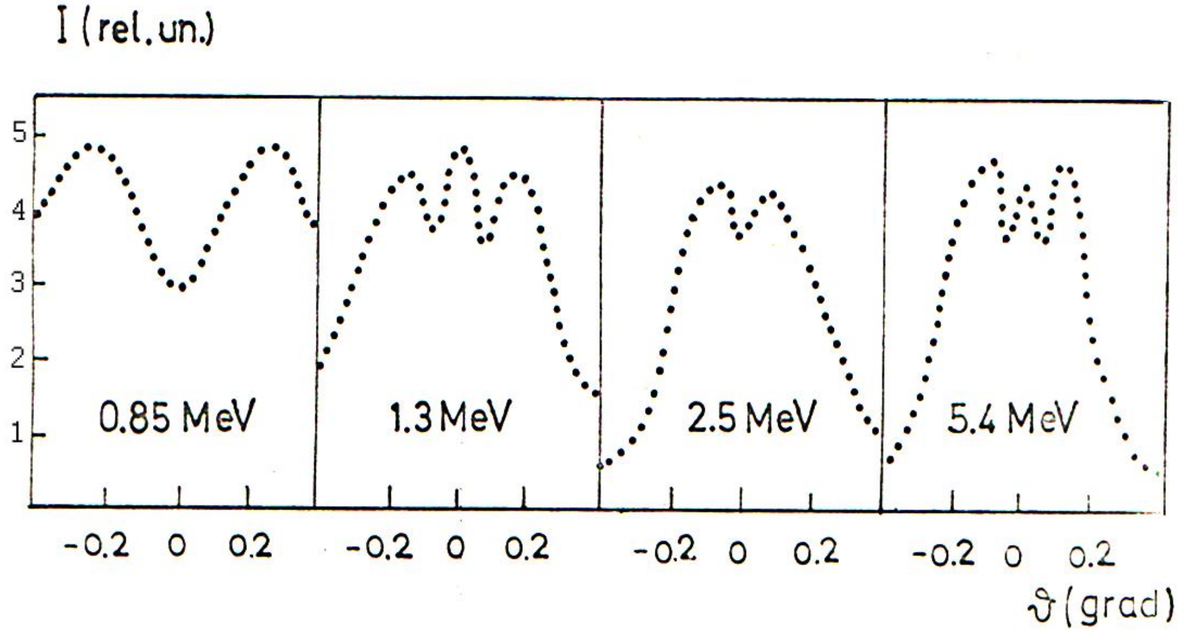

Fig. 4. Experimental angular distributions of electrons in the plane orthogonal to {110}-planes of silicon and passing through the axis of the incident beam.

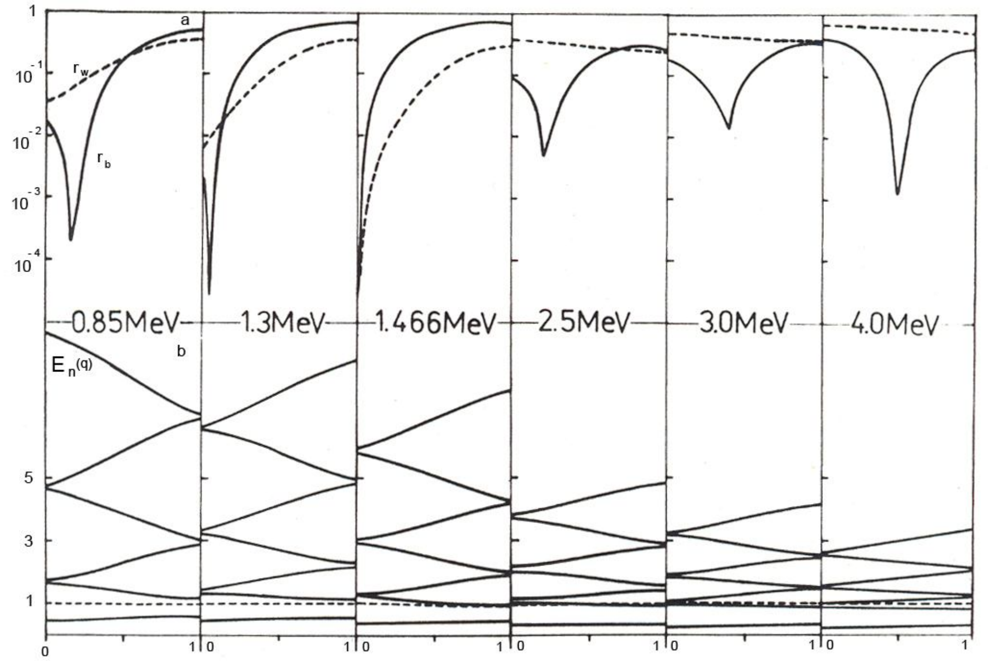

Fig. 5. (a) The AB-reflection coefficients dependence on the quasi-momentum into the Brillouin zone for the first AB-band by electrons of different energies;
(b) energy band spectrum.

Investigation of specificity of the energy spectrum and properties of the Bloch wave functions of the various states arising from the interaction of particles with a regular medium, revealed a special role in the phenomenon of channeling of negatively charged particles of the above-barrier states, manifested in the existence of a fraction of the electrons, which relatively weakly interact with the crystal atoms. As it turned out in a result of our investigations, just these states are responsible for the abnormally deep penetration of the electrons into the crystal under the channeling conditions [9,10,11].

So, realizing the conditions, under which the coherent phenomena have not damped (small thickness of a crystal), and, having measured the yield of inelastic processes on the crystal lattice nuclei, or interstitial impurity atoms, it is possible to find experimentally the periods of appropriate oscillations that will give the information about the energy band structure in case of particles moving in crystal [12,13,14].

In the research of channeling effect of charged particles in crystals the big importance has a finding of the energy spectrum structure (zones and gaps) in the periodic potential formed by chains or planes of atoms of the crystalline solid-state lattice.

For light particles, in particular, for electrons, the quantum number characterizing the number of bound states in the potential of a crystalline lattice, is less, than for positrons of the same energy, and much less, than for heavy particles.

In the one-dimensional potential (planar channeling) the transverse motion is described by Schrödinger's equation with some efficient one-dimensional periodic potential (see Fig. 2) [6, 15]. The wave function of the passing through a crystal particle represents the superposition of corresponding Bloch functions, which properties define, practically, the whole spectrum of physical phenomena observed under channeling conditions.

In simple cases the effective periodic potential is represented by a series of potential barriers of equal height. The particle states in such a potential are divided into two groups: the first one with energies less than the height of a barrier (so-called, below-barrier states), permits a simple consideration, for example, within the framework of the strong coupling approximation, and the above-barrier ones with energies in excess of a potential barrier height. The last play the special role, for instance, in the anomalous deep penetration of electrons into the crystal under channeling conditions [4,9,16,17,18].

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