Ballistic electron transport in cascade of $n^+ - i - n^+$ homo- and heterodiodes.

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We present a self-consistent theory of ballistic electron transport in $n^+ - i - n^+$ homo- and heterodiodes for steady-state and high-frequency regimes. The theory takes into account real injection/exclusion processes at the $n^+ - i$ interfaces, space-charge effects in the base region and diffusive electron transport in contacts. Numerical results are obtained for $InAs$ diodes.

For the steady-state problem, we derive the spatial distributions of electron concentration, electric field and electrostatic potential, and calculate the current-voltage characteristics. We demonstrate that widely accepted simplifications and results, such as the virtual cathode approximation, the Child law and others, cannot be applied to describe semiconductor ballistic diodes for realistic values of the applied electric biases. We develop the theory of real-space transit-time resonance in ballistic diodes and determine the small-signal frequency-dependent response of these devices.

The negative dynamic resistance (NDR) effect is identified and studied. We show that the thermal spreading of injected electrons over the energy greatly affects the transit-time resonance and suppresses the NDR effect. The parameters of the diodes and working temperatures necessary to achieve the maximum NDR effect in the THz frequency range are determined. Finally, we discuss the use of the NDR effect to generate THz radiation. With this aim, we analyze the coupled system of the ballistic diode and the resonator TEM mode. The cascade structure of ballistic diodes gives the larger gain coefficients than single diode. For this cascade, the criterion of THz generation can be readily achieved for a reasonable number of ballistic diodes [1]. The results indicate the perspectives for the development of THz sources based on ultra-short ballistic devices.

[1] V. V. Korotyeyev, V. A. Kochelap, A. A. Klimov, G. Sabatini, H. Marinchio, C. Palermo, and L. Varani, Journal of Nanoelectronics and Optoelectronics **6**, 169 (2011).