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Influence of strong magnetic and electric fields on the hot carriers kinetic processes in the semiconductors bulk

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With the extension of the upper extreme high frequency (EHF) range limit upper volume of modern radio engineering devices to the terahertz range, developers are faced with the possibility of taking into account the peculiarities of the physical processes occurring in the semiconductor structures bulks for constructing of new type converter devices. The chips of these devices are capable in their work to be exposed to strong external electric (EF) and magnetic (MF) fields with high intensities. Such conditions are created in the bulks of modern semiconductor structures and super lattices made of A^{III}B^V type materials operating in the mentioned range and usually do not take into account the volume diffusion nonlinearities, which as shown in a number of works, contribute significantly to the output current density. So recently, it has been proved that under conditions of external electric field intensities approaching and exceeding the threshold value of the Gunn effect (about 4 kV / cm), the diffusion component of the output current will be commensurable with the drift current. This account is made on the basis of the phenomenological representation of the processes of averaged drift and heating and considering the dependence of the effective mass (m) on the energy (W) represented by the Taylor series expansion result. The relaxation times of the quasimomentum (τ) and the energy (τ_e) were assumed to be independent of the charge carriers energy. It was found that the diffusion nonlinear components should be taken into account when calculating the output parameters of mixers, multipliers and self-excited generators using hot electrons in the mentioned frequency ranges. As a result of theoretical calculations, the amplitude dependences of the constant (D_0) and variable (D_1) diffusion coefficients were found, which can be defined as the "bulk diffusion detection effect" and that undoubtedly, is a poorly understood phenomenon. Also mutually orthogonal effects of electric and magnetic fields on the processes of carrier drift and diffusion are considered. It was found that the main electro physical parameters, due to the action of the Lorentz force, acquire a vector-component form along the x and y axes of the Cartesian coordinate system. In addition, a number of new effects on drift and diffusion characteristics have been discovered. Thus, it was found that the components of the drift velocity and the diffusion coefficient along the longitudinal (x -axis) of the main drift direction are independent of the transverse magnetic field but are determined only by the longitudinal EF along this direction and the transverse (y -axis) component of the drift velocity for strong magnetic induction values ($B_z > 4.0 T$) demonstrates the displacement of the falling section beginning on the drift (volt-ampere) characteristic in the direction of decreasing (by a factor of 2), which probably indicates a new "Gunn effect controlled by a magnetic field". Reducing the intensity of the threshold field of the Gunn effect from 4 to 2 kV / cm will allow to increase the efficiency of the bulk diode by 50% (assuming the output current density and load conductivity remains unchanged). Thus, the fundamental possibility of creating two-dimensional devices for frequency conversion (autodyne type mixers) has been revealed. In addition, in the case of realizing the possibility of magnetic field modulation (or manipulation according to a given function), it becomes possible to obtain the pulse-modulated (or manipulated) microwave or EHF oscillations. For obtained analytical experimental verification results a semiconductor structure sample construction and the experimental setup structural image are proposed.

Biography

Igor Vladimirovich Malyshev - graduated from the Taganrog Radioengineering Institute (TREI) in 1982. From 1988 – candidate of technical sciences and from 1989 – assistant professor at theoretic radio engineering basis department of TREI. From 2006 – assistant professor at radio engineering department of Nanotechnology, Electronics and Engineering Institute (NTEEI) of South Federal University (SFEDU). Since 1985 he passed training in leading universities in Russia and Germany. The scientific field of research lie in the area of solid-state dispersion medias transport physics. More than 60 publications are devoted to the electromagnetic propagation in this medias, including chiral type.

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