High frequency properties of mesoscopic structures

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Potential barriers of different types and quantum wells are substantial parts of a wide spectrum of mesoscopic devices. Depending on a layer composition, materials, doping profiles and external electric field electrons and holes in such structures participate in different emission and tunneling processes; thus quantum physics methods should be used to describe these phenomena. Typical situation in electronics is that a dc-bias together with a small ac-signal are applied to the structure. While the calculation of the potential barrier transmittance with dc-bias only is a classical and well-known problem of quantum mechanics, the application of a high-frequency signal to the barrier was studied only in the last decade. The aim of this paper is to present results achieved in the theoretical investigation of the high-frequency electron transport (THz frequency band) across different mesoscopic (nanoscale) structures: the rectangular, triangular, trapezoidal or parabolic potential barriers, the rectangular quantum well, the channel of the simplified model of a nanoscale metal-oxide semiconductor field effect transistor (MOSFET). If some region of the structure is modulated by the high frequency signal $V\cos(\omega t)$, electrons during their flight through the region can emit or absorb usually one or even more energy quanta $\hbar\omega$, thus their wave function is the superposition of different harmonics $\exp(\sim n\hbar\omega)$. The analytical formulae for the ac barrier transmittance are derived (convenient for compact device models), the transmission amplitudes as functions of electron energy and the position of resonance peaks is discussed (the effect of dc bias, of different electron effective mass inside the barrier region etc.). The high-frequency current coreesponding to the first and second harmonics is calculated and the complex admittance of the structure as a function of signal frequency and dc bias is found.

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