Femtosecond Evolution of Spatially Inhomogeneous Carrier Excitations: Part I: Kinetic Approach

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A Wigner equation for nanometer and femtosecond transport regime has been previously derived from a three equations set model based on the generalized Wigner function. The full version of the equation poses serious numerical challenges. Two simplified versions of the equation, the Wigner-Boltzmann equation and in the homogeneous case the Levinson equation have been previously analyzed.

Here we focus on a third limiting case where the electron-phonon interaction is described on the quantum-kinetic level of the Levinson equation, but the evolution problem becomes inhomogeneous due to the spatial dependence of the initial condition. The equation is relevant e.g. for description of the ultrafast dynamics of optically generated carriers. Particularly we consider a quantum wire, where the carriers are confined in the plane normal to the wire by infinite potentials. At low temperatures the carriers remain in ground state in the normal plane. In this way the evolution is described in the $2D$ phase space of the carrier wave vector and the position, while the phonons are three dimensional. The initial carrier distribution is assumed Gaussian both in energy and space coordinates, an electric field can be applied along the wire. A stochastic approach has been utilized to compute the behavior of the system. The approach, subtable for simulation of the general case of applied electric field is first applied to investigate the zero field case. The evolution of energy and space distributions are discussed. A spatial quantum effect, recently observed in the solutions of a density matrix model of the physical problem and solved by a deterministic approach is now confirmed by our Wigner model within a stochastic approach.

The numerical aspects are discussed in PartII