A Hierarchy of Kinetic Equations for Quantum Device Simulation

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A hierarchy of transport models describing quantum effects at different levels of approximation is presented. Approximations are introduced in the electron-phonon interaction only, while the influence of the device potential on the coherent transport is taken fully into account. The hierarchy is derived from the generalized Wigner function, which depends on position and momentum of one electron and two sets of phonon occupation numbers. Introducing the weak scattering limit and assuming an equilibrium phonon system yields an equation set consisting of a main equation for the reduced Wigner function and two auxiliary equations. From this set several quantum kinetic equations can be derived. Assuming a space homogeneous electric field the set reduces to the Levinson equation, which allows quantum effects in the electron-phonon interaction to be studied, such as collision broadening, collision retardation due to the memory character of the kernel, and the intra-collisional field effect. Solutions of the Levinson equation obtained by a backward Monte Carlo method will be discussed. By taking the classical limit in the phonon interaction the equation set reduces to a Wigner equation including a Boltzmann scattering operator. This equation is considered a feasible model for far from equilibrium transport in nano structures.