Monte Carlo Analysis of the Small-Signal Response of Charge Carriers

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Understanding the Monte Carlo method as a versatile tool to solve integral equations enables its application to a class of problems which are not accessible by purely physically-based, imitative Monte Carlo methods. One such class is the linearized small signal analysis of nonlinear systems. In this work the small signal response of charge carriers in semiconductors is investigated, assuming semi-classical transport.

Choosing a time domain formulation, a small perturbation is superimposed to the stationary electric field. By retaining only first order terms in the perturbation, the transient Boltzmann equation gets split into a stationary Boltzmann equation and a coupled Boltzmann-like equation. Assuming the perturbing field to be a Dirac impulse in time the latter equation describes the impulse response distribution function. The initial condition, which turns out to be proportional to the gradient of the stationary distribution function, cannot be interpreted as an initial distribution due to lack of positive definiteness. However, the initial condition can be expressed as a difference of two positive functions, and so can the impulse response distribution function. In this way the impulse response is understood in terms of the concurrent evolution of two carrier ensembles. Using different methods to generate the initial distributions of the two ensembles gives rise to a variety of Monte Carlo algorithms. Both existing and new algorithms for direct simulation of the impulse response are obtained in a unified way. Applications to technologically significant semiconductors are shown. A resonance effect occurring in Gallium Arsenide at low temperatures is discussed.