Femtosecond relaxation of hot electrons by phonon emission in presence of electric field

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The presence of the intra-collisional-field effect (ICFE) in the electron-phonon interaction has been investigated in regime of stationary transport [1], and it has been shown that ICFE plays a negligible role in this transport regime.

In this work we investigate the transient process of hot electron relaxation due to phonon emission in the presence of an applied electric field. Experimentally, such a process can be investigated by ultrafast spectroscopy, where the relaxation of electrons is explored during the first femtoseconds after an optical excitation [2]. We utilize the Barker-Ferry equation as a quantum-kinetic model of the process. This equation, the solution of which represents a tough numerical problem, has been solved for zero electric field using a backward Monte Carlo method [3]. Assuming an electric field increases the dimensionality of the problem. The solution $f(\mathbf{k}, t)$ at a given phase space point $\mathbf{k}$ at time t is linked to the solutions $f(\mathbf{k} - \mathbf{F}t_1, t_2)$ at a phase space point translated by the force field $\mathbf{F}$ at previous times $t_1, t_2 < t$. Thus no general integration domain in the phase space can be specified. To overcome this problem a variable transformation is proposed, where an efficient Monte Carlo algorithm was developed for the transformed equation.

Simulation results are obtained for $GaAs$ with physical parameters taken from [3]. The ICFE is clearly demonstrated in the solutions obtained at different evolution times and for different field values. Fig. 1 and 2 show solutions $|\mathbf{k}|f(|\mathbf{k}|, t)$ at $t = 200$ fs versus $|\mathbf{k}|^2$, which is proportional to the electron energy. The field leads to a change of the effective phonon energy which now depends on the field strength and direction. Solutions in direction normal to the field show that the field affects the broadening and retardation effects. The observed phenomena are understood from the the structure and the properties of the model equation.

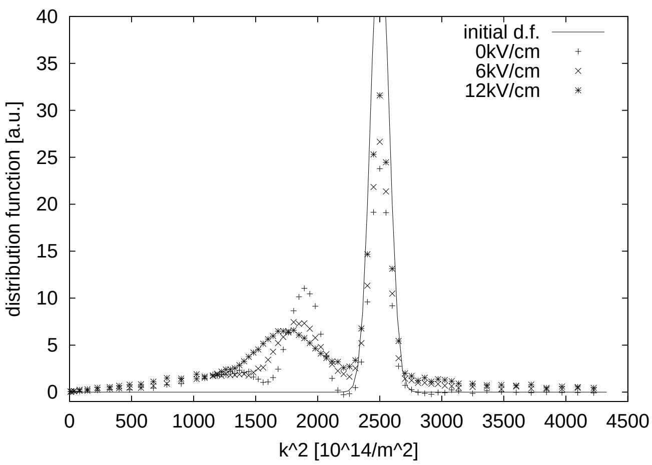

Figure 1: Solutions along the field direction

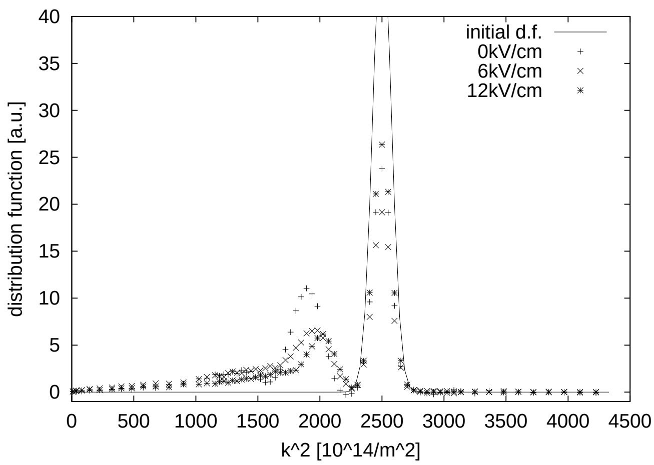

Figure 2: Solutions opposite to the field direction

1 P.Lipavski, F.Khan, F.Abdolsalami, and J. Wilkins. *Physical Review B*, 43(6):4885–4896, 1991.

2 J.Barker and D.Ferry. *Physical Review Letters*, 42(26):1779–1781, 1979.

3 M. Nedjalkov, H. Kosina, S. Selberherr, and I.Dimov, *VLSI Design Journal*, 2001. (in print).