# Phonon Decoherence in Wigner-Boltzmann Transport

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The Wigner-Boltzmann equation (WB) provides a relevant description of carrier transport in spatial, energy and time scales typical for modern semiconducting nanostructures [1]. As implied by the name, the two limiting coherent or classical components of the WB equation lead to very different physical effects. The reversible coherent evolution is characterized by oscillations and negative values of the Wigner function which are manifestations of quantum superpositions. We analyze the role of the Boltzmann component, which strives to modify the shape of the solution, until obtaining the classical equilibrium distribution, giving rise to decoherence which is inherent to the equation due to the trace operation on phonon or other variables used to derive the WB model [2]. Indeed it has been shown that for small phonon momenta the latter resembles the Fokker-Planck model of quantum Brownian motion which gives rise to classical localization in space. This effect is clearly presented in the dissipative evolution of a single wave packet [1]. A direct observation of the loss of coherence in an entangled state is a convenient alternative [3]. Here it is applied to suggest a physical model of the process of einselection by phonons. The Wigner function of two wave packets initially superimposed into a state with well pronounced oscillatory term, Fig. 1 on the left, which may be interpreted as formed by particles with positive and negative weights [4]. The coherent evolution causes a rotation due to spatial movement, but leaves the structure intact due to the conservation of momentum. Scattering redistributes the momentum bringing positive and negative particles together which causes the cancellation of weight [4]. The fine structure in the middle, which is the source of negative weights, is especially sensitive to this process. Simulations show that within 1ps of evolution of negative weights is suppressed in the sea of positive ones and the momentum distribution evolves towards the classical equilibrium distribution given by the solid line of shown on the right hand side of Fig. 1. The pointer states which survive the monitoring by phonons are the two Gaussian packets. The initially pure state evolved towards an object having completely different physical meaning: it is a mixed state, determined by the probabilities of the electron to be in one or the other packets related to the two wave functions. The speed of decoherence can be measured by the purity of the state, defined as the phase space integral of the square of the Wigner function. Fig.2 shows that the decrease of purity strongly depends on the thermally parametrized coupling with phonons. At higher temperatures the effect of decoherence due to the contacts is negligible, which is due to spatial localization.

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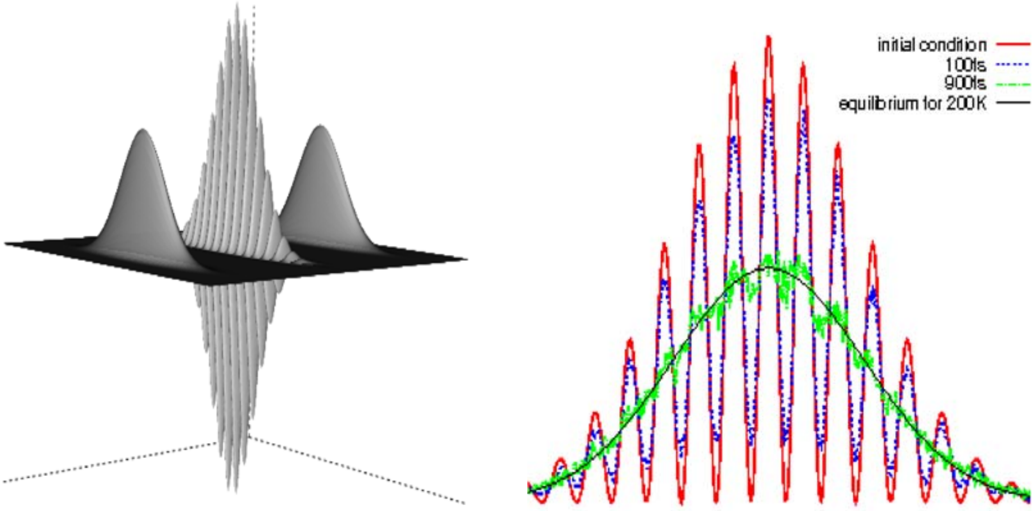

**Fig. 1**: Left: the initial Wigner function corresponds to a superposition of two wave packets having a width corresponding to the thermal equilibrium. Right: phonons redistribute the momentum striving towards equilibrium distribution, T=200K.

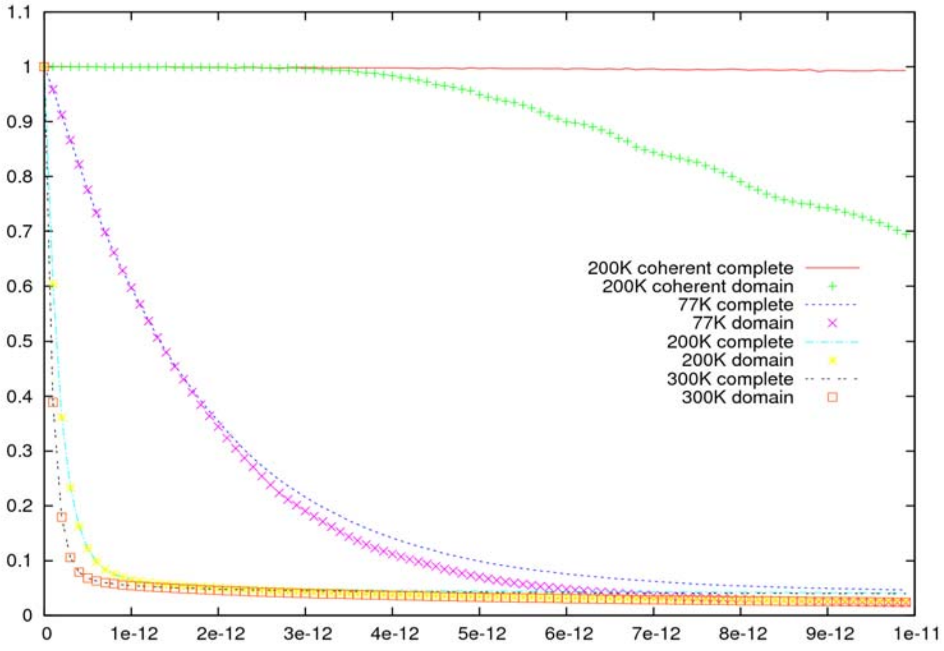

**Fig. 2:** The purity of a coherent state remains unity during its evolution, however quantum information is lost by particles leaving through the contacts: 'complete' and 'domain' refer to switching this effect off and on respectively. It is negligible at higher temperatures, which is due to a spatial localization due to phonons.