Dynamic Modelling of Quantum Transport within MGFETs

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The time-dependent analysis of quantum transport within MGFETs or quantum wires is of essential importance for their design. In order to analyze these components with the associated time-dependent effects, quantum kinetic models are important. The non-equilibrium Greens-function formalism (NEGF) [1] and the Wigner formalism [2] are usually available. Time-dependent simulations based on the NEGF are challenging in terms of numerical effort, especially for studies of non-ballistic transport [3]. The Wigner formalism, on the other hand, has some advantages in terms of numerical implementation and efficiency, as in the latter case, quantum transport is described in the phase space. This enables a description of coherent and incoherent phenomena, which can be taken into account by including suitable scattering operators [4].

Methodologies are needed to significantly reduce the computing time involved in the numerical analysis. For the analysis of MGFETs or especially quantum wire applications, in which the transport takes place in a preferred direction, there is the option of reducing the spatially three-dimensional problem to a spatially one-dimensional problem with regard to the transport direction. A spatial discretization takes place in the direction of transport, whereby the eigensolutions with their eigenenergies, also called modes, are determined in the lateral direction to the transport direction solving the Schrödinger equation [5, 6]. The wave function can be expanded according to these modes, so a one-dimensional problem arises, which then is solved by the von Neumann equation in center mass coordinates, which, with a spatial approximation based on a Finite Volume method and an expansion of the solution in direction of the relative coordinate on the basis of exponential functions, transforms into a Quantum Liouville von Neumann equation (QLNE) corresponding to the Wigner formalism [7].

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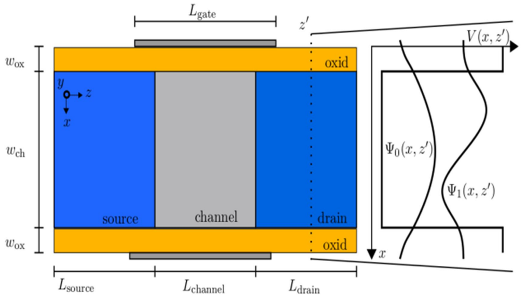


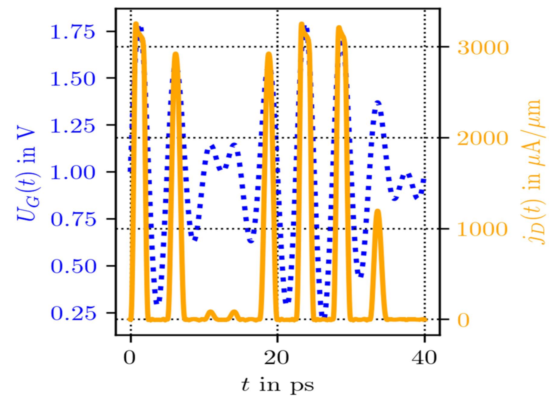
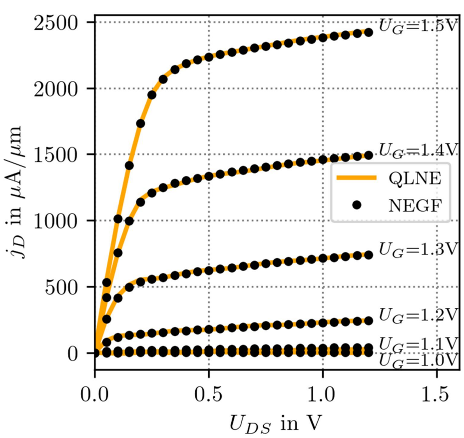


Fig.1: Schematic image of an InGaAs-DGFET with w_{ox}=1nm, w_{ch}=3nm, L_{source}= L_{drain}=15nm, $L_{channel}$=10nm. The potential profile V and the quantized wave functions ψ are shown. The donator concentration at source and drain is given by N=2 ·10^{19}cm^{-3}.

Fig.3a: Time dependent behavior of the current j_D and the applied voltage U_G in the case of a class C amplifier operation mode when considering the dynamic regime. Here, the applied voltage is defined by U_G =1V + 0.4V sin ($2\pi f_1$ t) +0.4V sin ($2\pi f_2$ t) at f_1= 180 GHz and f_2=220 GHz



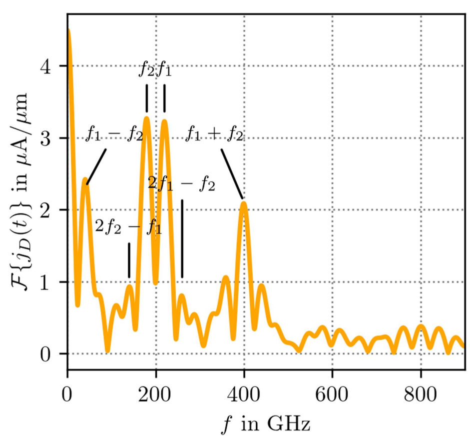


Fig.2: j_D-U_{DS} characteristic. Results of the proposed approach (QLNE) for the stationary regime compared with those from the NEGF approach (NEGF). Hereby, a self-consistent calculation [8] was carried out taking the Hartree potential into account, but the coupling between the individual modes and the scattering were neglected. The results obtained for the stationary case are compared with the NEGF formalism and show an excellent coincidence.

Fig.3b: The Fourier transform of the time dependent current is shown. As a consequence of intermixing (class C), the use of signals at 180 GHz and 220 GHz for example leads to an up converted larger frequency at 400 GHz and a down converted lower frequency at 40 GHz.