Self-consistent transport and boundary conditions in finite quantum Hall devices

Tobias Kramer[1,2]

[1] *Institut für Theoretische Physik, Universität Regensburg, Germany, and*
[2] *Department of Physics, Harvard University, USA*

The theoretical result for the current-density distribution in Hall devices depends critically on the choice of boundary conditions at the source (injection) and drain contacts. In the classical limit, I show results from the (to my knowledge) first microscopic ab initio calculation [1] of the Hall potential of 10,000 interacting electrons, resulting in the potential shown in Fig. 1.

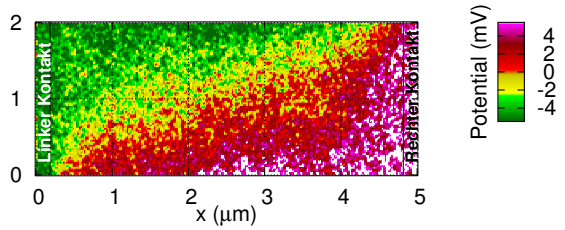

Fig. 1: Theoretical many-electron (10,000 Coulomb interacting electrons) computation of the classical Hall potential in a GaAs semiconductor device. The form of the Hall potential is directly linked to the boundary conditions at the injection source contact and requires a full account of electron-electron interactions [1].

In conventional semiconductor structures and graphene, a very similar potential to the one obtained in the classical case has been observed by various potential mapping methods, such as scanning probe microscopy and the photoelectric effect. On the theoretical side, this finding is surprising and shown to be incompatible with both, the edge state picture of the QHE and the bulk disorder picture of delocalized/localized states [1, 2]. I discuss how the different theoretical models of the QHE depend on the choice of boundary conditions and why the result show in Fig. 1 requires to solve the current distribution in a completely self-consistent fashion (including interactions) for a finite Hall device [2]. Both, the finite size and the self-consistently are often lacking in mesoscopic models of transport in a strong magnetic field and pose tremendous computational challenges. The usage of massively parallel graphics processing units (GPU) is crucial to obtain a self-consistent picture already for the classical case [1] and holds great promises to speed up fully quantum-mechanical simulations. I discuss how GPU computing can be applied to mesoscopic systems in an efficient way [3].

[1] T. Kramer, V. Krueckl, E. Heller, and R. Parrott *Self-consistent calculation of electric potentials in Hall devices* Phys. Rev. B, 81, 205306 (2010).
[2] T. Kramer, C. Kreisbeck, V. Krueckl, E. Heller, R. Parrott, and C.-T. Liang *Theory of the quantum Hall effect in finite graphene devices* Phys. Rev. B **81**, 081410(R) (2010).
[3] T. Kramer *electronic resource: GPU program resources available at* `http://quantumdynamics.wordpress.com/gpu`