Comment on "Screening model of metallic nonideal contacts in the integer quantized Hall regime"

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In this Comment we clarify the misconceptions expressed by Eksi *et al.* [D. Eksi, O. Kilicoglu, O. Göktas, and A. Siddiki, Phys. Rev. B **82**, 165308 (2010)] regarding our work on the self-consistent calculation of the electric potential in the Hall effect [T. Kramer, V. Krueckl, E. J. Heller, and R. E. Parrott, Phys. Rev. B **81**, 205306 (2010)]. In particular, we point out incorrect quotations and assumptions about our methods and results.

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In Ref. 1 Eksi *et al.* comment that our interacting many-body simulation of the classical Hall effect[2] does not take into account "poor density regions in front of the contacts" and the "density fluctuations near the contact/GaAs interface is left unresolved, which influences the current distribution drastically as shown by the experiments."[3] We model the classical Hall effect and do obtain—contrary to the statement made by Eksi *et al.*—excellent agreement with the experimentally measured Hall potential probed by optical methods[4] (Fig. 2) and by single-electron transistors[5] (Fig. 3). Reference 3 does investigate the potential next to a longitudinal voltage probe, and not next to a current source or drain contact, as we do in our work. The self-consistent Hall potential obtained in our simulation undergoes density changes in front of the contact, which cause the formation of hot spots. All these experimentally observed features do emerge from our interacting many-body simulation. Eksi *et al.* state that "an important drawback of this approach is, it cannot handle quantum mechanical effects in its present form, therefore cannot account for the integer quantized Hall effect." This statement is self-evident for our classical calculation. However, it is possible to construct a theory of the quantized Hall effect based on the obtained self-consistent Hall potential.[6] The underlying idea is to quantize the system based on the mean-field potential obtained from the classical, fully Coulomb-interacting system. Moreover, the potential distribution, which we obtain from our classical calculation, has been observed under conditions of the quantized Hall effect.[4] Our microscopic calculation traces the emergence of the Hall potential back to interactions and the current injecting contact regions, and thus highlights the importance of interactions and the choice of boundary conditions for the classical and integer quantized Hall effects. Eksi *et al.* imply that our results are not relevant for comparison with experimental measurement, since "the experimental parameters used (e.g., the dielectric constant ϵ is taken as 8, however, it is as large as 50%) are not the typical parameters resembling the real systems." This statement is taken out of context and misleading. It implies that we work with several unrealistic parameters for an AlGaAs/GaAs system. We have carefully evaluated the role of ϵ in our work and discuss in detail the importance of the dielectric constant for the potential: "We find that for decreased Coulomb interactions $\epsilon = 10$ the resulting potential does not resemble the conformal map result, but instead electrons start to pile up next to the converged contact region, while at the other side the electron density is reduced and results in a too positive value of the potential. Our finding shows that the electron must have a minimum degree of incompressibility in order to yield the classical Hall effect. Antisymmetrization and the Pauli principle, which are not part of the classical simulation, can provide other mechanisms to keep electrons apart and give an effective Pauli incompressibility." Our choice of $\epsilon = 8$ incorporates the Pauli repulsion to some extent by increasing the average electron distance compared to the bare value $\epsilon = 12$. We use an effective mass of $m^* = 0.067 m_e$, which matches the value reported for GaAs.[7] No other material-dependent parameters enter our simulation. Eksi *et al.* write "as a final remark to Ref. 2, in experiments the electrons are not injected to an empty sample, where the Hall potential develops." Contrary to the implication by Eksi *et al.*, we never inject into an empty Hall sample. We state clearly that the sample is initially populated with 7800 electrons besides 8094 positive charges fixed in the donor layer. The converged, self-consistent, steady-state solution is obtained *independent* of the choice of initial conditions and satisfies the three-dimensional Poisson equation.

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[1] D. Eksi, O. Kilicoglu, O. Göktas, and A. Siddiki, Phys. Rev. B **82**, 165308 (2010).
[2] T. Kramer, V. Krueckl, E. J. Heller, and R. E. Parrott, Phys. Rev. B **81**, 205306 (2010).
[3] E. Ahlswede, J. Weis, K. v. Klitzing, and K. Eberl, Physica E **12**, 165 (2002).
[4] R. Knott, W. Dietsche, K. von Klitzing, K. Eberl, and K. Ploog, Semicond. Sci. Technol. **10**, 117 (1995).
[5] E. Ahlswede, P. Weitz, J. Weis, K. von Klitzing, and K. Eberl, Physica B **298**, 562 (2001).
[6] T. Kramer, C. Kreisbeck, V. Krueckl, E. J. Heller, R. E. Parrott, and C.-T. Liang, Phys. Rev. B **81**, 081410(R) (2010).
[7] J. H. Davies, *The Physics of Low-Dimensional Semiconductors* (Cambridge University Press, Cambridge, UK, 1998).

