Theory of the integer quantum Hall transition broadening due to the electron-phonon interaction

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Although the integer quantum Hall effect has been studied intensively during the last three decades and general picture behind the phenomenon seems to be clear, a real quantitative approach suitable for description of the magnetotransport at given temperature is still lacking. As contrasted with the weak localization, one has to be satisfied with the only essential conclusion of the so-called scaling theory of the integer quantum Hall effect [1] that widths of the transitions between the adjacent plateaus scale with the temperature as $\Delta B \propto T^k$, with the exponent k to be found from something else. However, specific shape of the magnetotransport curves contains rich information about the system, especially on interaction and type of disorder [2], and it would be worth not to miss it.

It is not easy to decide which type of the interaction, electron-electron or electron-phonon, governs broadening of the quantum Hall transitions by disturbing coherence of the electron-impurity system. Here we focus on the electron-phonon interaction which has been addressed in a number of papers [3]-[5], however, without no specific magnetotransport curves being calculated. In order to describe conductivity of a quantum Hall system at finite temperatures we consider a network of random resistors $R_{\alpha\beta} = e^2/(T\Gamma_{\alpha\beta})$ connecting the nodes (α, β) associated with the one-electron states in a random potential, $\Psi_\alpha(\mathbf{r})$, which are localized according to $\xi \propto |E - E_n|^{-\nu}$ with $\nu \approx 2.3$ [1]. Here $\Gamma_{\alpha\beta}$ is the effective transition rate between the one-electron states with emission or absorption of a phonon. It accumulates statistics of the electrons and phonons and the quantum-mechanical rate $w_{\alpha\beta}$ which can be evaluated numerically as shown in Fig.1(a). On the other hand, temperature dependence of the averaged transition rate for the pair of states, which lie near the Fermi level and overlap in space, can be estimated as $\overline{w_{\alpha\beta}} \propto T^3$. Using this approximation and estimation for a number of the mutually overlapping states, $m \propto T\xi^2$, it is straightforward to estimate the longitudinal conductivity σ_{xx} [6], which becomes of the order of e^2/h as $\xi \propto T^{-1}$ leading to a simple relationship $k = \frac{1}{\nu} \approx 0.42$, in agreement with the numerical results shown in Fig. 1(c) and recent experimental data [7].

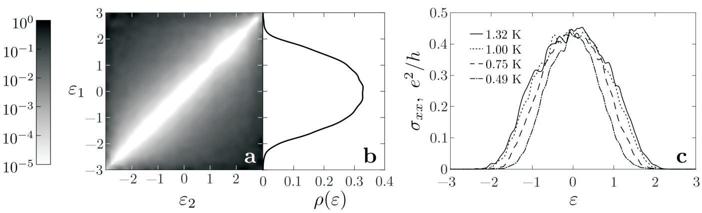

Figure 1: Electron-phonon transition probabilities (a), density of states (b), and longitudinal conductivity for various temperatures (c) are shown as functions of the energy.

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