Comment on “New Class of Resonances at the Edge of the Two-Dimensional Electron Gas.”

Recently, Zhitenev et al. [1] reported measurements of the capacitance of a gate covering the edge and part of a 2DEG in the quantized Hall regime. They observed a reproducible resonance structure as a function of magnetic field \( B \) and gate voltage \( V_g \). This structure was attributed to the variation in conductance of an incompressible strip separating the states of the \( N \)th and \( N + 1 \)th Landau levels (LL). Although the authors disfavored the explanation of the conductance resonances based on resonant tunneling (RT) through an impurity state, I believe that it should not be dismissed and can explain a number of experimental observations very well. In particular, I point out a new characteristic signature of RT in the quantized Hall regime: the quantization of the slopes of the resonance tracks on the \( B - V_g \) plot.

The authors argued that provided each resonance is due to a different impurity along the edge the similarity in structures for different sample lengths is puzzling. Contrary to their assumptions I suggest that a single location along the edge is responsible for each series of peaks in the resonance structure resolving the puzzle. In this location the long-range disorder potential creates in the middle of the incompressible strip a droplet of electrons (holes) belonging to the \( N + 1 \)th (\( N \)th) LL.

This situation is similar to the conventional Coulomb blockade (CB) with the incompressible region playing the role of an insulator surrounding the charged island. The existence of CB in the presence of extended lower LL states has been convincingly demonstrated by Alphenaar et al. [2]. As the gate voltage is varied the number of charges in the droplet changes giving rise to a series of resonance peaks. The spacing between these peaks is determined by the CB condition,

\[
\Delta V_g = e/C, \tag{1}
\]

yielding a periodic structure when the number of charges in the droplet is large. By using Eq. (1) the size of the droplet can be estimated. For \( \Delta V_g \approx 40 \text{mV} \) taken from Ref. [1] I find the droplet to be about \( 600 \times 600 \) Å. A droplet of this size may contain from one to ten electrons (holes). A relatively small number of particles leads to fluctuations in capacitance which may account for the observed deviations from periodic peak structure [3].

A major strength of the RT picture is its ability to explain the peak tracks in the \( B - V_g \) plot. The CB resonance condition requires having a half-integer number of particles in the droplet. As the magnetic field is varied, the density of electrons on the completely filled LL in the incompressible strip changes proportionally. To keep the number of particles in the droplet fixed, the total electron density in the droplet vicinity, \( n \), must be adjusted:

\[
n = N e B / hc + n_0. \tag{2}
\]

Here \( n_0 \) gives the average density of electrons (holes) on the \( N + 1 \)th (\( N \)th) LL in the droplet vicinity. It must be independent of \( V_g \) or \( B \) for a given resonance and vary from resonance to resonance. As the distance between the 2DEG and the gate is larger than the typical screening radius, the gate voltage, \( V_g \), is proportional to the total density, \( n \), over the geometrical capacitance per unit area, \( C_g \). By using this I find from Eq. (2)

\[
dV_g/DB = Ne/C_g hc. \tag{3}
\]

This result shows that the slopes of the peak tracks must be quantized, with \( N \) being the filling factor of the incompressible strip. Indeed, based on the available data from the authors of Ref. [1] I find that the ratios of the slopes for \( N = 1, 2, 4 \) in a given \( V_g \) interval agree with Eq. (3) with an order of 10% accuracy.

Zhitenev et al. [1] found that the resonance peak conductances grow with temperature, in contradiction with the RT model assuming that the tunneling amplitudes are temperature independent. However there are at least two reasons to believe that this assumption is unjustified. First, the thickness of the tunneling barrier is determined by the width of the incompressible strip which decreases with temperature. Second, electron correlations lead to the formation of fractional channels [4], tunneling into which has a non-trivial temperature dependence.

It is straightforward to extend the RT model to the fractional quantized Hall regime. There one should expect resonance tracks to be straight lines with quantized slopes given by the fractional filling factor in the incompressible strip. Since the charge of the droplet can now change by a fraction, Eq. (1) predicts a smaller distance between resonance peaks.

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