Charge Density Wave Instability in a Parabolic Well in Perpendicular Magnetic Field

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The integer quantum Hall effect (QHE) can be explained in the framework of noninteracting electrons [1]. Incorporation of the electron-electron interaction leads to a variety of the unusual electronic phases. Firstly, the discovery of the fractional quantum Hall effect demonstrated the importance of the Coulomb interactions for two-dimensional (2D) electron gas in presence of a strong magnetic field. Another famous example is the formation of stripe phases in high Landau levels (LL) at half-integer filling factor ν [2]. Lately, a broad class of phenomena related to ferromagnetic order in QHE regime due to Coulomb interaction and spin properties of 2D electrons has been intensively studied [1]. Finally, a variety of QHE correlated phases are expected, when additional degrees of freedom associated with numbers of 2D layers and subbands are introduced. For example, Brey [3] proposed a possible exchange induced charge density wave state in a wide parabolic well in a perpendicular magnetic field at Landau filling factor $\nu=1$. The parabolic well allows to form a wide (1000-5000 Å) layer of dilute, high mobility carriers with a uniform (in direction of growth) density. The Coulomb interaction induces the charge density wave (CDW) instability, which may lead to the distruction of the quantum Hall plateau at $\nu=1$.

In these experiments we sudy wide parabolic quantum wells (PQW) of 1000-3000 Å width with 2D electrons and holes. Samples with 2D holes were grown on (311)A GaAs substrate, and peak mobility was around 10^5 cm^2/Vs. Samples with 2D electrons were grown on (100) GaAs substrate, and has the same mobility. The dimensionless interelectron spacing $\boldsymbol{r_s}$ was around 2-3 in wells with electrons and 10-12 ($m^*=0.4m_0$) for holes, therefore more pronounced many –body effect were expected for parabolic wells with holes. We measured diagonal and Hall resistance as a function of magnetic field at different tilt angles Θ between the field and the normal to the sample, rotating our sample in situ. We found that in perpendicular magnetic field the Hall plateau and minima in R_{xx} at $\nu=1$ are missed at T=50mK for parabolic wells with ***2D hole gas***. In tilted field at $\Theta=30^\circ$ the Hall plateau is recovered and accompanied by the deep minima in R_{xx} . For 2D electrons we observed the typical quantum Hall effect behaviour. We attribute such behaviour of the wide 2D hole gas to the intersubband induced CDW instability predicted by Brey [3]. In wide PQW with several subbands occupied, the energy gap in a strong magnetic field is determined by the energy-level spacing in zero field ΔE_{ij}, which is much smaller than $\hbar\omega_c$ (ω_c is the cyclotron frequency). In 2D hole gas in PQW last minima in R_{xx} at $\nu=1$ corresponds to the intersubband splitting of the spin polarized states, because of the heavy mass and large Lande g-factor. Since the exchange -correlation energy E_{exc} in strong magnetic field is larger than ΔE_{ij} , the system undergoes a phase transition. In the tilted magnetic field CDW is destroyed and QHE is recovered.

References

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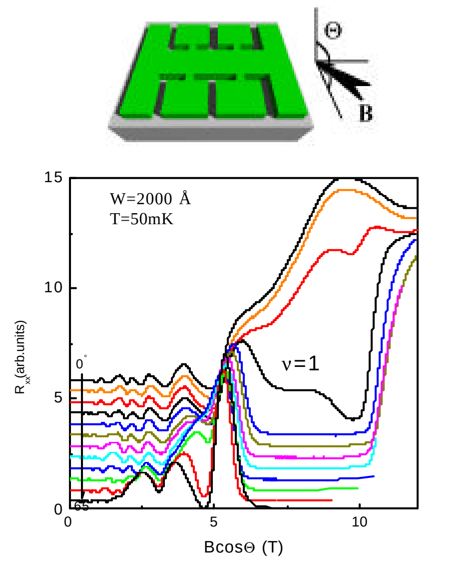
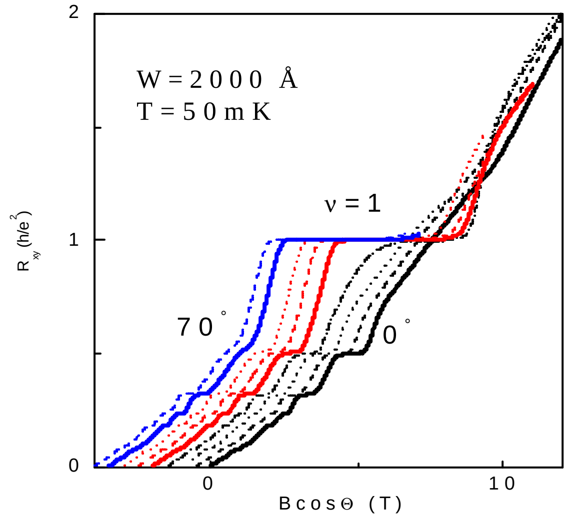
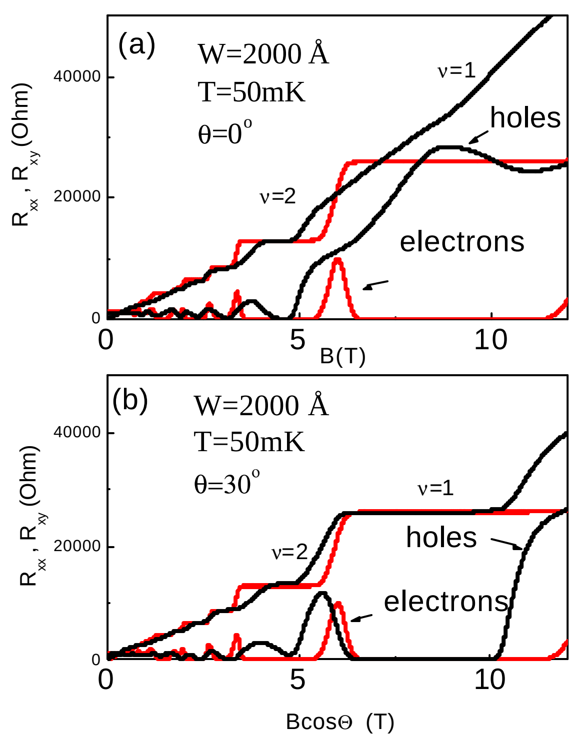


Magnetoresistance of a 2000 Å PQW with ***2D hole*** gas as a function of the normal component of the magnetic field for different tilt angles Θ between the applied magnetic field and the normal to the plane of the substrate at T = 50 mK. The in-plane magnetic-field component is directed along the y axis, perpendicular to the current flow.



Hall resistance of a 2000 Å PQW with ***2D hole*** gas as a function of the total magnetic field for different tilt angles Θ between the applied magnetic field and the normal to the plane of the substrate at T = 50 mK. Curves are shifted along B axis.



Comparison of the longitudinal R_{xx} and transverse R_{xy} resistance of a 2000 Å PQW for electrons and holes at $\Theta=0^{\circ}$ (a) and $\Theta = 30^{\circ}$ (b), T=50 mK.