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Phase Diagram of Bilayer 2D Electron Systems at $\nu_T = 1$[1]

ALEXANDRE CHAMPAGNE, Caltech

Bilayer 2D electron systems at total filling fraction $\nu_T = 1$ and small interlayer spacing can support a strongly correlated phase which exhibits spontaneous interlayer phase coherence and may be described as an excitonic Bose condensate. We use electron interlayer tunnelling and transport to explore the phase diagram of bilayer 2D electron systems at $\nu_T = 1$, and find that phase transitions between the excitonic $\nu_T = 1$ phase and bilayer states which lack significant interlayer correlations can be induced in three different ways: by increasing the effective interlayer spacing, d/ℓ, the temperature, T, or the charge imbalance, $\Delta\nu = \nu_1 - \nu_2$. First, for the balanced ($\Delta\nu = 0$) system we find that the amplitude of the resonant tunneling in the coherent $\nu_T = 1$ phase obeys an empirical power law scaling versus d/ℓ at various T, and the layer separation where the tunneling disappears scales linearly with T. Our results [1] offer strong evidence that a finite temperature phase transition separates the balanced interlayer coherent phase from incoherent phases which lack strong interlayer correlations. Secondly, we observe [2] that close to the phase boundary the coherent $\nu_T = 1$ phase can be absent at $\Delta\nu = 0$, present at intermediate $\Delta\nu$, and absent again at large $\Delta\nu$, thus indicating an intricate phase competition between it and incoherent quasi-independent layer states. Lastly, at $\Delta\nu = 1/3$ we report [2] the observation of a direct phase transition between the coherent $\nu_T = 1$ bilayer integer quantum Hall phase and the pair of single layer fractional quantized Hall states at $\nu_1 = 2/3$ and $\nu_2 = 1/3$.

[1] A.R. Champagne, *et al., Phys. Rev. Lett.* **100**, 096801 (2008).
[2] A.R. Champagne, *et al*, *Phys. Rev. B* **78**, 205310 (2008)

[1]Now at Concordia U.; Collaborators: Jim Eisenstein, Aaron Finck (Caltech) and Loren Pfeiffer, Ken West (Bell Labs);
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