Many-body states in bilayer quantum Hall systems: overview and latest topics

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Interplay of disorder and electron-electron interactions is the key element in the physics of quantum Hall systems, and until recently, has been believed to be the unique parameter that determines the fate of a two-dimensional electron system for a given Landau level filling factor ν upon $T \to 0$. There are mainly two new streams which have opened up new directions in the quantum Hall physics. One natural stream is to keep on further improving the material purity and to look for new correlated states that might have been hidden by disorder. Indeed, progress in the molecular-beam-epitaxy technology and concomitant achievement of ultra-high electron mobilities well in excess of $10^7\,\mathrm{cm}^2/\mathrm{Vs}$ have allowed physicists to witness 'wanted' highly correlated many-body states in the higher Landau levels, which are found to be qualitatively different from the fractional quantum Hall states in the lowest $N = 0$ Landau level [1].

The other major stream, which is the topic of this lecture, has been developed by exploiting a bilayer system, which consists of two parallel electron layers separated by a thin barrier. The additional degree of freedom arising from the fact that electrons can reside in either of the two layers has provided a vast field for many-body physics that has no counterpart in single-layer systems. Examples are the *even*-denominator fractional quantum Hall effect at the *total* filling factor of $\nu_\mathrm{T} = 1/2$ (i.e., 1/4 in each layer), and the quantum Hall effect at the *total* filling of $\nu_\mathrm{T} = 1$ (i.e., 1/2 in each layer) *in the absence of tunneling gap* [2]. The key ingredient behind the occurrence of these novel states is that in bilayer systems the relative strength of the Coulomb interactions between electrons in the same layer and between those in different layers can be controlled at will by appropriately designing the heterostructures and controlling the electron densities.

In this lecture, I first plan to give an overview of transport experiments in bilayer systems which have been carried out in the past 10 years by various groups, and to help researchers from different fields share common background. Then I would also like to mention latest developments achieved by Caltech group exploiting independent electrical access to the two layers [3].

References

[1] U. Zuelicke (Tuesday, 19th, 9:30-11:30) and N. Shibata (Thursday, 21st, 9:30-10:30) in this Workshop. For review, see M. M. Fogler, arXiv:cond-mat/0111001; J. P. Eisenstein, Solid State Commun. **117**, 123 (2001).

[2] For review, see J. P Eisenstein, Chap. 2, in *Perspectives in the Quantum Hall E ects*, Ed. by S. Das Sarma and A. Pinczuk (John Willey & Sons, New York, 1997).

[3] I. B. Spielman *et al.*, Phys. Rev. Lett. **84** 5808 (2000); *ibid* **87**, 036803 (2001); M. Kellogg *et al.*, *ibid* **88**, 126804 (2002); *ibid* **90**, 246801 (2003).