Gauge Fluctuations and Interlayer Coherence in Bilayer Composite Fermion Metals

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Introduction

The quantum Hall bilayer with total Landau level filling fraction $\nu = 1$ is a particularly rich system for studying quantum Hall physics. In this system, two parallel two-dimensional electron gases, separated by a distance *d*, have the total electron density of a filled Landau level for a single layer. For the symmetrically doped case, each layer has Landau level filling fraction $\nu = 1/2$, and if interlayer electron tunneling can be ignored, the only coupling between layers is through the Coulomb repulsion. The scale of this coupling, relative to the scale of interactions within each layer, is then set by the dimensionless ratio d/l_0, (l_0 = magnetic length). In the limit of large d/l_0 (weak interlayer coupling) the system decouples into two separate $\nu = 1/2$ composite fermion metals [1,2], while in the limit of small d/l_0 (strong interlayer coupling) it enters a remarkable bilayer quantum Hall state in which electrons develop spontaneous interlayer phase coherence [3]. Despite a great deal of experimental and theoretical work, the transitions between these two limiting states is still poorly understood.

Results and Discussion

In Ref. [4] we studied the effect of the Chern-Simons gauge fields on the transition to a possible phase which might occur at intermediate d/l_0 from two decoupled composite fermion metals to the interlayer coherent composite fermion state proposed by Alicea et al. [5]. In this transition, interlayer Coulomb repulsion leads to excitonic condensation of composite fermions (rather than physical electrons) which are then free to tunnel coherently between layers, even though physical electrons do not. We find that this coherent tunneling is strongly suppressed by the layer-dependent Aharonov-Bohm phases experienced by composite fermions as they propagate through the fluctuating gauge fields in the system. This suppression is analyzed by treating these gauge fluctuations within the random-phase approximation and calculating their contribution to the energy cost for forming an exciton condensate of composite fermions. This energy cost leads to (1) an increase in the critical interlayer repulsion needed to drive the transition; and (2) a discontinuous jump in the energy gaps to out-of-phase excitations (i.e., excitations involving currents with opposite signs in the two layers) at the transition.

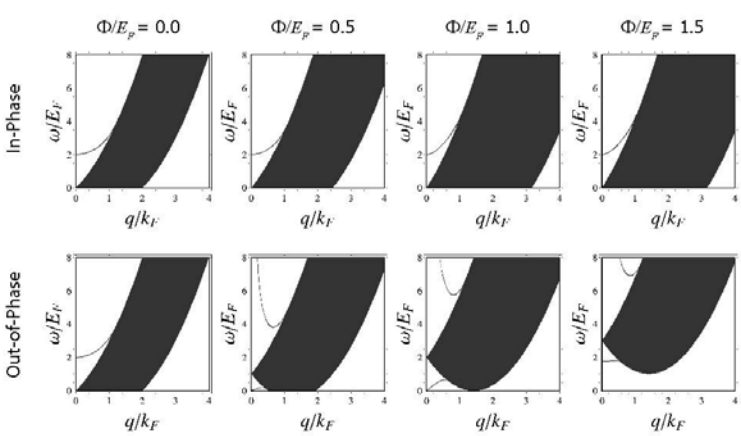

Figure 1 Excitation spectra of the □=1 bilayer as a function of the exciton condensate order parameter □□(which can be viewed as an effective interlayer tunneling amplitude for composite fermions). Results are shown for in-phase and out-of-phase sectors with currents having the same and opposite signs in the two layers, respectively. The particle-hole continuum associated with the composite fermion Fermi surfaces as well as in-phase and out-of-phase magnetoplasmon collective modes can clearly be seen. The significant effect of the order parameter on the out-of-phase spectrum translates into a significant energy cost for introducing the order parameter which goes beyond the usual mean field analysis. This contribution, which can be viewed as a gauge field contribution to the correlation energy, drives the transition to the interlayer coherent state strongly first order.

Acknowledgements

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References

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