Direct Measurement of the Layer Polarization of Bilayer Graphene

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Introduction

The lowest Landau level of bilayer graphene (BLG) is a rich platform for investigating the physics of interacting electrons because each electron carries *three* separate spin-1/2-like degrees of freedom - real spin, layer isospin, and orbital isospin - and thus there are many possibilities for ground-state ordering in this eight-dimensional space when interactions lift this degeneracy. Moreover, the relative importance of these degrees of freedom can be tuned with electric and magnetic fields, as has been shown in several new papers that have taken advantage of unprecedentedly high sample quality of bilayer graphene [1,2,3]. There are several ways to probe the spin degree of freedom, such as tilted-field magnetotransport [4], but a *direct* probe of the layer degree of freedom has so far been absent.

Experimental

We employ capacitance measurements of a bilayer graphene sample with both a top gate and a bottom gate, allowing us to tune both the displacement field and the density, as well as enabling measurement of the capacitance of the bilayer to the top gate and to the bottom gate, C_T and C_B; this is crucial, in BLG capacitance measurements can probe not just the density of states but also the distribution of electrons on the two layers that comprise the bilayer, a direct measurement of the layer-isospin texture of these interacting ground states. We used these capacitance techniques in SCM-1 at 18T and millikelvin temperatures.

Results and Discussion

Our results are shown in Fig. 1. The top, checkboard pattern is a measurement of C_T-C_B, which is proportional to the layer polarization $\partial(n_T - n_B)/\partial(\mu_T + \mu_B)$ in our device. In Fig. 1, at bottom, is a measurement of the density of states at 18T in which we begin to glimpse the lifting of the orbital degeneracy, a feature only recently observed in BLG (Ref. [1] and [2]). Phase transitions at different displacement fields, marked by closing of the gaps are accompanied by diagonal features in the layer polarization map (Fig. 1 top) whose origin is currently not understood.

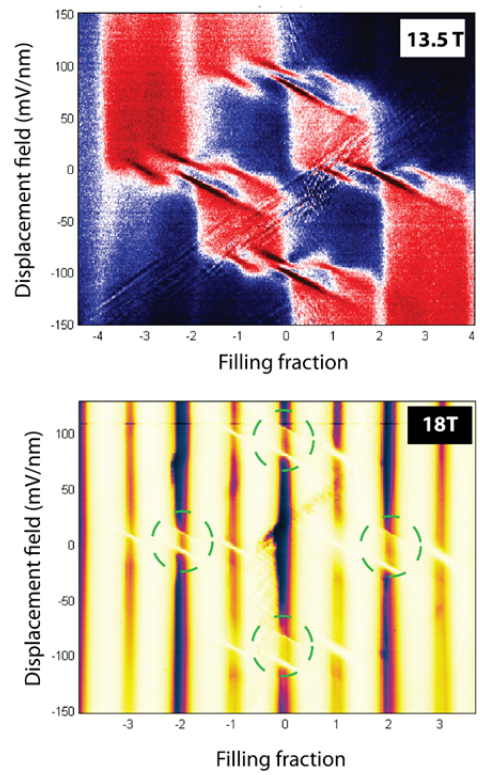

Fig.1 (top) Layer polarization of the lowest Landau level (LLL) of bilayer graphene. Red: charge added to top layer; blue: charge added to bottom layer. (bottom) Top gate capacitance measurement of a similar device in SCM-1. The green circles mark the appearance of the lifting of the orbital degeneracy in the LLL. Color scale: dark, incompressible states (gaps) between Landau levels; light, compressible Landau levels (high density of states).

Conclusions

We plan to measure capacitance of BLG in higher fields at the NHMFL, where we expect to be able to resolve the electron states associated with the lifting of the orbital degeneracy and study their layer distribution in these newly-discovered broken-symmetry states.

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References

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