Broken-Symmetry Quantum Hall States in Bilayer Graphene

Fu, H., Li, J., Huang, K., Chuang, Y.-W., Zhu, J. (Penn State University, Physics)

Introduction

The Quantum Hall States of bilayer graphene provide a rich platform to explore the intricate interplay of competing terms in the Hamiltonian of the system, which can be controlled by external experimental knobs such as an applied electric or magnetic field as well as the screening of the Coulomb interaction at different length scales. In bilayer graphene proximitized by mono- or bilayer WSe_2, we observed significantly enhanced gap energies at filling factors ν=1 and 3 while the gap of the ν=2 state is significantly reduced. Ongoing theory collaboration aims to acquire an understanding of these observations that will provide new insights into the many-body Quantum Hall States of bilayer graphene.

Experimental

We completed three runs on SCM1 using the dilution refrigerator and we published three journal articles in 2018 [1-3].

Results and Discussion

In Ref.[1], we constructed a phenomenological Landau level diagram for the symmetry-broken integer quantum Hall states of bilayer graphene in the filling factor range of $-4 < \nu < +4$. Many-body interactions were parameterized in approximate forms and fit to measurements to achieve a quantitative single-particle energy diagram that capture the existing experiments very well. We showed that the gaps at orbital splitting ν=1 are small and sensitive to the applied electric field and that the gap at ν=2 transitions from valley splitting to spin splitting while its magnitude remains approximately linear in B. Remarkably, in bilayer graphene placed adjacent to a one or two-layer WSe_2, these gap energies are drastically modified. These findings point to the crucial role played by the short-range component of Coulomb interactions and screening at the atomic scale. The understanding of our data should provide important insights into the exchange and correlation effects of Landau levels in bilayer graphene.

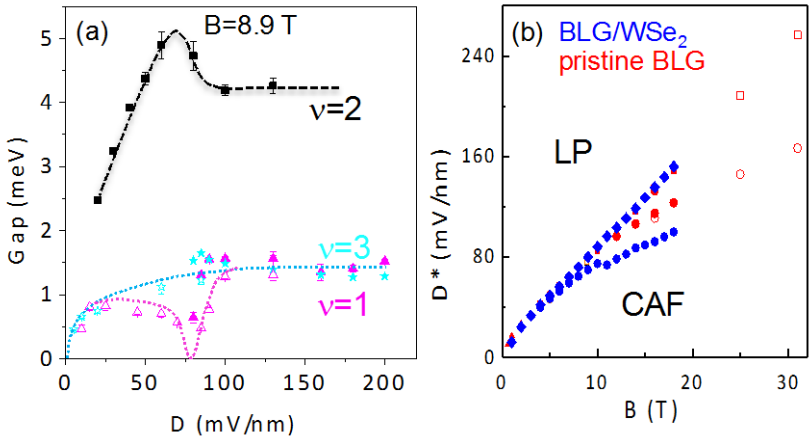

Fig. 1: Landau level modifications in WSe_2/bilayer graphene. (a) Gap energies at filling factors ν=1, 2, and 3 as a function of the applied perpendicular electric field D. B=8.9 T. (b) The coincidence electric field D^*_h and D^*_l of the $\nu \neq 0$ state in pristine bilayer graphene (red symbols) and WSe_2-proximitized bilayer graphene (blue symbols). The splitting between D^*_h and D^*_l occurs at ~ 5 T in BLG/WSe_2, compared to 12 T in pristine bilayer graphene. The size of the splitting is a measure of the strength of the orbital splitting, i.e. the gap size of ν=1 and 3.

Conclusions

Bilayer graphene proximitized by atomically thin WSe_2 exhibits Landau level gaps that are significantly different from pristine bilayer graphene, the understanding of which should quantitatively elucidate the role of exchange and correlation effects in bilayer graphene Quantum Hall States.

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References

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[2] J. Li, et al, Phys. Rev. Lett. **120**, 057701 (2018).
[3] J. Li, et al, Science **362**, 1149 (2018).