Integer and Fractional Quantum Hall effect in Ultra-high Quality Few-layer Black Phosphorus Transistors

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Introduction

As a high mobility two-dimensional semiconductor with strong structural and electronic anisotropy, atomically thin black phosphorus (BP) provides a new playground for investigating the quantum Hall (QH) effect. Outstanding questions include possible sub-linear functional dependence of Landau level (LL) gaps on magnetic field *B* due to its large electronic and lattice anisotroy, and possible anisotropic fractional QH states. Though integer quantum Hall effect has been observed in BP, LL gaps are measured only at very high magnetic fields and over a limited range (27 T ≤ B ≤ 33 T).

Experimental

We study the quantum Hall effect in ultra-high mobility black phosphorus devices up to 54T at NHMFL.

Results and Discussion

Using ultrahigh quality BP devices with field effect mobility up to 55,000 cm^2/Vs and strong anisotropy in conductivity, we report observations of the IQHE at magnetic fields as low as 10 T, and determination of LL gap scaling for QH states at filling factors -1 ≤ υ ≤ -4. The LL gaps are predominantly linear in B, despite the observed anisotropic conductivity, thus resolving a theoretical controversy. At very high magnetic fields, we observe fractional QH states at filling factor υ~-4/3 and υ~-0.56 ± 0.1. This work provides the first observation of fractional QHE in a non-graphene 2D material, underscoring BP as a tunable 2D platform for exploring electron interactions.

Conclusions

As the first observation of fractional quantum Hall effect in an anisotropic 2D material, our work shed light on electron/hole correlations and providing a new playground for exploring FQHE states with possible even-denominator states.

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References

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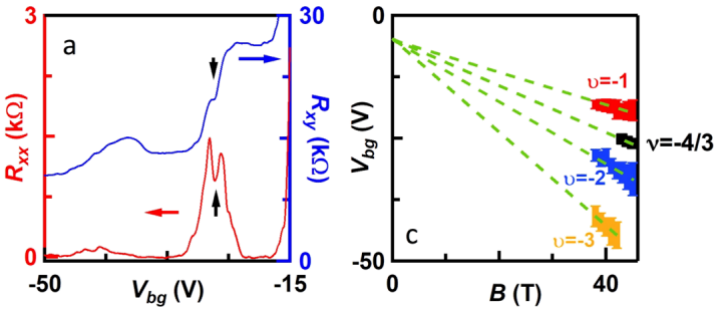

Fig. 1. Fractional QH states. Right panel: (a). R_{xx} (left axis) and R_{xy} (right axis) of a Hall bar devicevs V_{bg} at B=45 T. The fraction QH state manifests as a small plateau in R_{xy} and an accompanying dip in R_{xx}, as indicated by the black arrows. Left panels: a constructed Landau fan diagram showing the movement of QH plateaus with magnetic field.