Quantum Hall effect in the layered Dirac semimetal $BaMnSb_2$

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Introduction

Layered compounds $AMnBi_2$ (A=Ca, Sr, Ba, Eu or Yb) have been established as Dirac materials [1-6]. In these materials, Bi atoms form a square net which harbors Dirac fermions. We have studied isostructural compounds $AMnSb_2$ (A=Sr & Ba) and found that the 2D Sb layers in both $SrMnSb_2$ and $BaMnSb_2$ generate Dirac cone states [8,9]. As compared to $AMnBi_2$, $AMnSb_2$ exhibits distinct properties: $SrMnSb_2$ shows the coexistence of nearly massless Dirac fermion behavior and ferromagnetism [7], whereas $BaMnSb_2$ displays an exceptionally large electronic anisotropy [8], offering a rare opportunity to study the novel physics of bulk quantum Hall Effect (QHE). Theoretical studies have shown the multilayer Quantum Hall State can exhibit many new exotic properties, e.g. 2D chiral surface state [10] and emergent photons with long-range interactions [11].

Experimental

We have synthesized $BaMnSb_2$ single crystals using a flux method, and carried out measurements on the angular dependence of out-of-plane magnetoresistivity using the NHMFL's 65T pulse field facility in Los Alamos. Since we have observed bulk QHE on BaMnSb2 in our previous pulse-field experiments and as well as preliminary signature of spin splitting of Landau levels, the goal of this 65T experiment aims to find solid evidence of spin splitting.

Results and Discussion

In this experiment, we measured the out-of-plane resistivity ρ_{zz} (B,T) as a function of magnetic field under different field orientations at 4K and 0.5K (Fig. 1, left panels). We find the minima of ρ_{zz} splits near 40-50T at 0.5K and the magnitude of splitting varies with the field orientation. However, when the ρ_{zz} data are plotted again B(cosθ) where θ is the tilt angle of magnetic field relative to the c-axis, all data collapse into a single curve (Fig. 1, right panels), suggesting only the field component along the c-axis is responsible for the splitting. This observation can be well understood in terms of Landau level spin splitting and the variation of effective cyclotron mass with the field orientation angle.

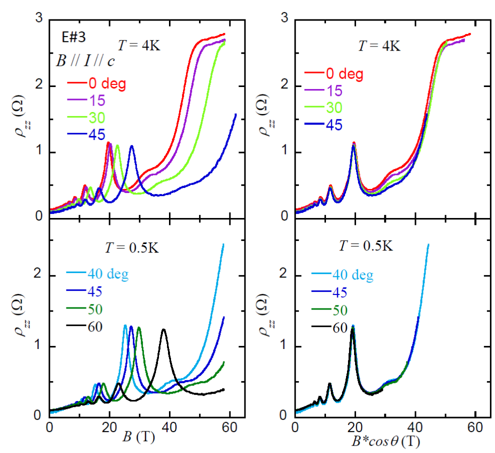

Fig. 1: Left two panels: the out-of-plane resistivity ρ_{zz} (B,T) as a function of field under different field orientations at 4K and 0.5K. Right panel: ρ_{zz} (B,T) vs. B(cosθ).

Conclusions

Combined with the results obtained from previous experiments, we conclude that $BaMnSb_2$ exhibits a bulk half-integer QHE. The pulse field up to 65T enables the access to the Quantum Hall State with the filling factor of 1/2 per layer at the quantum limit. Furthermore, we have also found unambiguous evidence for 2D chiral surface state in the quantum limit and a precursor signature of possible bulk fractional QHE in the extreme quantum limit. We are in the process of preparing a manuscript based on these findings.

Acknowledgements

A portion of this work was performed at the National High Magnetic Field Laboratory in Los Alamos, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490 and the State of Florida and the US DOE Basic Energy Science project `Science at 100 Tesla'. The work was supported by US Department of Energy under EPSCoR Grant No. DE-SC0012432 with additional support from the Louisiana Board of Regents at Tulane and the DOE Grant No. DE-SC0019068 at Penn State.

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