Chiral Landau levels in Weyl semimetal NbAs with multiple topological carriers

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Introduction

The lifting of the Weyl nodes degeneracy can be accessed by breaking inversion symmetry (IS) in Dirac semimetals. It was recently realized in non-centrosymmetric compounds NbAs family. The predicted chiral or Adler-Bell-Jackiw anomaly, a chirality imbalance phenomenon in Weyl semimetals, has been widely observed. Besides the Fermi arcs and chiral anomaly, one of the most important features of Weyl semimetals is the presence of the zeroth chiral Landau level. However, directly detecting this distinct zeroth Landau level through conventional photoemission or transport experiments remains an unprecedented challenge since both magnetic field and Landau level spectroscopy are required.

Experimental

NbAs single crystals were grown by enhanced chemical vapor transport method using iodine as the agent with tilted ampules angle to maximize the growth rate and crystal quality. The far-infrared and mid-infrared reflection were measured in a Faraday configuration with a superconducting magnet up to 17.5 T in SCM-3 in DC field of National high magnetic field lab, Tallahassee. NbAs samples were exposed to the globar infrared light through light pipes with (001) surface perpendicular to both the incident light and magnetic field. Infrared light was focused with parabolic cone. The reflected light was detected by a bolometer and analyzed by a Fourier transform infrared spectrometer (FTIR). All the light tube, samples and bolometer were kept at liquid helium temperature in a cryostat. The light path was pumped under vacuum to avoid the absorption of water and other gases.

Results and Discussion

To quantitatively study the spectrum and understand the origin of each transition, we extracted the frequency of inter-Landau-level transitions and plotted it against the magnetic field in **Fig. 1**. By analyzing the fan diagram, the origin of the optical transition can be determined by the corresponding field evolution.

Conclusions

we have studied the quasiparticle dynamics with contributions from multiple bands in NbAs through magneto-optical spectroscopy. All the optical features are summarized in Fig. 2a, Table I and Supplementary Note IV. Taking the advantage of probing Landau levels under high magnetic fields, unconventional optical transitions reveal the existence of the zeroth chiral Landau level. Different from other degenerated Landau levels with non-zero index, it unconventionally disperses linearly in kz direction and allows the optical transition without the limitation of or evolution. Finite scattering helps to enhance the feature from chiral Landau level. Besides, two inequivalent Weyl nodes are found with different Fermi velocity. Fitting the magnetic field dependence of optical transitions unveils that the Weyl node in NbAs with higher Fermi velocity possesses much stronger particle-hole asymmetry. Massive Dirac fermions and massive trivial fermions are also found by observing the linear-in-B cyclotron resonance. We summarize the overall Hamiltonian in Supplementary Note XIII and also provide a general picture of the zeroth Landau levels in topological materials. A comparison of the Landau quantization between Weyl fermions and massive fermions was made to further verify the unique feature of the zeroth chiral Landau levels.

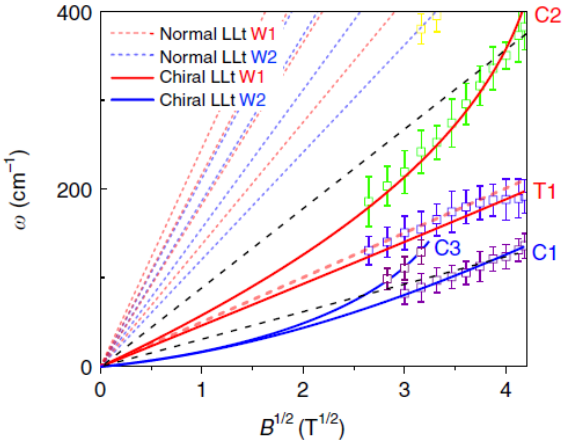

Fig.1 Inter-Landau-level transition in terahertz range where the intra-band transition is allowed.

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References

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