Unveiling the chiral states in multi-Weyl semimetals via theoretical investigation of magneto-optical spectroscopy and negative magneto-resistance

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Abstract

Multi Weyl semimetal (mWSM) hosts multiple zeroth Landau levels (chiral states) that fundamentally govern their quantum transport and optical responses. We develop a fully quantum-mechanical framework to analyse magneto-optical conductivity and magneto-transport in mWSM, deriving a generic Landau level spectrum for higher-order Weyl nodes. Our results reveal distinctive low-frequency optical peaks arising from transitions involving chiral states, which are strongly tunable by Weyl-cone tilting and manifest prominently in Faraday and Kerr rotation spectra. Furthermore, in the **E** | | **B** configuration, we demonstrate that multiple chiral Landau levels drive a quantised negative magnetoresistance (MR) through chiral anomaly. As the magnetic field increases, successive chiral branches cross the Fermi energy, producing discrete slope changes in the longitudinal conductivity and a step-like negative magnetoresistance. These features provide a direct and robust experimental signature of multi-Weyl topology, highlighting the central role of chiral states in both magneto-optical and magneto-transport phenomena.

References

[1] S Saha, *D Das, and A Mawrie J. Phys.: Condens. Matter* **37 405702**

[2] A Ghosh, S Saha and A Mawrie, arXiv:2512.24752

Figures

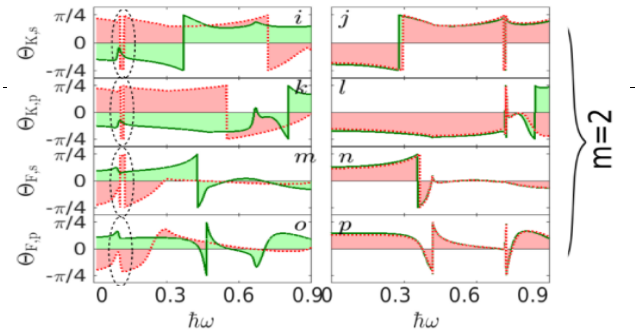

Figure 1: Faraday and Kerr rotation angle Θ_F & Θ_K for mWSMs with topological charges m = 2. The left panels in the figure represent the case with tilt parameters turned on, while the right panels correspond to the case with them turned off. The green & red curves show the quantities when η = −1 and η = 1, respectively. We encircle the low-frequency peaks associated with transitions among chiral LLs. The results shown here are obtained within the surface-conductivity (thin slab with thickness d) model.

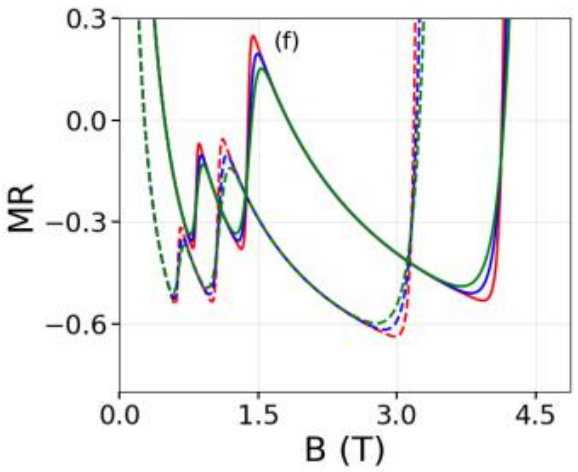

Figure 2: The MR curve is strongly negative and displays pronounced kinks marking the magnetic field values at which individual chiral branches are lifted above the Fermi energy