

Infrared Reflectance and Photoresponse of Weyl GdAlSi Single Crystal

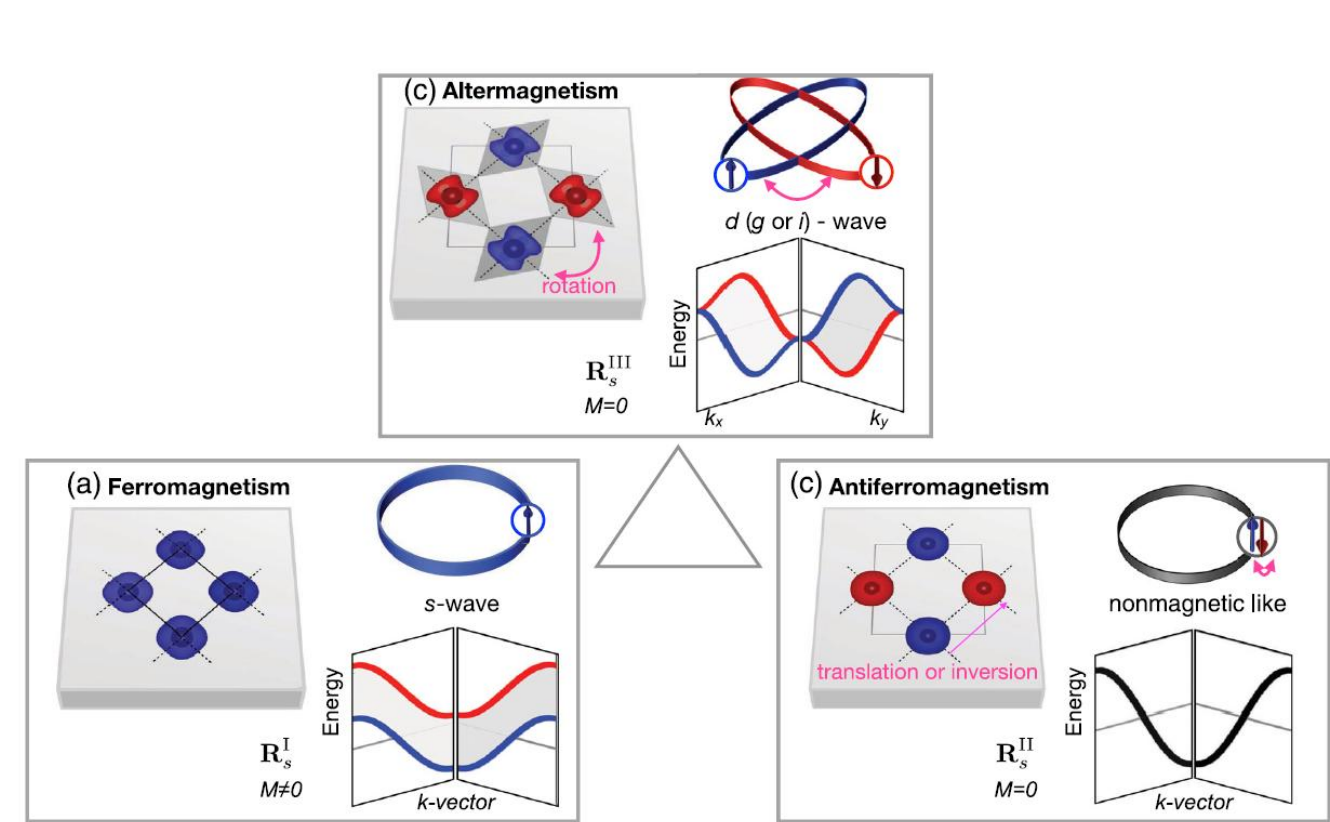


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Introduction

- Altermagnetism** is a distinct magnetic phase that combines compensated magnetic order with unconventional momentum-dependent spin splitting.
- In altermagnets, opposite-spin sublattices are related by crystal-rotation symmetries, producing alternating spin polarization in momentum space despite vanishing net magnetization.
- Weyl semimetals (WSMs)** host topological band crossings known as Weyl nodes, which can generate Berry-curvature-driven transport and unusual optical responses.
- The rare-earth RAISi/RAIGe** family (R = rare-earth element) provides a promising platform for investigating the interplay between magnetism, Weyl topology, and electronic transport.
- GdAlSi** is a noncentrosymmetric, antiferromagnetically ordered material with a Néel temperature of approximately 32 K, making it a promising Weyl altermagnetic candidate.
- Density functional theory (DFT) predicts Weyl nodes near the Fermi level and unconventional momentum-dependent spin splitting in GdAlSi, while ARPES measurements provide supporting evidence for its topological electronic structure.
- Although the magnetic and transport properties of GdAlSi have been investigated, its optical and optoelectronic responses remain comparatively unexplored.
- In this work**, we investigate the photothermal response of GdAlSi to probe magnetic phase transitions, its photoresponse to explore possible chirality-dependent signatures associated with Weyl electronic states, and its magneto-optical response in the mid-infrared regime.

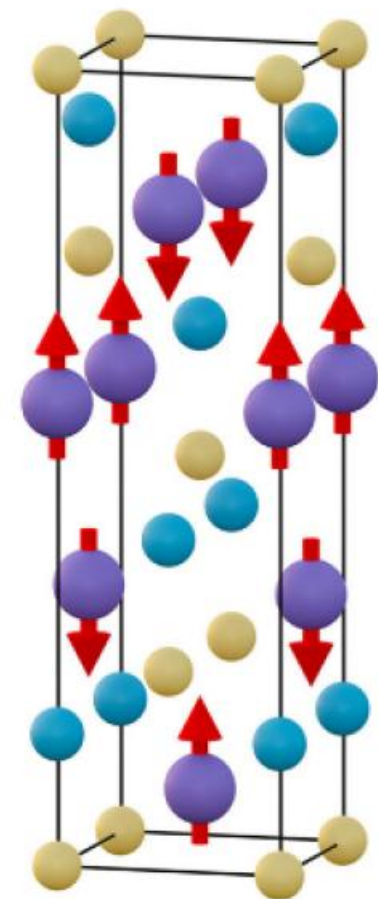


Models of FM, AFM, and altermagnetism with nonrelativistic electronic-structure in the momentum space and crystal-structure in real space.

<https://doi.org/10.1103/PhysRevX.12.040501>

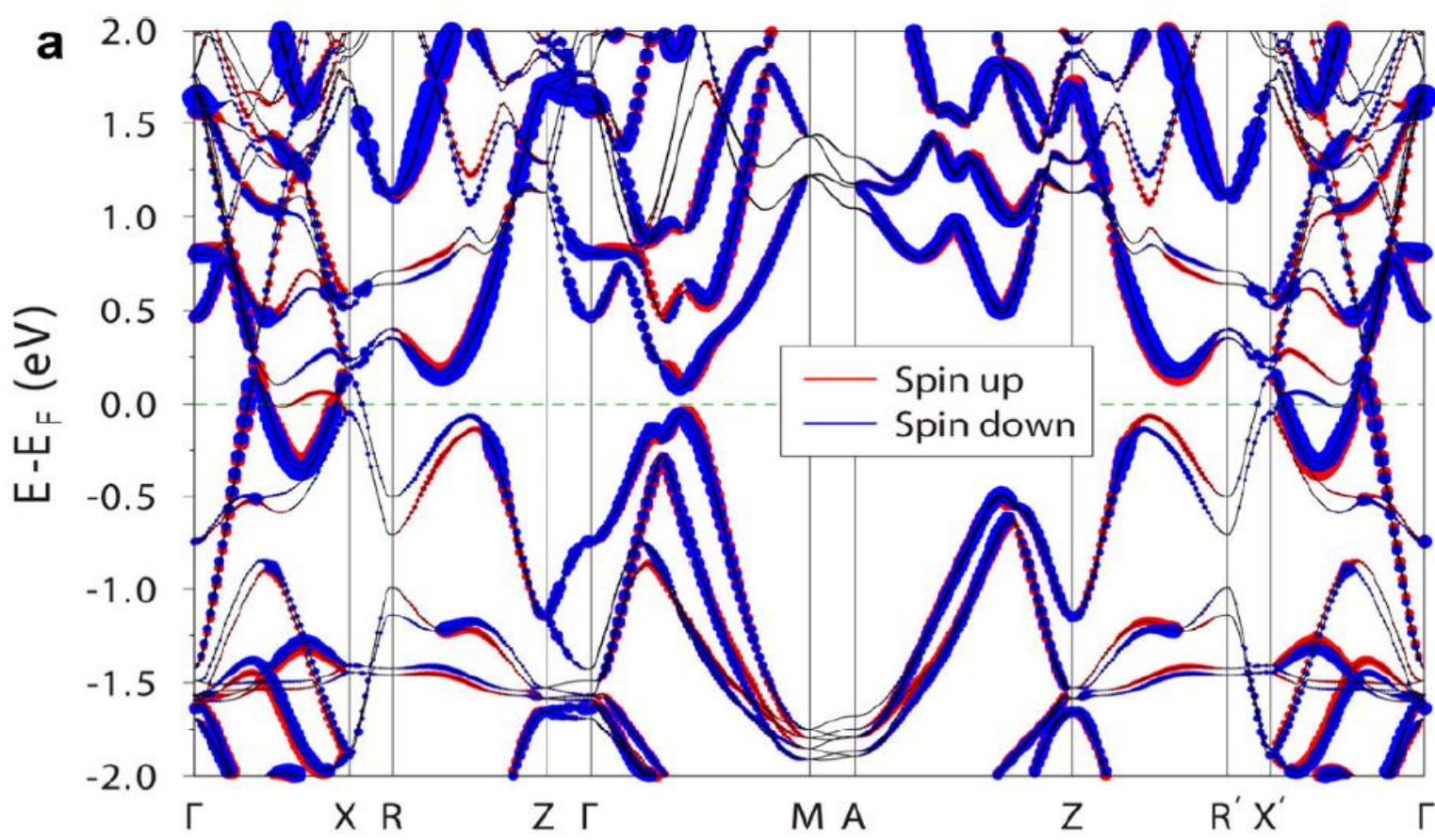


Samples of GdAlSi grown by the Dr. Eo group at Texas Tech University



Tetragonal crystal structure of GdAlSi, Gd atoms are surrounded by the Al (Blue) and Si (Venilla).

<https://pubs.acs.org/doi/full/10.1021/jacs.4c14891>



Calculated band structure of the bulk GdAlSi, conventional tetragonal unit cell, across the line $X' - \Gamma - X$. The bands with spin up and down marked as blue and red.

<https://pubs.acs.org/doi/full/10.1021/jacs.4c14891>

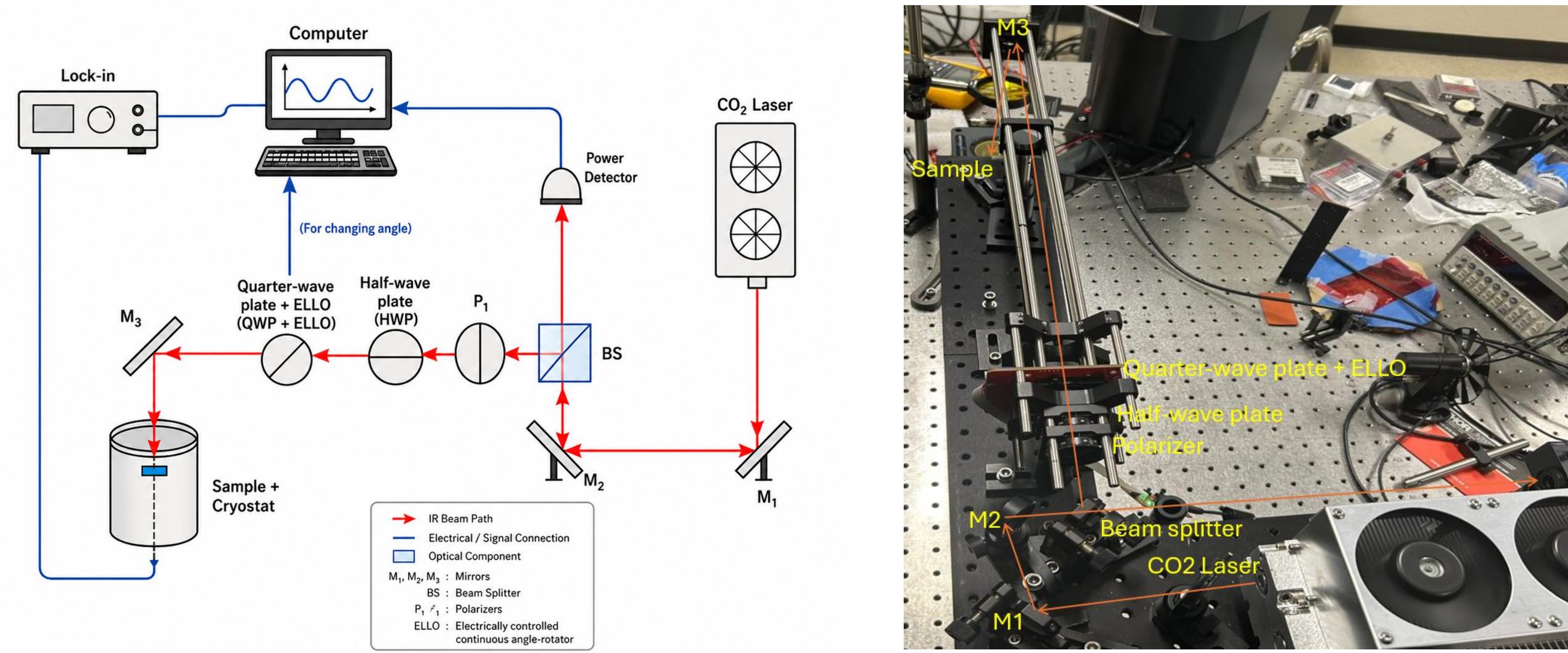
Experimental Methods

FTIR Reflectance Measurements

A Fourier-transform infrared (FTIR) spectrometer is employed to measure the mid-infrared reflectance of GdAlSi and investigate its optical properties. An external infrared microscope coupled to the spectrometer is used to collect the reflected signal from the sample. The measured reflectance spectra provide a basis for analyzing the frequency-dependent optical conductivity.

Mid-Infrared Photoresponse Measurements

The schematic and photograph of the experimental photoresponse setup are shown below. A mid-infrared CO₂ laser is used as the excitation source. The optical setup consists of mirrors, a beamsplitter, a polarizer, half-wave and quarter-wave plates, and a focusing lens. The polarizer and wave plates control the incident light polarization, while a power detector monitors the laser intensity for power normalization. All photoresponse measurements presented here were performed at room temperature, with the sample positioned outside the cryostat.



Conclusion: The mid-infrared reflectance of GdAlSi exhibits metallic-like behavior, characterized by enhanced low-frequency reflectivity and a spectral minimum near 1600–1800 cm⁻¹, which may indicate contributions from interband optical transitions. These observations motivate further analysis of the complex optical conductivity to investigate carrier dynamics and possible topology-related optical responses. Furthermore, room-temperature photoresponse measurements reveal polarization-dependent features that suggest possible helicity-sensitive carrier excitation. However, additional measurements are required to establish whether these features originate from Weyl fermions.

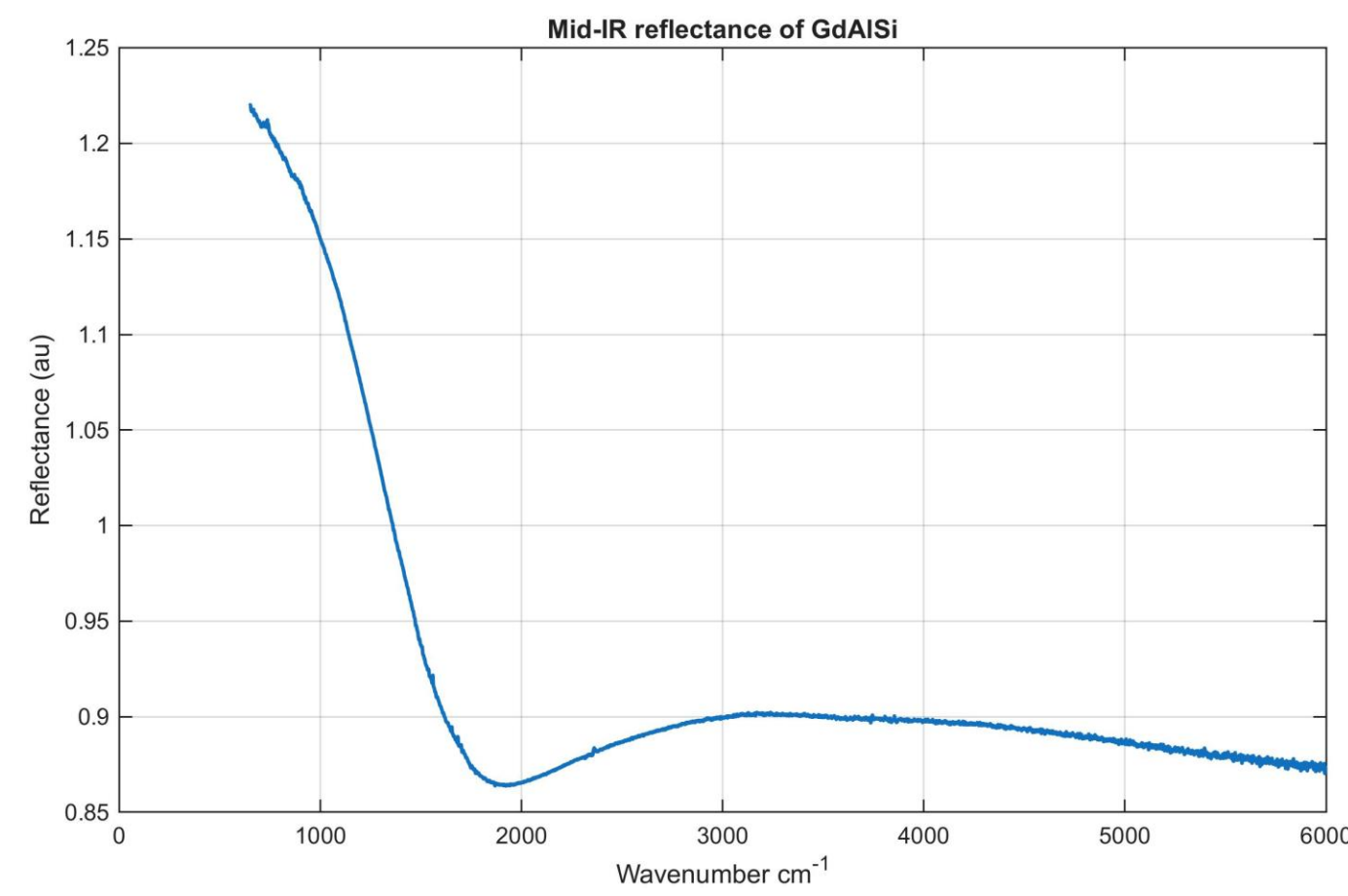
Future Plan: In the future, we aim to get temperature-dependent photoresponse measurements to check the chiral signature and photothermal response to check the magnetic phase transition of the candidate material. Also, our goal is to measure the other optical and photothermal responses in the presence of a magnetic field.

References

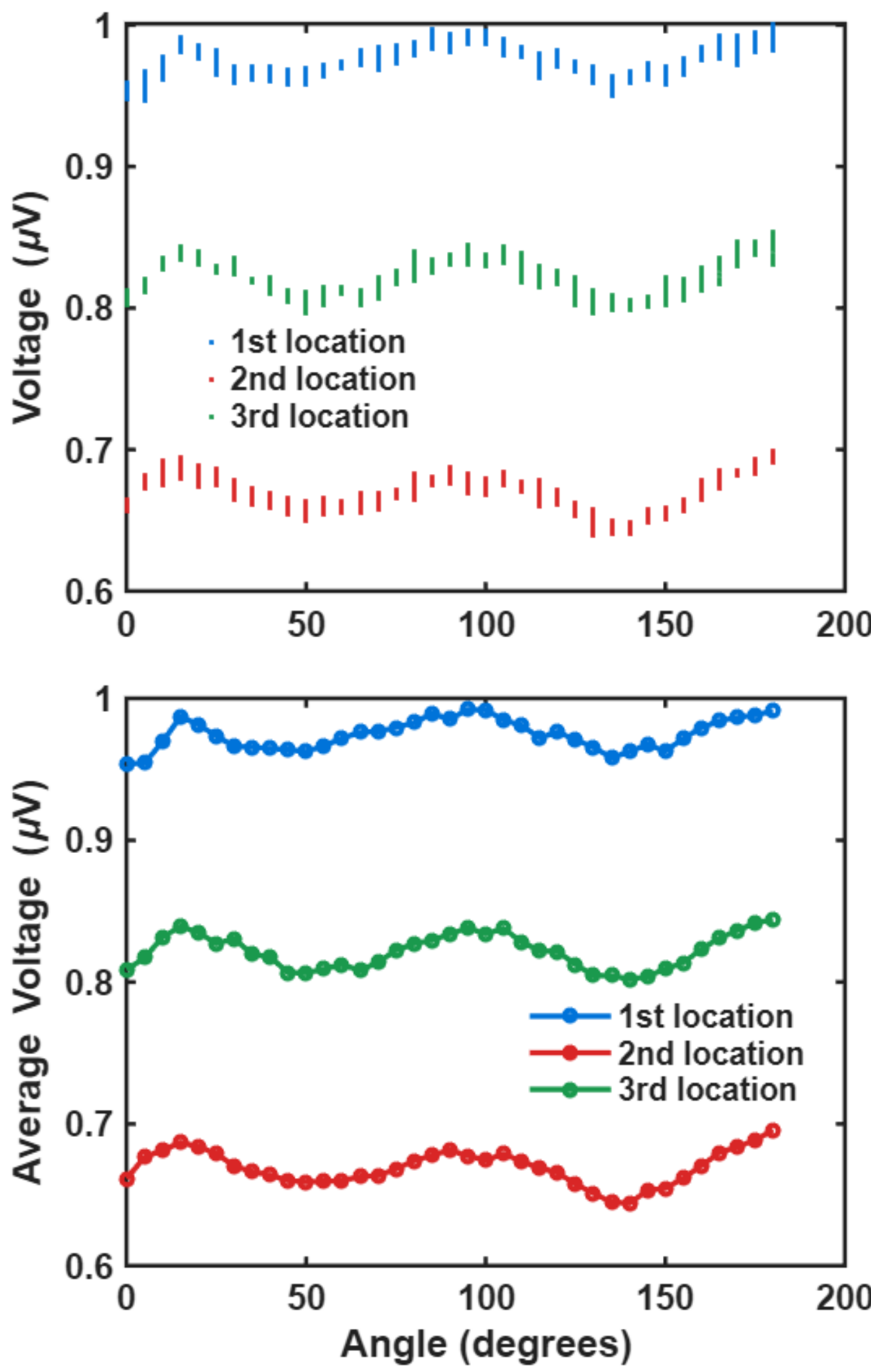
[1] L. Smejkal, J. Sinova, & T. Jungwirth (2022). Emerging Research Landscape of Altermagnetism. Physical Review X 12. <https://doi.org/10.1103/PhysRevX.12.040501>

[2] E. Parfenov, V. Averyanov, S. Sokolov, N. Mihalyuk, A. Kondratev, N. Taldenkov, & G. Storchak. JACS (2025). Pushing an Altermagnet to the Ultimate 2D Limit: Symmetry Breaking in Monolayer of GdAlSi. JACS Vol 147(7) <https://pubs.acs.org/doi/full/10.1021/jacs.4c14891>

Results



The IR reflection in the mid-infrared range from a rough surface of GdAlSi over the gold background shows a similar result to other Weyl Semimetals. At high wavenumber (3000–4000 cm⁻¹), the reflectivity is nearly constant. At 1600–1800 cm⁻¹, the reflectivity decreases and reaches a minimum. At the low wavenumber region (<1500 cm⁻¹), the reflectivity rises at 800 cm⁻¹. This upturn suggests the metallic nature of GdAlSi, where long-wavelengths are reflected completely due to free-carrier screening.



The polarization-dependent photovoltage of GdAlSi exhibits a reduced dip amplitude at different locations on the single crystal, suggesting spatial variations in the optical response. These variations may arise from differences in local absorption, photothermal effects, or helicity-dependent excitation of Weyl fermions by left- and right-circularly polarized light. However, the room-temperature measurements alone do not provide conclusive evidence of a chiral photoresponse. Since GdAlSi undergoes magnetic ordering near 32K, temperature-dependent measurements across this transition may reveal changes in the dip amplitude and help clarify the relationship between magnetic ordering and helicity-dependent optical response.