

Time-resolved polarization-dependent Raman microscopy of 2D magnetic heterostructures in 9-tesla magnet

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1. Physics & Astronomy Department, University of Wyoming (Team leader)

2. Chemistry Department, University of Wyoming

3. Chemical and Biological Engineering, University of Wyoming

The total amount requested: **\$24,684.**

- Project goal:** Due to proximity nature of 2D materials, the 2D heterostructures (2DH) involving 2D magnets and 2D semiconductors present themselves with promising intrinsic properties for magneto-optical manipulation that is essential for quantum technology development. One critical factor of the carrier behaviors in these 2DH is the interaction between charge carriers and the crystal lattice vibration, so called phonons. Since understanding phonon properties is the foundation of 2D optoelectronics, quantum computing, and quantum communication, this project aims to study **phonon response in 2DH by thoroughly testing the sample with the cutting-edge Raman microscopy** capable of temperature/electrical bias/external magnetic field control. Our team consists of 1) sample synthesis support by Prof. Leonard's group, capable of producing a range of compounds by intercalating the 2DH with magnetic ions, i.e. Fe-WO₂Cl₂ and Co-WO₂Cl₂; 2) theoretical calculation support from Prof. Oliveira's group for identifying phonon modes, phonon transport analysis, and polarized-Raman intensity analysis; and 3) experimental Raman technique from the team leader, Prof. Tsai's group, connecting the theoretical results with experimental data shown in Figure 1:

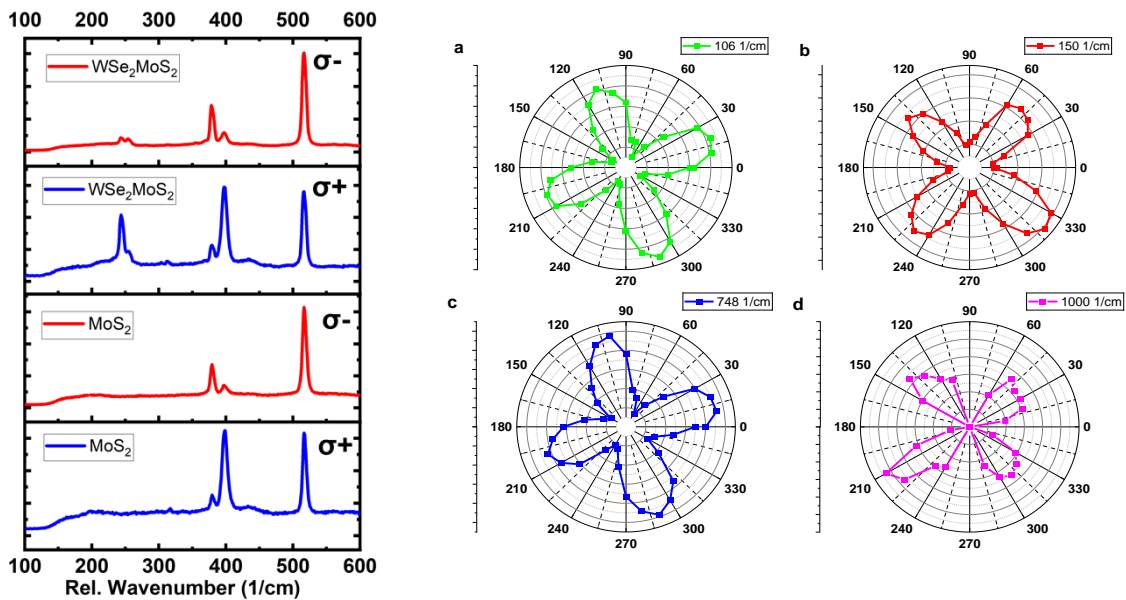


Figure 1 left) helicity-resolved Raman response from 2DH semiconductors. right) angle-dependent polarization Raman response from 2D layered WO₂I₂, synthesized by Prof. Leonard's group. Both data are taken in 2D opTic lab led by Prof. Tsai in Physics & Astronomy department at UW.

The specific research problems targeting funding programs to pursue are following from a short-term deliverable (a) leading to long-term research projects (b):

- a. Study of phonon behavior in 2DH and domain boundaries by polarization-dependent Raman microscopy. (NSF-DMR-fundamental material characterization, focus on fundamental phonon studies in 2DH by Raman microscopy.)
 - b. Pseudo-angular momentum of phonons revealed by circularly polarized Raman microscopy in high magnetic fields. (NSF-MRI, NSF-EPSCoR E-Core/E-Rise in 2026, DEPSCoR-CB, targeting advanced Raman spectrometer as major research instrument and further DOE/NSF Early Career Award, and NSF-Global Center.)
- **Long-term benefits:** a state-of-the-art Raman microscope at the University of Wyoming serving basic science research across bio/geology/chemistry/physics/engineering departments, capable of temperature/magnetic field/electric bias-dependent Raman investigations in a vibration-free environment.
 - **Short-term objectives:** **a)** Current Raman analysis of 2D sample WO₂I₂ leading to the first joint publication serving as preliminary data for an external proposal and **b)** one collaborative NSF-DMR proposal delivered at the end of the funding period.
 - **Work plan** (objective “b” continues after 5/2025):

	7/2024-10/2024	11/2024-2/2025	3/2025-5/2025
a	Complementary Raman data for Raman analysis with calculation support	Manuscript preparation and submission	Manuscript revision and publication
b	Key concepts development	Objectives development	Objectives finalized for proposal /work plan and budget development
	6/2025-9/2025	10/2025-1/2026	2/2026-6/2026
b	Proposal submission for NSF-Global Center	Proposal finalized for NSF-DMR submission	Proposal finalized for NSF/DOE-Early Career Award and EPSCOR submission

- **List of potential collaborators (7 out of 24):**

Name	Institution	Relation
Shih, Chih-Kang	University of Texas at Austin, TX	advisor
Petrou, Athos	University at Buffalo, NY	advisor
Han, Yimo	Rice University, TX	collaborator
Koch, Norbert	Humboldt University at Berlin, Germany	collaborator
Luo, Chih-Wei	National Synchrotron Radiation Research Center, Taiwan	collaborator
Zuerch, Michael	University of California at Berkeley, CA	collaborator
Tung, Vincent	University of Tokyo, Japan	collaborator

- **Funding sources and programs:**
DOE/NSF Early Career Award, NSF-DMR, NSF-MRI, NSF-Global Centers, NSF-EPSCOR (E-Core and E-Rise), DOE-FAIR and RENEW, DOD-DEPSCoR.

- **Budget description:**

One month Summer Salary		Notes
Yu-Tsung Tsai	\$12,684	Fringe 40.8% included
Conferences (per group)		For group members including postdocs or students
Yu-Tsung Tsai	\$4,000	Estimate based on APS participation
Laura de Sousa Oliveira	\$2,000	Estimate based on ACS participation
Brian M. Leonard	\$2,000	Estimate based on ACS participation
John Ackerman	\$2,000	Estimate based on ACS participation
Consumables (materials)	\$2,000	For Brian M. Leonard's group
Total Expenditures	\$24,684	

- **Justification:**

The scientific research problem, phonon responses in 2DH, is under investigation currently, as preliminary data shown in Figure 1. However, to deliver a competitive proposal for NSF-DMR program, the budget will be used to support the team leader for a summer month to collect further data, coordinate the project, and develop a grant proposal. The additional funding will be used to support the co-PIs and/or students traveling to national conferences to network with others in this field. This will help us suggest potential grant/publication reviewers and identify collaborators. Lastly, part of the funding will be used for material expense.