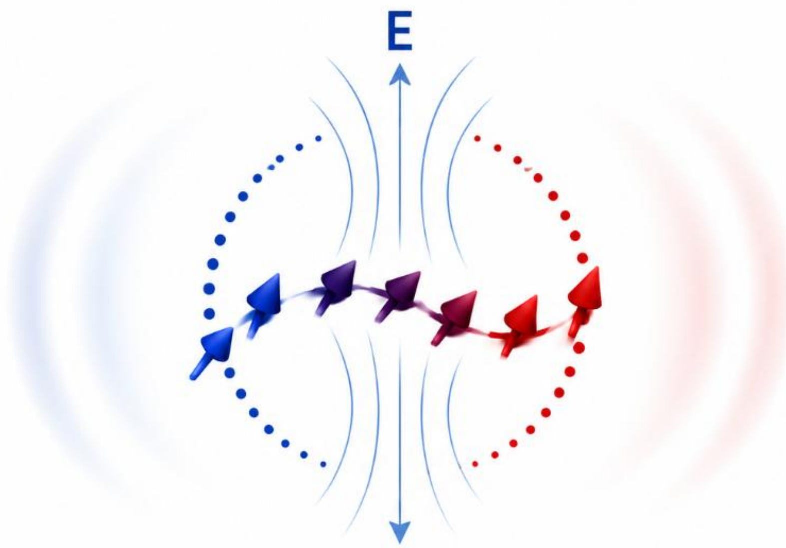


WORKSHOP ON

Efficient High-Frequency All-Electrical Control of Spin Dynamics in Quantum Magnetic Topological Insulators

Pittsburgh Quantum Institute

July 20-21, 2026 – PQI/CMU, Pittsburg, PA, USA

Workshop on Efficient High-Frequency All-Electrical Control of Spin Dynamics in Quantum Magnetic Topological Insulators

This workshop brings together leading researchers in condensed matter physics, materials science, electrical engineering, and ultrafast spectroscopy to explore emerging approaches for the efficient, high-frequency, all-electrical control of magnetic order in quantum materials.

A central focus of the meeting is the development of new mechanisms for controlling spin dynamics without charge transport or Joule heating, particularly through adiabatic spin–orbit torques in intrinsic magnetic topological insulators. These advances open a fundamentally new paradigm for spin–charge coupling and create exciting opportunities for ultrafast, energy-efficient spintronic technologies.

The workshop will foster interdisciplinary discussions on electrically driven magnetic dynamics, symmetry and topology in quantum materials, high-frequency and THz spin phenomena, nanoscale device integration, and advanced experimental probes including THz spectroscopy and time-resolved magneto-optics. By connecting theory, materials development, device engineering, and advanced characterization, the meeting aims to define key scientific challenges and catalyze future collaborations in this rapidly evolving field.

Chairs: Enrique del Barco and Simranjeet Singh
Organizing Committee: Ran Cheng, Andrew Kent, and Dario Arena

Sponsors:

This workshop has been sponsored by the Army Research Laboratory, the Pittsburgh Quantum Institute, The University of Central Florida, The University of South Florida, and the Center for Quantum Phenomena at NYU.

Invited Speakers

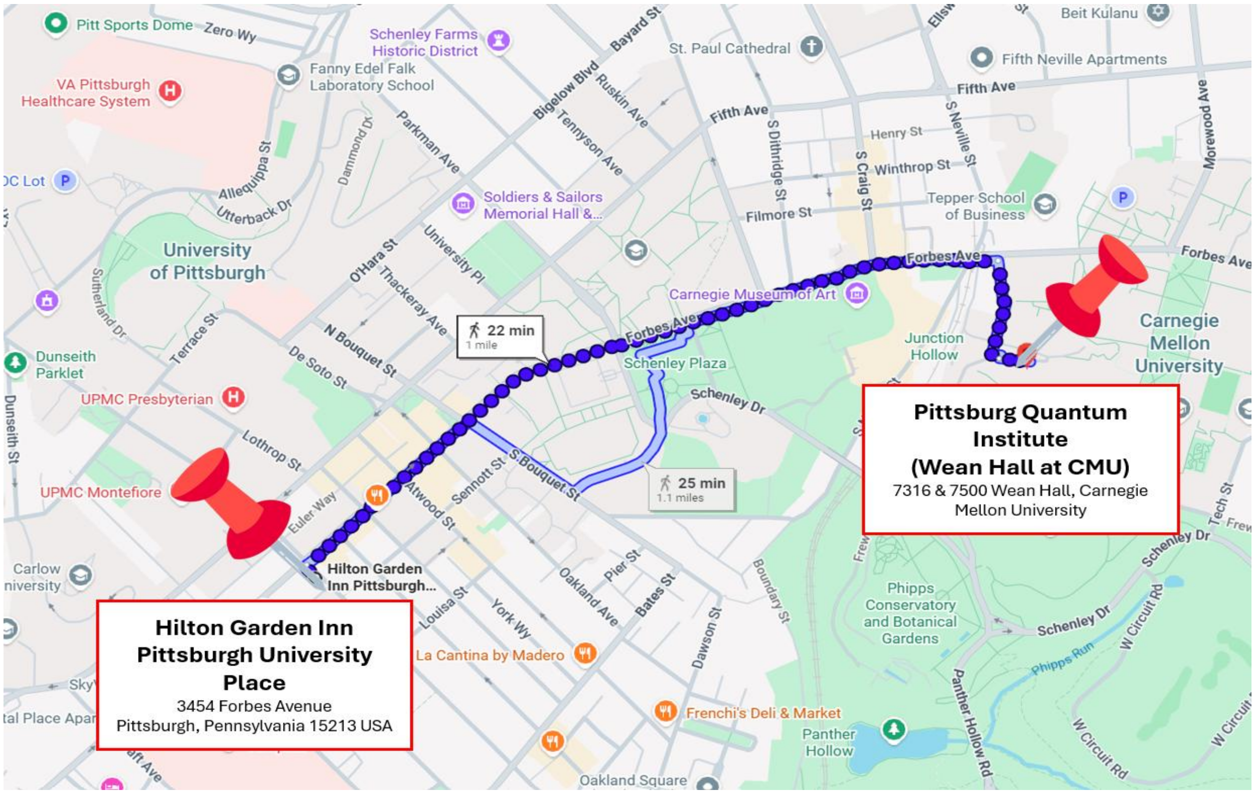
- Dario Arena (USF)
- Eunice Bae (Cornell)
- Salvador Barraza-Lopez (UArk)
- Enrique Cobas (NRL)
- Ran Cheng (UCR)
- Enrique del Barco (UCF)
- Jacob Gayles (USF)
- Axel Hoffman (UI)
- Roland Kawakami (OSU)
- Kota Katsumi (NYU)
- Andrew Kent (NYU)
- Michael Newburger (AFRL)
- Joe Ngai (UTA)
- Branislav Nikolic (UD)
- Yafei Ren (UD)
- Simranjeet Singh (CMU)
- Fengyuan Yang (OSU)

Scientific Program (All the talks are in Wean Hall 7500)

	Monday, July 20th		Tuesday, July 21st
8:00am – 9:00am	**Registration and Breakfast** (Wean Hall 7316)		**Breakfast** (Wean Hall 7316)
9:00am	**Opening Remarks**		
9:10-9:40am	**Ran Cheng:** Driving magnetic dynamics using adiabatic current-induced torques	**9:00-10:30am**	**Eunice Bae:** Excitonic Spin Torque in a Magnetic Semiconductor
9:40-10:10am	**Enrique del Barco:** Electric Field-induced Antiferromagnetic Resonance in MnPS3	**9:00-10:30am**	**Yafei Ren:** Feedbacks in the Coupled Dynamics of Spin and Bloch Electrons: From Berry Curvature to Nonadiabatic Metric
10:10-10:40am	**Andy Kent:** Quantum-Limited Magneto-Optical Detection of Spin-Orbit Torques	**9:00-10:30am**	**Axel Hoffman:** Making Yttrium Iron Garnet Topological
10:40am	Coffee Break (Wean Hall 7316)	**10:30am**	Coffee Break (Wean Hall 7316)
11:00-11:30am	**Simran Singh:** Emergent Magnetotransport Phenomena in Atomically Precise Heterostructures of 2D Magnets and Topological Systems	**11:00-11:30am**	**Branislav Nikolic:** Ultrafast Optical Excitation of Antiferromagnetic or Inertial Magnons in 2D Magnets
11:30am-12:00pm	**Dario Arena:** Element-Specific Spin Dynamics and Coherent Magnon Control in Quantum and Ferrimagnetic Materials	**11:30am-12:00pm**	**Roland Kawakami:** High-Frequency Magnetization Dynamics in Engineered Magnetic Heterostructures
12:00-12:30pm	**Kota Katsumi:** Terahertz-Driven Nonequilibrium Spin Dynamics in Quantum Antiferromagnets	**12:00-12:30pm**	**Enrique Cobas:** Topological Heterostructure Materials Considerations
12:30-1:30pm	Lunch Break (Wean Hall 7316)	**12:30-2:00pm**	Lunch Break (Wean Hall 7316)
1:30-2:30pm	Poster Session (Scott Hall 6142)	**2:00-2:30pm**	**Michael Newburger:** Investigation of RF Excitations in Ferroics Via Brillouin Light Scattering
		2:30-3:00pm	**Salvador Barraza-Lopez:** Engineering magnetoelastic and magnetoelectric two-dimensional multiferroics
2:30-3:00pm	**Joe Ngai:** Realizing novel quantum materials and devices in epitaxial oxide heterostructures	**3:00-3:30pm**	**Jacob Gayles:** Tunable of Universal Quantum States at Weyl Semimetal Interstitial Interfaces with Magnetic Textures
3:00-3:30pm	**Fengyuan Yang:** Electrical Switching and Imaging of Antiferromagnetic Spins in Perovskite Epitaxial Films	**3:30pm**	Closing remarks
4:00pm	Refreshment Break (Wean Hall 7316)		
4:30-5:30pm	**Round table**		
7pm-10pm	Workshop Banquet (The Oaklander Hotel)		

Workshop Venue:

7500 & 7316 Wean Hall, Carnegie Mellon University



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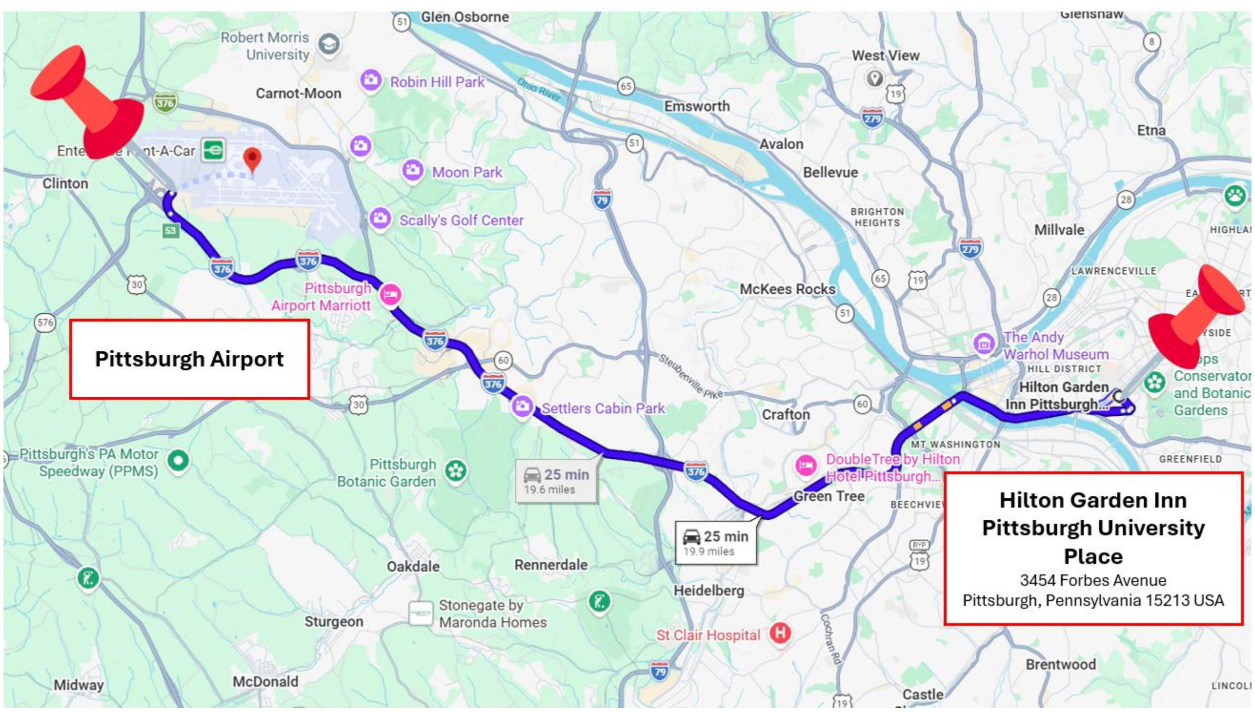

Book of Abstracts

Monday, July 20th @ 9:10-9:40am

Driving magnetic dynamics using adiabatic current-induced torques

Ran Cheng

Departmet of Physics and Astronomy, University of California; Riverside, CA 92521, USA

Abstract: Electrical control of magnetism is conventionally achieved through current-induced torques, in which spin angular momentum is carried by conduction electrons and is therefore inevitably accompanied by significant Joule heating. We propose a fundamentally different mechanism for driving magnetic dynamics using the adiabatic motion of valence electrons, eliminating Ohmic conduction and offering a route towards dissipationless transfer of angular momentum. In the ideal limit, these adiabatic current-induced torques can, in principle, achieve a perfect 100% mechanical efficiency in generating magnetic dynamics. The key mechanism originates from an effective gauge structure characterized by the Berry curvature entangling the crystal momentum with spin orientation. Furthermore, this new form of spin torques can be fully generated within a single magnetic material without relying on adjacent systems, which enables monostructural operation of spintronics that conventionally require multilayer heterostructures. As concrete demonstrations, we study electrically driven antiferromagnetic resonances and find an unexpectedly strong resonance peak whose power absorption exceeds that of conventional magnetic-field-driven resonances by orders of magnitude.

Monday, July 20th @ 9:40-10:10am

Electric Field-induced Antiferromagnetic Resonance in MnPS3

Enrique del Barco

Department of Physics, university of Central Florida, Orlando FL - USA

Abstract: I will present our recent experimental demonstration of electrically induced antiferromagnetic resonance in the topological antiferromagnetic insulator $MnPS_3$, providing the first direct validation of a revolutionary theoretical framework in spintronics [1,2]. This theory, rooted in the concept of adiabatic spintronics, proposes that the dynamics of magnetic order in certain topological materials can be driven by a pure voltage—completely bypassing the need for electrical currents and, with them, the ubiquitous problem of Joule heating. Such a mechanism has profound implications for the future of information technology, particularly as data manipulation is projected to become the dominant source of global energy consumption. Our results confirm that the Néel spin-orbit torques can be generated electrically within a single insulating magnetic structure, eliminating the need for external spin sources or engineered heterostructures [3]. The experiments were performed at frequencies in the 100 GHz range using a home-made, quasi-optical sub-THz microwave spectrometer. By continuously varying the polarization of the microwave excitation from linear to circular in both the Faraday and Voigh geometries, we were able to controllably switch the driving mechanism of the resonance from magnetic (Zeeman-type) to purely electrical (via the Neel spin-orbit torque). This polarization-tuning approach allowed us to isolate and unambiguously identify the electrically induced component of the resonance (see Fig.1)—offering direct evidence of adiabatic pumping effects predicted by the theory.

References:

[1] J. Tang and R. Cheng, Lossless spin-orbit torque in antiferromagnetic topological insulator MnBi2Te4, Phys. Rev. Lett. 132, 136701 (2024).

[2] J. Tang, H. Zhang, and R., Néel Spin-Orbit Torque in Antiferromagnetic Quantum Spin and Anomalous Hall Insulatorshttps://arxiv.org/abs/2410.21751 (2025).

[3] . Hanson-Flores, J. Tang, A. Regmi, J. Keum, A. I. Ojo, A. D. Kent, S. Singh, D. A. Arena, J.-G. Park, R. Cheng, and E. del Barco, Electric-Field-Driven Antiferromagnetic Resonance by Dissipationless Néel Spin–Orbit Torque, Submitted to Science.

Monday, July 20th @ 10:10-10:40am

Quantum-Limited Magneto-Optical Detection of Spin-Orbit Torques

Koral Aykin & Andrew D. Kent

Center for Quantum Phenomena, Department of Physics, New York University, USA

Abstract: Spin-orbit torques provide an efficient route for electrical control of magnetic order and underpin a broad range of spintronic phenomena and devices. Quantitative determination of spin-orbit torque efficiencies and symmetries, however, remains challenging, particularly in emerging quantum magnetic materials where unconventional torque mechanisms have been predicted.

In this talk, I will discuss our implementation at NYU of a zero-area-loop Sagnac magneto-optic Kerr microscope, adapted for highly sensitive measurements of spin-orbit torques in magnetic heterostructures and quantum materials. The instrument achieves quantum-shot-noise-limited performance with nanoradian-scale sensitivity, enabling direct optical detection of current-induced magnetic responses and providing a powerful platform for symmetry-resolved studies of spin-orbit torques.

I will present our initial measurements of damping-like spin-orbit torques in conventional heavy-metal/ferromagnet bilayers and ferrimagnetic heterostructures, demonstrating quantitative determination of SOT effective magnetic fields and torques. I will also discuss ongoing efforts to apply this technique to quantum magnetic topological materials, where there are predictions of unconventional spin-orbit torques, including layer-dependent Néel-type ones. Our recent modeling indicates that these torques generate experimentally distinguishable magneto-optical signatures that are detectable with our Sagnac interferometer, opening a pathway toward direct optical studies of current-driven spin dynamics in topological antiferromagnets.

Monday, July 20th @ 11:00-11:30am

Emergent Magnetotransport Phenomena in Atomically precise Heterostructures of 2D Magnets and Topological Systems

Simranjeet Singh

Department of Physics, Carnegie-Mellon University; Pittsburg, PA, USA

Abstract: Phenomena originating from the interaction of electrons and magnetic order is at the heart of condensed matter physics and is responsible for numerous breakthrough applications. We will discuss the experimental realization of novel magnetotransport phenomena emerging in van der Waals (vdW) based atomically precise heterostructures` . First, we will discuss the discovery of an unconventional unidirectional magnetoresistance (UMR) response in heterostructures of a topological semimetal (WTe2) and a ferromagnetic insulator (Cr2Ge2Te6, CGT), which allows to electrically read the up and down magnetic states of the CGT layer by measuring the longitudinal resistance [1]. Secondly, we will discuss the experimental realization of an unconventional form of anomalous Hall effect (AHE) in a low-dimensional heterostructure, wherein the Hall response is not only proportional to the out-of-plane magnetization component but also to the in-plane magnetization component [2]. By interfacing a low-symmetry topological semimetal (TaIrTe4) with a ferromagnetic insulator (CGT), we create a low-dimensional magnetic system, where only one mirror symmetry is preserved. We show that if the magnetization has a finite component in the mirror plane, this last mirror symmetry is broken, allowing the emergence of an AHE signal proportional to in-plane magnetization. Finally, we will discuss our recent experimental demonstration of a novel transport methodology to detect Néel vector reversal in atomically thin films of a vdW based antiferromagnet (AFM) [3]. For this, we utilize spin-dependent electronic band properties of CrSBr by coupling it to a spin-polarized layer, separated by a tunnel barrier. In this configuration, the spin-dependent tunnelling magnetoresistance (MR) becomes sensitive to the relative orientation between the magnetization of the reference electrode and the interfacial sublattice magnetization of the AFM layer, in turn enabling electrical detection of the Néel vector orientation.

References:

[1]. Kao et. al., Nature Materials 24, 1049 (2025).

[2]. Kao et. al., Nature Materials (2026) (https://www.nature.com/articles/s41563-026-02611-9).

[3]. Post et. al, arXiv:2606.24527 (2026) (under review).

Monday, July 20th @ 11:30-12:00pm

Element-Specific Spin Dynamics and Coherent Magnon Control in Quantum and Ferrimagnetic Materials

Dario Arena

Department of Physics, University of South Florida, Tampa, FL USA

Abstract: High-frequency control of spin dynamics in thin films with antiferromagnetic order parameters, particularly ones with topological features in their electronic structure, requires a quantitative understanding of the intrinsic parameters that set precession frequencies, damping, and magnon propagation. Broadband ferromagnetic resonance (FMR), x-ray detected FMR (X-FMR), extreme ultraviolet magneto-optic Kerr effect spectroscopy from high-harmonic generation (HHG) sources, and polarized neutron reflectometry (PNR) together provide element-, sublattice-, and depth-resolved views of such parameters. In this talk I will draw on this set of techniques to examine spin ordering and dynamics in three families of materials: a magnetic Weyl semimetal (Co_2MnGa), insulating spinel ferrimagnets (Ni-ferrites and substituted variants), and rare-earth/transition-metal ferrimagnets (Fe-Gd). I will also discuss observations of coherent magnon propagation in an ultralow-damping spinel ferrite imaged by scanning transmission x-ray microscopy. In Co_2MnGa a weak temperature-dependent tetragonal distortion shifts the Weyl nodes in momentum space and drives measurable changes in exchange stiffness, effective anisotropy, and magnetization, while the films retain ultralow Gilbert damping down to cryogenic temperatures [1,2]. In Ni ferrites, HHG-based transverse magneto-optic Kerr effect (T-MOKE) spectroscopy resolves elemental asymmetries in ultrafast demagnetization and reveals a substrate-dependent delay between Fe and Ni cations in the onset of coherent phonon oscillations, pointing to Jahn-Teller-active electronic configurations as a coupling channel between lattice and spin [3]. Precision FMR combined with XMCD on identical samples quantifies the spin-mixing parameter $\langle b^2 \rangle$ in transition-metal ferromagnets, providing an experimental handle on a quantity that is central to Elliott-Yafet scattering and to the description of spin states in Weyl semimetals, antiferromagnets, and topological insulators [4]. In $Fe_{1-x}Gd_x$ films, PNR and elemental mapping reveal thickness-dependent compensation behavior and Fe/Gd segregation that divides nominally uniform films into magnetically distinct layers with different compensation temperatures [5]. Building on the coherent, collinear cation dynamics established by X-FMR in resonantly driven NiZnAl-ferrite [6], I will discuss recent x-ray microscopy measurements of propagating magnons in spinel ferrite thin films, which

point to a route for engineering magnonic waveguides in insulating materials with antiferromagnetic order parameters

References:

[1] N. Schulz, D.A. Arena et al., Phys. Rev. B 110, 054419 (2024).

[2] A. I. Ojo, D.A. Arena et al., Phys. Rev. Mater. 10, 024410 (2026).

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[4] J. M. Shaw, D.A. Arena et al., Phys. Rev. Lett. 127, 207201 (2021).

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[6] C. Klewe, D.A. Arena et al., Appl. Phys. Lett. 122, 132401 (2023).

Monday, July 20th @ 12:00-12:30pm

Terahertz-Driven Nonequilibrium Spin Dynamics in Quantum Antiferromagnets

Kota Katsumi

Department of Physics, New York University, New York, NY, USA

Abstract: Antiferromagnets offer a promising platform for ultrafast spintronic technologies, as their spin dynamics can occur in the terahertz frequency range owing to the strong exchange interaction between spin sublattices, far beyond the typical gigahertz precession frequencies of ferromagnets [1]. Nevertheless, their vanishingly small net magnetization makes it challenging to probe antiferromagnetic order using common magnetometry and or magnetic resonance techniques. Ultrashort laser pulses provide one of the fastest and most energy-efficient routes to controlling spin degrees of freedom [2]. In particular, optical excitation at the terahertz frequency provides direct access to ultrafast magnetic dynamics by resonantly driving antiferromagnetic magnons. However, it remains unclear how terahertz fields couple to antiferromagnetic order, and how this coupling is governed by symmetry and microscopic interactions.

To address these questions, we will focus on two complementary examples of quantum antiferromagnets: a spin–orbit-coupled antiferromagnet Sr2IrO4 [3], and a multiferroic polar antiferromagnet Fe2Mo3O8 [4]. In Sr2IrO4, strong spin-orbit coupling leads to anisotropic magnetic interactions and low-energy spin excitations that can be resonantly addressed by terahertz fields. On the other hand, in Fe2Mo3O8, the magnetoelectric coupling gives rise to additional channels for coupling terahertz electric fields to spin dynamics through intertwined spin, lattice, and electric-dipole degrees of freedom. Using terahertz pump-optical probe spectroscopy, we investigate how these different microscopic interactions mediate nonequilibrium antiferromagnetic dynamics. These examples illustrate how terahertz pump-probe spectroscopy can clarify the microscopic pathways by which electromagnetic fields couple to antiferromagnetic dynamics in materials with strong spin-orbit and magnetoelectric interactions.

References:

[1] V. Baltz et al., Rev. Mod. Phys. 90, 015005 (2018)

[2] P. Němec et al., Nat. Phys. 14, 229–241 (2018)

[3] B. J. Kim et al., Phys. Rev. Lett. 101, 076402 (2008)

[4] T. Kurumaji et al., Phys. Rev. X 5, 031034 (2015)

Monday, July 20th @ 2:30-3:00pm

Realizing novel quantum materials and devices in epitaxial oxide heterostructures

Joseph Ngai

Department of Physics, University of Texas-Arlington, TX, USA

Abstract: Epitaxial oxide heterostructures provide a platform to realize novel quantum materials and devices. We will review the physics governing the emergence of material behavior in oxide heterostructures that are comprised of compositionally diverse layers. The growth of these heterostructures using oxide molecular beam epitaxy enables material composition to be controlled atomic-layer by atomic-layer, wherein the electronic and structural degrees of freedom between compositionally diverse constituents can couple across interfaces to realize novel phases. By virtue of their ionic nature, oxides exhibit a variety of behaviors not found in conventional semiconductors, which potentially enable spin and other degrees of freedom to be manipulated in devices beyond dissipative electrical transport. We will also review recent advancements in technology transfer that have paved the way to the commercialization of epitaxial oxide devices. Finally, we will discuss how the interplay between structural and electronic degrees of freedom within oxide heterostructures could be exploited to potentially realize novel topological magnetic insulators and actively manipulate their behavior in devices.

Monday, July 20th @ 3:00-3:30pm

Electrical Switching and Imaging of Antiferromagnetic Spins in Perovskite Epitaxial Films

Fengyuan Yang

Department of Physics, The Ohio State University, Columbus, OH, USA

Abstract: Electrical switching and detection of the Néel vector in antiferromagnets (AFMs) is a promising approach for utilizing AFMs in spintronics. To date, electrical switching has been demonstrated in several AFM conductors and insulators. Néel vector switching in insulators has been focused on simple oxides, while many complex oxide AFMs, which exhibit rich physics in AFM ordering, have been much less studied. Of particular interest is the large family of AFM perovskites which possess many desired attributes, such as high Néel temperatures and closely matched lattice structures, allowing for strain engineering and great tunability of AFM characteristics. In addition, altermagnets, which were previously considered AFMs but with spin-split bands, have attracted significant interest recently with potential for new paradigms of spintronics. In this regard, many perovskite AFMs have been predicted to be altermagnets. Thus, it is important to understand and control magnetic ordering in AFM perovskite epitaxial films.

Here, we report the first demonstration of reversible electrical switching of AFM LaFeO3 epitaxial films, which is detected by two complementary techniques of spin Hall magnetoresistance (SMR) and X-ray Magnetic Linear Dichroism Photoemission Electron Microscopy (XMLD-PEEM). LaFeO3 films of 3 and 10 nm thicknesses are deposited on SrTiO3 (001) using off-axis magnetron sputtering, which exhibit a biaxial anisotropy1 with two in-plane easy axes. We fabricate simple Hall cross devices of Pt(2 nm)/LaFeO3 bilayers to allow for both electrical pulse switching2 and electrical detection by transverse SMR. Electrical current pulses are sent along Ch1 or Ch2, after which we measure SMR. We observe clear, step-like plateaus at a current density of Jc = 7.40 × 1011 A/m2. By comparing with the high/low SMR states in the field-induced SMR, we note that the Néel vector aligns perpendicularly to the current pulse direction, which is opposite to the behavior observed in Pt/α-Fe2O3 and Pt/NiO bilayers. To probe AFM domain evolution after electrical switching, we image AFM domains in Pt/LaFeO3 Hall crosses after a series of electrical pulses at 300 K using XMLD-PEEM, which reveals clear dark and bright AFM domains. The 3-nm LaFeO3 film has large AFM domain sizes of >10 μm while the 10-nm film has sub-micron to a few μm domains. The XMLD-PEEM results are consistent with the SMR result that the Néel vector tends to align perpendicularly to the current pulse direction. This work offers the opportunity for electrical manipulation of epitaxial films of

AFM perovskites and provides a new materials platform for the exploration of predicted altermagnets in AFM perovskites with switchable Néel vector.

This work was supported by the Department of Energy, Office of Science, Basic Energy Sciences, under Grant No. DE-SC0001304.

References:

[1] J. Lanier, J. Michel, J. Flores and F. Y. Yang, *Nano Lett.* **25**, 4667 (2025).

[2] J. Lanier, J. Michel, D. Russell, B. Z. Liu, F. Kronast, B. Achinuq, J. Hwang, and F. Y. Yang, “Electrical Switching and Imaging of Antiferromagnetic Spins in Perovskite Epitaxial Thin Films,” *ACS Nano* **20**, 1507 (2026).

Tuesday, July 21st @ 9:00-9:30am

Excitonic Spin Torque in a Magnetic Semiconductor

Eunice Bae

Department of Chemistry & Chemical Biology, Cornell University, Ithaca, NY, USA

Abstract: Efficient control of magnetic order without charge transport or Joule heating is a central goal for ultrafast and energy-efficient spintronic technologies. In this talk, I will discuss a complementary route based on excitonic spin torque in the two-dimensional magnetic semiconductor CrSBr, where a bound exciton reservoir exerts coherent damping-like and anti-damping-like torques on magnetic order.

This excitonic spin torque drives non-trivial trajectories on the magnetic potential energy surface, enabling rapid and repeated switching between antiferromagnetic configurations from a single optical pulse. Unlike conventional spin torques that are often determined by heterostructure symmetry, interface design, or charge-current flow, excitonic spin torque emerges from intrinsic light–matter coupling in a magnetic semiconductor.

These results establish excitons as active drivers of high-frequency spin dynamics and suggest new opportunities for controlling magnetic order in quantum materials, with implications for optospintronic devices, spintronic memory, bidirectional quantum transduction, and non-equilibrium magnetic phase transitions.

Tuesday, July 21st @ 9:30-10:00am

Feedbacks in the Coupled Dynamics of Spin and Bloch Electrons: From Berry Curvature to Nonadiabatic Metric

Yafei Ren

Department of Physics & Astronomy, University of Delaware, Newark, DE, USA

Abstract: While topology has reshaped the classification of quantum matter in equilibrium, geometry governs the dynamics of various degrees of freedom in solids. The evolution of electronic states gives rise to geometric effects. Those geometric effects not only determine the electronic responses to the spin dynamics but also feed back on it.

In this talk, I will show that, the adiabatic electronic dynamics driven by spin precession generates orbital magnetization, which is related to the Chern-Simons form in the hybrid parameter space of electronic momentum and spin orientation [*PRL 134, 176702 (2025)*]. Going beyond the adiabatic limit, the electronic evolution can have nonadiabatic inter-band transitions, described by metric tensors in the hybrid parameter space, which influences not only the electron responses but also the spin dynamics. Such metric tensor, dubbed nonadiabatic metric, is related to the energy gap-renormalized quantum metric beyond the Berry phase effects [*PRB 113, 235107 (2026); PRB 113, 134309 (2026)*].

Together, these two geometric structures—Berry curvature and the nonadiabatic metric—provide a unified framework for describing particle and spin dynamics in solids. The former acts as a gauge field, while the latter plays the role of a metric tensor.

If time permits, I will also discuss how the feedback between subsystems stabilize steady states with spontaneous symmetry breaking when they are driven out of equilibrium.

Tuesday, July 21st @ 10:00-10:30am

Making Yttrium Iron Garnet Topological

Bobby Kaman,[1] Jinho Lim,[1] Yingkai Liu,[2] and Axel Hoffmann[1,2]

[1] Department ofMaterials Science and Engineering and Materials Research Laboratory, The Grainger College of Engineering, University of Illinois Urbana-Champaign, Urbana, IL, United States.

[2] Department of Physics, The Grainger College of Engineering, University of Illinois Urbana-Champaign, Urbana, IL, United States

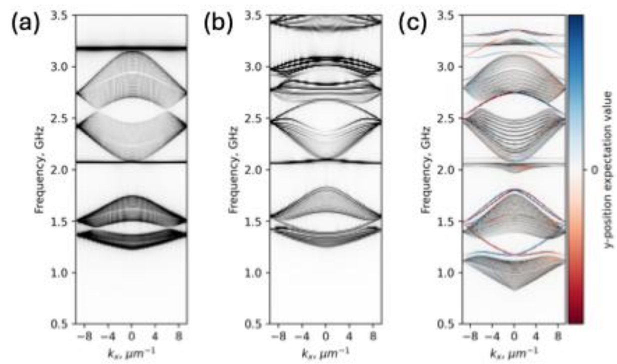

Figure 1: Magnon dispersions for patterned YIG films. (a) thin (15 nm) YIG with circular holes resembling graphene. (b) thin YIG with asymmetric holes resulting in quantum valley Hall edge states. (c) thick (60 nm) YIG with circular holes resembling a Chern insulator with chiral edge states.

Abstract: Two-dimensional magnetic materials can have magnon dispersions that are reminiscent to electronic band-structures in related two-dimensional materials, such as graphene, which has Dirac cones with linear dispersions. However, these magnons are typically at high frequencies and short wavelengths that make them hard to access experimentally and utilize for applications.

We demonstrated via micro–magnetic simulations and simple tight binding models that patterning of yttrium iron garnet (YIG) can realize similar physics in magnonic crystals at more accessible frequency and length scales [1]. A regular hexagonal array of circular holes (200-nm in diameter and 333-nm lattice spacing) in YIG results in a magnon dispersion that includes Dirac points and flat bands [Figure 1(a)]. By using asymmetric holes, it is possible to open gaps at the Dirac points, and by combining magnonic crystals with opposite symmetries one can generate boundary modes that are analogous to Quantum Valley Hall edge states [Figure 1(b)]. Furthermore, by increasing the thickness of the YIG films with circular holes dipolar interactions also open up gaps at the Dirac points in a way that results in chiral edge states [Figure 1(c)]. This work therefore provides simple design rules for engineering desired functionality. We are also currently working on demonstrating these topological magnons experimentally.

This work was supported by NSF, DOE, and ONR.

References:

[1] B. Kaman, J. Lim, Y. Liu, and A. Hoffmann, Phys. Rev. X **16**, 011034 (2026).

Tuesday, July 21st @ 11:00-11:30am

Ultrafast Optical Excitation of Antiferromagnetic or Inertial Magnons in 2D Magnets

Branislav K. Nikolić

Department of Physics & Astronomy, University of Delaware, Newark, DE, USA

Abstract: For applications in magnonics, there is a considerable experimental effort to excite coherent magnons by ultrafast light, whose frequencies are as high as possible and wavelengths as short as possible. In particular, the advent of two-dimensional (2D) magnetic materials—such as 2Dantiferromagnetic semiconductors CrSBr, NiPS3, and MnPS3 and their van der Waals heterostructures—has made possible recent experiments observing how femtosecond laser pulse excites magnons via exciton mediation. Our theory explains [1] such excitation as the consequence of a novel spin-transfer torque mechanism mediated by excitons, which is also supported by very recent experiments [2]. We additionally predict novel charge pumping signatures of exciting magnons [1]. For metallic (i.e., gapless) 2D magnets, we explain [3] how the bath of light-driven electrons can dramatically modifiy Landau-Lifshitz dynamics to introduce either a non-Markovian kernel with fractal properties in double time plane or magnetic inertia when such a kernel can be expanded, depending on the intensity of light [3]. Our extended Landau-Lifshitz equation [3], rigorously derived from field-theoretic methods, predicts the possibility of excitation of coherent inertial magnons at frequencies above the standard band of thermal magnons. Thus, both examples offer realizations of high-frequency and all-electrical control of magnetic order in quantum materials where initially electrons interact with the fast-changing electric field of light, which then leads to them changing the orientation of local magnetization.

References:

[1] J. Varela-Manjarres, Y. Ren, B. K. Nikolić, Ultrafast optical excitation of magnons in two-dimensional antiferromagnetic semiconductors via spin torque mediated by unbound electron-hole pairs and excitons: Signatures in magnonic charge pumping, Phys. Rev. B 113, 134403 (2026).

[2] N. J. Brennan et al., Excitonic spin torque in a magnetic semiconductor, Nat. Mater. https://doi.org/10.1038/s41563-026-02643-1 (2026).

[3] F. Reyes-Osorio and B. K. Nikolić, Optically induced magnetic inertia and magnons from non-Markovian extension of the Landau-Lifshitz-Gilbert equation, Phys. Rev. Lett. 135, 246701 (2025).

Tuesday, July 21st @ 11:30-12:00pm

High-Frequency Magnetization Dynamics in Engineered Magnetic Heterostructures

Roland Kawakami

Department of Physics, The Ohio State University, Columbus, OH, USA

Abstract: Understanding and controlling high-frequency magnetization dynamics in magnetic heterostructures is central to next-generation spintronic and magnonic technologies. Here, we present complementary studies of ultrafast optically driven and current-controlled spin dynamics in two classes of magnetic heterostructures: van der Waals semiconductor/magnet bilayers and metallic kagome ferromagnet/heavy-metal systems.

In WS2/CrGeTe3 van der Waals heterostructures, time-resolved magneto-optic Kerr effect (TR-MOKE) measurements reveal a new way to optically drive magnetization dynamics. Specifically, we observe enhanced precessional magnetization dynamics in WS2/CrGeTe3 compared to bare CrGeTe3, including a striking ~180° phase reversal and significantly larger oscillation amplitude. These results are explained by an ultrafast light-induced magnetoelectric effect arising from interfacial charge transfer in a type-II band-aligned heterostructure. Landau–Lifshitz–Gilbert modeling, density functional theory calculations, and photocurrent measurements support a mechanism in which photoexcited charge transfer modifies the perpendicular magnetic anisotropy on picosecond timescales, thereby generating a torque that drives GHz-frequency precession.1 This highlights a general principle for photon-spin interactions that should be applicable more broadly to other 2D magnet/semiconductor heterostructures.

Magneto-optic methods are also useful for investigating spin–orbit torque (SOT) controlled dynamics. In epitaxial Fe3Sn2/Pt bilayers,2 we use both quasistatic and time-resolved MOKE to quantify damping-like SOT. Consistent analysis yields an effective spin Hall angle of ~0.06, demonstrating efficient conversion of charge current into spin torque within the heterostructure. Moreover, the TR-MOKE studies illustrate how current-induced SOT can be used to control the magnetization dynamics, including changes in relaxation rate and precession frequency in the GHz regime. We have recently applied this approach to investigate SOT in other materials of interest.

Together, these results highlight the rich interplay between charge, spin, and topology in heterostructures, and establish multiple routes for ultrafast, high-frequency control of

magnetization. These findings open opportunities for tunable magnonics and energy-efficient spintronic devices operating on picosecond timescales.

References:

[1] Zhou, W., Bandapelli, R. K., Paudyal, H., Han, B., Kao, I.-H., Li, Z., Zhu, Y., Paudyal, D., Katoch, J., Singh, S. & Kawakami, R. K. Ultrafast Light-Induced Magnetoelectric Effect in van der Waals Magnetic Semiconductor Heterostructures. *ArXiv preprint:* arXiv.2604.19080 (2026).

[2] Lyalin, I., Cheng, S. & Kawakami, R. K. Spin–Orbit Torque in Bilayers of Kagome Ferromagnet Fe3Sn2 and Pt. Nano Lett. 21, 6975–6982 (2021).

Tuesday, July 21st @ 12:00-12:30pm

Topological Heterostructure Materials Considerations

Enrique Cobas

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Abstract: I discuss our group's recent work on spin-orbit torque (SOT) heterostructures, specifically on Fermi level engineering and conductivity mismatch. The importance of Fermi level engineering is highlighted by a comparison of bulk-insulating and bulk-conducting bismuth selenide. The spin torque efficiency of otherwise identical samples is measured by the magnetization switching of an overlaid permalloy layer. On similar heterostructures, we use terahertz emission spectroscopy to determine spin-to-charge interconversion efficiency at high frequencies. We find an apparent contradiction between our terahertz emission efficiency and the spin orbit torque efficiency results. I will discuss how the discrepancy is resolved by accounting for conductivity mismatch between the two layers. This talk underscores the importance of material selection, materials control and interface control for topological spintronics devices and highlights the current capabilities in this area at the Naval Research Laboratory.

Tuesday, July 21st @ 1:30-2:00pm

Investigation of RF Excitations in Ferroics Via Brillouin Light Scattering

Michael Newburger

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Abstract: Traditional radio frequency (RF) devices including those used in filtering, communications, and sensing, and alternative computing, rely on magnetic and ferroelectric materials. In particular, ferro- and ferri-magnets have shown great promise for agile RF devices due to their narrow linewidths, field-tunable resonance, and the ability to modulate GHz signals at compact length scales (~1um). However, while significant progress has been made impact improve SWaP, bandwidth, and sensitivity, further advances will demand new materials, heterostructures, and engineered interactions which can which can be manipulated to enhance coupling, localize fields, or reduce loss. Towards this end, our team has been focused on development of electrically and acoustically coupled magnetic systems which take advantage of ferroic properties to enable frequency tunable and non-reciprocal devices. However, one of the primary challenges to future development comes from limited characterization techniques which can accurately disentangle phenomena, particularly at frequencies and length scales of interest.

In this talk, I will discuss our recent work in utilizing Brillouin light scattering (BLS) microscopy to study RF phenomena in novel materials and devices. Starting with an introduction to BLS, I will use our recent work in the topological ferrimagnet LnMn6Sn6 (Ln = lanthanide) to highlight some of the advantages of BLS in characterizing RF properties of new materials. I will then show results from devices which demonstrate how BLS can be incorporated into complex systems to disentangle spatial dynamics and quasiparticle contributions. Finally, I will discuss applications of BLS into characterization of spatio-temporal resolved magnon dynamics, including in some of our recent work, to demonstrate complementary capability for next-gen materials and devices.

Tuesday, July 21st @ 2:00-2:30pm

Engineering magnetoelastic and magnetoelectric two-dimensional multiferroics

Salvador Barraza-Lopez

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Abstract: Two dimensional magnets are novel magnetic materials with spin configurations readily tunable by small amounts of strain (magnetoelastic coupling) or by a judicious choice of stacking (stacking engineering). In the first part of this presentation, I will argue that a deep understanding of magnetoelectric couplings in 2D materials requires developing an intuition of the atomistic structure for which spin is "turned off;" this is done by establishing magnetism as a "perturbation" of the lattice, and semiclassical arguments [1]. On the second part, I will describe recent attempts to produce ferroelectricity out of two-dimensional magnets by stacking [2], and will also discuss results of an ongoing experimental/theoretical collaboration in which magnetoelastic couplings are engineered in few-monolayer CrI3 [3].

This work has been supported by NSF (grants DMR-1906383 and OAC-2346752) and by the US DOE (grant DE-SC0022120).

References:

[1] J. M. Davis, A. Garcia-Fuente, J. Ferrer, and S. Barraza-Lopez. Phys. Rev. B 111, L220405 (2025).

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[3] C. Fox, J. D. Mella, J. Rollins, Y. He, Y. Mao, H. Jiang, A. Drew, H. Ma, T. Taniguchi, K. Watanabe, Y. Wang, D. Rhodes, S. Barraza-Lopez, and J. Xiao. arXiv:2510.03220.

Tuesday, July 21st @ 2:30-3:00pm

Tunable of Universal Quantum States at Weyl Semimetal Interstitial Interfaces with Magnetic Textures

Jacob Gayles

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Abstract: Magnetic multilayers of alternating Weyl and Skyrmionic topologies are highly sought for novel device technology due to the possibility of efficiently manipulating magnetic textures and realizing phenomena such as the quantum anomalous Hall effect. In magnetic Weyl semimetals, the electronic band structure features pairs of Weyl nodes with opposite chirality charges, and the momentum space position of these nodes can reverse across a planar interface, giving rise to Fermi-arc-like bound states. We use a low-energy approximation to show that a magnetic interstitial layer can tune these states in three distinct ways: the electrostatic potential and in-plane magnetic potential components control the shape of the bound-state Fermi-arcs, with moderate in-plane magnetic potentials spin-filtering electrons across the interface1. Additionally, both in-plane magnetic components and electrostatic potentials regulate electron transmission, while the ratio of in-plane to out-of-plane magnetic components modulates magnetic potential effects. This tunability stems from spin-momentum locking and chirality reversal at the interface, allowing for a material-dependent interchange of states. Our model can be universally extended to investigate 2D planar twinning interfaces in B20 compounds using first-principles calculations, focusing on the Weyl semimetal CoGe2 with a FeGe3 interstitial. By employing supercell calculations that restrict the interface to the primitive cell, we demonstrate that the spin and anomalous Hall effects are significantly enhanced due to increased spin-orbit coupling and atomic potential variations at the interface. We explore the interplay between nonmagnetic Weyl semimetals and magnetic skyrmion-hosting systems in heterostructures across two thickness regimes: one with a semi-infinite Weyl system and a thin skyrmion-hosting film and the other with a semi-infinite skyrmion system and a thin Weyl film. This work defines the physical bounds of skyrmion-Weyl interactions and determines methods to maximize the synergy of these two systems.

References:

[1] Thareja, E., Pantano, G., Vekhter, I. & Gayles, J. Tuning Quantum States at Chirality-Reversed Planar Interface in Weyl Semimetals using an Interstitial Layer. (2025).

[2] Spencer, C. S. et al. Helical magnetic structure and the anomalous and topological Hall effects in epitaxial B20 $Fe_{1-y}Co_yGe$ films. Phys. Rev. B 97, 214406 (2018). [3] C. Fox, J. D.

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[3] Gayles, J. *et al.* Dzyaloshinskii-Moriya Interaction and Hall Effects in the Skyrmion Phase of $Mn_{1-x}Fe_xGe$. *Phys. Rev. Lett.* 115, 036602 (2015).