MAGNETO-OPTICS IN QUANTUM MATERIALS CONFERENCE

Co-hosted by Quantum Design & Chicago Quantum Exchange

Monday, September 9 and Tuesday, September 10, 2024

University of Chicago
William Eckhardt Research Center, Room 161
5640 S. Ellis Ave., Chicago, Illinois

About the Conference

The Magneto-Optics in Quantum Materials conference is an intensive two-day event featuring the latest advancements in magneto-optics, the study of ultrafast phenomena in magnetic fields, and scanning probe nanoscopy for quantum materials. Participants can join the inauguration of the Teaching & Materials Discovery Laboratory at the University of Chicago featuring the Quantum Design OptiCool, interact with the Quantum Design Q-Works team responsible for designing the OptiCool, and discover the newest measurement customizations including the Lake Shore FastHall measurement-ready system for the OptiCool.

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Conference Venue

University of Chicago
William Eckhardt Research Center, Room 161
5640 S. Ellis Ave., Chicago, Illinois
Map of the venue

TALK ABSTRACTS
Monday (Sept. 9th)

9:15 – 10:30 am Collective Excitations in Quantum Magnets

Exciton-Magnon Coupling in CrSBr

Xiaodong Xu, University of Washington

In this talk, I will present exciton, magnon, and their coupling effects in CrSBr. I will discuss the nonlinear opto-magnonic coupling by presenting exciton states dressed by up to 60th harmonics of magnons resulting from their nonlinear interactions. The optical side bands are tunable, which results in sum- and difference-frequency generation between two optically bright magnon modes under symmetry breaking magnetic fields. Moreover, the difference-frequency generation mode can be continuously tuned into resonance with one of the fundamental magnons, resulting in magnon parametric amplification. These findings realize the modulation of the optical frequency exciton with the extreme nonlinearity of magnons at microwave frequencies, which could find applications in magnonics and hybrid quantum systems.

Collective excitations in a quantum magnet

Elaine (Xiaoqin) Li, University of Texas at Austin

The interaction of charge, spin, lattice, and orbital degrees of freedom in correlated materials often leads to diverse and unique properties. Recent research has provided fresh insights into bosonic collective excitations in these materials. For example, inelastic neutron scattering has demonstrated non-trivial band topology for magnons and spin-orbit excitons in the quantum magnet $CoTiO_3$. In this talk, I will discuss novel phonon properties in $CoTiO_3$ resulting from strong spin-orbit coupling, substantial crystal field splitting, and trigonal distortion. Notably, the coupling between spin-orbit excitons and phonons introduces chirality to two phonon modes, leading to significant phonon magnetic moments as seen in magneto-Raman spectra. In addition, I will discuss unusually long-lived zone-boundary magnons observed via two-magnon resonance. Both band topology and magnetic anisotropy are critical elements endowing a long lifetime to the THz magnons in the antiferromagnetic phase.

Observation of the dynamical Axion quasiparticle by coherent control of Berry curvature in 2D $MnBi_2Te_4$

Suyang Xu, Harvard University

The Axion is an elusive boson, defined by the coherent oscillation of the theta field in QCD. Its existence can solve multiple fundamental questions including the strong CP problem of QCD and the dark matter. However, its detection is challenging because it has almost no interaction with existing particles. We report the observation of the Axion quasiparticle in 2D $MnBi_2Te_4$. Its electronic properties feature a nonzero theta angle that relates electric and magnetic fields within the material. We observed coherent oscillation of the theta angle in real time at a frequency of 44 GHz by exciting a specific magnetic coherent mode, thereby demonstrating the existence of the Axion quasiparticle based on its definition. Interestingly, in 2D $MnBi_2Te_4$, the Axion quasiparticle arises from the magnon-induced coherent modulation of Berry curvature. Such ultrafast control of quantum wavefunction can be generalized to manipulate Berry curvature and quantum metric of other materials in ultrafast time-scale. Beyond condensed matter, the Axion quasiparticle can serve as a detector of the dark matter Axion particle. We estimate the detection frequency range and sensitivity in the critically-lacking meV regime, contributing to one of the most challenging questions in fundamental physics.

10:45 am 12:00 pm Current and field switching in quantum states.

Electrical switching of a polar odd-parity magnet

Riccardo Comin, Massachusetts Institute of Technology

In recent years, significant developments have been made in the realization and characterization of magnetic, ferroelectric, and multiferroic materials in the ultrathin (2D) limit. In this limit, additional tuning knobs are available to modify the materials' physical properties by electrostatic gating, create new interfacial phases by heterostructuring, and more generally realize microelectronic devices in a

layer-by-layer fashion. Multiferroic systems are particularly interesting in this realm because of their potential to realize electric field control and switching of magnetism. A small but significant fraction of multiferroic systems is also characterized by a net spin chirality when all mirror symmetries are broken by spin order. This chirality of spin origin can be thought of as an emergent degree of freedom and can be used to store and manipulate information robustly and with low-power consumption.
Nickel iodide (NiI_2) is a type-II van der Waals magnetic insulator that develops a type-II multiferroic state in its low-temperature helimagnetic phase (T < 59 K). The spin helices (pitch ~ 7 unit cells) that characterize this phase breaks inversion symmetry, leading to an induced electrical polarization of purely electronic origin. In the past, we have explored the physics of the multiferroic state of NiI_2 in the ultrathin limit. Here, I will present recent developments including tuning of the multiferroic by substrate control, as well as a demonstration of voltage-based switching of ferroelectricity and spin chirality. In the end, I will discuss the prospects for potential applications of the physics of NiI_2 and spin-chiral multiferroics as magnetic memories.

Viscous terahertz photoconductivity caused by the super-ballistic flow of hydrodynamic electrons in graphene.

Denis Bandurin, National University of Singapore

Light incident upon materials can induce changes in their electrical conductivity, a phenomenon referred to as photo resistance. In semiconductors, the photo resistance is negative, as light-induced promotion of electrons across the band gap enhances the number of charge carriers participating in transport. In superconductors and normal metals, the photo resistance is positive because of the destruction of the superconducting state and enhanced momentum-relaxing scattering, respectively. In this presentation, I will demonstrative a qualitative breakdown of the standard behavior in metallic graphene [arXiv:2403.18492 (2024)]. I will show that Dirac electrons exposed to continuous wave (CW) terahertz (THz) radiation can be thermally decoupled from the lattice which activates hydrodynamic electron transport. In this regime, the resistance of graphene constrictions experiences a decrease caused by the THz-driven super ballistic flow of correlated electrons. We will discuss the dependencies of the negative photo resistance on the carrier density, and the radiation power, and see that such super ballistic devices operate as sensitive phonon cooled bolometers and can thus offer a picosecond-scale response time. Beyond their fundamental implications, our findings underscore the practicality of electron hydrodynamics in designing ultra-fast THz sensors and electron thermometers.

Symmetry Instability of Topological States Controlled by Magneto-THz Photocurrent Switches

Jigang Wang, Ames National Laboratory, Iowa State University

The interplay between symmetry and topology classifies topological states within the constraints of specific fixed symmetries, which can be controlled by varying structural or electronic states. However, current explorations of these control mechanisms have predominantly adopted a one-sided perspective, focusing on tuning electronic bands and electric currents by altering lattice parameters, e.g., driving coherent phonons of selective infrared [Nature Materials, 20, 329–334 (2021)] and Raman symmetries [Physical Review X 10, 021013 (2020)]. Here, we employ magneto-THz spectroscopy to complete this full circle, demonstrating how lattice symmetry breaking and coherent control result from light-induced THz photocurrent switches in centrosymmetric topological materials. Ultrafast magneto-THz photocurrent emission signals reveal an approximate two orders of magnitude enhancement in broken infrared symmetry phonon generation, induced by photo-Nerst current under a 7 tesla magnetic field. More interestingly, THz chiral-magnetic currents lead to a dynamic brightening of dark phonon modes and coherently control the p-honon generation assisted by the magnetic field. Finally, our cryogenic magneto-scanning near-field microscopy measurements will provide real-space evidence of THz chiral magnetic currents and edge states. This work was supported by the Ames Laboratory, the US Department of Energy, Office of Science, Basic Energy Sciences, Materials Science and Engineering Division under contract no. DEAC0207CH11358.

2:00 – 3:15 pm THz and Cyclotron Resonances

THz range cyclotron resonance experiments on interacting metals

Peter Armitage, Johns Hopkins University

The renormalization of effective electronic masses in materials is a well-established consequence of electron- electron and electron-lattice interactions in metals. However, precisely how this renormalization manifests can depend on the particular measurement and comparison between results gives insight into the underlying interactions. Angle-resolved photoemission, quantum oscillation studies in high magnetic fields (such as Shubnikov-de Haas or de Haas-van Alphen measurements), and heat capacity all measure masses that reflect the underlying renormalized quasiparticle dispersion. In contrast, susceptibility or compressibility measurements are sensitive to electronic correlations, but not electron-phonon renormalizations. Cyclotron resonance (CR) experiments merit special consideration. Cyclotron resonance is an established technique that was first developed to study semiconductors in the 1950s and has proved important for probing two-dimensional (2D) electron gases, fractional quantum Hall systems, topological semimetals, and surface states of topological insulators. However, the technique has only been applied to a small number of correlated systems. Access to higher THz-range frequencies and larger (pulsed) magnetic fields have opened the door to the cyclotron resonance studies of materials like high-temperature superconductors. Famously, Kohn showed that in Galilean-invariant systems, CR reveals a cyclotron mass $m_c = eB/\omega_c$ (where B is the magnetic field and ω_c is the cyclotron frequency) that is not affected by electron-electron interactions. Approximate Galilean-invariance is realized in very low charge density systems (e.g., lightly-doped semiconductors) where the Fermi wavelength greatly exceeds the lattice constant. Then the band mass plays the role of the free electron mass. However, these considerations do not apply in higher density systems (e.g., most metals) where, for example, umklapp scattering can be significant. Moreover, finite disorder or even small deviations from parabolicity can cause electron-electron interactions to manifest in the cyclotron mass. The key point is that electron-electron correlations can influence effective masses measured by CR very differently in comparison to other experimental methods. In this talk, I will review recent THz cyclotron resonance experiments on a number of interesting interacting systems as diverse as cuprate superconductors, nickelate metals, and 2D electron gasses and discuss what we learn about the physics of these systems.

Cyclotron resonance probe of the canted antiferromagnet in bilayer graphene

Erik Henriksen (University of Washington, St. Louis)

We use infrared magneto spectroscopy to explore the \nu=0 state in both mono- and bilayer graphene. In the latter, multiple transitions appear and disperse non-monotonically as a displacement field is applied perpendicular to the sheet. To better understand these complicated spectra, we have performed detailed theoretical calculations of the allowed transitions, using a realistic model of the bilayer graphene band structure and including electronic correlations. We find this theoretical picture only partially explains the observed resonances, leaving room for additional phase transitions between the CAFM and the fully layer polarized state, and a potential role for pseudospin coherence.

Cavity electrodynamics of van der Waals heterostructures

J.W. McIver, Max Planck Institute for the Structure and Dynamics of Matter, Columbia University

Van der Waals (vdW) heterostructures host many-body quantum phenomena that can be tuned *in situ* using electrostatic gates [Nature Materials 19, 1265 (2020), Nature Physics 16, 725 (2020), Nanotechnology 17, 686 (2022)]. These gates are often microstructured graphite flakes that naturally form plasmonic cavities, confining light in discrete standing waves of current density due to their finite size. Their resonances typically lie in the GHz - THz range, corresponding to the same μeV - meV energy scale characteristic of many quantum effects in the materials they electrically control. This raises the possibility that built-in cavity modes could be relevant for shaping the low-energy physics of vdW heterostructures. However, capturing this light-matter interaction remains elusive as devices are significantly smaller than the diffraction limit at these wavelengths, hindering far-field spectroscopic tools. Here, we report on the sub-wavelength cavity electrodynamics of graphene embedded in a vdW heterostructure plasmonic microcavity [arXiv:2403.19745 (2024)]. Using on-chip THz spectroscopy, we observed spectral weight transfer and an avoided crossing between the graphite cavity and graphene plasmon modes as the graphene carrier density was tuned, revealing their ultra strong coupling [Fig. 1]. Our findings show that intrinsic cavity modes of metallic gates can sense and manipulate the low-energy electrodynamics of vdW heterostructures. This opens a pathway for deeper understanding of emergent phases in these materials and new functionality through cavity control [Applied Physics Reviews 9(1) (2022)].

3:50 – 5:30 pm Twisting, Topology and Fractional States

Milli-Kelvin Microwave Imaging of Topological Edge States

Keji Lai, University of Texas at Austin

Near-field microwave microscopy has been an actively evolving research field in the past few decades. For the study of quantum materials, the technique is usually configured in cryogenic environments such that the thermal energy is comparable to or smaller than the scales of intrinsic quantum mechanical energy in the system. In this work, we implement a dilution refrigerator-based scanning microwave impedance microscope with a base temperature of 100 mK. The vibration noise of our apparatus with tuning-fork feedback control and close-cycled helium recovery is as low as 1 nm. Using this setup, we have demonstrated the imaging of quantum anomalous Hall state in magnetically (Cr and V) doped (Bi, Sb)2Te3 thin films grown on mica substrates. Both the conductive edge modes and topological phase transitions near the coercive fields of Cr- and V-doped layers are visualized in the field-dependent results. We have also imaged the quantum Hall edge states in gated graphene devices. Our study establishes the experimental platform for investigating nanoscale quantum phenomena at ultralow temperatures.

In-situ twisting and imaging of moiré superlattices

Monica Allen, University of California, San Diego

Moiré superlattices, which form in twisted stacks of 2D materials, constitute a versatile platform for the exploration of topological and correlated phenomena. Here we present a route to mechanically tune the twist angle of individual atomic layers with a precision of a fraction of a degree inside a scanning probe microscope, which enables continuous control of the electronic band structure in-situ. In twisted bilayer graphene, we demonstrate nanoscale control of the moiré wavelength via mechanical rotation, as revealed using piezo response force microscopy. We also extend this methodology to create twistable boron nitride devices, enabling dynamic control of the ferroelectric domain structure. This approach provides a route for real-time manipulation of moiré materials, which may allow for systematic investigation of the phase diagrams at multiple angles in a single device. We will also discuss progress on the construction of a new millikelvin microwave impedance microscope in a dilution refrigerator, which supports spatially-resolved detection of topological states in the GHz regime. As an application, I will briefly discuss the imaging of edge modes in a Chern insulator.

"Integer and Fractional Quantum Anomalous Hall Effects in Rhombohedral Graphene"

Long Ju, Massachusetts Institute of Technology

The fractional quantum anomalous Hall effect (FQAHE), the analog of the fractional quantum Hall effect at zero magnetic field, is predicted to exist in topological flat bands under spontaneous time-reversal-symmetry breaking. The demonstration of FQAHE could lead to non-Abelian anyons which form the basis of topological quantum computation. In this talk, I will report the observation of integer and fractional QAH effects in a rhombohedral pentalayer graphene/hBN moiré superlattice. In addition to FQAHE induced by the moire effect, I will report the observation of integer quantum anomalous Hall effect in pentalayer graphene without a moire effect. This state features a Chern number C=5 and a distinct mechanism from those of magnetic topological insulators and 2D moire superlattice materials. The rich family of FQAH and IQAH states in our high-quality graphene provide an ideal platform for exploring charge fractionalization and exotic quasiparticles for topological quantum computation.

Local microwave probe of bulk and edge states in a fractional Chern insulator

Zhurun Ji, Stanford & Massachusetts Institute of Technology

Nanoscale electrodynamics provides unique insights into states with bulk-edge correspondence and spatially dependent excitations. I will present our latest advancements in optically coupled microwave impedance microscopy (OC-MIM), a technique that enhances our ability to explore electrodynamics at the nanometer scale. OC-MIM allows us to extract spectroscopic information on exciton excitations in TMD systems and harness excitons as localized quantum sensors to measure material properties at the nanoscale. Additionally, I will share our recent findings on measuring bulk and edge states of fractional Chern insulators in twisted homobilayer $MoTe_2$. OC-MIM enables direct visualization of these fractional edge states and reveals their composite nature.

Tuesday (Sept. 10th)

9:00 – 10:15 am Ultrafast Dynamic of Quantum Matter

Time Domain Views of 2D van der Waals Quantum Matter

Xiaoyang Zhu, Columbia University

Interfaces of two dimensional (2D) van der Waals (vdW) crystals constitute the most versatile material platforms for the exploration of new physical phenomena, particularly emergent quantum phases. Here we apply femtosecond pump-probe spectroscopy/microscopy to develop a time-domain view of quantum phases at 2D vdW interfaces of semiconducting, ferro/antiferro-magnetic, and ferroelectric materials. For transitional metal dichalcogenide (TMDC) moiré interfaces, we show the robustness of correlated electron phases and their coupling to phonons. In the layered magnetic semiconductors, we discover the coupling between interlayer electronic hybridization to magnetic order and, as a result, the strong coupling of excitons to coherent magnons. In the layered ferroelectric semiconductors, we discover the strong coupling of across-gap electronic excitation to the ferroelectric order. These time-domain views reveal not only the nature of the quantum phases, but also prospects of controlling these quantum phases by light.

Ultrafast imaging of magnetic excitations in two-dimensional magnets

Chenhao Jin, University of California Santa Barbara

Two-dimensional (2D) magnets open new exciting opportunities for realizing novel magnetic states and device concepts thanks to their exceptional tunability and flexibility. On the other hand, their atomically thin nature makes it challenging to probe the magnetic excitations within due to the small cross section. In this talk, I will discuss our recent efforts to address the challenge with a novel ultrafast wide-field optical imaging technique. It allows us to capture complete space-time evolution of magnetic excitations in 2D magnets from 100 fs to >1ms. By applying this technique to different systems, we uncover various intriguing behaviors of magnetic excitations, such as non-diffusive propagation of magnons and formation of metastable magnetic textures.

Light induced metastable magnetization in a 2D antiferromagnet.

Alexander von Hoegen, Massachusetts Institute of Technology

The XPS3 (X=Mn, Ni, Fe, Co) family of van der Waals antiferromagnets has recently attracted a lot of attention due to their strongly coupled spin, lattice and electronic degrees of freedom. They offer a rich testing ground for 2D magnetism and provide an opportunity to explore its interplay with other correlated order parameters and their ultrafast control. In particular, the perturbation of the electronic degrees of freedom via resonant pumping of specific electronic transitions in these materials was explored to find new ways to control spins and lattice at an ultrafast timescale. In our work we go along a different avenue, by using intense THz light pulses, we resonantly drive the fundamental eigenmodes of the spin and lattice degrees of freedom, i.e., magnons and phonons, in $FePS_3$ directly. This way, the electronic degrees of freedom remain unperturbed, and we can study the low energy physics associated with the magnetism along non-thermal pathways. Our THz excitation launches spin and lattice dynamics in the form of coherent magnons and phonons, which we follow as a function of temperature by recording the polarization rotation (dichroism) and ellipticity (birefringence) of a transmitted 800-nm wavelength ultra-short laser pulse. Besides these fast dynamics, we also observe the emergence of a slow component close to the Neel temperature T_N = 118 K. These slow dynamics are concomitant with the appearance of a long-lived circular dichroism (CD), strongly suggesting a finite out-of-plane magnetization inside the sample. This CD signal shows a nonlinear dependence on the excitation field strength, appears only when the THz pump spectrally covers the relevant long-energy modes and has a lifetime of about 1.4 ms. To understand our results, we employed first principles calculations to evaluate the spin-lattice coupling. We found that one lattice vibrational mode, which is strongly hybridized with the AF-magnon at zero field, distorts the lattice in such a way that the exchange coupling between first-, second-, and third-nearest neighbor Fe atoms favors a ground state with a finite magnetization. These findings demonstrate how the magnetic ground state in 2D van der Waals magnets can be efficiently manipulated along non-thermal pathways using THz light. The long lifetime of the light-induced magnetization in $FePS_3$ promises possible applications in micro- and optoelectronic devices and impacts the field of spintronics in general.

10:20- 12:10 pm Optical Sensing of Quantum States

Exciton sensing of condensed matter phenomena

Kin Fai Mak, Cornell University

Many-body Effects on Nonlinear Optics and High Harmonic Generation in Low-Dimensional Solids

Diana Qiu, Yale University

Many-body effects play an important role in enhancing and modifying optical absorption and other excited-state properties of solids in the perturbative regime, but their role in high harmonic generation (HHG) and other nonlinear response beyond the perturbative regime is not well-understood. In this talk, I will present a new ab initio many-body method to study nonperturbative HHG based on the real-time propagation of the non-equilibrium Green's function with the GW self energy. As a first application of our methodology, we calculate the HHG of monolayer transition metal dichalcogenides and obtain excellent agreement with experiment, including the reproduction of characteristic patterns of monotonic and nonmonotonic harmonic yield in the parallel and perpendicular responses, respectively. We find that many-body effects are essential to accurately reproduce these spectral features, which reflect a complex interplay of electron-hole interactions (or exciton effects) in tandem with the many-body renormalization and Berry curvature of the independent quasiparticle band structure. Our results show that exciton effects may be especially important in the perpendicular response, where the Berry curvature plays a role in localizing the electron and hole. We also quantify the role of valley dynamics under elliptically polarized light in the nonperturbative regime, and we show that such a first principles approach is essential for providing microscopic insight into complex nonlinear spectra in solids.

Magneto-optics of hidden quasiparticles in topological semimetals

Yinming Shao, Pennsylvania State University

The discovery of nodal-line semimetal ZrSiS extends the notion of Dirac fermions from points to lines and loops in the momentum space [Nat. Commun. 7, 11696 (2016)]. Identifying new nodal-line fermions is challenging since often the Dirac nodal-lines are dispersive, submerged within a Fermi sea, and gapped by spin-orbit-coupling. I will first introduce how precise power-law behavior of the optical response function can reveal the hidden nodal-line fermions, using NbAs2 as an example [PNAS 116, 1168 (2019)]. Adding strong magnetic field further brings out more exotic quasiparticles in topological semimetals. I will discuss the impact of electronic correlations on Dirac fermions revealed through Landau level spectroscopy in ZrSiSe [Nat. Phys. 16, 6 (2020)]. Then, I will explain how the complex momentum-space structures of Dirac nodal-lines can host exotic quasiparticles that are massless in one direction and massive in the perpendicular direction. These so-called semi-Dirac fermions ignited intense theoretical interest since their prediction 16 years ago but remain undetected. Using magneto-optical spectroscopy, we demonstrate the defining feature of semi-Dirac fermions –B^(2/3) scaling of Landau levels – in a prototypical nodal-line metal ZrSiS [Under Review (2024)]. Our work sheds light on the hidden quasiparticles emerging from the intricate topology of crossing nodal-lines in topological semimetals.

Sensing and manipulating magnetic phenomena in 2D semiconductors

Alexander High, University of Chicago

To begin, I will provide a brief overview of our recent development of ultra-thin, single-crystal diamond membranes that hosts quantum coherent color centers [Nano Letters 21, 10392 (2021)]. The diamond membranes can be directly integrated with van der Waals heterostructures or other solid state platforms and are ideally suited for quantum sensing of electronic and magnetic phenomena. Next, I will present two experimental studies that leverage the optically-addressable valley degree of freedom in transition metal dichalcogenide monolayers (TMDs) to locally manipulate the symmetry of optical and magnetic processes. First, I will discuss our realization of an electrically-tunable chiral nanophotonic interface with a TMD [Nature Photonics 16, 330 (2022)]. We demonstrate a non-invasive method to fabricate high-performance optical waveguides directly on the surface of low disorder, boron nitride-encapsulated tungsten diselenide (WSe2). The underlying excitonic states in the WSe2 enable scattering into the waveguide that can be electrically switched between directionally-biased and balanced. We also demonstrate that the optical modes of the waveguide can act as a local source for diffusive, spin-polarized excitonic fluxes. Second, I will discuss our observation that ferromagnetic order in electrostatically-doped TMDs – which arises due to interactions between conduction band electrons - can be stabilized and controlled at zero magnetic field by local optical pumping [Science Advances 8 (39), eabq7650 (2022)]. We show that a circularly-polarized optical pump can break symmetry between oppositely-polarized magnetic states and stabilize long-range magnetic order, with carrier polarization exceeding 80% over an 8 μm x 5 μm extent. The local control of optical and magnetic symmetry in TMDs can unlock new spin and optical technologies and provide versatile tools in the study of correlated phases in two-dimensional electron gases.

1:30 – 2:45 pm Nonlinear Spectroscopy and quantum sensing I

Resonant optical detection of 2D spin textures

Xiao-xiao Zhang, University of Florida

The recently discovered atomically-thin magnetic crystals provide a unique playground for understanding magnetization in 2D confinement and developing new approaches to manipulating magnetism for novel spintronic devices. In particular, antiferromagnets (AFMs) are promising for realizing high-speed information processing given their THz magnetic resonance frequency. However, they are also less sensitive to optical and electrical detection due to their net zero magnetization. In this talk, I will discuss our recent results on 2D AFM transition-metal Tri chalcogenides, where we couple the magnetic transitions into the mechanical degree of freedom. We observed the expected steady-state spin transitions based on magnetostriction effects and also saw signatures of additional transition points related to the magnetic domain dynamics.

Magento-nonlinear optical responses in 2D antiferromagnets

Liang Wu, U Penn

In my talk, I will present recent advances in my group of using second harmonic generation under the magnetic field at the diffraction limit to study the Neel vector rotation and Neel temperature down to the monolayer antiferromagnet (arXiv:2404.06010). I will also talk about domain switching by the magnetic field (Manuscripts in preparation). If time permits, I will talk about nonlinear THz responses in 2D antiferromagnets under magnetic field to study quantum geometry (Manuscripts in preparation).

Visualizing two subsequent magnetic phase transitions in a helimagnet candidate

Liuyan Zhao, University of Michigan

Helimagnetism develops upon the competitions between different types of magnetic exchange couplings, for example, between the symmetric ferromagnetic coupling and the antisymmetric Dzyaloshinskii–Moriya (DM) interaction. Chiral crystal structure is one venue to turn on the DM interactions, and thus, intercalated transition metal dichalcogenides (TMDCs) of chiral structure are a recent platform to realize the structural chirality-induced magnetic helicity. Despite the creation of helimagnetic orders in intercalated TMDCs, the magnetic phase transition and the helimagnetic domain distribution remain elusive. In this presentation, we will use second harmonic generation spectroscopy and microscopy to study a $Cr_{1/3}NbS_2$. We will show the experimental data on the two magnetic phase transitions, six helimagnetic domain states, and the interplay between structural chirality and magnetic helicity. We will discuss the potential origins for the multi-stage phase transitions and multi-domain states in $Cr_{1/3}NbS_2$.

3:34 – 4:35 pm Nonlinear Spectroscopy and quantum sensing II

Interfacing Biomolecules with Coherent Quantum Sensors

Peter Maurer, University of Chicago

Micromotion of many-body state observed by pump-probe Raman spectroscopy

Dr. Hoon Kim (Postdoctoral Research Associate at Caltech)

Ultrafast pulsed lasers offer intriguing opportunities to control the magnetic and electronic properties of quantum materials. An outstanding question is how these properties can be coherently manipulated in the presence of strong optical electric fields. Here, we show that the optical pulses in Mott insulators induce micromotion of the many-body ground state. The micromotion generates coherent quasiparticle excitations whose population oscillates with the electric fields, leading to a transient metallic state. Our finding suggests a new pathway for coherent doping with selective symmetry-breaking, enabling the systematic exploration of the exotic phases in quantum materials.