



Day 1: Tuesday, December 16, 2025	
8:45 - 9:00 AM	Opening Remark
9:00 - 9:30 AM	TBD David Snoko (U Pitt)
9:30 - 10:00 AM	<i>Toward Bosonic Topological Quantum Phases in Semiconductor Moiré Superlattices</i> Ming Xie (UT Dallas)
10:00 - 10:30 AM	Coffee Break
10:30 - 11:00 AM	<i>Correlated Interlayer Excitons in Atomically Thin van der Waals Semiconductor Heterostructures</i> Philip Kim (Harvard)
11:00 - 11:30 AM	<i>Giant Elastoresistance in Magic-Angle Twisted Bilayer Graphene</i> Matthew Yankowitz (UW)
11:30 - 12:00 PM	<i>Novel Excitonic States by Coupling Many-body Interactions and Spatial Confinement in Moiré Materials</i> Felipe Jornada (Stanford)
12:00 - 2:00 PM	Lunch & Poster Session
2:00 - 2:30 PM	<i>Fractional Quantum Anomalous Hall Effect and Chiral Superconductivity in Graphene</i> Long Ju (MIT)
2:30 - 3:00 PM	TBD Zhengguang Lu (FSU)
3:00 - 3:30 PM	Coffee Break
3:30 - 4:00 PM	<i>Electron Solids in Atomically Thin Semiconductors</i> Feng Wang (Berkeley)
4:00 - 4:30 PM	TBD Shubhayu Chatterjee (CMU)
4:30 - 5:00 PM	TBD Zhenglu Li (USC)



Day 2: Wednesday, December 17, 2025	
9:00 - 9:30 AM	TBD Mohamod Hafezi (Maryland)
9:30 - 10:00 AM	Revealing Neutral Collective Modes through Ultrafast Imaging Chenhao Jin (UCSB)
10:00 - 10:30 AM	Coffee Break
10:30 - 11:00 AM	TBD Steven Louie (Berkeley)
11:00 - 11:30 AM	What Can Ultracold $SU(N)$ Hubbard Models Teach Us About Strongly Correlated Matter? Kaden Hazzard (Rice)
11:30 - 12:00 PM	Finding a Technological Edge for your 2D Material - Graphene Single Photon Detection Ethan Arnault (Syracuse)
12:00 - 2:00 PM	Lunch & Poster Session
2:00 - 2:30 PM	AI-Driven First-Principles Modeling of Moiré Superlattices Ting Cao (UW)
2:30 - 3:00 PM	Composite Fermions in Fractional Chern Insulators Di Xiao (UW)
3:00 - 3:30 PM	Coffee Break
3:30 - 4:30 PM	Round Table Discussion PQI leadership
4:30 - 5:00 PM	Poster Awards and Closing

Toward Bosonic Topological Quantum Phases in Semiconductor Moiré Superlattices

Ming Xie

University of Texas, Dallas

Twisted moiré materials have emerged as versatile systems for creating correlated and topological electronic states. At the same time, moiré superlattices consisting of semiconductor layers can also host strongly bound excitons and provide a unique platform for realizing strongly interacting and potentially topological bosonic quantum phases. In this talk, I will first review our recent theoretical proposal showing how interlayer exciton hybridization in a TMD trilayer heterostructure produces nearly flat bosonic Chern bands, realizing a bosonic version of the Kane–Mele model with long-lived, topological excitons. I will then introduce an alternative route based on twisted hBN layers, where electrostatic potentials arising from ferroelectric moiré domains can be used to engineer exciton band structure and topology. Together, these approaches outline emerging pathways toward realizing correlated and topological bosonic quantum matter in moiré materials, including prospects for bosonic fractional Chern states.

Correlated Interlayer Excitons in Atomically Thin van der Waals Semiconductor Heterostructures

Philip Kim

Harvard University

Atomically thin semiconductor heterostructures based on transition metal dichalcogenides (TMDs) are electrically tunable platforms for developing coherent, on-chip optoelectronic devices. In these systems, interlayer excitons (IEs) form out-of-plane dipoles and have long lifetimes because of the spatial separation of electrons and holes. Their bosonic nature and strong dipolar interactions make IEs ideal candidates for studying Bose-Einstein condensation in two-dimensional materials. In this talk, we discuss how to create high densities of controllable excitons, which is an essential step in studying the phase diagram of dipolar exciton gases in atomically thin $\text{MoSe}_2/\text{WSe}_2$ heterostructures. Using electrostatic gating, we modulate the vertical electric fields to create a quasi-1D trap for diffusive IEs, enabling control over the diffusion profile and local IE densities. Electrically modulating the density demonstrates linewidth broadening at the Mott density, independent of the local electrostatic profile. We also demonstrate photon emission from the IEs formed by electrically driven carrier injection by employing these heterostructures as light-emitting diodes across the van der Waals (vdW) interface. As we increase the applied forward bias with balanced electron and hole injection, we observe a threshold in the electroluminescence of interlayer excitons. We further characterize this transition by performing second-order correlation function measurements. We observe strong photon number correlations near the IE emission threshold, indicating correlations among IEs in this regime. We unveil the novel phenomenon of steady-state cooperative electroluminescence from incoherently injected, electrically generated IEs. These results expand our understanding of non-equilibrium phases of matter and could advance the development of optoelectronic devices for future classical and quantum technologies.

Giant Elastoresistance in Magic-Angle Twisted Bilayer Graphene

Matthew Yankowitz

University of Washington, Seattle

Two-dimensional moiré materials host flat electronic bands with substantial Berry curvature, enabling studies of strong correlations, topology, and unconventional superconductivity. In these systems, emergent quantum phases are highly sensitive to lattice geometry at both the atomic and moiré length scales. Twist angle and pressure are now established tuning knobs, whereas strain has largely remained uncontrolled. Using a recently developed technique for applying continuously tunable uniaxial strain down to millikelvin temperatures, we present strain-dependent electrical transport measurements in magic-angle ($\approx 1.1^\circ$) twisted bilayer graphene. The resistivity exhibits a large elastoresponse that depends sensitively on band filling and temperature, with a gauge factor more than two orders of magnitude larger than that of conventional metals. In selected doping regimes the elastoresistance shows Curie–Weiss-like temperature dependence, consistent with a strain-coupled electronic susceptibility. We discuss possible microscopic origins, including nematic fluctuations and enhanced electronic entropy from fluctuating local isospin moments. Our work establishes uniaxial strain as a versatile probe of correlated physics in a moiré material.

Novel Excitonic States by Coupling Many-body Interactions and Spatial Confinement in Moiré Materials

Felipe Jornada

Stanford University

Low-dimensional materials, such as monolayer transition metal dichalcogenides (TMDCs), display various attributes desirable for sensing, transducing, and quantum-information applications. They include, among others, their large optical absorption; coupled valley, spin, and optical-polarization degrees of freedom; presence of strong many-electron interactions; and tunable Coulomb interactions by proximity effects, such as by dielectric engineering. The stacking of layered materials into bilayers and multi-layer artificial materials further increases the phase space of the electronic, optical, and vibrational properties that can be realized, especially as one considers available chemical compositions of layered materials and their possible interfacial twist angles.

In this talk, we will discuss novel excitonic states that can be engineered by judiciously considering the synergistic interactions between many-body and structural effects in such materials. Our results are revealed by *ab initio* calculations based on many-body perturbation theory (MBPT) formalisms, which provide unbiased, parameter-free insights into how to control light-matter interactions in real materials. We will discuss spectroscopic signatures of excitons modulated by moiré patterns, unusual selection rules associated with the coupling of interlayer and intralayer excitons in moiré materials, and how excitons can be localized and acquire qualitatively different selection rules by proximity effects, such as induced by ferroelectric twisted hBN. In particular, the last example illustrates how spatial confinement, many-body interactions, and valley physics can be engineered synergistically, and could form a robust platform to engineer controllable arrays of two-level systems in layered materials.

Fractional quantum anomalous Hall effect and chiral superconductivity in Graphene

Long Ju

Massachusetts Institute of Technology

Fractional quantum Hall effect and superconductivity are two famous examples of emergent quantum phenomena driven by electron topology and correlations. They usually happen in very different materials and experimental settings. In this talk, I will discuss how they can be unified in one crystalline material, known as rhombohedral graphene. More than being hosted by the same materials, the settings challenge the conventional understandings of these phenomena: the fractional quantum Hall effect happens at zero magnetic field, while the superconductor behaves as a spin and orbital magnet. I will also discuss the implications of these phenomena in the context of non-Abelian quasiparticles and topological quantum computation.

Electron solids in atomically thin semiconductors

Feng Wang

University of California Berkeley

Free electrons in a semiconductor are usually described by weakly interacting Fermi liquid that conducts electricity. However, Wigner pointed out 90 years ago that Coulomb interactions become dominant at low electron density and low temperature, resulting in the formation of the electron solid, known as the Wigner crystals. Atomically thin two-dimensional (2D) semiconductors and heterostructures offer a highly tunable platform for exploring the electron solid phases. In this talk, I will describe our effort to directly image the Wigner crystal and its quantum melting behavior in atomically thin semiconductors using scanning tunneling microscopy. I will discuss a wide variety of Wigner solid behaviors that can emerge, including zero-dimensional Wigner molecules, one-dimensional Wigner crystals, and two-dimensional hexagonal and anisotropic Wigner lattices.

Revealing Neutral Collective Modes through Ultrafast Imaging

Chenhao Jin

University of California Santa Barbara

Transport measurements are considered a gold standard for identifying novel states of matter by providing direct and quantitative information on low energy responses. While electrical transport is widely used to investigate charge-carrying (quasi)particles, it remains an experimental challenge to probe emergent collective modes decoupled from the charge sector, which lie at the heart of numerous quantum phenomena. In this talk, I will discuss our recent efforts to investigate space-and-time-resolved transport of neutral collective modes in two-dimensional flatband systems through an ultrafast imaging technique. This non-equilibrium approach overcomes intrinsic limits of steady-state measurements and allows us to simultaneously capture and separate multiple neutral modes from their distinct propagation, such as the phase and amplitude modes of U(1) symmetry-broken phases.

What can ultracold $SU(N)$ Hubbard models teach us about strongly correlated matter?

Kaden Hazzard

Rice University

Experiments with ultracold fermions in optical lattices have probed many features of the $SU(2)$ Hubbard model, including its magnetism and correlations in the doped system. An exciting frontier is experiments on highly symmetric $SU(N)$ Hubbard models, with N as large as 10, using ultracold alkaline-earth atoms. These exhibit rich, exotic magnetism, interesting effects of itineracy, and novel properties upon doping. Experiments on the $SU(N)$ Hubbard model are now deeply in the regime of quantum simulation -- roughly ten times colder than we are able to accurately calculate -- providing an exciting window into paradigmatic models of strong correlations. I will describe our efforts in theory and collaborations with experimentalists to understand the properties of $SU(N)$ Hubbard models and their implications for correlated matter.

Finding a Technological Edge for your 2D Material - Graphene Single Photon Detection

Ethan Arnault

Syracuse University

Two-dimensional materials provide us with a plethora of exciting states of matter, each with their own unique functionalities. However, bridging the gap between fundamental materials science and useful real-world devices represents a multi-disciplinary challenge. In this talk, I will discuss our work on "getting graphene out of the lab" by leveraging its minute heat capacity and broadband optical absorption to develop single photon detectors. Here, I will show the full-stack development from our proof-of-concept theoretical work on heat propagation in graphene, to materials and device design through full implementation of a graphene single photon detector. We demonstrate single photon detection of NIR 1550 nm photons with noise-equivalent-powers comparable to state-of-the-art SNSPDs. Our work demonstrates that highly sensitive single photon detection using the thermal properties of graphene is possible, opening avenues for exploration of exoplanets, maximal extraction of quantum information from a photon, and hopes for single microwave photon detection.

AI-Driven First-Principles Modeling of Moiré Superlattices

Ting Cao

University of Washington, Seattle

Moiré superlattices in two-dimensional materials offer a rich platform for analog quantum simulation, where structural reconstruction, band topology, and layer degrees of freedom intertwine. However, modeling these systems at scale—across twist angles, layer numbers, and material combinations—requires approaches beyond conventional first-principles methods.

In this talk, I present a physics-informed, AI-driven framework for understanding and designing moiré quantum materials. We show how machine-learning force fields trained on ab initio data can capture emergent features such as layerwise stratification in twisted multilayer moiré materials including MoTe_2 . This effect leads to coexisting triangular and honeycomb lattice motifs and Chern band reordering tunable by gating and doping. To generalize this approach, we have further developed a foundation model framework, allowing for large-scale screening of moiré systems in the high-dimensional feature space.

Composite Fermions in Fractional Chern Insulators

Di Xiao

University of Washington, Seattle

The discovery of fractional Chern insulators in moiré superlattices has opened a new frontier for strongly correlated topological phases. I will present a composite-fermion theory that ties Bloch-band geometry directly to many-body topology. The resulting composite-fermion Hofstadter description provides accurate phase diagrams and wavefunction benchmarks, and clarifies the geometric conditions that favor FCIs in systems such as twisted MoTe_2 .