Department of Materials Science and Engineering Seminar Series 2026

THz driven 2D materials: from interaction effects to out-of-equilibrium transport

Mikhail Kravtsov

Date and time: Friday, 27th November 2026, 9:30 AM

Venue: S9, Level 9, Conference Room

Abstract

Two-dimensional (2D) materials give access to transport regimes beyond the picture of independent electrons: hydrodynamic flow governed by electron-electron collisions, non-perturbative electron-hole pair creation under a strong DC bias, and flat electronic bands whose ground state is shaped by interactions. In this thesis, terahertz (THz) radiation is used to probe these regimes beyond conventional transport measurements and to turn them into new optoelectronic functionality.

First, graphene point contacts are brought into the regime where their conductance exceeds the ballistic limit. Sub-THz radiation selectively heats the electrons, lowers their viscosity and produces an anomalous negative photoresistance in a metal, which enables superballistic electron thermometry. Under a strong DC bias, where the conductance is governed by Schwinger-like pair creation, the photoresistance turns positive, an effect discussed within the dynamically assisted Schwinger mechanism.

Second, a few-layer black phosphorus tunnel field-effect transistor with an electrostatically defined Esaki junction is biased into the bistable region of its negative differential conductance. THz radiation switches the device between its two stable current states, yielding a responsivity above 4 A/W.

Third, polarization-resolved THz photocurrents in magic-angle twisted bilayer graphene reveal a linear photogalvanic response consistent with Hartree-renormalized shift currents. At charge neutrality, the photocurrent acquires a component odd in magnetic field, attributed to the large valley-contrasting orbital magnetic moment of the $\nu = 0$ state.

Together, these results establish the THz photoresponse as a probe of interacting and out-of-equilibrium electron systems that is inaccessible to conventional DC measurements.

Biography

Mikhail Kravtsov is a PhD candidate at the National University of Singapore, supervised by Prof. Denis Bandurin at the Institute for Functional Intelligent Materials (IFIM). His research focuses on terahertz optoelectronics and out-of-equilibrium transport in 2D materials: graphene, black phosphorus and magic-angle twisted bilayer graphene. His work on viscous terahertz photoconductivity of hydrodynamic electrons in graphene was published in Nature Nanotechnology (2025), and he has co-authored further studies of terahertz photoresponse in twisted bilayer graphene in Nature Communications.

Please join us!

HOST: Assoc Prof Andreeva-Baeumler, Daria