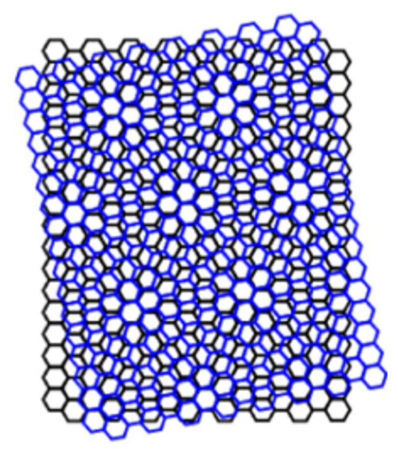
Physics Department, Condensed Matter Experiment

Bockrath Laboratory: Quantum Transport in Nanostructured Materials

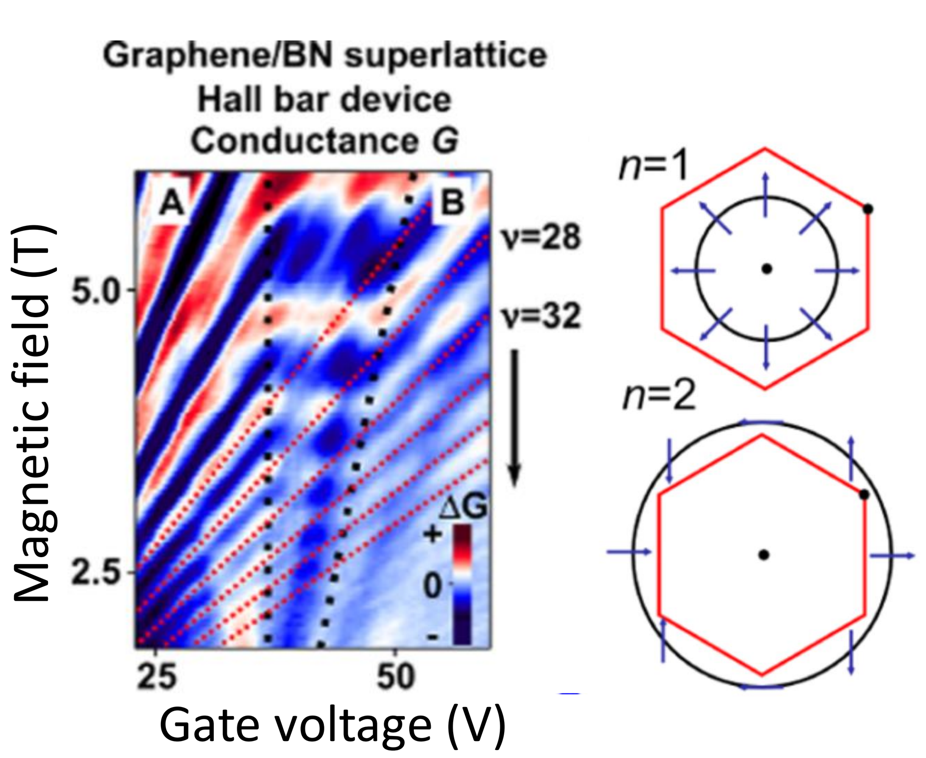
Rui Lyu, Zachary Tuchfeld, Adrian Nosek, Dongying Wang, Nicholas Mazzucca, Sean Nelson

Twistronics: Moiré superlattices

The ability in experiments to control the relative twist angle between successive layers in two-dimensional (2D) materials offers a new approach to manipulating their electronic properties; we refer to this approach as “twistronics.” We are applying this approach to fabricate magic angle graphene and beyond.



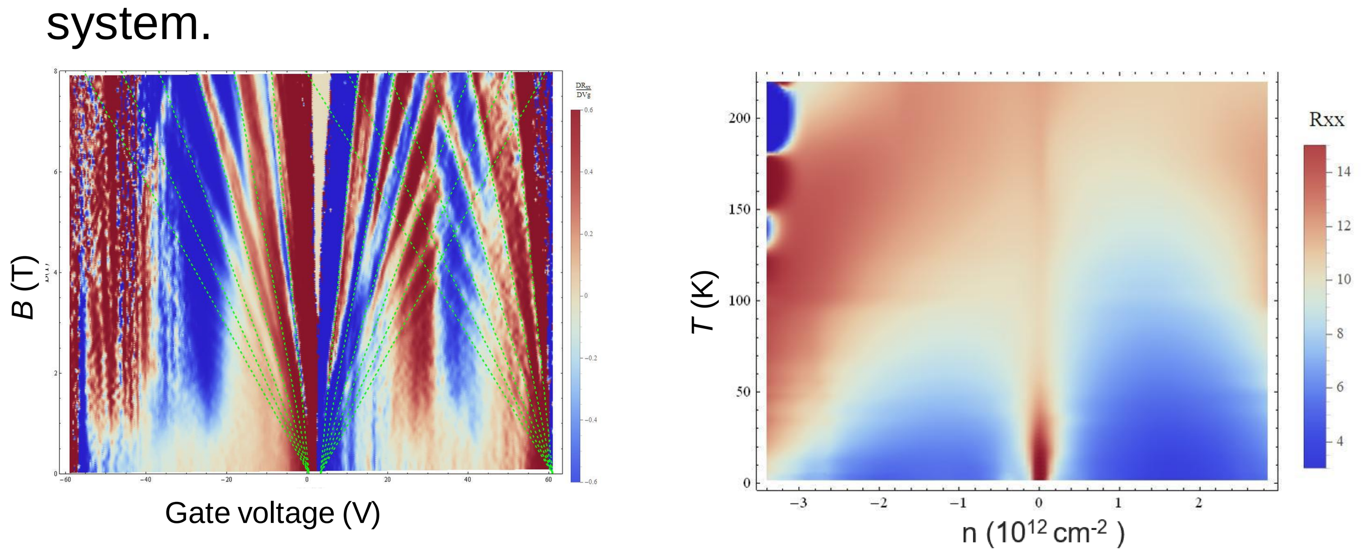
Topological Winding Number Change and Broken Inversion Symmetry in a Hofstadter’s Butterfly (Peng Wang)



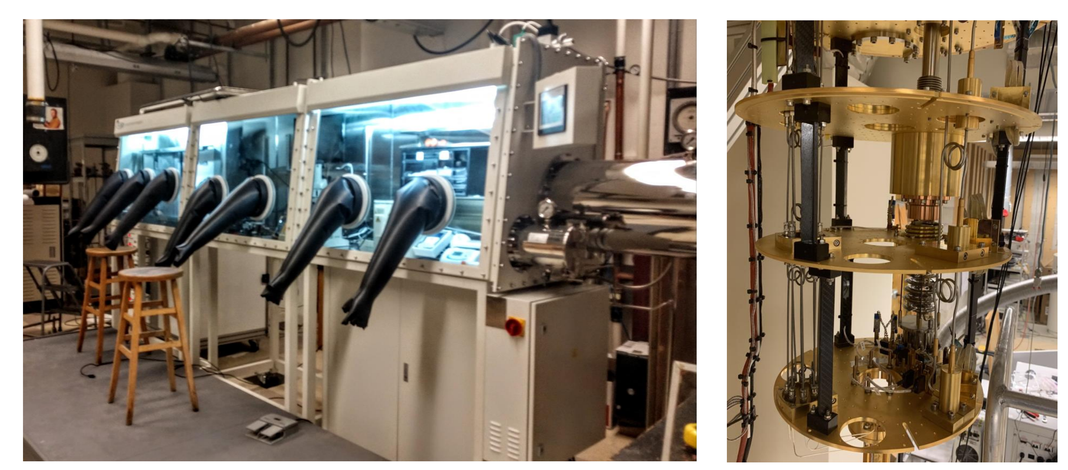
In nearly aligned graphene hexagonal Boron Nitride heterostructures, the lattice and orientation mismatch produce a moiré superlattice potential, yielding secondary Dirac points in graphene’s electronic spectrum, and under a magnetic field, a Hofstadter butterfly-like energy spectrum.

Twisted-Bilayer Graphene Devices Fabricated with Polymer-Free Graphene (Rui Lv/Zachary Tuchfeld)

The emergence of flat bands and correlated behavior such as superconductivity in “magic angle” twisted bilayer graphene (tBLG) has sparked tremendous interest, though many aspects of the system are under intense debate. Here we employed a polymer-free method to prepare graphene for the stacks so that we are better able to explore the intrinsic properties of this system.

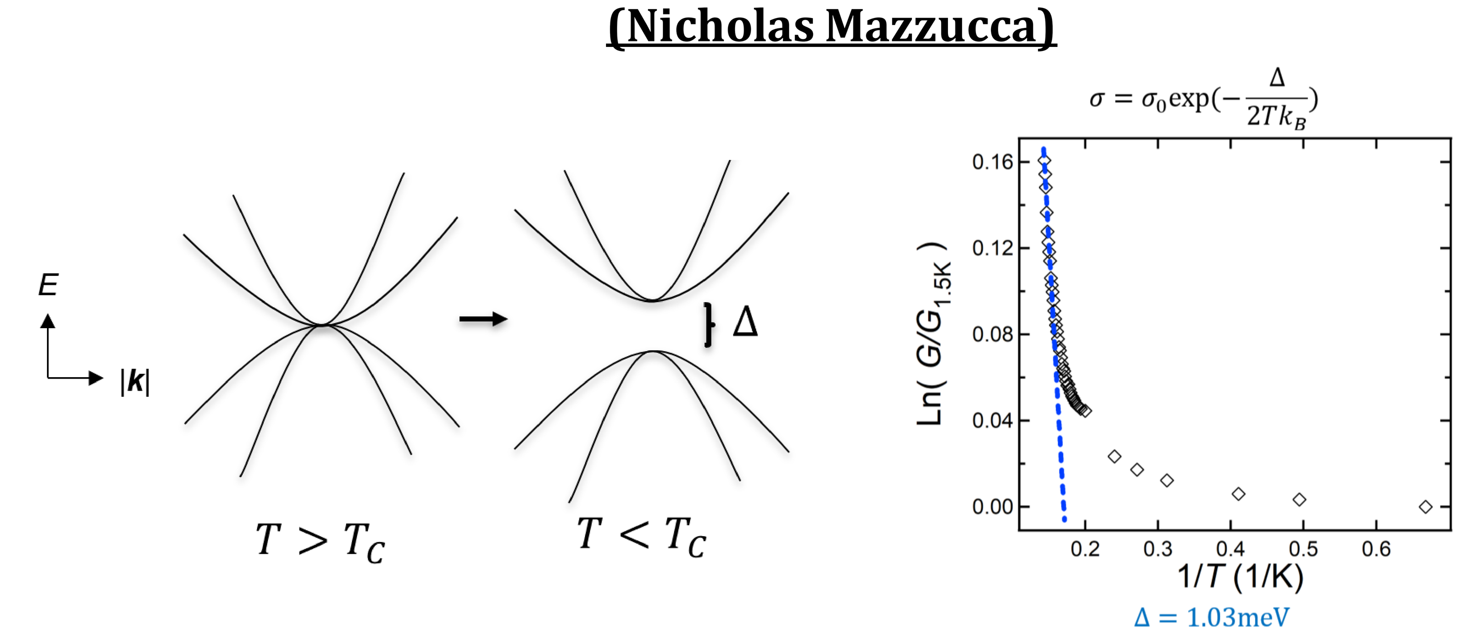


Novel physics in 2D materials and their heterostructures



Laboratory equipment for experiments. Glove box to handle air-sensitive materials (left), dilution refrigerator with base temperature down to 15 mK (right).

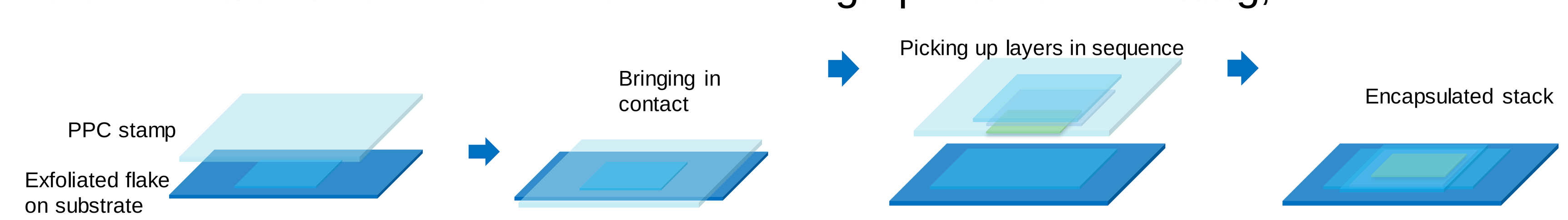
Low Temperature Insulating State in hBN-Encapsulated Multilayer Graphene (Nicholas Mazzucca)

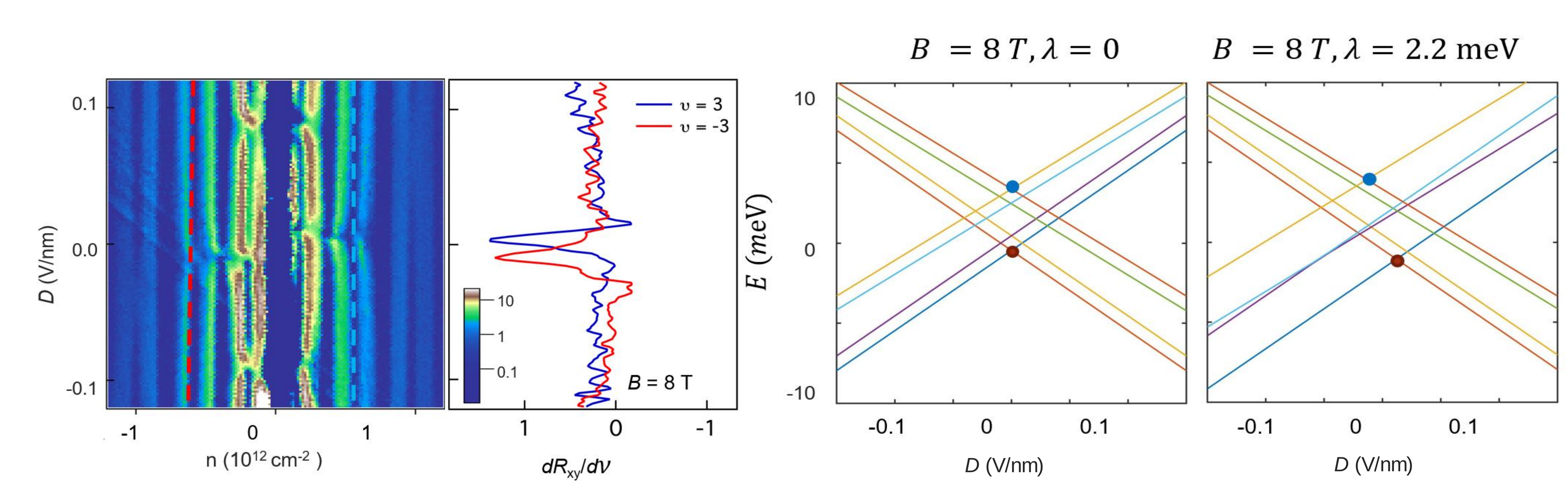


Multilayer graphene can exhibit spontaneous symmetry breaking at low Ts with the associated opening of a gap. Here we study evidence of this phenomena in hBN-encapsulated multilayer graphene.

Strong Spin-Orbit Interaction in Ultra Clean Graphene/ Transition-Metal Dichalcogenide Heterostructures (Dongying Wang)

The strong spin-orbit coupling and broken inversion symmetry in 2H transition metal dichalcogenide (TMD) monolayers leads to coupled spin and valley degrees of freedom. Here we induce this SOC into graphene via stacking,

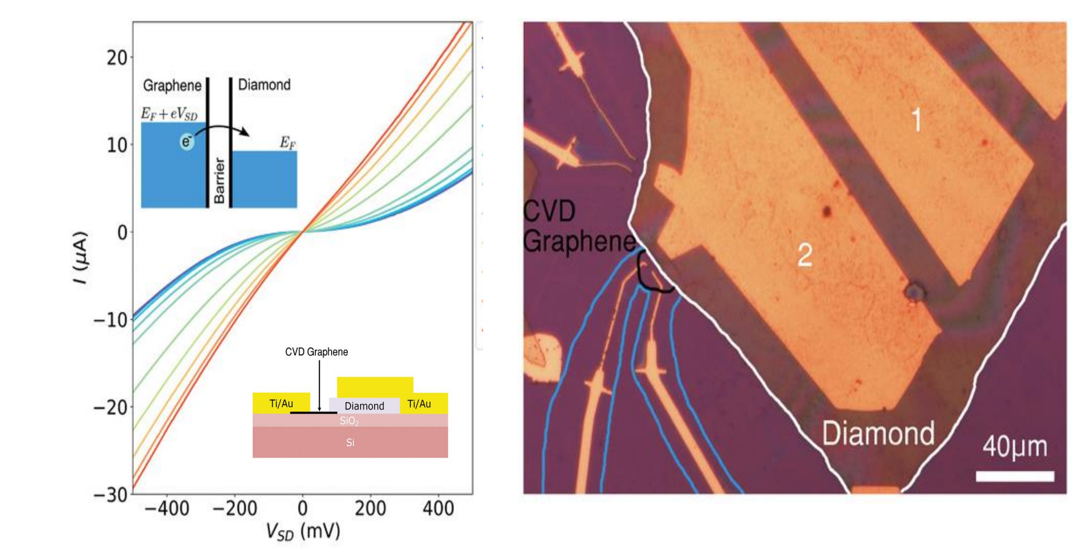




Multifunctional devices based on beyond-graphene materials

Boron-Doped Diamond-on-Graphene Heterostructures (Adrian Nosek)

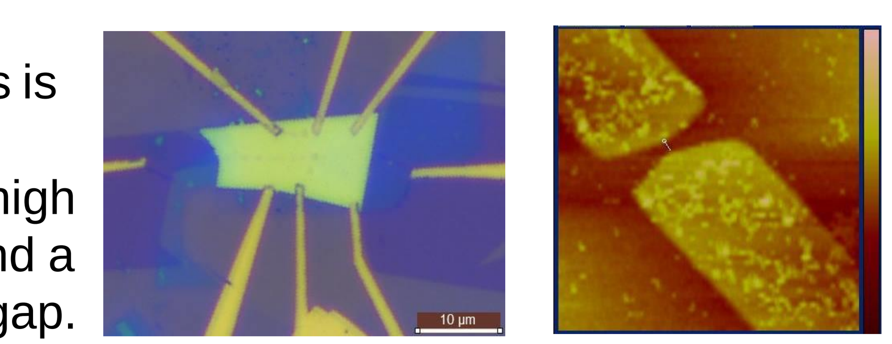
We developed a prototypical diamond nanosheet–graphene field effect transistor-like (DNGfet) device and studied its electronic transport properties as a function of temperature.



These demonstrate the first step towards a diamond-based barrister device capable of operating at high temperatures.

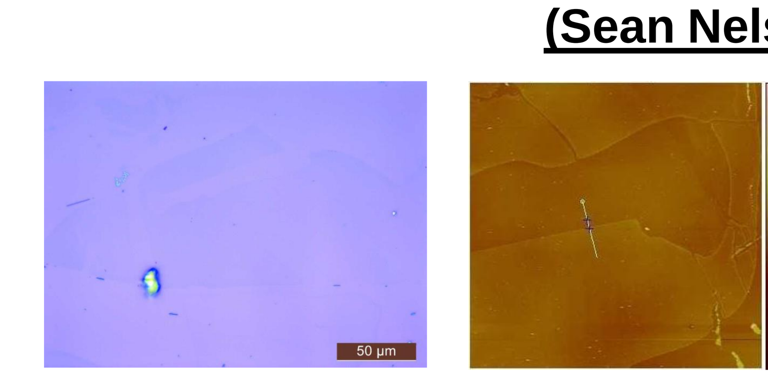
Gate-Defined Quantum Confinement in Few-Layer Black Phosphorus Transistor (Zachary Tuchfeld)

Black phosphorus is a two-dimensional semiconductor with high electronic mobility and a tunable, direct bandgap.



Quantum confinement through the combination of a split gate and a global backgate allows for the conduction of few-layered black phosphorus devices to be tuned with increased precision.

Large Scale Exfoliation of Single Layer Fe_3GeTe_2 (FGT) (Sean Nelson)



FGT is a two-dimensional magnet up to room temperature.

The magnetic properties of FGT highlights its potential for integration into van der Waals magnetic heterostructures, paving the way for spintronics research and applications based on these devices.

The Ohio State University