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Strongly correlated electronic phases in twisted and stretched bilayer semiconductor nanostructures

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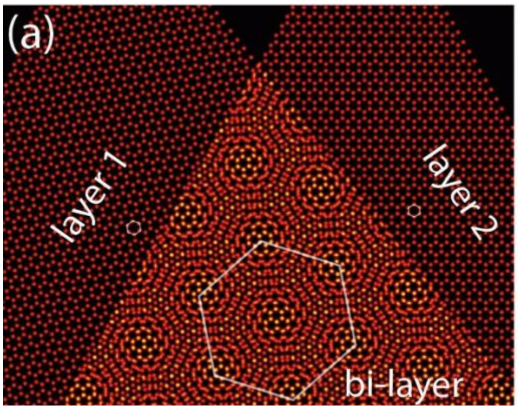
Strongly interacting electrons give rise to a large variety of physical phenomena, ranging from high-temperature superconductivity to ferromagnetic phases and exotic quasi-particle excitations [1]. Recent research on graphene shows that **combining two atomic layers into an artificial crystal can result in highly tunable model systems for strongly correlated electrons**. As shown schematically in the figure, if one combines two layers of the same (or slightly different) hexagonal 2D lattices on top of each other, with a **twist angle** between the two crystal orientations, the resulting potential landscape forms a **moiré pattern**, or a **superlattice**, with a much larger spatial period than the original crystals. At low electron densities, single carriers can occupy moiré lattice sites achieving a large inter-particle distances while being only weakly confined, such that electron-electron interactions can become dominant. In bilayer graphene with a twist angle in a very narrow range around the “magic angle” of 1.1°, **strongly correlated phases** were found, for example a **Mott insulator** [2], or **intrinsic superconductivity** [3]. We also demonstrated “super superlattices” when combining three different layers [4]. However, major drawbacks of graphene are the lack of strong spin-orbit interaction and of an energy gap, and the large degeneracy in bilayer graphene.



Superlattice moié pattern that develops when two hexagonal layers are superimposed.

In this project, we will **stack and twist monolayers of semiconducting transition metal dichalcogenides** (TMDCs) **to investigate strongly correlated emergent electron phases** using our unique experimental facilities. TMDCs exhibit a large range of electrically tunable optical and electronic properties [5], a large effective mass, and a strong intrinsic **spin-orbit interaction**, possibly resulting in many complex correlated phases [6]. Importantly, various **magnetic phases** are expected [7].
We will fabricate twisted TMDC bilayer electronic devices and establish electrical contacts based on our **vertical interconnect access (VIA) contacts** [8]. These devices we will characterize at cryogenic temperatures by *simultaneous* transport, Raman spectroscopy, and photoluminescence experiments in magnetic fields up to 8T. In addition, we will investigate suitable devices using scanning **NV center spectroscopy** [9] and apply **uni-axial strain** [10, 11] to investigate the resulting effects on the TMDC bandstructure.

References:
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