Turning new “knobs” on Hamiltonians of 2D materials

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We demonstrate new ways to use electric fields, mechanical strain, and twist-angle control to manipulate the properties of 2D materials and their heterostructures.

First, we demonstrate ultra-strong electric fields in 2D materials via "molecular gating" — sandwiching a 2D material between donor and acceptor molecular layers whose charge transfer generates fields exceeding 4 V/nm, the highest measured in a solid-state device. We show that these fields close the bandgap of bilayer semiconductors, driving a semiconductor-to-metal transition, lifting excitonic degeneracies, bringing distinct excitons into resonance, and giving rise to new excitonic states.

Second, we demonstrate in situ strain engineering of transition-metal dichalcogenides at cryogenic temperatures, including controlled uniaxial, biaxial, and spatially non-uniform strain distributions. Strain tunes transport, valley properties, and excitonic lifetimes and couplings. Using uniform strain, we realize a new excitonic state arising from the hybridization of long-lived dark free excitons with strongly coupled localized excitons — combining the advantages of both and making it uniquely suited for quantum information storage.

Finally, we describe a variant of the Quantum Twist Microscope that enables in-situ twist-angle control with simultaneous optical measurements. Using this platform, we demonstrate on-demand control of chiral polaritons in heterostructures of the anisotropic magnet CrSBr.

References:

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