17

Formation and stability of 2D Wigner crystal states

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Abstract

The strong Coulomb interaction in transition metal dichalcogenides (TMDs) gives rise to rich exciton physics and facilitates the formation of charge-ordered states including conventional and generalized Wigner crystals. Here, we use a microscopic and material-specific density matrix formalism to predict that Wigner crystal states could be experimentally observed via their THz spectrum, which exhibits a characteristic sequence of internal optical transitions. In addition, by combining a phonon mode expansion with the Lindemann criterion, we investigate the quantum and thermal stability of generalized Wigner crystal states in TMD heterostructures. We find that the moiré potential acts as a harmonic trap, flattening the energy dispersion of Wigner phonon excitations and resulting in up to an order of magnitude larger melting temperatures for generalized Wigner crystals compared to conventional 2D Wigner crystals. The gained microscopic insights on the formation and stability of charge-ordered states could be combined with the rich exciton physics of TMDs and used to also study excitonic phenomena including exciton propagation in the vicinity of Wigner crystal states.