Nano-optical probing of quantum geometry and correlations in moiré graphene systems

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Since the initial experimental observation of correlated insulators and superconductivity in the flat Dirac bands of magic angle twisted bilayer graphene, a search for the microscopic description that explains its strong electronic interactions has begun. We discuss several infrared and terahertz optoelectronics probes using near-field photocurrent nanoscopy, and terahertz photocurrent microscopy.

We use a cryogenic scanning near-field optical microscope with an oscillating atomic force microscopy (AFM) tip irradiated by the infrared photons to create a nanoscopic hot spot in the planar samples, which generates a photocurrent that we probe globally. We observe a breakdown of the non-interacting Mott formalism in local photothermoelectric measurements in the flat electronic bands of twisted symmetric trilayer graphene (TSTG). We explain these observations using the interacting topological heavy-fermion model.

Second, we report on polarization-resolved photocurrent measurements to probe magic-angle twisted bilayer graphene, leveraging its sensitivity to the Berry connection that encompasses quantum "textures" of electron wavefunctions. Using terahertz light resonant with optical transitions of its flat bands, we observe bulk photocurrents driven by broken symmetries and reveal the interplay between electron interactions and quantum geometry. The large and tunable terahertz response intrinsic to flat-band systems offers direct insights into the quantum geometry of interacting electrons and paves the way for innovative terahertz quantum technologies.

References

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Figures