

Engineering lattice potentials and electron localisation in double moire systems

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The localisation of electrons in a lattice potential is an intrinsically quantum mechanical phenomenon and often associated with remarkable physical properties of solids involving electron spins, electric polarizations and topological effects. In particular, even a small amount of distortion of the lattice potential can localise otherwise delocalised quantum states in low-dimensional electron systems, dramatically influencing the properties of the systems and charge transport behaviours. Study of such electron localisation induced by an aperiodic lattice potential remains exceptionally challenging in solid state systems since extrinsic disorders can trivially trap electrons in potential minima near disorders, obscuring the underlying quantum mechanical origin of localisation phenomena. Van der Waals heterostructures can provide an alternative route for explorations of the phenomena via the emergence of superlattice potentials, generated by rotating and stacking individual layers, unattainable in the individual constituent materials.

In this talk, I will present experimental results of electron localisation in helical trilayer graphene, where the interplay of two moire patterns give rise to a moire-of-moire superlattice with distinct regions of moire-periodic and moire-aperiodic potentials. The data reveal the presence of double moire-induced bands and high-order Brown-zak oscillations, which are direct reflections of the periodic region with two constituent moire patterns, and a superimposed anomalous hysteretic signal attributable to the aperiodic region. The data strongly suggest that electron wave functions are partially localised driven by the loss of a periodic lattice potential. This work can provide insight into the effects of spatially inhomogeneous lattice potentials on the low-dimensional electronic states and introduces a promising approach to control electron localisation for practical applications in solid-state devices. If time permits, I will also discuss a scanning-probe approach to resolve the spatial pattern of electronic phases intertwined with the moire-of-moire lattice.