Tata Institute of Fundamental Research

Survey No. 36/P, Gopanpally Village, Serilingampally, Ranga Reddy Dist., Hyderabad – 500 046

Seminar

SQUID-on-tip imaging of topological currents in magic-angle graphene

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The emergence of flat bands in twisted bilayer graphene leads to strongly correlated and superconducting phases. Charge carriers come in eight flavours described by a combination of their spin, valley, and sublattice polarizations. When the inversion and time reversal symmetries are broken by the substrate or by strong interactions, the degeneracy of the flavours can be lifted and their corresponding bands can be filled sequentially. Due to their non-trivial band topology and Berry curvature, each of the bands is classified by a topological Chern number, leading to the quantum anomalous Hall and Chern insulator states.

A nanoscale SQUID fabricated on the apex of a quartz pipette (a 'SQUID-on-tip') can be used as an ultra-sensitive scanning probe to measure local magnetic fields. Utilising such a scanning SQUID-on-tip, I will describe two experiments for imaging equilibrium currents and equilibrium orbital magnetisation in magic angle graphene.

Using a scanning SQUID-on-tip, we image the equilibrium currents in the quantum Hall regime and obtain tomographic imaging of Landau levels and map their local evolution with carrier density. This renders a nanoscale high precision map of the local twist-angle and reveals substantial twist-angle gradients and a network of jumps. We show that the twist-angle gradients generate large gate-tunable in-plane electric fields, unscreened even in the metallic regions, which drastically alter the Quantum Hall State by forming edge channels in the bulk of the samples. The correlated states are found to be particularly fragile with respect to twist-angle disorder. We establish the twist-angle disorder as a fundamentally new kind of disorder, which alters the local band structure and may significantly affect the correlated and superconducting states.

In a separate experiment, we probe a twisted bilayer graphene device that exhibits the anomalous Hall Effect. Using a SQUID-on-tip, we image the nanoscale Berry-curvature-induced equilibrium orbital magnetism and show that the Chern number C, rather than being a global topological invariant, becomes position dependent, governing the polarity of the orbital magnetism. We detect the two constituent components of the orbital magnetisation associated with the drift and the self-rotation of the electronic wave packets. At filling factor $\nu=1$, we observe local zero-field valley-polarized Chern insulators forming a mosaic of microscopic patches with $C=-1$, 0, or 1. Upon further filling, we find a first-order phase transition due to recondensation of electrons from valley K to K', which leads to irreversible flips of the local Chern number and the magnetisation, and the formation of valley domain walls giving rise to a hysteretic anomalous Hall resistance. The findings shed new light on the structure and dynamics of topological phases and call for exploration of the controllable formation of flavour domain walls and their utilisation in twistronic devices.

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4:00 PM (Tea / Coffee 03.45 PM)

Auditorium, TIFR-H