PhD THESIS DEFENSE: Near-field photocurrent in correlated 2D moire materials

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12:00
ICFO Auditorium

Since the discovery of graphene, two-dimensional (2D) materials have garnered significant attention from the condensed matter physics community owing to their potential to engineer new physical, optical, and mechanical properties. The 2D material class now includes insulators (hexagonal boron nitride, hBN), semiconductors (transition metal dichalcogenides, TMDs), superconductors (NbSe2), topological insulators (Bi2Te3), and ferromagnets (CrI3). Beyond their inherent properties, layered materials allow for new characteristics through vertical stacking. Recent developments have led to the discovery of moire materials, in which electronic properties are significantly altered by twisting adjacent 2D layers.
The discovery of superconductivity in magic-angle twisted bilayer graphene (MATBG) marked a milestone in moire physics, initiating a rapidly growing field. The resulting phase diagrams

of other high-Tc superconductors, MATBG, serve as a platform for exploring highly tunable strongly correlated states. At a twist angle of approximately 1.1°, the "magic angle,i¿½ MA BG shows significant band flattening near the Dirac points, reducing the Fermi velocity nd making the kinetic energy smaller than the repulsive Coulomb interactions. This results in superconductivity and various emergent phases dominated by many-body physics, includ ng correlated insulators, orbital magnetism, nematic orders, and topological stat s. Moire materials with large superlattice unit cells facilitate the exploration of stron ly correlated phenomena at low charge carrier densities. Local back-gate electrodes ena le capacitive tuning between strongly correlated states in-situ, a unique feature not available in other high-Tc superconductors. Advances in scanning probe techniques have allo ed researchers to determine local properties at the sub-nanometer scale. Scattering-t pe scanning near-field optical microscopy (s-SNOM) is particularly suited for exploring MA BG because it can measure scattering and photovoltage signals at the nanometer scale wh le simultaneously probing mesoscopic electron transpor
. Utilizing a groundbreaking cryo-near-field nanoscopy method, we will conduct s-NOM measurements at cryogenic temperatures (as low as 8 K) to assess the optical and photovoltage near-field responses. This approach employs energies in the mid-infrared (IR) and terahertz (THz) ranges, which align with the anticipated optical transition energies in the band structures of these materi
ls. The primary objectives of this thesis are to ascertain the pertinent optical and thermoelec ric coefficients in twisted moire materials, evaluate the impact of inhomogeneities thr ugh gate-tuned near-field photovoltage and optical measurements, visualize correl ted phenomena and broken symmetry states, and comprehend the nature of dephased signal in various measurements. This dissertation seeks to highlight crucial advancements in qua tum phases, quantum nano-optoelectronics, and thermoelectricity, while supporting interes in unresolved questions, such as the characteristics of low-temperature correlated sta es. Additionally, it outlines future objectives for near- and far-field photovoltage experime

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