

Felicidades a la nueva graduada de doctorado del ICFO

La Dra. Ipsita Das se ha graduado con una tesis titulada ?Investigation of the Interaction Driven Quantum Phases in Magic-Angle Twisted Bilayer Graphene'

May 24, 2023

Felicitamos la Dra. Ipsita Das que hoy ha defendido su tesis en el auditorio del ICFO.
La Dra. Das obtuvo su master Fisica por la Universidad de Jadavpur, en India. Se unio como estudiante de doctorado en el grupo de investigacion de Low-dimensional quantum materials en ICFO dirigido por el profesor Dmitri Efetov. La tesis de la Dra. Das titulada ?Investigation of the Interaction Driven Quantum Phases in Magic-Angle Twisted Bilayer Graphene' fue supervisada por el profesor Dmitri Efetov.

RESUMEN:

The discovery of two dimensional materials opened a unique pathway to study the electronic

properties of quantum materials which are otherwise absent in bulk systems. Soon after the discovery of graphene (2004), a plethora of 2D materials were found with various diverse properties such as, metals, insulators, semiconductors, superconductors, magnets etc. These materials can be assembled by using the van der Waals (vdW) force, which greatly extends the possibilities of studying new phenomena. Initially vdW heterostructures have been made by vertically stacking different layers. However, twist angle plays an interesting tuning knob to engineer the electronic properties of the 2D heterostructures. Following long standing theoretical predictions, people have observed exotic quantum phenomena in twisted bilayer graphene in 2018.

In this thesis, we have studied the electronic properties of magic angle twisted bilayer graphene (MATBG), which consists of two graphene layers rotated by an angle ? = 1.1°. It ha been experimentally shown that MATBG possesses flat electronic bands in the low energ scale, which hosts multiple correlated phenomena such as correlated insulators superconductivity, magnetism etc.

We studied different phases of MATBG in the presence of a magnetic field to reveal the zero-field ground state of the system. In the presence of a small magnetic field (B

We have also studied the evolution of the phase space of MATBG in high magnetic field and explored the Hofstadter spectrum. Due to the large moire unit cell area, MATBG reaches one full flux quantum (?0) per moire unit cell close to 30 T. We studied a detailed magneto-transport behaviour of MATBG upto B = 31 T. At ?0, reentrant correlated insulators are observed at ? = +2, +3. Interaction driven Fermi surface reconstruction is also observed at other fillings of the band which are identified by the emergence of a new set of Landau levels (LLs).

We further studied the higher energy dispersive bands in the presence of a magnetic field. The analysis of the LL crossings in the Rashba-like dispersive bands enables a parameter free comparison to a newly derived magic series of level crossings in a magnetic field and provides constraints on the parameters of the Bistritzer-MacDonald Hamiltonian. For the first time, this allows us to experimentally verify the band structure of MATBG.

In the next section of this thesis, we have studied the effect of Coulomb screening on the ground state of the quantum phases such as correlated insulator and superconductor. The coexistence of these two states prompts intriguing questions about their relationships. We have directly tuned the electronic correlations by changing the separation between the graphene and a metallic screening layer. Correlated insulators are suppressed when the separations are smaller than the typical Wannier orbital size (~ 15 nm) and also in devices with twist angles slightly away from magic angle (? = 1.1° ± 0.05°). Upon extinction of he insulating orders, the vacated phase space is taken over by the superconductors. Finally, we study the temperature depe0ndence of the resistance and unveil a strange metal phase u to a very low temperature T = 40 mK.

We thus have experimentally demonstrated the effect of several external parameters

(magnetic field, screening, temperature etc.) on the ground state of MATBG and how they alter the microscopic mechanism of different correlated phenomena in the system.

Comite de Tesis:

Prof. Dr. Georgia Papadakis, ICFO

Prof. Dr. Klaus Ensslin, ETH Zurich

Dr. Milan P. Allan, Leiden Institute of Physics