



PhD THESIS DEFENSE: Optoelectronic studies of correlated 2d materials

RAFAEL LUQUE MERINO

September 02, 2024

11:00

ICFO Auditorium and Online (Teams)

The study of strongly-correlated matter in two-dimensional materials has emerged as an exciting prospect for the exploration of condensed matter physics, as well as the design of novel device platforms. Moire engineering, where the 2D layers feature an interlayer twist angle of 1.1° between the graphene layers generates a moire superlattice potential. A flat electronic band appears at the Fermi level, in which a variety of interaction-driven many-body quantum phases can emerge. Another avenue to study strong electronic correlations in two dimensions is the exfoliation of intrinsically correlated bulk crystals into the atomic limit

The optoelectronics study of strongly-correlated systems in 2D heterostructures stands out as a powerful probe, as it can provide insight into both the electronic transport properties and the fundamental light-matter interaction in these systems. In this thesis, we study tw

strongly correlated 2D materials: MATBG and the cuprate superconductor Bi₂Sr₂CaCu₂O_{8-δ} (BSCCO-2212). We leverage different optoelectronic techniques to study the fundamental properties of the correlated electrons in the MATBG flat bands and the potential of two-dimensional BSCCO-2212 layers for applications in quantum sensing.

First, we investigate the electronic spectrum of the MATBG flat bands through the study of their thermoelectric transport. We use an optical excitation to induce a thermal gradient which in turn generates a charge current. We report anomalous thermoelectricity which provides strong evidence for the coexistence of localized and de-localized electronic states in the strongly-interacting flat bands.

Next, we study the dynamics of hot carrier cooling in the MATBG flat bands using frequency-resolved photomixing technique. Strikingly, we find that hot carriers can efficiently relax their energy down to cryogenic temperatures; in contrast to the case of bilayer graphene samples. We propose a novel Umklapp electron-photon scattering mechanism for hot carriers in MATBG, enabled by the moiré superlattice potential.

Lastly, we explore the development of superconducting photodetectors with high-T_c based on ultrathin BSCCO-2212 flakes. We fabricate high quality samples that exhibit remarkable performance at telecom wavelengths. We observe fast and sensitive bolometric response at T = 77 K in free-space and waveguide-coupled devices, as well as single-photon sensitivity at T = 20 K through a non-bolometric, avalanche detection mechanism.

Monday September 02, 11:00 h. ICFO Auditorium and Online (Teams)

Thesis Director: Prof. Dr. Dmitri K. Efetov

Hosted by: Prof. Dr. Dmitri K. Efetov