MASTER PHYSIQUE ET APPLICATIONS

Master 2 Dispositifs Quantiques

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Internship offer 2025/2026

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Non-Abelian states at zero magnetic field in next-generation moiré $MoTe_2$ heterostructures (TOPOMAX)

Scientific project: The recent discovery of states hosting the fractional quantum Hall effect at zero magnetic field in a lattice system – zero field fractional Chern insulators (FCIs) – has caused tremendous excitement within the condensed matter physics community. These zero-field FCIs were first observed in a molybdenum ditelluride ($MoTe_2$) moiré superlattice. The states, analogs of the Jain sequence FQH states, host Abelian anyon excitations. However, for certain twist angles, moiré $MoTe_2$ is also predicted to host states with non-Abelian anyons - the main requirement for achieving scalable topologically protected quantum computation. These non-Abelian states have yet to be observed. Perhaps the largest difficulty in moiré systems is sample quality and twist angle control. Contact resistance, strain, twist angle inhomogeneity, bubbles, and polymer residue can preclude the formation and observation of delicate non-Abelian FCIs. The main goal of TOPOMAX is to investigate, using optical and transport measurements, the existence of non-Abelian states at zero magnetic field in ultra-high quality twisted $MoTe_2$ heterostructures. To achieve this, we will implement cutting-edge fabrication techniques that enable unprecedented twist angle control and homogeneity while allowing for devices compatible with optical and transport measurements. In particular, the bent bilayer nanomanipulator technique will enable systematic investigation of zero-field FCIs as a continuous function of twist angle. Determining whether the moiré $MoTe_2$ system hosts non-Abelian states would lay the groundwork for study of zero-field non-Abelian anyons – and perhaps, one day, topologically protected qubits.

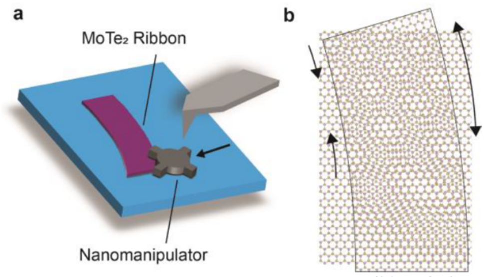

Fig. 1| Bent bilayer technique. a, $MoTe_2$ ribbon is bent with a nanomanipulator pushed by an AFM tip. **b,** Local twist angle varies in the longitudinal direction. Moving the ~1μm beamspot enables optical measurements as a continuous function of twist angle in a single device. Local heterostrain varies from compressive to tensile in the transverse direction, and is small along the center axis.

Methods and techniques: Atomic force microscopy, van der Waals heterostructure fabrication via dry transfer, electron beam lithography, reactive ion etching, e-beam metal evaporation, cryogenic optical spectroscopy (photoluminescence), millikelvin charge transport measurements.

Possibility to go on with a PhD ?

Envisaged fellowship ?