PhD position in Condensed Matter physics

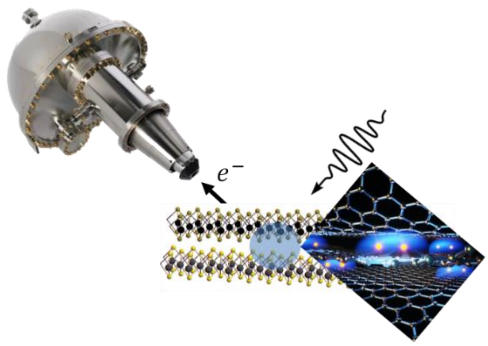
Institut de Physique de Rennes (IPR) UMR CNRS 6251

Starting date Oct. 2023

# Moiré superlattices in transition-metal dichalcogenides heterostructures

**Funding agency :** Agence Nationale de la Recherche (ANR)

**PhD supervisors:** Thomas Jaouen (CNRS Researcher) / Jean-Christophe Le Breton (CNRS Researcher)/ Philippe Schieffer (Professor)




**General Scope**: The history of condensed matter physics demonstrates the ubiquity of unconventional electronic states in the emergence of remarkable new properties such as giant magnetoresistance, high-critical temperature superconductivity, multiferroicity, or thermoelectricity. While these fascinating properties of matter naturally suggest answers to current societal issues related to electronics, energy or the environment, their understanding remains a real challenge for the scientific community due to the intrinsic complexity of the many-body problem at work in correlated materials. As a matter of fact, correlated electron systems often support competing electronic phases very sensitive to so-called control parameters such as temperature, doping, pressure, strain, electric and magnetic fields or light pulses. Moreover, the low dimensionality which enhance proximity, surface and interfaces effects, an important spin-orbit coupling or a particular crystalline symmetry can also lead to emergent electronic phases even in the absence of electronic correlations.

The recent progress in controlling the stacking of atomic sheets in van der Waals heterostructures has opened up new avenues for manipulating electronic properties by moiré superlattices, i.e. by long-wavelength periodic potential landscapes. In two-dimensional (2D) materials, a moiré superlattice can be formed by vertically stacking two layered materials with a twist angle and/or a difference in lattice constant that generally modifies the electronic band structure. In twisted stacks, it has been shown that at so-called “magic angle twist”, low-energy flat subbands can appear, in which electron interactions become the dominant energy scale and lead to emergent electronic phases, such as correlated insulators, superconductors, magnetism and topological electronic structures. Until recently, correlated phases emerging from isolated flat bands were only realized in twisted graphene-based stacking. Their discovery in twisted transition metal dichalcogenides (TMDs) homo- and hetero-bilayers offers the additional fascinating perspective of a solid-state platform in which plenty of correlated states may be realized. Although these last two years studies on semiconductor-based TMD moiré systems have revealed novel phenomena driven by strong Coulomb interactions such as the Mott insulating state, Wigner crystal states, stripe phases, antiferromagnetism and pseudospin ferromagnetism, the twisted TMDs physics is in its infancy and many exotic states of matter remain to be uncovered.

**Subject**: This PhD project aims at **exploring and exploiting the electronic band structures of TMDs heterostructures** generated either by twist or by in-situ intercalation of alkali atoms that induces lattice mismatches and strain effects. The PhD candidate will be strongly involved in **developing samples elaboration strategies on a recently acquired transfer system** (hq graphene company), devoted to selectively pick up large sections of TMD flakes, rotate and transfer them with a sub-degree control of twist angles. Since some exfoliated TMDs tend to degrade when exposed to air, this transfer system, which is fully motorized, will be installed within a glovebox and externally controlled using a computer. An important component of the PhD project will also be the use of **angle-resolved photoemission spectroscopy (ARPES)** for accessing to the electronic band structures of the as-obtained TMDs heterostructures and under different doping with in-situ chemical gating. In that context, the PhD candidate will take part to an exciting experimental development at IPR devoted to low-temperature ARPES using monochromatized micro-focused UV source. In parallel, regular **applications for beamtimes at synchrotron facilities** will be conducted in order to efficiently target the scientific questions that need facilities only available on synchrotron to be addressed such as tunable polarization and photon energy.

**Environment:** The candidate will benefit from a unique experimental environment combining sample growth environments and photoemission spectroscopies allowing for elaborating and characterizing the materials in the laboratory. Strong interplay with local theoreticians will also offer the possibility of performing ab-initio calculations of electronic structures and spectral functions within the density functional theory (DFT) and multiple scattering framework.

**Required skills**: Applicants should have a master in physics, or materials science with a strong background in solid-state physics, with emphasis on the study of the structural and electronic properties of solids. Motivation for experimental studies is needed, as well as willing to mobility. Enthusiasm, curiosity, spirit of initiative, ability to work in a team, tenacity and rigor would be appreciated qualities.

**Possible collaboration and networking:** The PhD proposal will benefit from experimental collaborations with the "Ultrafast spectroscopy" group of Prof. C. Monney in Switzerland as well as researchers from France [S. Beaulieu CELIA (Bordeaux), P. Le Fèvre synchrotron SOLEIL, T. Cren INSP (Paris)]. It will also take profit from strong theoretical support thanks to the EUSpec consortium that involves collaborations between researchers from IPR (D. Sébilleau, S. Tricot) and Pr. Jan Minar of the University of West Bohemia (Pilsen, Czech Republic).

**Practical aspects:** the position is available starting Oct. 2023 and lasts for 36 months. The net take home salary is about 1800 euros/month. Applicants should provide a CV, a letter of motivation, and the names and e-mail addresses of 2 or 3 references to: Dr. Thomas Jaouen, thomas.jaouen@univ-rennes.fr, Dr. Jean-Christophe Le Breton, jean-christophe.lebreton@univ-rennes.fr, Pr. Philippe Schieffer, philippe.schieffer@univ-rennes.fr.