SR4. Quantum transport in Van der Waals heterostructures

Laboratories: Nanoelectronics (SPEC), Meso (LPS) & Phynano (C2N)

Scientific context: Van der Waals (VdW) heterostructures are artificial compounds made of layered two-dimension (2D) materials held together by electrostatic forces. The ability to assemble arbitrary 2D crystals and combine their electronic, optical or thermal properties is extremely promising in order to engineer materials with new quantum functionalities. Chiefly known are graphene, a 2D crystal of carbon atoms in a honeycomb lattice with exceptional properties such as high mobility and broadband optical absorption, and hexagonal boron nitride (hBN), its electrically insulating counterpart. By encapsulating a graphene flake between two thicker hBN film [L. Wang *et al.,* Science **342,** 614 (2013)], one can obtain ultra-clean samples where striking phases of quantum matter are observed, such as quantum Spin Hall effect [A.F. Young *et al.,* Nature **505,** 528 (2014)], fractional fractal quantum Hall effect [L. Wang *et al.,* Science **350,** 1231 (2015)], and hydrodynamic electron quantum transport [D. A. Bandurin *et al.,* Science **351,** 1055 (2016)]. Graphene can be combined with other 2D materials to induce new properties, *e.g.* strong spin-orbit coupling with the transition metal dichalcogenide MoS_2, or superconductivity with $NbSe_2$ [D. K. Efetov *et al.,* Nature Physics **12,** 328–332 (2016)]. The ability to locally open energy gaps in ultra-clean graphene in a high magnetic field, by either entering the electrically insulating nu=0 filling factor of the quantum Hall effect, or by creating a periodic Moiré pattern in the electrostatic potential felt by a graphene flake slightly misaligned with hBN crystals, can be used to engineer electrically tunable complex quantum circuits with Dirac fermions.

Objectives: Our aim is to set up a reliable and efficient VdW heterostructures assembly platform that would benefit all scientific actors in the Université Paris-Saclay. A first step towards this platform was taken with the construction of a prototype of an assembly station in the Nanoelectronics group of SPEC, which was funded by the Labex PALM (project ZerHall), and the acquisition of a growth furnace in C2N to synthesize transition metal dichalcogenide crystals such as WSe_2. The fabricated samples will first be tailored to investigate heat transport in the nu=0 filling factor of the quantum Hall effect in ultra-clean graphene, to perform quantum plasmonics experiments in ballistic graphene in the THz range, and enhance the optical response of graphene by coupling it to WSe_2. Our ultimate goal is to be able to obtain a functional source of VdW heterostructures with production capacities comparable to the molecular beam epitaxy sources of III-V semi-conductor heterostructures of C2N, such as GaAs/Ga(Al)As, which have benefitted a large portion of the physics community in France and Europe.

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