Master thesis proposal

Laboratoire Charles Coulomb (L2C), UMR 5221 CNRS-Université de Montpellier, Montpellier, France.
Director : Pierre Lefebvre

Title: **Topological properties of semiconductor heterostructures**

Keywords: Condensed Matter physics, Semiconductors, heterostructures, spin, quantum spin Hall effect, topology.

Scientific description:

The student will be integrated into a long-term research project, whose objective is to probe unusual topological phases in III-V heterostructures via electronic transport and Terahertz magneto-optical measurements. Topological phases in solids have indeed attracted considerable attention, particularly since the award of the Nobel Prize in 2016 for topological concepts in condensed matter physics. Since then, these topological phases have been observed in many materials, but only a small number of them have a sufficiently mastered growth and technological process to consider their possible use for the foundations of a new topological electronics and to contribute to the current advent of quantum technologies. In this context, III-V semiconductor heterostructures based on antimony prove to be particularly interesting. One of the most striking topological phenomena, called the quantum spin Hall effect (see Fig. 1), has indeed been observed in there [1]. Our team predicted and finally observed the existence of a wide and temperature insensitive topological gap in specific Sb-based quantum wells [2-6]. This breakthrough makes it possible to consider the observation of electronic edge states protected from backscattering by the non-trivial topology of the band structure, even at liquid nitrogen temperatures. It turns out that very recent measurements indeed suggest the presence of these exotic electronic states in these structures at temperatures much higher than that of liquid helium [7].

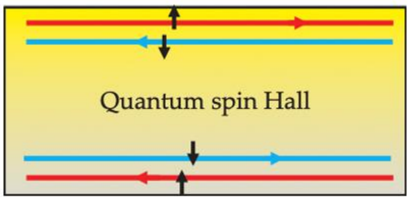

Figure 1; typical representation of the QSH state with spin polarized edge states.

1) L. Du *et al*., Phys. Rev. Lett. **114**, 096802 (2015). 2) S. S. Krishtopenko and F. Teppe, *Sci. Adv.* **4**, eaap7529 (2018). 3) S. S. Krishtopenko *et al*., *Phys. Rev. B* **97**, 245419 (2018). 4) S. S. Krishtopenko *et al*., *Phys. Rev. B* **99**, 121405 (2019). 5) S. S. Krishtopenko*, Scientific Reports 11, 21060 (2021). 6)* C. Avogadri *et al*., Phys. Rev. Res. **4**, L042042 (2022). 7) M. Meyer *et al*., Phys. Rev. B, **104**, 085301 (2021).

Techniques/methods in use: the Internship student will have access to state-of-the-art topological field effect transistors, and to cryostats allowing measurements of electronic transport at low temperatures (down to 260 mK) and strong magnetic fields (up to 16 T). The student will participate to the transport measurements. He will also discuss the optimization of both band structures and fabrication of the devices with the other researchers involved in the project.

Applicant skills: strong background in solid state physics, interest for experiments, patience and dedication, passion for understanding experimental results.

Internship supervisor: Benoit Jouault, benoit.jouault@umontpellier.fr

Internship location: Laboratoire Charles Coulomb, Université de Montpellier, Montpellier, France

Possibility for a Doctoral thesis: Yes (already financed/ANR)