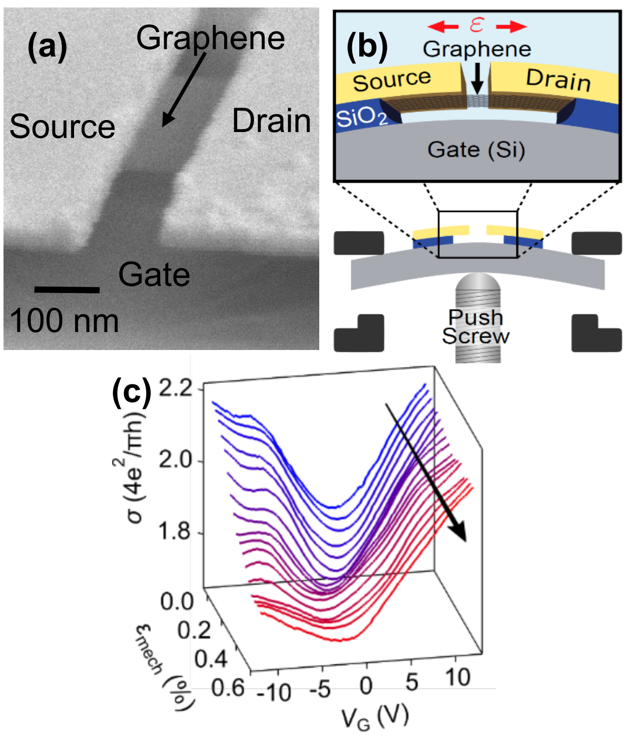
Concordia University
Arts and Science
Department of Physics

Ph.D. in Experimental Quantum Electro-Mechanical Physics of Graphene

Fall 2021 in the group of Prof. Alex Champagne, Department of Physics,

Concordia University, Montréal, Canada



This PhD project will most likely be part of the "QSciTech: Bridging the Gap between Quantum Science and Quantum Technologies" (NSERC-CREATE training program). This program includes a network of 11 research teams in quantum science and technology across Canada, offers transdisciplinary courses, and can offer you a one-semester-long paid industrial internship as part of your PhD. *The candidates must be well prepared for this research, with past experience either in advanced nanofabrication skills, or/and electron transport measurements, or/and an advanced understanding of quantum mechanics.*

Experimental Quantum Electro-Mechanical Physics of Graphene

This PhD project starts with a focus on developing an applied theoretical model, while getting trained on experimental methods. The student will gain a deeper understanding of quantum transport, strain-engineering of band structure and Hamiltonians, and magic-angle bilayer superconductors. After four semesters, the PhD student will have completed their course work, technical training, and a short applied theoretical project leading to a publication. They will then focus on nanofabrication and quantum transport measurements leading to their thesis. They will learn about data analysis, writing scientific manuscripts, and giving effective presentations.

To deliver on the promises of nanoscale quantum materials, we must understand the strong interdependence between their mechanics and electronics. Atomically-thin 2D materials have shown recently that controlling their mechanical configuration (via heterostructures) makes a dramatic different in their electronic behavior. We have a unique experimental capability to study suspended 2D crystals, Fig. (a), where we apply *tunable* and *smooth* mechanical strains, Fig. (b), to control their quantum transport, Fig. (c). In the honeycomb carbon lattices, mechanical strains create both scalar and pseudomagnetic potentials acting on the pseudospin of Dirac electrons, and offer the possibility to create quantum straintronics devices.

In bilayer graphene, each K valley has four Dirac cones at low energy. Uniaxial strain is expected to modify this topology are reduce the degeneracy to two (Liftshitz transition). This transition should have signatures in ballistic conductivity, and magnetotransport. Magic angle bilayer graphene is made of two monolayers stamped onto one another with a $\theta \approx 1.05$ degree rotation (the superlattice leads to flat electronic bands). It displays unconventional superconductivity, and offers unique opportunities to engineer and explore the superconducting phase diagram. Uniaxial straining is expected to accurately tune θ *in-situ* and control the phase transitions. Making modifications to our instrumentation, Fig. (b), to clamp the samples along three sides, we will generate tri-axial strain fields. We aim to make the first demonstration of large and *tunable* pseudomagnetic fields (10s of Tesla) in graphene. The combination of pseudomagnetic fields (opposite in K and K') and real magnetic field (same in K and K'), will make it possible to create a zero total field in one of the two valleys, and generate valley-polarized currents. These charge neutral valley currents are measurable, and would find applications in quantum electronics.

Concordia's Department of Physics is growing rapidly. We have over 45 graduate students, several postdocs, and are regularly hiring new faculty members in cutting edge research fields such as Condensed Matter Physics (theoretical, computational, and experimental), Photonics, Molecular Biophysics, Medical Physics / Imaging, Theoretical High Energy Physics, and Physics Education. Successful PhD applicants to this position will be offered financial packages consisting of RA, TA and various awards of at least 24,000 CAD per year, for 4 years. International students will be offered tuition remissions or other awards to compensate for the international tuition fees. For information about this specific position, please contact Prof. Alex Champagne (a.champagne@concordia.ca). For information about our graduate programs in general, please contact Prof. Valter Zazuvobits (valter.zazubovits@concordia.ca).