Master thesis proposal

Service de Physique de l'Etat Condensé, CEA Saclay
Director: Patrice Roche

Title: Fractionalisation and anyons in integer quantum Hall circuits

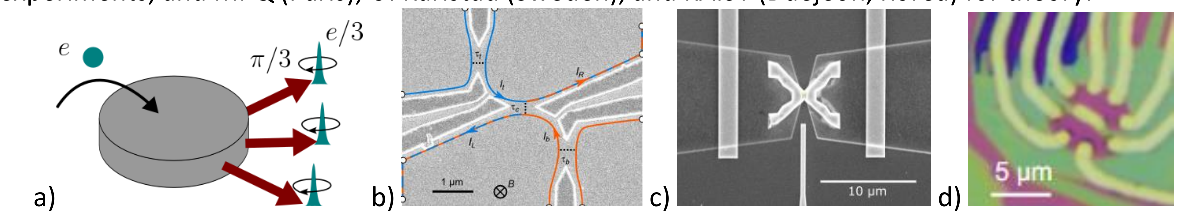
Keywords: Anyons, Fractionalization, Quantum Hall effect, 2D electron gases, noise

Scientific description:

In reduced dimensionality, particles coined "anyons" can evade the familiar division between fermions and bosons with a fractional exchange phase between 0 and pi, with applications to topological quantum computation. Early on, quasiparticles of the Fractional Quantum Hall regime were identified as anyon candidates, and their fractional statistics was experimentally established in a few pioneer experiments in the early 2020s [1]. It has been suggested [2] that their existence extends way beyond this restrictive framework, and that they emerge for instance in bidimensional ballistic electron systems with strong Coulomb interactions, resulting in electron charge and statistics fractionalization.

The goal of this internship is to follow this novel approach with quantum circuit tools, combining quantum point contacts, single electron physics at high charging energies and ballistic edge channels of the Integer quantum Hall regime [3]. The student will learn a variety of techniques mastered in the team (ultrasensitive conductance and quantum shot noise measurements, quantum thermal transport, electron interferometry), in order to reveal the anyonic nature of the system's excitations, and characterize their quantum coherence.

Collaborations are already established with C2N (Palaiseau) and LPENS (Paris) for nano-fabrication and experiments, and MPQ (Paris), U. Karlstad (Sweden), and KAIST (Daejeon, Korea) for theory.



a) Schematic fractionalisation of a single electron that cannot dwell on an island with high charging energy. b) SEM picture of quantum point contacts creating and scattering 1D diluted beams of electrons. c, d) examples of mesoscopic islands with high charging energies interfaced with c) GaAs 2D electron gases and d) graphene.

[1] H. Bartolomei *et al.*, Science **368**, 173-177 (2020) ; J. Nakamura *et al.*, Nat. Phys. **16**, 931-936 (2020) ; P. Glidic *et al.*, Phys. Rev. X **13**, 011030 (2023) [2] T. Morel *et al.*, Phys. Rev. B **105**, 075433 (2022) [3] P. Roche *et al.*, Phys. Rev. Lett. **136**, 196301 (2026)

Techniques/methods in use: Quantum transport, dilution refrigeration, high resolution electrical measurements (conductance, low- and high-frequency noise), clean room fabrication based on semiconducting two-dimensional electron gases and graphene.

Applicant skills: A Master level in quantum physics/condensed matter and a taste for quantitative theory/experiment confrontation are required. Prior experience with cryogenics, mesoscopic physics or nanofabrication is good but not mandatory: motivation is a key factor.

Internship supervisor(s) Olivier Maillet/Carles Altimiras/Patrice Roche

Internship location: Service de Physique de l'Etat Condensé (SPEC, CEA/CNRS), CEA Saclay, l'Orme des Merisiers

Possibility for a Doctoral thesis: Yes! Funding shall be obtained through CEA (CFR) or EDPIF.