Annual Report

Student: Giacomo Rebora (XXXV cycle)

Supervisor: Dr. Dario Ferraro

Activity

The central topic of my first-year of Ph.D. research activity has been the electron quantum optics. This branch of mesoscopic physics aims at revising long-standing tools developed for the conventional quantum optics with photons in order to properly characterize the ballistic propagation of electronic wave-packets in solid state devices. In order to mimic the propagation of photons, electron wave guides, realized for example by means of quantum edge channels of the integer quantum Hall effect, and quantum point contact, used as beamsplitter, are employed while single electron sources are needed to inject a controlled flow of electrons in the sample. In such systems, the quantum behaviour of electrons dramatically emerges in interference effects experimentally observable by investigating transport properties of mesoscopic devices. In this framework I have focused on the theoretical investigation of the electronic counterpart of Hong-Ou-Mandel and Mach-Zehnder interferometers by calculating physical quantities such as current and noise (i.e. current fluctuations) which are deeply affected by the presence of the Fermi sea and of Coulomb interactions among electrons.

In detail, the topics that I have addressed during the past year are:

- **Hong-Ou-Mandel interferometer**. I have considered an interferometer with two arms through which electrons ballistically propagate toward each other and then collide. In relevant experimental conditions, the excitations are injected via time-dependent voltage pulses in wave guides obtained by using two quantum Hall edge channels. Here, due to Coulomb interactions between these channels the injected wave-packets fractionalize before partitioning at the quantum point contact. In order to characterize this process, I have investigated the current fluctuations, which play a role analogous to a photon coincidence measurement in quantum optics. Furthermore, this quantity is necessary to characterize the anti-bunching properties of electrons because of their fermionic nature. I have also demonstrated that even in presence of interactions is possible to achieve a situation where the noise is equal to zero, in correspondence of a synchronized injection, which means that there is no loss of quantum information. These results have been published in [1].
- **Mach-Zehnder interferometer.** For this interferometer, a single electron source emits electron excitations into wave guides, such as quantum Hall edge channels. The

electrons, traveling along the channels, split at a first quantum point contact then pass through two arms are finally recombined at a second quantum point contact. Currently, I am studying the electrical current after the recombination and the visibility of the interferometer in presence of inter-edge interactions along the arms which dramatically affect the physics of the system. A publication related to this work will be submitted shortly in [2].

This work represents an important preliminary step in order to explain the experimental measurements realized by P. Roche and coworkers in Saclay whose theoretical interpretation is still debated.

Courses and Exams

- **Quantum Optics** (PhD course)

  Exam passed on 22/06/2020

- **Crash Course on Theoretical Condensed Matter Physics** (PhD course)

  Exam passed on 20/07/2020

- **Classical and Quantum Phase Transitions** (PhD course)

  Exam passed on 24/07/2020

Publications

[1] G. Rebora, M. Acciai, D. Ferraro and M. Sassetti, *Collisional interferometry of levitons in quantum Hall edge channels at* $\nu = 2$, Phys. Rev. B **101**, 245310 (2020).

[2] G. Rebora, D. Ferraro and M. Sassetti, *Interaction effect in a Mach-Zehnder interferometer in the integer Hall regime*, In preparation.

Conferences and School

Due to the present pandemic situation I was unable to attend any conference or school. The physics' school I have planned to take part is the Meso School 2020 in Cargese (France) *Fundamentals and Advances Quantum Physics: Quantum Circuits, Topology and Correlations*“ but it has been re-scheduled for the next year.