Annual Report

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Activity

The central topic of my second-year of Ph.D. research activity has been the electron quantum optics. This branch of mesoscopic physics aims at revising the tools developed for the conventional quantum optics with photons in order to properly describe individual electronic wave-packets propagation in solid state devices. In order to mimic the propagation of photons, electronic wave guides, realized for example by means of quantum edge channels of the integer quantum Hall (QH) effect, and quantum point contact (QPC), used as beamsplitter, are employed while single electron sources are needed to inject a controlled flow of electrons in the sample. However, Coulomb interactions among electrons must be taken into account in order to properly investigate the transport properties of mesoscopic devices. In this framework, I have considered a quantum Hall system at filling factor two where the two neighbor channels interact through a short-range capacitive coupling.

In the first part of my research activity, I have focused on theoretical investigation of the energy evolution of the peak height of injected electrons into QH edge channels. This quantity is related to the elastic scattering amplitude for the fermionic excitations evaluated at different injection energies. In order to be close to experimental observations, I have considered a wave-packet crossing an interacting region of tunable length where the edges are coupled due to electron-electron interactions. I assumed a short-range coupling and phenomenologically included a dissipative contribution in order to take into account energy losses towards additional degrees of freedom. Together with the conventional non-dissipative case, I have considered a dissipation that is both linear and quadratic in the injection energy. In particular, I observed that the comparison with the experimental results in [R. H. Rodriguez et al., *Nat. Comm.* 10, 3915 (2019)] allows to rule out the non-dissipative and the quadratic cases and indicates the linear energy loss rate as the more probable candidate for describing the behavior of the wave-packet for these set-up at short enough lengths ($L < 1\,\mu$m). These results, which gives a better understanding of the strength of the interactions and the dissipation, have been published in [1].

In the second part of my activity, I have studied the quantum fluctuations of the two quadratures of the emitted electromagnetic radiation generated by a QH device in a QPC geometry. In particular, I have focused on the role played by unavoidable electron-electron interactions between the two edge channels. I investigated the squeezing property of emitted microwave radiation, by relating it to the current fluctuations (noise) at finite frequency, accessible through a two-filters set-up placed just after the QPC. In this case, the injection of excitations into the system is done through time dependent voltage pulses. By comparing two different drives, respectively a cosine and a train of Lorentzian pulses, I observed that the quantum features are reduced due to the interactions. However, the Lorentzian drive is still characterized by a robust squeezing effect which can have important application in a quantum information perspective. These results have been published in [2].

Currently [3], I am studying the current fluctuations associated to the electron tunneling between two fractional quantum Hall edge channels at different filling factor belonging to the Laughlin sequence. Differently from what usually done in literature we are investigating the role played by a thermal imbalance between the channels, namely the so called Delta-T noise. This work is done in collaboration with the group of Prof. Thierry Martin at the CPT Marseille.

Courses and Exams

- **Introduzione alle tecnologie quantistiche** (LM course, 15/02/2021)
- **Fasi topologiche della materia condensata** (LM course, 26/04/2021)

Publications

[1] G. Rebora, D. Ferraro, R. H. Rodriguez, F. D. Parmentier, P. Roche and M. Sassetti, *Electronic wave-packets in integer quantum Hall edge channels: relaxation and dissipative effects*, Entropy **23**, 138 (2021).

[2] G. Rebora, D. Ferraro and M. Sassetti, *Suppression of the radiation squeezing in interacting quantum Hall edge channels*, New J. Phys. **23**, 063018 (2021) [The paper has been published thanks to the funding of "Dipartimento Eccellenza MIUR 2018-2022"].

[3] G. Rebora, D. Ferraro, J. Rech, T. Jonckheere, T. Martin and M. Sassetti, *Delta-T noise in an asymmetric quantum Hall junction*, in preparation.

Conferences and School

During this academic year I have attended two conferences, which were held online due to the current pandemic situation, in which I have contributed with two different posters. The first one is the *GDR Quantum Mesoscopic Physics* conference (Aussois, November 2020) while the second one is the *Frontiers of Quantum and Mesoscopic Thermodynamics* (Prague, July 2021). Furthermore I will attend (13-17 September 2021) the *Congresso Nazionale* organized by the Società Italiana di Fisica (SIF) with a communication contribution. The physics' school I have planned to take part is the *Topological Quantum Matter* school (Erfurt, October 2021).