Electron quantum optics in quantum Hall edge channels

A. Marguerite[1], V. Freulon[1], J.-M. Berroir[1], B. Plaçais[1], A. Cavanna[2], Y. Jin[2] & G. Fève[1]

[1] *Laboratoire Pierre Aigrain, Ecole Normale Supérieure, CNRS, Université Pierre et Marie Curie 24 rue Lhomond, 75231 Paris, France*

[2] *Cnrs-laboratoire de photonique et nanostructures, Route de Nozay,91460, Marcoussis, France*

arthur.marguerite@lpa.ens.fr

Quantum effects have been studied on photon propagation in the context of quantum optics since the second half of the last century. In particular, using single photon emitters, fundamental tests of quantum mechanics were explored by manipulating single to few photons in Hanbury-Brown and Twiss and Hong Ou Mandel [1] experiments.

In nanophysics, there is a growing interest to translate these concepts of quantum optics to electrons propagating in nanostructures. In two-dimensional electron gases, electronic propagation can be guided along the edge channels of the quantum Hall effect and quantum point contacts can be used as electronic beam-splitters to implement electronic interferometers [2]. Single electron emitters have also been realized such that single elementary electronic excitations can now be manipulated in the analog of pioneer quantum optics experiments. However, these electron quantum optics experiments go beyond the mere reproduction of optical setups using electron beams, as electrons, being interacting fermions, differ strongly from photons.

I will discuss in particular the electronic analog [3, 4] of the Hong-Ou-Mandel experiment (see Figure) where two single electrons collide on a beam-splitter. Two-particle interferences between two indistinguishable single electrons can then reveal the coherence properties of single electron states and probe how they are affected by the Coulomb interaction along propagation [5, 6].

The interaction of an elementary excitation with neighboring conductors favors the emergence of collective modes, which eventually leads to the destruction of the Landau quasiparticle. In particular at filling factor 2, an electron injected into the outer edge channel and interacting with the inner one, tends to fractionalize into separated pulses carrying a fraction of the electron charge. By studying both channels, I analyze the propagation of the single electron and the generation of interaction-induced collective excitations in the inner channel. These complementary pieces of information reveal the fractionalization process [7] in the time domain and establish its relevance for the destruction of the quasiparticle, which degrades into the collective modes.

[1] C. K. Hong, Z. Y. Ou, and L. Mandel Physical Review Letters **59**, 20442046 (1987).

[2] Y. Ji et al. Nature **422**, 415–418 (2003).

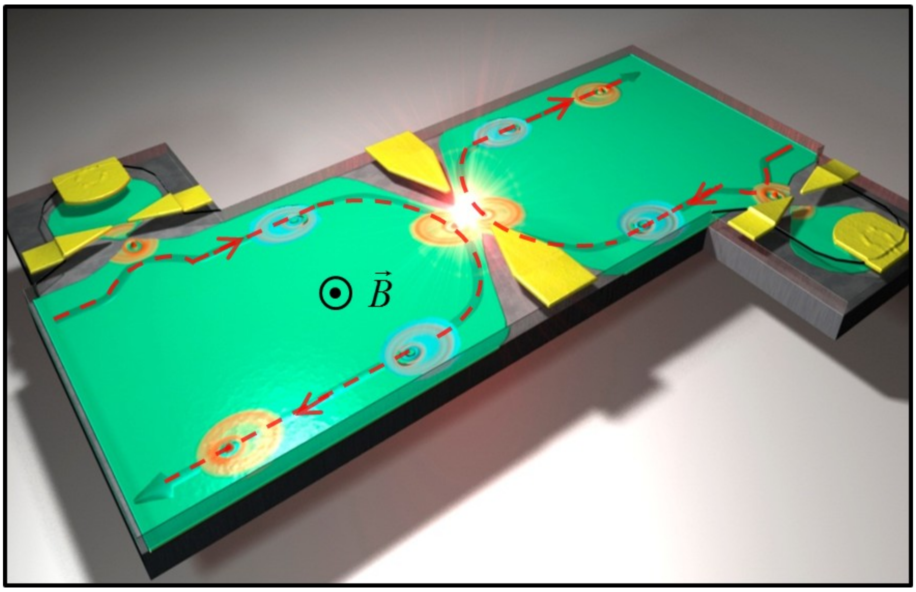
[3] S. Ol'khovskaya, J. Splettstoesser, M. Moskalets, M. Büttiker, Phys. Rev. Lett. **101**, 166802 (2008)

[4] E. Bocquillon et al., Science **339**, 1054 (2013).

[5] D. Ferraro et al., Phys. Rev. Lett. **113**, 166403 (2014).

[6] C. Wahl, J. Rech, T. Jonckheere, T. Martin, Phys. Rev. Lett. **112**, 046802 (2014).

[7] V. Freulon et al., Nat. Commun. **6**, 6854 (2015).



Sketch of electronic Hong-Ou-Mandel experiment: the two dimensional electron gas is pictured in green, the metallic gates in gold and the edge channels by red dashed lines