Charge Fractionalization in Tunneling Experiment

Short visit grant reference: 2444
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to visit
Prof. Ines Safi, Laboratoire de Physique des Solides, Universit´e Paris-Sud, Bat. 510, 91405 Orsay, France
Period of visit: July 14-July 24, 2008

1. Purpose of the visit:

The purpose of this visit was to do joint work with Prof. Ines Safi, on the theory of charge fractionalization in Luttinger liquids in conjunction with recent experimental observation of this phenomenon in a tunneling experiment [H. Steinberg et al., Nature Physics 4, 116 - 119 (2008)]. In this experiment right-moving electrons were injected into a 1-dimensional quantum wire and left-going current was detected in a tunneling drain contact, which was positioned to the left of the source. The results of this experiment were interpreted as evidence for the fractionalization of the charge of particles (electrons) injected into the wire [Karyn Le Hur, Bertrand I. Halperin, Amir Yacoby, arXiv:0803.0744]

2. Description of the work carried out during the visit:

During the visit we concentrated on the question of the influence of boundary conditions on the possibility of fractionalization of current as described in [Karyn Le Hur, Bertrand I. Halperin, Amir Yacoby, arXiv:0803.0744]. Particular attention was paid to the conditions of smooth opening of a 1d channel into Fermi liquid, which is the situation in actual experiment. A simplified model of the actual experiment with two tunneling contacts (source and drain) was also considered in the linear response regime at a finite temperature. Calculation of the source-drain current was performed using the analytic continuation of the corresponding Matsubara response function.

3. Important results

Most important, it was demonstrated that in the presence of realistic boundary conditions (corresponding to a smooth opening of the 1-dimensional channel into the Fermi liquid) the picture proposed in [Karyn Le Hur, Bertrand I. Halperin, Amir Yacoby, arXiv:0803.0744] is not valid. Explicit calculation shows that under these boundary conditions current does not fractionalize and no counterflow current can be observed away from the source. However, if the drain is situated close enough to the source a “virtual” process is possible in which an electron is dragged by the electrons of opposite chirality and is detected upstream. This effect decays with the distance between the source and the drain and is sensitive to the temperature and disorder in the system. Explicit expressions for these dependencies have been obtained in some simplified models of the experiment.

4. Future collaboration with host institution

Future work is planned on a better theoretical understanding of the experiment of [H. Steinberg et al., Nature Physics 4, 116 - 119 (2008)]. In particular, developing a full non-equilibrium theory based on Keldysh formalism is needed for the interpretation of actual experimental data. I am planning a visit to Orsay in October 2008.

5. Dissemination of results

The results of this work will be published as an arXive pre-print and submitted to the Physical Review Letters within several weeks from now.