Interaction and disorder in helical conductors

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Abstract

Different effects from electron-electron interactions and disorder in helical and quasi-helical conductors are studied using bosonisation and renormalisation group methods.

The combined effects of Rashba spin-orbit interaction and magnetic Kondo-type impurities in the helical edge liquids of quantum spin Hall insulators, are investigated. The Kondo temperature is shown to depend on the strength of the Rashba coupling, which allows for electrical control of the Kondo physics by an external electric field.

Anderson localisation due to disordered impurity backscattering in a quasi-helical conductor is also studied. A quasi-helical conductor is a one-dimensional system in which half of the available states are effectively removed from the system with the combination of spin-orbit interaction and magnetic or electric fields. The resulting conductor have counterpropagating modes that are approximately, but not completely, spin-filtered. It is shown that an applied magnetic field can be tuned to make the system pass through two metal-insulator transitions at different magnetic fields, allowing for a conducting quasi-helical phase for intermediate field strengths.

Furthermore, biased and unbiased point contact tunnelling between two quantum spin Hall edges are investigated, in addition to the study of combined effects of electron-electron interaction and different types of Rashba interactions on the quantum spin Hall edges. A disordered Rashba coupling is shown to localise the electrons for sufficiently large Rashba and electron-electron interaction strengths.

The thesis also contains a quick introduction to one-dimensional physics, bosonisation and renormalisation group theory, to set the stage for the topics to be discussed.