On topological Properties of Superconducting Nanowires

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Summary

Topological superconductivity is a novel phenomenon, that has recently been predicted to exist in quantum wires. The first signatures of this new superconducting state have recently been reported. The difference with usual superconductors is the appearance of conducting edge states. It is of interest to investigate how all the well-known effects of superconductivity are modified by these edge states, and also to discover new effects that appear only in topological superconductors. This investigation is the main topic of the thesis.

We start with the examination of the usual thermodynamic properties of phase transitions, as they appear in topological phase transitions. Phase transitions become crossovers in finite systems, so strictly speaking, there are no topologically non-trivial finite systems. This apparent contradiction with previous research is discussed and resolved in chapter 2. Our analysis reveals a different type of topological transition in a finite system, concerning the poles in the complex energy plane of the scattering matrix.

We continue in chapter 3 with a study of the properties of the topological phase transition in a general model, universally valid near the transition. We show that the pole transition is displaced relative to the topological transition, but always occurs in its vicinity. We examine the universal behaviour of the conductance near the two transitions.

In chapter 4 we turn to the problem of the conductance of a realistic superconducting nanowire, both in the topological and non-topological regimes. We show that interference effect known as weak antilocalization, which enhances the conductance, may produce a zero-bias peak in the topologically trivial regime. It therefore may obscure the observation of the zero-bias peak due to topologically nontrivial Majorana bound states. We study both the average conductance and the conductance for

a single measurement. The zero-bias peak for a single measurement is explained in terms of the pole transition of chapters 2 and 3.

In chapter 5 we continue with the Josephson effect in topological superconductors. We derive a universal effective model of a Josephson junction and study its dynamics under constant voltage bias. We find an unexpected noise pattern, incommensurate with the Josephson frequency, which we call *any-π* Josephson effect.

In chapter 6 we compare long and short Josephson junctions at the edge of a Quantum Spin Hall insulator. We show that the long junction shows a difference between the parity-conserving and parity-non-conserving supercurrents, which can be measured in phase-insensitive measurements.

Finally, in chapter 7 we study the Nernst effect in superconductors with anisotropic Fermi surfaces and anisotropic scattering on impurities. We show that the widely accepted relaxation-time approximation fails to capture the features of the effect, to the extent that it may give a wrong sign of the Nernst coefficient.