Circuit QED devices for probing Majorana zero modes

Popular description of Master's thesis. Oscar Erlandsson, 2018.

The evolution of information technology (IT) in the 20th century has had a major impact on the world. The ability to make transistors, the building blocks of classical computers, smaller and smaller has led to mass production of computational devices that can fit in the palm of your hand. Although the general progress of IT is sure to continue, physics tells us that the shrinking size of transistors is approaching the quantum realm, where strange effects such as superposition of states and quantum tunneling will affect the performance of the devices.

The quantum computer represents a new paradigm in IT. In such a machine, the classical bit, which can be either 0 or 1, is replaced by a qubit (quantum bit) which can exist in an arbitrary superposition of 0 and 1. Quantum computation directly exploits the quantum effects, which means, in theory, that it could solve certain problems much faster than classical computation. So far, however, the quantum computers that have been successfully realized have too few qubits to perform useful calculations. Part of the challenge is finding the right physical system to use as a qubit. In this Master's thesis, one potential qubit system is investigated experimentally.

The qubit system studied in this project is a hybrid device, combining the approach of a superconducting qubit and a Majorana qubit. Superconducting qubits are one of the most promising qubit implementations, used in many leading efforts to realize a quantum computer. Majorana qubits are theoretically believed to have potential for extreme robustness, but are still in very early development.

In this project, qubit devices with nanometer-scale features have been fabricated in a cleanroom using state of the art technology, and subsequently probed below 50 millikelvin in a dilution refrigerator. For comparison, a nanometer is a million times smaller than a millimeter, and 50 millikelvin is about 5,000 times colder than a typical Scandinavian winter. The small size and low temperature is what makes the quantum realm accessible in the laboratory.

The results obtained in the thesis are not conclusive and indicate that more work is needed to successfully realize the hybrid device that has been investigated. In fact, the results show no signs that Majorana features are at all present in the devices. The information obtained, however, could be useful for future research and constitutes additional knowledge about the requirements for implementing a robust quantum computer.