Lab Course in Superconductivity Summer Term 2016

Lab Course 4: Multiple Andreev Reflections in Atomic Contacts
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Mesoscopic Superconductivity

The basic phenomena of superconductivity can be found in macroscopic samples and can be described by classical formalism. However, at mesoscopic dimensions, additional quantum effects take place, which can only be described as a proper quantum system (e.g. Josephson junctions, quasi particle tunneling, coherent transport effects).

In this experiment, we want to investigate the behavior of metallic weak links formed by single atomic contacts of superconducting material. In particular we will study mesoscopic superconducting tunnel junctions and SNS contacts. The later form so-called Dayem bridges, where the weak link is created in a constricted region bridging two superconductors, where critical current is reduced. For this, we will use a Mechanically Controlled Break Junction (MCBJ) setup with lead (Pb) samples [1]. The advantage of the MCBJ technique is that the cross-section of the junction can be tuned with atomic precision, which allows tuning the transmission of the junction. In atomic-scale junctions, the conductance as a function of the electrode separation displays distinct steps, which reflect the number of atoms contributing to the current transport. These so-called opening traces can be compiled in a conductance histogram showing the preferred conductance values of atomic junctions of a particular material. In a regime of low transmission $0 < \tau < 1$ multiple Andreev reflections appear in the transport spectra, whose analysis reveals fundamental physical properties of these contacts.

Preparation and Literature

Familiarize yourself with the MCBJ technique [1]. A superconducting tunnel contact with applied bias of $eV < 2\Delta$ should not exhibit any current flow, since no quasi particle states are available. In fact, for partly transmitting contacts, a sub-gap contribution can be found, due to Multiple Andreev Reflections (MAR), which are sensitive to the microscopic channel assembly. The theoretical description of the transport [2,3] can then be used to gain microscopic insight into the transport though atomic point contacts [4].

Revise the transport properties of SNS junctions discussed in the lectures. What are Andreev reflections? Which transport processes are best described in the semiconductor picture and the boson condensation model of superconductivity? The measurements are carried out in a $^3$He dip stick with a base temperature of 300 mK. What is the literature value for $T_c$, $B_c$ and $\Delta$ of Pb?
Literature:


Report, Questions and Exercises

• Compare the measured values of $T_c$, $B_c$ and $\Delta$ according to the BCS theory.

• Evaluate the histogram data and estimate the conductance of a single lead atom.

• Fit the data to obtain the number and transmissions of conductance channels of at least two contacts (a fitting tool is available).