Superconductivity

Lab in 2B1711 Solid State Physics

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Condensed Matter Physics (KMF) // IMIT // KTH

March 24, 2005

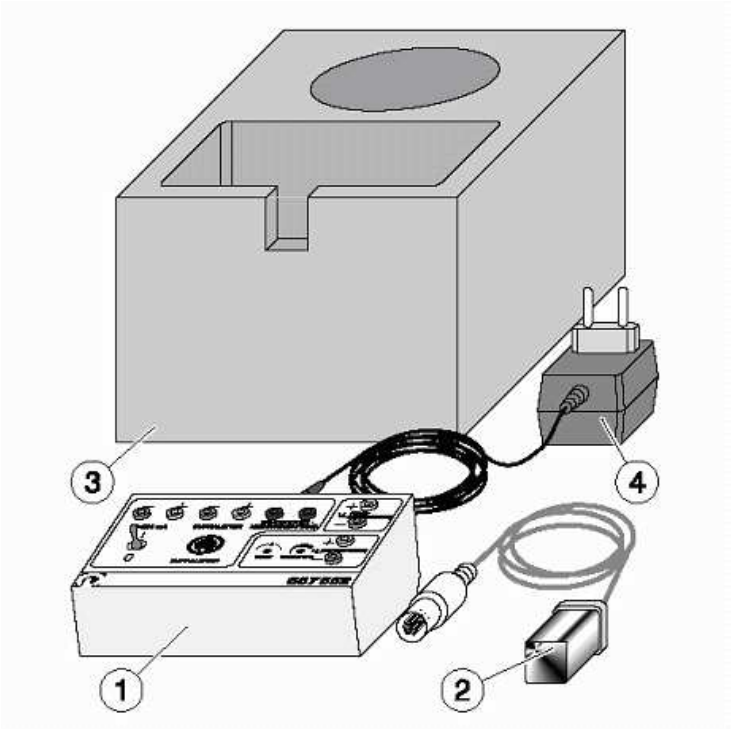

Figure 1: Measurement setup.

1 Introduction

Many elements and compounds become superconductors at low enough temperatures. Two main features are present in all superconductors: their electrical resistivity vanishes at a certain critical temperature, T_c, and they behave as perfect diamagnets (the magnetic field **B** inside the superconductor is always zero). The latter is a phenomenon known as *Meissner effect*.

In this lab, the electrical resistance of a superconducting sample is measured as a function of temperature. The superconductor is a bulk ceramics sample of the material $YBa_2Cu_3O_{7-\delta}$ (YBCO), which is a type-II superconductor. Liquid nitrogen is used to cool the sample below the superconducting transition temperature.

2 Experimental setup

The experiment kit, shown in Fig. 1, consists of the following parts:

1. Measurement adapter for data acquisition.
2. Integrated measuring module in aluminum housing, with a special cable and plug.

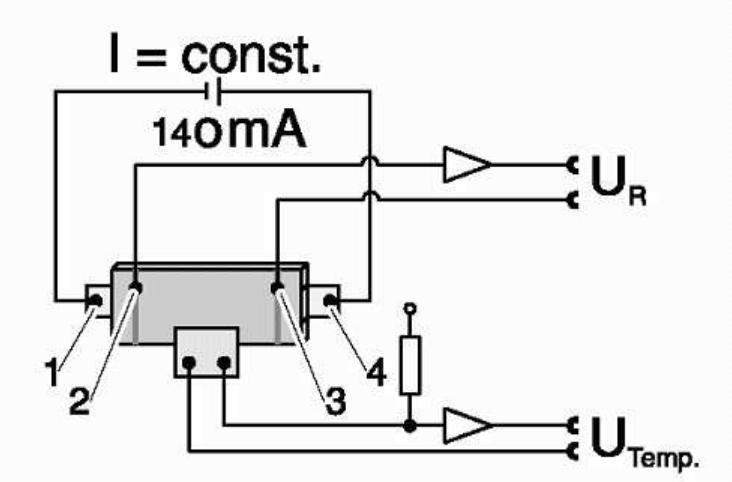

Figure 2: Measurement setup.

3. The box for packaging is used as dish for liquid nitrogen. The circular hole has special moulds to accommodate the measuring module.

4. Plug-in power supply for the measurement adapter.

The connections inside the measuring module are shown in Fig. 2. A constant measuring current of 140 mA is sent through the YBCO sample via contacts 1 and 4. The voltage drop U_R across the YBCO sample is measured via contacts 2 and 3. This type of measurement is called four-point measurement. It makes it possible to measure resistance with a high accuracy because the voltage drops at the contacts with the YBCO sample do not influence the measurement of the voltage drop. The voltage measured between contacts 2 and 3 is amplified by the measurement adapter with factor of between 33 and 330, depending on how the measurement adapter is adjusted (this adjustment has already been done by the laboratory responsible and is specific to every setup). The amplified voltage is accessible as output voltage U_A (Supraleiter) on the measurement adapter.

The sample temperature is measured with an iridium resistor that is glued onto the sample. The resistance of the iridium resistor depends on the temperature and the voltage U_{Temp} is therefore a measure of the temperature of the YBCO sample. U_{Temp} is accessible as output voltage U_A (Temp.-Messwiderst.) on the measurement adapter.

The connections of the measurement adapter are shown in Fig. 3.

1. The measurement adapter is connected to the sensor cassy via cables with banana-plug connectors. The output voltage U_a (Temp.-Messwiderst.) on the measurement adapter is connected to the voltage input of input A on the sensor cassy. The output voltage U_a (Supraleiter) on the measurement adapter is connected to the input B on the sensor cassy.

2. The special cable from the measuring module is connected to the corresponding input (Supraleiter) on the measurement adapter.

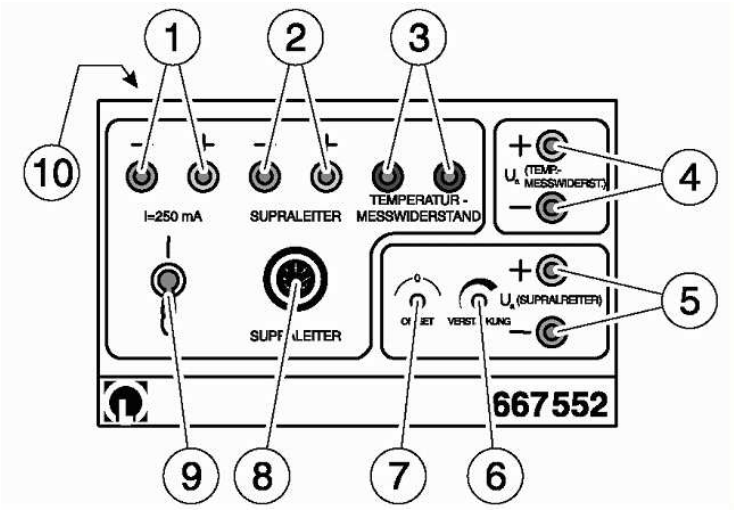

Figure 3: Measurement setup.

3 Lab procedure

1. Place the measuring module inside the circular hole of the black foam box, with the corners into the small mouldings.
2. Connect the measuring module and measurement adapter.
3. Connect the measurement adapter and sensor cassy.
4. Connect the sensor cassy via the USB cable with the computer.
5. Start the software 'cassy lab'.
6. Open the measurement (F3 or second buttom from the right) 'superconductivity laboratory'.
7. Start the measurement (press the clock button).
8. Ask the laboratory assistant to fill in liquid nitrogen for you.
9. Watch and wait until the temperature has fallen below the transition temperature.
10. Press the clock button again to start a new measurement. The data will be superimposed with the previous measurement
11. Carefully remove the measuring adapter from the circular hole and place it inside the rectangular hole.
12. Watch and wait until the temperature has reached room temperature.
13. Save your data (F2 or third button from the right) in your home folder and email it to yourself for later evaluation and the laboratory report.

4 Lab report

The report should be a self-consistent piece of work. It should contain the following sections: Introduction, experimental procedure, measurement results, discussion of the results, and conclusions. This is the typical format of a regular scientific article and that is what you are supposed to practice with this lab report. In order to determine (at least in parts) what you will write about, we give you a number of questions below. The answers to ALL of the questions should be included into your report in a natural way (do not write something like: 'The answer to question 1 is ...').

5 Questions

1. What is a superconductor?
2. What is the difference between type I and type II superconductors?
3. Why does this laboratory require the four-point technique to measure the resistance of the YBCO sample?
4. What is the critical temperature of the sample?
5. Why can you have small deviations between the measurements of resistance during cooling and warming?