4. **Experimental Objectives**

   1) Learn liquid nitrogen cryogenic technology;

   2) Measure the critical temperature of a BSCCO wire material and master the measurement method of resistance-temperature relationship;

   3) Understand the basic properties of superconductors and master the basic methods for determining superconductor states.

5. **Precautions**

   1) The experimental sample is wound at the end of the probe and can be observed by unscrewing the cover shell, but it is recommended not to touch it;

   2) When the sample probe is put into the liquid nitrogen Dewar, it should be carried out slowly and carefully to avoid damaging the container.

   3) Do not touch the liquid nitrogen to avoid freezing hurt. Be careful when pouring liquid nitrogen!

6. **Experimental Procedures**

   1) Connect the experimental probe to the main electric unit with the 7-core cable;

   2) Turn on the power. Press down the key "I(mA)" to display the current flowing through the sample. Turn "I-Adj" knob to adjust the current through the sample to zero. Press down the key "V(V)" to display the voltage on the sample. Turn the "V-Adj." knob to adjust the voltage on the sample to zero. Then, press down key "I(mA)" again to change back to display the sample current.

   3) Adjust the "I-Adj." knob to apply an appropriate current (e.g. 100.0 mA) to the sample. Carefully immerse the end of the experimental probe (i.e. the experimental sample) into the Dewar (note: after loosening the positioning cap in the middle of the probe, the immersing depth of the experimental sample at the end of the probe in liquid nitrogen can be adjusted, the user can adjust it to a suitable position).

   4) Press down the key "V(V)" to display voltage on the sample. Sample voltage will change as the sample temperature decreasing. After the sample temperature reaches the liquid nitrogen temperature (usually wait 10-15 minutes), the sample voltage should be near zero.

   5) When the sample temperature reaches the temperature of liquid nitrogen, record the sample voltage and temperature voltage (on the platinum resistance) at this time. Then carefully pull the end of the experimental probe from the Dewar to above the liquid nitrogen surface or directly take out from the Dewar bottle (note, do not touch the part immersed in liquid nitrogen during the process). The temperature of the sample will slowly rise. The resistance of the platinum resistance thermometer and the voltage of the sample will change simultaneously.

   6) Record multiple sets of data of the resistance and the voltage. Plot the relationship curve between the resistance of the platinum resistance thermometer and the voltage of the sample. The superconducting critical temperature can be obtained. Be patient during

the process, especially to take more data points near the transition temperature.

7) Due to the hysteresis effect for the sample temperature measurement by the thermometer, to obtain a more accurate superconducting transition temperature, we can measure it again during the sample cooling process, i.e., immerse the sample from the room temperature environment into liquid nitrogen again. Check the difference between the two curves of warming and cooling processes. Make an average to achieve more accurate superconducting transition temperature.

8) Connect the main electric unit to the computer with a data cable, and use the special software provided by the apparatus to record the superconducting transition temperature curve of the sample in real time. Please read Appendix for the connection of the computer and the instructions of the software use.

9) Turn off the power. Due to the low temperature, the water vapor in the air may condense on the experimental probe. It is recommended to use a blower to dry it.

7. An example of data recording and processing

Note: Following data are for reference only, not the criteria for apparatus performance:

Figure 2 is a set of superconducting transition temperature measurement data recorded and saved by the computer in real time, where the two sets of data points are measured under the sample warming and cooling processes
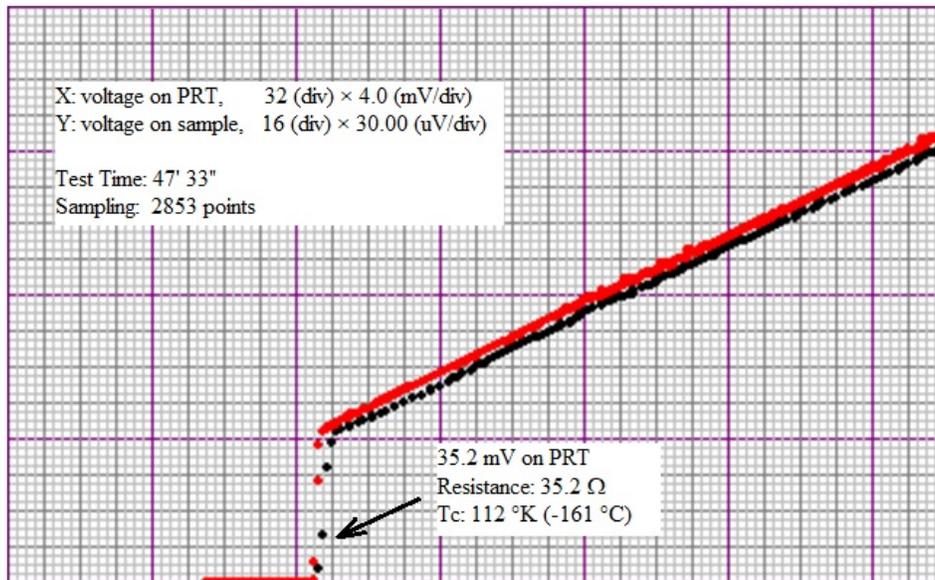

Figure 2 Computer recorded data for superconducting transition temperature measurement

From Fig. 2, it can be seen that when the voltage on the platinum resistance thermometer is about 35.2 mV, the sample voltage suddenly changes. Since the current through the platinum resistance thermometer is a constant at 1 mA, the resistance of the platinum resistance at the point of sample voltage suddenly changing is 35.2 Ω, and the superconducting transition temperature of the sample is about -161 ℃, which is 112 K.

8. Appendix- About the Software

The software is set to serial port input (select COM1 or COM2). The measured data is recorded on the horizontal and vertical coordinate system. The X coordinate corresponds to the voltage value at both ends of the platinum resistance thermometer (the current through the platinum resistance thermometer is constant at 1 mA), and the Y coordinate corresponds to the sample voltage.

The recorded curve can be operated such as save, print, etc., or delete and restart the recording. When sampling, we can choose different colors to distinguish the cooling and warming curves. After recording, we can click the mouse to display the coordinate value of each point on the curve. The temperature value of the abscissa can directly display the corresponding Celsius or Kelvin temperature, without looking up the table.

The window interface of the software is as follows:
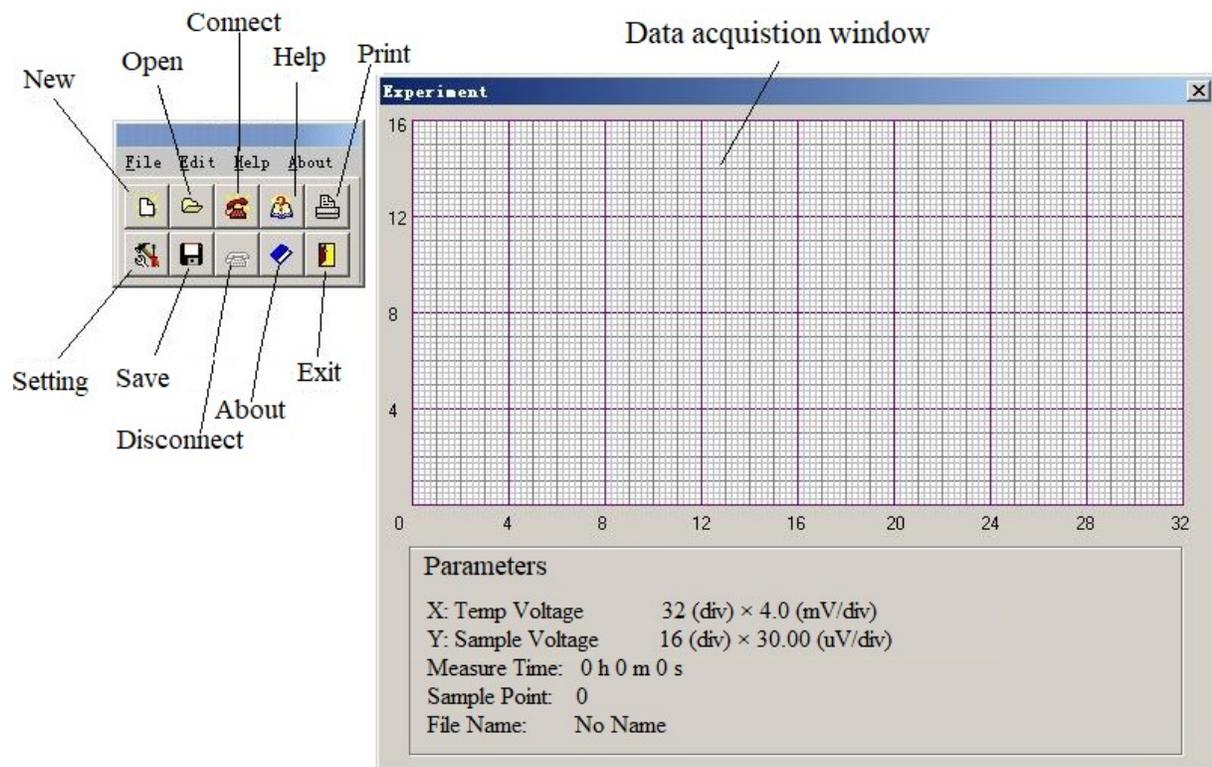
A. Software interface description:

1) Function bar (left side):

   a) "New": Create a new blank coordinate according to the current settings, ready for data collection;

   b) "Open": Open the files saved in the computer, including data files (* .rtd) and image files (* .bmp);

   c) "Connect": Connect the apparatus with the computer to communicate in real time;

   d) "Help": Provide help information;

   e) "Print": print the image displayed in the real-time data collection window;

f) "Setting": Set all relevant parameters for real time sampling. After clicking, a window will pop up as shown in the figure below:
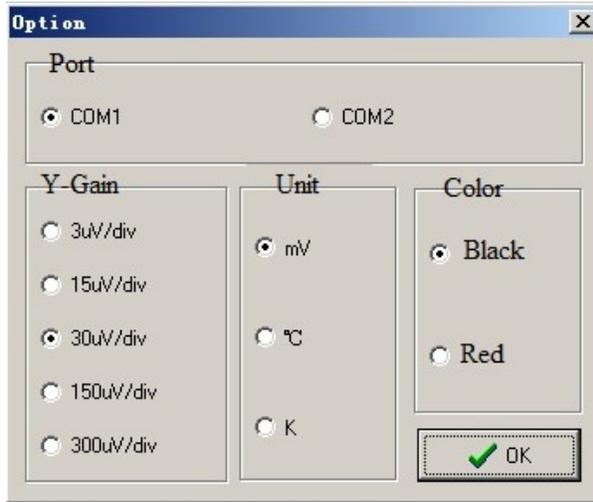
a. "Port": Select the serial port used by the computer;

b. "Y-Gain": select the voltage division represented by each grid of the Y coordinate in the real-time data collection window;

c. "Unit": select the display unit of the X coordinate when the mouse clicks a certain point in the coordinate system (voltage value on the platinum resistance, Celsius temperature or Kelvin temperature);

d. "Color": select the color of the sampling point depicted in the real-time data collection window, which can be switched in real time;

g) "Save": save the sampled image as an image file (* .bmp) or as a data file (* .rtd);

h) "Disconnect": disconnect the connection between the apparatus and the computer, and suspend the collection of experiment data;

i) "About": provide company profile and other information;

j) "Exit": Exit the measurement software.

2) Real-time data collection window (right side):

Real-time collected data is displayed in the coordinate axis; the column of "Parameters" can display the experimental information such as the X and Y axis coordinates, the experimental time and the number of collected data points.

B. Software operation

1) Open the software. In "Setting", select the appropriate serial port (COM1 or COM2), Y-axis gain, coordinate unit, and sampling point color;

2) Click "New" to create a new blank coordinate in the real-time data collection window;

3) Prepare the experimental sample in a warming or cooling process;

4) Click "Connect" to start collecting experimental data in real time.