

Superconducting Magnet Operation Manual

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STM experiments using superconducting magnet is time-consuming. Carefully consider the purpose and plan before starting the experiment.

Notice:

- Never rush during the experiment. Be slow and patient.
- There are no shortcuts. Never skip any steps to reduce time.
- Never change the tips and samples while the magnetic field is applied.

Even if you follow this instruction very carefully, the superconducting state with a large current can suddenly break into the normal state. That is called quench. If quenching happens, much of the He gas is released from the cryostat. Please be calm when the quench happens.

- Inform all members in the room to get out of the room to avoid suffocation.
- If the He gas is released into the air, instruments are rarely damaged. The instruments are still available after the quench.

Notice: To release the He gas from the He tank, do not forget to equip a pressure regulating valve to the output of the He tank in advance.

- If the pressure regulating valve is not used, high pressure is applied to the STM system. The STM chamber's stainless steel and copper tubes will be seriously deformed. In that case, STM and the cooling system will be unrepairable. Be careful!

1 · Operation at the largest magnetic field (9T)

Before starting the operation, ensure that the temperature is lower than the T_c of the superconducting wire and that the liquid Helium is enough (above 300 mm).

- I. Turn on the magnet power supply.
- II. Make sure that "HEATER" is ON (red light lighting). If not, press the "HEATER" button to turn it ON.
- III. Press the "SELECT" button to display the window for setting "RampRate." Input "RampRate" = 0.1 A/s and press "ENTER."
- IV. If the magnetic field is not displayed, press "TESLA" to change the displayed value from the current (A) to the magnetic field (T).
- V. Press "MAX" to gradually increase the magnetic field from 0 T to 9 T. Wait until the current rises to reach the maximum magnetic field.
- VI. Make sure the maximum value is reached. Wait for 1 minute. Then turn off the "HEATER". Now, the system is in the permanent current mode.
- VII. Wait for 3 minutes. Then, Press "ZERO". Wait until the voltage (and displayed magnetic field) drops to 0 V. Now, you can start the STM measurement. You can turn off the controller.

P.S. The temperature of the STM head may change by the HEATER of the superconducting magnet. It can cause thermal drift in STM measurements. Thus, step VI can be done slowly and patiently. Even if you set a high RampRate to let the voltage drop quickly, you should wait until the drift disappears.

Notifications for STM measuring under the magnetic field

Never press "HEATER" while measuring. It breaks the superconducting state. Huge resistive heat causes the rapid vaporization and expansion of He gas (this state is called quench). When quench occurs, the pressure of He gas rises rapidly. Thus, a pressure regulating valve at the helium tank (gas outlet) should be installed to release the gas. As the He gas can fill the room, get out of the room to avoid suffocation. If there is no pressure regulating valve, the He gas pressure will be directly applied to the STM chamber, and the STM will be damaged and unrepairable.

- Make sure that the liquid Helium is enough (above 300 mm).

Transfer enough liquid Helium before using the superconducting magnet. Or stop the measurement (turn off the magnet) to transfer more liquid Helium.

- **Never use the transfer rod to change the samples and tips while applying the magnetic field. The magnetic field is stronger beyond imagination.**
- **The tip will crash on the sample during the superconducting magnet operation (because the temperature increases). Retract the tip and the sample before operating the superconducting magnet.**

Instructions for ending the measurement

- **Do not switch “HEATER” to “ON” before step I.**
- I. Press “MAX” until the voltage (and displayed field) reaches the maximum (you can set “RampRate” = 0.5 A/s). You can press “TESLA” to change the displayed value from the current (A) to the magnetic field (T).
 - II. Wait for 1 minute after reaching the maximum voltage. Then, switch “HEATER” to “ON”.
 - III. Wait for 1 minute. Press “SELECT” and set the “RampRate” = 0.1 A/s.
 - IV. Press “ZERO”. Wait for the magnetic field to drop to 0 T.
 - V. Ensure that the magnetic field is 0 T, then turn the power “OFF” if it is not used anymore. If the power remains on, switch the “HEATER” to “OFF” (to save liquid Helium).

2. Operation at the intermediate magnetic field

Before starting the operation, ensure that the temperature is lower than the T_c of the superconducting wire and that the liquid Helium is enough (above 300 mm).

- I. Turn on the magnet power supply.
- II. Make sure that "HEATER" is ON (red light lighting). If not, press the "HEATER" button to turn it ON.
- III. Press the "SELECT" button to display the window for setting "RampRate." Enter "RampRate" = 0.1 A/s and press "ENTER."
- IV. If the magnetic field is not displayed, press "TESLA" to change the displayed value from the current (A) to the magnetic field (T).
- V. Use "SELECT" to call the window for setting "MidPoint". Enter the magnetic field you want to apply and press "ENTER."
- VI. Press the "MID". The magnetic field will gradually increase from 0 T to the set value. Wait for the magnetic field to reach the set value.
- VII. Confirm that the magnetic field reaches the set value. Then, wait for 1 minute. After that, turn the "HEATER" to "OFF". The system enters the permanent current mode.
- VIII. Wait for 1 minute again. Then, press "ZERO". Wait for the voltage (and displayed field) to drop to 0 V. After confirming that it reaches 0 V, you can start the measurement.

Notifications for STM measuring under the magnetic field

Never press "HEATER" while measuring. It breaks the superconducting state. Huge resistive heat causes the rapid vaporization and expansion of He gas (this state is called quench). When quench occurs, the pressure of He gas rises rapidly. Thus, a pressure regulating valve at the helium tank (gas outlet) should be installed to release the gas. As the He gas can fill the room, get out of the room to avoid suffocation. If there is no pressure regulating valve, the He gas pressure will be directly applied to the STM chamber, and the STM will be damaged and unrepairable.

- Make sure that the liquid Helium is enough (above 300 mm). Transfer enough liquid Helium before using the superconducting magnet. Or stop the measurement (turn off the magnet) to transfer more liquid Helium.

- **Never use the transfer rod to change the samples and tips while applying the magnetic field. The magnetic field is stronger beyond imagination.**
- **The tip will crash on the sample during the superconducting magnet operation (because the temperature increases). Retract the tip and the sample before operating the superconducting magnet.**

Instructions for ending the measurement

- **Do not switch “HEATER” to “ON” before step I.**
- I. Press “MID”. Wait until the voltage (and displayed field) gradually rises to the maximum (“RampRate” can be set as 0.5 A/s). You can press “TESLA” to change the displayed value from the current (A) to the magnetic field (T).
 - II. Confirm that the voltage reaches the maximum. Wait 1 minute and then turn “HEATER” to “ON”.
 - III. Wait for 1 minute again. Press the “SELECT” and set the “RampRate” to 0.1 A/s.
 - IV. Press “ZERO”. Waiting for the magnetic field to drop to 0 T gradually.
 - V. After confirming that it reaches 0 T, turn the power “OFF” if it is not used anymore. If you want to keep the power on, turn “HEATER” to “OFF” (to save liquid Helium).

3 · Change the magnetic field during the measurement.

- **Do not switch "HEATER" to "ON" before step II.**

- I. Turn on the magnet power supply.
- II. Press "MID". Wait until the voltage (and displayed field) gradually rises to the maximum ("RampRate" can be set as 0.5 A/s). You can press "TESLA" to change the displayed value from the current (A) to the magnetic field (T).
- III. Confirm that the voltage reaches the set value. Then, wait for 1 minute. After that, turn "HEATER" to "ON."
- IV. Wait for 1 minute again. Press "SELECT" and set the "RampRate" to 0.1 A/s.
- V. Use "SELECT" to call the window for setting "MidPoint". Enter the magnetic field you want to apply and press "ENTER."
- VI. The magnetic field will gradually change to the setting value. Wait for the magnetic field to reach the set value.
- VII. Confirm that the magnetic field reaches the set value. Wait for 1 minute. Then turn the "HEATER" to "OFF." The system enters the permanent current mode.
- VIII. Wait for 1 minute again. Then press "ZERO". Wait for the voltage (and displayed field) to drop to 0V gradually. After ensuring it reaches 0 V, you can start the measurement.

Instructions for ending the measurement

- **Do not switch "HEATER" to "ON" before step I.**

- VI. Press "MID". Wait until the voltage (and displayed field) gradually rises to the maximum ("RampRate" can be set as 0.5 A/s). You can press "TESLA" to change the displayed value from the current (A) to the magnetic field (T).
- VII. Confirm that the voltage reaches the maximum. Wait 1 minute and then turn "HEATER" to "ON".
- VIII. Wait for 1 minute again. Press the "SELECT" and set the "RampRate" to 0.1 A/s.
- IX. Press "ZERO". Waiting for the magnetic field to drop to 0 T gradually.
- X. After confirming that it reaches 0 T, turn the power "OFF" if it is not used anymore. If you want to keep the power on, turn "HEATER" to "OFF" (to save liquid Helium).