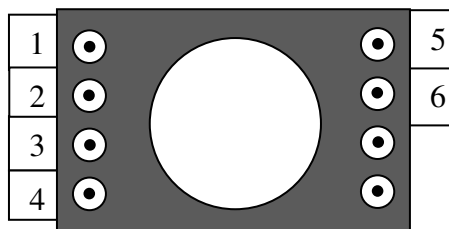
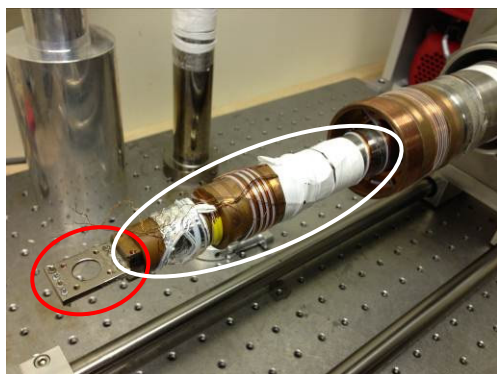


Operation notes for the ARS close-cycle cryostat.



1. Above left: sample holder (red circle) and cold finger (white circle) of the close-cycle cryostat; above right: schematics of the sample holder. Numbered pins are for electrical connection to a sample and the external measurement circuit. They correspond to the numbered BNC connectors on the external splitting box. The two unnumbered pins are reserved for a calibrated Lakeshore thermometer and should not be used for other purposes. When precise determination of the sample's temperature is required, the calibrated Lakeshore thermometer can be installed. Each of the three pairs: 1-2, 3-4, 5-6, is connected to a twisted pair of wires that go to the external measurement circuit. The twisted pairs help to minimize noise and inductive pickups. Whenever possible, use these pairs for source-drain, longitudinal and Hall voltage signals. Sometimes the gold wires wiring the sample to the pins may cross. Be careful to avoid shorting between the gold wires.

2. Before sample installation, carefully inspect the electrical connection pins to make sure that they are clean: the Teflon insulation between the pins and the metallic body of the sample holder should have no leftover silver paint, since it may cause a short circuit. When necessary, clean the pins and surrounding area with small tissue soaked in acetone **LOCALLY** (avoid exposing the entire sample holder to acetone). Sometimes gentle scratch with tweezers or a razor blade is necessary to remove dried stuff. After cleaning, make sure (by using a multimeter) that there are no electrical shorts between the pins and between the pins and the ground.

3. One option is to apply a small amount of rubber cement or high-vacuum grease (the grease will harden at low T and the substrate may detach or crack) in the middle (away from the electrical pins) of the sample holder, and place the substrate (with your sample on it) onto the sample holder. Gently press the substrate to make it attached to the sample holder nicely. Make sure the substrate is properly aligned with the sample holder, so that it will not get in the way of the radiation shield that will be installed at a later stage.

4. Connect gold wires from your sample to the pins using silver paint (ultrasonicate the silver paint bottle well before use). Make sure that silver paint does not overflow to cause a short circuit. Make sure that the free ends of the gold wires are short enough and do not touch

anything. Make sure that crossing wires are not touching each other. Wait for a few minutes for silver paint to dry.

5. Rotate the whole cryostat to correct position: when making measurements using the electromagnet, sample needs to be in a specific orientation with respect to the magnetic field; when doing optical experiments, sample needs to be aligned with your optical components accordingly. To do that, loosen the four nuts that keep the cryostat in position on the base rack and gently rotate it to the desired orientation, then re-lock the four nuts evenly until the cryostat is secured. Do not over-tighten the nuts. Finger-tightening plus $\frac{1}{4}$ to $\frac{1}{2}$ turns of further tightening with a wrench should be sufficient.

6. Connect the measurement circuit (connecting BNC cables from the splitting box to instruments) and make sure that both the sample and the measurement setup are functioning properly. If problems occur (short circuit, open circuit, etc.), diagnose and fix them.

7. Install the radiation shield. Slide the shield slowly and coaxially onto the cold finger. Make sure that it does not bump into the sample holder. Do not over-tighten the shield.

8. Install the outer jacket. Carefully inspect the two O-rings at the base of the cryostat and make sure they are clean and properly oiled with a high-vacuum grease. Slide the outer jacket slowly onto the cryostat. When the jacket is about to meet the O-rings, gently push it until it is in secure contact with the base area of the cryostat (NOTE: the pumping valve must be open to allow the air in the chamber to go out as the jacket is being pushed). Rotate the jacket to a correct position: when making measurements using the electromagnet, the wide side of the front rectangular part of the jacket should be parallel to the surface of the magnet poles; when doing measurements involving optics, use the optical outer jacket: the optical windows of the jacket need to be facing the optics.

9. Check again that the sample functions properly.

10. Install all necessary vacuum parts: pumping line, vacuum gauge, etc.



11. Close the pumping valve (marked in the picture above, shown as open). This is to prevent a sudden rush-out flow of air when the pump starts. Such a flow may ruin the wiring of your sample.



12. Make sure the venting valve on the back side of the pumping station is closed (marked in the picture above).



13. Turn on the pumping station power. Select parameter 309 by pressing the right pointing triangle soft button on the control panel (see picture above). This parameter gives the actual rotation speed of the turbo pump and should be 1,500 Hz during normal operation.

14. Start pumping by pressing the soft button marked in the above picture. After 2 to 3 seconds, slowly open the pumping valve (again, to avoid a sudden gas flow). The turbine will spin up steadily if everything is fine. In a steady normal operation, the control panel indicators should look like that shown at the picture above: an actual speed of 1,500 Hz with the green LED on.

15. Sometimes when the pumping station is not used for a long time, there could be water vapor accumulated inside. If this is the case, the pumping station will not function properly: the pressure will go down very slowly and the turbo will not be able to reach the maximum speed. If there is too much accumulated vapor, the pumping station will shut down automatically after about 15 minutes. To remove the accumulated water vapor, slide down the gas ballast valve (indicated in the picture below) and leave it open for the initial pumping phase (~ 15 to 30 minutes), until a normal pumping operation is reached (pressure steadily going down). After that,

close the valve. In the normal situation, when the pumping station is not used, this valve should remain closed (slide upwards to close).



If after 10 minutes of pumping with the gas ballast valve opened, the maximum rotation speed (1,500 Hz) still cannot be reached, and/or the pressure reading goes down too slowly, it means there may be a leak in the system. If this occurs, stop pumping and fix the leak.

16. Wait until the pressure is below 10^{-3} Torr (typical waiting time ~ 40 min). The pump should be left working.



17. Start the cryostat. Above left: compressor for the cryostat; above middle: water cooling unit for the compressor. The two units are electrically coupled in series, so that the power switch on the water cooling unit (marked) turns on and off both units. The power switch on the compressor should be left “ON” all the time (even when not being used). The system requires a special power outlet: a marked power outlet can be found on the aluminum electrical supply post near the water cooling unit in FO-210 (pictured above).

18. At normal operating conditions, the pressure in the cryostat chamber should drop below the measurable range of the orange *Edwards* vacuum gauge soon after the cooling starts. In addition, the outer jacket of the cryostat should be close to room temperature. If it feels cold to touch or sweats in humid days (water condensation), this means the chamber vacuum is soft (either due to leaks or initial pumping is not good enough) and needs to be improved before proceeding further.

19. Without any external temperature control either by the Lakeshore unit or the LabVIEW data acquisition program, it usually takes around 70 minutes for the system to reach the base temperature (~ 7 K if the opening on the radiation shield is covered with a metal foil; if the opening is not covered (such as in optical measurements), the base temperature will be higher).

20. Temperature control using the *LakeShore* unit.



If measurements need to be performed at certain temperature, this can be done by setting T from the front panel of the Lakeshore unit (shown above). Press “Setpoint” button (yellow circle), key in the desired temperature, and press “Enter”. Press “Heater range” (red circle) and choose High to turn on the heater. Press “Heater Off” to turn off heating. For more advanced functions, please refer to the original “Lakeshore Model 331” manual. (Data acquisition using the LabVIEW program as well as control of the electromagnet and temperature can be found in separate technical notes.)

21. Warming up procedure:

If upon finishing your measurements the system is below room temperature, it should be first warmed up to room temperature before turning the pump off. This can be done in different ways. For fast warming, simply turn off the cryostat by flipping the power switch of the water cooling unit to OFF. Set the target temperature on the Lakeshore control unit to room temperature and the heater range at “high”. Leave the pumping station on. Wait for the inside of the cryostat to warm up to room temperature. Be aware that fast warming may permanently damage the sample. To slowly warm up the system, leave the cryostat operating and sweep temperature up slowly under the control of Lakeshore (sweeping rate can be set in Lakeshore’s control panel). During the sweep, the heater range should be set to “high”.

After the temperature reading comes close to room temperature, and the heater output is around only a few percent, keep the pumping station run for at least another hour. After that, close the pumping valve and watch for the outer jacket of the cryostat for a few minutes. If water condensation occurs (this should be very unlikely at this point), it means the interior of the cryostat is still too cold. In this case, slowly open the pumping valve and keep the pump on for some additional time, then repeat the check again until no water condensation appears. Next, close the pumping valve and shut down the turbo pump. After the turbo stops spinning, shut down the pumping station.

At this time, even though the sample holder is at room temperature, most of the colder finger is still too cold (the temperature reading on Lakeshore only indicates the temperature around the sample holder, where thermometer and heater are installed) to be exposed to the atmosphere. Leave the system to warm up for 5 to 6 hours with the heater on and set to “high” before venting the chamber.