Custom Designed UHV Compatible He-3 Cryostats

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We have developed two custom designed bottom loading He-3 cryostats with sample in UHV space for basic research. The first cryostat is a single-shot, bottom loading system for Scanning Tunnelling Microscopy (STM) applications with a number of design enhancements. The second cryostat is a continuous flow system with relatively high cooling power that is developed for sub-K Angular Resolution Photoemission Spectroscopy (ARPES). Design and performance details will be discussed.

1. Janis Model HE-3-BLSUHV-STM
Custom designed He-3 cryostats with sample in UHV space continue to play an important role in basic research, and we report two such systems with novel features. The first system is a Janis Research next generation model HE-3-BLSUHV-STM bottom loading He-3 system for STM with sample in UHV space as shown in the first figure. It incorporates the following design enhancements for improved performance and ease of use as compared with the previous generation.

1.1. "Helium-only" dewar and its UHV compatibility
A "helium-only" dewar (no LN2) with four aluminum floating radiation shields was developed for this system in order to completely eliminate the vibrations associated with boiling liquid nitrogen. Two of the radiation shields are vapor cooled while the other two are conductively cooled. Copper tubes are epoxied onto the outer wall of the vapor cooled radiation shields and cold helium gas from the main helium reservoir passes through the copper tubes and cools down the radiation shields before it vents outside the cryostat. An independent "isolation" helium reservoir (HE-4-II) separates the main helium reservoir (HE-4-I) from the UHV space. Multi layer insulation (MLI) can thus be installed on the four radiation shields, which greatly reduces the room temperature radiation heat load onto the cryostat. This feature is necessary for the "helium-only" type of cryostat. The magnet is installed in the main helium reservoir which is not part of the UHV space, and the user can bake the UHV space with the magnet submerged in liquid nitrogen and well protected.

1.2. Alignment.
A self-contained UHV compatible He-3 insert is included in the system and with care taken to guarantee good alignment for this long He-3 insert. A custom made adjustable aligning mechanism is installed at the top of the insert to correct the tilting of the He-3 insert. UHV compatible Be-Cu finger stocks are attached to the radiation cold plates to ensure good alignment of the guide tube on the He-3 insert. Two sets of adjustable concentricity spacers are installed at the top and the bottom of the HE-4-II helium reservoir. Last but not the least, the lower section of the He-3 insert is supported from the
upper section (mainly the radiation baffles) by three threaded rods, which can be adjusted to achieve good alignment of the He-3 insert lower section.

![Diagram of the cryostat](image)

**Figure 1. Model HE-3-BLUHV-STM Cryostat**

1.3. Bottom loading shutters
The cryostat bottom flange is designed to mate with a user supplied UHV sample preparation chamber, and the user can then lower the He-3 insert and STM into the UHV chamber for sample change via an integrated linear motion manipulator. Three pairs of cooled (custom made Be-Cu) spring loaded radiation shutters (shown in Figure 2) are installed on the cryostat at several critical flange locations, with temperatures of approximately 7K, 95K, and 180K respectively. The shutters are pushed open by the wedge-shape bottom of the 1K radiation shield during sample exchange, and then close automatically when the He-3 insert is returned to the experimental position.
1.4. Performance
The system reaches a base temperature of less than 300mK, and holds for 120 hours at the base temperature (see Figure 3). It can also be operated with no pumping at the 1K pot after the system reaches the base temperature, which turns the whole system into a vibration-free cryostat.

2. Janis model HE-3-UHV-CF
The second system is a Janis model HE-3-UHV-CF bottom loading, UHV compatible, continuous flow He-3 cryostat developed for sub-K Angular Resolution Photoemission Spectroscopy (ARPES) as shown in Figure 4.

The continuous flow He-3 system includes a UHV compatible He-3 insert (with 1K pot, He-3 condensing impedance, and He-3 pot) and an external gas handling system. The He-3 insert is installed inside a liquid nitrogen shielded helium dewar, and all the surfaces inside the dewar are UHV compatible. The gas handling system includes the cabinet with gas dumps, the operating valves, the connecting hoses, etc., as well as an Alcatel RSP601/2063H1 hermetically sealed pumping station, which includes an Alcatel RSV601B water cooled Roots pump and 2063H1 rotary vane pump. The pumping station is used to continuously pump on the He-3 and generate a relatively large permanent cooling power to match the room temperature radiation heat load at the sample. The returning He-3 gas is condensed in a heat exchanger that is located inside the 1K pot before it enters the He-3 pot.

A special sample positioner is provided with the system and it is equipped with separate motorized linear motion manipulators along X-, Y-, and Z- directions, as well as a rotational stage. The He-3 pot and the cold finger are located in vacuum and require a long time to cool down from room temperature. A self-contained pre-cooling assembly was thus designed to reduce this cool down time.
This includes a copper coil inside the helium reservoir and a copper pot on the He-3 reservoir. Nitrogen (or helium) gas is introduced into the assembly at atmospheric pressure during the liquid nitrogen temperature pre-cooling (or liquid helium temperature cooling). The gas gets partially liquefied inside the assembly, drips down into the warmer He-3 pot, and evaporates. This convection process inside the assembly dramatically reduces the cool down time of the He-3 pot.

A calibrated Cernox sensor, installed at the bottom of the cold sample mount, measures a temperature of 850mK, while facing the slot which allows room temperature radiation to fall directly at the cold finger. Additional heating power was applied on the He-3 pot, and results are as shown in Figure 5.

Figure 5 Cooling power of HE-3-UHV-CF He-3 system