Application Note: Ultra-High Vacuum System

What pressure is "ultra-high vacuum"?

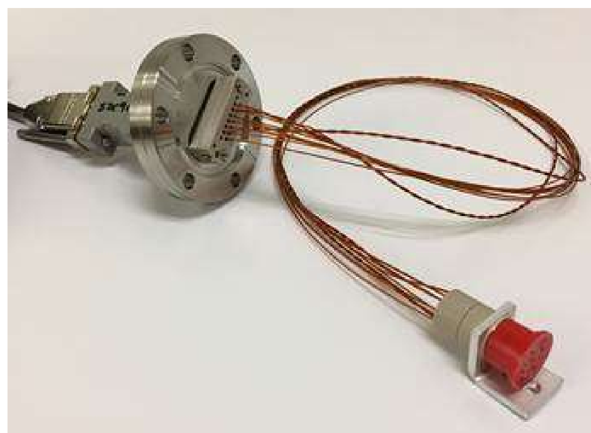
By convention, ultra-high vacuum (UHV) means pressures below 10^{-5} Pa, which is roughly 10^{-7} torr, 10^{-10} bar, and 10^{-10} atm.

What is special about ultra-high vacuum?

Achieving and maintaining UHV requires special vacuum system design and equipment, careful attention to cleaning and operating procedures, and the use of some special low-outgassing materials. Most conventional plastics and dielectrics outgas too much for use in UHV.

What is different in Amptek's UHV product?

For Amptek's products, the X-ray detector module (including the detector and input JFET on a thermoelectric cooler (TEC)) is mated directly to a preamplifier circuit board. But the materials used in the printed circuit board and the standard connectors are not low outgassing. The X-ray detector module is quite suitable for UHV but the preamplifier board and its connectors are not.



Amptek UHV system, shown to the right, uses the FASTSDD® (which includes the detector, the thermoelectric cooler, and an ASIC charge amplifier) inside the vacuum chamber, attached to a heat sink. It uses a wiring harness and connectors with low outgassing dielectrics. The printed circuit board with the rest of preamp (with filter circuits and a buffer amplifier) is on the flange, outside the vacuum chamber. BNC and LEMO cables connect the preamp to the PX5 signal processor.

Amptek makes each wiring harness to order so that the length can match the customer's needs. The customer needs to provide a good thermal path between the heat sink and ambient.

How long can the cable be between the flange and the detector?

When a user asks "How long can I make it," we respond "How short can you make it?" Shorter provides the best performance. Most Amptek UHV products use 30-40 cm cable lengths and work quite well. They can be made 1 or even 2 meters but the system will be more susceptible to interference, risetimes may be affected, and other performance loss is possible. The closer the charge amplifier is to the filters and to the buffer amplifier, the better.

- **Using longer cables increases susceptibility to interference.** There is no specific maximum length at which EMI is a problem; it depends very much on the system, on the noise sources and grounding and such. Please refer to Amptek's application note "Grounding and shielding in Amptek products" for advice.
- **Using longer cables reduces the voltage applied to the TEC, decreasing cooling.** This arises from ohmic losses in the cables. A 2 meter cable typically leads to a 5K increase in detector temperature, for the same heat sink. Amptek can customize a PX5 to compensate.

What heat sinking is recommended?

The thermoelectric cooler (TEC) can generate a maximum ΔT of about 85°C; the SDD chip inside the detector module will be up to 85°C cooler than the heat sink attached to the back of the detector module. This occurs at 3.5V across the TEC, where it draws 0.35A for about 1 watt dissipation.

When Amptek's spectrometers are used in air, convection helps cool the system. In vacuum, the user must provide a good thermal path between the heat sink on the detector (the small aluminum bracket) and ambient, capable of dissipating 1 watt with minimal thermal rise.

Note that 1 watt is dissipated at maximum cooling; if the heat sink is at 25°C, the detector can cool to about 215K. But the performance is largely unchanged below 235K; if you raise the set point to this, the TEC will dissipate considerably less power and stabilizing the detector temperature often improves spectroscopic results. The exact optimum will depend on your thermal system design.

Can Amptek detectors sustain repeated cycling from vacuum to atmosphere?

Most UHV systems remain under vacuum, to avoid contamination, but Amptek's detectors can certainly withstand thousands of vacuum cycles.

Are there special precautions that should be taken?

One special concern in vacuum systems is that, when the system is vented, any debris in the vacuum chamber can be blown at a high velocity; any high velocity debris or dust particles striking the detector window may break it (the C1 and C2 windows are more susceptible than Be windows). We recommend placing a sintered filter on the incoming air and maintaining a clean chamber. Because UHV systems are quite clean, this is less a concern for UHV applications than for standard vacuum chambers.

C1 and C2 windows

- The C1 and C2 windows, using very thin Si_3N_4, are more susceptible to damage than are Be windows. They are not damaged by vacuum cycling but can be damaged by debris.
- The C2 window is not light tight; the SDD is a very sensitive photodiode, so any light in the chamber will induce a photocurrent, leading to shot noise and degraded performance.
- The C2 window is epoxied to the cover so is not helium-tight; helium will leak into the detector and its pressure will degrade cooling performance.

Windowless detectors

Amptek can provide windowless detectors, which have the very highest sensitivity at the lowest energies. These are particularly susceptible to damage by contamination or debris so special precautions must be used. Fortunately, the needed precautions are often met in UHV chambers so the windowless detectors are common in UHV systems. There is a separate application note describing the use of windowless detectors.

Other questions

What materials are inside the chamber?

- The wires use a Kapton dielectric. The connectors (at the flange and behind the detector module) use PEEK.
- The detector module has a nickel cover, welded to a Kovar header, with Be or C1/C2 window.