

XP Camera Technology

Lifetime Vacuum... Guaranteed

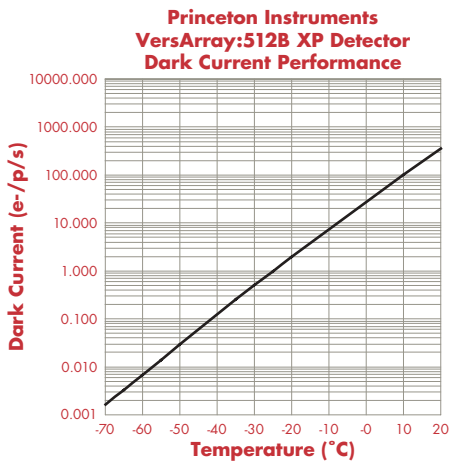


Figure 1. Dark current is inversely proportional to temperature. (Data for a back-illuminated CCD with XP cooling technology.)

New XP cameras from Princeton Instruments are the only deep-cooled, CCD-based systems in the world that provide guaranteed high-vacuum performance for the entire working lifetime of the detector. Exclusive XP technology is available in both the Princeton Instruments VersArray® (imaging) and Spec-10® (spectroscopy) product lines. Dark current rates of 0.001 to 0.002 e-/p/s, along with system read noise as low as 2.5 to 2.6 e- rms, assure all XP users truly superb sensitivity.

The Need to Be Cool

The classic struggle to minimize dark current in high-performance CCDs is well known. Thermally generated dark current, which grows linearly as pixel area increases, is inversely proportional to temperature (see **Figure 1**). As a rule of thumb, it is halved for every 5 to 7°C of additional cooling. Keeping a detector's dark current — and associated dark noise — low is one of the elements critical to the success of scientific imaging and spectroscopy applications.

Cool Then, Cool Now

Historically, several methods have been available to achieve deep cooling, such as the use of thermoelectric devices, liquid nitrogen, or external cryogenic compressors. Of these techniques, thermoelectric cooling offers the most convenience — but only if designed and implemented properly.

Presently, there are several other manufacturers offering cameras that claim -70 to -90°C cooling. However, these systems must employ forced circulation of water as cold as +10°C to achieve it. The additional requirement for external water circulation (see **Figure 2**) eliminates the biggest benefit of thermoelectric cooling — convenience. Moreover, a +10°C water supply is not particularly common in a typical lab setting. Even when it is available, cold water can lead to unwanted problems (e.g., condensation).

So, when Princeton Instruments engineers set out to design a robust, deep-cooled detector, the goal was clear:

“Provide 100% air-cooled systems that offer the low temperatures required for scientific imaging and spectroscopy. Make sure the camera’s vacuum never fails!”

The Vacuum

To achieve deep cooling, a world-class vacuum chamber needed to be designed to house the CCD. The contents of the vacuum chamber had to be minimized to keep the thermal load and out-gassing as small as possible. An innovative “getter” material was used to absorb any residual out-gassing, albeit minute, that might occur over time. The XP design also called for customized UHV (ultrahigh vacuum) components made of stainless steel. Additionally, the metal-glass interface between the chamber and the input optical window was brazed, hermetically sealing the entire detector (see **Figure 3**).



Figure 2. Be wary of “deep cooling” claims in the marketplace. Often, in addition to a Peltier device, a bulky, chilled-coolant circulator — like the one shown above — is needed to guarantee cited specifications. XP technology, however, does not require any external assistance to achieve its deep cooling.

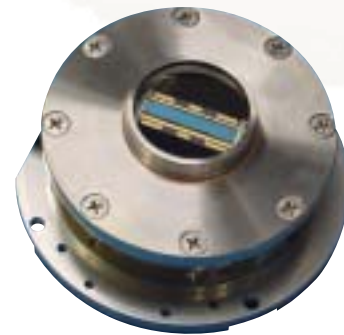


Figure 3. Hermetic vacuum seal in an XP detector.

Next came the thermoelectric cooler itself. Princeton Instruments engineers worked to create a Peltier device that would keep the CCD at a very low temperature while also stabilizing a “control” point to minimize the variation in dark current. Princeton Instruments addressed these criteria by designing a “feedback” circuit that can provide ±0.05°C stability across a wide temperature range (+20 to -85°C for Spec-10 XP models; +20 to -70°C for VersArray XP models).

XP Cooling Technology

Manufacturing Prowess

While designing the world's best CCD vacuum technology involved overcoming a number of formidable challenges, all the hard work would be for naught if the XP detectors could not be manufactured reliably. Fortunately, years of manufacturing experience at Princeton Instruments made this task a relatively easy endeavor, even though the process is actually quite complex.

For starters, all vacuum parts are stored in special, "dry" containers until they are handled (see **Figure 4**). The vacuum processing is done using oil-less "molecular" pumps. During vacuum processing, which is one of the longest steps in the detector assembly, the seals are continually checked for leaks. Once assembled, every XP detector undergoes a strictly defined, comprehensive inspection to ensure that rigorous specification limits are met. This process ensures the best performance and reliability available on the market today.



Figure 4. XP detector being assembled at Princeton Instruments' state-of-the-art manufacturing facility.

About Princeton Instruments

Over the past two decades, Princeton Instruments has been the leading pioneer of high-performance detection systems for digital imaging and spectroscopy. Princeton Instruments' innovations include the world's first spectroscopy camera to use a photodiode array (and later, the first to use a CCD), as well as the introduction of the first high-performance, gated, intensified CCD camera. In addition to breaking new ground in the field of spectroscopy, Princeton Instruments has also designed the highest-sensitivity CCD cameras available for scientific imaging applications (read noise of approximately 2 e⁻ rms with quantum efficiency eclipsing 90%).

Today, Princeton Instruments continues to expand the boundaries of technology:

- High-frame-rate, gated, intensified CCD cameras (PI•MAX®)
- Integrated, state-of-the-art Programmable Timing Generator™ (PTG)
- Latest plug-and-play data interfaces (USB 2.0)
- **Guaranteed lifetime vacuum (XP platform)**
- Thermoelectric cooling to -100°C without liquid assistance (XTE platform)
- InGaAs detectors with sensitivity to 2.2 μm (OMA ∇™)

The Basics

Dark current, which is typically specified in electrons per pixel per second, arises from thermal energy within the CCD's silicon lattice. Over time, electrons are created that are independent of the light falling on the detector. These electrons are captured by the CCD's potential wells and counted as signal.

Additionally, this increase in signal carries a statistical fluctuation known as **dark noise**. CCDs can be cooled thermoelectrically (e.g., via the Peltier effect) or cryogenically (e.g., with liquid nitrogen) to minimize the dark current rate. Ideally, the dark noise should be reduced to a point where its contribution is negligible over a typical exposure time.

The **Peltier effect** is the transference of heat in the opposite direction of current flow. By pumping current through a "Peltier stack" attached to a CCD, heat can be removed from the detection device. (A heat sink attached to the Peltier stack is cooled by circulating liquid or air.) The temperature is typically regulated by a feedback circuit that involves a thermocouple readout as well as current control.