

ProEM

Frequently Asked Questions

1. What is ProEM?

ProEM is the latest EMCCD camera platform from Princeton Instruments launched in January 2009. Currently two models -ProEM: 512B (512x512) and ProEM: 1024B (1kx1k) are available.

2. What are the salient features of ProEM?

ProEM is the highest performance EMCCD camera on the market. It features the most advanced low noise electronics, precise timing and ultra deep cooling required for challenging low light, high frame rate as well as steady state imaging and spectroscopy applications

- **XP vacuum technology:**
 - All metal, hermetic vacuum seals
 - No epoxies or o-ring seals used that degrade vacuum/cooling over time
 - Permanent vacuum guarantee
 - Metal-to-glass brazing is used to attach the vacuum window
 - Thousands of cameras in operation around the world
- **Advanced thermal design:**
 - TE cooling down to -95°C (-70°C guaranteed for life)
 - Cooling by air or liquid or both.
 - When using liquid cooling, turn off fan permanently to reduce vibration.
 - Thermostating precision of +/- 0.05°C
- **OptiCAL™**
 - Linearized, self-calibrated electron multiplication gain via built-in precision light source
 - User accessible for field calibration
- **PINS™ (Princeton Instruments Noise Suppression technology)**
 - Lowest read noise in both EM and Non-EM readout ports
 - EM Mode
 - ~25 e- rms @ 5MHz (best in the industry!)
 - ~50 e- rms @ 10MHz
 - Non-EM (Traditional) readout
 - ~2.5 - 3 e- rms @ 100 kHz (best in the industry!)
 - ~6 e- rms @ 1MHz (best in the industry!)
 - ~10 e- rms @ 5MHz (best in the industry!)
- **Gigabit Ethernet data interface**
 - High bandwidth data transmission

- Operate camera from more than 50 m (150 ft) away.
- **All digital design**
 - Independent signal paths to optimize performance of each port and readout speed.
 - The most comprehensive testing protocols to optimize multiple performance parameters at the same time.
- **Integrated shutter**
 - 25 mm integrated shutter for vignette free operation *or*
 - ability to directly drive an external shutter (no need for external shutter drivers)
- **Comprehensive Software support**
 - Use the renowned WinView/Spec under Windows 2000/XP
 - LabView SITK (Scientific Imaging Toolkit) with pre-defined Vis.
 - PVCAM universal interface for custom programming

3. How can ProEM achieve such low noise?

ProEM uses PINST™ technology-the most advanced electronics of any CCD or EMCCD camera on the market today. It minimizes the electronic noise so that the ultimate noise performance is only limited by what the sensor can offer. Every readout port, speed is individually optimized for the best performance. The result is the noise performance is as much as 2x better than any competing designs in the industry. Now, you can see even the faintest of low light samples with clarity.

4. Why does ProEM offer slow speed such as 100 kHz readout?

The main benefit of EMCCDs is their ability to achieve <1 e- rms noise at high frame rates. However, the use of multiplication or amplification causes excess noise which reduces the overall signal-to-noise ratio by a factor of 1.4. This might be acceptable for applications that require high frame rate (e.g., >30 fps) and have light levels below the read noise. However, for steady state applications that rely on very long exposures (e.g., seconds to minutes), the normal readout port offers the best SNR possible. Especially, the slowest readout rate such as 100 kHz allows read noise of $\sim 2.5 - 3$ e- rms to be achieved which is close to the limits of the sensor preamplifier sensitivity.

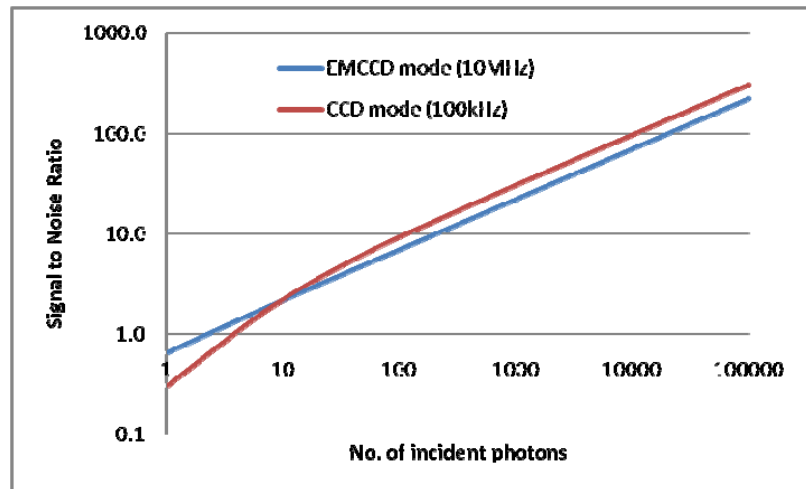


Figure: Comparison of SNR in Non-EM (100 kHz) and EM (10MHz) readout modes. Non-EM mode is ideal for slow speed imaging applications and offers higher signal to noise ratio

5. Any EMCCD camera achieves < 1 e- rms read noise with EM gain applied. Then, what is the advantage of lower read noise in ProEM?

It is true that all EMCCD cameras can achieve 1 e- rms read noise with EM gain applied for single photon sensitivity. However the amount of gain applied varies with the starting read noise of a given camera. For example, ProEM achieves the lowest read noise of 25 e- rms (@ 5MHz) in EM mode which is as much as 1.7x better than other EMCCD cameras. It requires only 25x EM gain to achieve 1 e- rms read noise. It is better as little gain as possible for the following reasons

- Lower EM gain degradation
- Preserve dynamic range –capture low light signals while preventing saturation of bright areas in the image.

6. What is OptiCAL™?

It is a method to calibrate the absolute electron multiplication (EM) gain of the ProEM camera. User can vary the real EM gain in precise linear steps. ProEM has a built-in, precision light source built in the nose of every camera for fast, precise calibration. Since the calibration is user accessible, it can be performed in the field without need for external light sources.

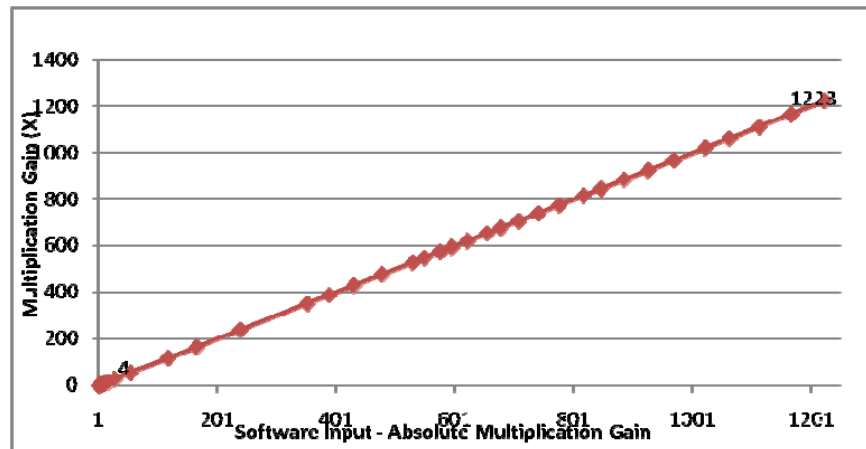


Figure: OptiCAL™ allows users to set the EM gain in absolute linear steps.

7. How can PI guarantee lifetime vacuum?

Princeton Instruments is the first and only company to guarantee lifetime vacuum performance. PI developed XP vacuum technology after years of research into ultra high vacuum (UHV) designs and production equipment. It involves eliminating materials that can cause out-gassing (slow release of gas molecules over time) and all-metal seals. In fact, even the vacuum window is brazed (brazing is a high temperature process by which two dissimilar materials are fused at molecular level). Each vacuum chamber undergoes a long vacuum process for more than five days and checked and rechecked with sensitive leak detectors to make sure that the seals are perfect. Only through such extensive experience and advanced facilities, a company can guarantee lifetime performance of its vacuum and cooling. Thousands of cameras based on this technology (PIXIS, PhotonMAX and XP cameras) that are already in the field are a testament to the PI's research, design and production capabilities.

8. What frame rates can be expected from ProEM?

ProEM offers 10MHz EM readout port for high frame rate applications. It can achieve >34 fps at full resolution (512x512) and >1000 fps at reduced ROI and binning. It has variable vertical shift rates and custom chip readout modes to further increase the frame rates by as much as 2x to 4x from standard ROI/binning modes. For full frame rate information, please refer to the datasheet.

9. What is "custom chip" mode?

"Custom chip" mode allows users to redefine the size of the active area right from the software. By ignoring the pixels outside the active area, the readout time is reduced. As a result, the

frame rate can be increased from the standard operation by up to 2 to 4 times when only a small region needs to be imaged. In order to effectively use the “custom chip” mode, the area outside the active area must be externally blocked from light. The following graph provides sample frame rates that can be achieved by ProEM: 512B at 10MHz readout speed using both standard and custom chip readout modes.

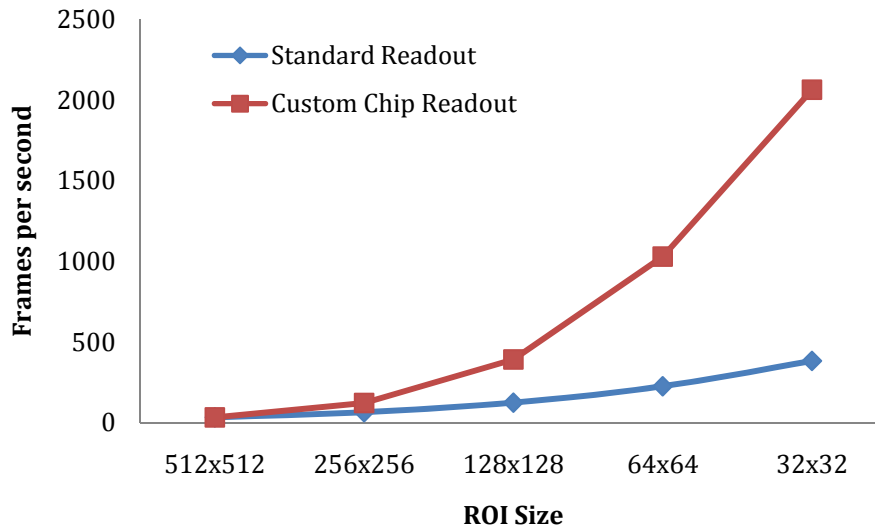


Figure: Frame rates of ProEM: 512B (10MHz) in standard and custom chip readout modes

10. What Binning modes are supported in ProEM?

ProEM has full flexible binning in Y-direction. In X-direction, it has 1x, 2x, 4x, 8x, 16x and 32x in X-direction.

11. What are the mounting options available for ProEM?

ProEM comes with an adjustable c-mount –ideal for getting the best focus with lenses or ensuring par-focality on microscopes. To attach F-mount lenses and optical equipment, a C-to-F mount adapter is available.

12. What is the purpose of integrated mechanical shutter?

ProEM uses frame transfer EMCCDs, which do not require mechanical shutter for normal operation. However, an integrated mechanical shutter can be used conveniently to capture

reference dark images, to protect the sensor from debris or dust and during EM gain calibration procedure.

13. What types of cooling options are available for ProEM?

Every ProEM camera provides both air and liquid cooling options. Air cooling is provided by the integrated fan while the liquid assist can be provided by an external circulator.

14. What are the advantages of liquid (only) cooling option?

The innovative thermal design of ProEM allows users to turn off the fan completely and cool the detector using circulating liquid in vibration or heat sensitive environments. The liquid only cooling option has the following benefits

- Removes vibration from the camera head
- Eliminates thermal air currents that would cause smear from sensitive optics such as telescopes and microscopes.

By using a liquid circulator, the temperature of the CCD is maintained without adverse effects of internal fan. In addition, if liquid chillers are used with sub ambient liquid circulation, much deeper temperature can be achieved.

Ability to turn off fan completely is superior to other options such as -temporarily shutting off fan as the latter could compromise temperature stability –a critical requirement for EMCCDs. As a result, when extended integration times or long sequences are captured

15. What type of vacuum window is used in the camera?

The standard vacuum window is a 3.17mm (0.125”) fused silica window. ProEM uses only one window in the light path that can be anti-reflective coated for the best throughput.

16. What are the options for AR coating the vacuum window?

UV, VIS and NIR anti-reflective AR coatings are available for the standard fused silica window. Following graph gives a comparison of transmission of windows with various AR coatings. MgF₂ window is available for deep UV applications. *IMPORTANT NOTE: The AR coatings are designed to give optimal performance over a specified wavelength region. However, outside this region, they may have much worse performance even compared to an uncoated window. So, care must be taken when specifying the AR coatings.*

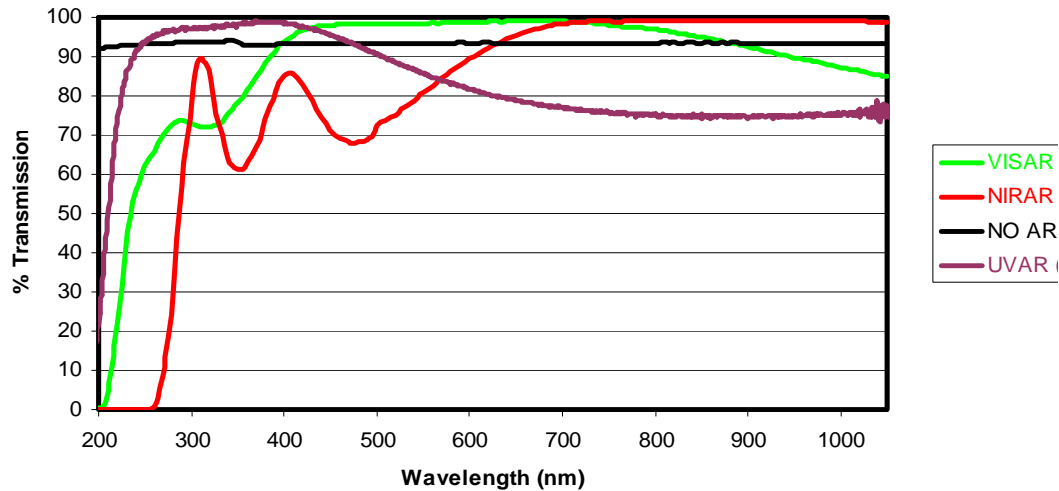


Figure 2: Available AR coating options for the vacuum window

17. What do I need to operate the ProEM camera?

ProEM comes with everything needed to run out of the box. It comes with c-mount w/shutter, power supply, gigabit Ethernet cable, gigabit Ethernet card and trigger cables. Users require a PC with XP (32-bit, SP3) or Vista (32-bit) operating system to run the camera. For enhanced performance, a fast hard drive (10,000 rpm) and 2GB RAM is recommended.

18. I need to operate the camera remotely. What are the options?

ProEM, with its GigE data interface, can be remotely operated from up to 50m or 150ft over standard Cat 5e/6 cables. For even longer distances, GigE-to-fiber optic converter boxes may be available that can extend the range to > 1km. Please contact factory for additional details.