ProEM™ EMCCD Camera System

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Princeton Instruments

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Chapter 1

Introduction

Thank you for purchasing a ProEM EMCCD camera system from Princeton Instruments. Your system has been thoroughly tested to meet Princeton Instruments' exacting standards and to meet the demanding requirements of many low light level imaging applications.

Please read the manual carefully before operating the camera. This will help you optimize the many features of this camera to suit your research needs.

ProEM™ Cameras

The new ProEM™ cameras feature on-chip multiplication gain, a technology that enables the multiplication of photon generated charge right on the CCD. This approach offers an effective alternative to traditional ICCD cameras for many non-gated, low-light applications.

The ProEM:512B features square, 16 x 16 µm pixels in a 512 x 512, frame-transfer format. The ProEM:1024B incorporates a larger 1024x1024, 13 um pixels frame transfer CCD. The back-illuminated EMCCDs with dual amplifiers ensure optimal performance not only for applications that demand the highest available sensitivity but also for those requiring a combination of high quantum efficiency and wide dynamic range. Deep thermoelectric cooling and state-of-the-art electronics are employed to help suppress system noise. The cameras can be operated at 10 MHz for high-speed imaging or more slowly for high-precision photometry. Supravideo frame rates are achievable via subregion readout.

EMCCD Technology and On-Chip Multiplication Gain

The principal difference between an electron-multiplying CCD (EMCCD) and a traditional CCD is the presence of an extended serial register in the new device (see Figure 1). Electrons are accelerated from pixel to pixel in the extended portion of the serial register (also referred to as a multiplication register) by applying higher-than-typical CCD clock voltages. This causes secondary electrons to be generated in the silicon by impact ionization. The degree of multiplication gain is controlled by increasing or decreasing the clock voltages for this register (gain is exponentially proportional to the voltage). Although the probability of generating secondary electrons is fairly low (typically 0.01 per stage), over the large number of stages of a typical multiplication register, the total gain can be quite high.

This technology combines the ease of use and robustness of a traditional CCD with the gain capabilities of an intensified CCD in a single device. The combination of this technology with frame-transfer readout makes the ProEM cameras excellent choices for experiments where fast framing and low light sensitivity are required.

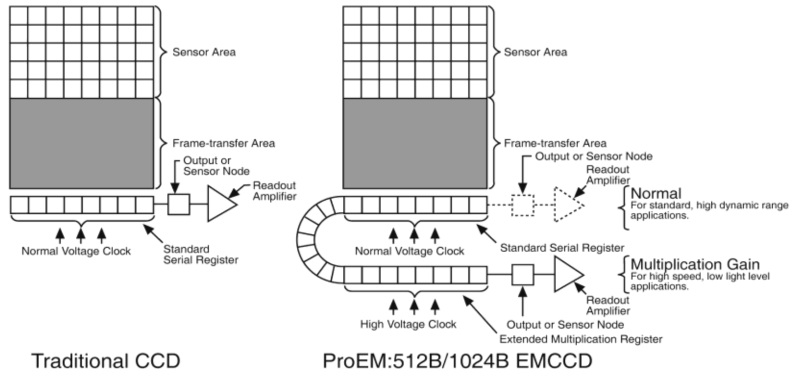


Figure 1. Comparison of Traditional CCD and ProEM EMCCD Array Structures

Note: As the on-chip multiplication introduces additional noise, it is recommended that the multiplication be used only as required. For more information, refer to the "On-Chip Multiplication Gain" technical note. This technical note can be accessed by going to the Princeton Instruments web site at www.princetoninstruments.com.

Integrated Controller

The operation of the ProEM camera is regulated by its internal controller. These electronics contain the circuitry required to accept input from the host computer and software and convert it to appropriate control signals for the camera. These signals include extensive capabilities for synchronizing the operation of the ProEM system with the rest of your experiment. The controlling electronics also collect the analog signal from the CCD, digitize it, and send it to the computer.

The ProEM allows you to specify read rate, binning parameters, and regions of interest — all under software control. For instance, if your experiment requires rapid image acquisition, then the CCD's on-chip binning can be set to increase frame rates.

Grounding and Safety

Before turning on the power supply, the ground prong of the power cord plug must be properly connected to the ground connector of the wall outlet. The wall outlet must have a third prong, or must be properly connected to an adapter that complies with these safety requirements.

WARNING! If the wall outlet is damaged, the protective grounding could be disconnected. Do ***not*** use damaged equipment until its safety has been verified by authorized personnel. Disconnecting the protective earth terminal, inside or outside the apparatus, or any tampering with its operation is also prohibited.

Inspect the supplied power cord. If it is not compatible with the power socket, replace the cord with one that has suitable connectors on both ends.

WARNING! Replacement power cords or power plugs must have the same polarity as that of the original ones to avoid hazard due to electrical shock.

Precautions

To prevent permanently damaging the system, please observe the following precautions:

- The CCD array is very sensitive to static electricity. Touching the CCD can destroy it. Operations requiring contact with the device can only be performed at the factory.
- If you are using high-voltage equipment (such as an arc lamp) with your camera system, be sure to turn the camera power ON LAST and turn the camera power OFF FIRST.
- When turning off and on the power supply, wait at least 10 seconds before switching it on. "TEC Fault" LED might come on if the power supply on/off state is switched too quickly.
- Use caution when triggering high-current switching devices (such as an arc lamp) near your system. The CCD can be permanently damaged by transient voltage spikes. If electrically noisy devices are present, an isolated, conditioned power line or dedicated isolation transformer is highly recommended.
- Do not block air vents on the camera. Preventing the free flow of air overheats the camera and may damage it.

UV Coating

Caution

> If you have a camera with a UV (lumogen or Unichrome™) coated CCD, protect it from unnecessary exposure to UV radiation. This radiation slowly bleaches the coating, reducing sensitivity.

Cleaning

WARNING!

> Turn off all power to the equipment and secure all covers before cleaning the units. Otherwise, damage to the equipment or injury to you could occur.

Camera

Although there is no periodic maintenance that *needs* to be performed on a ProEM camera, users are advised to wipe it down with a clean damp cloth from time to time. This operation should only be done on the external surfaces and with all covers secured. In dampening the cloth, use clean water only. No soap, solvents or abrasives should be used. Not only are they not required, but they could damage the finish of the surfaces on which they are used.

Optical Surfaces

The ProEM camera has an integrated shutter that protects the camera window from dust when not in use. Should a need to clean the optical window arise due to the accumulation of atmospheric dust, we advise that the *drag-wipe* technique be used. Before starting the procedure, run the camera and disable the shutter open to get access to the window. Then, dip a clean cellulose lens tissue into clean anhydrous methanol and drag the dampened tissue over the optical surface to be cleaned. Do not allow any other material to touch the optical surfaces. Pay extra attention if the optical window is coated with AR (anti-reflection) materials as they can be susceptible to scratches. Please contact factory if you have any questions.

Repairs

Because the ProEM camera system contains no user-serviceable parts, repairs must be performed by Princeton Instruments. Should your system need repair, contact Princeton Instruments customer support for instructions. For contact information, refer to page 98 of this manual.

Save the original packing materials and use them whenever shipping the system or system components.

About this Manual

Manual Organization

This manual provides the user with all the information needed to install a ProEM camera and place it in operation. Topics covered include detailed description of the cameras in the ProEM family, installation, applications, cleaning, specifications and more.

Note: "WinX" is a generic term for WinView/32, WinSpec/32, and WinXTest application software.

Chapter 1, ***Introduction*** provides an overview of the ProEM cameras.

Chapter 2, System Component Descriptions provides information about the camera, interface card, cables and application software.

Chapter 3, Installation Overview cross-references system setup actions with the relevant manuals and/or manual pages. It also contains system layout diagrams.

Chapter 4, System Setup provides detailed directions for setting up the camera for imaging or spectroscopic applications and presents over-exposure protection considerations.

Chapter 5, Operation discusses a number of topics, including cooling and effects of high humidity and includes a step-by-step procedure for verifying system operation.

Chapter 6, Advanced Topics discusses standard timing modes (Free Run, External Sync, and Continuous Cleans), Fast and Safe speed modes, Logic Level control, and the Kinetics mode option.

Chapter 7, Tips provides tips regarding CCD ageing, maximizing throughput, and reducing readout time.

Chapter 8, Troubleshooting provides courses of action to take if you should have problems with your system.

Appendix A, Specifications includes camera specifications.

Appendix B, Outline Drawings includes an outline drawing of the C-mount ProEM cameras and the power supply.

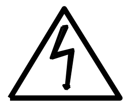
Appendix C, Spectrograph Adapter includes instructions for installing a C-mount to Acton Series spectrograph adapter.

Declaration of Conformity contains the Declaration of Conformity for ProEM systems.

Warranty & Service contains the warranty and customer support contact information.

Safety Related Symbols Used in this Manual

Caution! The use of this symbol on equipment indicates that one or more nearby items should not be operated without first consulting the manual. The same symbol appears in the manual adjacent to the text that discusses the hardware item(s) in question.



Warning! Risk of electric shock! The use of this symbol on equipment indicates that one or more nearby items pose an electric shock hazard and should be regarded as potentially dangerous. This same symbol appears in the manual adjacent to the text that discusses the hardware item(s) in question.

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Chapter 2
System Component Descriptions

System Components

Standard Components

A typical ProEM EMCCD camera system consists of the camera head (with built-in shutter), a power supply (with power cable), and an Intel® PRO/1000 GigE card for your computer, a Gigabit Ethernet cable, MCX to BNC adapter cables, coolant hoses, and the user manual.

Figure 2. Typical ProEM System Components

Optional System Components

Optional items include the WinView/WinSpec application software and manual, Scientific Imaging ToolKit™ (SITK™) for LabVIEW®, a C-mount to spectroscopy-mount adapter, and the Princeton Instruments CoolCUBE coolant circulator. In addition, custom anti-reflective (AR) coatings for the vacuum window and UV coatings for the CCD may be available. If specified, your camera has already been configured with those options.

ProEM Camera

CCD Array: The ProEM:512B and ProEM:1024B camera systems are the most advanced EMCCD cameras available on the market today, utilizing the latest low-noise read out electronics and back-illuminated EMCCDs to deliver single photon sensitivity. In addition, these cameras feature, for the first time, the latest Gigabit Ethernet (GigE) interface that allows remote operation over a single cable without the need for custom frame grabbers. The all metal, hermetic vacuum seals used in the ProEM cameras are warranteed for life - the only such guarantee in the industry.

The ProEM:512B features a high speed EM mode to capture fast kinetics and a low speed normal CCD mode with very low read noise for precision photometry applications. It provides advanced features such as solid baseline stability and linear EM gain control. The ProEM: 512B is cooled to below -80°C using either air or liquid, or a combination of both.

The ProEM:1024B provides a large field of view with 13.3 x 13.3-mm imaging area, and features a high speed EM mode to capture fast kinetics and a low speed normal CCD mode with very low read noise for precision photometry applications. It provides advanced features such as solid baseline stability and linear EM gain control. The ProEM: 1024B is cooled to below -65°C using either air or liquid, or a combination of both.

Cooling: Dark current is reduced in ProEM camera systems through thermoelectric cooling of the CCD arrays. Cooling by this method uses a Peltier cooler in combination with air-circulation (i.e., fan) and/or circulating coolant. To prevent condensation and contamination from occurring, cameras cooled this way are evacuated. Due to CCD size/packaging differences, the lowest achievable temperature can vary from one ProEM model to the next. Please refer to the specific system's data sheet for cooling performance.

A feature of air-cooled ProEM cameras is software control of the fan On/Off status. When vibration may affect results, the user can turn off the fan operation while making sure that the coolant is circulating through the camera to maintain the CCD cooling temperature.

The camera needs to have at least two (2) inches (50 mm) clearance around the vented covers. The operating environment of the camera can be from 0 to 30°C with a 0 to 80% relative humidity (non-condensing). For better performance the ambient temperature should be at or less than 20ºC (above this temperature, the CCD temperature can begin to degrade). If the camera is inside an enclosure, the enclosure needs to have unrestricted air flow to an open environment.

Fan: Air-cooled cameras contain an internal fan. Its purpose is:

- to remove heat from the Peltier device that cools the CCD array and
- to cool the electronics.

An internal Peltier device directly cools the cold finger on which the CCD is mounted. Air drawn into the camera through the back of the camera removes the heat produced by the Peltier device and then vents out through the slots on the side panels. By default, the fan is always in operation and air-cooling of both the Peltier and the internal electronics takes place continuously. In most cases, the low-vibration fan action does not adversely affect the image. However, if vibration would reduce image quality and *the Pro-EM is also being cooled via a coolant circulator*, the fan can be turned Off. For the fan to function properly, free circulation must be maintained between the sides of the camera and the laboratory atmosphere (see **"Cooling"** paragraphs above).

Connectors:

GigE: Gigabit Ethernet connector. Used with the Cat 5e/6 Gigabit Ethernet cable (supplied) interconnecting the camera and the GigE interface card in the host computer. A high quality cable must be used to preserve data integrity during transmission. The cable can extend the distance between camera and the host computer by more than 50m.

Shutter: LEMO® connector provides the shutter drive pulses for driving a Princeton Instruments-supplied 25 mm external shutter. Camera power must be OFF before connecting to or disconnecting from this connector.

Note: When there is an installed internal shutter, this connector cannot drive an external shutter.

LOGIC OUT: 0 to +3.3V programmable logic level output (TTL-compatible). The output can be programmed via software as ACQUIRING, EXPOSE (Effective), EXPOSE (Program'd), IMAGE SHIFT, LOGIC 1, READ OUT, SHUTTER, or WAIT FOR TRIGGER signal. For detailed definition of each output, please see "***LOGIC OUT Control***" (page 62). The output can also be inverted through software. Default is Expose (Program'd).

EXT SYNC: 0-+3.3V logic level input (TTL-compatible) that has a 10 kΩ pull-up resistor. Allows data acquisition and readout to be synchronized with external events. Through software, positive or negative (default) edge triggering can be selected.

Power: 24 VDC (5.3 A max) input and TEC control from power supply.

Coolant Ports: QDC (Low Profile) Male Shutoff Nozzles (Koolance, part number VL2-MG). Located on the side of the camera, these are interchangeable quick-disconnect inlet/outlet ports. ProEM-compatible female barbs (part number VL2-F10B-P) are available from Koolance (www.koolance.com).

Coolant Circulator

ProEM cameras can be optionally cooled by circulating coolant to provide a low vibration system for data acquisition. They are equipped with two ports with quick-disconnect fittings for connection to an external circulator. Two 10 mm (3/8") ID, 3 meter (10 ft) coolant hoses with ProEM-compatible fittings are provided with each ProEM system.

The coolant circulator can be any commercially available circulator (provided that it is capable of continuously pumping a 50:50 mixture of room temperature (23ºC) water and ethylene glycol at 1 liter per minute) or the Princeton Instruments CoolCUBE. Please contact the factory for recommendations.

Cables

Ethernet Cable: This standard 5 meter (16.4') cable is a Cat 5e/6 Ethernet cable (6050-0621) for interconnecting the camera and the host computer. The distance between the camera and the computer can be over 50 meters. Please contact the factory for longer cables.

MCX to BNC Adapter Cables*:* Two MCX to BNC adapter cables (6050-0540) are provided with the ProEM system. These connect to the EXT SYNC and the LOGIC OUT connectors on the rear of the ProEM.

Power Cable*:* The power cable (6050-0596) interconnects the ProEM camera and its power supply. This cable is approximately is 3 m long (approximately 10 ft).

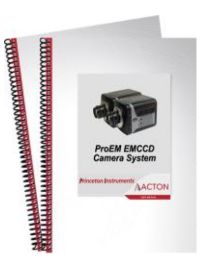
Hoses

Coolant Hoses: Two 10 mm (3/8") ID, 3 meter (10') hoses are supplied with every ProEM system. Quick-disconnects that mate to the ProEM's coolant ports have been installed on one end of each hose. Refer to your coolant circulator's specifications regarding circulator-compatible hose fittings. If a Princeton Instruments CoolCUBE circulator is ordered with the camera, hoses are supplied with appropriate connectors on both ends.

Certificate of Performance

Each ProEM camera has a Certificate of Performance. This certificate states that the camera system was assembled and tested according to approved Princeton Instruments procedures. It documents the camera performance data as measured during the testing of your ProEM and lists the Sales Order, Purchase Order, and Camera Serial numbers (useful if you ever need to contact Princeton Instruments Customer Support).

User Manuals



ProEM System User Manual: This manual describes how to install and use the ProEM camera and its components. The most up-to-date version of this manual and other Princeton Instruments manuals can be found and downloaded from ftp://ftp.princetoninstruments.com/public/Manuals/Princeton Instruments/

WinView/WinSpec32 User Manual: This manual describes how to install and use the application program. A PDF version of this manual is provided on the installation CD. Additional information is available in the program's on-line help.

Optional Components:

Application Software

WinX/32 (WinView or WinSpec): The ProEM camera can be operated by using either WinView/32 or WinSpec/32, Princeton Instrument's 32-bit Windows® software packages designed specifically for high-end imaging and spectroscopy, respectively. The Princeton Instruments' software provides comprehensive image/spectral capture and display functions. The package also facilitates snap-ins to permit advanced operation. Using the optional built-in macro record function, you can also create and edit your own macros to automate a variety of operations. WinView and WinSpec take full advantage of the versatility of the ProEM camera and even enhance it by making integration of the detection system into larger experiments or instruments an easy, straightforward endeavor.

PVCAM®: The standard software interface for cooled CCD cameras from Princeton Instruments. It is a library of functions that can be used to control and acquire data from the camera when a custom application is being written. For example, in the case of Windows, PVCAM is a dynamic link library (DLL). Also, it should be understood that PVCAM is solely for camera control and image acquisition, not for image processing. PVCAM places acquired images into a buffer, where they can then be manipulated using either custom written code or by extensions to other commercially available image processing packages.

Scientific Imaging ToolKit™: SITK™ is a collection of LabVIEW® VIs for scientific cameras and spectrographs. This third party software can be purchased from Princeton Instruments.

Note: ProEM may also be operated by several other third-party software packages. Please check with the providers of the packages for compatibility and support information.

CoolCUBE Circulator

In addition to using an internal fan to remove heat, ProEM cameras also incorporate a closed loop system for circulating fluid. The CoolCUBE circulator unit provides the power to the camera and continuously pumps the 50:50 mixture of room temperature (23ºC) water and ethylene glycol.

C-Mount to Spectroscopy Adapter

A C-mount to Spectroscopy-mount adapter can be ordered separately.

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Chapter 3
Installation Overview

The list and diagrams below briefly describe the sequence of actions required to install your system and prepare to gather data. Refer to the indicated references for more detailed information.

Action	Reference
1. If the system components have not already been unpacked, unpack them and inspect their carton(s) and the system components for in-transit damage.	Chapter 4 System Setup, page 23
2. Verify that all system components have been received.	Chapter 4 System Setup, page 24
3. If the components show no signs of damage, verify that the appropriate power cord has been supplied with the power supply.	Chapter System Setup, page 24
4. If the Ethernet adapter card provided with the system is not already installed in the host computer, install it.	Refer to the manufacturer's instructions
5. If the application software is not already installed in the host computer, install it.	Chapter 4 System Setup, page 27 & Software manual
6. Depending on application, attach lens to the camera or mount the camera to a spectrograph.	Chapter 4 System Setup, page 25 Appendix C Spectrograph Adapter, page 91
7. With the power supply disconnected from the camera, connect the Ethernet cable to the GigE connector on the rear of the camera and to the Ethernet port on the installed Ethernet card.	
8. **Air-Cooled System:** Plug the power supply into the rear of the camera and plug the power supply into the power source. **Liquid Cooling (optional):** Make the hose connections to the camera and plug the circulator into the power source. Add coolant if necessary. Turn on the circulator.	Chapter 4 System Setup, page 27
9. **Turn the camera ON.**	
10. Turn on the computer and begin running the application software.	Software manual
11. Enter the hardware setup information.	Software manual
12. Set the target array temperature.	Chapter 5 Operation, page 40
13. When the system reaches temperature lock, wait an additional 20 minutes and then begin acquiring data in focus mode.	Chapter 5 Operation, page 33 or page 36

Action	Reference
14. Adjust the focus for the best image or spectral lines. If you are using WinSpec/32, you may want to use the Focus Helper function for spectroscopy applications.	Chapter 5 Operation, page 33 or page 36

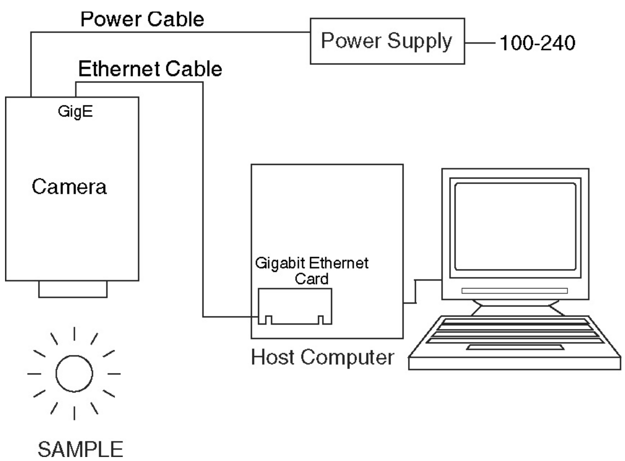

Figure 3. Typical Imaging Experiment Layout with Air-cooled Camera

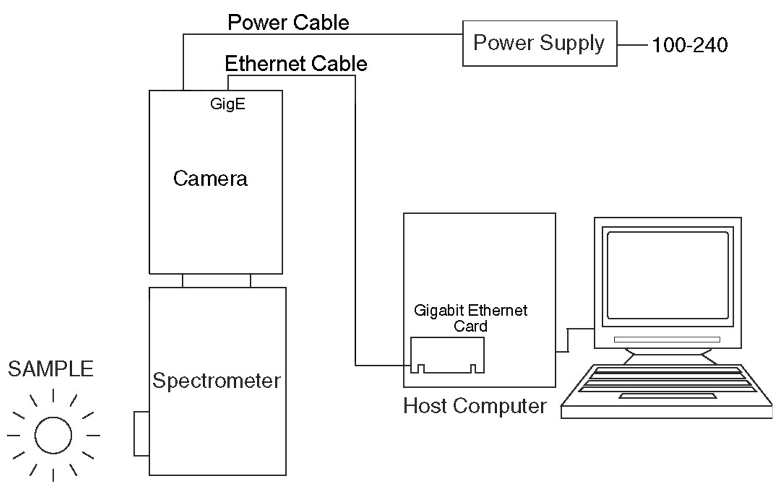

Figure 4. Typical Spectroscopy Experiment Layout with Air-cooled Camera

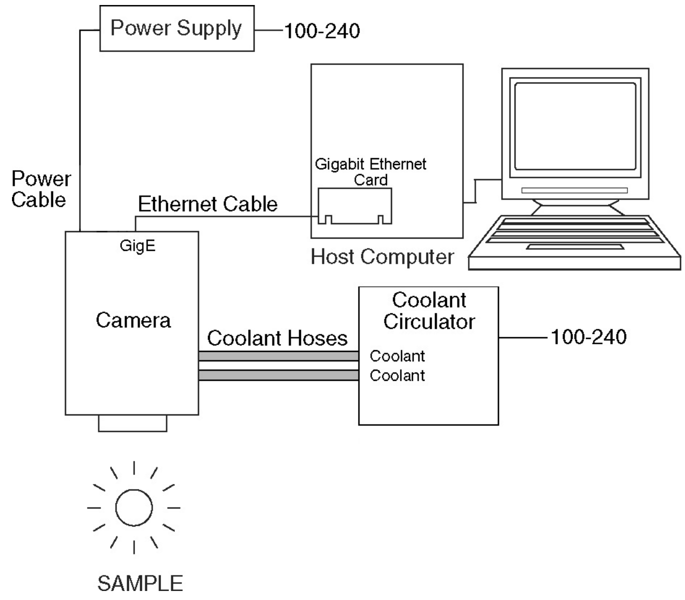

Figure 5. Typical Imaging Experiment Layout with Air/Liquid-cooled Camera

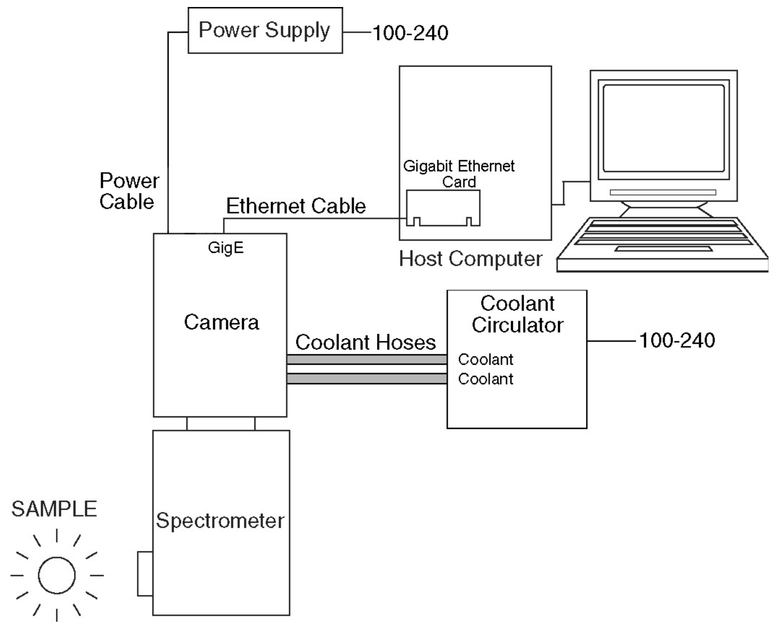

Figure 6. Typical Spectroscopy Experiment Layout with Air/Liquid-cooled Camera

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Chapter 4

System Setup

To minimize risk to users or to system equipment, turn the system **OFF** before any cables are connected or disconnected.

Introduction

A ProEM™ camera system consists of four hardware components:

- Camera
- Power supply
- GigE adapter card
- Cables: Ethernet, Power, MCX-to-BNC

All of the components and cables required for your configuration should be included with your shipment. Your ProEM system has been specially configured and calibrated to match the camera options specified at the time of purchase. The CCD window and coatings you ordered have been installed in your camera head.

Keep all the original packing materials so you can safely ship the ProEM system to another location or return it for service if necessary. If you have any difficulty with any step of the instructions, call Princeton Instruments Customer Support. For contact information, refer to page 98.

Hardware installation consists of:

- Installing a dedicated GigE interface card.
- Attaching a lens to a C-mount on the camera or to a C- to F-mount adapter.
- Mounting the camera to a spectrograph (for spectroscopy applications).
- Software installation depends on the application software you will be using to run the system. Refer to the manual supplied with the software for information about installing and setting it up.

Unpacking the System

During the unpacking, check the system components for possible signs of shipping damage. If there are any, notify Princeton Instruments and file a claim with the carrier. If damage is not apparent but camera or controller specifications cannot be achieved, internal damage may have occurred in shipment. Please save the original packing materials so you can safely ship the camera system to another location or return it to Princeton Instruments for repairs if necessary.

Checking the Equipment and Parts Inventory

Confirm that you have all of the equipment and parts required to set up the ProEM system. A complete system consists of:

- **Camera**
- **Power Supply**
- **Host Computer:** Can be purchased from Princeton Instruments or provided by user. For enhanced performance, a fast hard drive (10,000 rpm) and 2GB RAM is recommended.
- **Operating System:** Windows XP (32-bit, SP3 or later) or Vista (32-bit required for WinView/32 or WinSpec/32 application).
- **Computer Interface Components:**
  - **Ethernet Cable:** 15 ft (5 meter) cable (6050-0621) is standard.
  - **GigE Interface Card** (provided with the ProEM system)
- **External Sync and Logic Out Cables:** MCX-to-BNC adapter cables.
- **Hoses:** Two coolant hoses with ProEM-compatible quick-disconnects.
- **ProEM System User Manual**
- **WinView/32 or WinSpec32** (Ver. 2.5.25 or later) **CD-ROM** (optional)
- **Software User Manual** (provided with WinView/32 or WinSpec/32)

System Requirements

Environmental Requirements

Storage temperature: ≤55°C

Operating environment temperature: +5ºC to +30ºC; the environment temperature at which system specifications can be guaranteed is +20ºC

Relative humidity ≤50%; non-condensing

Note: For TE-cooled cameras, the cooling performance may degrade if the room temperature is above +20°C.

Ventilation

Camera: Allow at least two (2) inches (50 mm) clearance around the vented covers. The air needs to be less than 25ºC (above this temperature the CCD temperature can begin to degrade). Where the camera is inside an enclosure, the enclosure needs to have unrestricted flow to an open environment. The camera vents its heat out the vents near the nose. The air intake is near the rear of the camera.

Power

Camera: The ProEM camera receives its power from the supplied power supply, which in turn plugs into a source of AC power.

Power Supply: The receptacle on the power supply should be compatible with the line-voltage line cords in common use in the region to which the system is shipped. If the power supply receptacle is incompatible, a compatible adapter should be installed on the line cord, taking care to maintain the proper polarity to protect the equipment and assure user safety.

Maximum Power Output: 112 W

Input: 90-240 VAC, 47-63 Hz, 140W

Output: 24 VDC Maximum; power supply also supplies required TEC power.

Host Computer

Note: Computers and operating systems all undergo frequent revision. The following information is only intended to give an approximate indication of the computer requirements. Please contact the factory to determine your specific needs.

- Windows® XP (32-bit with SP3 or later) or Vista (32-bit)
- 2 GHz Pentium® 4 (or greater)
- 1 GB RAM (or greater)
- CD-ROM drive
- At least one unused PCI card slot (PCI 2.3 compliant 32-bit 33/66 MHz bus)
- Super VGA monitor and graphics card supporting at least 65535 colors with at least 128 Mbyte of memory. Memory requirement is dependent on desired display resolution.
- Hard disk with a minimum of 1 Gbyte available. A complete installation of the program files takes about 50 Mbytes and the remainder is required for data storage, depending on the number and size of images/spectra collected. Disk level compression programs are not recommended. Drive speed of 10,000 RPM recommended.
- Mouse or other pointing device.

Note: The above requirements are the minimum for operating a ProEM camera. A faster computer with 2GB or larger memory (RAM) and a fast hard drive (10,000 rpm) will greatly enhance the software performance during live mode operations.

Attaching a Lens to a C-Mount Adapter

Caution

Overexposure protection: Cameras that are exposed to room light or other continuous light sources will quickly become saturated. Set the lens to the smallest aperture (highest f-number) and cover the lens with a lens cap to prevent overexposure.

ProEM cameras for imaging applications incorporate an integral C-mount adapter. *Other mounts may be available. Consult the factory for specific information relating to your needs.* *See page 98 for information on accessing the Princeton Instruments Customer Support Dept.*

Mounting the Lens

C-mount lenses simply screw into the front of these cameras. Tighten the lens by hand only.

Notes:

1. C-mount cameras are shipped with a dust cover lens installed. Although this lens is capable of providing surprisingly good images, its throughput is low and the image quality is not as good as can be obtained with a high-quality camera lens. Users should replace the dust-cover lens with their own high-quality laboratory lens before making measurements.

2. If the CCD is cooled to low temperatures (below -50°C), exposure to ambient light will over-saturate it. This may increase dark charge significantly. If the camera remains saturated after all light sources are removed, you may have to bring the camera back to room temperature to restore dark charge to its original level.
3. Saturation is not harmful to a non-intensified camera, but it , should be avoided.

Adjusting the C-Mount Adapter

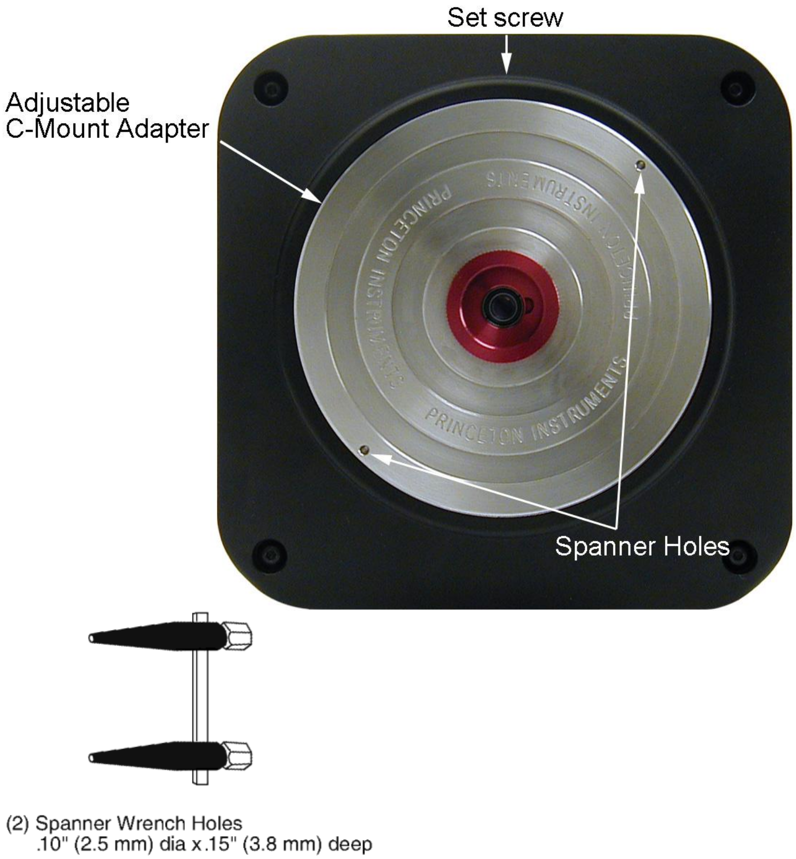


Figure 7. Adjustable C-Mount Adapter

The ProEM features an adjustable C-mount adapter that allows you to change the focal depth. Use the hex key supplied with your system (or a .050" hex key) to loosen the setscrew securing the adapter. Using a spanner wrench or equivalent (distance between holes is 3.85” [97.8 mm]), rotate the ring to the desired height. Tighten the screw to lock the adapter in place.

Note: To lock the setscrew, the face of the adapter should be no further than .1" (2.5 mm) out from the front surface of the camera nose.

Caution

The C-mount lens thread-depth should be .21" (5.33 mm) or less. Otherwise, depending on the adapter in-out location, the lens could bottom out and damage the shutter. If you are not certain of the thread depth, remove the adapter from the camera nose, thread the lens into the adapter until the lens threads are flush with the back surface of the adapter. Note the depth at the front surface, remove the lens, and then re-insert the adapter into the camera nose.

Making the Camera-Circulator Connections

For liquid-cooled setups, a circulator provides a vibration-free method of heat removal.

1. Make sure the camera and the circulator power switches are turned off.
2. If you are using a Princeton Instruments CoolCUBE, make sure the circulator is 6 inches (150 mm) or more below the camera. The vertical distance should not exceed 10 feet (3 m). Typically, the camera is at table height and the circulator is on the floor.
3. Using the hoses provided with the system, make the coolant connections between the circulator and the camera. It does not matter which hose from the circulator is plugged into a coolant port on the camera.

   Note: Make sure that there are no kinks in the hoses that impede the coolant flow. Lack of sufficient flow can seriously harm the camera and any resulting damage is not covered under warranty

4. Plug the circulator into an appropriate power source.
5. Turn the circulator on and make sure the liquid is flowing.
6. Turn the camera on.
7. Start the application software.

Software Installation

Notes:

1. Install the GigE Adapter card BEFORE installing the WinView/32 or WinSpec/32 application software.
2. Leave the interface cable disconnected from the camera until you have installed WinView/32 or WinSpec/32 (Ver. 2.5.25 or later).

The following installation is performed via the WinView/32 or WinSpec/32 software installation CD.

1. On the **Select Installation Type** dialog box (see Figure 8), click on **Typical** radio button to install the required drivers and the most commonly installed program files. Select the **Custom** radio button if you would like to choose among the available program files or do not want to install the drivers. **Complete** installs all of the application features.

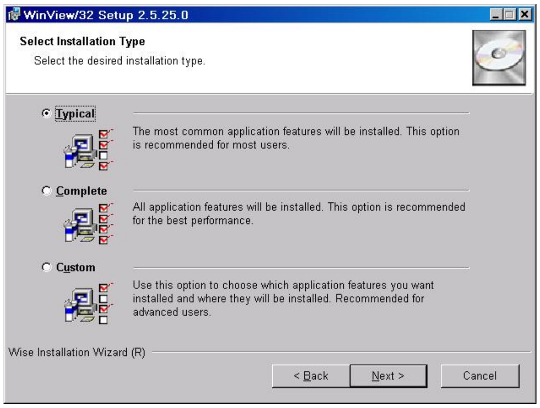


Figure 8. WinView Installation: Select Components dialog box

2. Make sure the camera is connected to the host computer and that the camera power supply is turned on.
3. Reboot the computer.
4. At bootup, Windows will detect the GigE card.

Entering the Default Camera System Parameters into WinX (WinView/32, WinSpec/32, or WinXTest/32)

WinX Versions 2.5.25 and later

1. Make sure the ProEM is connected to the host computer and that it is turned on.
2. Run the WinX application. The **Camera Detection wizard** will automatically run if this is the first time you have installed a Princeton Instruments WinX application (WinView/32, WinSpec/32, or WinXTest/32) and a supported camera. Otherwise, if you installing a new camera type, click on the **Launch Camera Detection Wizard…** button on the **Controller/CCD** tab page to start the wizard.
3. On the **Welcome** dialog (Figure 9), leave the checkbox unselected and click on **Next**.

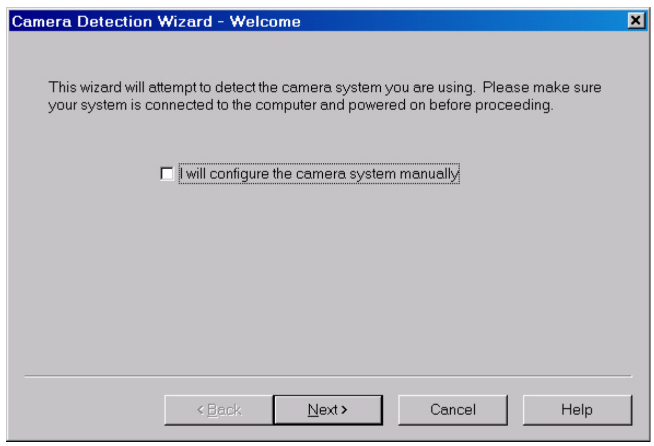


Figure 9. Camera Detection Wizard - Welcome dialog box

4. Follow the instructions on the dialog boxes to perform the initial hardware setup: this wizard enters default parameters on the **Hardware Setup** dialog box tab pages and gives you an opportunity to acquire a single test image to confirm the system is working. Note that this is a test image and it is not acquired using the settings needed for true data acquisition.
5. To finalize the setup, make the following selections on the **Controller/Camera** tab page so you can control the camera and acquire data at the default **Detector Temperature** setting:
   - On the **Controller/Camera** tab page: Make sure "**Frame Transfer**" is selected as the Readout Mode.

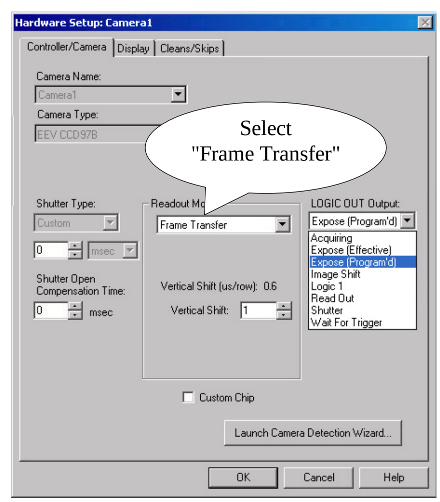


Figure 10. Controller/Camera tab page

Note: For a step-by-step procedure on basic system operation, refer to the appropriate ***"First Light"*** section, beginning on page 30 (Imaging applications) or page 34 (Spectroscopy applications).

Chapter 5

Operation

Introduction

Once the ProEM camera has been installed as explained in the preceding chapters, operation of the camera is straightforward. In most applications you simply establish optimum performance using the **Focus** mode (in WinView/32 or WinSpec/32, for example), set the target camera temperature, wait until the temperature has stabilized, and then do actual data acquisition in the **Acquire** mode. Additional considerations regarding experiment setup and equipment configuration are addressed in the software manual.

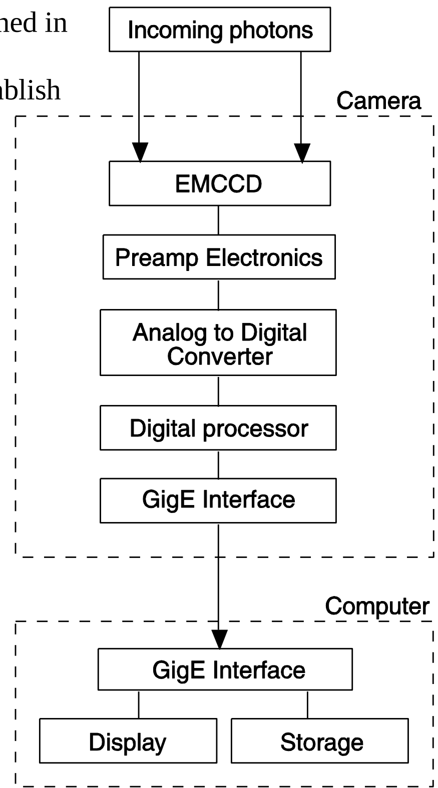


Figure 11. Block Diagram of ProEM System

During data acquisition, the CCD array is exposed to a source and charge accumulates in the pixels. After the defined exposure time, the accumulated signal is readout of the array, digitized, and then transferred to the host computer. Upon data transfer, the data is data is displayed and/or stored via the application software. This sequence is illustrated by the block diagram shown in Figure 11.

Whether or not the data is displayed and/or stored depends on the data collection operation (**Focus** or **Acquire**) that has been selected in the application software. In WinView and WinSpec, these operations use the Experiment Setup parameters to establish the exposure time (the period when signal of interest is allowed to accumulate on the CCD). As might be inferred from the names, **Focus** is more likely to be used in setting up the system (see the ***"First Light"*** discussions) and **Acquire** is then used for the collection and storage of data. Briefly:

- In **Focus** mode, the number of frames is ignored. A single frame is acquired and displayed, another frame is acquired and overwrites the currently displayed data, and so on until Stop is selected. Only the last frame acquired before Stop is selected can be stored. When Stop is selected, the File Save function can be used to save the currently displayed data. This mode is particularly convenient for familiarization and setting up. For ease in focusing, the screen refresh rate should be as rapid as possible, achieved by operating with axes and cross-sections off, and with Zoom 1:1 selected.
- In **Acquire** mode, every frame of data collected can be automatically stored (the completed dataset may include multiple frames with one or more accumulations). This mode would ordinarily be selected during actual data collection. One limitation of Acquire mode operation is that if data acquisition continues at too fast a rate for it

to be stored, data overflow will eventually occur. This could only happen in Fast Mode operation.

The remainder of this chapter provides "First Light" procedures (these provide step-by-step instruction on how to initially verify system operation) and discusses factors that affect exposure, readout, and digitization of the incoming signal. By understanding the exposure, readout, and digitization factors and making adjustments to software settings you can maximize signal-to-noise ratio. For information about synchronizing data acquisition with external devices, please refer to ***Chapter 6, Advanced Topics***.

First Light (Imaging)

This section provides step-by-step instructions for acquiring an imaging measurement for the first time. The intent of this procedure is to help you gain basic familiarity with the operation of your system and to show that it is functioning properly. Once basic familiarity has been established, then operation with other operating configurations, ones with more complex timing modes, can be performed.

Assumptions

The following procedure assumes that

1. You have already set up your system in accordance with the instructions in the previous chapters.
2. You have read the previous sections of this chapter.
3. You are familiar with the application software.
4. The system is being operated in imaging mode.
5. The target is a sharp image, text, or a drawing that can be used to verify that the camera is "seeing" and can be used to maximize focus.

Getting Started

1. Mount a test target in front of the camera.
2. Power ON the camera (the power switch is on the back of the power supply).

   Note: The camera must be turned on before WinView/32 or WinSpec/32 is opened, and WinView/32 or WinSpec/32 must be closed before the camera is turned off.
3. Turn on the computer power.
4. Start the application software.
5. Block light from the lens.

Setting the Parameters

Note: The following procedure is based on WinView/32: you will need to modify it if you are using a different application. Basic familiarity with the WinView/32 software is assumed. If this is not the case, you may want to review the software manual or have it available while performing this procedure.

Set the software parameters as follows:

Controller/Camera tab page (Setup|Hardware): These parameters should be set automatically to the proper values for your system.

- **Controller type:** This information is read from the camera.
- **Camera type:** This information is read from the camera.
- **Shutter type:** Custom (System dependent).
- **Readout mode:** Available modes are read from the camera. Select **Frame Transfer**.

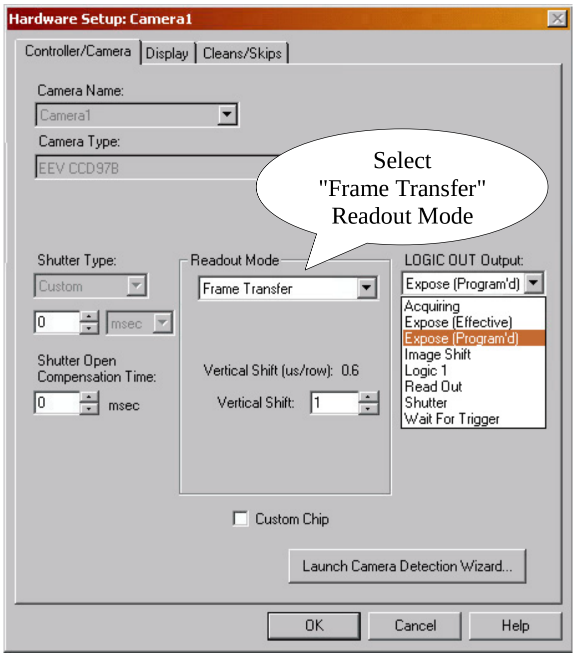


Figure 12. Controller/Camera tab page

Detector Temperature (Setup|Detector Temperature…): The default temperature setting is read from the camera. When the array temperature reaches the set temperature, the **Detector Temperature** dialog box will report that the temperature is **LOCKED** (Figure 13 shows the default temperatures for the ProEM:512B and 1024B). Note that some overshoot may occur. This could cause temperature lock to be briefly lost and then quickly re-established. If you are reading the actual temperature reported by the application software, there may be a small difference between the set and reported temperature when lock is established. This is normal and does not indicate a system malfunction. Once lock is established, the temperature will be stable to within ±0.05°C.

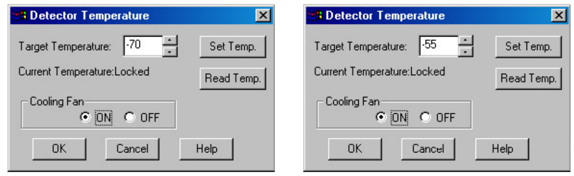


Figure 13. Detector Temperature dialog box (512B on left, 1024B on right)

Note: The Detector Temperature dialog box will not display temperature information while you are acquiring data.

Experiment Setup|Main tab page (Acquisition|Experiment Setup…):

- **Exposure Time:** 50 ms
- **Accumulations & Number of Images:** 1

Experiment Setup|ROI tab page (Acquisition|Experiment Setup…): Use this function to define the region of interest (ROI).

- **Imaging Mode:** Select this mode if you are running WinSpec.
- Clicking on **Full** loads the full size of the chip into the edit boxes.

Experiment Setup|Timing tab page (Acquisition|Experiment Setup…):

- **Timing Mode:** Free Run
- **Shutter Control:** Disabled Opened. (Note: In FT mode, the shutter must be disabled open for regular imaging.)
- **Safe Mode vs. Fast Mode:** Fast Mode

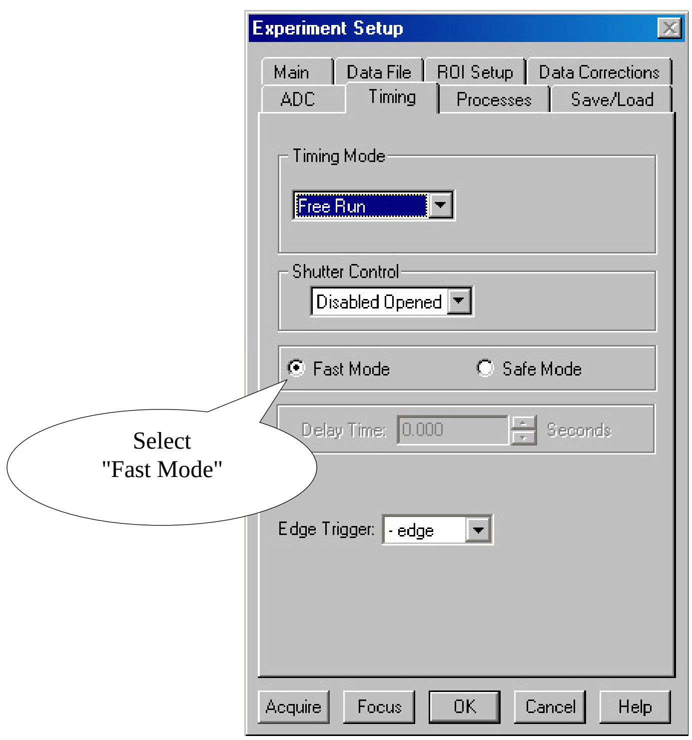


Figure 14. Experiment Setup|Timing tab page

Acquiring Data

1. If you are using WinView/32 and the computer monitor for focusing, select **Focus** from the **Acquisition** menu. Successive images will be sent to the monitor as quickly as they are acquired.
2. Adjust the lens aperture, intensity scaling, and focus for the best image as viewed on the computer monitor. Some imaging tips follow:
    - Begin with the lens blocked off and then set the lens at the smallest possible aperture (largest f-stop number).
    - Make sure there is a suitable target in front of the lens. An object with text or graphics works best.
    - Adjust the intensity scaling (by clicking the **5%-95%** button at the bottom left corner of the data window) and adjust the lens aperture until a suitable setting is found. Once you've determined that the image is present, select a lower setting for better contrast. Check the brightest regions of the image to determine if the A/D converter is at full-scale. *A 16-bit A/D is at full scale when the brightest parts of the image reach an intensity of 65535.* Adjust the aperture to where it is just slightly smaller (higher f-stop) than the setting where maximum brightness on any part of the image occurs.
    - Set the focus adjustment of the lens for maximum sharpness in the viewed image.
3. After you have focused the camera, you can stop **Focus** mode, continue **Focus** mode, begin **Acquire** mode, or wait for the CCD to reach the operating temperature before going to **Acquire** mode.

First Light (Spectroscopy)

The following paragraphs provide step-by-step instructions for operating ProEM in a spectroscopy setup for the first time. The intent of this simple procedure is to help you gain basic familiarity with the operation of your system and to show that it is functioning properly. Once basic familiarity has been established, then operation with other operating configurations, ones with more complex timing modes, can be performed. An underlying assumption for the procedure is that the camera is to be operated with a spectrograph (such as an Acton Series 2300 spectrograph) on which it has been properly installed (refer to Appendix C for instructions for mounting a spectrograph adapter to the ProEM). A suitable light source, such as a mercury pen-ray lamp, should be mounted in front of the entrance slit of the spectrograph. Any light source with line output can be used. *Standard fluorescent overhead lamps have good calibration lines as well.* If there are no "line" sources available, it is possible to use a broadband source such as tungsten for the alignment. If this is the case, use a wavelength setting of 0.0 nm for alignment purposes.

Caution ***Overexposure Protection:*** Cameras that are exposed to room light or other continuous light sources will quickly become saturated. If the camera is mounted to a spectrograph, close the entrance slit of the spectrograph to reduce the incident light.

Assumptions

The following procedure assumes that

1. You have already set up your system in accordance with the instructions in previous chapters. This includes mounting the spectrograph adapter to the camera (refer to Appendix C).
2. You have read the previous sections of this chapter.
3. You are familiar with the application software.
4. The system is being operated in spectroscopy mode.

Getting Started

1. Set the spectrograph entrance slit width to minimum (10 µm if possible).
2. Mount the camera to the spectrograph exit port.
3. Power ON the (the power switch is on the back of the power supply).
4. Turn on the computer power.
5. Start the application software.

Setting the Parameters

Note: The following procedure is based on WinSpec/32: you will need to modify it if you are using a different application. Basic familiarity with the WinSpec/32 software is assumed. If this is not the case, you may want to review the software manual or have it available while performing this procedure.

Set the software parameters as follows:

Controller/Camera tab page (Setup|Hardware): These parameters should be set automatically to the proper values for your system.

- **Controller type:** This information is read from the camera.
- **Camera type:** This information is read from the camera.
- **Shutter type:** Custom (System dependent).

- **Readout mode:** Available modes are read from the camera. Select **Frame Transfer**.

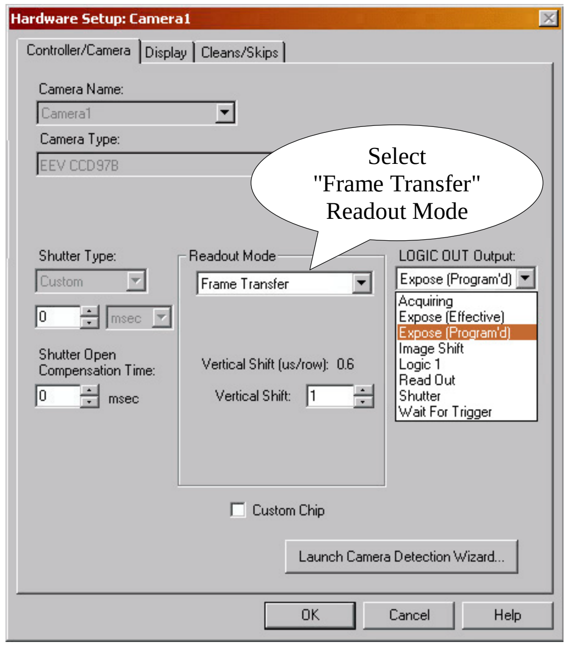


Figure 15. Controller/Camera tab page

Detector Temperature (Setup|Detector Temperature…): The default temperature setting is read from the camera. When the array temperature reaches the set temperature, the **Detector Temperature** dialog box will report that the temperature is **LOCKED**. Note that some overshoot may occur. This could cause temperature lock to be briefly lost and then quickly re-established. If you are reading the actual temperature reported by the application software, there may be a small difference between the set and reported temperature when lock is established. This is normal and does not indicate a system malfunction. Once lock is established, the temperature will be stable to within ±0.05°C.

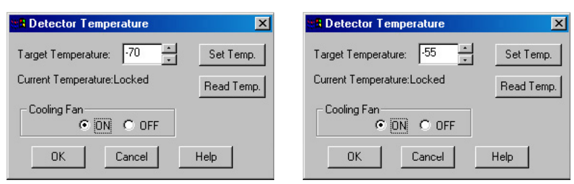


Figure 16. Detector Temperature dialog box (512B on left, 1024B on right)

Note: The Detector Temperature dialog box will not display temperature information while you are acquiring data.

Experiment Setup|Main tab page (Acquisition|Experiment Setup…):

- **Exposure Time:** 50 ms
- **Accumulations & Number of Images:** 1

Experiment Setup|ROI tab page (Acquisition|Experiment Setup…): Use this function to define the region of interest (ROI).

- **Spectroscopy Mode:** Selected
- Clicking on **Full** loads the full size of the chip into the edit boxes.

Experiment Setup|Timing tab page (Acquisition|Experiment Setup…):

- **Timing Mode:** Free Run
- **Shutter Control:** Disabled Opened.
- **Safe Mode vs. Fast Mode:** Fast Mode

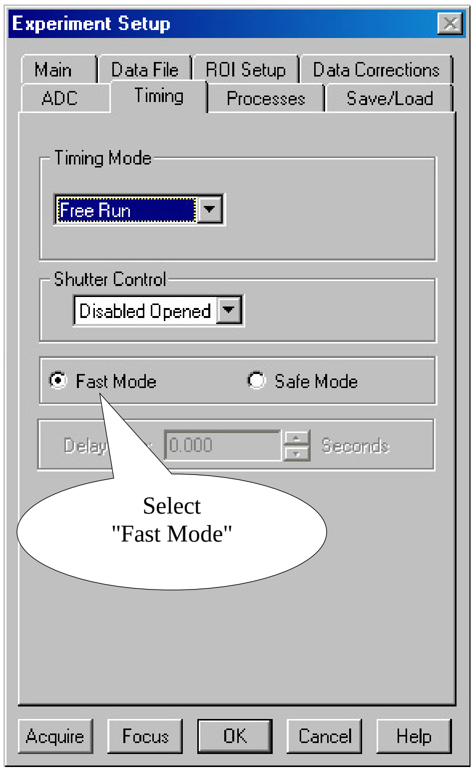


Figure 17. Experiment Setup|Timing tab page

Focusing

The mounting hardware provides two degrees of freedom, focus and rotation. In this context, focus means to physically move the camera back and forth through the focal plane of the spectrograph. The approach taken is to slowly move the camera in and out of focus and adjust for optimum while watching a live display on the monitor, followed by rotating the camera and again adjusting for optimum. The following procedure, which describes the focusing operation with an Acton SP-2356 spectrograph, can be easily adapted to other spectrographs.

1. Mount a light source such as a mercury pen-ray type in front of the entrance slit of the spectrograph. Any light source with line output can be used. *Standard fluorescent overhead lamps have good calibration lines as well.* If there are no "line" sources available, it is possible to use a broadband source such as tungsten

for the alignment. If this is the case, use a wavelength setting of 0.0 nm for alignment purposes.

2. With the spectrograph properly connected to the camera, turn the power on, wait for the spectrograph to initialize. Then set it to 435.8 nm if using a mercury lamp or to 0.0 nm if using a broadband source.

   Hint: Overhead fluorescent lights produce a mercury spectrum. Use a white card tilted at 45 degrees in front of the entrance slit to reflect overhead light into the spectrograph. Select 435.833 as the spectral line.

3. Set the slit to 25 µm. *If necessary, adjust the Exposure Time to maintain optimum (near full-scale) signal intensity.*

4. In WinSpec, select **Focus** (on the **Acquisition** menu or on the **Experiment Setup** dialog box) to begin data accumulation. Data will be continuously acquired and displayed but will not be stored until you stop acquisition and use the **Save** function on the File menu.

5. Slowly move the camera in and out of focus. You should see the spectral line go from broad to narrow and back to broad. Leave the camera set for the narrowest achievable line. You may want to use the **Focus Helper** function (**Process|Focus Helper…**) to determine the narrowest line width: it can automatically locate peaks and generate a report on peak characteristics during live data acquisition (see the WinSpec/32 on-line help for more information).

   Note that the way focusing is accomplished depends on the spectrograph, as follows:

   - **Long focal-length spectrographs such as the Acton SP-2356:** The mounting adapter includes a tube that slides inside another tube to move the camera in or out as required to achieve optimum focus.
   - **Short focal-length spectrographs:** There is generally a focusing mechanism on the spectrograph itself which, when adjusted, will move the optics as required to achieve proper focus.
   - **No focusing adjustment:** If there is no focusing adjustment, either provided by the spectrograph or by the mounting hardware, then the only recourse will be to adjust the spectrograph's focusing mirror.

6. Next adjust the rotation. You can do this by rotating the camera while watching a live display of the line. The line will go from broad to narrow and back to broad. Leave the camera rotation set for the narrowest achievable line.

   Alternatively, take an image, display the horizontal and vertical cursor bars, and compare the vertical bar to the line shape on the screen. Rotate the camera until the line shape on the screen is parallel with the vertical bar.

   Note: When aligning other accessories, such as fibers, lenses, optical fiber adapters, first align the spectrograph to the slit. Then align the accessory without disturbing the camera position. The procedure is identical to that used to focus the spectrograph (i.e., do the focus and alignment operations while watching a live image).

Exposure and Signal

Exposure Time

Exposure time (set on the **Experiment Setup|Main** tab page) is the time between commands sent by the application software to start and stop signal accumulation on the CCD. In combination with triggers, these commands control when continuous cleaning of the CCD stops and when the accumulated signal will be read out. Cleaning prevents buildup of dark current and unwanted signal before the start of the exposure time. At the end of the exposure time, the CCD is readout and cleaning starts again.

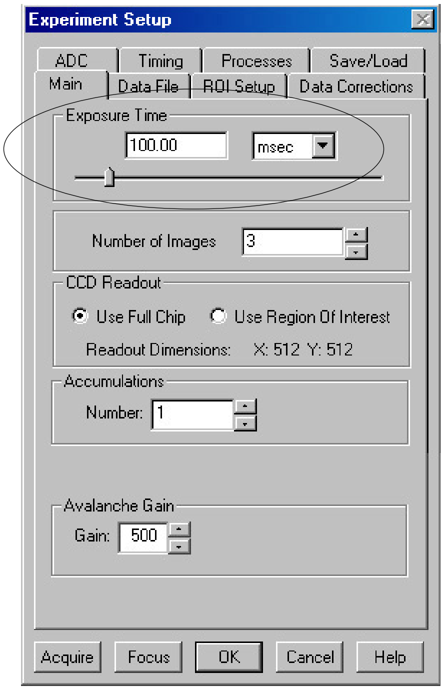


Figure 18. Setting the Exposure Time (Experiment Setup|Main tab page)

The *effective* exposure time of the array depends on the active readout mode (Frame transfer or full frame).

Frame Transfer: In this mode, the effective exposure time depends on the frame readout time. When the set exposure time is greater than or equal to the frame readout time, the effective exposure time is the set exposure time. However, if the set exposure time is less than the frame readout time, the first exposure will be the set exposure time and subsequent exposures in a sequence will be exposed for the frame readout time.

Full Frame: In this mode, the effective exposure time is the set exposure time.

For detailed information on these modes, see "***Exposure-Readout Modes"*** (page 48).

Avalanche Gain (EM Gain)

As explained previously, the ProEM uses a unique EMCCD capable of multiplying the charge (electrons) generated in the pixels. When the multiplication is sufficiently high, it is possible to see extremely low-light events. The amount of multiplication is controlled by the voltage applied to multiplication register clocks. ProEM has built-in EM gain calibration so that users can control the gain in absolute values. A user-accessible EM gain recalibration program is available if the EM gain needs to be recalibrated due to ageing or other factors.

When the Multiplication Gain port is selected (**Experiment Setup|ADC** tab page), the Avalanche Gain can be set by entering the desired gain value on the **Experiment Setup|Main** tab page. A Gain setting of one (1) refers to a no-gain state where the camera behaves like a standard high speed CCD (with rather high read noise). As the result of EM gain calibration, values 1 to ~1000 are mapped linearly to the internal serial clock voltages that vary the multiplication gain for a one-to-one relationship between entered gain value and actual gain.

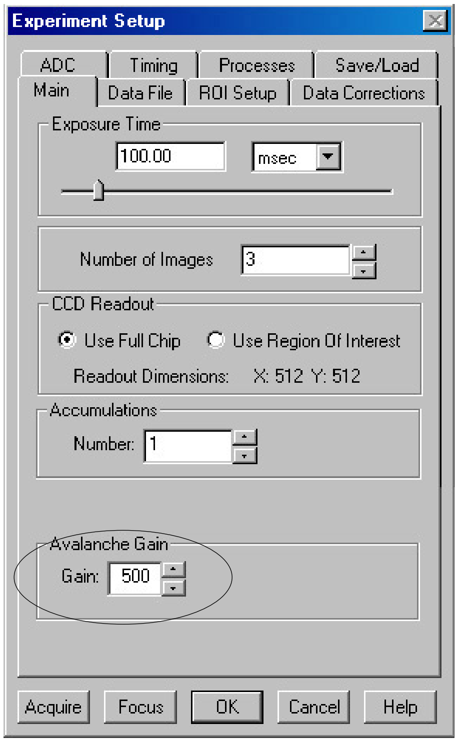


Figure 19. Setting the Avalanche Gain (Experiment Setup|Main tab page)

Even though the camera is capable of delivering large multiplication gain factors, EM gain should be used only as needed to preserve as much dynamic range as possible.

Note: As the on-chip multiplication introduces additional noise and reduced effective dynamic range, it is recommended that the multiplication be used only as required. Typically, only 100x or lower EM gain is required to achieve <1 e- rms effective read noise. Using higher EM gain does not improve signal-to-noise ratio, but it can accelerate sensor EM gain ageing while lowering effective dynamic range. For more information, refer to the "On-Chip Multiplication Gain" technical note. This technical note can be accessed by going to the Princeton Instruments web site at www.princetoninstruments.com and searching for that title.

EM Gain Calibration

Each Pro-EM camera is factory-calibrated for linearized EM Gain and can also be calibrated in the field using a standalone program called “EMCalibUtility.exe.” Once the EM gain calibration has been performed, the gain value you enter in the software will be the actual multiplication gain applied to the input signal.

Over time, however, ageing of the EMCCD array may degrade gain linearity. Because ageing appears to be a strong function of the amount of charge that flows through the multiplication register, users who consistently operate the camera at high gain at high light levels may need to recalibrate EM gain more frequently than those who are looking at lower light levels at lower gain. To compensate for ageing, each Pro-EM contains a built-in shutter and light source that allow you to perform an on-demand EM Gain Calibration.

To Perform EM Gain Calibration:

1. Locate the EMGainCalib.exe program (located in the application program directory.
2. Make sure the ProEM camera system is running.
3. Exit the application program (in most cases, either WinView/32 or WinSpec/32).
4. Launch the EMGainCalib.exe program.
5. Upon initiation of the calibration, the built-in shutter closes, the built-in light source illuminates the array, a succession of data frames are acquired, and the calibration map is calculated. A progress indicator is displayed during the calibration.
6. Wait until the calibration (it might take 10 minutes or longer) has been completed before restarting the application program.

Note: Do not operate the camera while EM gain calibration is in process.

CCD Temperature

As stated before, lowering the temperature of the CCD will generally enhance the quality of the acquired signal by lowering dark noise. In EMCCD cameras, lower temperatures will also result in higher EM gain. When WinView or WinSpec is the controlling software, temperature control is done via the **Detector Temperature** dialog box (see Figure 20) accessed from the **Setup** menu. Initially, the dialogue shows default temperature appropriate for your specific model.

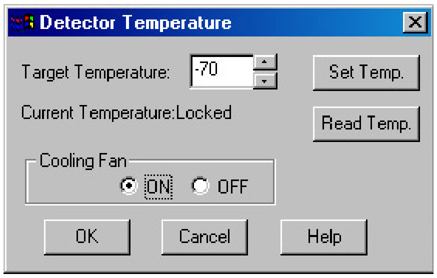


Figure 20. Setting the Temperature (Detector Temperature dialog box)

Once the target array temperature has been set, the software controls the camera's cooling circuits to reach set array temperature. On reaching that temperature, the control loop locks to that temperature for stable and reproducible performance. When temperature lock has been reached (temperature within 0.05°C of set value) the Detector Temperature dialog box reports that the current temperature is **Locked**. The on-screen indication allows easy verification of temperature lock.

The time required to achieve lock can vary over a considerable range, depending on such factors as the camera type, CCD array type, ambient temperature, etc. Once lock occurs, it is okay to begin focusing. However, you should wait an additional <u>twenty minutes</u> before taking quantitative data so that the system has time to achieve optimum thermal stability.

When vibration may affect results, you can turn off the fan operation while making sure that the coolant is circulating through the camera to maintain the CCD cooling temperature. If the fan is turned off and there is no coolant circulating through the camera, the built-in thermo-protection switch may shut the camera down to prevent thermal damage. In the event that this occurs, wait about ten minutes, correct the situation that caused the shutdown, and re-power the camera.

The deepest operating temperature for a system depends on the CCD array size and packaging. Refer to Table 3 (page 84), for default cooling temperatures.

Note: If the CCD is cooled to low temperatures (below -50°C), exposure to ambient light will over-saturate it. This may increase dark charge significantly. If the camera remains saturated after all light sources are removed, you may have to bring the camera back to room temperature to restore dark charge to its original level.

Dark Charge

Dark charge (or dark current) is the thermally induced buildup of charge in the CCD over time. The statistical noise associated with this charge is known as dark noise. Dark charge values vary widely from one CCD array to another and are temperature dependent.

With the light into the camera completely blocked, the CCD pixels accumulate thermally generated electrons, dependent on the exposure time and camera temperature. The longer the exposure time and the warmer the camera, the less uniform this background will appear. Thus, to minimize dark-charge effects, you should operate at the default CCD temperature.

Bias Active Stabilization Engine (BASE™)

All CCDs and EMCCDs produce a baseline output signal even when there is no incident light and the exposure is zero. Camera electronics process this information to produce what is known as a bias image. For quantitative applications, it is critical that the bias reference values be above zero. This allows the reference to be above zero so that the variation (read noise) can be measured. When quantifying input light level, the bias value must be subtracted from the real signal frame.

In EMCCDs, due to complex nature of the sensor and its drive electronics, the bias can vary frame to frame depending on parameters including but not limited to the temperature, speed, and EM gain. To counter this, ProEM has a built-in bias active stabilization engine or BASE™. The camera reads "overscan" pixels — the pixels outside the region of the CCD to account for any change in bias — and "actively" correct the bias frames. As a result, each bias frame is self-corrected irrespective of the camera settings and the bias value remains stable over extended sequences.

Since active bias stabilization is ON by default, no user input is required.

Clock Induced Charge (CIC)

Clock-induced charge (CIC) is a noise source that must be taken into account when operating EMCCDs at single-photon levels. As charge is shifted from pixel to pixel during readout, a random electron may be generated in the pixel purely due to clock transitions. Once an electron is generated in the pixel, it undergoes the same multiplication process as a photon-induced electron. Since this noise is generated during readout, it is independent of exposure time. Empirical tests show that CIC is only weakly dependent on the temperature of the sensor. Dark current, meanwhile, is a function of exposure time and is dependent on temperature.

	CIC	Dark current
Source of noise	electronic	thermal
Function of exposure time	no	yes
Temperature dependent	no (or weakly)	yes
Units of measure	e-/pixel/frame	e-/pixel/second

Table 1. Major differences between dark current and clock-induced charge

The presence of CIC creates an error in photon estimation. The state-of-the-art ProEM minimizes spurious charge by optimizing clock voltages and timing edges, down to 0.005 e-/pixel/frame (ProEM: 512B).

Saturation

ProEM uses a special EMCCD to amplify input signal (electrons) to achieve low read noise. Though, unlike intensified CCD cameras, EMCCDs can withstand bright light sources, care must be taken not to (1) overexpose (2) use excessive EM gain. If the camera is used in high light conditions and with excessive EM gain, the EM gain rapidly degrades over time.

When signal levels in some part of the image are very high, charge generated in one pixel may exceed the "well capacity" of the pixel, spilling over into adjacent pixels in a process called "blooming." In this case a shorter exposure is advisable, with signal averaging to enhance S/N (Signal-to-Noise ratio) accomplished through the software.

For signal levels low enough to be readout-noise limited, longer exposure times, and therefore longer signal accumulation in the CCD, will improve the S/N ratio approximately linearly with the length of exposure time. There is, however, a maximum time limit for on-chip accumulation, determined by either the saturation of the CCD by the signal or the loss of dynamic range due to the buildup of dark charge in the pixels.

Note: Do not be concerned about the DC level of this background. What you see is not noise. It is a fully subtractable bias pattern. Simply acquire and save a dark charge "background image" under conditions identical to those used to acquire the "actual" image. Subtracting the background image from the actual image will significantly reduce dark-charge effects.

Caution If you observe a sudden change in the baseline signal, there may be excessive humidity in the camera vacuum enclosure. Turn off the camera and contact Princeton Instruments Customer Support. See page 98 for contact information.

Cleaning

The basic cleaning function is implemented by clean cycles. These cycles start when you turn the camera on and a clean pattern is programmed into the camera. Their purpose is to remove charge that accumulates on the array while the camera not acquiring data (i.e., exposing and reading out the array). Figure 21 is a timing diagram for an experiment set up to acquire four (4) images in Freerun timing mode. In this diagram clean cycles occur before the first exposure and after the last readout period.

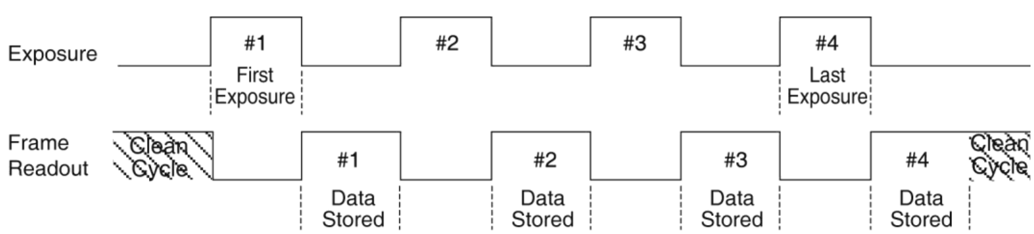


Figure 21. Clean Cycles Timing Diagram

Note: The start of the exposure is signaled by SCAN going high but will not occur until the current clean cycle has finished.

The configuration of clean cycles is performed on the Hardware Setup|Cleans/Skips tab page. When you set up the camera for the first time, default values are automatically inserted into these fields. These will give the best results for most applications. Even so it is a good idea to know what these entries mean with regard to cleaning.

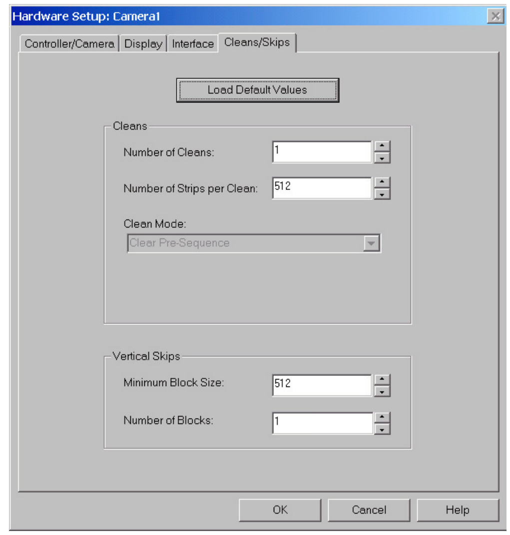


Figure 22. Clean/Skips tab page

The Number of Cleans value is usually set to one (1). These are additional clean cycles that can be required after a start exposure signal is received and the current clean cycle has finished. The maximum value for this entry depends on the camera.

The Number of Strips per Clean sets the number of rows that will be shifted and discarded per clean cycle. While a large number such as the number of rows in the array may result in the best cleaning of the array, the tradeoff is that there may be a significant delay between the receipt of a start exposure signal and the beginning of the actual exposure. This delay occurs because the current clean cycle must be completed before a start exposure signal received during the cycle will be implemented. Typically, the default setting is much smaller and in time critical experiments, the setting should be 1 or 2.

Readout

Introduction

The ProEM:512B and 1024B models use frame transfer CCDs with 512x512 and 1024x1024 active pixels, respectively. These frame transfer CCDs also have an equivalent number of “frame transfer or masked” pixels as shown in Figure 23. (Note: typically there are additional rows and columns for internal reference).

In standard frame transfer mode, the sensor area is exposed for certain time, typically milliseconds to seconds. The acquired image data is then transferred to frame transfer area before reading it out via extended multiplication gain register or standard serial register. Region of Interest (ROI) and/or binning can be used to improve the time resolution, limited to a millisecond regime. For more information on the CCD exposure-readout operations, see ***“Exposure - Readout Modes”*** (page 48).

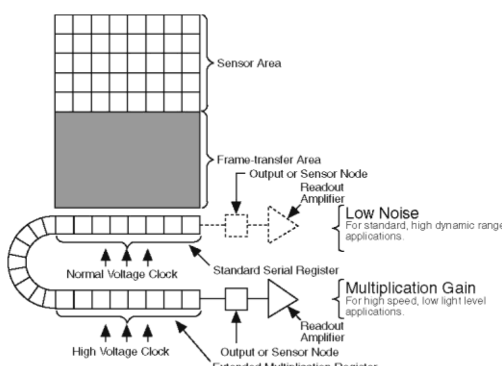


Figure 23. EMCCD Array Structure

WinView and WinSpec allow you to specify the type of readout (full frame or binned), the output amplifier, and the gain (the number of electrons required to generate an ADU).

Dual-Readout Port Operation

The ProEM: 512B and 1024B models are configured with software-selectable dual-readout amplifiers, also referred to as "ports", shown in Figure 23. The two amplifiers are listed below.

Port #1: Multiplication Gain

Port #2: Low Noise (Normal CCD)

If your camera is configured with two readout amplifiers (ports), the software automatically allows port selection (Multiplication Gain or Low Noise). An example of a software dialogue to select the ports is shown in Figure 24.

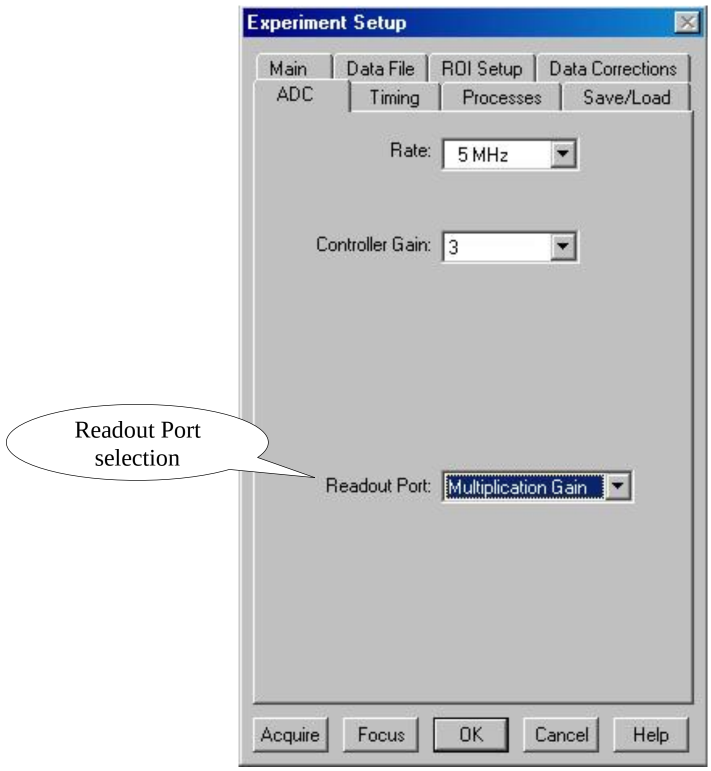


Figure 24. Selecting the Readout Port (Experiment Setup|Main tab page)

Note: As the user interface may be different, please refer to your software manual for specific information on readout amplifier/port selection.

1. **Multiplication Gain:** When this port is selected, the EM gain value can be entered on the **Experiment Setup|Main** tab page. Since the multiplication gain can be used to overcome the read noise of the fast amplifier, this mode is most useful in applications requiring low-light sensitivity at high frame rates (e.g., Single molecule fluorescence, ion imaging, etc.). Only 25x - 100x EM gain is required to overcome the read noise of the detector. Using excessive EM gain will not improve the overall signal to noise ratio (SNR).

Note: When used with a standard lens, the Multiplication Gain port produces an image in the correct orientation. The first pixel is read out at the bottom left of the array.

2. **Low Noise:** When the camera is using this amplifier, electrons (signal) generated in pixels are clocked through the standard serial register. The amplifier is designed to take advantage of the dynamic range of the CCD and is most useful when the frame rate is not critical. (e.g., bright field, fixed cell fluorescence, etc.)

Note: Since the first pixel to be read out from the Low Noise port is at the bottom right (closest to the Low Noise port), the resulting image is a mirror image of the same image if it were read out of the Multiplication Gain port. Some software packages do a "horizontal-flip" in the software when the Low Noise port is selected to ensure the correct orientation for all ports. In WinView and WinSpec, you can specify a horizontal-flip on the **Hardware Setup|Display** tab page.

Controller Gain

Controller gain (a function of the preamplifier and analog electronics) is software-selectable and is used to change the relationship between the number of electrons acquired on the CCD and the Analog-to-Digital Units (ADUs or counts) generated. In WinView and WinSpec, gain selection is made on the **Acquisition|Experiment Setup…|ADC** tab page (Figure 25). The choices are **1 (Low)**, **2 (Medium)**, and **3 (High)**. Users who measure high-level signals may wish to select **Low** to allow digitization of larger signals. **Medium** is suitable for experiments within the mid-level intensity range. Users who consistently measure low-level signals may wish to select **High**, which requires fewer electrons to generate an ADU and reduces some sources of noise.

The "Certificate of Performance" supplied with the camera lists the measured gain values at all settings.

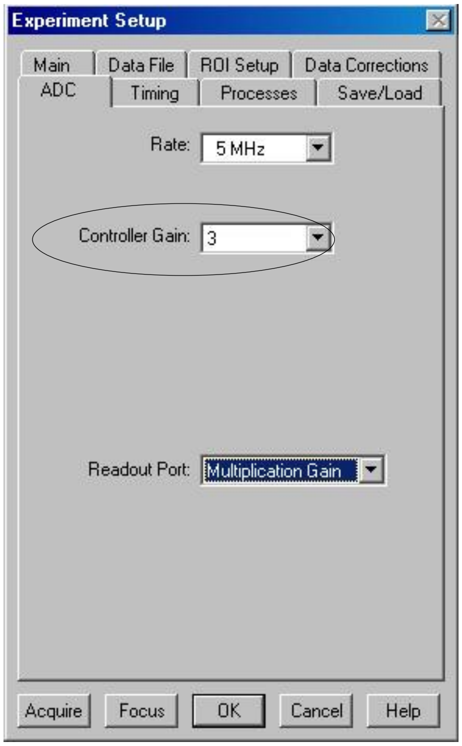


Figure 25. Selecting the Controller Gain (Experiment Setup|ADC tab page)

Readout Amplifier (Port)	Readout Rates	Typical Controller Gain for 512B (e^- /ADU)	Typical Controller Gain for 1024B (e^- /ADU)
Multiplication Gain	5 MHz 10 MHz	#1: 12e^- /ADU #2: 6e^- /ADU #3: 3e^- /ADU	#1: 12e^- /ADU #2: 6e^- /ADU #3: 3e^- /ADU
Low Noise	100 kHz 1 MHz 5 MHz	#1: 3.2e^- /ADU #2: 1.6e^- /ADU #3: 0.8e^- /ADU	#1: 3e^- /ADU #2: 1.5e^- /ADU #3: 0.7e^- /ADU

Table 2. Typical Controller Gains

Readout Rate

ProEM has the following readout rates available:

Multiplication Gain Port	Low Noise
10MHz	5MHz
5MHz	1MHz
	100kHz

The Low Noise readout port is ideal when high speed acquisition is not required and/or long integration times can be used to build up the signal. Lower readout speeds (e.g., 100kHz) and lack of excess noise in this mode offers better signal to noise ratio when high frame rate is not required. On the other hand, increased frame readout rate can be achieved by one or more of the following

- higher readout speed,
- subregion selection,
- binning.

For more information on frame rate, please refer to the product data sheet.

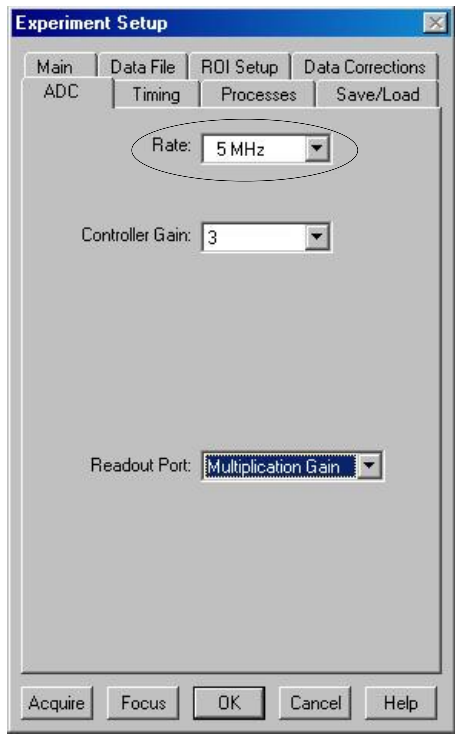


Figure 26. Selecting the Readout Rate (Experiment Setup|ADC tab page)

Region of Interest

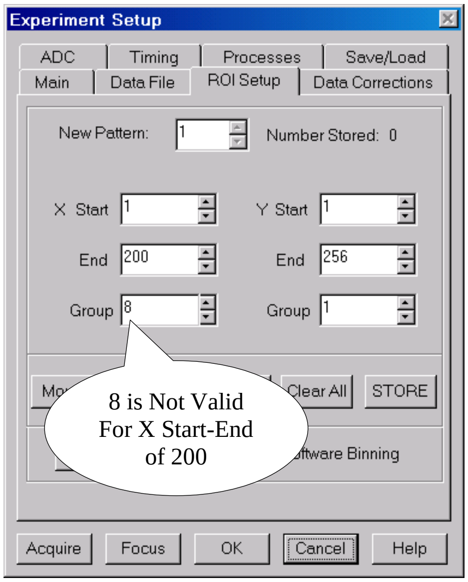
A Region of Interest (ROI) may be the entire CCD array or it may be a rectangular subregion of the array. In WinView and WinSpec, the definition of such a region is done either from the Easy Bin dialog box accessed from the Acquisition menu or from the ROI Setup tab page, accessible after selecting Experiment Setup from the Acquisition menu. Easy Bin is a simple way of a defining a single full chip width ROI. ROI Setup allows you to create ROIs with greater flexibility in ROI location and width.

Each ROI is defined in the X and Y direction by a start pixel, an end pixel, and a group/height (binning) factor. After one or more regions have been defined and stored, data acquisition will use these regions to determine which information will be read out and displayed and which information will be discarded.

When ROIs are used to acquire data, the ROI parameter information (for the first 10 ROIs) is stored in the data file when that data is saved to disk. You can review this information for the active data display by using the File Information functionality (accessible from the File menu or from the Display Context menu).

Notes:

1. For Flatfield Correction, Background Subtraction, etc., the images must be ***exactly*** the same size.
2. References to X and Y axes assume that the shift register is parallel to the X-axis and that the data is shifted to the shift register in the Y direction.



When setting up a partial frame ROI, keep in mind that for the ProEM the following constraint applies: **the number of pixels in the serial (horizontal) direction must evenly divisible by 4, even after binning.** The software may refer to the horizontal as X or Wavelength depending on the application.

Examples: These examples include partial frame ROIs with and without binning. The terminology is based on the WinView tab page shown to the right.

X Start to End = 200 pixels, no grouping (binning). Since 200/4=50, this is a valid ROI setup.

X Start to End = 200 pixels and grouping (binning) is by 8. The resulting number of super pixels is 25. Since 25/4=6.25, this is not a valid ROI setting for the horizontal direction.

X Start to End = 240 pixels, no grouping (binning). Since 240/4=60 this is a valid ROI setup.

X Start to End = 240 pixels and grouping (binning) is by 3. The resulting number of super pixels is 80. Since 80/4=20, this is a valid ROI setup.

X Start to End = 240 pixels and grouping (binning) is by 16. The resulting number of super pixels is 15. Since 15/4=3.75, this is not a valid ROI setting for the horizontal direction.

Binning

Binning (combining pixels into one super pixel) allows you to increase the sensitivity and frame rate. On the other hand, binning reduces spatial resolution. ProEM supports flexible vertical binning and binning of 2x-32x in the horizontal. When binning, keep in mind that the resulting number of super pixels in the horizontal must be evenly divisible by 4.

Array Orientation

For square format CCDs (for example, 512 × 512 or 1024 × 1024) you may orient the CCD to achieve binning along either direction of the CCD.

- Binning along columns (parallel mode) provides maximum scan rate and lowest noise.
- Binning along the rows (perpendicular mode) minimizes crosstalk and is therefore better for multi-spectral applications. The drawback to this method is that scanning is slower and noise may increase somewhat.

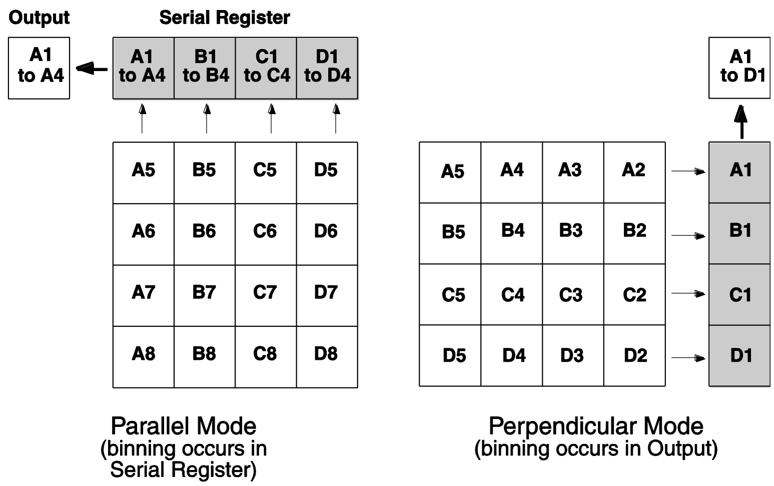


Figure 27. Binning and Array Orientation

You can easily switch between these orientations by rotating the camera 90° and changing the binning parameters in the application software.

Exposure - Readout Modes

The frame transfer CCDs used by the ProEM support both Frame Transfer and Full Frame (sequential) readout modes. If you are planning to use Frame Transfer mode, be aware that the set exposure time (**Experiment Setup|Main** tab page) may not be the effective exposure time.

Frame Transfer Mode (Simultaneous Exposure-Readout)

Frame Transfer mode is extremely useful in applications requiring continuous imaging (100% duty cycle). Once a frame is exposed and transferred into the frame transfer area, the next exposure immediately starts and continues until the previous frame is read out of the frame transfer area or until the exposure time is finished, whichever is longer (so the minimum effective exposure time in this mode is the readout time). This mode of operation allows you to continuously image a specimen to obtain better kinetic information about a process.

In WinView and WinSpec, Frame Transfer is the default mode of operation for this camera. If necessary, you can change the readout mode on the Hardware Setup/Controller/Camera tab page.

Figure 28 shows the required selections for Frame Transfer mode.

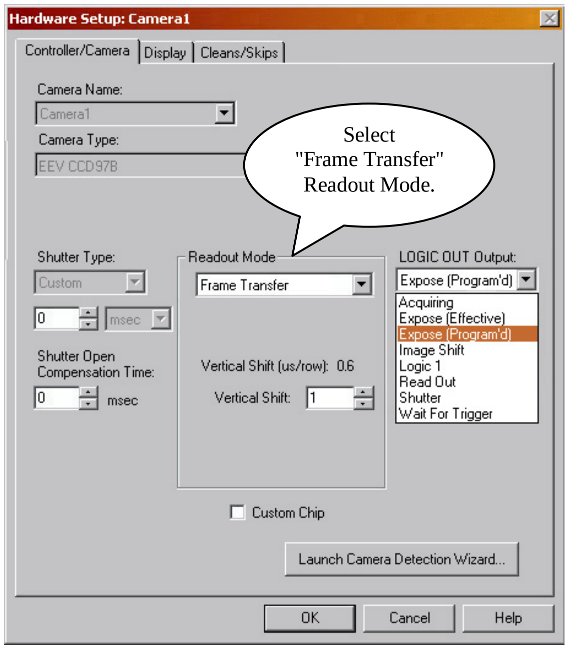


Figure 28. Frame Transfer Readout Mode Selection

Note: In Frame Transfer mode, the minimum effective exposure time is the readout time.

The simultaneous exposure-readout mechanism is illustrated with two examples for the 512B model. This mechanism applies to the 1024B as well but with a larger readout time.

Example 1: Frame Transfer Mode when Exposure Time < Readout Time

Consider a situation where full frame readout is 30 ms, the exposure time is 10 ms, and three frames are taken in Frame Transfer mode. The first frame is exposed precisely for the length of time entered into the software (10 ms) and all subsequent frames are exposed for the readout time. The total time to acquire 3 frames is then 100 ms (3 × 30 ms + 10 ms), equivalent to a frame rate of 33.33 fps (3 frames ÷ 0.100 seconds).

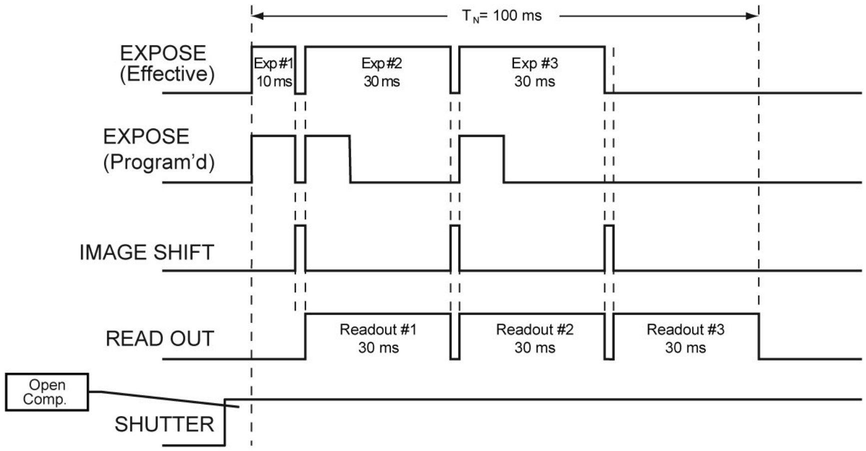
Note: Because the first frame is exposed for 10 ms and the others for 30 ms, the first frame may look less bright compared to all other frames.

In Frame Transfer mode when exposure time < readout time, the total time (T_N) taken to capture N frames is given by:

$$T_N = (t_R \times N) + t_{exp}$$

Where

T_N = Total time taken to capture a sequence of N frames
t_R = readout time for one frame
N = total number of frames in a sequence
t_{exp} = exposure time



Logic Out Signal Descriptions:

EXPOSE (Effective) = High during the time when the CCD is collecting light.
EXPOSE (Program'd) = High during programmed exposure (as entered in the software). Can be used for gating the light source.
IMAGE SHIFT = High while the image is being shifted under the mask. When low, the CCD is light-sensitive.
READ OUT = High during "Vertical Transfer + Digitization."
SHUTTER = High during "Shutter open comp + Exposure". Follows Disabled Opened or Disabled Closed.

Figure 29. Timing Diagram for Frame Transfer Mode when Exposure Time < Readout Time. Timing information shown is for illustration purpose only. Specific readout times vary depending on the model.

Example 2: Frame Transfer Mode when Exposure Time > Readout Time

If the exposure time is set to 50 ms with the readout time remaining at 30 ms, the time taken to acquire 3 frames will be 180 ms (3 × 50 ms + 30 ms), which is equivalent to a frame rate of 16.67 fps.

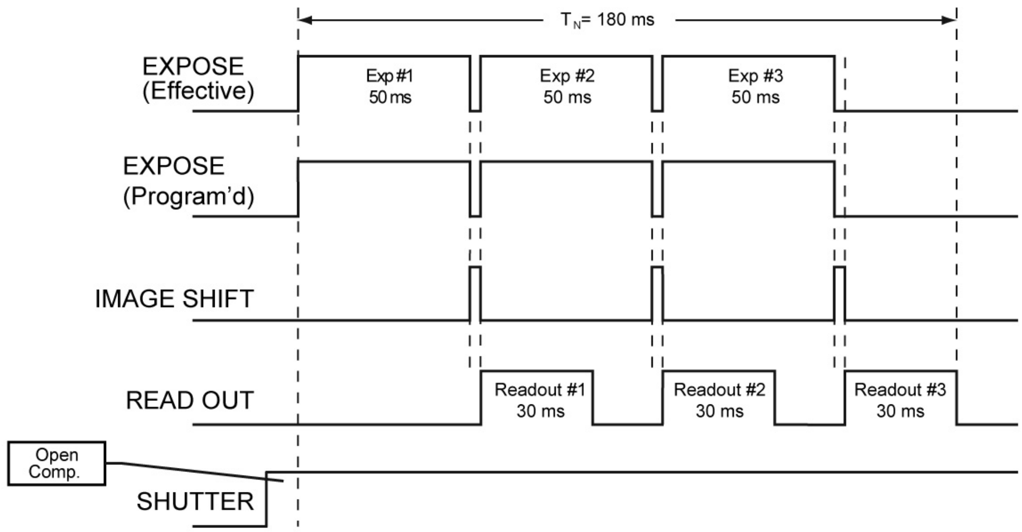
In Frame Transfer mode when exposure time > readout time, the total time (T_N) taken to capture N frames is expressed as:

$$T_N = (t_{exp} \times N) + t_R$$

Where

T_N = Total time taken to capture a sequence of N frames
t_{exp} = exposure time
N = total number of frames in a sequence
t_R = readout time for one frame

From the timing diagram, you can see that because the exposure time is greater than the readout time, all frames are precisely exposed for the duration entered into the software and have similar intensities.



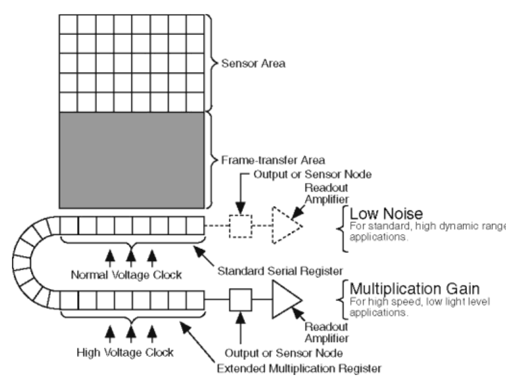
Logic Out Signal Descriptions:

Expose (Effective) = High during the time when the CCD is collecting light.
EXPOSE (Program'd) = High during programmed exposure (as entered in the software).
IMAGE SHIFT = High while the image is being shifted under the mask. When low, the CCD is light-sensitive.
READ OUT = High during "Vertical Transfer + Digitization."
SHUTTER = High during "Shutter open comp + Exposure". Follows Disabled Opened or Disabled Closed.

Figure 30. Timing Diagram for Frame Transfer Mode when Exposure Time > Readout Time. Timing information shown is for illustration purpose only. Specific readout times vary depending on the model.

Full Frame (Sequential) Mode

Full Frame mode allows you to expose the array for the exposure time specified in the software and is similar in performance to a normal, full-frame CCD device. The operational sequence for this mode is:



1. Clearing the CCD,
2. Exposing for the specified exposure time,
3. Shifting the image from the sensor area to the frame-transfer area, and
4. Reading out the CCD.

Steps 1-4 are repeated for each frame in a sequence. Steps 1 and 3, clearing the CCD and shifting the image, are usually very short and do not impact the frame rate.

In WinView and WinSpec, Full Frame mode can be selected from Hardware Setup|Controller/Camera tab page. Figure 31 shows this selection.

Note: Since the software you are using may show the settings differently, you should refer to the software documentation for accurate information.

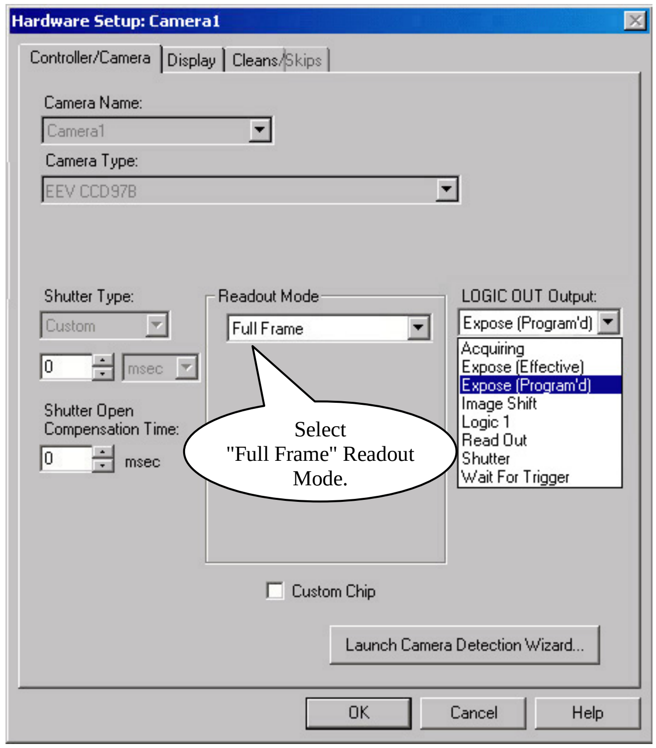
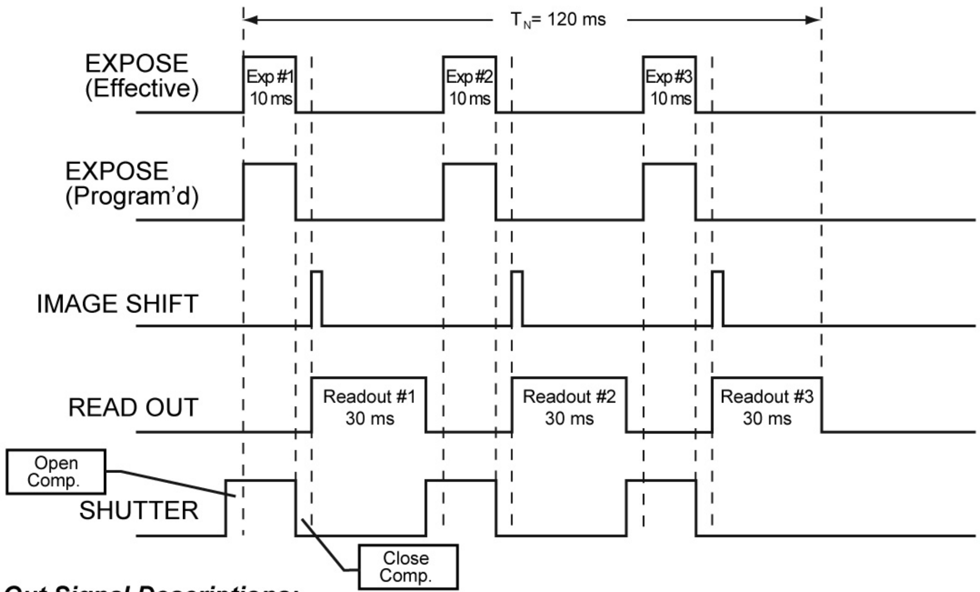


Figure 31. Full Frame Mode Selection

Example: Full Frame Mode

Operation in Full Frame mode is illustrated in the timing diagram below. In this example, the exposure time is 10 ms and the readout time is 30 ms. The total time to take 3 frames is 120 ms (3 × 10 ms + 3 × 30 ms), equivalent to a frame rate of 25 fps (3 frames ÷ 0.120 seconds).

Note: The exposure and readout times listed are for illustration purpose only. Actual values may vary. Refer to the product data sheet for the actual readout times.



Logic Out Signal Descriptions:

EXPOSE (Effective) = High during the time when the CCD is collecting light.
EXPOSE (Program'd) = High during programmed exposure (as entered in the software).
IMAGE SHIFT = High during "Image to storage" time.
READ OUT = High during "Vertical Transfer + Digitization."
SHUTTER = High during "Shutter open comp + Exposure". Follows Disabled Opened or Disabled Closed.

Figure 32. Timing Diagram for Full Frame Mode. Timing information shown is for illustration purpose only. Specific readout times vary depending on the model.

Referring to Figure 32, it can be seen that exposure and readout are carried out in a sequential fashion. As a result, each frame in the sequence is precisely exposed for the time specified (i.e., 10 ms).

Readout Time

Readout time can be obtained from WinView/Spec by going to the Acquisition menu and selecting Readout time menu. It is calculated based on the current ROI/Binning/Vertical shift rate settings.

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Chapter 6
Advanced Topics

Introduction

Previous chapters have discussed setting up the hardware and the software for basic operation. This chapter discusses topics associated with experiment synchronization (set up on the **Experiment Setup|Timing** tab page in WinView and WinSpec). With the exception of Edge Trigger, the topics are addressed in order of their appearance on the Timing tab page (see Figure 33).

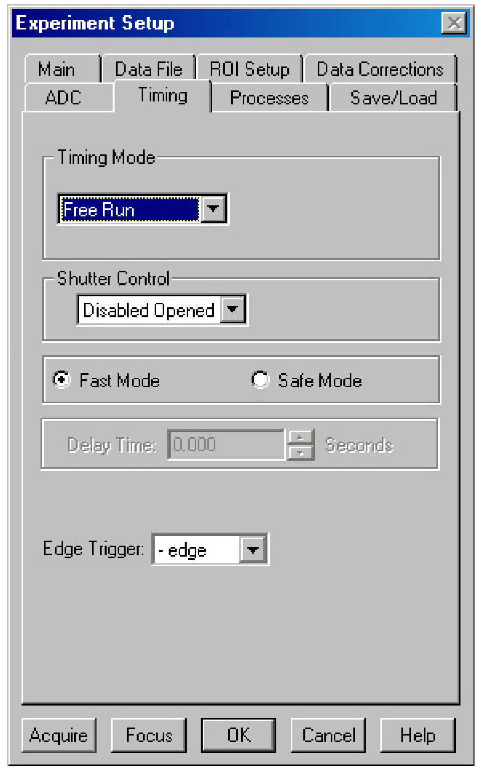


Figure 33. Timing tab page

"Timing Modes", the first topic, discusses Timing Modes, and Shutter Control.

"Fast and Safe Modes", the second topic, discusses the Fast and the Safe modes. Fast is used for real-time data acquisition and Safe is used when coordinating acquisition with external devices or when the computer speed is not fast enough to keep pace with the acquisition rate.

"Logic Out Control" discusses the Ext Sync and Logic Out connectors on the rear of the ProEM. The levels at these connectors can be used to monitor camera operation or synchronize external equipment.

"Kinetics Mode" discusses Kinetics mode. This form of data acquisition relies on mechanical or optical masking of the CCD array for acquiring time-resolved images.

"Custom Chip", the final topic, discusses Custom Chip mode. This mode allows you to specify an active sub-area of the CCD array for the purpose of increased frame rate (pixels outside of the area are not read). This mode requires mechanical or optical masking of the array to prevent smearing.

Frame Transfer/Full Frame Timing Modes and Shutter Control

Overview

The basic ProEM timing modes for Frame Transfer and Full Frame operations are Free Run, External Sync and Bulb Trigger. These modes are combined with the Shutter Control options to provide the widest variety of modes for precision experiment synchronization. The shutter options available for Frame Transfer and Full Frame operations are Disabled Opened and Disabled Closed.

Disabled simply means that the shutter will not operate during the experiment. Disabled closed is useful for making dark charge measurements. PreOpen, available in the External Sync and External Sync with Continuous Cleans modes, opens the shutter as soon as the ProEM is ready to receive an External Sync pulse. This is required if the time between the External Sync pulse and the event is less than a few milliseconds, the time it takes the shutter to open.

The shutter timing is shown in the timing diagrams that follow. Except for Free Run, where the modes of shutter operation are identical, both Normal and PreOpen lines are shown in the timing diagrams and flow chart.

Free Run

In Free Run mode, there is no external triggering and all settings are read from the setup parameters, making the duration of each exposure time constant and the interval times between exposures constant (see Figure 34).

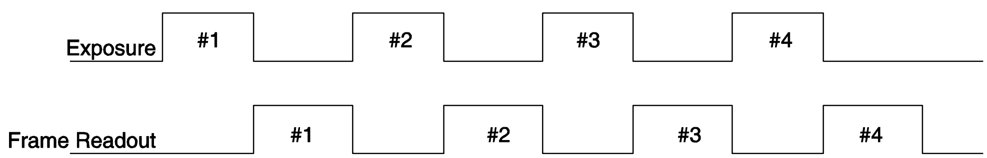


Figure 34. Free Run Timing Diagram

External Sync

In External Sync mode, each frame in a sequence requires a trigger. Each frame is exposed for the length of time entered into the software and is then read out. If a trigger arrives during the exposure-readout of the previous frame, it is ignored (see Figure 35). For a sequence of one frame, strobe mode and trigger-first mode are the same. The shaded areas denote the idle time between exposures.

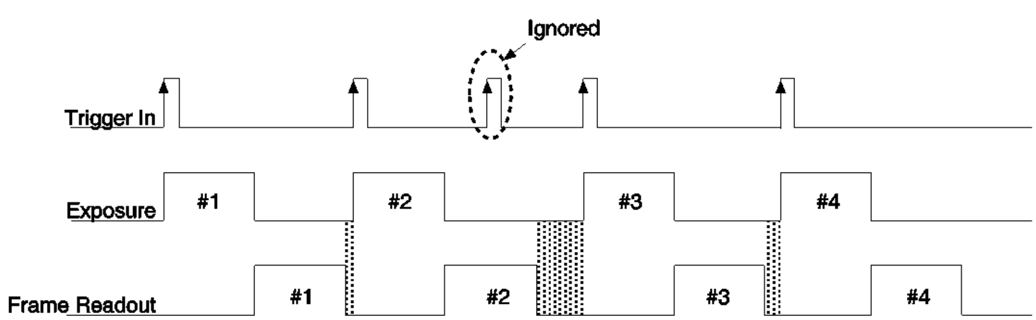


Figure 35. External Sync Timing Diagram

External Sync with Continuous Cleans Timing

Another timing mode available with the ProEM is called Continuous Cleans. In addition to the standard "cleaning" of the array, which occurs after the camera is enabled, Continuous Cleans will remove any charge from the array until the moment the External Sync pulse is received.

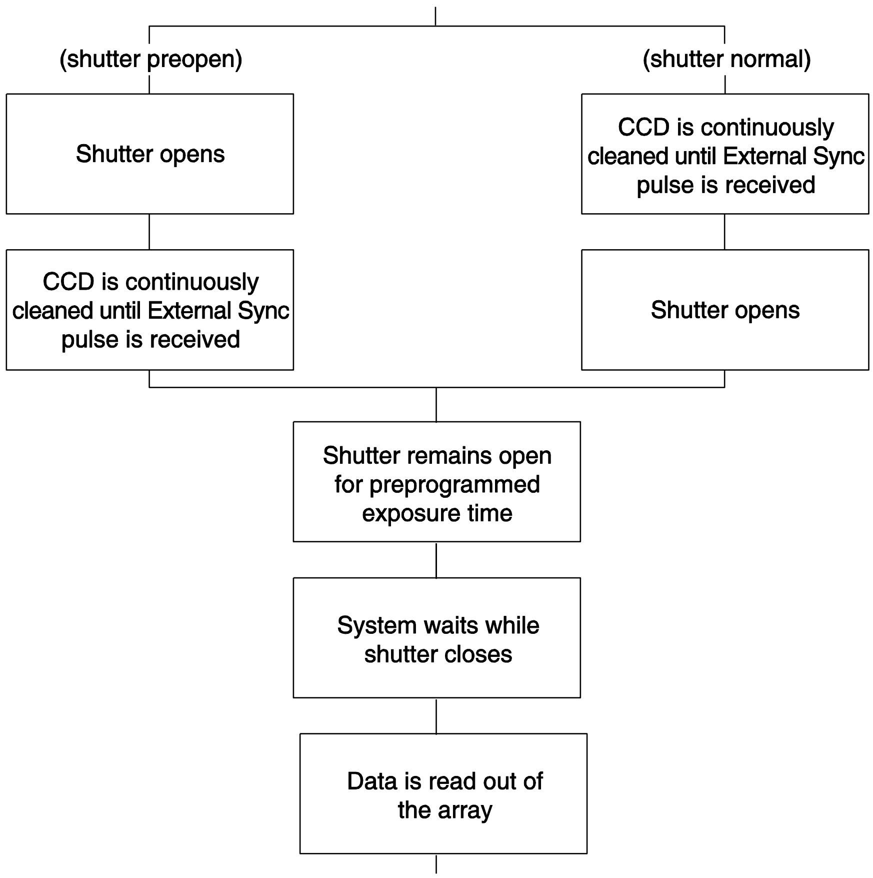


Figure 36. Continuous Cleans Flowchart

Once the External Sync pulse is received, cleaning of the array stops as soon as the current row is shifted, and frame collection begins. With Normal Shutter operation the shutter is opened for the set exposure time. With PreOpen Shutter operation the shutter is open during the continuous cleaning, and once the External Sync pulse is received the shutter remains open for the set exposure time, then closes. If the vertical rows are shifted midway when the External Sync pulse arrives, the pulse is saved until the row shifting is completed, to prevent the CCD from getting "out of step." As expected, the response latency is on the order of one vertical shift time, from 1-30 μsec depending on the array. This latency does not prevent the incoming signal from being detected, since photo generated electrons are still collected over the entire active area. However, if the signal arrival is coincident with the vertical shifting, image smearing of up to one pixel is possible. The amount of smearing is a function of the signal duration compared to the single vertical shift time.

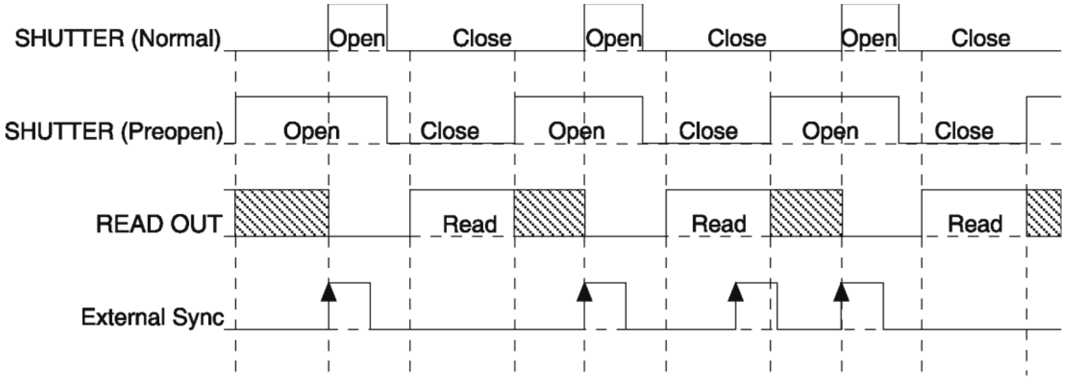


Figure 37. Continuous Cleans Timing Diagram

EXT SYNC Trigger Input

The selected Timing Mode determines how the camera will respond to an External Sync pulse that is input at the **EXT SYNC** connector on the rear of the camera. Things to keep in mind when setting up the External Sync pulse input are:

Pulse Height: 0 to +3.3V logic levels (TTL-compatible).

Pulse Width (trigger edge frequency): The time between trigger edges.

EXT SYNC Connector Impedance: 50 Ω

Trigger Edge: + (rising) or - (falling) edge must be indicated on the **Experiment Setup|Timing** tab page.

Figure 38. Rear of ProEM Camera

Bulb Trigger Timing

When "Bulb Trigger" timing is selected, the camera exposure is set by the External Sync input at the EXT SYNC connector. This allows an external timing generator to control the exposure time of the camera.

In Full Frame, Frame transfer, or Kinetic modes, the transition from the inactive state to the active state of the External Sync at the EXT SYNC connector starts the exposure; and the transition from the active state to the inactive state ends the Expose.

When the camera is ready to accept the external sync through the EXT SYNC connector, the Wait for Trigger (WFT) signal at the LOGIC OUT connector is high (if WFT is the selected output signal): WFT goes HIGH immediately after readout (or after preopen if it is active). It goes LOW when an active edge (+ or – edge depending on your setting) occurs and, if continuous cleans is not enabled, the exposure begins. If continuous cleans is enabled, the camera will check for an active edge at the EXT SYNC connector before entering a continuous clean cycle. If none has occurred, a cycle will begin and complete. The EXT SYNC connector is checked again to see if an active edge has occurred and exposure will begin if it has.

In Kinetics mode-Multiple Trigger, the first exposure is the same as described above. The subsequent exposures really start when WFT on the LOGIC OUT connector goes high.

The External Sync on the EXT SYNC connector must then transition to the active state. The exposure will end when the External Sync transitions back to the inactive state.

Notes:

1. Kinetics mode-Single trigger is not a valid option for Bulb Trigger mode.
2. “Continuous Clean” is only executed on the first trigger in a sequence. The subsequent triggers will not run the Continuous Clean Programmed pattern.

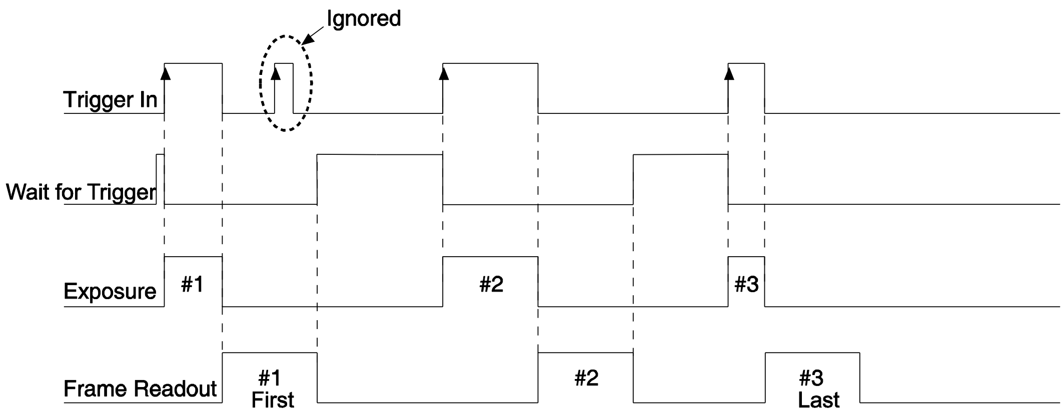


Figure 39. Bulb Trigger Timing Diagram: Non-Overlap Mode, Three Exposure Sequence, No Preopen, No Continuous Cleans

Fast and Safe Modes

Introduction

The ProEM has been designed to allow the greatest possible flexibility when synchronizing data collection with an experiment. The fundamental difference between the Fast and Safe modes is how often the acquisition start and acquisition stop commands are sent by the computer for a data collection sequence. With Safe Mode, the computer sends a start and a stop command for **each frame** of a data sequence. With Fast Mode, the computer sends only one start and one stop command for **each data sequence**. Once the start command is sent, the selected timing mode and the shutter condition determine when charge will be allowed to fall on the CCD array.

In WinView/32 and WinSpec/32, the choice of **Fast** or the **Safe** data collection is made on the **Experiment Setup|Timing** tab page. The flowcharts in Figure 40 show the differences between the two modes.

Fast Mode

In Fast operation, the ProEM runs according to the timing of the experiment, with no interruptions from the computer. Fast operation is primarily for collecting "real-time" sequences of experimental data, where timing is critical and events cannot be missed. Once the ProEM is sent the start command by the computer, all frames are collected without further intervention from the computer. The advantage of this timing mode is that timing is controlled completely through hardware. A drawback to this mode is that the computer will only display frames when it is not performing other tasks. Image display has a lower priority, so the image on the screen may lag several images behind. A second drawback is that a data overrun may occur if the number of images collected exceeds the amount of allocated RAM or if the computer cannot keep up with the data rate.

Safe Mode

In Safe Mode operation, the computer processes each frame as it is received: the ProEM cannot collect the next frame until the previous frame has been completely processed. Safe Mode operation is useful when the camera is operated from a slower computer that cannot process the incoming data fast enough. It is also useful when data collection must be coordinated with external devices such as external shutters and filter wheels. As seen in Figure 40, in Safe Mode operation, the computer controls when each frame is taken. After each frame is received, the camera sends the stop command to the camera, instructing it to stop acquisition. Once that frame is completely processed and displayed, another start command is sent from the computer to the camera, allowing it to take the next frame. Display is therefore, at most, only one frame behind the actual data collection. One disadvantage of the Safe mode is that events may be missed during the experiment, since the camera is disabled for a short time after each frame.

Note: Safe Mode must be used whenever the system is set up for the optional Kinetics Readout Mode. See ***"Kinetics Mode"*** (page 63) for more information about this type of image acquisition and readout.

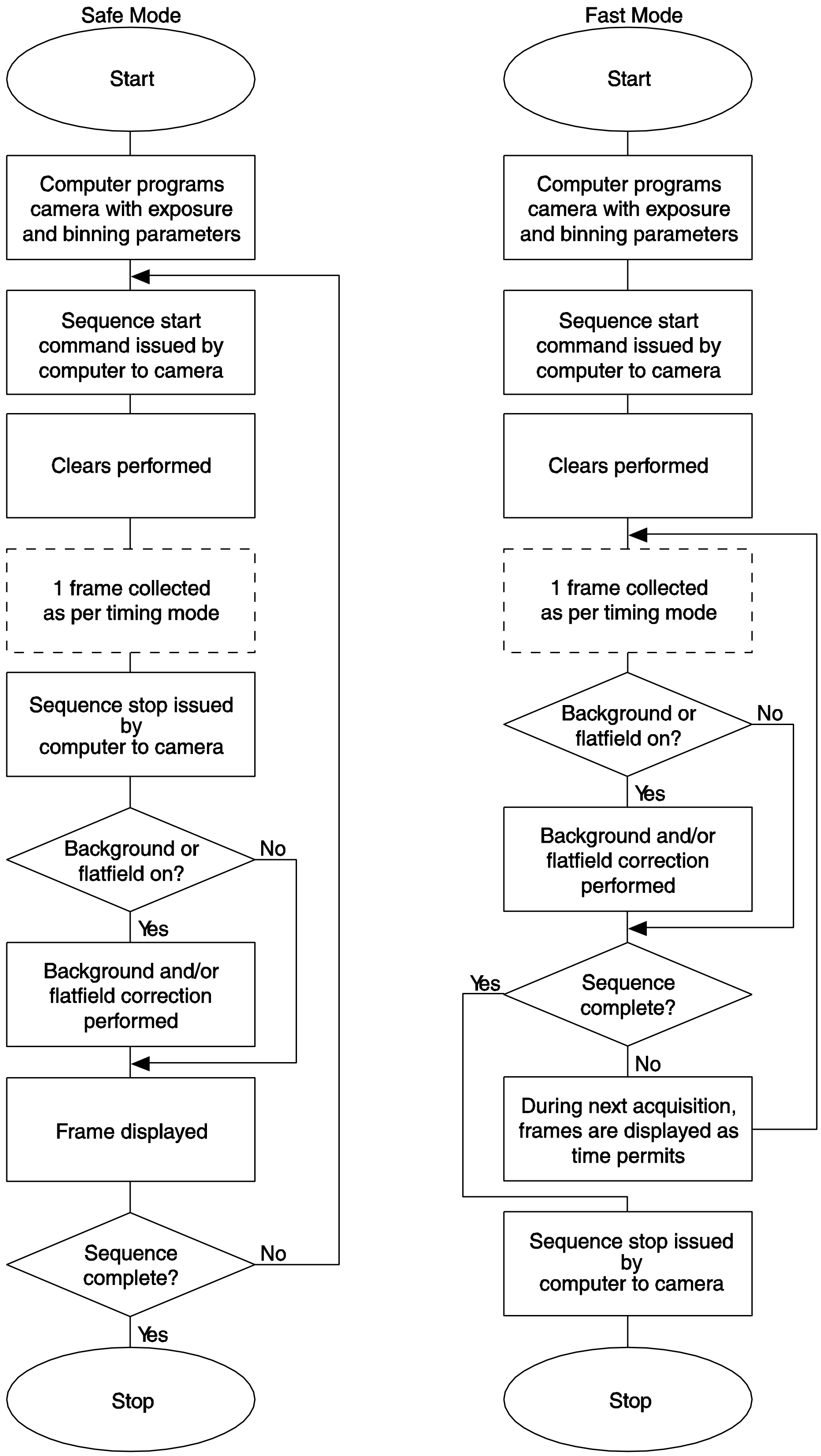


Figure 40. Flowcharts of Safe and Fast Mode Operation

LOGIC OUT Control

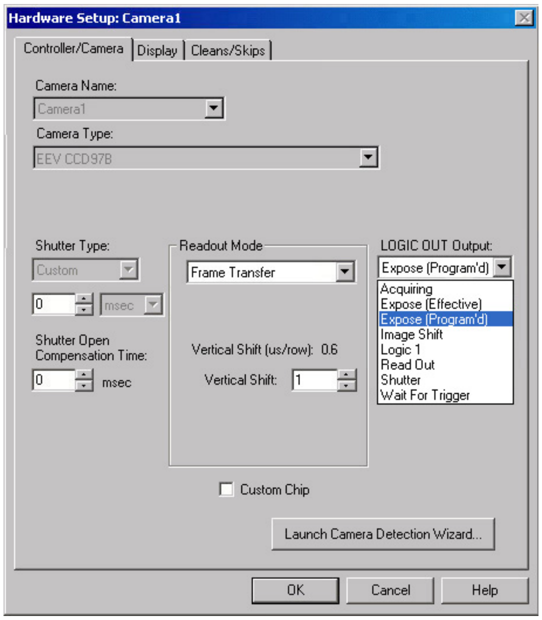


Figure 41. Hardware Setup|Controller/ Camera tab page

The TTL-compatible logic level output (0 to +3.3 V) from the **LOGIC OUT** connector on the rear panel can be used to monitor camera status and control external devices. By default, the logic output level is high while the action is occurring. The timing of the level changes depends on the output type selected on the **Hardware Setup|Controller/Camera** tab page:

- **Acquiring:** After a start acquisition command, this output changes state on completion of the array cleaning cycles that precede the first exposure. Initially low, it goes high to mark the beginning of the first exposure. In free run operation it remains high until the system is halted. If a specific number of frames have been programmed, it remains high until all have been taken and then returns low. Figure 42 assumes 3 frames have been programmed.
- **Expose (Effective):** This level is at a logic high during the effective exposure time. This exposure time equals the read out time in frame transfer mode when the exposure time is less than the readout time. Otherwise, Expose (Effective) and Expose (Program'd) are identical.
- **Expose (Program'd):** This level is at a logic high during the programmed exposure time (i.e., the time set in the software).
- **Image Shift:** This level is at a logic high while the image is being shifted under the mask.
- **Logic 1:** The level at the connector is high.
- **Read Out:** It is at a logic high when CCD is being read; otherwise low.
- **Shutter:** This level is at a logic high when the shutter is open. The output precisely brackets shutter-open time (exclusive of shutter compensation, t_c) and can be used to control an external shutter or to inhibit a pulser or timing generator.
- **Wait for Trigger:** This level is at a logic high when the camera is ready to acquire and is waiting for an external trigger (through the EXT SYNC connector) before exposing the CCD. The level goes low when a trigger is detected: exposure begins. The Wait for Trigger (WFT) signal goes high immediately after readout or after preopen (if it is active). If continuous cleans is enabled, the camera will check for a trigger at the EXT SYNC connector before entering a continuous clean cycle. If none has occurred, a cleaning cycle is initiated and

completed. Before the next cycle begins, the EXT SYNC connector is checked again, and exposure will start if a trigger has occurred.

When the **Invert LOGIC** check box is checked, the output is at a logic low when the action is occurring.

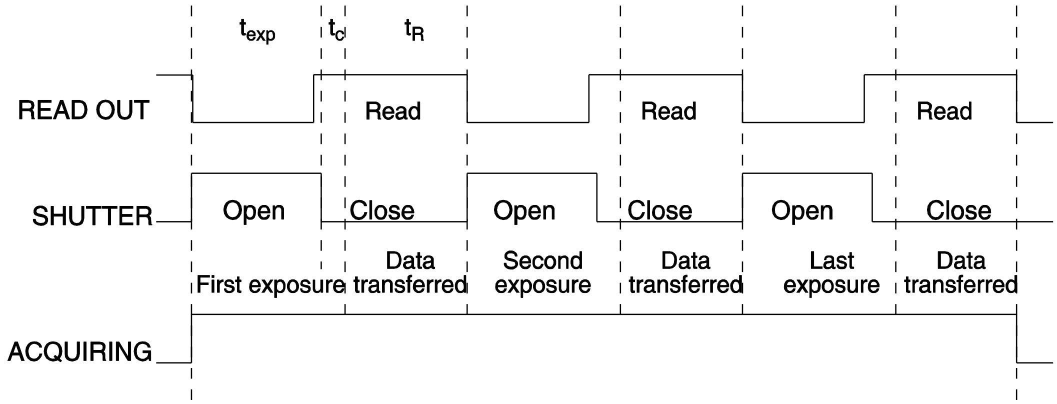


Figure 42. Comparison of READ OUT, SHUTTER, and ACQUIRING Logic Output Levels

Kinetics Mode

Introduction

"Kinetics" refers to a special readout mode in which a portion of the CCD is illuminated while the rest of the active area is used to store a series of frames. At the end of the exposure-shift sequence, the entire CCD is readout to give a series of subframes (kinetic frames) separated in time. In order to support this special mode of operation, it is essential that the camera architecture be made flexible with special access to underlying CCD control functions Aided by the back illumination technology for high QE and multiplication gain for sub-electron read noise, the kinetics mode provides the powerful combination of speed and sensitivity.

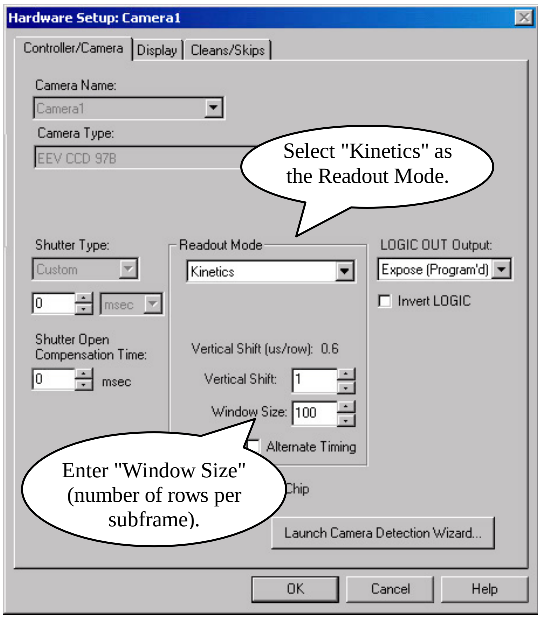


Figure 43. Hardware Setup Dialog Box: Kinetics Readout Mode

Kinetics Readout

Kinetics readout allows a burst of subframes be captured with μsec resolution. This is accomplished by shifting each subframe exposure under the mask before reading it out. Since there is no overhead of readout time between each exposure, faster time resolution is achieved. At the end of a series "exposure-shift" cycles, the entire frame is typically read out at a slower readout speed, which does not affect the time resolution. The use of multiplication gain (EM Gain) in ProEM further improves the SNR when the signal is below the read noise.

In kinetics mode, a portion of the CCD image is optically masked in order to minimize the cross-talk between subframes. Typically, in imaging applications, this is accomplished by placing a “knife edge” or an optical mask in the collimated beam path. Whereas, in spectroscopy, this is best achieved by limiting the height of the entrance slit of the spectrograph. In most of the applications, ability to mask as few rows as possible sets the ultimate limit on the temporal resolution. The operation is illustrated with examples in Figure 44 using an optical test target image.

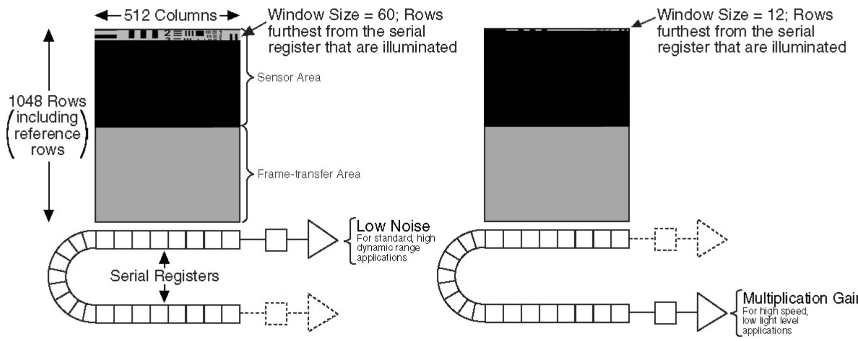
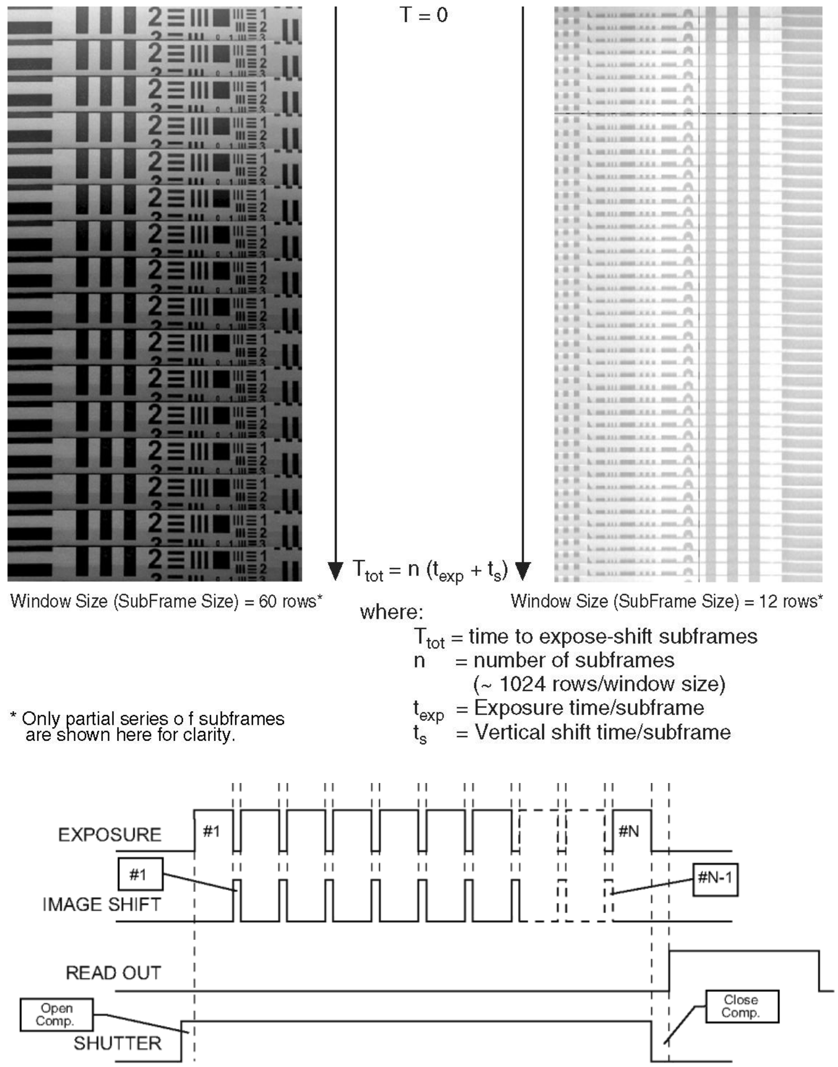


Figure 44. Two Examples illustrating Partial Illumination of CCD for Kinetics Mode in ProEM: 512B

Note: The illuminated area is the furthest from the serial register.

- The left image shows an illuminated area of 60 rows. Window Size is 60 rows high.
- The right image shows an illuminated area of 12 rows. Window Size is 12 rows high.



Logic Out Signal Descriptions:

EXPOSURE = High during programmed exposure (as entered in the software).
IMAGE SHIFT = High during "Image to storage" time.
READ OUT = High during "Vertical Transfer + Digitization."
SHUTTER = High during "Shutter open comp + All Exposures + Shift Cycles". Follows Disabled Opened or Disabled Closed.

Figure 45. Kinetics Data acquired based on Masked Images shown in Figure 44.

Notes:

1. The timing diagram represents the exposure-readout sequence. Time resolution between subframes is given by $t_{exp} + t_s$.
2. A reduced number of rows in the right image illustrate a way to achieve better time resolution between subframes.

Kinetics Timing Modes and Shutter Control

For Kinetics, the timing modes are Free Run, Single Trigger, and Multiple Trigger. Free run mode is used for experiments that do not require any synchronization with the experiments. The other two modes (single trigger and multiple trigger) require that an external TTL pulse be applied to the camera via the Trigger In connector on the I/O cable. The camera can be triggered either on +ve or -ve edge of the incoming TTL pulse.

In the Free Run Kinetics mode, the ProEM takes a series of images, each with the Exposure time set through the software (in WinView32 or WinSpec/32, the exposure time is set on the **Experiment Setup|Main** tab page). The time between image frames, which may be as short as a few microseconds, is limited by the time required to shift an image under the mask: this interimage time equals the Vertical Shift rate (specified in nsec/row) multiplied by the Window Size (the number of rows allocated for an image frame). The exact number of frames depends on the selected Window Size and is equal to the number of pixels perpendicular to the shift register divided by the Window Size. Integrate signals (SHUTTER) or Readout signals (READ OUT) are provided at the **LOGIC OUT** connector for timing measurements.

The Shutter Control options are Normal (PreOpen selectable), Disabled Open and Disabled Closed. Normal means that the Shutter opens at the beginning of the first exposure-shift kinetics cycle and closes at the end of the last exposure-shift cycle. Disabled simply means that the shutter will not operate during the experiment. Disabled closed is useful for making dark charge measurements. PreOpen, available in the External Sync and External Sync with Continuous Cleans modes, opens the shutter as soon as the ProEM is ready to receive an External Sync pulse. This is required if the time between the External Sync pulse and the event is less than a few milliseconds, the time it takes the shutter to open.

Triggered Operation

In single trigger mode, the camera requires only one trigger to initiate an entire series of "exposure-shift" cycles as shown in the timing diagram below. Here, the camera uses the exposure time as entered into the software. The trigger is applied at the **Ext. Sync** connector on the rear of the ProEM.

In multiple trigger mode, each "exposure-shift" cycle is triggered independently by a pulse applied at the **Ext. Sync** connector. This mode is useful when each subframe needs to be synchronized with a pulsed external light source such as a laser.

Note: It is particularly important to keep ambient light to a minimum while multiple trigger mode is used. In the case of this mode, automatic cleaning of the CCD only occurs until the first trigger arrives. Once the series of "exposure-shift" cycles begins, cleaning does not occur and, at the end of a cycle, ambient light will be collected through the window until the next trigger arrives. Depending on the time between triggers and the amount of ambient light, some subframes may appear brighter than others.

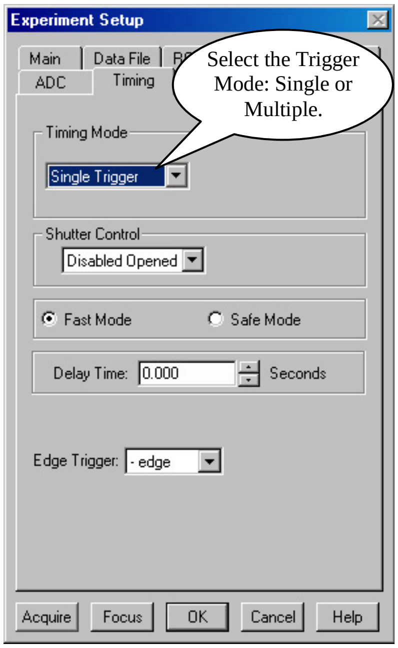


Figure 46. Experiment Setup| Timing tab page

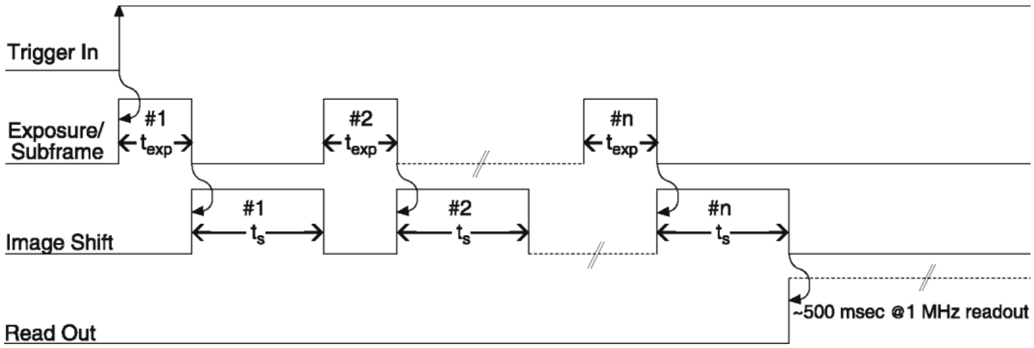


Figure 47. Example showing Kinetics Operation using "Single Trigger"

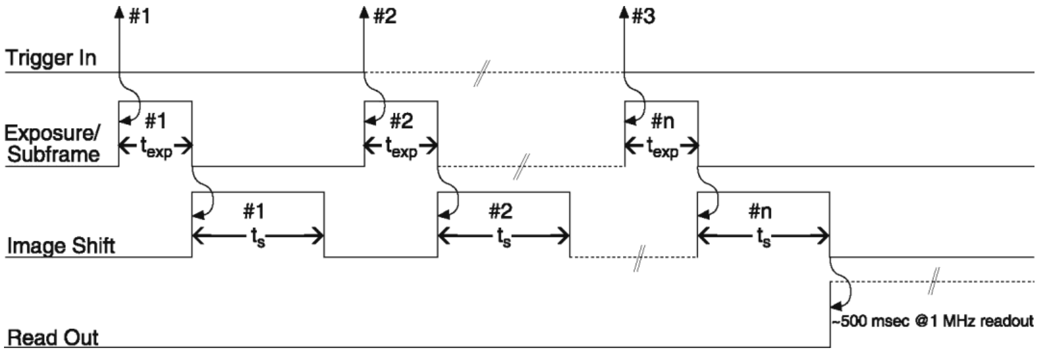


Figure 48. Example showing Kinetics Operation using "Multiple Trigger"

Cleaning the CCD

Since kinetics is most often used in asynchronous, single-shot experiments, it is important that CCD be cleared of accumulating background or dark charge while it is waiting for an external trigger. To take care of this, ProEM automatically cleans the CCD "one row at a time" before the arrival of the first trigger. This keeps the charge buildup on the CCD to a minimum at the same time minimizing the timing jitter (determined by vertical shift time of a single row). If desired, the number of cleans can be set to zero for the best jitter performance. However, the camera must be in dark environment to minimize the background.

Setting up a Kinetics Experiment

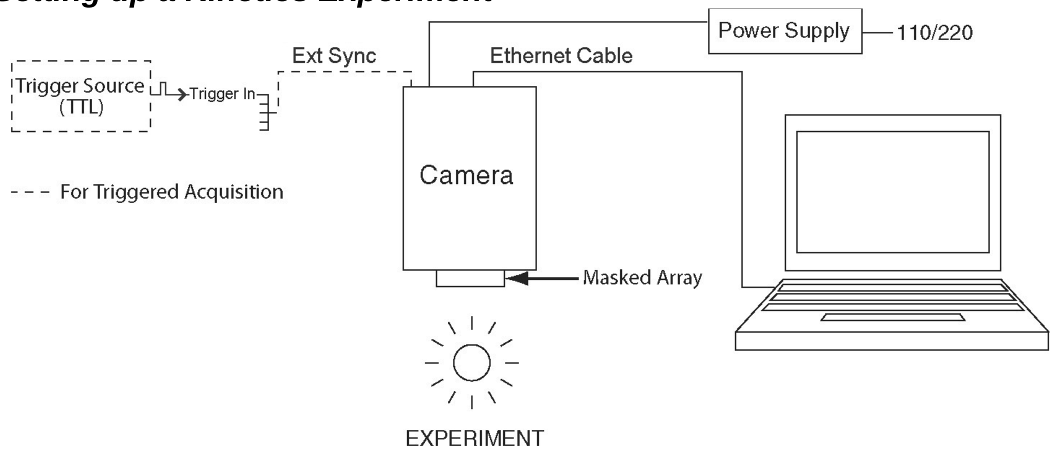


Figure 49. Typical Kinetics Experiment Layout

This procedure assumes that:

1. You have already set up your system in accordance with the instructions in the previous chapters.
2. You have read the previous sections of this chapter.
3. You are familiar with the application software.
4. The system is being operated in imaging mode.
5. The target is a sharp image, text, or a drawing that can be used to verify that the camera is "seeing" and can be used to maximize focus.
6. You are only illuminating a portion of the CCD as shown in Figure 44.

Setting the Software Parameters:

> **Note:** The following procedure is based on WinView/32: you will need to modify it if you are using a different application. Basic familiarity with the WinView/32 software is assumed. If this is not the case, you may want to review the software manual or have it available while performing this procedure.

Set the software parameters as follows:

Controller/Camera tab page (Setup|Hardware): These parameters should be set automatically to the proper values for your system.

- **Controller type:** This information is read from the camera.
- **Camera type:** This information is read from the camera.

- **Shutter type:** Custom (System dependent).
- **Readout mode:** Available modes are read from the camera. Select **Kinetics**.
- **Window Size:** Enter the number of exposed rows.

Cleans tab page (Setup|Hardware): Automatically set.

Detector Temperature (Setup|Detector Temperature…): The default temperature setting is read from the camera. When the array temperature reaches the set temperature, the **Detector Temperature** dialog box will report that the temperature is **LOCKED**.

Experiment Setup|Main tab page (Acquisition|Experiment Setup…):

- **Exposure Time:** 100 µsec
- **Accumulations & Number of Images:** 1

Experiment Setup|ROI tab page (Acquisition|Experiment Setup…): Use this function to define the region of interest (ROI).

- **Imaging Mode:** Select this mode if you are running WinSpec.
- Clicking on **Full** loads the full size of the chip into the edit boxes.

Experiment Setup|Timing tab page (Acquisition|Experiment Setup…):

- **Timing Mode:** Free Run, Single Trigger, or Multiple Trigger
- **Shutter Control:** Normal
- **Safe Mode vs. Fast Mode:** Safe Mode must be selected for Kinetics mode operation.

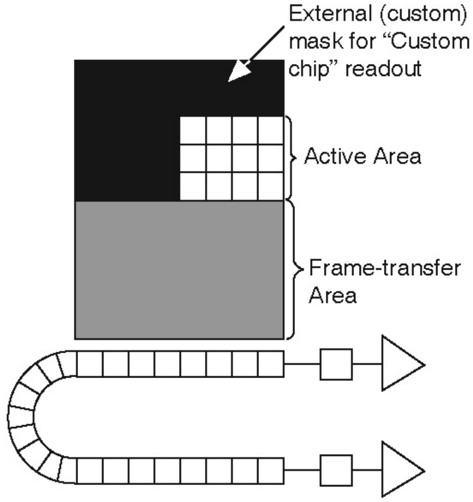
Summary

The kinetics is a powerful feature that allows a burst of subframes to be captured with microsecond time resolution. However, careful attention must be paid to the optical and timing considerations, namely

- The rows furthest from the serial register need to be illuminated.
- The rest of the active area must be optically masked.
- Single trigger mode allows capture the burst of frame with just one trigger.
- In multiple trigger mode, the camera requires a trigger for each "exposure-shift" cycle.
- The highest time resolution between kinetic frames is determined by the window (subframe) size.
- Acquisition must be in Safe Mode.
- Binning and ROI selections are supported as in the standard operation.

Custom Chip Mode

Introduction



In addition to Binning and ROI (previously discussed in the manual), there is a third way to reduce Readout Time – Custom Chip. This feature allows you to redefine the size of the EMCCD's active area via software. Unlike setting a smaller region of interest (ROI), which also involves reading out fewer pixels, Custom Chip mode does not incur overhead from discarding or skipping the rest of the rows. And, unlike both Binning and ROI, Custom Chip also relies on some form of array masking to ensure that no light falls outside the currently set active area.

The following example compares the time savings achieved by using Custom Chip vs. ROI to read out a 128x128 region of a 512x512 array. Using the ROI method to read out the 128x128 pixels would take 8.2 msec, or a frame rate of 122 fps (1/0.0082). Using the Custom Chip feature, the readout time for the same region would drop to 3.1 msec (equivalent to a frame rate of 323 fps). See Figure 50 for a graphic comparison of the ProEM:512B camera's expected frame rates using standard ROI readout and custom chip readout.

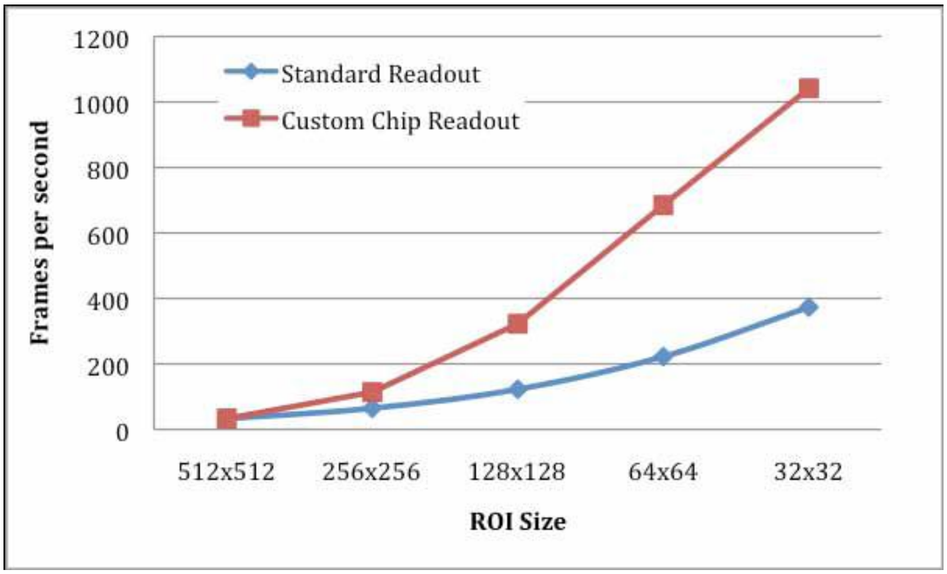


Figure 50. Comparison of Standard ROI and Custom Chip Readout Rates

Software Settings

Princeton Instruments does not encourage users to change these parameter settings. For most applications, the default settings will give the best results. We ***strongly advise*** contacting the factory for guidance before customizing the chip definition.

If Custom Chip has been installed, selecting **Show Custom Chip** checkbox on the Controller/Camera tab page adds the Custom Chip tab page to the dialog box. The Custom Chip parameters are shown in Figure 51. The default values conform to the physical layout of the CCD array and are optimum for most measurements.

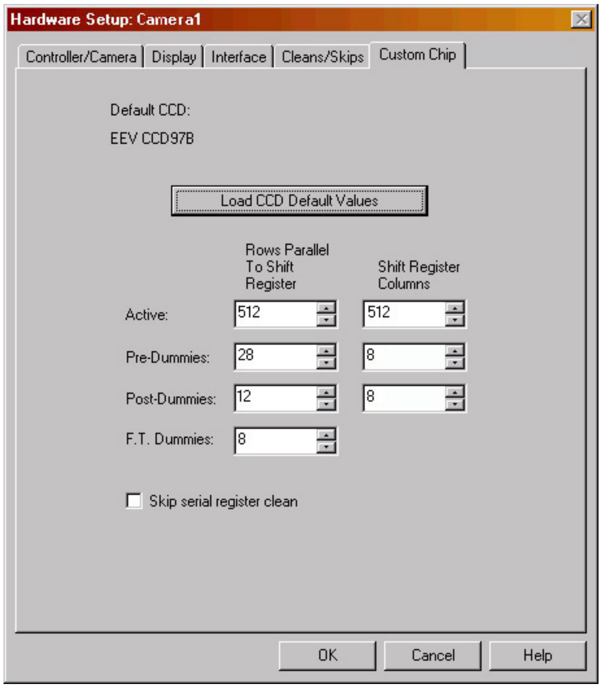


Figure 51. Custom Chip tab page

By changing the values in the Active fields, you can increase image acquisition speed by reducing the size of the active area in the definition. The result will be faster but lower resolution data acquisition. Operating in this mode would ordinarily require that the chip be masked so that only the reduced active area is exposed. This will prevent unwanted charge from spilling into the active area or being transferred to the shift register.

By default, if there are no Pre-Dummy rows, the serial register will be cleared before rows are shifted. If the **Skip Serial Register Clean** box is selected when there are no Pre-Dummy rows, the register cleanout will be skipped and the chip readout will be faster. This feature is not available for PVCAM-supported cameras.

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Chapter 7

Tips

Counter the Effects of Aging

EM gain can degrade over time, especially when large gain is used under high-light-level conditions. The ProEM utilizes many anti-aging measures, including clock-voltage optimization. Deep cooling allows the camera's high-voltage clocks to be operated well below their maximum rating while still achieving greater than 1000x EM gain.

Despite the anti-aging measure built into the ProEM, some general precautions are helpful in further countering the effect of aging:

- Use the minimum required EM gain for a given light level. For example, only ~50x - 100x gain is needed to achieve <1 e- RMS read noise. Once <1 e- RMS effective read noise is achieved, there will be no further improvement in signal-to-noise ratio for most applications.
- Turn down the EM gain to 1x when used with bright light sources.
- Use maximum gain only when there is a need to amplify single-photon events above the background for the purpose of thresholding.

Maximize Throughput by Choosing the Right Vacuum Window Coating

To maximize light throughput, the ProEM uses a highly advanced single-window vacuum design. This means the vacuum window is the only optical surface encountered by incident photons before they reach the EMCCD detection surface. Although the design is the best available, each uncoated optical surface of the vacuum window can still have 3.5% to 4% transmission loss, or a total loss of 7% to 8%. For light-starved imaging applications, this loss can result in a significant reduction of signal-to-noise ratio. Moreover, any light reflected inside the system can lead to glare and fringing, especially when used with coherent illumination. The solution is to apply anti-reflective coatings on the window in the optical path, which reduces total losses to below 1% and sometimes even to 0.5%.

All Princeton Instruments cameras, including the ProEM, are designed with a single window made of high-grade fused silica/quartz that acts as a vacuum viewport. Any shipping-protection windows on the EMCCD are removed prior to installing it in the vacuum chamber. The vacuum window can be customized with single- or multi-layer AR coatings to match the wavelength of interest. Customers should note that AR coatings typically provide the best performance when they are tuned for a narrow wavelength range. Since they may have poorer transmission outside their optimum wavelength range, care must be taken before choosing an AR coating. Princeton Instruments representatives can help you select the most appropriate AR coating for your application needs.

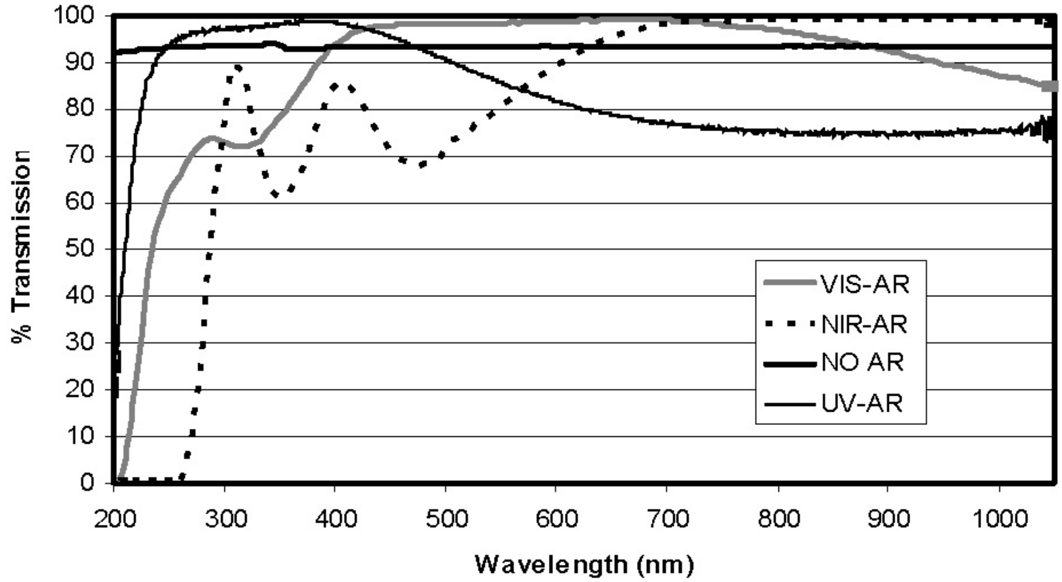


Figure 52. Vacuum Window Transmission Data

Reduce Readout Time by Using the Custom Chip Feature

This feature allows you to redefine the size of the EMCCD's active area via software. Unlike setting a smaller region of interest (ROI), which also involves reading out fewer pixels, Custom Chip mode does not incur overhead from discarding or skipping the rest of the rows. And, unlike both Binning and ROI, Custom Chip also relies on some form of array masking to ensure that no light falls outside the currently set active area.

Chapter 8

Troubleshooting

WARNING! Do not attach or remove any cables while the camera system is powered on.

Introduction

The following issues have corresponding troubleshooting sections in this chapter.

Acquisition Started but Data Display is Empty

If you have started a data acquisition but no data is appearing in the data display, stop the acquisition. Look at the Data Display title bar and verify that the first number in the Region of Interest (ROI) is evenly divisible by 4. Figure 53 shows an invalid ROI: the 30 (in 30x512x1) is not evenly divisible by 4.

If the number of horizontal pixels (or superpixels if there is binning in the horizontal) is not divisible by 4, go to Experiment Setup. On the ROI Setup tab page, change the Region of Interest (ROI) and Binning parameters for your experiment so that the resulting number of horizontal pixels or superpixels is divisible by 4. Then, re-run the acquisition.

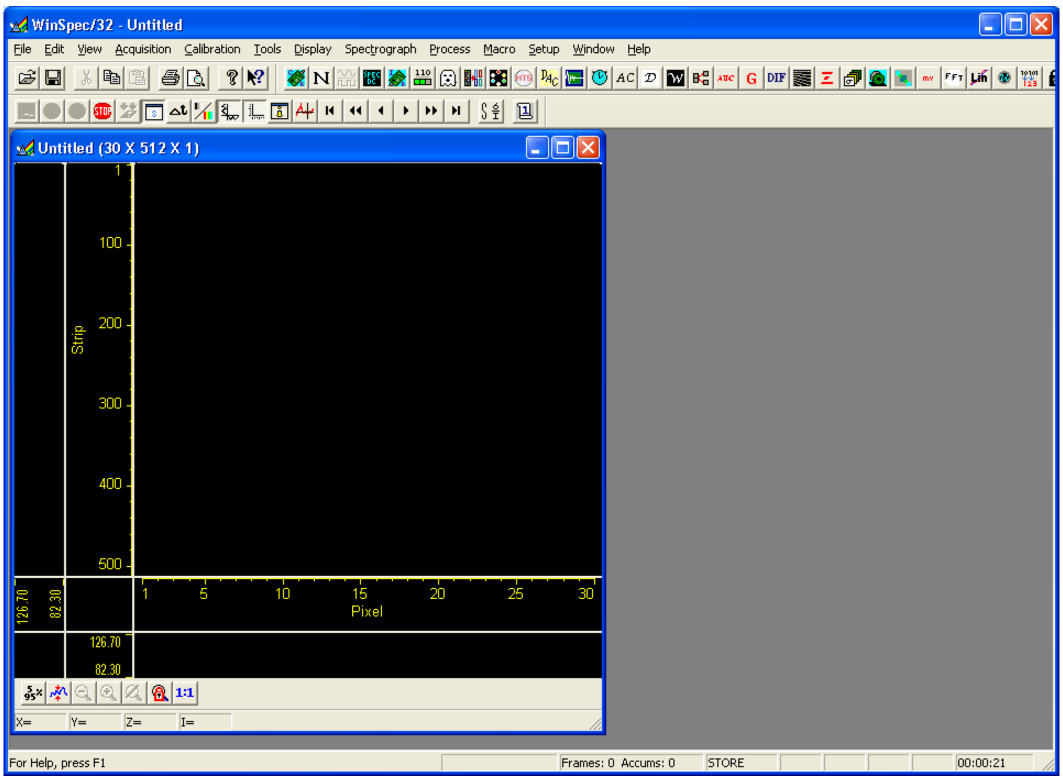


Figure 53. Acquisition Display and Invalid ROI

Baseline Signal Suddenly Changes

A change in the baseline signal is normal if the temperature, gain, or speed setting has been changed. If this occurs when none of these settings have been changed, there may be excessive humidity in the camera vacuum enclosure. Turn off the camera and contact Princeton Instruments Customer Support. See page 98 for contact information.

Camera Not Found

This message will be displayed if no camera is detected when you launch the WinX application.

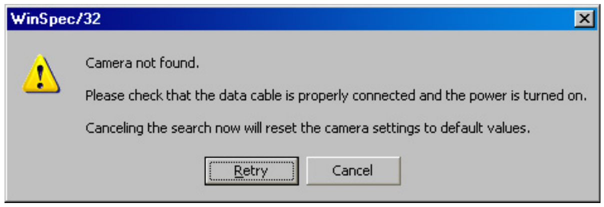
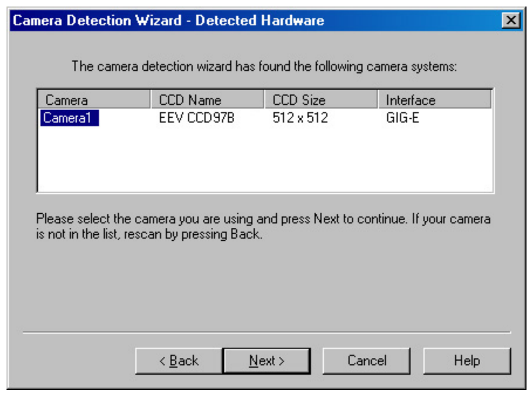


Figure 54. Camera Not Found dialog box

1. Verify that the Ethernet cable is connected to the camera and the GigE interface adapter board in the host computer.
2. Verify that the camera is connected to the ProEM power supply and that the power supply is plugged in and turned on.
3. Click on the **Retry** button.
4. If the camera is still not found, click on the **Cancel** button. After the WinX application opens, launch the Camera Detection Wizard (button located on the Hardware Setup dialog box).
5. If the camera is connected to the computer and has power, the wizard should be able to locate it and load it into the Camera Detection Wizard - Detected Hardware dialog box.



   - If the camera is found, select it, click on the **Next** button, and continue the wizard.
   - If the camera is still not detected, click on **Cancel** and contact Princeton Instruments Customer Support.

Camera Stops Working

Problems with the host computer system or software may have side effects that appear to be hardware problems. If you are sure the problem is in the camera system hardware, begin with these simple checks:

- Turn off all AC power.
- Verify that all cables are securely fastened.
- Turn the system on.

If the system still does not respond, contact Princeton Instruments Customer Support.

Camera1 (or similar name) in Camera Name field

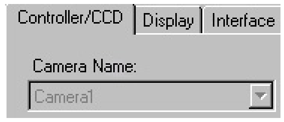
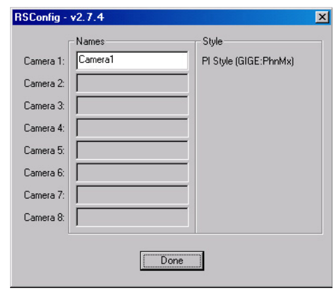


Figure 55. Camera1 in Camera Name Field

When the Camera Detection Wizard installs a new camera, the camera is automatically named “Camera#” (where # = 1, 2 , or 3.., depending on the number of cameras detected) This name will appear in the Hardware Setup title bar and as the active camera on the Hardware Setup|Controller/Camera tab page. If you would prefer a more specific name, you can run RSConfig.exe (located in the WinX application directory) and rename the camera. The new name will then be used by the system until the Camera Detection Wizard is run again.



To change the default Camera Name:

1. Close the application program if it is running.
2. Run RSConfig.exe from the **Windows|Start|Programs|Pi Acton** menu or from the directory where you installed WinView, WinSpec, or WinXTest.
3. Edit the name.
4. Click on the **Done** button.
5. The next time you start the WinX application, the new name will be displayed on the Hardware Setup dialog.
6. If you later re-run the Camera Detection Wizard, the name will be changed back to the default name (i.e., Camera1).

Cooling Troubleshooting

Temperature Lock Cannot be Achieved or Maintained.

Possible causes for not being able to achieve or maintain lock could include:

- Ambient temperature greater than +20°C. This condition affects TE-cooled cameras. If ambient is greater than +20°C, you will need to cool the camera environment or raise the set temperature.
- Airflow through the camera and/or circulator is obstructed. The camera needs to have approximately two (2) inches (50 mm) clearance around the vented covers. If there is an enclosure involved, the enclosure needs to have unrestricted flow to an open environment. The camera vents its heat out the side vents near the nose. The air intake is at the rear of the camera.
- A hose is kinked. Unkink the hose.
- Coolant level is low. Add 50:50 mix of ethylene glycol and water. Refer to manufacturer’s instructions for adding coolant.

- There may be air in the hoses. Remove air and add 50:50 mix of ethylene glycol and water. Refer to manufacturer's instructions for removing excess air and adding coolant.
- Circulator pump is not working. If you do not hear the pump running when the circulator is powered on, turn off the circulator and contact the manufacturer's Customer Support.
- CoolCUBE: The CoolCUBE circulator is higher than the camera. Reposition the circulator so that it is 6 inches (150 mm) or more below the camera. The vertical distance should not exceed 10 feet (3 m). Typically, the camera is at table height and the circulator is on the floor.
- The target array temperature is not appropriate for your particular camera and CCD array.
- The camera's internal temperature may be too high, such as might occur if the operating environment is particularly warm, if you are attempting to operate at a temperature colder than the specified limit, or if you have turned off the fan and are not circulating coolant through the camera. TE cameras are equipped with a thermal-protection switch that shuts the cooler circuits down if the internal temperature exceeds a preset limit. Typically, camera operation is restored automatically in about ten minutes. Although the thermo-protection switch will protect the camera, you are nevertheless advised to power down and correct the operating conditions that caused the thermal-overload to occur.

Gradual Deterioration of Cooling Capability

While unlikely with the ProEM camera (guaranteed permanent vacuum for the life of the camera), if you see a gradual deterioration of the cooling capability, it might due to damaged camera vacuum. This can affect temperature performance such that it may be impossible to achieve temperature lock at the lowest temperatures. In the kind of applications for which cooled CCD cameras are so well suited, it is highly desirable to maintain the system's lowest temperature performance because lower temperatures result in lower thermal noise and better the signal-to-noise ratio. Contact the factory to make arrangements for returning the camera to the support facility.

Data Overrun Due to Hardware Conflict message

Figure 56. Data Overrun Due to Hardware Conflict dialog box

If this dialog box appears when you try to acquire a test image, acquire data, or run in focus mode, check the CCD array size and then check the DMA buffer size. A large array (for example, a 2048x2048 array), requires a larger DMA buffer larger setting than that for a smaller array (for example, a 512x512 array).

To change the DMA buffer setting:

1. Note the array size (on the **Setup|Hardware|Controller/CCD** tab page or the **Acquisition|Experiment Setup|Main** tab page Full Chip dimensions).
2. Open **Setup|Environment|Environment** dialog box.

3. Increase the DMA buffer size to a minimum of 32 Mb (64 Mb if it is currently 32 Mb or 128 Mb if it is currently 64 Mb), click on **OK**, and close the WinX application (WinView or WinSpec).
4. Reboot your computer.
5. Restart the WinX application and begin acquiring data or focusing. If you see the message again, increase the DMA buffer size.

Ethernet Network is not accessible

When the Princeton Instruments software is installed, all Intel Pro/1000 interface card drivers found on the host computer are updated with the Intel Pro/1000 Grabber Adapter (Vision High-Performance IP Device) driver provided by Pleora Technologies, Inc. If this computer is connected to an Ethernet network via an Intel Pro/1000 card that does not use the Pleora driver, the network connection will be broken.

To restore the driver for the Ethernet card that is used to connect to the network:

1. Locate the EbDriverTool.exe file.
   - Download the **EbDriverTool.exe** file to your computer from ftp://ftp.princetoninstruments.com/public/software/official/winx32/v2525/patches
   - Or open the default Pleora directory. Typically it is located at **C:\Program Files\Common Files\Pleora Technologies Inc.** The **EbDriverTool.exe** file may be in a subdirectory.
2. Run the file.
3. When this program executes, select the appropriate Ethernet card and under the **Action** category, choose "**Install Manufacturer Driver**" from the pulldown menu.

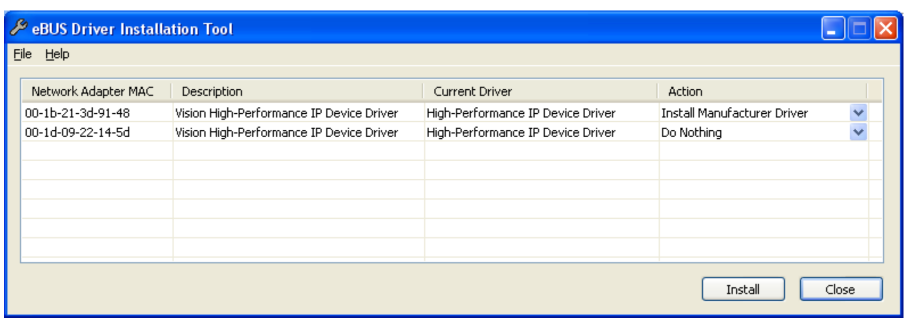


Figure 57. Ebus Driver Installation Tool dialog box

4. After making the selection, click on **Install**.
5. After the installation you will be asked to reboot the computer. You can
   - Click on "**Yes**" to initiate the reboot.
   - Click on "**No**" to wait before rebooting. If you select "**No**," you may be required to close the **eBUS Driver Installation Tool** dialog. Reboot the computer at your convenience.
6. After the reboot, verify that the network connection has been re-established.

Program Error message

Figure 58. Program Error dialog box

This dialog may appear if you have tried to acquire a test image, acquire data, or run in focusing mode and the DMA buffer size is too small. A large array (for example, a 2048x2048 array), requires a larger setting than that for a smaller array (for example, a 512x512 array).

To correct the problem:

1. Click on **OK**.
2. Reboot WinView.
3. Note the array size (on the **Setup|Hardware|Controller/CCD** tab page or the **Acquisition|Experiment Setup|Main** tab page Full Chip dimensions). If your camera contains a large array (such as a 2048x2048 array), and the DMA buffer size is too small, there will not be enough space in memory for the data set.
4. Open **Setup|Environment|Environment** dialog box.
5. Increase the DMA buffer size to a minimum of 32 Mb (64 Mb if it is currently 32 Mb or 128 Mb if it is currently 64 Mb), click on **OK**, and close WinView.
6. Reboot your computer.
7. Restart WinView and begin acquiring data or focusing. If you see the message again, increase the DMA buffer size.

Serial violations have occurred. Check interface cable.

Figure 59. Serial Violations Have Occurred dialog box

This error message dialog will appear if you try to acquire an image or focus the camera and either (or both) of the following conditions exists:

- The camera system is not turned ON.
- There is no communication between the camera and the host computer.

To correct the problem:

1. Turn **OFF** the camera system (if it is not already OFF).
2. Make sure the computer interface cable is secured at both ends.
3. After making sure that the cable is connected, turn the camera system power **ON**.
4. Click **OK** on the error message dialog and retry acquiring an image or running in focus mode.

Note: This error message will also be displayed if you turn the camera system OFF or a cable comes loose while the application software is running in Focus mode.

Smeared Images

ProEM uses a frame-transfer CCD which allows simultaneous exposure-readout operations (see pages 48-53 for more information). However, when the exposure time is small compared to the frame-transfer time, smearing may appear in the images. To alleviate this problem:

1. Use a longer exposure time, or
2. Use the SHUTTER signal from the camera to control a fast external shutter (such as an LCD shutter) to block light during the frame-transfer readout cycle.

TEC Fault LED comes on

When turning off and on the power supply, wait at least 10 seconds before switching it on. “TEC Fault” LED might come on if the power supply on/off state is switched too quickly.

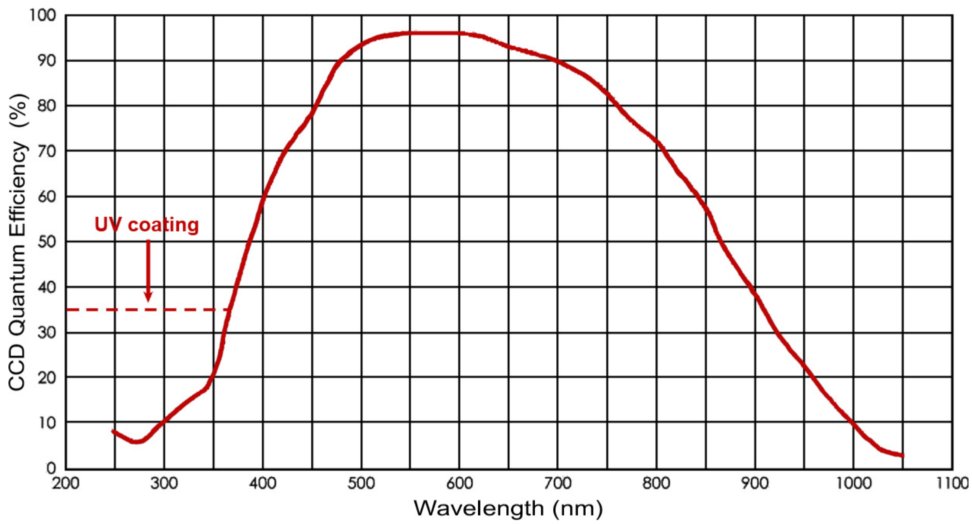
Appendix A
Basic Specifications

Note: This appendix provides some of the basic specifications of a ProEM™ system. If the information you are looking for is not here, it may be available in ***Appendix B, "Outline Drawings"*** or on the appropriate data sheet. Data sheets can be downloaded from the Princeton Instruments website (www.princetoninstruments.com).

Window

SI-UV fused-silica quartz. Princeton Instruments offers a choice of multi-layer VIS-AR, UV-AR, and NIR-AR coating options on the vacuum window. For enhanced sensitivity in the UV region, a proprietary Unichrome™ coating is available. For broadband applications, a choice of $MgFl_2$ or broadband AR coatings is available upon request.

Quantum Efficiency



CCD Arrays

	ProEM:512B	**ProEM:1024B**
CCD:	e2v CCD97B	e2v CCD201B
Image Type:	Monochrome	Monochrome
Resolution:	512 x 512	1024 x 1024
Pixel Size:	16 µm x 16 µm	13 µm x 13 µm
Active Area:	8.2 mm x 8.2 mm	13.3 mm x 13.3 mm
Peak Q.E.	95%	95%
Frame Rate	> 33 fps (full frame)	> 8.5 fps (full frame)

	ProEM:512B	ProEM:1024B
Readout Amplifiers (Ports):	2	2
Digitization (Readout) Rate:	10 MHz, 5 MHz, 1 MHz, 100 kHz	10 MHz, 5 MHz, 1 MHz, 100 kHz

Note: The arrays listed are those that were available at the time that the manual was written. Contact Princeton Instruments for an updated list of arrays supported by the ProEM.

Mounts

C-mount: Standard threaded video mount. Optional C- to Spectroscopy-mount adapter.

Focal Distance (Optical)

C-mount, Front Surface to Focal Plane: 0.690" (17.53 mm)

Camera

Cooling: Thermoelectric; air or circulating coolant

Coolant Ports: The inlet/outlet ports on the side of the camera allow you to connect the camera to an external coolant circulator. Two 10 mm (3/8”) ID, 3 meter (10 ft) coolant hoses with the appropriate fittings for the ProEM are supplied with each system.

Additional ProEM-compatible female barbs (part number VL2-F10B-P) are available from Koolance (www.koolance.com). Refer to your circulator’s documentation for information about circulator-compatible fittings.

CCD Operating Temperature:

CCD Size	Default
512x512	-70°C
1024x1024	-55°C

Table 3. Default Operating Temperature

Temperature Stability: ±0.05°C; closed-loop stabilized-temperature control

Gain: Software-selectable [1 (low), 2 (medium), 3 (high)]

Dimensions: See ***Appendix B, "Outline Drawings"*** (page 87).

Connectors:

Gig-E: Gigabit Ethernet connector.

Shutter: LEMO® connector provides the shutter drive pulses for driving a Princeton Instruments-supplied 25 mm external shutter in lieu of integrated shutter. Camera power must be OFF before connecting to or disconnecting from this connector. Cable not supplied.

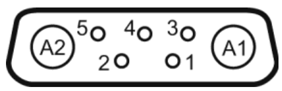
Caution: When there is an installed internal shutter, this connector cannot drive an external shutter.

Ext Sync: 0 to +3.3 V logic level input to allow data acquisition to be synchronized with external events. Trigger edge can be positive- or negative-going as set in software. Synchronization and Timing Modes are discussed in Chapter 6. MCX-to-BNC adapter cable supplied with system.

Logic Out: 0 to +3.3V programmable logic level output (TTL-compatible). The output can be programmed via software as ACQUIRING, EXPOSE (Effective), EXPOSE (Program'd), IMAGE SHIFT, LOGIC 1, READ OUT, SHUTTER, or WAIT FOR TRIGGER signal. For detailed definition of each output, please see ***"LOGIC OUT Control"*** (page 62). The output can also be inverted through software. Default is Expose (Program'd).

Power Connector:

Pinout:



A1 TEC Return
A2 TEC Power
1 INT Return
2 +24V In
3 INT Out
4 +24V In Return 1
5 +24V In Return 2

Power Supply: 90-240 VAC, self-switching, 140 W. DC power to the camera and TE cooler is provided by the power supply via the Power connector on the rear of the camera.

Fan: 24 CFM fan capacity at full power.

Options

A partial listing of options includes the WinView/WinSpec application software and manual, Scientific Imaging ToolKit™ (SITK™) for LabVIEW®, C-mount to spectroscopy mount adapter, and the CoolCUBE coolant circulator. Contact the factory for more information regarding options available for your system.

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Appendix B

Outline Drawings

Note: *Dimensions are in inches [mm].*

ProEM Camera: C-mount

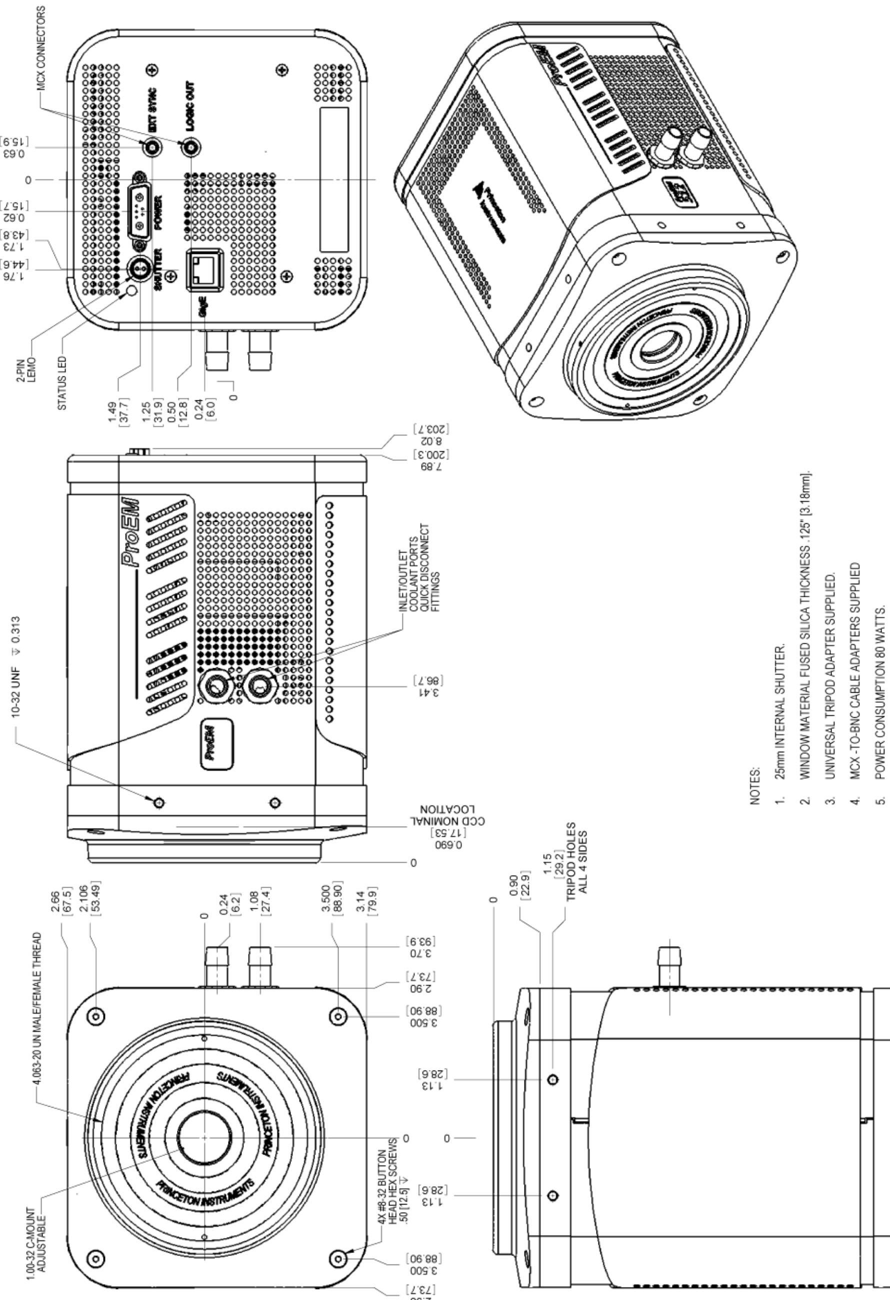

Figure 60. ProEM Camera Outline Drawing

Power Supply

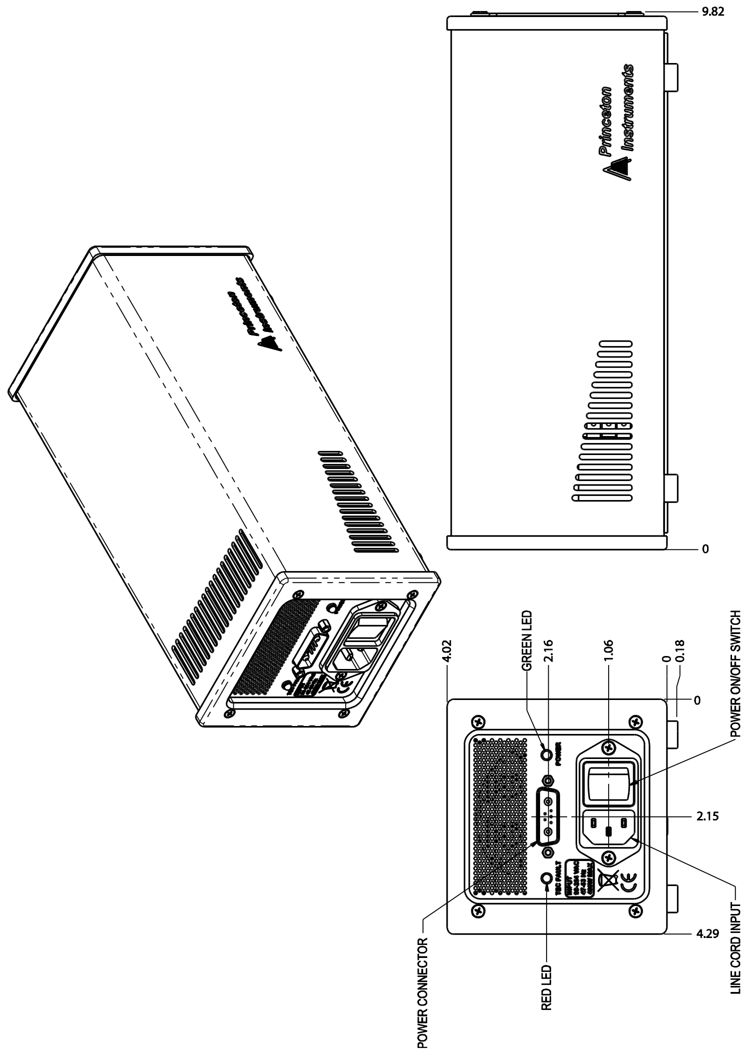

Figure 61. ProEM Power Supply Outline Drawing

CoolCUBE (optional)

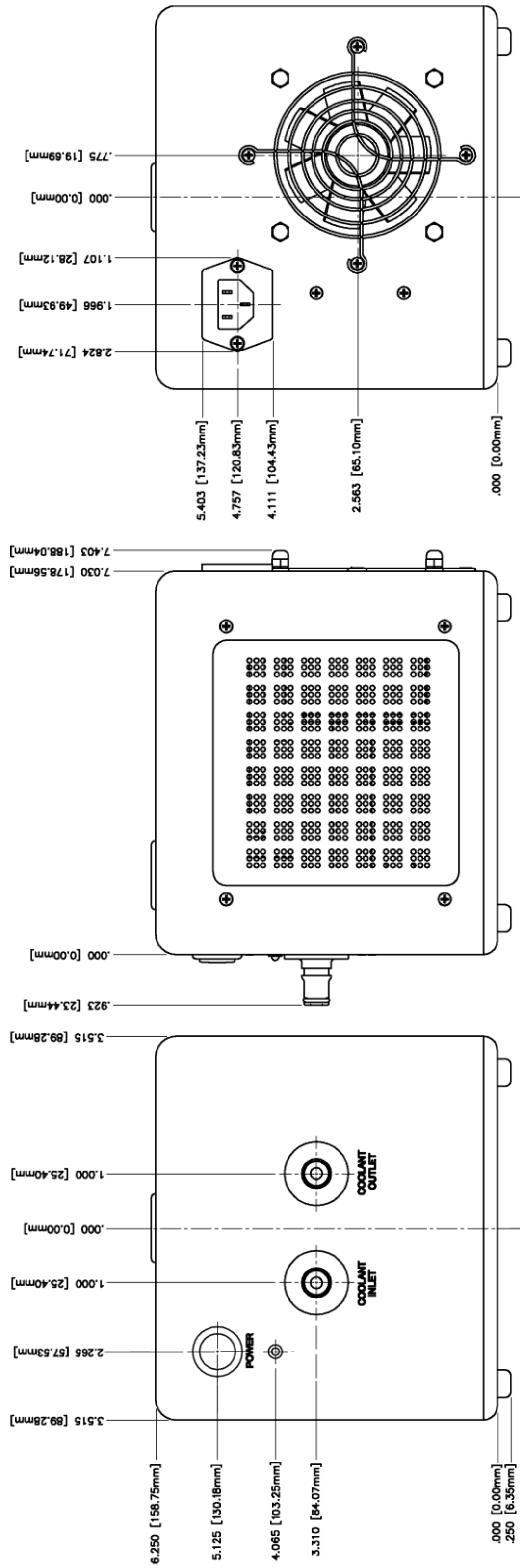

Figure 62. CoolCUBE Outline Drawing

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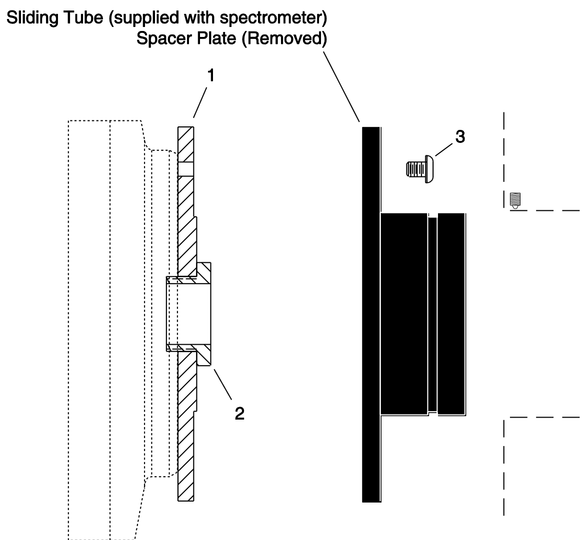
Appendix C
Spectrograph Adapter

Introduction

The ProEM is designed with a C-mount adapter to accommodate C-mount lenses. Before mounting this camera to an Acton Series spectrograph, you will need to follow the instructions below for attaching the appropriate spectrograph kit.

Note: When mounted to a spectrograph, the text on the back of the ProEM should be right side up.



	Qty	P/N	Description
1.	1	8401-071-01	Adapter Plate
2.	1	8401-071-02	Threaded C-Mount Adapter
3.	3	2826-0127	Screw, 10-32 × 1/4, Button Head Allen Hex, Stainless Steel

Assembly Instructions

1. Make sure that the shipping cover has been removed from the detector port on the spectrograph.
2. Loosen the setscrews holding the sliding tube in the spectrograph and remove the tube. If there is a spacer plate installed on the sliding tube, remove it.
3. Place the flat side of the adapter plate against the face of the detector.
4. Insert the threaded C-mount adapter through the center hole in the plate and screw the adapter into the detector's C-mount.

5. Using three (3) 1/4" long button head screws, secure the sliding tube to the adapter plate.
6. Gently insert the sliding tube into the spectrograph and fasten with the setscrews.

Note: Spectrograph parts are machined to provide a tight fit. It is necessary to rotate the detector back and forth when inserting the sliding tube into the spectrograph. Forcing the tube into the spectrograph could permanently damage the tube and the spectrograph opening.

Declaration of Conformity

This section of the ProEM system manual contains the declaration(s) of conformity for ProEM systems.

DECLARATION OF CONFORMITY

We

ROPER SCIENTIFIC

(PRINCETON INSTRUMENTS)

3660 QUAKERBRIDGE ROAD

TRENTON, NJ 08619

Declare under our sole responsibility, that the product

ProEM CAMERA SYSTEM

To which this declaration relates, is in conformity with general safety requirement for electrical equipment standards:

IEC 1010-1:1990, EN 61010-1:1993/A2:1995, and EN 61326-1:2006, Clause 7.2 and Table 1 (CISPR 11 Edition 4:2003 (Conducted and Radiated Emissions, Group 1, Class A), IEC 61000-3-2:2000, IEC 61000-3-3:2002, IEC 61000-4-2:2001, IEC 61000-4-3:2002, IEC 61000-4-4:2004, IEC 61000-4-5:2001, IEC 61000-4-6:2003, IEC 61000-4-11:2004)

Which follow the provisions of the

CE LOW VOLTAGE DIRECTIVE 2006/95/EC

And

EMC DIRECTIVE 2004/108/EC.

Date: April 1, 2009
TRENTON, NJ

William Asher
Vice President of New Product Development

Warranty & Service

Limited Warranty

Princeton Instruments, a division of Roper Scientific, Inc. ("Princeton Instruments", "us", "we", "our") makes the following limited warranties. These limited warranties extend to the original purchaser ("You", "you") only and no other purchaser or transferee. We have complete control over all warranties and may alter or terminate any or all warranties at any time we deem necessary.

Basic Limited One (1) Year Warranty

Princeton Instruments warrants this product against substantial defects in materials and / or workmanship for a period of up to one (1) year after shipment. During this period, Princeton Instruments will repair the product or, at its sole option, repair or replace any defective part without charge to you. You must deliver the entire product to the Princeton Instruments factory or, at our option, to a factory-authorized service center. You are responsible for the shipping costs to return the product. International customers should contact their local Princeton Instruments authorized representative/distributor for repair information and assistance, or visit our technical support page at www.princetoninstruments.com.

Limited One (1) Year Warranty on Refurbished or Discontinued Products

Princeton Instruments warrants, with the exception of the CCD imaging device (which carries NO WARRANTIES EXPRESS OR IMPLIED), this product against defects in materials or workmanship for a period of up to one (1) year after shipment. During this period, Princeton Instruments will repair or replace, at its sole option, any defective parts, without charge to you. You must deliver the entire product to the Princeton Instruments factory or, at our option, a factory-authorized service center. You are responsible for the shipping costs to return the product to Princeton Instruments. International customers should contact their local Princeton Instruments representative/distributor for repair information and assistance or visit our technical support page at www.princetoninstruments.com.

XP Vacuum Chamber Limited Lifetime Warranty

Princeton Instruments warrants that the cooling performance of the system will meet our specifications over the lifetime of an XP style detector (has all metal seals) or Princeton Instruments will, at its sole option, repair or replace any vacuum chamber components necessary to restore the cooling performance back to the original specifications at no cost to the original purchaser. *Any failure to "cool to spec" beyond our Basic (1) year limited warranty from date of shipment, due to a non-vacuum-related component failure (e.g., any components that are electrical/electronic) is NOT covered and carries NO WARRANTIES EXPRESSED OR IMPLIED.* Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

Sealed Chamber Integrity Limited 12 Month Warranty

Princeton Instruments warrants the sealed chamber integrity of all our products for a period of twelve (12) months after shipment. If, at anytime within twelve (12) months from the date of delivery, the detector should experience a sealed chamber failure, all parts and labor needed to restore the chamber seal will be covered by us. *Open chamber products carry NO WARRANTY TO THE CCD IMAGING DEVICE, EXPRESSED OR IMPLIED.* Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

Vacuum Integrity Limited 12 Month Warranty

Princeton Instruments warrants the vacuum integrity of “Non-XP” style detectors (do not have all metal seals) for a period of up to twelve (12) months from the date of shipment. We warrant that the detector head will maintain the factory-set operating temperature without the requirement for customer pumping. Should the detector experience a Vacuum Integrity failure at anytime within twelve (12) months from the date of delivery all parts and labor needed to restore the vacuum integrity will be covered by us. Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

Image Intensifier Detector Limited One Year Warranty

All image intensifier products are inherently susceptible to Phosphor and/or Photocathode burn (physical damage) when exposed to high intensity light. Princeton Instruments warrants, with the exception of image intensifier products that are found to have Phosphor and/or Photocathode burn damage (which carry NO WARRANTIES EXPRESSED OR IMPLIED), all image intensifier products for a period of one (1) year after shipment. *See additional Limited One (1) year Warranty terms and conditions above, which apply to this warranty.* Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

X-Ray Detector Limited One Year Warranty

Princeton Instruments warrants, with the exception of CCD imaging device and fiber optic assembly damage due to X-rays (which carry NO WARRANTIES EXPRESSED OR IMPLIED), all X-ray products for one (1) year after shipment. Se*e additional Basic Limited One (1) year Warranty terms and conditions above, which apply to this warranty.* Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

Software Limited Warranty

Princeton Instruments warrants all of our manufactured software discs to be free from substantial defects in materials and / or workmanship under normal use for a period of one (1) year from shipment. Princeton Instruments does not warrant that the function of the software will meet your requirements or that operation will be uninterrupted or error free. You assume responsibility for selecting the software to achieve your intended results and for the use and results obtained from the software. In addition, during the one (1) year limited warranty. The original purchaser is entitled to receive free version upgrades. Version upgrades supplied free of charge will be in the form of a download from the Internet. Those customers who do not have access to the Internet may obtain the version upgrades on a CD-ROM from our factory for an incidental shipping and handling charge. *See Item 12 in the following section of this warranty ("Your Responsibility") for more information.*

Owner's Manual and Troubleshooting

You should read the owner’s manual thoroughly before operating this product. In the unlikely event that you should encounter difficulty operating this product, the owner’s manual should be consulted before contacting the Princeton Instruments technical support staff or authorized service representative for assistance. If you have consulted the owner's manual and the problem still persists, please contact the Princeton Instruments technical support staff or our authorized service representative. *See Item 12 in the following section of this warranty ("Your Responsibility") for more information.*

Your Responsibility

The above Limited Warranties are subject to the following terms and conditions:

1. You must retain your bill of sale (invoice) and present it upon request for service and repairs or provide other proof of purchase satisfactory to Princeton Instruments.
2. You must notify the Princeton Instruments factory service center within (30) days after you have taken delivery of a product or part that you believe to be defective. With the exception of customers who claim a "technical issue" with the operation of the product or part, all invoices must be paid in full in accordance with the terms of sale. Failure to pay invoices when due may result in the interruption and/or cancellation of your one (1) year limited warranty and/or any other warranty, expressed or implied.
3. All warranty service must be made by the Princeton Instruments factory or, at our option, an authorized service center.
4. Before products or parts can be returned for service you must contact the Princeton Instruments factory and receive a return authorization number (RMA). Products or parts returned for service without a return authorization evidenced by an RMA will be sent back freight collect.
5. These warranties are effective only if purchased from the Princeton Instruments factory or one of our authorized manufacturer's representatives or distributors.
6. Unless specified in the original purchase agreement, Princeton Instruments is not responsible for installation, setup, or disassembly at the customer’s location.
7. Warranties extend only to defects in materials or workmanship as limited above and do not extend to any product or part which has:
   - been lost or discarded by you;
   - been damaged as a result of misuse, improper installation, faulty or inadequate maintenance or failure to follow instructions furnished by us;
   - had serial numbers removed, altered, defaced, or rendered illegible;
   - been subjected to improper or unauthorized repair; or
   - been damaged due to fire, flood, radiation, or other "acts of God" or other contingencies beyond the control of Princeton Instruments.
8. After the warranty period has expired, you may contact the Princeton Instruments factory or a Princeton Instruments-authorized representative for repair information and/or extended warranty plans.
9. Physically damaged units or units that have been modified are not acceptable for repair in or out of warranty and will be returned as received.

10. All warranties implied by state law or non-U.S. laws, including the implied warranties of merchantability and fitness for a particular purpose, are expressly limited to the duration of the limited warranties set forth above. With the exception of any warranties implied by state law or non-U.S. laws, as hereby limited, the forgoing warranty is exclusive and in lieu of all other warranties, guarantees, agreements, and similar obligations of manufacturer or seller with respect to the repair or replacement of any parts. In no event shall Princeton Instruments' liability exceed the cost of the repair or replacement of the defective product or part.
11. This limited warranty gives you specific legal rights and you may also have other rights that may vary from state to state and from country to country. Some states and countries do not allow limitations on how long an implied warranty lasts, when an action may be brought, or the exclusion or limitation of incidental or consequential damages, so the above provisions may not apply to you.
12. When contacting us for technical support or service assistance, please refer to the Princeton Instruments factory of purchase, contact your authorized Princeton Instruments representative or reseller, or visit our technical support page at www.princetoninstruments.com.

Contact Information

Roper Scientific's manufacturing facility for this product is located at the following address:

Princeton Instruments
3660 Quakerbridge Road
Trenton, NJ 08619 (USA)

Tel: 1-800-874-9789 / 1-609-587-9797
Fax: 1-609-587-1970

Customer Support E-mail: techsupport@princetoninstruments.com

For immediate support in your area, please call the following locations directly:

America	+1 877 4 PIACTON (+1 877 474 2286)
Benelux	+31 (347) 324989
France	+33 (1) 60 86 03 65
Germany	+49 (0) 89 660 7793
Japan	+81 (3) 5639 2741
UK & Ireland	+44 (0) 28 3831 0171

Otherwise, see our Support web page at www.princetoninstruments.com. An up-to-date list of addresses and telephone numbers is posted on the www.princetoninstruments.com/Support page. In addition, links on this page to support topics allow you to send e-mail based requests to the customer support group.

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