ProEM® System Manual

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Issue 3
September 26, 2019

www.princetoninstruments.com

Revision History

Issue	Date	List of Changes
Issue 3	September 26, 2019	Issue 3 of this document incorporates the following changes: • Rebranded as Teledyne Princeton Instruments; • Converted to standard FrameMaker template.
Issue 2	March 14, 2016	Issue 2 of this document incorporates the following changes: • Updated description of Shutter {Shutter Open} LOGIC OUT Control.
Issue 1.C	December 21, 2011	Issue 1.C of this document incorporates the following changes: • Updated Chapter 4, System Setup; • Updated Chapter 8, Troubleshooting; • Updated Appendix A, Technical Specifications;; • Updated Appendix C, Spectrograph Adapters; • Updated Appendix D, WinSpec/32/LightField Cross Reference; • Updated Warranty and Service; • Global screen shot updates; • Global signal terminology updates.
Issue 1.B	November 18, 2010	Issue 1.B of this document incorporates the following changes: • Updated signal terminology; • Added Appendix C, Spectrograph Adapters; • Updated: — Chapter 1, About this Manual; — Chapter 8, Troubleshooting; • Added support for: — ProEMBK Camera; — ProEM:1600 Camera; — eXcelon; — LightField; — Spectra-Kinetics.
Issue 1	April 7, 2009	This is the initial release of this document.

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Chapter 1: About this Manual

Thank you for purchasing a ProEM camera system from Teledyne Princeton Instruments. Since 1981 Teledyne Princeton Instruments has been the legendary name behind the most revolutionary spectroscopy and imaging products for cutting edge research.

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.

If you have any questions about the information contained in this manual, contact the Teledyne Princeton Instruments customer service department. Refer to Contact Information on page 160 for complete contact information.

1.1 Intended Audience

This manual is intended to be used by scientists and other personnel responsible for the installation, setup, configuration, and acquisition of imaging data collected using an ProEM system.

This document provides all information necessary to safely install, configure, and operate the ProEM, beginning with the system's initial installation.

1.2 Related Documentation

Table 1-1 provides a list of related documentation and user manuals that may be useful when working with the ProEM camera system. To guarantee up-to-date information, always refer to the current release of each document listed.

Table 1-1: Related Documentation

Document Number	Document Title
4411-0046	WinView/32 Imaging Software User Manual
4411-0048	WinSpec/32 Spectroscopy Software User Manual
4411-0103	WinXTest Software User Manual
–	LightField 6 Online Help
–	ProEM Camera System Data Sheet

Teledyne Princeton Instruments maintains updated documentation and user manuals on their FTP site. Visit the Teledyne Princeton Instruments FTP Site to verify that the most recent user manual is available and being referenced:

ftp://ftp.piacton.com/Public/Manuals/Princeton Instruments

ftp://ftp.piacton.com/Public/Manuals/Acton

1.3 Document Organization

This manual includes the following chapters and appendices:

- Chapter 1, About this Manual

  This chapter provides information about the organization of this document, as well as related documents, safety information, and conventions used throughout the manual.
- Chapter 2, ProEM Camera System

  This chapter provides information about the camera, interface card, cables and application software.
- Chapter 3, Installation Overview

  This chapter cross-references system setup actions with the relevant manuals and/or manual pages. It also contains system block diagrams.
- Chapter 4, System Setup

  This chapter provides detailed directions for setting up the camera for imaging or spectroscopic applications and presents over-exposure protection considerations.
- Chapter 5, Operation

  This chapter 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

  This chapter discusses standard timing {Trigger Response} modes (Free Run {No Response}, External Sync {Readout Per Trigger}, and Continuous Cleans {Clean Until Trigger}), Fast and Safe speed modes, Logic Level control, and the Kinetics mode option.
- Chapter 7, Tips

  This chapter provides tips regarding CCD ageing, maximizing throughput, and reducing readout time.
- Chapter 8, Troubleshooting

  This chapter provides courses of action to take if you should have problems with your system.
- Appendix A, Technical Specifications

  This appendix provides CCD, system, and other technical specifications for the ProEM system.
- Appendix B, Outline Drawings

  This appendix provides outline drawings of the ProEM system.
- Appendix C, Spectrograph Adapters

  This appendix includes instructions for mounting a ProEM to a Teledyne Acton Research spectrograph adapter.
- Appendix D, WinSpec/32/LightField Cross Reference

  This appendix includes two alphabetically sorted tables that cross reference terms used by WinX/32 and LightField.
- Warranty and Service

  This section provides the warranty and customer support contact information.

1.3.1 Conventions Used In this Document

WinX/32 is a generic term for WinSpec/32, WinView/32, and WinXTest/32 application software. Often WinX/32 and LightField use different terms for the same functions or parameters. When a topic pertains to both WinX/32 and LightField, curly brackets { } are used to denote a LightField term or location.

Refer to Table 1-2 for the conventions utilized throughout this document.

Table 1-2: Terminology Conventions Used

Topic	Convention Used
WinX/32-Specific Topic	WinX/32 Term/Location
LightField-Specific Topic	LightField Term/Location
WinX/32 and LightField Shared Topic	WinX/32 Term/Location {LightField Term/Location}

1.4 Safety Related Symbols Used in this Manual

CAUTION!

A Caution provides detailed information about actions and/or hazards that may result in damage to the equipment being used, including but not limited to the possible loss of data.

WARNING!

A Warning provides detailed information about actions and/or hazards that may result in personal injury or death to individuals operating the equipment.

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.

1.5 ProEM Safety Information

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.

WARNINGS!

1. If the ProEM camera system is used in a manner not specified by Teledyne Princeton Instruments, the protection provided by the equipment may be impaired.
2. If the equipment or 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 and power rating as that of the original ones to avoid hazard due to electrical shock.

1.6 Precautions

To prevent permanently damaging the ProEM system, observe the following precautions at all times.

CAUTION!

1. 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.
2. When using high-voltage equipment (e.g., an arc lamp,) with the camera system, be sure to turn the camera power ON LAST and turn the camera power OFF FIRST.
3. When turning off and on the power supply, wait at least 10 seconds before switching it on. The TEC Fault LED might come on if the power supply on/off state is switched too quickly.
4. Use caution when triggering high-current switching devices near the system (e.g., an arc lamp.) 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.
5. Do not block air vents on the camera. Preventing the free flow of air overheats the camera and may damage it.
6. If the ProEM camera system is used in a manner not specified by Teledyne Princeton Instruments, the protection provided by the equipment may be impaired.

1.6.1 UV Coatings

CAUTION!

If using 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.[1]

1. Footnote text

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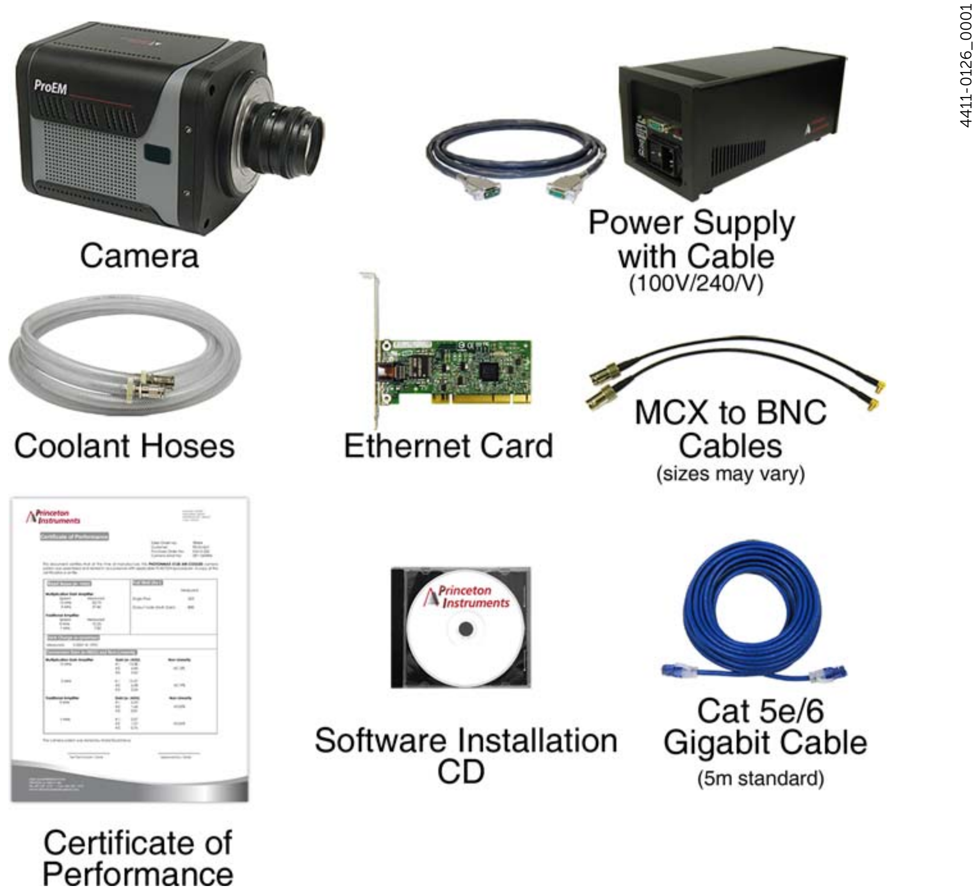
Chapter 2: ProEM Camera System

This chapter provides an introduction to, and overview information about, Teledyne Princeton Instruments's ProEM camera system.

2.1 System 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, and coolant hoses. Figure 2-1 shows those items that are typically included as part of a standard ProEM Camera system.

Figure 2-1: Typical ProEM System Components



2.1.1 Optional System Components

Optional items include the WinX/32 application software, Scientific Imaging ToolKit™ (SITK™) for LabVIEW®, a C-mount to spectroscopy-mount adapter, and the Teledyne Princeton Instruments CoolCUBE$_{II}$ 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.

2.2 ProEM Camera

The ProEM 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. The all metal, hermetic vacuum seals used in the ProEM cameras are warrantied for life, the only such guarantee in the industry.

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 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.

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.

In addition to the standard version of these EMCCDs, eXcelon versions offer the lowest etaloning in the NIR, and enhanced QE in blue and red. Refer to Section 2.2.3, eXcelon, on page 21 for additional information.

Figure 2-2 illustrates a typical ProEM camera.

Figure 2-2: Typical ProEM Camera

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2.2.1 CCD Arrays

REFERENCES:

For complete specifications and information about the CCDs used in ProEM cameras, refer to Table A-1, CCD Specifications by ProEM Model, on page 137.

ProEM:512B

The ProEM:512B features square, 16 μm x 16 μm pixels in a 512 x 512, frame-transfer format. It includes 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.

The ProEM:512B 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.

ProEM:512BK

The ProEM:512BK also offers 16 μm x 16 μm pixels and frame-transfer format but has a custom 8.2 mm x 8.2 mm imaging area with a special on-chip mask for 2 open, 98 masked and 410 open rows.

The ProEM:512BK features a high speed EM mode to capture fast kinetics, a low speed normal CCD mode with very low read noise for precision photometry applications, and advanced features such as solid baseline stability and linear EM gain control.

The ProEM:512BK is cooled to below -90° C using either air or liquid, or a combination of both.

ProEM:1024B

The ProEM:1024B incorporates a larger 1024 x 1024, 13 μm pixels frame transfer CCD. It provides a large field of view with 13.3 mm 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.

The ProEM:1024B 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.

ProEM:1600$^{(2)}$ and ProEM:1600$^{(4)}$

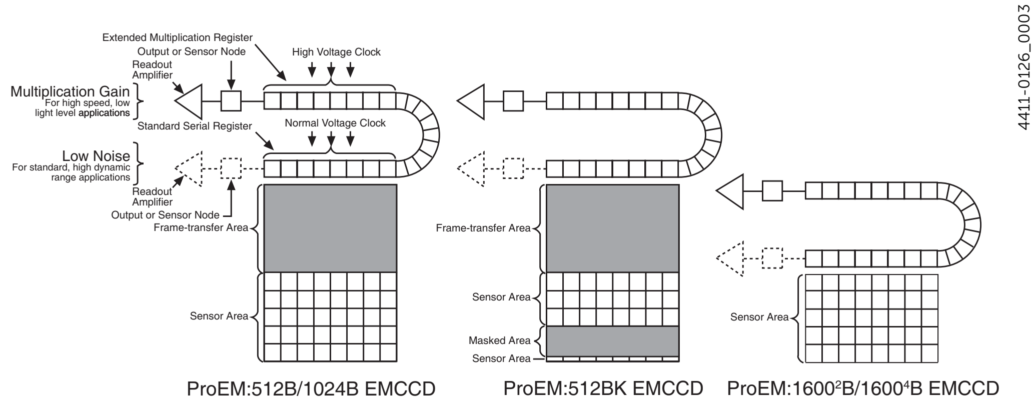
The ProEM:1600$^{(2)}$ and ProEM:1600$^{(4)}$ are full frame format EMCCDs (1600 x 200 and 1600 x 400, respectively,) with 16 μm x 16 μm pixels. The cameras are available with or without eXcelon.

The ProEM:1600$^{(2)}$ and ProEM:1600$^{(4)}$ feature back-illuminated full frame spectroscopy EMCCDs with the benefit of eXcelon technology. These cameras incorporate an internal manual shutter and have 3.60 inch and 3.88 inch bolt circles for mounting Teledyne Acton Research spectrograph adapters.

2.2.1.1 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 2-3.

Figure 2-3: EMCCD Array Structure Comparison: Frame Transfer, Kinetics, Full Frame



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.

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 Teledyne Princeton Instruments web site: www.princetoninstruments.com.

2.2.2 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. 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 20°C. When operating 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.

2.2.2.1 Fan

Air-cooled cameras include an internal fan. Its purpose is to:

- Remove heat from the Peltier device that cools the CCD array, and
- 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 ProEM 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 as described above.

2.2.3 eXcelon

eXcelon is a CCD/EMCCD sensor technology jointly developed by Teledyne Princeton Instruments, Teledyne e2v, and Teledyne Photometrics®. Imaging CCDs using this technology provide three significant benefits:

- Improved Sensitivity

  Improved QE over broader wavelength region compared with back-illuminated sensors;
- Reduced Etaloning

  Up to 10 times lower etaloning or unwanted fringes in near infrared (NIR) region compared with standard back-illuminated CCDs;
- Lower Dark Current

  Comparable to back-illuminated CCDs, or 100 times lower than deep depletion CCDs.

2.2.4 Integrated Controller

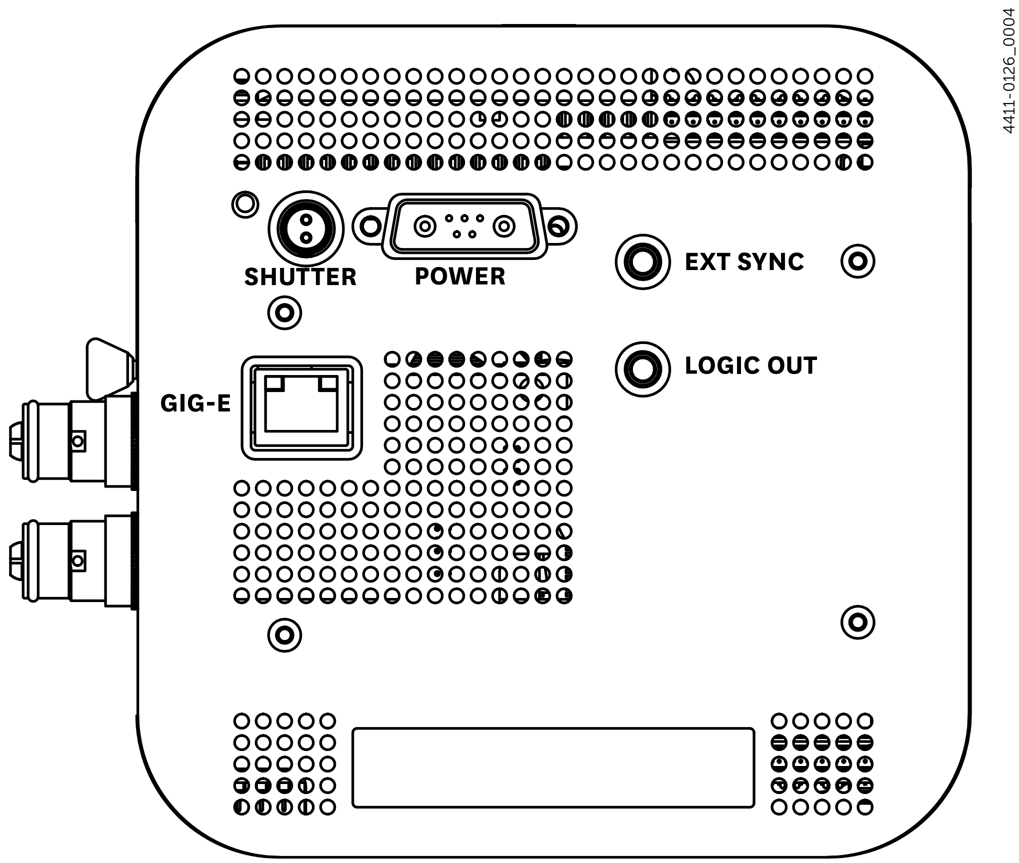
The operation of the ProEM camera is regulated by its internal controller. These electronics contain the circuitry required to accept input from the host computer and software and convert it to appropriate control signals for the camera. These signals include extensive capabilities for synchronizing 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.

2.2.5 Connectors

Figure 2-4 shows the connectors and indicators found on the rear of the ProEM camera.

Figure 2-4: ProEM Connectors and Indicators



Refer to Table 2-1 for information about each connector and indicator on the camera.

Table 2-1: ProEM Connectors and Indicators (Sheet 1 of 2)

Connector	Description
Gig-E	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 50 m.
Shutter	LEMO® connector provides the shutter drive pulses for driving a Teledyne 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.
Power	24 V_{DC} (5.3 A max) input and TEC control from power supply.
Ext Sync	0 to +3.3 V 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.

Table 2-1: ProEM Connectors and Indicators (Sheet 2 of 2)

Connector	Description
LOGIC OUT	0 to +3.3V programmable logic level output (TTL-compatible). The output of this connector can be programmed and can also be inverted via the application software. Refer to Section 6.3, LOGIC OUT Control, on page 97 for complete information about each LOGIC OUT signal.

2.2.5.1 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`).

2.3 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 inch] ID, 3 meter [10 foot] coolant hoses with ProEM-compatible fittings are provided with each ProEM system.

The coolant circulator can be any commercially available circulator that is capable of continuously pumping a 50:50 mixture of room temperature (23°C) water and ethylene glycol at 1 liter per minute, or the Teledyne Princeton Instruments CoolCUBE$_{II}$. Contact the factory for recommendations. Refer to Contact Information on page 160 for complete information.

2.4 Cables

Table 2-2 describes the cables included with a standard ProEM Camera System.

Table 2-2: Standard ProEM Camera System Cables (Sheet 1 of 2)

Cable	Part Number	Description/Purpose	Length
Ethernet Cable	6050-0621	This standard cable is a Cat 5e/6 Ethernet cable for connecting the camera and the host computer. The distance between the camera and the computer can be over 50 meters. Contact the factory for longer cables. 	5 m [16.4 ft]

Table 2-2: Standard ProEM Camera System Cables (Sheet 2 of 2)

Cable	Part Number	Description/Purpose	Length
MCX to BNC	6050-0540	Two MCX to BNC adapter cables are provided with the ProEM system. These connect to the EXT SYNC and the LOGIC OUT connectors on the rear of the ProEM.. 	Varies
Power Cable	6050-0596	The power cable connects the ProEM camera to its power supply.. 	3 m [9.8 ft]

2.5 Hoses

Table 2-2 provides information about hoses included with a standard ProEM Camera System.

Table 2-3: Standard ProEM Camera System Hoses

Hose	Description/Purpose	Length
Coolant Hoses	Two 10 mm [3/8-inch] ID 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 the coolant circulator's specifications regarding circulator-compatible hose fittings. If a Teledyne Princeton Instruments CoolCUBE$_{II}$ circulator is ordered with the camera, hoses are supplied with appropriate connectors on both ends. 	3 m [9.8 ft]

2.6 Certificate of Performance

Each ProEM camera is shipped with a Certificate of Performance which states that the camera system has been assembled and tested according to approved Teledyne Princeton Instruments procedures. It documents the camera's performance data as measured during the testing of the ProEM and lists the following camera- and customer-specific information:

- Sales Order Number;
- Purchase Order Number;
- Camera Serial Numbers

This information is useful when contacting Teledyne Princeton Instruments Customer Support.

2.7 Application Software

Teledyne Princeton Instruments offers a number of data acquisition software packages for use with ProEM camera systems, including:

- WinX/32

  The ProEM camera can be operated by using either WinView/32 or WinSpec/32, Teledyne Princeton Instruments' 32-bit Windows® software packages designed specifically for high-end imaging and spectroscopy, respectively. The Teledyne 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 32-bit software interface for cooled CCD cameras from Teledyne 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.

- LightField®

  The ProEM camera can be operated using LightField, Teledyne Princeton Instruments' 64-bit Windows® compatible software package.

  LightField combines complete control over Teledyne Princeton Instruments' cameras and spectrographs with easy-to-use tools for experimental setup, data acquisition and post-processing. LightField makes data integrity priority #1 via automatic saving to disk, time stamping and retention of both raw and corrected data with full experimental details saved in each file. LightField works seamlessly in multi-user facilities, remembering each user's hardware and software configurations and tailoring options and features accordingly. The optional, patent-pending IntelliCal™ package is the highest-performance wavelength calibration software available, providing up to 10X greater accuracy across the entire focal plane than competing routines.

- PICam

  The standard 64-bit software interface for cooled CCD cameras from Teledyne Princeton Instruments. PICam is an ANSI C library of camera control and data acquisition functions.

  Refer to the PICam Programmer's Manual for the list of supported operating systems.
- Scientific Imaging ToolKit™ (SITK™)

  A collection of LabVIEW® VIs for scientific detectors and spectrographs. This third party software can be purchased from Teledyne Princeton Instruments.

NOTE:

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

2.8 Accessories

Teledyne Princeton Instruments offers a number of optional accessories that are compatible with ProEM. For complete ordering information, contact Teledyne Princeton Instruments. Refer to Contact Information on page 160 for complete information.

2.8.1 CoolCUBE$_{II}$ Circulator

4411-0126_0009

In addition to using an internal fan to remove heat, ProEM cameras also incorporate a closed loop system for circulating fluid.

The CoolCUBE$_{II}$ circulator unit continuously pumps the 50:50 mixture of room temperature (23ºC) water and ethylene glycol.

To prevent voiding the warranty, use only the circulator and hoses shipped with your system.

2.8.2 C- to Spectroscopy-Mount Adapter

4411-0126_0010

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

2.8.3 Adjustable C- to Spectroscopy-Mount Adapter

4411-0126_0011

An adjustable C- to Spectroscopy-mount adapter can be ordered separately.

2.9 Unpack the System

All required items should be included with the shipment. The ProEM system has been manufactured according to the camera options specified at the time of purchase, including the CCD window and coatings that were ordered.

When unpacking the system, examine the system components for any signs of shipping damage. If there are any, notify Teledyne Princeton Instruments immediately and file a claim with the carrier. Be sure to save the shipping carton for inspection by the carrier. If damage is not apparent but system specifications cannot be achieved, internal damage may have occurred in shipment.

Retain all original packing materials so that the ProEM system can be easily and safely packaged and shipped to another location or returned for service if necessary. If assistance is required at any time, contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 160 for complete information.

2.9.1 Verify Equipment and Parts Inventory

Verify all equipment and parts required to set up the ProEM system have been delivered.

A typical system consists of:

- ProEM Camera;
- Power Supply and Cable;
- Window Heater Cable;
- USB3 Interface Cable;
- MCX to BNC Adapter Cables[a];
- Certificate of Performance;
- Data Acquisition Software, including:
  - Installation disk;
  - Hardware Key

a. Length May Vary

Accessories that may have been purchased include:

- External Shutter(s).

2.10 ProEM Camera and System Maintenance

WARNING!

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

2.10.1 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.

2.10.2 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. Contact factory if you have any questions. Refer to Contact Information on page 160 for complete information.

2.10.3 Repairs

Because the ProEM camera system contains no user-serviceable parts, repairs must be performed by Teledyne Princeton Instruments. Should the system need repair, contact Teledyne Princeton Instruments customer support for instructions. Refer to Contact Information on page 160 for complete information.

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

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Chapter 3: Installation Overview

Table 3-1 lists the sequence of actions required to install a ProEM system and prepare to gather data. Refer to the indicated references for additional information.

Refer to Section 3.1, System Block Diagrams, on page 32 for high-level block diagrams of typical system configurations.

Table 3-1: ProEM Installation Actions (Sheet 1 of 2)

Action	Refer to...
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.	Section 4.1, Unpacking the System, on page 35
2. Verify that all system components have been received.	Section 4.1, Unpacking the System, on page 35
3. If the components show no signs of damage, verify that the appropriate power cord has been supplied with the power supply.	Section 4.1, Unpacking the System, on page 35
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.	Section 4.8, Software Installation, on page 45, and software manual.
6. Depending on application, attach lens to the camera or mount the camera to a spectrometer.	Section 4.4, Attaching a Lens to a C-Mount Adapter, on page 38. Appendix C, Spectrograph Adapters, on page 147
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-Cooled System: Make the hose and power connections to the camera and plug the circulator into the power source. Add coolant if necessary. Turn on the circulator.	— Section 4.7, Making the Camera-Circulator Connections for a CoolCUBE$_{II}$, on page 43
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

Table 3-1: ProEM Installation Actions (Sheet 2 of 2)

Action	Refer to...
12. Set the target array temperature.	Section 5.3.4, CCD Temperature, on page 72
13. When the system reaches temperature lock, wait an additional 20 minutes and then begin acquiring data in focus mode.	Acquiring Data on page 55 or Acquiring Data on page 63
14. Adjust the focus for the best image or spectral lines. If using WinSpec/32, you may want to use the Focus Helper function for spectroscopy applications. If you are using LightField, you may want to use the Align Spectrometer function.	 Focusing on page 59 Focusing on page 67

3.1 System Block Diagrams

This section provides typical system-level block diagrams.

Figure 3-1: Block Diagram: Typical Imaging Experiment with Air-Cooled ProEM

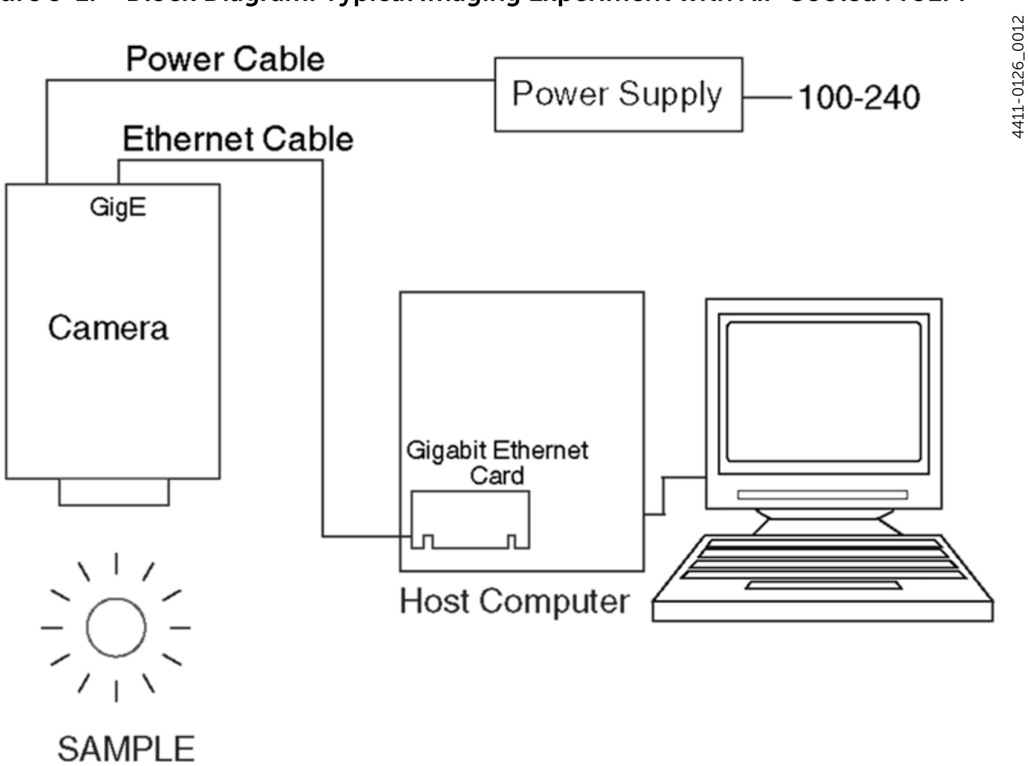


Figure 3-2: Block Diagram: Typical Spectroscopy Experiment with Air-Cooled ProEM

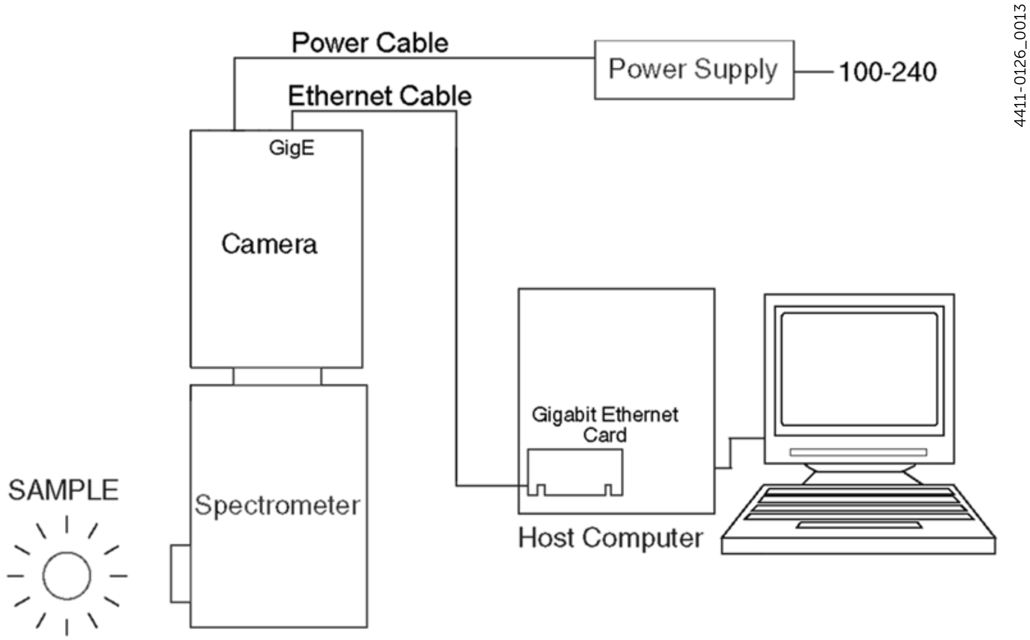


Figure 3-3: Block Diagram: Typical Imaging Experiment with Air/Liquid-Cooled ProEM

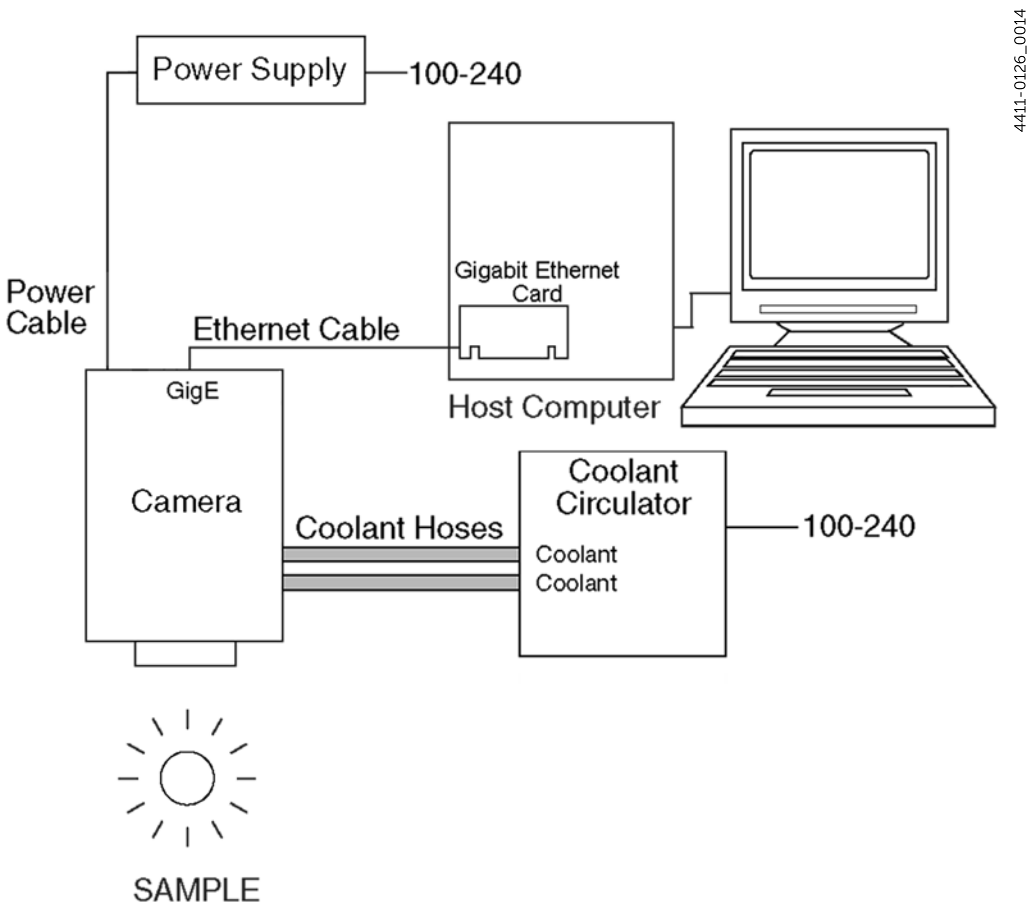
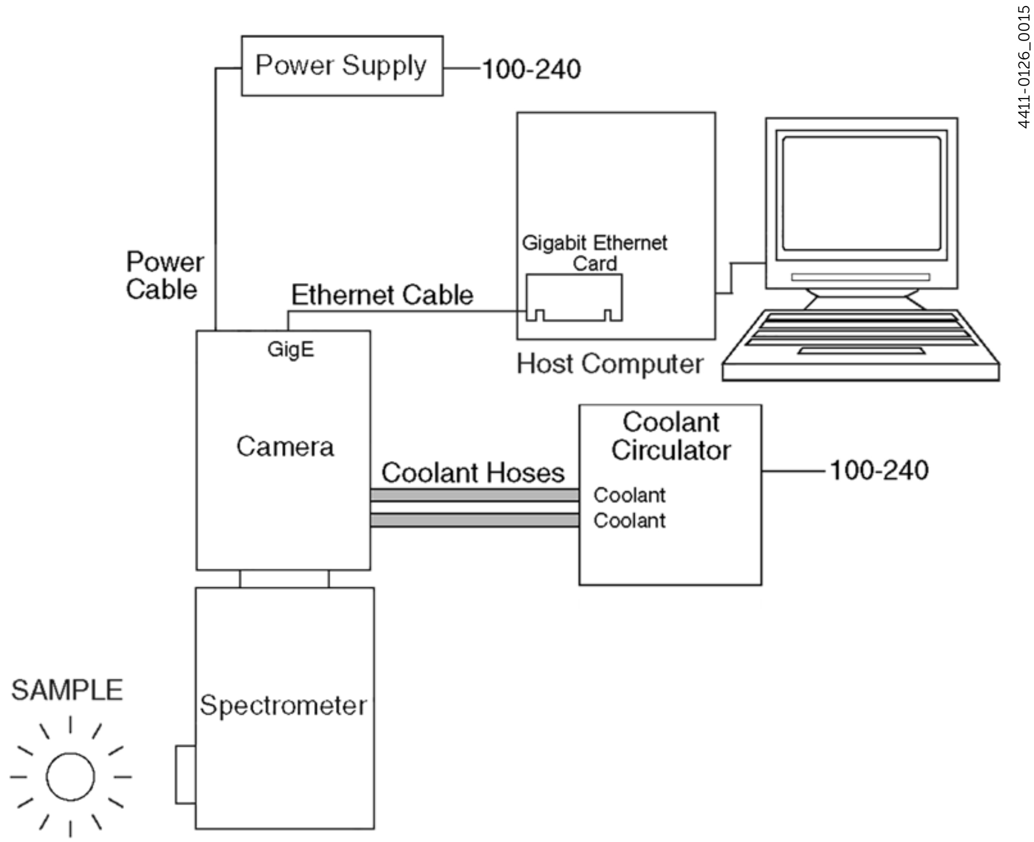


Figure 3-4: Block Diagram: Typical Spectroscopy Experiment with Air/Liquid-Cooled ProEM



Chapter 4: System Setup

NOTE:

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

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, contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 160 for complete information.

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.

4.1 Unpacking the System

During the unpacking, check the system components for possible signs of shipping damage. If there are any, notify Teledyne 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 Teledyne Princeton Instruments for repairs if necessary.

4.2 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 Teledyne Princeton Instruments or provided by user. For enhanced performance, a fast hard drive (10,000 rpm) and 2GB RAM is recommended.
- Operating System:
  - WinView/32 or WinSpec/32: Windows® XP (32-bit, SP3 or later) or Vista® (32-bit)
  - LightField: Windows Vista (64-bit) or Windows 7 (64-bit)
- 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.
- Application Software:
  - WinView/32 or WinSpec32 (Ver. 2.5.25 or later) CD-ROM (optional)
  - LightField CD-ROM (optional)
- Software User Manual (provided with application software)

4.3 System Requirements

4.3.1 Environmental Requirements

Storage temperature: ≤55°C

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

Relative humidity ≤50%; non-condensing

NOTE:

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

4.3.2 Ventilation

- Camera

  Allow at least two (2) inches [50 mm] clearance around the vented covers. The air needs to be less than 25°C (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.

4.3.3 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 V_{AC}, 47-63 Hz, 140 W
- Output: 24 V_{DC} Maximum; power supply also supplies required TEC power.

4.3.4 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.

4.3.4.1 WinX Requirements

- 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 MB of memory. Memory requirement is dependent on desired display resolution.
- Hard disk with a minimum of 1 GB available. A complete installation of the program files takes about 50 MB 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 2 GB or larger memory (RAM) will greatly enhance the software performance during live mode operations.

4.3.4.2 LightField Requirements

- Windows Vista (64-bit) or Windows 7 (64-bit)
- 2 GHz dual core processor
- 4 GB RAM (or greater)
- CD-ROM drive
- Super VGA monitor and graphics card supporting at least 65535 colors with at least 128 MB of memory. Memory requirement is dependent on desired display resolution.
- Hard disk with a minimum of 1 GB available for installation. Additional space is required for data storage: the amount of space required depends 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 5 GB or larger memory (RAM) will greatly enhance the software performance during live mode operations.

4.4 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. Contact the factory for specific information relating to your needs. Refer to Contact Information on page 160 for complete information.

4.4.1 Mounting the Lens

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

NOTE:

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.

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.

Saturation is not harmful to a non-intensified camera, but it, should be avoided.

4.4.2 Adjusting the 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 0.050 inch hex key) to loosen the set screw securing the adapter. Using a spanner wrench or equivalent (distance between holes is 3.85 inches [97.8 mm]), rotate the ring to the desired height. Tighten the screw to lock the adapter in place.

NOTE:

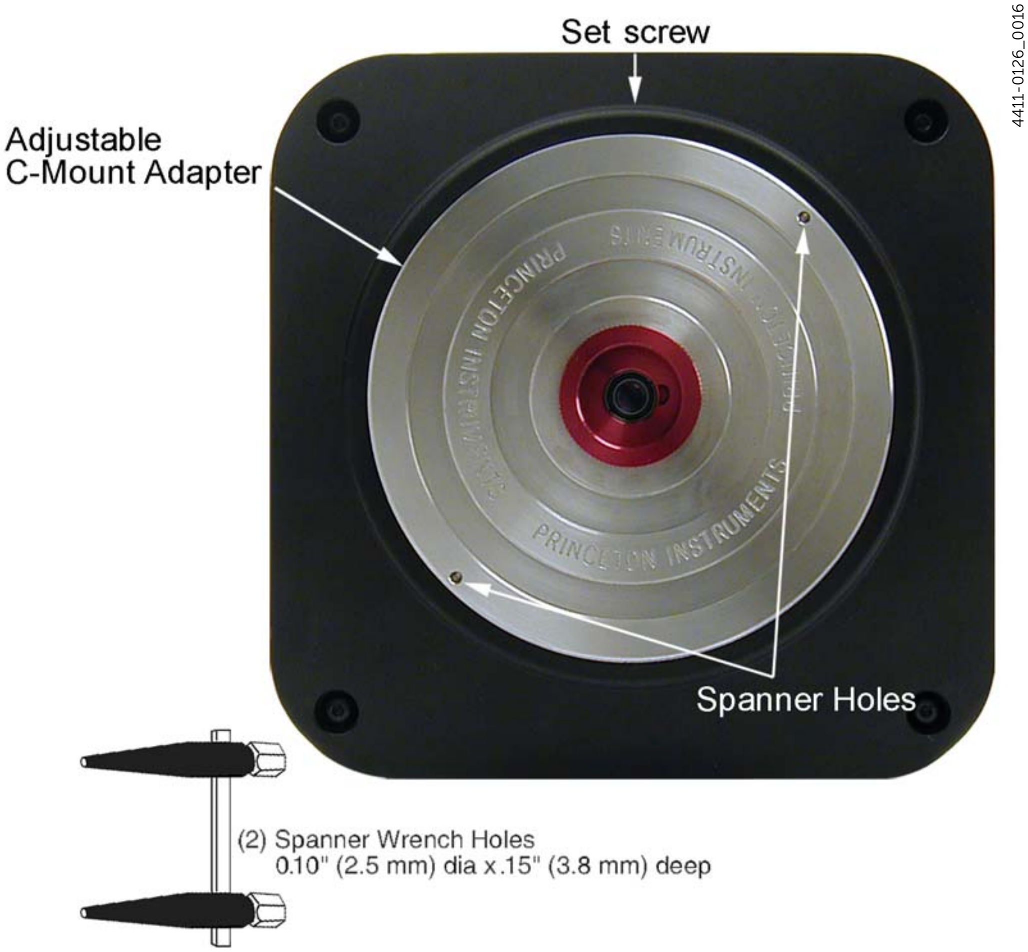
To lock the set screw, the face of the adapter should be no further than 0.1 inch [2.5 mm] out from the front surface of the camera nose.

CAUTION!

The C-mount lens thread-depth should be 0.21 inch [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.

See Figure 4-1.

Figure 4-1: Typical Adjustable C-Mount Adapter



4.5 Mounting the Adjustable C- to Spectroscopy-Mount Adapter

The adjustable C- to spectrograph-mount adapter allows you to move the camera vertically at the exit plane of a Teledyne Acton Research Series spectrograph in order to align the kinetics rows at the middle of the focal plane for the best spectral quality. The adapter is mounted to the front of a ProEM camera and is secured to the camera by a threaded insert screwed into the camera's C mount opening. Refer to Figure 8 when mounting the adapter to the camera.

Tools Required

- 0.050 inch Hex key
- 3/32 inch hex key
- Flat screwdriver
- Spanner wrench (1.17 inch/29.7 mm between 0.094 inch/2.38 mm diameter holes)

Equipment

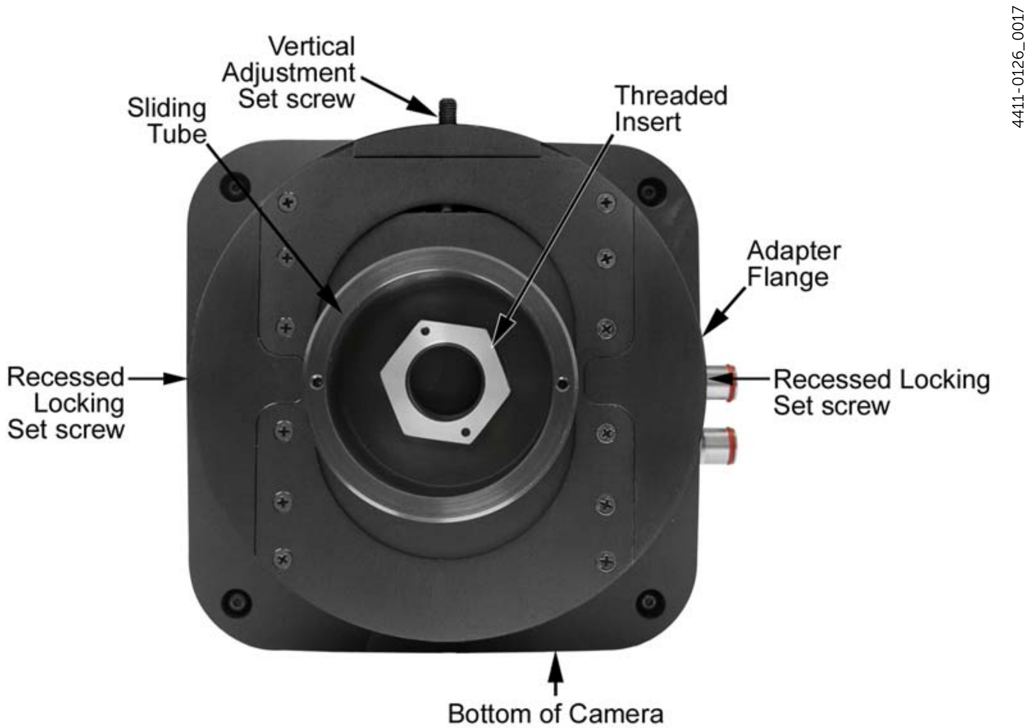
- Teledyne Acton Research Series Spectrograph with light source at entrance port
- Kinetics Adapter
  — SP-2150 and SP-2750 Spectrographs: Use the Model 7050-0107 adapter
  — SP-2350 and SP-2550 Spectrographs: Use the Model 7050-0104 adapter
- Camera with C-mount nose

Procedure

Perform the following procedure to mount the Adjustable C- to Spectroscopy-Mount adapter:

1. If a light baffle is mounted to the front of the adapter, remove the two 2-56 screws securing it and set the baffle aside.
2. Orient the adapter with the setscrew at the top and, using a spanner wrench or equivalent (distance between holes is 1.17 inch [29.7 mm]), tighten the threaded insert into the C-mount opening on the camera. See Figure 4-2.

Figure 4-2: Typical Adjustable C- to Spectroscopy-Mount Adapter

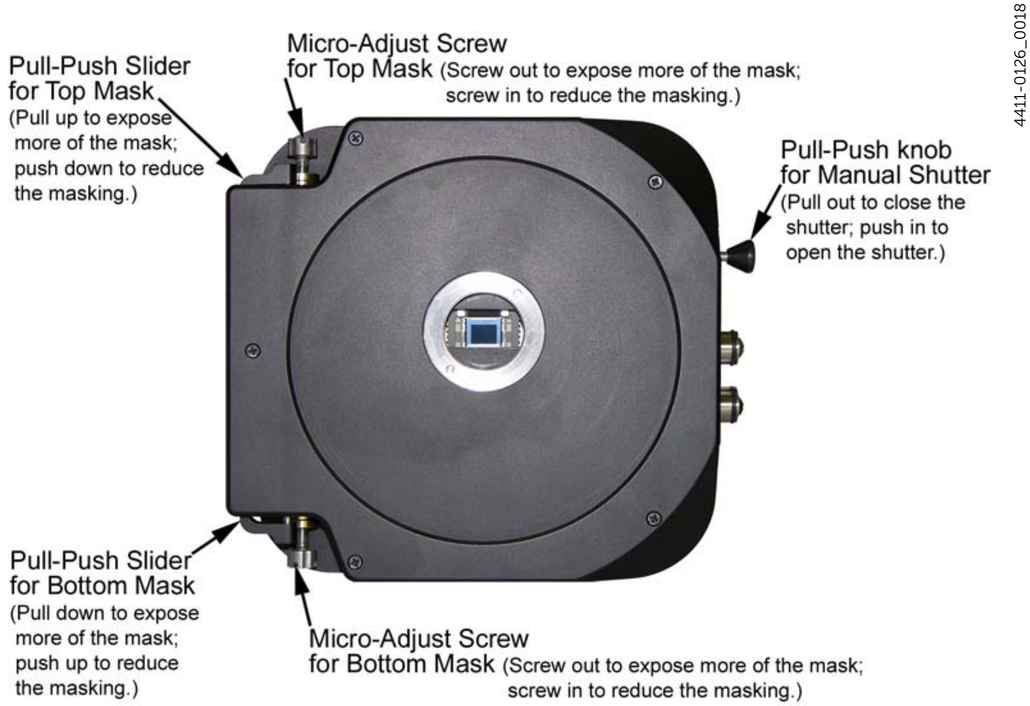


3. If you are using a light baffle, mount the light baffle to the front of the adapter.
4. Gently rotate the camera and sliding tube assembly as you insert it into the spectrograph's exit port.
5. With the spectrograph, camera, and light source powered on and connected to the computer (as required), start the application software. Refer to the appropriate **First Light** instructions in this manual when focusing and rotationally aligning the camera to the spectrograph optics.
6. When you have finished with focusing and rotational alignment, secure the sliding tube in place with the spectrograph set screws.
7. If they have already been installed, loosen the adapter's two recessed locking setscrews (use a 0.050 inch hex key). If they have not been installed, insert the setscrews into the holes at the sides of the adapter and screw them in a couple of turns.
8. When the camera opening is centered within the sliding tube, you can adjust the camera up or down 0.4 inch [4.06 mm] by tightening or loosening the vertical adjustment setscrew (use a 3/32 inch hex key).
9. After you have completed the adjustment, tighten the recessed locking setscrews in the adapter flange to lock the position.

4.5.1 Positioning the ProEM:512BK Masks

The ProEM:512BK camera has a kinetics nose that provides built-in precision masking capability and manual shutter adjustment. After using the pull-push sliders to coarsely set the position of the top and bottom masks, you can then use the micro-adjust screws while viewing images being acquired by the application software to fine tune the masking. The pull-push knob for the manual shutter allows you to block all light from the camera while you are acquiring a background. See Figure 4-3.

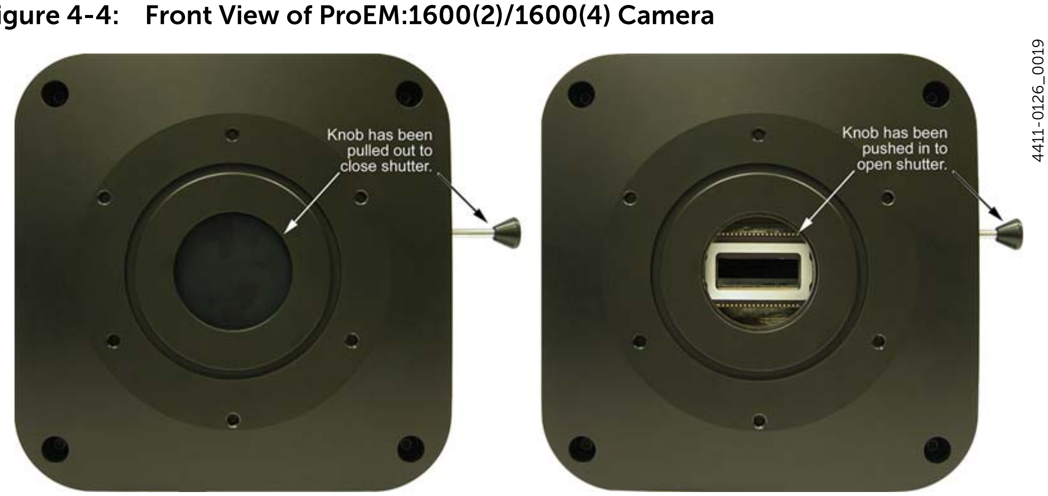
Figure 4-3: Front View of ProEM:512BK Camera



4.6 Opening/Closing ProEM:1600 Manual Shutter

ProEM:1600 cameras contain a built-in manual shutter that allows you to block all light from the camera while you are acquiring a background. To operate the shutter, pull the knob out to close the shutter and push it in to open it. See Figure 4-4.

Figure 4-4: Front View of ProEM:1600(2)/1600(4) Camera



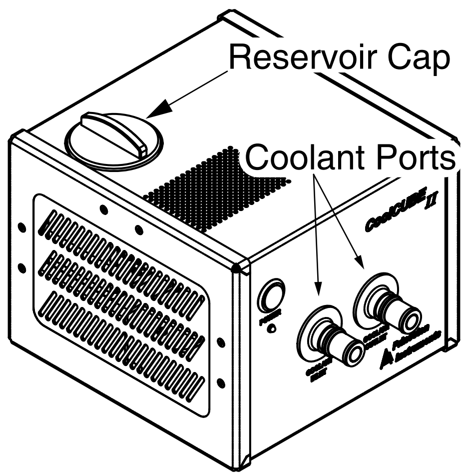
4.7 Making the Camera-Circulator Connections for a CoolCUBE$_{II}$

For liquid-cooled cameras, the CoolCUBE$_{II}$ circulator provides a vibration-free method of heat removal.

Perform the following procedure to connect the ProEM to a CoolCUBE$_{II}$:

1. Make sure the camera and the circulator power switches are turned off.
2. 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. 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. See Figure 4-5.

Figure 4-5: Typical CoolCUBE$_{II}$ Circulator



4. It is recommended that hoses be secured to the camera hose barbs with the clamp supplied.

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.

Damage caused by water leaking into the ProEM voids the warranty.

5. Unscrew the reservoir cap on top of the CoolCUBE$_{II}$ and make sure that the coolant reservoir contains coolant. See Figure 4-6..

Figure 4-6: CoolCUBE$_{II}$ with Reservoir Cap Removed

If additional coolant is required, fill with a 50:50 mixture of water and ethylene glycol.

6. Screw the reservoir cap back in.
7. Plug the circulator into a 100-240 V_{AC}, 50-60 Hz power source.
8. Turn the circulator on. Make sure there are no leaks or air bubbles in the hoses.
   a. If there are no problems, proceed to step 9.
   b. If there are leaks or air bubbles, turn the circulator off and correct the problem(s) by securing the hoses or adding more coolant to the reservoir. Turn the circulator back on. Recheck and if there are no problems, proceed to step 9.
9. Turn the camera on.
10. Start the application software.

4.8 Software Installation

4.8.1 WinX/32

NOTE:

Install the GigE Adapter card BEFORE installing the WinX application software.

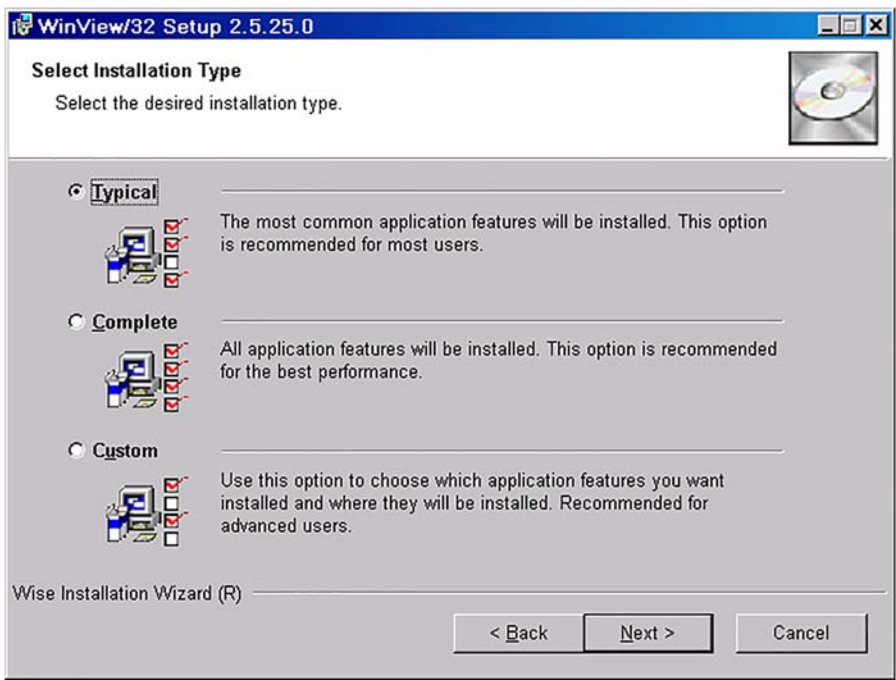
Leave the interface cable disconnected from the camera until you have installed WinX/32 (Ver. 2.5.25 or later).

The following installation is performed via the WinX/32 software installation CD.

1. Insert the CD and follow the installation wizard prompts.
2. On the Select Installation Type dialog select:
   - Typical to install the required drivers and the most commonly installed program files;
   - Custom to choose among the available program files or do not want to install the drivers;
   - Complete to install all application features.

   See Figure 4-7.

Figure 4-7: Typical WinX/32 Setup Dialog: Select Installation Type



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

4.8.2 LightField

NOTE:

Install the GigE Adapter card BEFORE installing the LightField application software.

The following installation is performed via the LightField software installation CD.

1. Before starting the installation:
   - Verify that the computer operating system is Windows Vista (64-bit) or Windows 7 (64-bit).
   - Confirm that the GigE adapter card has been installed.
   - Verify that your computer is connected to the Internet. Internet connection is required for product activation.
2. Insert the CD and follow the installation wizard prompts. See Figure 4-8.

Figure 4-8: Typical LightField Installation Wizard Dialog

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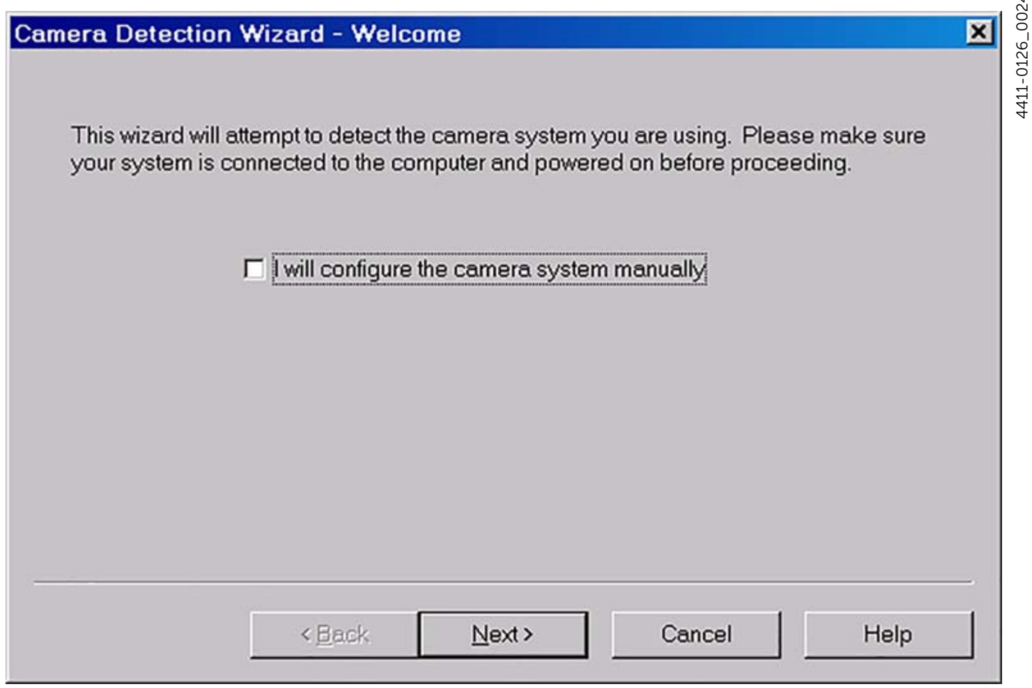
3. After the installation finishes, reboot the computer.
4. Connect the ProEM system components to your computer and power them on.
5. Start LightField, activate it, and begin setting up your experiment.

4.9 Entering the Default Camera System Parameters

4.9.1 WinX/32 Versions 2.5.25 and later

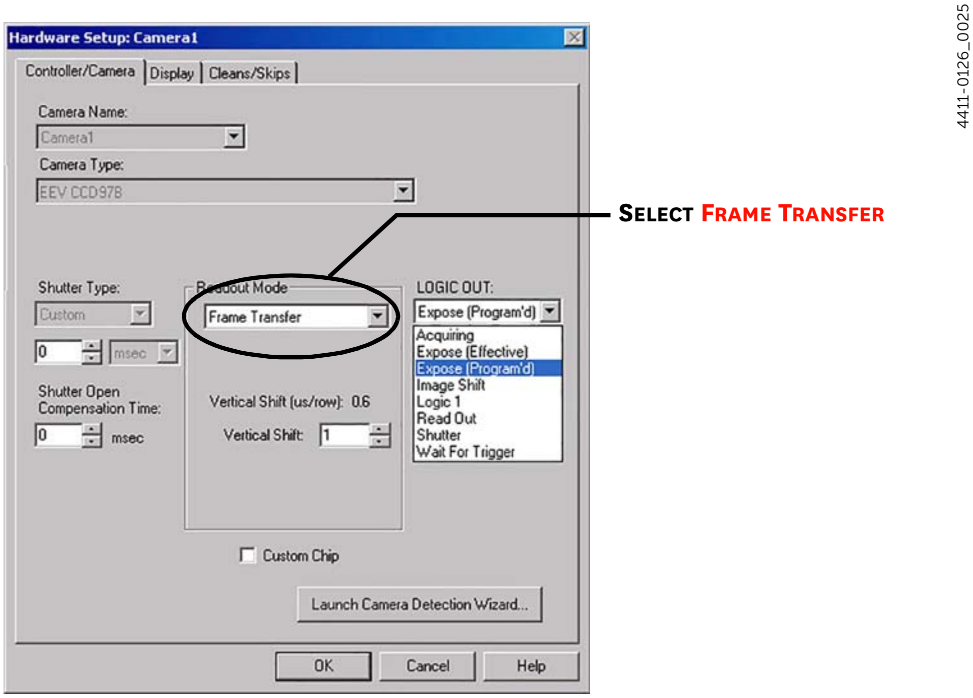
1. Make sure the ProEM is connected to the host computer and that it is turned on.
2. Run the WinX/32 application. The Camera Detection wizard will automatically run if this is the first time you have installed a Teledyne Princeton Instruments WinX application (WinView/32, WinSpec/32, or WinXTest/32) 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 to start the wizard.
3. On the Welcome dialog leave the check box unselected and click on Next. See Figure 4-9.

Figure 4-9: Typical WinX/32 Camera Detection Wizard - Welcome Dialog



4. Follow the instructions on the dialogs to perform the initial hardware setup: this wizard enters default parameters on the Hardware Setup dialog tabs 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 so you can control the camera and acquire data at the default Detector Temperature setting:
   - On the Controller/Camera tab: Make sure **Frame Transfer** is selected as the Readout Mode. See Figure 4-10.

Figure 4-10: Typical WinX/32 Controller/Camera Tab



NOTE:

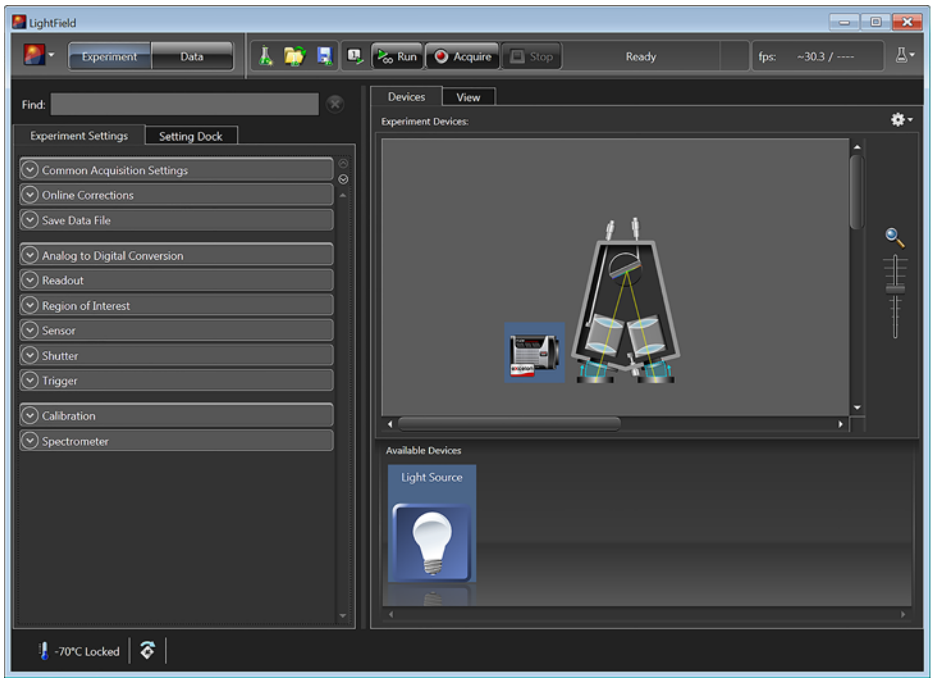
For a step-by-step procedure on basic system operation (Imaging and Spectroscopy), refer to the appropriate **First Light** sections:

- Section 5.1.1, Imaging Applications, on page 52;
- Section 5.1.2, Spectroscopy Applications, on page 56.

4.9.2 LightField

1. Make sure the ProEM (and spectrograph, if this is a spectroscopy system) is connected to the host computer and that the camera (and spectrograph) power supply is turned on.
2. Start LightField.
3. While LightField is starting up, it will detect the available device(s) and load the appropriate icons into the Available Devices area in the Experiment workspace.
4. When you drag an icon into the Experiment Devices area, the appropriate expanders will be loaded into the Experiment Settings stack on the lefthand side of the window.

Figure 4-11: Typical LightField Experiment Workspace



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5. Because this is a new experiment, the default settings will automatically be entered for the experiment device(s). These settings will allow you to begin previewing (Run button) or acquiring (Acquire button) data.

NOTE:

For a step-by-step procedure on basic system operation (Imaging and Spectroscopy), refer to the appropriate **First Light** sections:

- Section 5.2.1, Imaging Applications, on page 61;
- Section 5.2.2, Spectroscopy Applications, on page 65.

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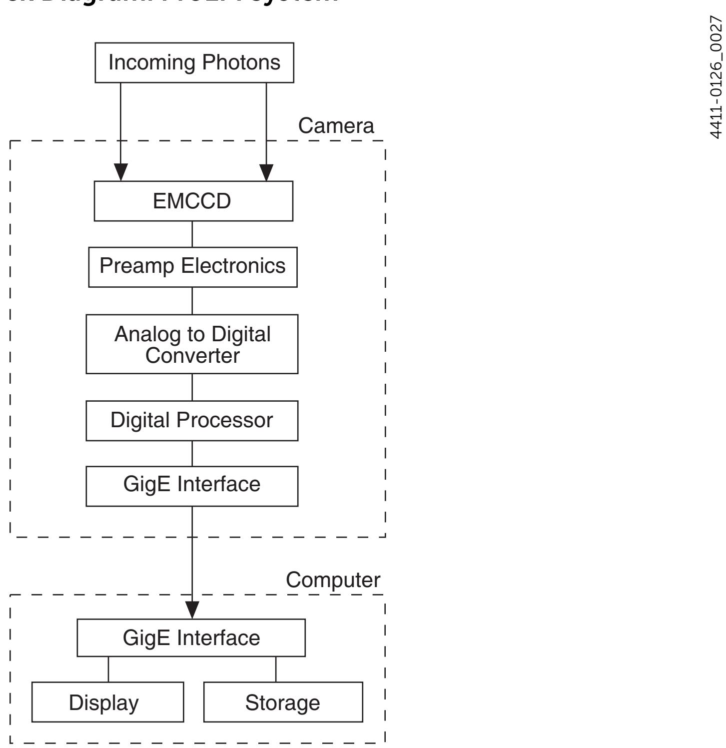
Chapter 5: Operation

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 {Preview} mode (in WinX, 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.

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 are displayed and/or stored via the application software. This sequence is illustrated by the block diagram shown in Figure 5-1.

Whether or not the data are displayed and/or stored depends on the data collection operation that has been selected in the application software.

Figure 5-1: Functional Block Diagram: ProEM System



In WinX/32 and LightField, the data collection operations use the Experiment Setup parameters to establish the exposure time (the period when signal of interest is allowed to accumulate on the CCD). Focus {Preview} is more likely to be used in setting up the system (refer to the **First Light** discussions) and Acquire is then used for the collection and storage of data.

Briefly:

- In **Focus {Preview}** 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. In WinX, the last frame acquired before Stop is selected can be stored; in LightField, this frame cannot be stored. Focus {Preview} 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 may occur. In WinX, 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. Refer to Chapter 6, Advanced Topics, on page 89 for information about synchronizing data acquisition with external devices.

5.1 WinX First Light Instructions

5.1.1 Imaging Applications

This section provides step-by-step instructions for acquiring an imaging measurement in WinView/32 or WinSpec/32 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

- You have already set up your system in accordance with the instructions in the previous chapters.
- You have read the previous sections of this chapter.
- You are familiar with the application software.
- The system is being operated in imaging mode.
- 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 WinX is opened, and WinX must be closed before the camera is turned off.

3. Turn on the computer power.
4. Start the application software.

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 (**Setup** ► **Hardware**)

  These parameters should be set automatically to the proper values for your system.

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

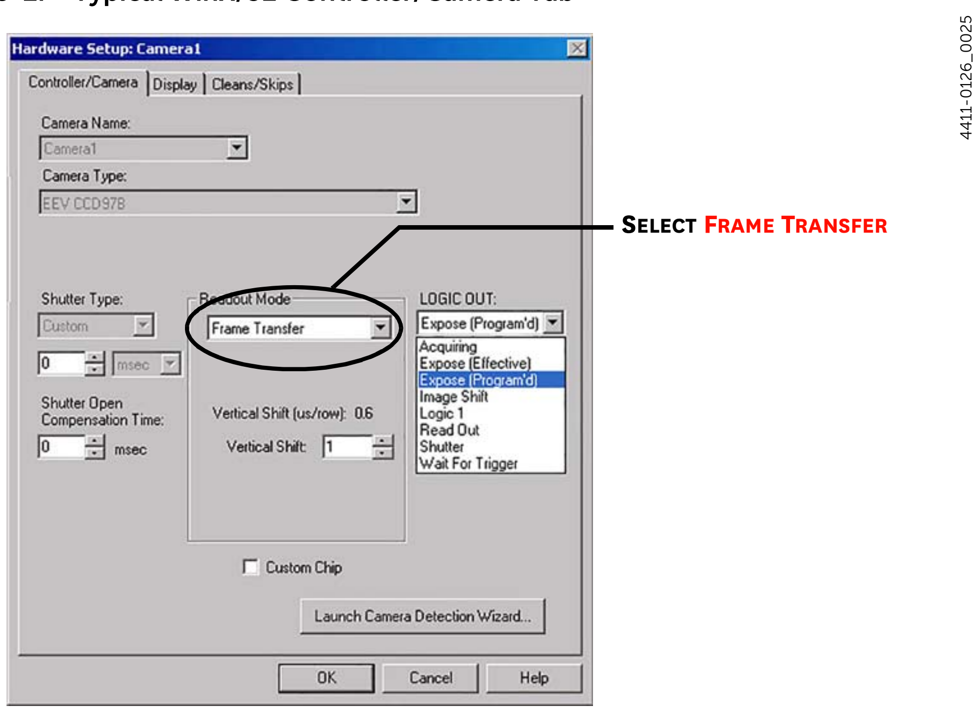
  — **Camera type**: This information is read from the camera.

  — **Shutter type**: Custom (System dependent).

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

  See Figure 5-2.

Figure 5-2: Typical WinX/32 Controller/Camera Tab

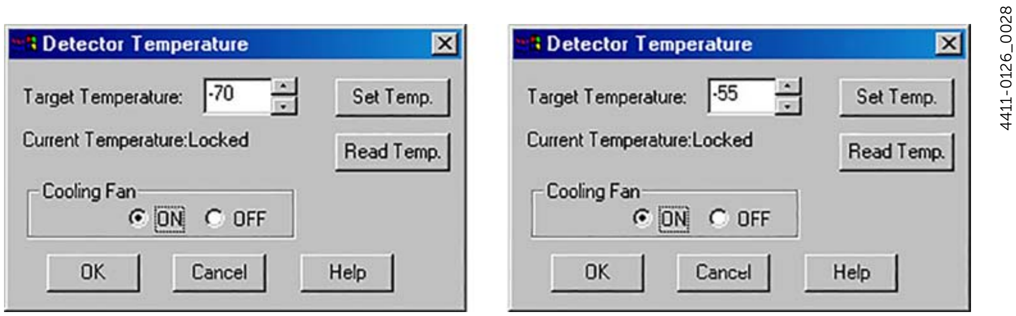


- **Detector Temperature** (**Setup** ► **Detector Temperature**...)

  The default temperature setting is read from the camera. When the array temperature reaches the set temperature, the **Detector Temperature** dialog 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 5-3 shows the default temperatures for the ProEM:512B and 1024B.

Figure 5-3: Typical WinX/32 Detector Temperature Dialog



PROEM:512B **PROEM:1024B**

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

- **Experiment Setup** ► **Main** Tab (**Acquisition** ► **Experiment Setup**...)
  - **Exposure Time**: 50 ms
  - **Accumulations & Number of Images**: 1
- **Experiment Setup** ► **ROI** Tab (**Acquisition** ► **Experiment Setup**...)

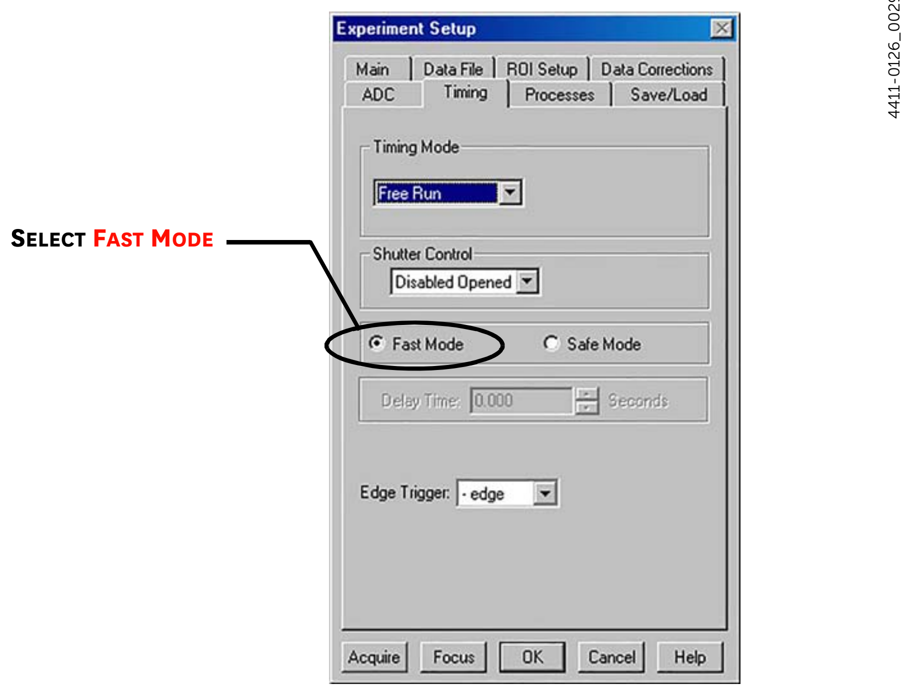
  Use this function to define the region of interest (ROI).
  - **Imaging Mode**: Select this mode if you are running WinSpec.
  - Clicking on **Full** loads the full size of the chip into the edit boxes.
- **Experiment Setup** ► **Timing** Tab (**Acquisition** ► **Experiment Setup**...)
  - **Timing Mode**: 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

  See Figure 5-4.

Figure 5-4: Typical WinX/32 Experiment Setup ► Timing Tab



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.

5.1.2 Spectroscopy Applications

The following paragraphs provide step-by-step instructions for operating ProEM in a WinX 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 a Teledyne Acton Research Series 2300 spectrograph) on which it has been properly installed. Refer to Appendix C, Spectrograph Adapters, on page 147 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:

- 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, Spectrograph Adapters, on page 147.
- You have read the previous sections of this chapter.
- You are familiar with the application software.
- 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 camera (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 (**Setup** ▶ **Hardware**)

  These parameters should be set automatically to the proper values for your system.

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

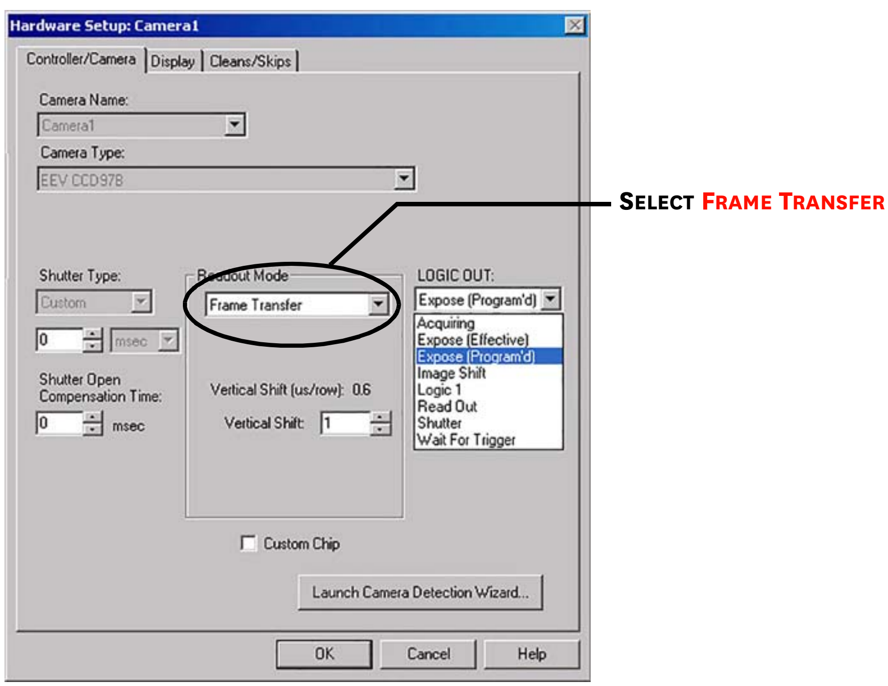
  — **Camera type**: This information is read from the camera.

  — **Shutter type**: Custom (System dependent).

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

  See Figure 5-5.

Figure 5-5: Typical WinX/32 Controller/Camera Tab



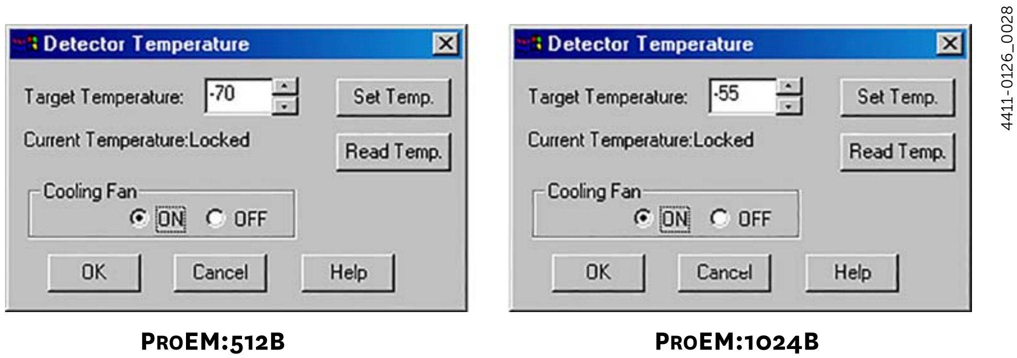
4411-0126_0025

- **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 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.

  See Figure 5-6.

Figure 5-6: Typical WinX/32 Detector Temperature Dialog



NOTE:

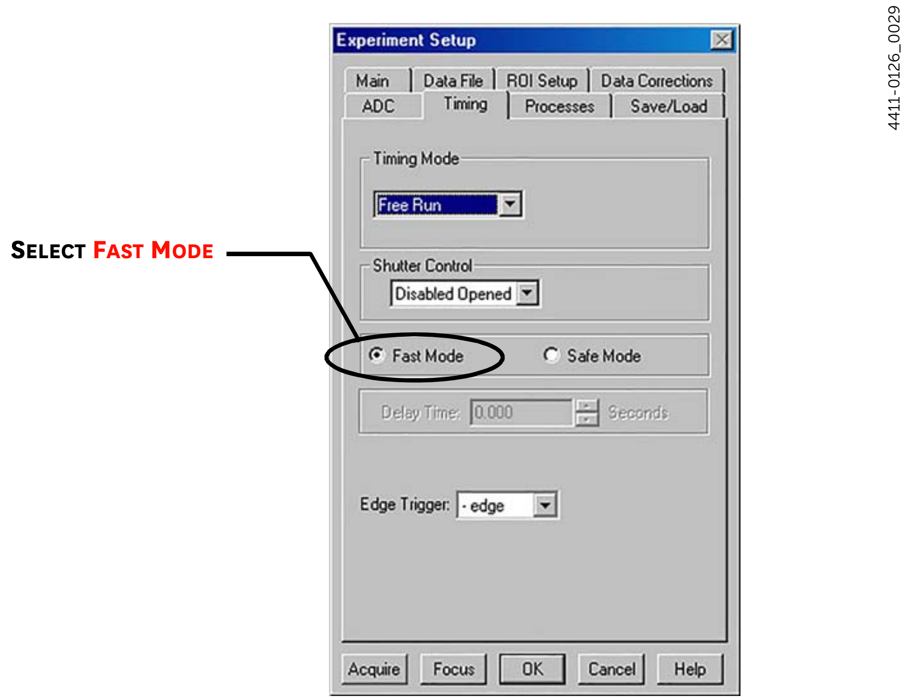
The Detector Temperature dialog will not display temperature information while you are acquiring data.

- **Experiment Setup** ► **Main** Tab (**Acquisition** ► **Experiment Setup...**)
  - **Exposure Time**: 50 ms
  - **Accumulations & Number of Images**: 1
- **Experiment Setup** ► **ROI** Tab (**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 (**Acquisition** ► **Experiment Setup...**)
  - **Timing Mode**: Free Run
  - **Shutter Control**: Disabled Opened.
  - **Safe Mode** vs. **Fast Mode**: Fast Mode

  See Figure 5-7.

Figure 5-7: Typical WinX/32 Experiment Setup ► Timing Tab



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 a Teledyne Acton Research 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.

NOTE:

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/32, select **Focus** (on the **Acquisition** menu or on the **Experiment Setup** dialog) 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 on line help for more information).

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

   - Long focal-length spectrographs

     For example, the Teledyne Acton Research 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).

5.2 LightField First Light Instructions

5.2.1 Imaging Applications

This section provides step-by-step instructions for acquiring an imaging measurement in LightField 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

- You have already set up your system in accordance with the instructions in the previous chapters.
- You have read the previous sections of this chapter.
- You are familiar with the application software.
- The system is being operated in imaging mode.
- 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).
3. Turn on the computer power.
4. Start the application software.

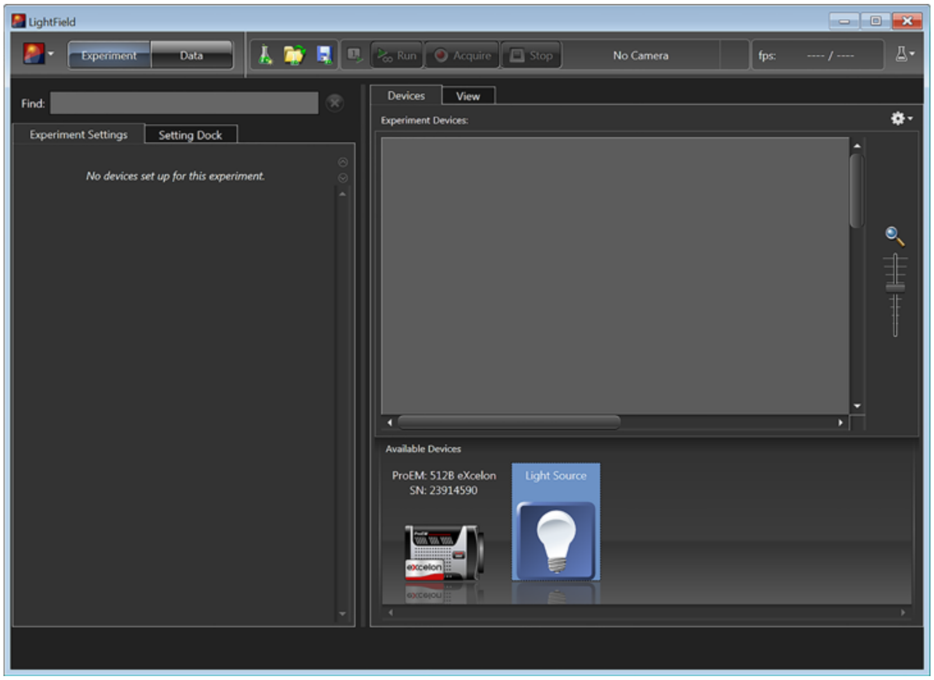
Setting the Parameters

NOTE:

The following procedure is based on LightField. Basic familiarity with the LightField 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.

1. After LightField opens, you should see an icon representing your camera in the **Available Devices** area. In Figure 5-8 the camera is a ProEM:512B eXcelon.

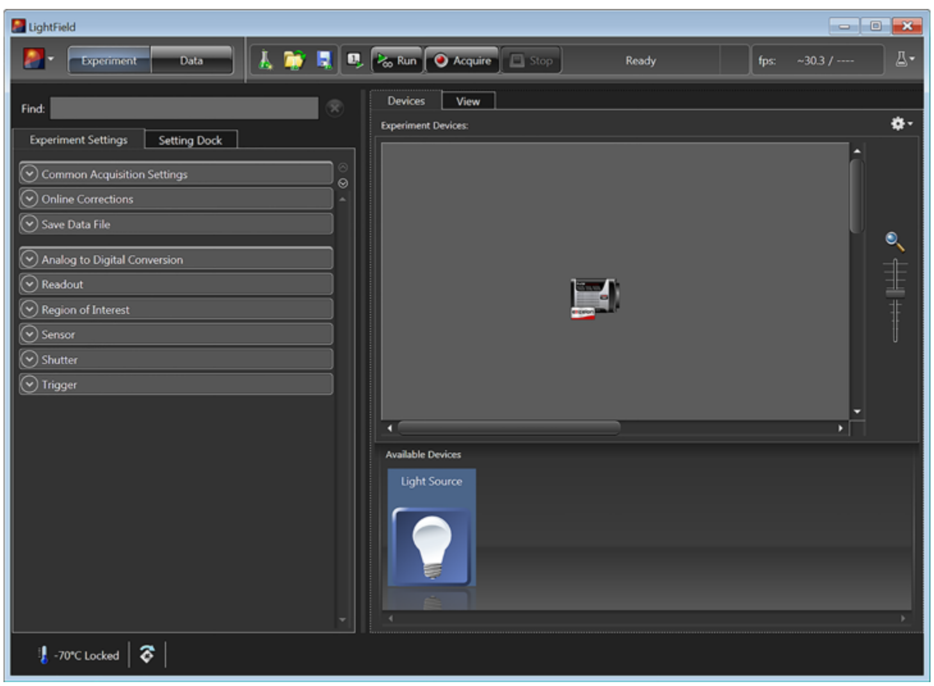
Figure 5-8: Typical LightField Available Devices Area



4411-0126_0030

2. Drag the icon into the **Experiment Devices** area. See Figure 5-9.

Figure 5-9: Typical LightField Experiment Devices Area



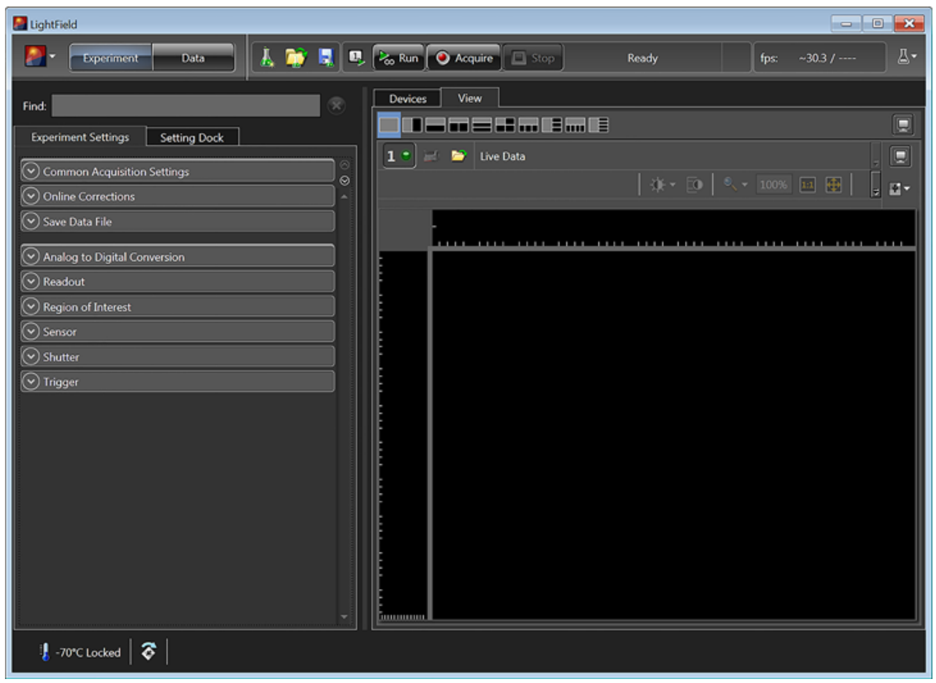
4411-0126_0031

3. Note that the **Experiment Settings** stack on the left now displays several expanders. Because this is a new experiment, the default settings for the camera will be active. The Status bar (at the bottom of the window) displays icons for temperature status and orientation.
   - Temperature status reports the current temperature and whether the set temperature has been reached. Clicking on the icon, opens the Sensor expander which is where the set temperature can be changed.
   - Orientation is displayed because the default readout port is Electron Multiplied. Clicking on the icon pops a panel that describes how the image orientation was corrected.

Acquiring Data

1. Click on the **View** tab, just above **Experiment Devices**, to change to the display area. See Figure 5-10.

Figure 5-10: Typical LightField View Area

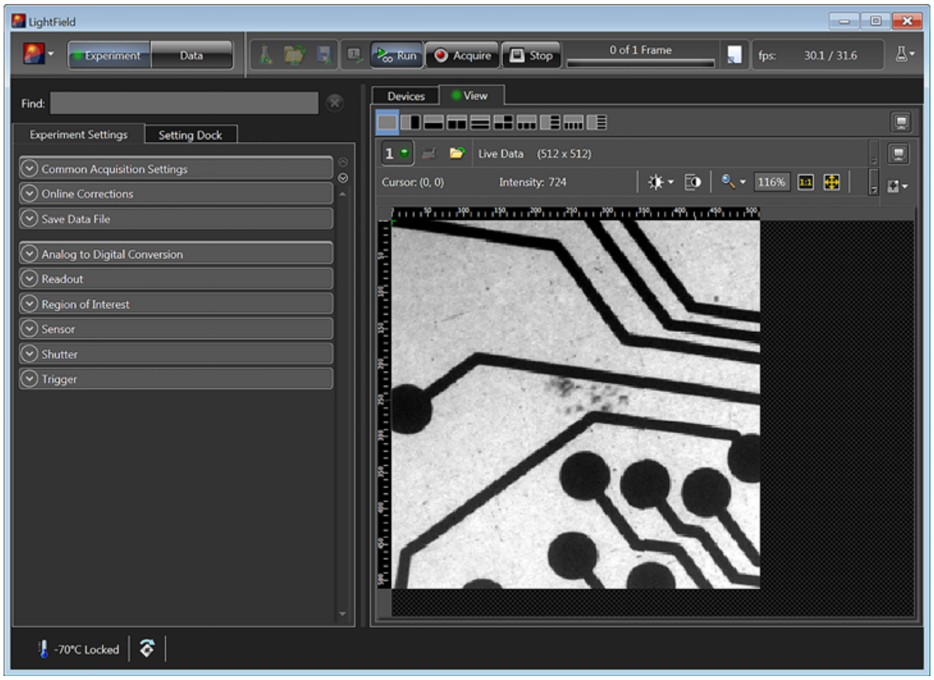


4411-0126_0032

2. Click on the **Run (Infinite)** button 

to start **Preview** mode. In this mode, images will be continuously acquired and displayed. See Figure 5-11.

Figure 5-11: Typical LightField View Area Displaying an Image



4411-0126_0033

3. 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.
   - 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.
4. After you have focused the camera, you can stop **Preview** mode, continue **Preview** mode, begin **Acquire** mode, or wait for the CCD to reach the operating temperature before going to **Acquire** mode.

5.2.2 Spectroscopy Applications

The following paragraphs provide step-by-step instructions for operating ProEM in a spectroscopy setup in LightField 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 a Teledyne Acton Research Series 2300 spectrograph) on which it has been properly installed. Refer to Appendix C, Spectrograph Adapters, on page 147 for information about 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:

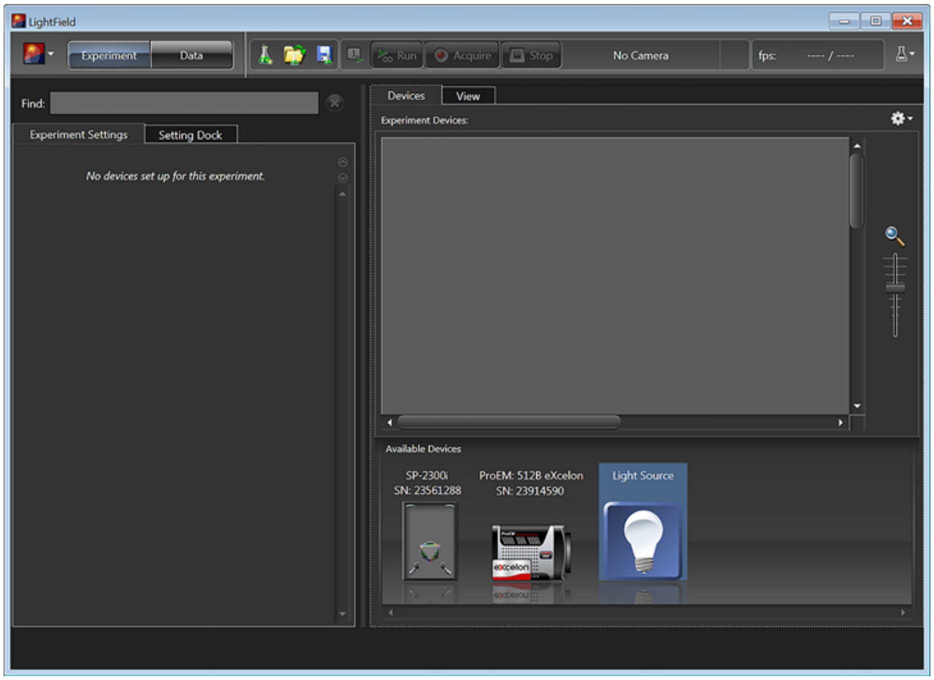
- You have already set up your system in accordance with the instructions in previous chapters. This includes mounting the spectrograph adapter to the camera. Refer to Appendix C, Spectrograph Adapters, on page 147.
- You have read the previous sections of this chapter.
- You are familiar with the application software.
- 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 camera (the power switch is on the back of the power supply).
4. Power ON the spectrograph.
5. Turn on the computer power.
6. Start the application software.
7. After LightField opens, you should see icons representing your camera and the spectrograph in the **Available Devices** area.

   In Figure 5-12 the camera is a ProEM:512B eXcelon and the spectrograph is an SP-2356.

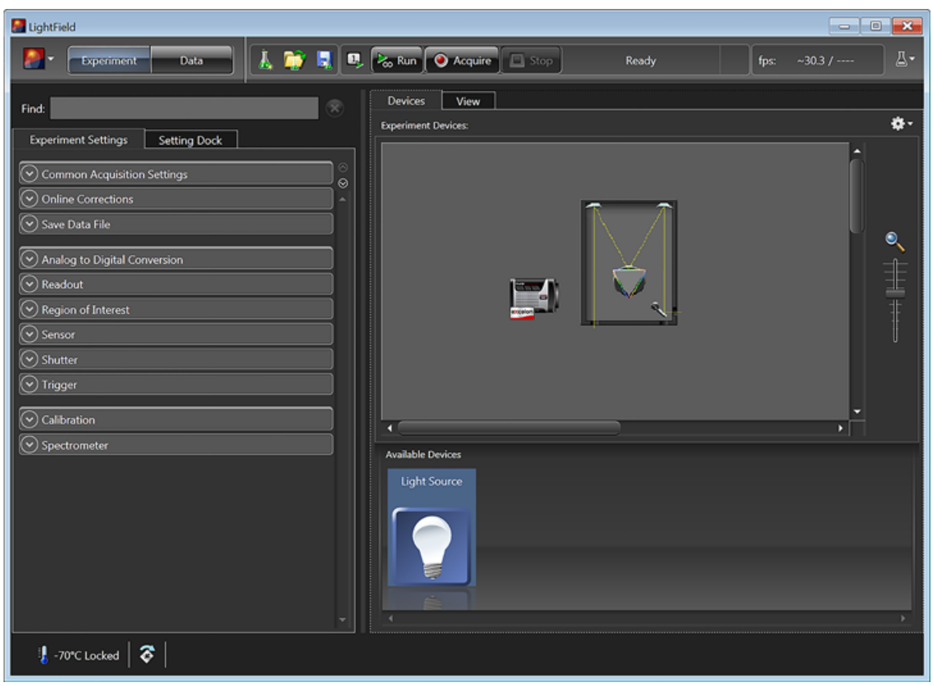
Figure 5-12: Typical LightField Available Devices Area



4411-0126_0034

8. Drag the icons into the **Experiment Devices** area. See Figure 5-13.

Figure 5-13: Typical LightField Experiment Devices Area



4411-0126_0035

Note that the **Experiment Settings** stack on the left now displays several expanders. Because this is a new experiment, the default settings for the camera will be active. The **Status** bar (at the bottom of the window) displays icons for temperature status and orientation.

- Temperature status reports the current temperature and whether the set temperature has been reached. Clicking on the icon opens the Sensor expander where the set temperature can be changed.
- Orientation is displayed because the default readout port is Electron Multiplied. Clicking on the icon pops a panel that describes how the image orientation was corrected.

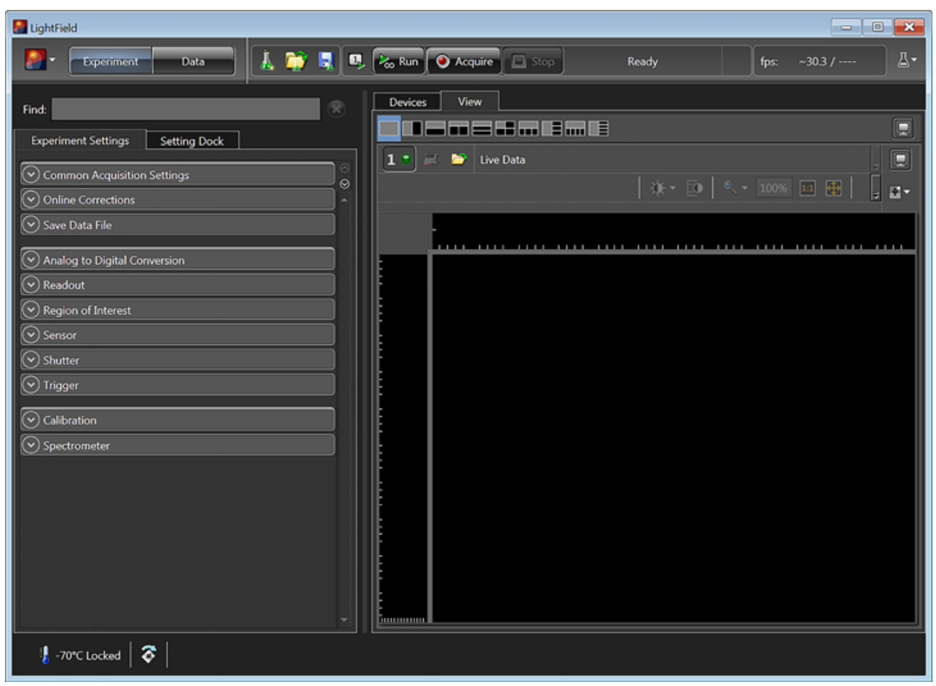
Focusing

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 a Teledyne Acton Research SP-2356 spectrograph, can be easily adapted to other spectrographs.

The following procedure assumes that the camera and spectrograph have already been turned on and their icons have been dragged into the Experiment Devices area as shown in Figure 5-13.

1. Click on the View tab, just above **Experiment Devices**, to change to the display area. See Figure 5-14.

Figure 5-14: Typical LightField View Area



4411-0126_0036

2. 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.

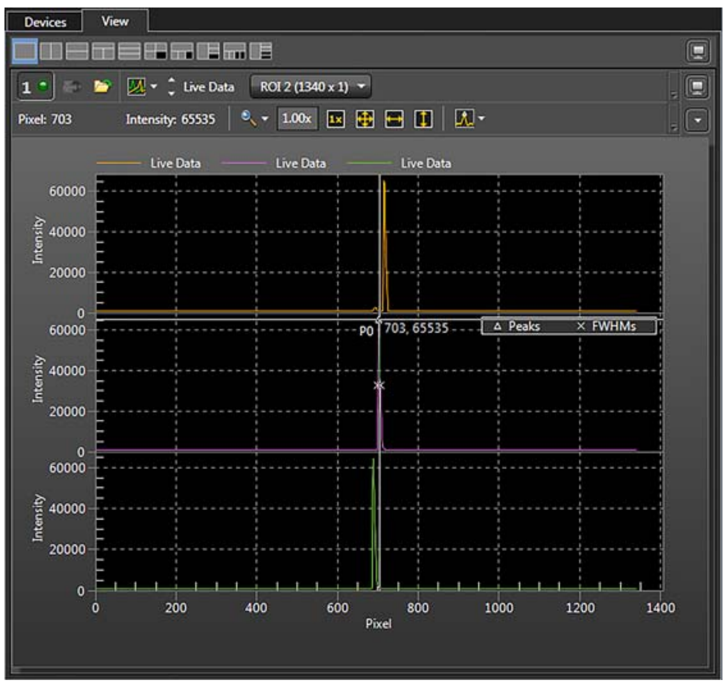
3. Open the **Spectrometer** expander, select the grating and set the center wavelength to 435.8 nm if using a mercury lamp or to 0.0 nm if using a broadband source.

NOTE:

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.

4. Set the slit to 25 μm. If necessary, adjust the Exposure Time to maintain optimum (near full-scale) signal intensity.
5. Make sure that the spectroscopy-mount adapter moves freely at the spectrograph.
6. Select **Align Spectrometer**... from the **Experiment Options** menu. Review the displayed information and then click on the Begin button. Typically, this feature creates three 1-row high ROIs (one near the top of the array, one in the middle, and one near the bottom) and begins data acquisition. Data will be continuously acquired and displayed but will not be stored. See Figure 5-15.

Figure 5-15: Typical LightField Align Spectrometer View: Pre-Adjustment



4411-0126_0037

7. 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. Note that the Peak Finding function is active for the center graph to allow you to monitor the FWHM information to achieve the narrowest line width.

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

   - Long focal-length spectrographs such as theTeledyne Acton Research 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.

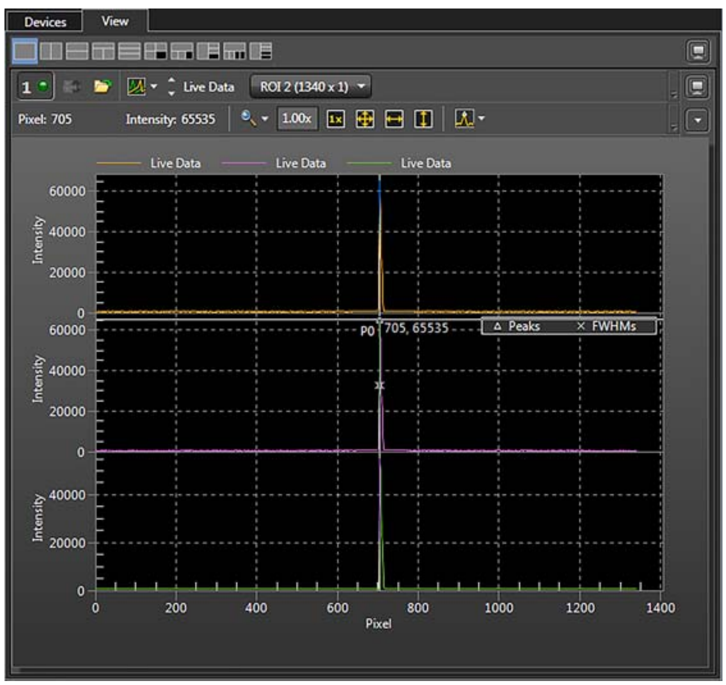
   - No focusing adjustment

     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.

8. Next adjust the rotation. Click on the peak you want to monitor during the rotational alignment. This positions the large cursor to provide a vertical reference line across all of the ROIs.

9. Rotate the camera while watching the live display of the lines until the selected peak is aligned horizontally in all of the ROIs. Tighten the setscrews securing the spectrograph adapter at the spectrograph. See Figure 5-16.

Figure 5-16: Typical LightField Align Spectrometer View: Post-Adjustment



4411-0126_0038

NOTE:

When aligning accessories (e.g., 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 a spectrograph (i.e., focus and align while watching a live image).

5.3 Exposure and Signal

5.3.1 Exposure Time

Exposure Time, which is set on the **Experiment Setup** ► **Main** tab {**Common Acquisition Settings** expander}, is the time between commands sent by the application software to start and stop signal accumulation on the sensor. 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.

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 complete information about these modes, refer to Section 5.4.6, Exposure – Readout Modes, on page 82.

5.3.2 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.

When **Multiplication Gain** {**Electron Multiplied**} is selected on the **Experiment Setup** ► **ADC** tab {**Analog to Digital Conversion** expander}, the **Avalanche** {**EM Gain**} can be set by entering the desired gain value on the **Experiment Setup** ► **Main** tab {**Analog to Digital Conversion** expander}. 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.

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 aging 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 Teledyne Princeton Instruments web site at www.princetoninstruments.com and searching for that title.

5.3.3 EM Gain Calibration

NOTE:

EM Gain Calibration is not currently available in LightField.

Each ProEM camera is factory-calibrated for linearized EM Gain. Over time, however, aging of the EMCCD array may degrade gain linearity. Because aging 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 aging, each ProEM contains a built-in shutter and light source that allow you to perform an on-demand EM Gain Calibration. 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.

To Perform EM Gain Calibration in WinX/32:

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 (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.

CAUTION!

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

5.3.4 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 WinX/32 is the controlling software, temperature control is done via **Setup** ► **Detector Temperature**.
- When LightField is being used, temperature control is done on the **Sensor** expander.

Initially, the default temperature appropriate for your specific model is displayed.

Once the **Target Temperature** {**Temperature Setpoint**} 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 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 twenty minutes 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 5 (page 108), 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.

5.3.5 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.

5.3.6 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 corrects 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.

5.3.7 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.

Table 5-1: Major Differences: Dark Current versus Clock-Induced Charge

	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

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).

5.3.8 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, and (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.

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 Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 160 for complete information.

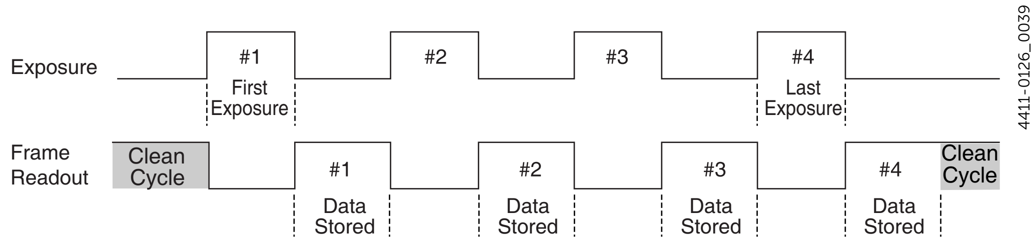
NOTE:

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.

5.3.9 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 5-17 is a timing diagram for an experiment set up to acquire four (4) images in Freerun {No Response} timing mode. In this diagram clean cycles occur before the first exposure and after the last readout period.

Figure 5-17: Timing Diagram: Clean Cycles



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 {via the **Sensor Cleaning** pane accessed on the **Sensor** expander}. 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.

Cleaning Parameters

- **Number of Cleans** {**Number of Clean Cycles**} 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.
- **Number of Strips per Clean** {**Clean Cycle Height**} 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 trade off 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.

- **Clean Before Exposure** {**Clean Before Exposure**} is only provided for cameras that have a Frame Transfer CCD and is only available for selection when in Full Frame mode is active. Normally, cleaning occurs until the acquisition starts. When Clean Before Exposure is active, cleaning occurs up until acquisition starts and the entire CCD will be cleaned once right after the readout occurs. It is a clean operation for the next exposure and it matters only when multiple images are taken with a short exposure time.

NOTE:

Clean Before Exposure is not relevant when using a triggered mode.

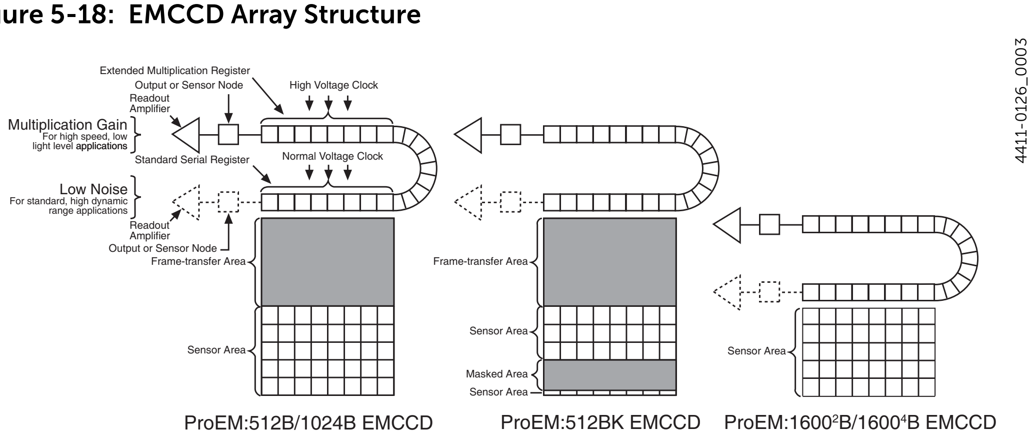
- **Continuous Cleans** {**Clean Until Trigger**} is available when the start of exposure is tied to an external trigger.
  - In WinX/32, this cleaning becomes active when **External Sync** timing mode is selected.
  - In LightField, it becomes active when **Trigger Response** is set to Readout Per Trigger or Shift **Per Trigger**.

  Figure 6-6 on page 93 illustrates a timing diagram for LightField's Clean Until Trigger.
- **Skip Serial Register Clean** (deselected) {**Clean Serial Register**} The Top margin inactive parallel strips on a CCD are made up of the dark pixels that come before the active strips on a sensor as they exit to the serial register. When these are available (i.e., Pre Dummies {Top Margin} > 0), they serve the purpose of cleaning the serial register before readout of the active strips. In LightField, if there are no inactive parallel strips (i.e., {Top Margin} = 0), selecting **Clean Serial Register** forces a clean of the serial register before readout of the active strips.

5.4 Readout

The ProEM:512B/512BK and ProEM: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 5-18.

Figure 5-18: EMCCD Array Structure



The ProEM:1600$^{(2)}$ and ProEM:1600$^{(4)}$ models use full frame CCDs with 1600 x 200 and 1600 x 400 active pixels, respectively.

NOTE:

Typically there are additional rows and columns for internal reference.

In standard frame transfer mode, the sensor area is exposed for certain time and the acquired image data are then transferred to frame transfer area before reading the data out via the multiplication gain register or standard serial register.

In standard full frame transfer mode, the sensor area is exposed for certain time and the acquired image data are then read out via the selected register.

Region of Interest (ROI) and/or binning can be used to improve the time resolution, limited to a millisecond regime.

For additional information about the CCD exposure-readout operations, refer to Section 5.4.6, Exposure – Readout Modes, on page 82.

WinX/32 and LightField allow you to specify the type of readout (i.e., full frame or binned,) the output amplifier, and the gain (i.e., the number of electrons required to generate an ADU.)

5.4.1 Dual-Readout Port Operation

The ProEM:512B/BK, 1024B, 1600$^{(2)}$, and 1600$^{(4)}$ models are configured with software-selectable dual-readout amplifiers, also referred to as ports, illustrated in Figure 5-18.

The two amplifiers are:

- Port #1: **Multiplication Gain {Electron Multiplied}**
  When this port is selected, the EM gain value can be entered on the **Experiment Setup** ▶ **Main** tab {**Analog to Digital Conversion** expander.} 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 camera. Using excessive EM gain will not improve the overall signal to noise ratio (SNR).

NOTE:

An image read out of the Multiplication Gain {Electron Multiplied} port is the mirror image of the same image read out of the Low Noise port. Unless the application software automatically corrects the orientation when the selected port changes, you may need to specify a horizontal-flip of the image.

- Port #2: **Low Noise** (Normal CCD)

  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:

  An image read out of the Low Noise port is the mirror image of the same image read out of the Multiplication Gain {Electron Multiplied} port. Unless the application software automatically corrects the orientation when the selected port changes, you may need to specify a horizontal-flip of the image.

If your camera is configured with two readout amplifiers (ports), the software automatically allows port selection.

NOTE:

Because the user interface may be different, refer to your software manual for specific information about readout amplifier/port selection.

5.4.2 Controller Gain {Analog Gain}

Controller Gain {Analog gain} 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.

Selecting the amount of gain is done on the **Acquisition** ► **Experiment Setup...** ► **ADC** tab {**Analog to Digital Conversion** expander.} 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. Typical values are provided in Table 5-2.

Table 5-2: Typical Controller Gains

Readout Amplifier (Port)	Readout Rates	Typical Gain for 512B(e- /ADU)	Typical Gain for 1024B (e- /ADU)
Multiplication Gain {Electron Multiplied}	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

5.4.3 Readout Rate

Refer to Table 5-3 for the list of Readout Rate supported by ProEM

Table 5-3: Readout Rates

CCD Type	Multiplication Gain {Electron Multiplied}	Low Noise
Frame Transfer	5 MHz 10 MHz	100 kHz 1 MHz 5 MHz
Full Frame	1 MHz 4 MHz 6.67 MHz	100 kHz 1 MHz 5 MHz

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., 100 kHz) 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, and/or binning.

For additional information about frame rate, refer to the product data sheet.

5.4.4 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 WinX/32, the definition of such a region is done either from the **Easy Bin** dialog accessed from the **Acquisition** menu or from the **ROI Setup** tab, 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.
- In LightField, ROIs are set up via the **Region of Interest** expander.

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.

- In WinX/32, 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 are 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).

- In LightField, when ROIs are used to acquire data, the ROI parameter information for ALL of the ROIs is stored in the data file when the data are saved to disk. You can review this information for the active data display by using the **Show File Information** functionality (accessible from the **Data Options** menu in the **Comparison Viewer**.)

NOTE:

For Flatfield Correction, Background Subtraction, etc., the images must be exactly the same size.

References to X and Y axes assume that the shift register is parallel to the X-axis and that the data are shifted to the shift register in the Y direction.

When setting up a partial frame ROI in WinX/32, 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.

NOTE:

This constraint does not apply to LightField.

Examples

These WinX examples include partial frame ROIs with and without binning. The terminology is based on the WinX/32 **Experiment Setup** ▶ **ROI Setup** tab.

- **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 in WinX. However, this setting would be valid in LightField.
- **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 in WinX. However, this setting would be valid in LightField.

5.4.5 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 in WinX, keep in mind that the resulting number of super pixels in the horizontal must be evenly divisible by 4.

NOTE:

This constraint does not apply to LightField.

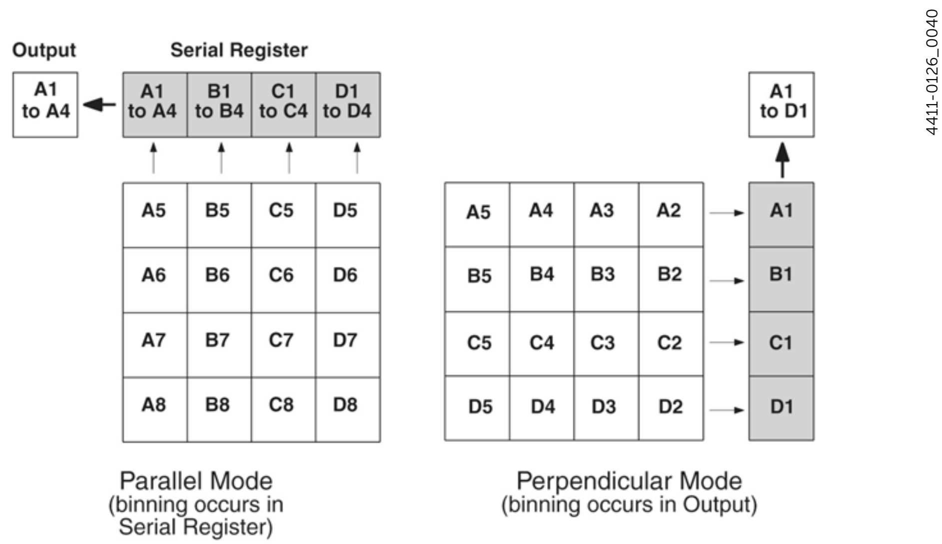
Array Orientation

For square format CCDs (e.g., 512 x 512 or 1024 x 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.

See Figure 5-19.

Figure 5-19: 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.

5.4.6 Exposure – Readout Modes

The frame transfer CCDs used by the ProEM:512B/BK and 1024B support Frame Transfer, Full Frame (sequential), Kinetics, and Spectra-Kinetics readout modes. If you are planning to use Frame Transfer mode, be aware that the set exposure time may not be the effective exposure time. The full frame CCDs used by the ProEM:1600$^{(2)}$ and 1600$^{(4)}$ support Full Frame and Kinetics readout modes.

NOTE:

Kinetics and Spectra-Kinetics are typically options for the frame transfer ProEM cameras. For additional information about these readout modes, refer to Section 6.4, Kinetics Mode, on page 98, and Section 6.5, Spectra-Kinetics (Option), on page 106.

5.4.6.1 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 WinX/32 and LightField, Frame Transfer is the default mode of operation for cameras with frame transfer CCDs. If necessary, you can change the readout mode on the **Hardware Setup** ► **Controller/Camera** tab {**Sensor** expander}.

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 longer readout time.

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

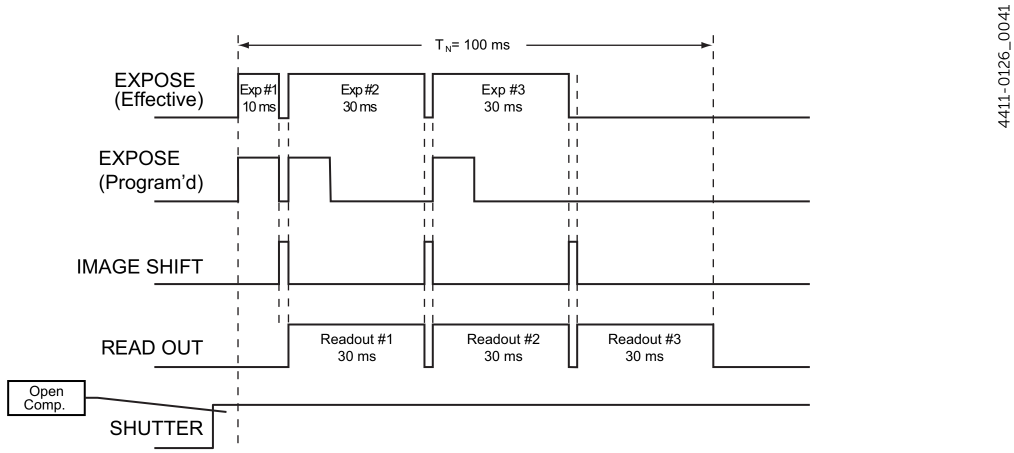
Consider a situation where full frame readout is 30 ms, the exposure time is 10 ms, and three frames are taken in Frame Transfer mode. The first frame is exposed precisely for the length of time entered into the software (10 ms) and all subsequent frames are exposed for the readout time. The total time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

See Figure 5-20.

Figure 5-20: Timing Diagram: Frame Transfer Mode, Exposure Time < Readout 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.

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

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

where:

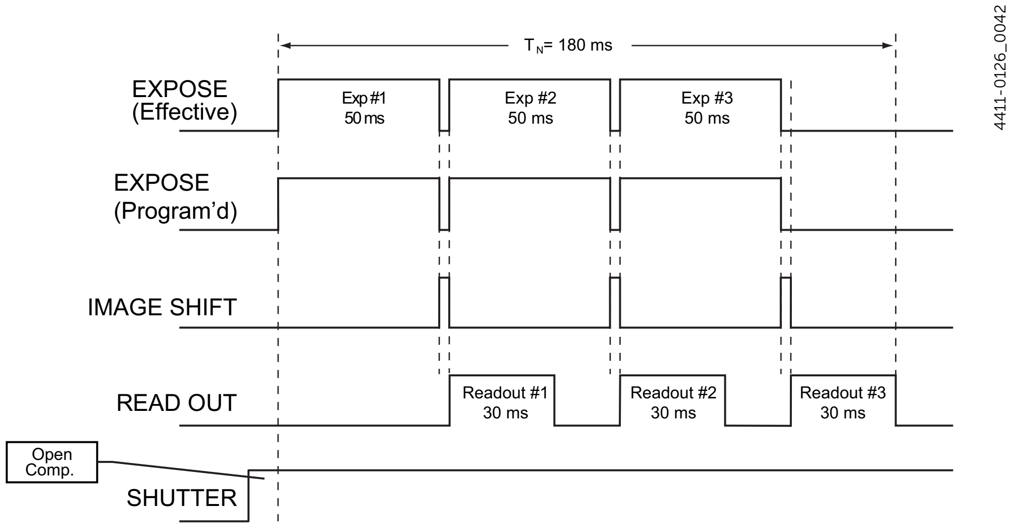
- T_N = Total time taken to capture a sequence of N frames;
- t_R = readout time for one frame;
- N = total number of frames in a sequence;
- t_{exp} = exposure time.

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 x 50 ms + 30 ms), which is equivalent to a frame rate of 16.67 fps.

See Figure 5-21.

Figure 5-21: Timing Diagram for Frame Transfer Mode when



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.

In Frame Transfer mode when exposure time > readout time, the total time (TN) 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.

Exposure Time > Readout Time. Timing information shown is for illustration purpose only. Specific readout times vary depending on the model.

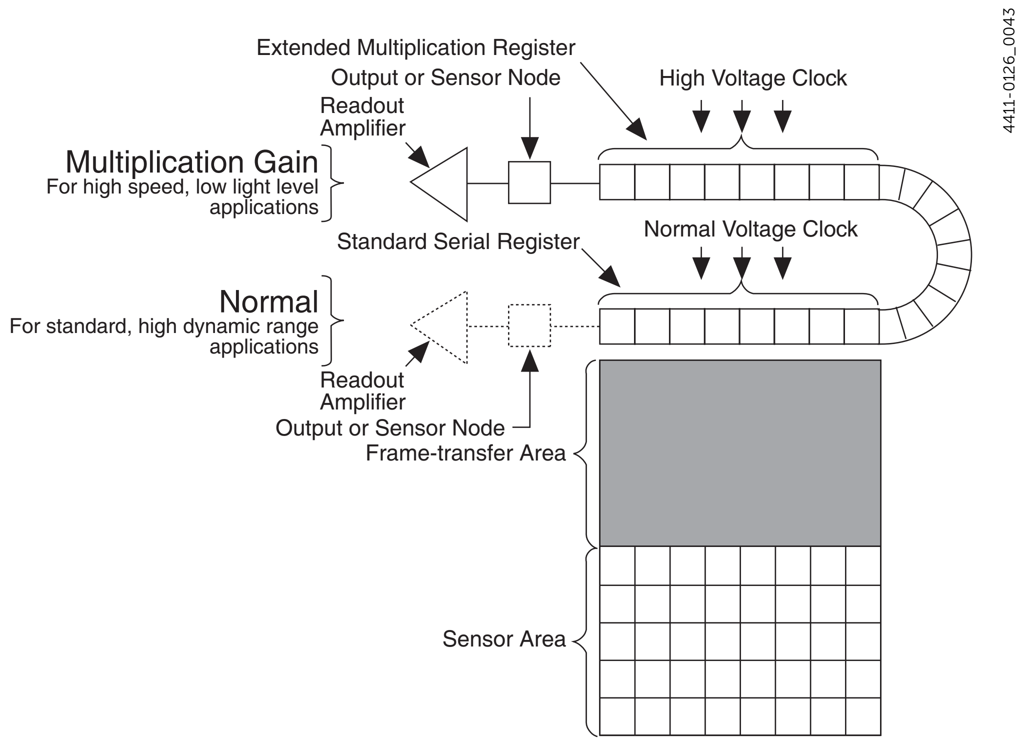
5.4.6.2 Full Frame (Sequential) Mode for Frame-Transfer EMCCD

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.
4. Reading out the CCD.

See Figure 5-22.

Figure 5-22: Functional Array Structure Diagram: Frame-Transfer EMCCD



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

- In WinX/32, Full Frame mode can be selected from **Hardware Setup ▶ Controller/Camera** tab.
- In LightField, it is selected on the **Sensor** expander.

NOTE:

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

Example: Full Frame Mode for Frame-Transfer EMCCD

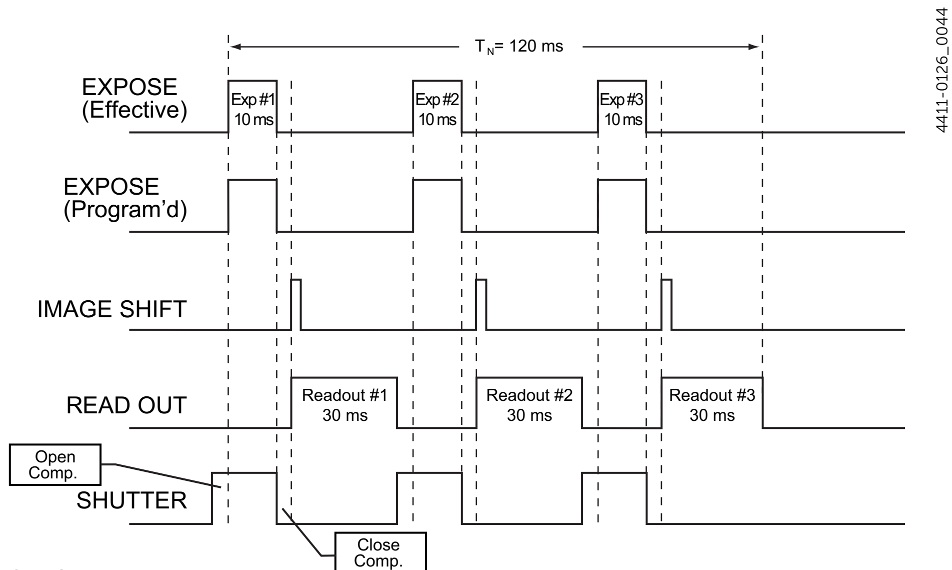
Operation in Full Frame mode is illustrated in the timing diagram below. In this example, the exposure time is 10 ms and the readout time is 30 ms. The total time to take 3 frames is 120 ms [(3 x 10 ms) + (3 x 30 ms)], equivalent to a frame rate of 25 fps (3 frames ÷ 0.120 seconds).

NOTE:

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

As illustrated in Figure 5-23, 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.)

Figure 5-23: Timing Diagram: Full-Frame Mode



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.

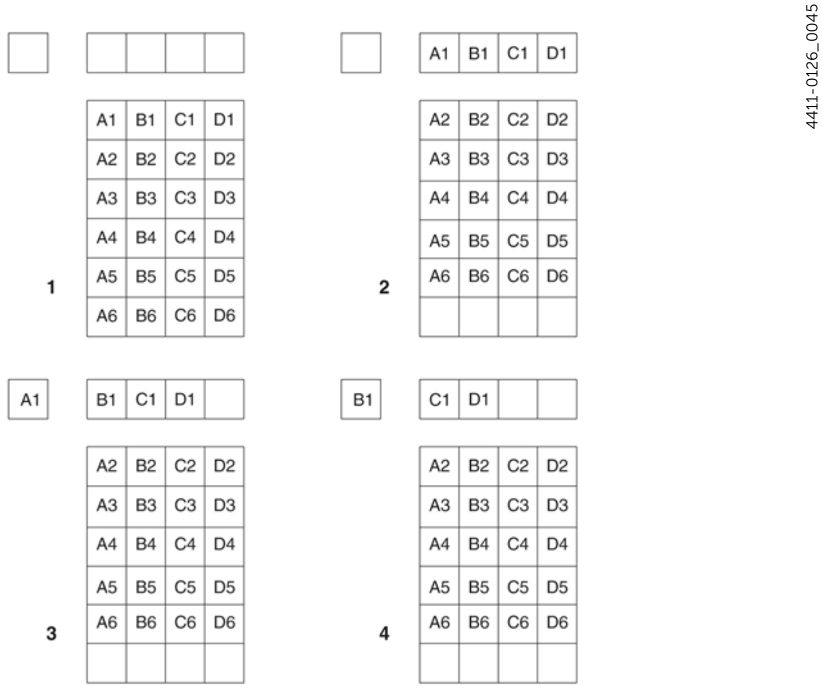
5.4.6.3 Full Frame Readout for Full Frame EMCCD

In Figure 5-24, the upper left section (i.e., Section 1,) represents a full frame EMCCD after exposure but before the beginning of readout. The capital letters represent different amounts of charge, including both signal and dark charge. This section explains readout at full resolution, where every pixel is digitized separately. In this drawing, the charge is being read out of the Low Noise port.

NOTE:

The Multiplication {Electron Multiplied} port is not shown.

Figure 5-24: Full Frame at Full Resolution



Readout of the CCD begins with the simultaneous shifting of all pixels one row toward the shift register, in this case the row on the top. The shift register is a single line of pixels along the edge of the EMCCD, not sensitive to light and used for readout only. Typically the shift register pixels hold twice as much charge as pixels in the imaging area of the CCD.

After the first row is moved into the shift register, the charge now in the shift register is shifted toward the output node, located at one end of the shift register. As each value is emptied into this node it is digitized. Only after all pixels in the first row are digitized is the second row moved into the shift register. The order of shifting in our example is therefore A1, B1, C1, D1, A2, B2, C2, D2, A3.... After charge is shifted out of each pixel, the remaining charge is zero, meaning that the array is immediately ready for the next exposure.

A subsection of the CCD can be read out at full resolution, sometimes dramatically increasing the readout rate while retaining the highest resolution in the Region Of Interest (ROI).

5.4.7 Readout Time

In WinX/32, readout time can be obtained by going to the **Acquisition** menu and selecting **Readout Time...**.

In LightField, it is reported on the **Sensor** expander.

Readout Time is calculated based on the current ROI/Binning/Vertical shift rate settings.

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Chapter 6: Advanced Topics

Previous chapters have discussed setting up the hardware and the software for basic operation. This chapter discusses topics associated with experiment synchronization.

Synchronization, is configured on the **Experiment Setup** ► **Timing** tab in WinX/32 and on the **Shutter** and **Trigger** expanders in LightField.

- Section 6.1, Frame Transfer/Full Frame Timing {Trigger Response} Modes and Shutter Control {Shutter Mode} discusses Timing Modes {Trigger Response} and Shutter Control {Shutter Mode}.
- Section 6.2, Fast and Safe Modes on page 95 discusses the Fast and the Safe modes. Fast is used for real-time data acquisition and Safe is used in WinX when coordinating acquisition with external devices or when the computer speed is not fast enough to keep pace with the acquisition rate.
- Section 6.3, LOGIC OUT Control, on page 97 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 with external equipment.
- Section 6.4, Kinetics Mode, on page 98 discusses Kinetics mode. This form of data acquisition relies on mechanical or optical masking of the CCD array for acquiring time-resolved images. In addition, topics related to the special Spectra-Kinetics mode are included. Refer to Section 6.5, Spectra-Kinetics (Option) on page 106 for complete information.
- Section 6.6, Custom Modes, on page 108 discusses the Custom Chip {Custom Sensor} and Custom Timing modes. These modes allow you to specify an active sub-area of the CCD array and/or a faster vertical shift rate for the purpose of increased frame rate (pixels outside of the area are not read). Custom Chip {Custom Sensor} mode requires mechanical or optical masking of the array to prevent smearing.

6.1 Frame Transfer/Full Frame Timing {Trigger Response} Modes and Shutter Control {Shutter Mode}

The basic ProEM timing {Trigger Response} modes for Frame Transfer and Full Frame operations are **Free Run** {**No Response**}, **External Sync** {**Readout Per Trigger**}, **Bulb Trigger** {**Expose During Trigger Pulse**} and **Trigger Start** {**Start On Single Trigger**}. These modes are combined with the Shutter Control {Shutter Mode} options to provide the widest variety of modes for precision experiment synchronization. The shutter options available for Frame Transfer and Full Frame operations are Normal, 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 {Open Before Trigger}, available in the External Sync and External Sync with Continuous Cleans {Clean Until Trigger} 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 {No Response}, where the modes of shutter operation are identical, both Normal and PreOpen {Open Before Trigger} lines are shown in the timing diagrams and flow chart.

6.1.1 EXT SYNC Trigger Input

The selected Timing Mode {Trigger Response} 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. See Figure 6-1.

Figure 6-1: Rear of ProEM Camera

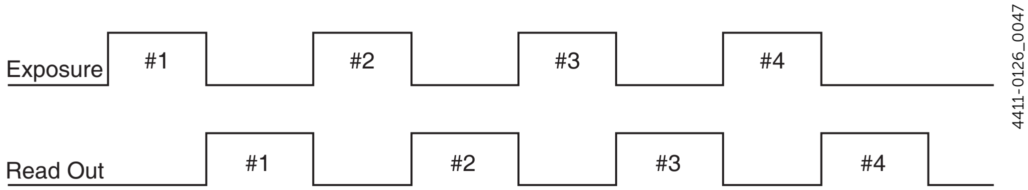
Things to keep in mind when setting up the External Sync pulse input are:

- **Pulse Height**: 0 to +3.3V logic levels (TTL-compatible).
- **Pulse Width (trigger edge frequency)**: The time between trigger edges.
- **EXT SYNC Connector Impedance**: High impedance.
- **Trigger Edge {Trigger Determined By}**: rising or falling edge must be indicated on the **Experiment Setup** ► **Timing** tab {**Trigger** expander}.

6.1.2 Free Run {No Response}

In this mode, there is no external triggering {or the camera is ignoring external triggers} 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 6-2.

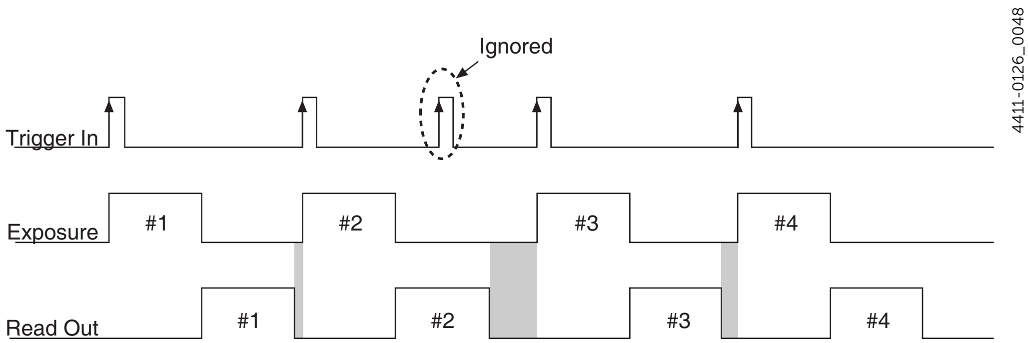
Figure 6-2: Free Run Timing Diagram



6.1.3 External Sync {Readout Per Trigger}

In this 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 6-3.

Figure 6-3: External Sync Timing Diagram

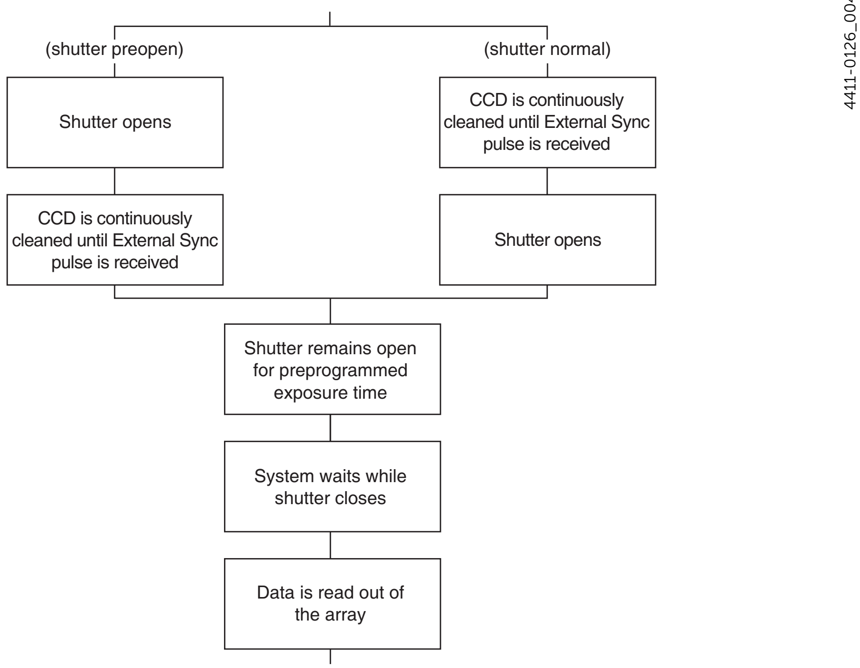


For a sequence of one frame, bulb mode and trigger-first mode are the same. The shaded areas denote the idle time between exposures.

6.1.4 External Sync with Continuous Cleans {Clean Until Trigger} Timing

Another timing mode available with the ProEM is called Continuous Cleans {Clean Until Trigger}. In addition to the standard cleaning of the array, which occurs after the camera is enabled, this mode will remove any charge from the array until the moment the External Sync pulse is received. See Figure 6-4.

Figure 6-4: Flowchart: Continuous Cleans {Clean Until Trigger}



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 {Normal} shutter operation, the shutter is opened for the set exposure time. With PreOpen {Open Before Trigger} shutter operation, the shutter is open during the Continuous Cleaning {Clean Until Trigger}, 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 μs 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 6-5: Timing Diagram: WinX/32 Continuous Cleans

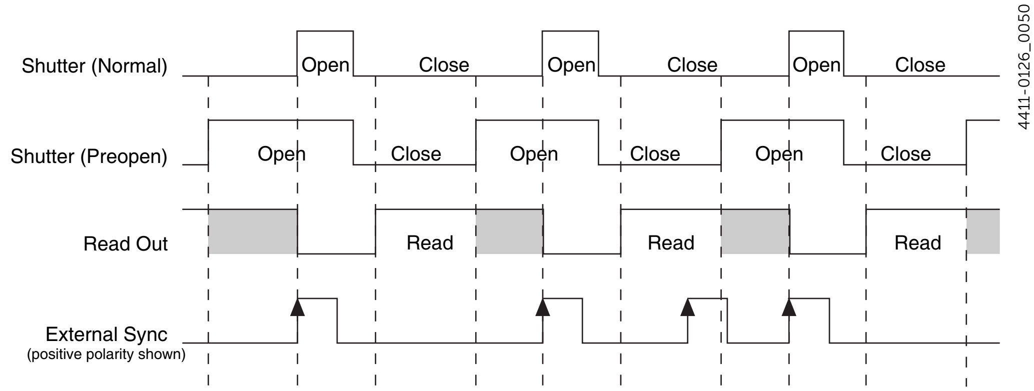
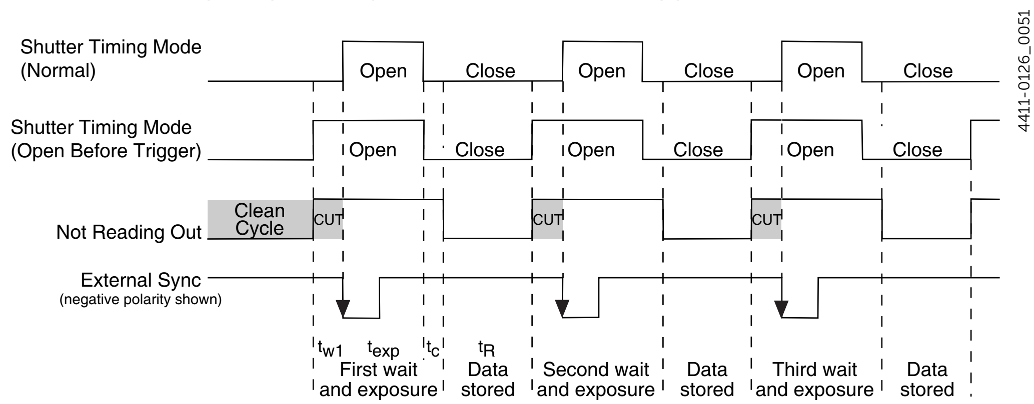


Figure 6-6: Timing Diagram: LightField Clean Until Trigger (CUT)



6.1.5 Bulb Trigger {Expose During Trigger Pulse} Timing

When Bulb Trigger {Expose During Trigger Pulse} 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, Kinetics, and Spectra-Kinetics 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 {Waiting 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 {Clean Until Trigger} 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 {Shift Per 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.

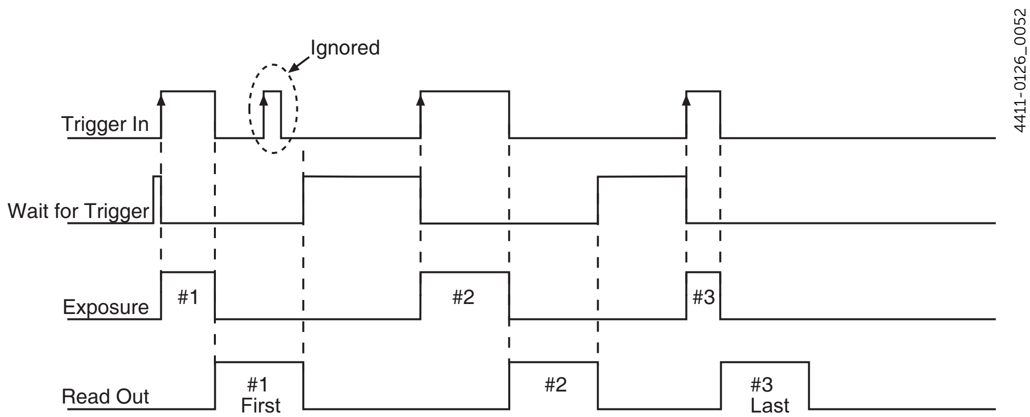
NOTES:

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 6-7 illustrates the timing diagram for the following configuration:

- Bulb Trigger {Expose During Trigger Pulse};
- Non-Overlap Mode;
- Three Exposure Sequence;
- No Preopen;
- No Continuous Cleans.

Figure 6-7: Timing Diagram: Bulb Trigger {Expose During Trigger Pulse}



6.1.6 Trigger Start {Start On Single Trigger}

In this mode, the camera requires only one trigger to acquire a sequence of frames. Once the initial trigger is received, the camera ignores any further triggers until the entire exposure/readout sequence is completed.

6.2 Fast and Safe Modes

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 WinX, the choice of **Fast** or **Safe** data collection is made on the **Experiment Setup ▶ Timing** tab. Figure 6-8 shows flowcharts that illustrate the differences between the two modes. In LightField, **Fast** data collections is always used.

6.2.1 Fast Mode (WinX and LightField)

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.

NOTE:

LightField always uses Fast Mode.

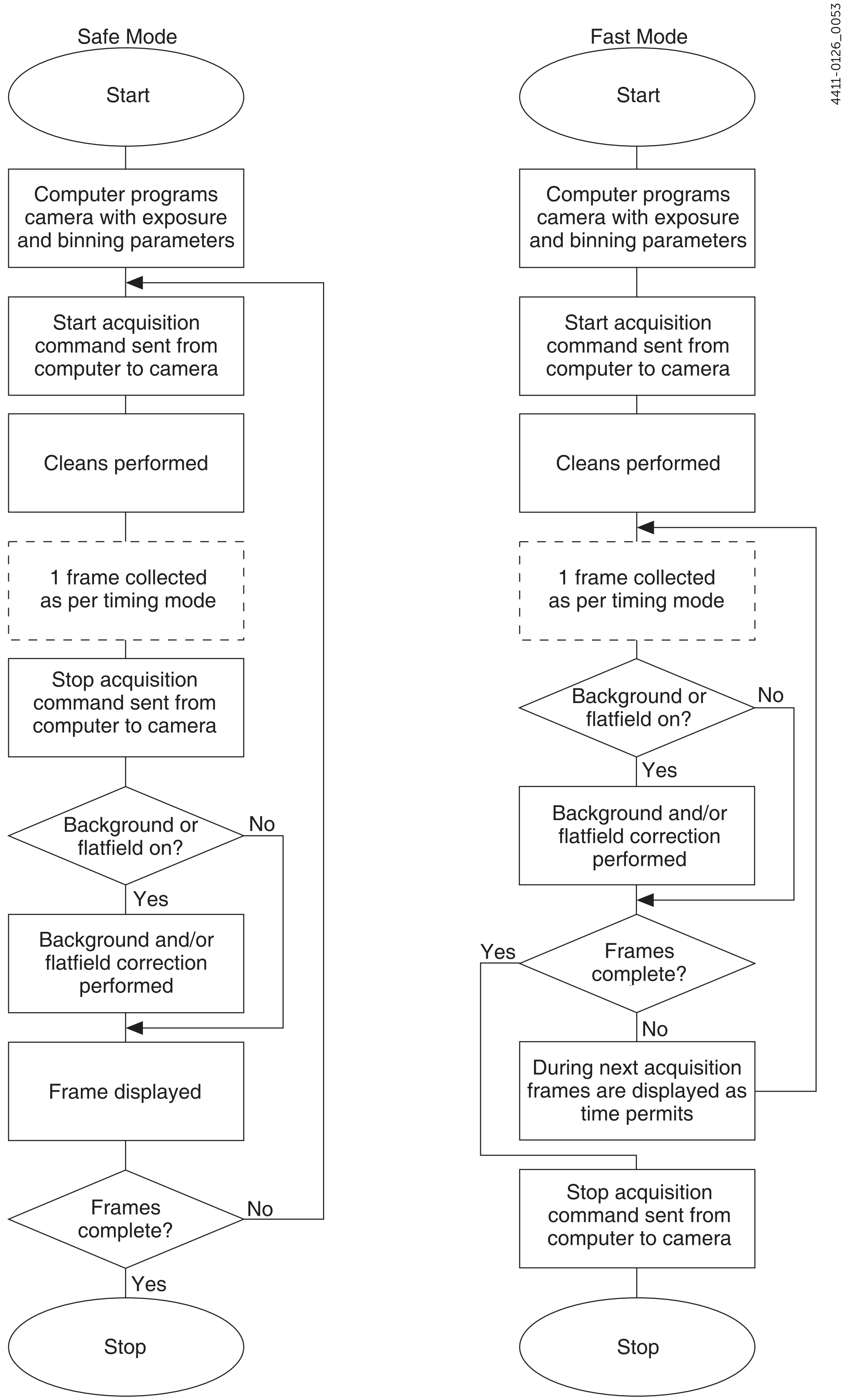
6.2.2 Safe Mode (WinX)

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 6-8, 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:

When running WinX/32, Safe Mode must be used whenever the system is set up for the optional Kinetics Readout Mode. Refer to Section 6.4, Kinetics Mode, on page 98 for more information about this type of image acquisition and readout.

Figure 6-8: Flowcharts of Safe and Fast Mode Operation



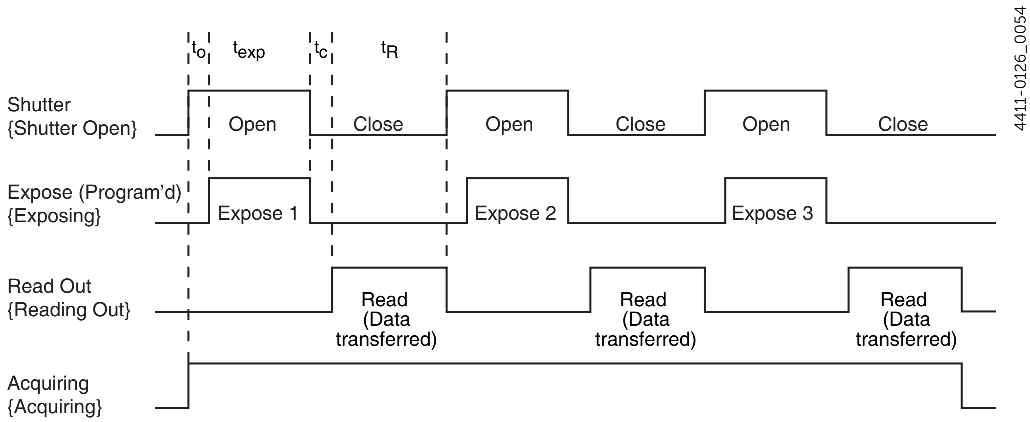
6.3 LOGIC OUT Control

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 {**Trigger** expander}:

- **Acquiring {Ready For Start}**
  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 6-9 assumes 3 frames have been programmed.

Figure 6-9: Comparison of READ OUT, SHUTTER, and ACQUIRING Logic Out Levels



- **Expose (Effective) {Effectively Exposing}**
  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) {Exposing}**
  This level is at a logic high during the programmed exposure time (i.e., the time set in the software).
- **Image Shift {Shifting Under Mask}**
  This level is at a logic high while the image is being shifted under the mask.
- **Logic 1 {Always High}**
  The level at the connector is high.
- Read Out {Reading Out}
  It is at a logic high when CCD is being read; otherwise low.
- **Shutter {Shutter Open}**
  This level is at a logic high while the shutter is opening and during the programmed exposure time. The output precisely brackets shutter-open time (exclusive of the shutter close compensation time tc) and can be used to control an external shutter.

- **Wait for Trigger {Waiting 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 {Open Before Trigger} (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 {Invert Output Signal}** check box is checked, the output is at a logic low when the action is occurring.

6.4 Kinetics Mode

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 6-10 and Figure 6-11 illustrate how to configure Kinetics in WinX/32 and LightField, respectively.

Figure 6-10: Typical WinX/32 Hardware Setup Dialog: Kinetics Readout Mode

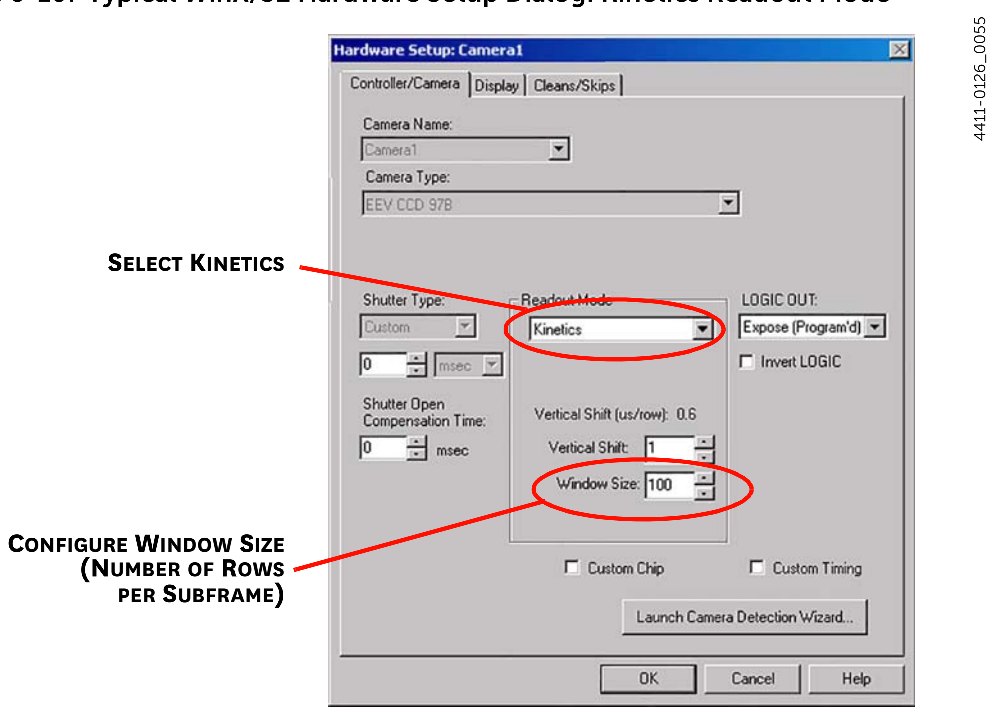
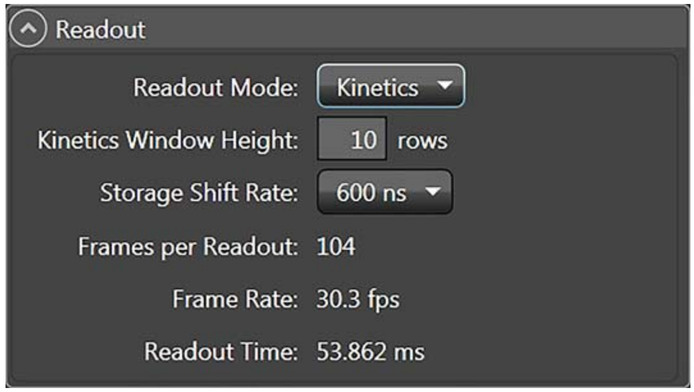


Figure 6-11: Typical LightField Sensor Expander: Kinetics Readout Mode



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6.4.1 Kinetics Readout

Kinetics readout allows a burst of subframes to be captured with microsecond 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, the ability to mask as few rows as possible sets the ultimate limit on the temporal resolution.

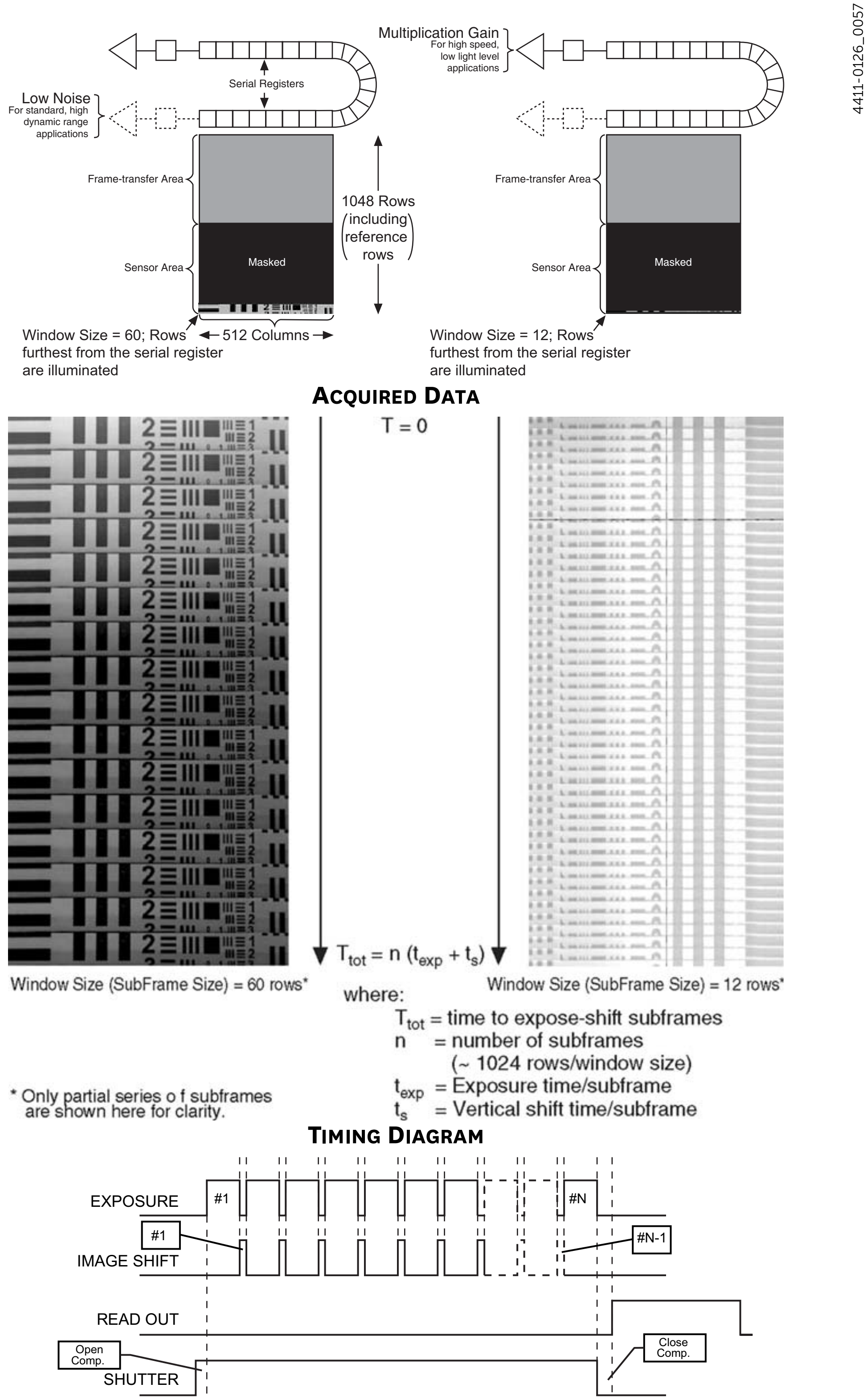
See Figure 6-12 for two examples that comare using an optical test target image:

NOTE:

The illuminated area is the furthest from the serial register.

- The left image shows an illuminated area of 60 rows with a Window Size of 60 rows high.
- The right image shows an illuminated area of 12 rows with a Window Size of 12 rows high.
- A reduced number of rows in the right image illustrate a way to achieve better time resolution between subframes.
- The timing diagram represents the exposure-readout sequence. Time resolution between subframes is given by [t_{exp} + t_s].

Figure 6-12: Kinetics Mode: Partial CCD Illumination, ProEM:512B



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.

6.4.2 Kinetics Timing Modes and Shutter Control

For Kinetics, the timing modes are Free Run {No Response}, Single Trigger {Readout Per Trigger}, and Multiple Trigger {Shift Per Trigger}. Free run {No Response} mode is used for experiments that do not require any synchronization with the experiments. The other two modes (i.e., 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 {Positive} or -ve {Negative} edge of the incoming TTL pulse.

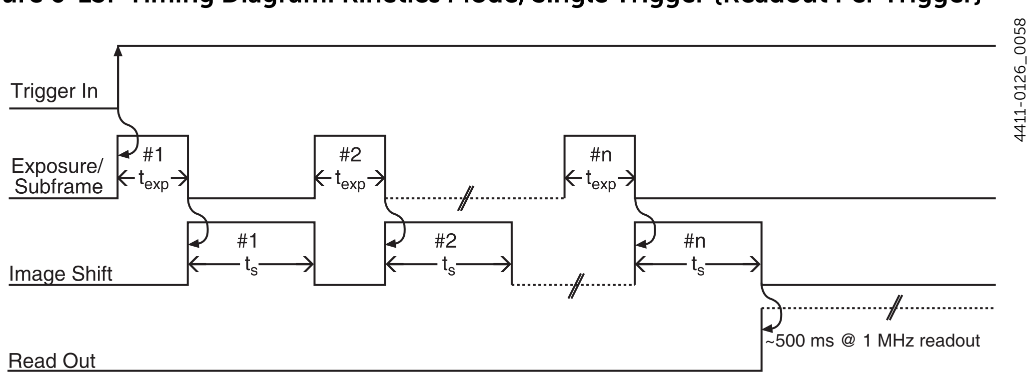
In the Free Run Kinetics mode, the ProEM takes a series of images, each with the Exposure time set through the software (in WinX/32, the exposure time is set on the **Experiment Setup** ▶ **Main** tab). The time between image frames, which may be as short as a few microseconds, is limited by the time required to shift an image under the mask. This inter-image time equals the Vertical Shift rate (specified in ns/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 {Open Before Trigger}, Disabled Open {Always Open} and Disabled Closed {Always 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 {Open Before Trigger}, available in the External Sync and External Sync with Continuous Cleans {Clean Until Trigger} 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.

6.4.3 Triggered Operation

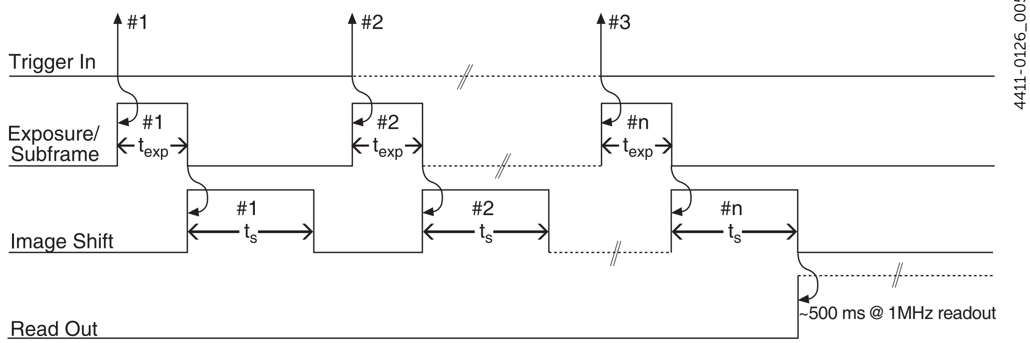
In Single Trigger {Readout Per Trigger} mode, the camera requires only one trigger to initiate an entire series of exposure-shift cycles as shown in Figure 6-13. Here, the camera uses the exposure time as entered into the software. The trigger is applied at the **Ext Sync** connector on the rear of the ProEM.

Figure 6-13: Timing Diagram: Kinetics Mode, Single Trigger {Readout Per Trigger}



In multiple trigger {Shift Per 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. Figure 6-14 illustrates the timing diagram.

Figure 6-14: Timing Diagram: Kinetics Mode, Multiple Trigger {Shift Per Trigger}



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.

See Figure 6-15 and Figure 6-16 for configuration information.

Figure 6-15: Typical WinX/32 Experiment Setup Dialog: Timing tab

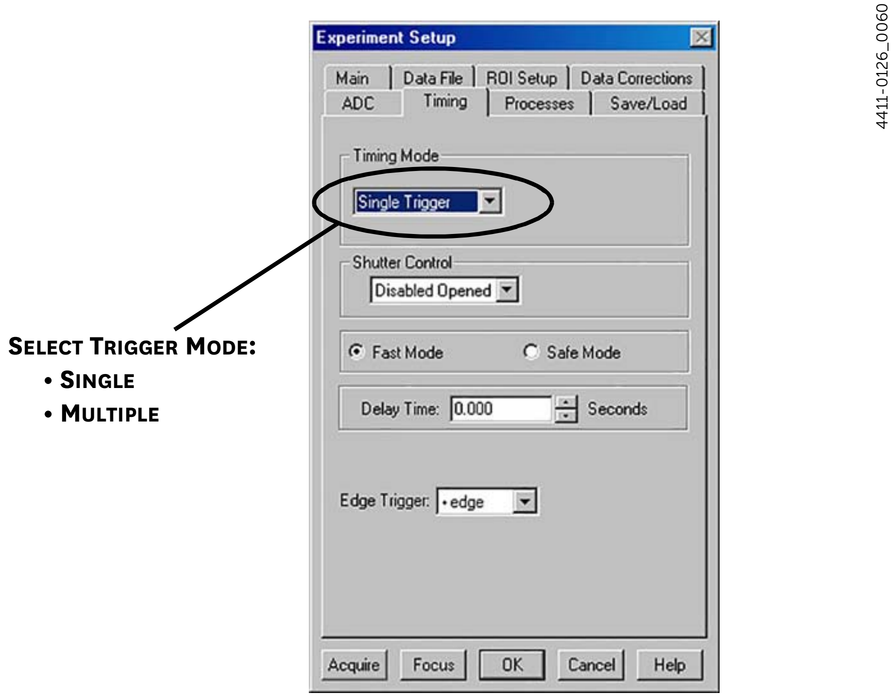
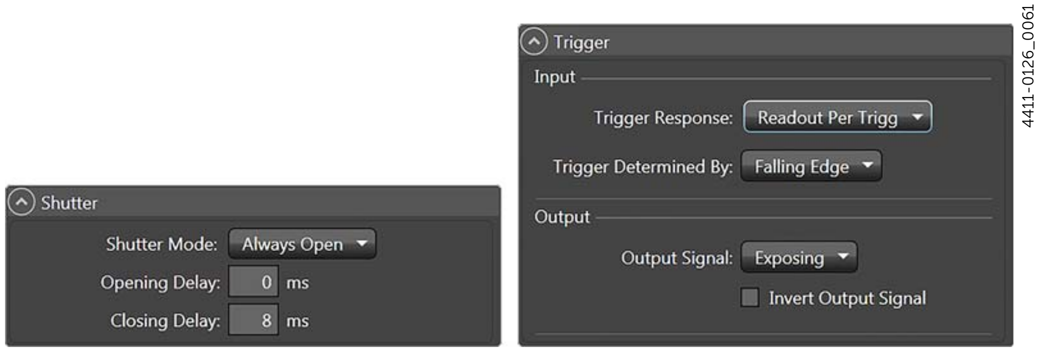


Figure 6-16: Typical LightField Shutter and Trigger Expanders



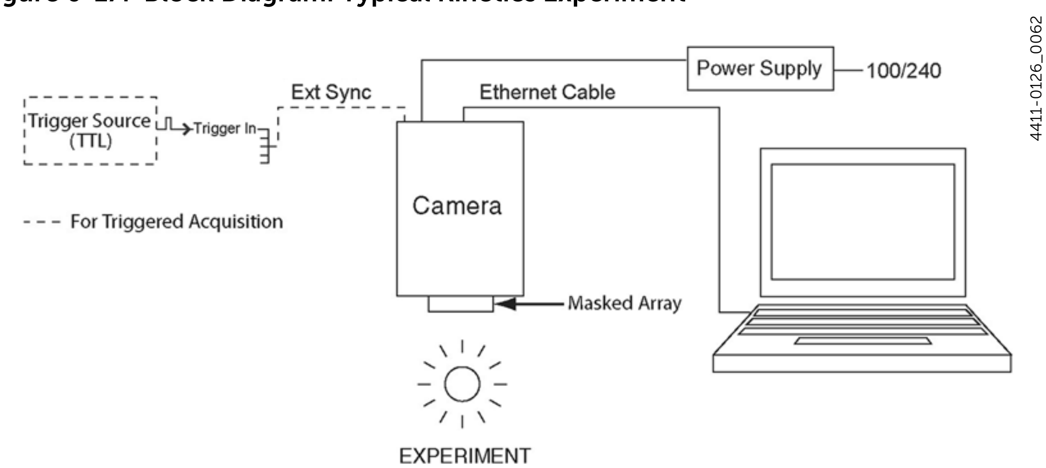
6.4.4 Cleaning the CCD

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 a dark environment to minimize the background.

6.4.5 Configuring a Kinetics Experiment

Figure 6-17 illustrates the block diagram for a typical Kinetics experiment.

Figure 6-17: Block Diagram: Typical Kinetics Experiment



This procedure assumes:

- You have already set up your system in accordance with the instructions in the previous chapters.
- You have read the previous sections of this chapter.
- You are familiar with the application software.
- The system is being operated in imaging mode.
- 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.
- You are only illuminating a portion of the CCD as illustrated in Figure 6-12.
- You are using either WinX/32 or LightField. WinX/32 parameter configuration is presented first; LightField, second.

6.4.5.1 Configuring Software Parameters in WinX/32

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.

Configure the software parameters as follows:

- **Controller/Camera** Tab (**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 (**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 will report that the temperature is LOCKED.

- **Experiment Setup** ▶ **Main** Tab (**Acquisition** ▶ **Experiment Setup...**):

  — **Exposure Time**: 100 µs
  — **Accumulations & Number of Images**: 1

- **Experiment Setup** ▶ **ROI** Tab (**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 (**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.

6.4.5.2 Configuring Software Parameters in LightField:

NOTE:

The following procedure is based on LightField. You will need to modify it if you are using a different application. Basic familiarity with the LightField 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.

Configure the software parameters as follows:

- **Sensor** expander

  These parameters should be set automatically to the proper values for your system.
  - **Readout Mode**: Available modes are read from the camera. Select Kinetics.
  - **Kinetics Window Height**: Enter the number of exposed rows.
- **Temperature Setpoint** (**Sensor** expander)

  The default temperature setting is read from the camera. When the array temperature reaches the set temperature, that status will be reported as Locked in the Sensor expander and in the Status bar.
- **Common Acquisition Settings** expander:
  - **Exposure Time**: 100 μs
  - **Number of Frames**: 1
  - **Exposures per Frame**: 1
- **Region of Interest** expander

  Use the functions on this expander to define the region of interest (ROI).
  - Clicking on **Full Sensor** selects the full window (without binning)
- **Shutter** expander:
  - **Shutter Mode**: Normal
- **Trigger** expander:
  - **Trigger Response**: No Response, Readout Per Trigger, or Shift Per Trigger

6.4.6 Summary

Kinetics mode 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 {Readout Per Trigger} mode allows the capture of a burst of frame with just one trigger.
- In Multiple Trigger {Shift Per 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 if you are using WinView/32 or WinSpec/32.
- Binning and ROI selections are supported as in the standard operation.

6.5 Spectra-Kinetics (Option)

Spectra-Kinetics, which is standard on the ProEM:512BK, is a software option available for purchase for use with ProEM:512B and ProEM:1024B cameras. When this option is available you will be able to select Spectra-Kinetics as the readout mode. Refer to Table 6-1 for a comparison of specifications.

Table 6-1: ProEM:512B/BK and ProEM:1024B Kinetics versus Spectra-Kinetics

Rows Illuminated	Total Number of Kinetic Frames			
	ProEM:512B/BK		ProEM:1024B	
	Kinetics	Spectra-Kinetics	Kinetics	Spectra-Kinetics
32	32	528	64	1037
64	16	528	32	1037
128	8	528	16	1037
256	4	528	8	1037

Unlike standard kinetics mode where binning is performed in the serial register, spectra-kinetics hardware bins the exposed rows into a single row as the rows are being shifted into the frame transfer area (or under an external mask). By using this technique, the spectra-kinetics option is able to capture longer-duration events and provide higher sensitivity than standard kinetics mode. Use of spectra-kinetics allows the ProEM camera to acquire the full masked height's worth of spectra regardless of the height of the illuminated rows – all while delivering the same temporal resolution as standard kinetics.

For the fastest possible acquisition, this mode requires that an external mask blocks light from all but a window of rows just below the frame transfer area. During acquisition, the window is exposed and then the rows are shifted into the frame transfer area where they are binned into a single row. The next exposure occurs, followed by shifting and binning. And so on.... By binning into a single row, up to 528 kinetics frames can be acquired for a ProEM:512B/BK and up to 1037 kinetics frames for a ProEM:1024B. See Figure 6-18 and Figure 6-19.

Figure 6-18: ProEM:512BK EMCCD

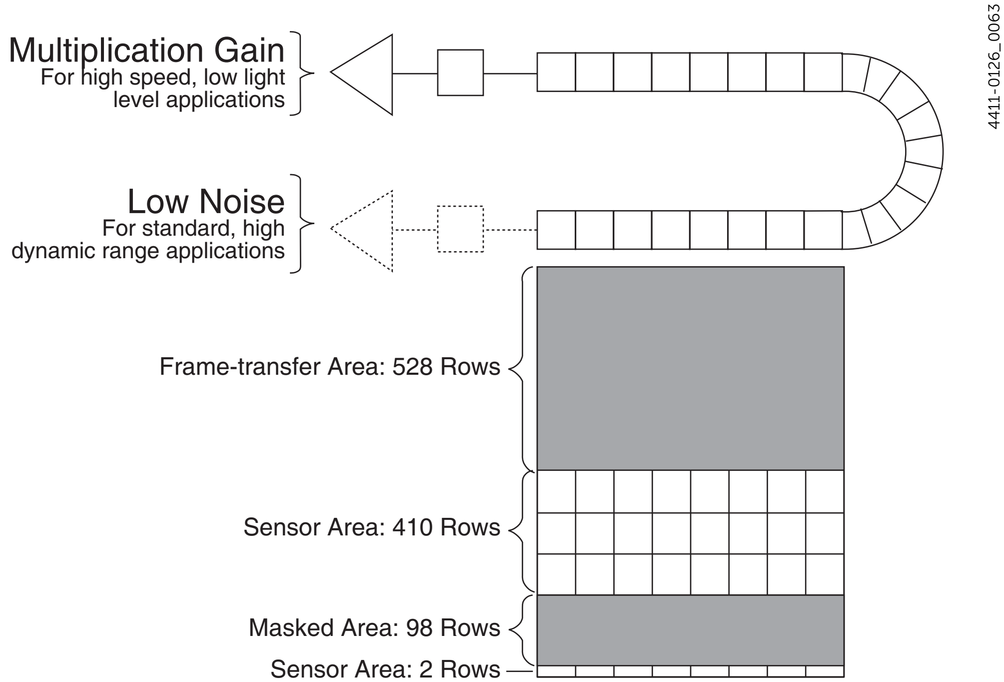
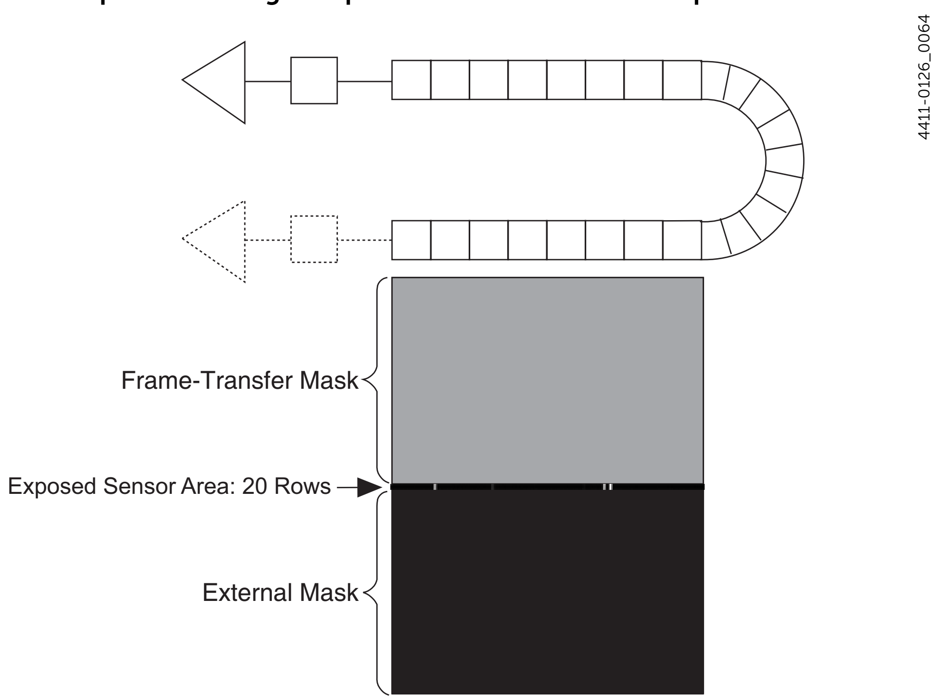


Figure 6-19: Example of Masking for Spectra-Kinetics: 20 Rows Exposed



6.5.1 Summary

Spectra-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:

- The rows closest to the serial register need to be illuminated. As can be seen in Figure 58, these rows are immediately below the frame transfer area.
- The rest of the active area must be optically masked.
- Single trigger {Readout Per Trigger} mode allows the capture of a burst of frame with just one trigger.
- In multiple trigger {Shift Per 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.
- Hardware binning is automatically applied.

6.6 Custom Modes

Custom Chip mode is available as an option for the WinX applications; {Custom Sensor} and Custom Timing are standard {sensor-dependent} in LightField. These modes are intended to allow data acquisition at the fastest possible rates for your camera. Custom Chip {Custom Sensor} allows you to reduce the apparent size of the CCD array and Custom Timing allows you to select a faster vertical shift time.

6.6.1 Custom Chip {Custom Sensor}

In addition to Binning and ROI which have been discussed previously in the manual, there is a third way to reduce Readout Time - Custom Chip {Custom Sensor}. 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, this mode does not incur overhead from discarding or skipping the rest of the rows. And, unlike both Binning and ROI, Custom Chip {Custom Sensor} also relies on some form of array masking to ensure that no light falls outside the currently set active area.

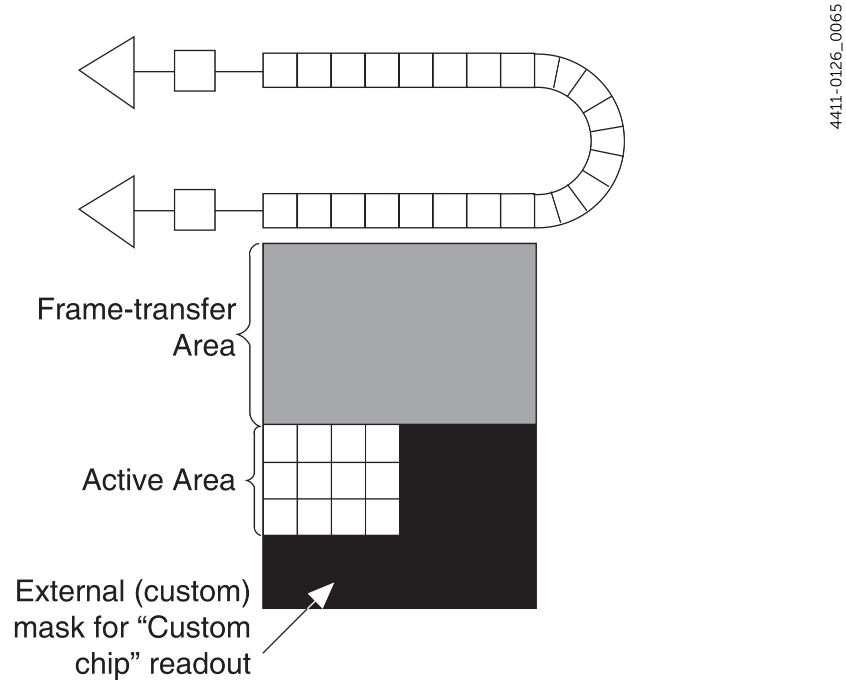
NOTE:

Custom Chip is a WinX/32 option.

Custom Sensor is standard with LightField: availability is sensor-dependent.

See Figure 6-20.

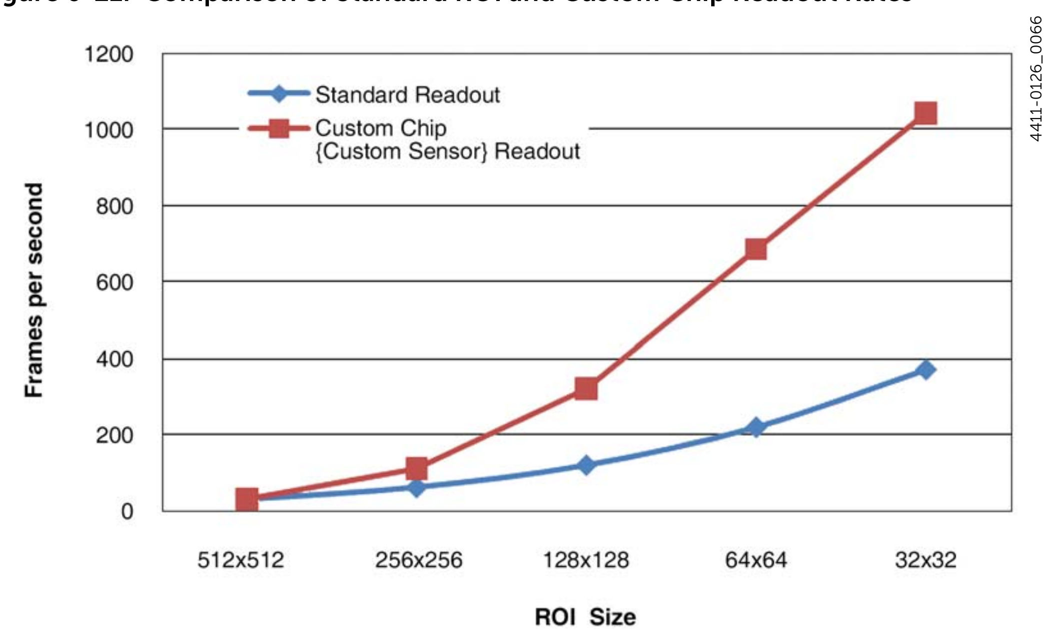
Figure 6-20: Functional Block Diagram: CCD Array



The following example compares the time savings achieved by using Custom Chip {Custom Sensor} vs. ROI to read out a 128 x 128 region of a 512 x 512 array.

Using the ROI method to read out the 128 x 128 pixels would take 8.2 ms, or a frame rate of 122 fps (1/0.0082). Using the Custom Chip {Custom Sensor} feature, the readout time for the same region would drop to 3.1 ms (equivalent to a frame rate of 323 fps). See Figure 6-21 for a graphic comparison of the ProEM:512B camera's expected frame rates using standard ROI readout and custom chip readout.

Figure 6-21: Comparison of Standard ROI and Custom Chip Readout Rates

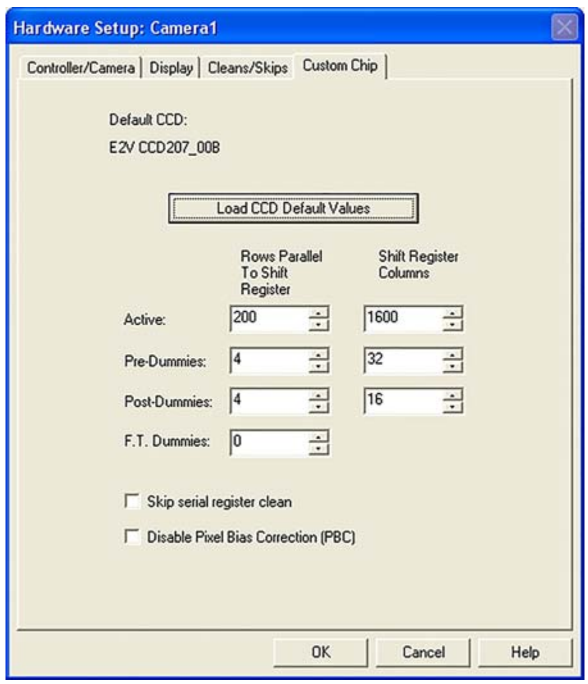


6.6.1.1 Software Settings

CAUTION!
Teledyne 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.

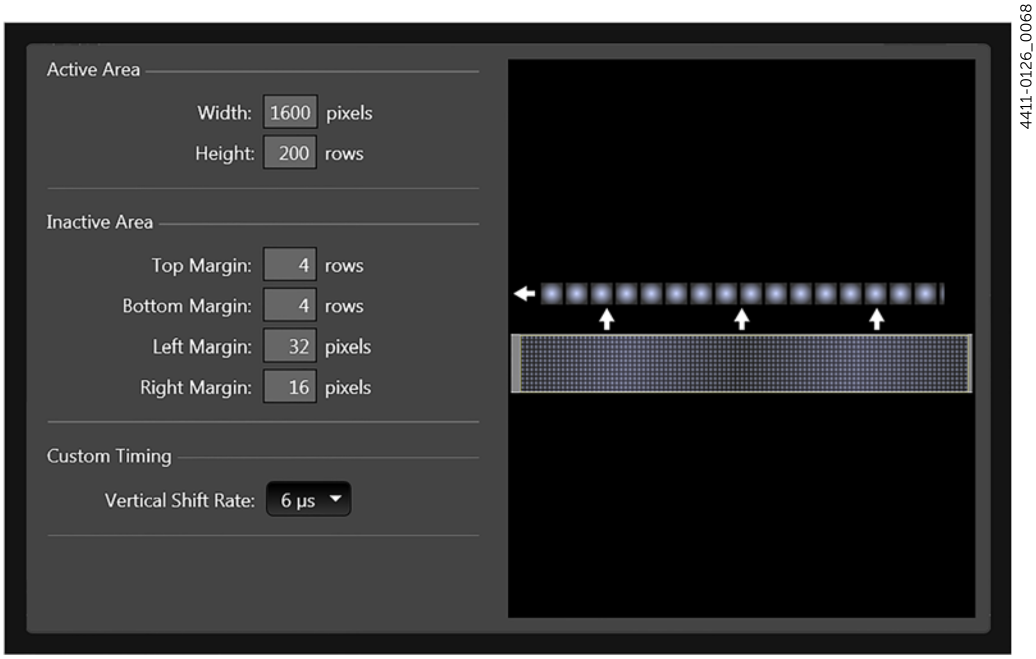
In WinX/32, if Custom Chip has been installed, selecting **Show Custom Chip** check box on the **Controller/Camera** tab adds the **Custom Chip** tab to the **Hardware Setup** dialog. The Custom Chip parameters are shown in Figure 6-22. The default values conform to the physical layout of the CCD array and are optimum for most measurements.

Figure 6-22: Typical WinX/32 Hardware Setup: Custom Chip Tab



In LightField, the **Custom Sensor** pane, illustrated in Figure 6-23, is accessed by opening the **Sensor** expander and clicking on the **Custom Sensor** button.

Figure 6-23: Typical LightField Custom Sensor Pane



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 clean out will be skipped and the chip readout will be faster. This feature is not available for PVCAM-supported cameras.

NOTE:

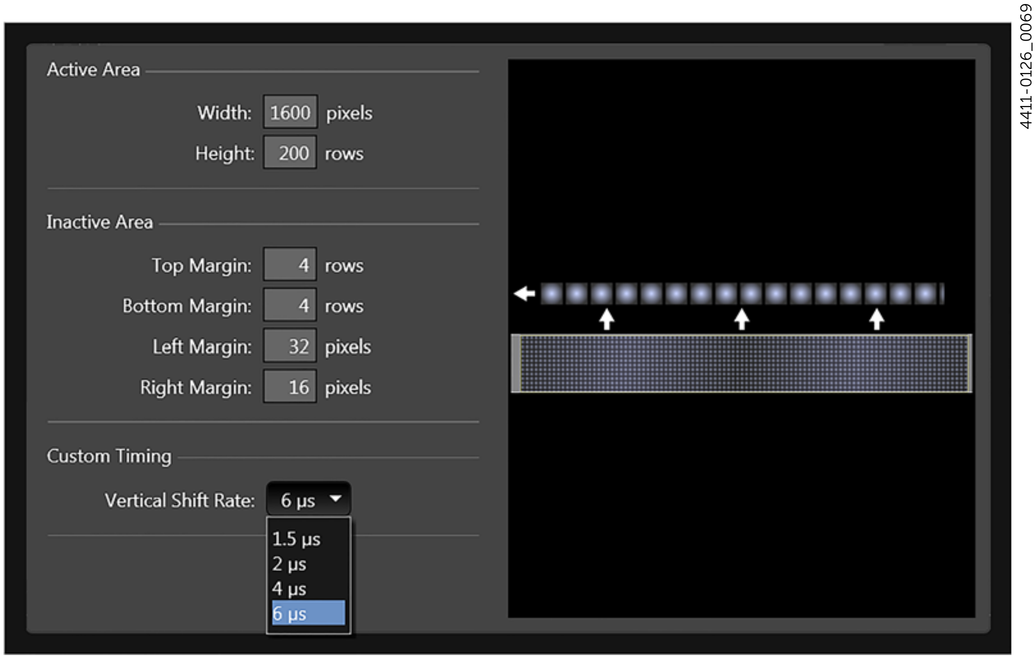
In LightField, the **Clean Serial Register** function only appears in the **Sensor Cleaning** pane when the **Inactive Area Top Margin** has been set to 0 rows. Deselect the check box to deactivate the serial register cleaning.

6.6.2 Custom Timing

NOTE:
This mode is standard with LightField for a ProEM full frame EMCCD camera such as the ProEM:1600[2].

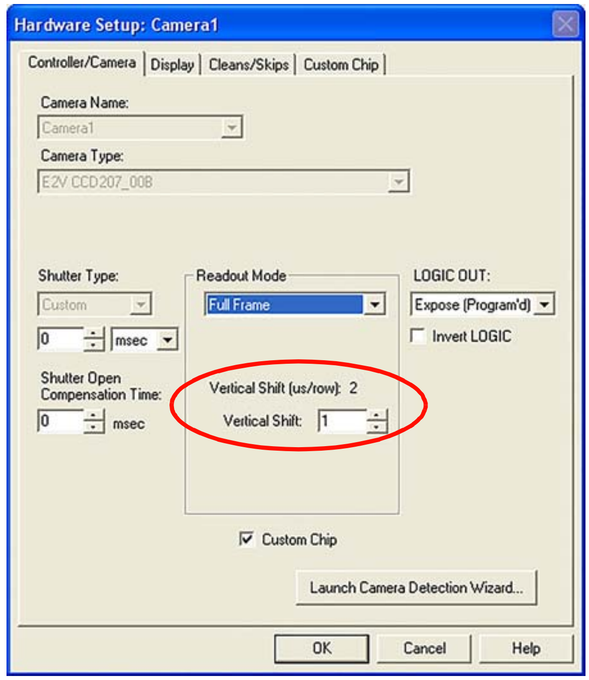
In LightField, Custom Timing is accessed via the **Custom Sensor** button on the **Sensor** expander. In the **Custom Timing** panel, you can select from among the listed vertical shift rate choices (see Figure 6-24). Vertical shift rate is the time required to shift one row into the serial register. The smaller the value, the faster charge will be shifted up one row at a time toward the serial register.

Figure 6-24: Typical LightField Custom Timing Pane



In WinX/32, the equivalent function is located on the **Camera/Controller** tab on the **Hardware Setup** dialog. See Figure 6-25.

Figure 6-25: Typical WinX/32 Hardware Setup Controller/Camera Tab: Vertical Shift



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Chapter 7: Tips

7.1 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.

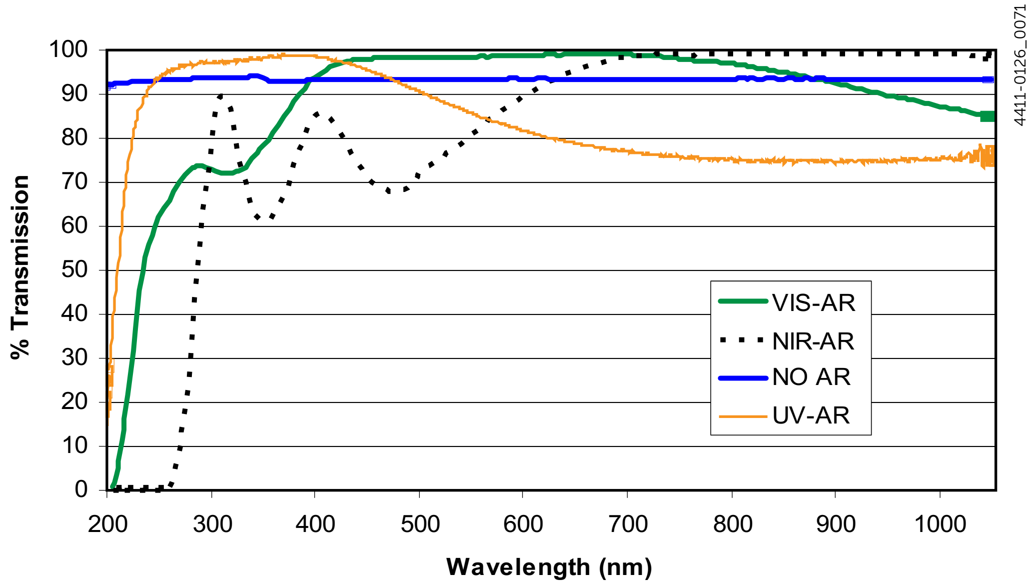
7.2 Maximize Throughput by Choosing the Right Vacuum Window Coating

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 Teledyne Princeton Instruments cameras, including the ProEM, are designed with a single window made of high-grade fused silica/quartz that acts as a vacuum view port. 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. Teledyne Princeton Instruments representatives can help you select the most appropriate AR coating for your application needs.

See Figure 7-1.

Figure 7-1: Vacuum Window Transmission Data



7.3 Reduce Spectral Readout Time by Using the Custom Chip/Timing {Custom Sensor} 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 {Custom Sensor} 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 array masking to ensure that no light falls outside the currently set active area.

To take full advantage of the outstanding speed offered by Teledyne Princeton Instruments ProEM:1600 cameras for spectral data acquisition, users need to utilize the Custom Chip {Custom Sensor} and Custom Timing modes via Teledyne Princeton Instruments WinX or LightField software. These custom modes yield much faster spectral rates than those achievable using a region of interest (ROI).

Teledyne Princeton Instruments PVCAM® /PICam and National Instruments LabVIEW™ users can utilize Custom Chip and Custom Timing modes, as explained in their respective manuals.

7.3.1 Approximation of Spectral Readout Time

Calculating the precise spectral rate is quite complicated. Assuming that Full Vertical Binning (FVB) is active, vertical shift time is 2 μs and the Analog to Digital Conversion settings are Multiplication Gain {Electron Multiplied} and Rate {Speed} = 4 MHz, then for a ProEM:1600[2], you can get the approximate rate by adding up the following approximate contributions to the readout time:

	0.4 ms for shifts
	0.4 ms for EM register clean
	0.4 ms for reads
	0.4 ms x 2 for pre- and post-dummy skips
	A little bit of overhead
Total:	2.07 ms

7.3.2 WinX/32 Step-by-Step Procedure

The following procedure uses a ProEM:1600$^{(2)}$ camera. This same procedure can be used to increase the spectral readout rate for a ProEM:1600$^{(4)}$.

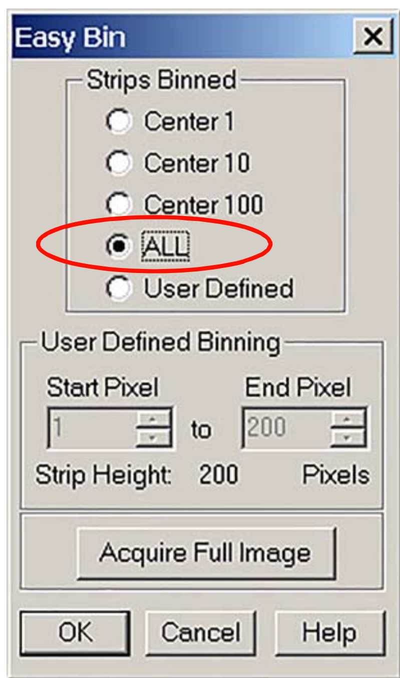
NOTE:

The Readout Times you get may differ from those reported in this procedure. These values are intended to show the effect of the changes on Readout Time reduction.

1. On the **Experiment Setup** ► **ADC** tab, select:
   - Rate: 4 MHz
   - Readout Port: Multiplication Gain
2. On the **Hardware Setup** ► **Controller/Camera** tab, select:
   - Vertical Shift = 2 μs
3. Select **Easy Bin** from the **Acquisition** menu.
   - Select **ALL**. This will result in **Full Vertical Binning**.

   See Figure 7-2.

Figure 7-2: Typical WinX/32 Easy Bin Dialog



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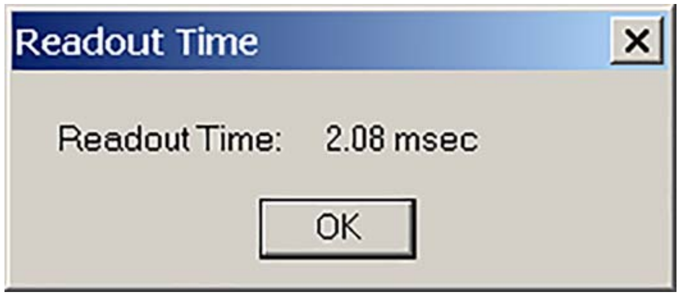
4. Acquire a spectrum.

5. Select **Readout Time** from the **Acquisition** menu.
   The readout time is reported on the **Readout Time** dialog as 2.08 ms. See Figure 7-3.

Figure 7-3: Typical WinX/32 Readout Time Dialog: 2.08 msec



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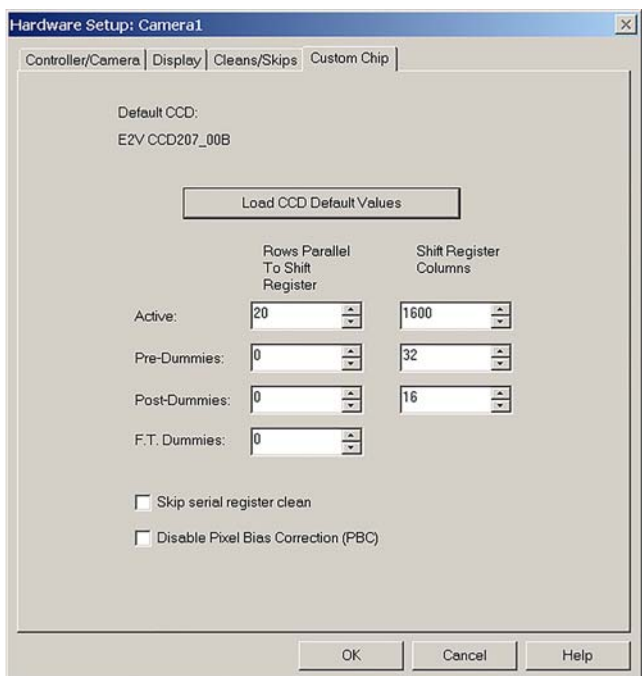
6. Now go to the **Hardware Setup** ► **Controller/Camera** tab.
   - Check the **Custom Chip** box.
   - Select the **Custom Chip** tab.
   - Make the following changes:
     — Change **Active** to 20
     — Change **Pre-Dummies** to 0
     — Change **Post-Dummies** to 0

   See Figure 7-4.

Figure 7-4: Typical WinX/32 Hardware Setup Dialog: Custom Chip Tab



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7. Now go to the **Hardware Setup** ► **Controller/Camera** tab.
8. Select **Easy Bin** from the Acquisition menu.
   - Select **ALL**. This will bin the 20 rows together.
9. Acquire a spectrum.

10. Select **Readout Time** from the **Acquisition** menu.
    The readout time is reported on the **Readout Time** dialog as 0.88 ms. See Figure 7-5.

Figure 7-5: Typical WinX/32 Readout Time Dialog: 0.88 msec

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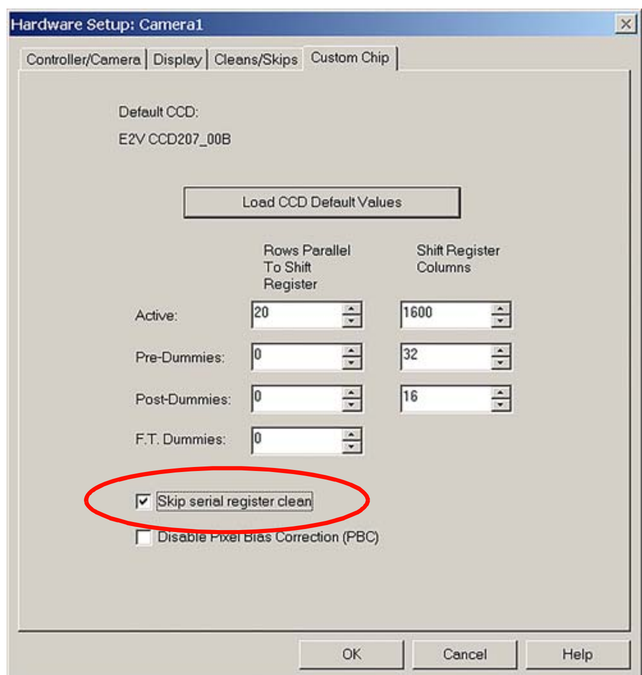
11. To further reduce the readout time, open the **Hardware Setup** ► **Camera/ Controller** tab, set shutter compensation time(s) to 0 and on the **Hardware Setup** ► **Custom Camera** tab, select Skip Serial Register Clean.
    See Figure 7-6.

Figure 7-6: Typical WinX/32 Hardware Setup Dialog: Custom Chip Tab



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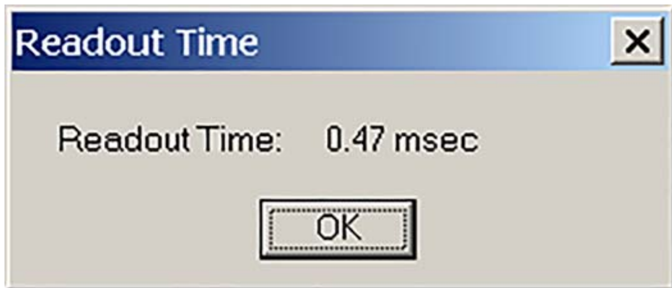
12. Acquire a spectrum.
13. Select **Readout Time** from the **Acquisition** menu. The readout time is reported on the **Readout Time** dialog as 0.47 ms.

> **NOTE:**
> Entering 0 for the Pre- and Post-Dummies and skipping the serial register clean means that there will be some spectral artifacts in the data.

Figure 7-7: Typical WinX/32 Readout Time Dialog: 0.47 msec



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7.3.3 LightField Step-by-Step Procedure

The following procedure uses a ProEM:1600[2] camera and is meant to give you a sense of how you can reduce readout time and increase the number of frames per second. Keep in mind when using the approaches in this procedure that there is trade off between increased spectral readout rate and data quality (increasing the frames per second tends to decrease data quality).

> **NOTES:**
> 1. This same procedure can be used to increase the spectral readout rate for a ProEM:1600[4].
> 2. The Readout Times and Frames Per Second (FPS) that you get may differ from those reported in this procedure. These values are intended to show the effect of the changes on Readout Time reduction and FPS.

7.3.3.1 Default Settings

Some of the default settings for a ProEM:1600[2] are listed below. Because software changes often occur, the default settings for your system may differ but you could change the settings to match those presented here:

- Exposure Time: 33 ms
- Quality: Low Noise
- Speed: 100 kHz
- Region of Interest: Full Sensor (1600x200)
- Sensor Cleaning
  - Number of Clean Cycles=1
  - Clean Cycles Height=200
  - Final Section Height=4
  - Final Section Count=1

7.3.3.2 Procedure:

1. Check the **Readout Time** (on the **Readout** expander) and the **Frames Per Second** (reported in the upper right corner of the **Experiment** workspace).

   Based on the camera default settings, the **Readout Time** is 2.640 s and **FPS** is ~0.373.
2. Change the **Exposure Time** to **0 ms**. The **Readout Time** and **FPS** remain approximately the same.

   The Readout Time is 2.640 s and FPS is ~0.378.
3. Change the **Analog to Digital Conversion Quality** to **Electron Multiplied** and the **Speed** to **4 MHz**.

   The Readout Time is 85.677 ms and FPS is ~10.7.
4. Change the **Region of Interest** setting to **Rows Binned (1600 x 1)** Ctr 200.

   The Readout Time is 2.918 ms and FPS is ~91.6.
5. Change the **Region of Interest** setting to **Rows Binned (1600 x 1)** Ctr 10 and **Cleaning and Skipping** to **Final Section Height** of 2 and **Final Count** of 5.

   The Readout Time is 10.403 ms and FPS is ~54.3.
6. Now change **Cleaning and Skipping** to **Final Section Height** of 200 and **Final Count** of 1.

   The Readout Time is 2.918 ms and FPS is ~91.6.
7. Set the **Shutter Closing Delay** time to 0.

   The Readout Time is 2.918 ms and FPS is ~343.
8. Set **Vertical Shift Time** to 2 µs.

   The Readout Time is 2.086 ms and FPS is ~479.
9. In the **Custom Sensor** fly out pane, set **Active Area Height** to 208 rows and change the **Top Margin** and **Bottom Margin** to 0.

   The Readout Time is 2.086 ms and FPS is ~479.
10. Change the **Region of Interest** setting to **Rows Binned (1600 x 1)** Ctr 208.

    The Readout Time is 1.258 ms and FPS is ~795.
11. Change the **Custom Sensor Active Area Height** to 20 rows and **Vertical Shift Rate** to 2 µs, Change the **Region of Interest** setting to **Rows Binned (1600 x 1)** Ctr 20.

    The Readout Time is 881.750 µs and FPS is ~1140.
12. Deselect **Clean Serial Register**.

    The Readout Time is 465.975 µs and FPS is ~2150.
13. Change **Electron Multiplied Speed** to 6.67 MHz and change **Vertical Shift Rate** to 1.5 µs.

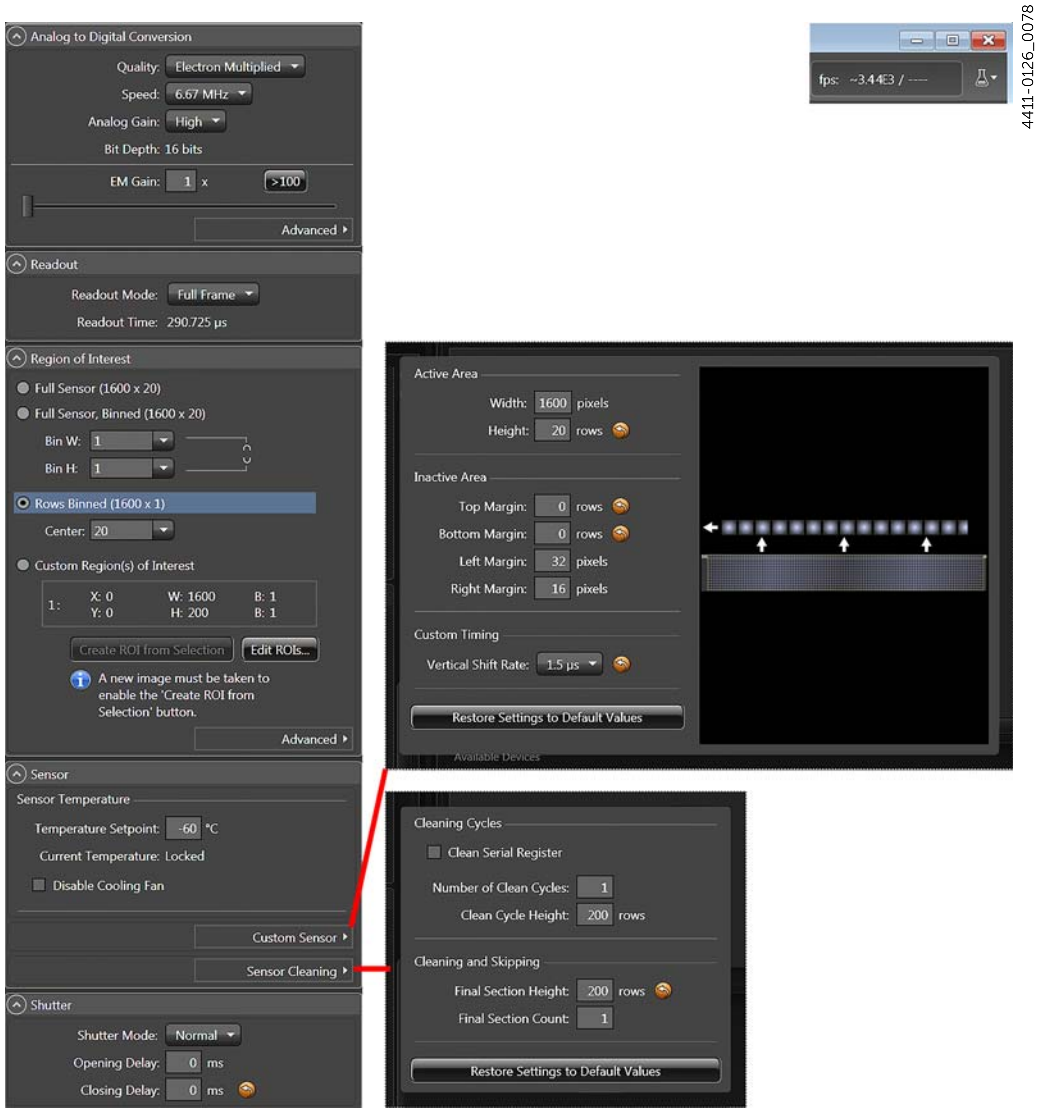
    The Readout Time is 290.725 µs and FPS is ~3440.

NOTE:

Pixel Bias Correction adds 10 µs of overhead.

Figure 7-8 shows the relevant settings and results (i.e., Readout Time and FPS,) at the conclusion of the procedure. Note that Exposure Time (not shown) was 0 ms.

Figure 7-8: LightField Settings



Chapter 8: Troubleshooting

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

Refer to Table 8-1 for issues which have recommended troubleshooting procedures in this chapter.

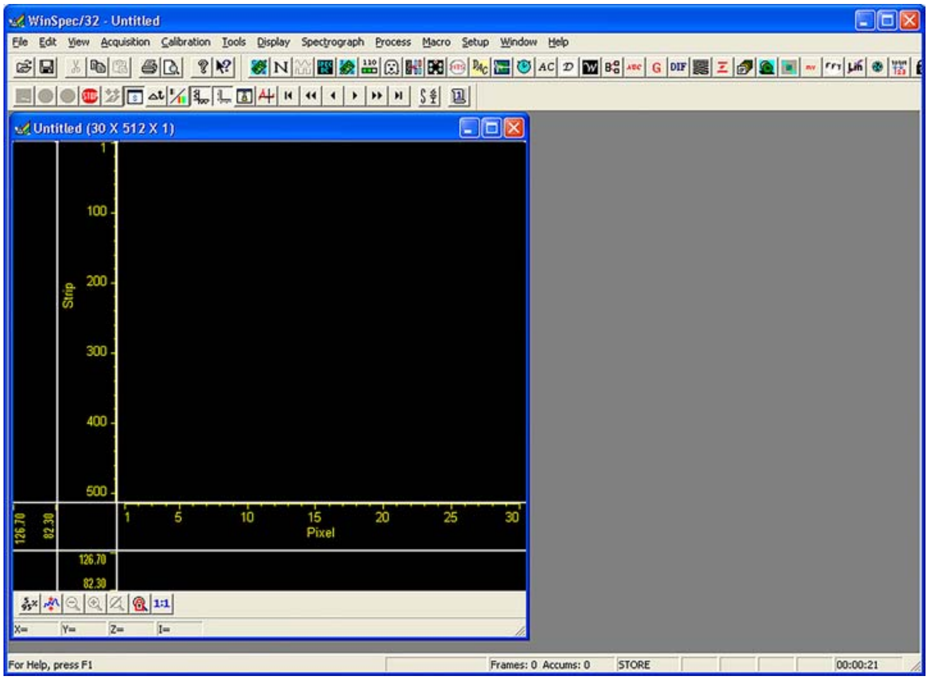
Table 8-1: List of Recommended Troubleshooting Procedures

Issue	Information begins on...
Acquisition Started but Data Display is Empty	page 124
Acquisition Started but Viewer Contents Do Not Update	page 125
Baseline Signal Suddenly Changes	page 125
Camera Not Found	page 126
Camera Stops Working	page 126
Camera1 (or similar name) in Camera Name field	page 126
Temperature Lock Cannot be Achieved or Maintained.	page 128
Gradual Deterioration of Cooling Capability	page 128
Data Overrun Due to Hardware Conflict message	page 129
Device Is Not Found	page 130
Device is Occupied	page 131
Ethernet Network is Not Accessible	page 131
Program Error Message	page 132
Serial Violations Have Occurred. Check Interface Cable.	page 133
Smeared Images	page 133
TEC Fault LED Comes On	page 133
WinX/32 or LightField Crashes When Adding GigE Camera to System	page 134

8.1 Acquisition Started but Data Display is Empty

If you have started a data acquisition but no data are 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 8-1 shows an invalid ROI: the 30 (in 30 x 512 x1) is not evenly divisible by 4.

Figure 8-1: Acquisition Display and Invalid ROI



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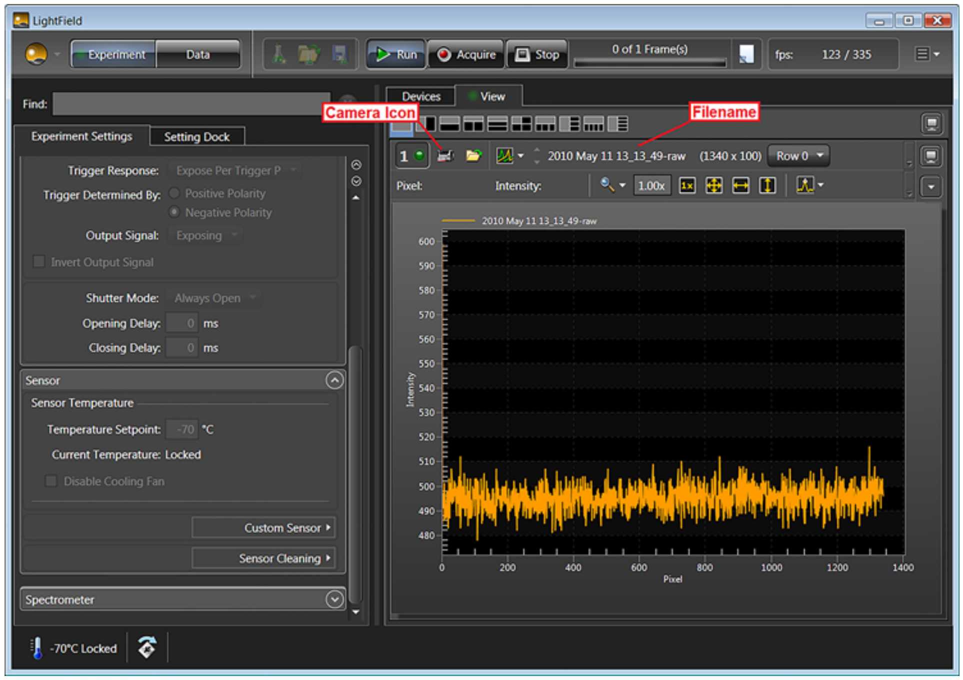
If the number of horizontal pixels (or super pixels if there is binning in the horizontal) is not divisible by 4, go to Experiment Setup. On the ROI Setup tab, change the Region of Interest (ROI) and Binning parameters for your experiment so that the resulting number of horizontal pixels or super pixels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

8.2 Acquisition Started but Viewer Contents Do Not Update

In LightField, live data is normally displayed in the Experiment workspace viewer as it is being acquired (Preview or Acquire mode). If the viewer is not being updated and acquisition is occurring, check to see if there is a filename in the top row of the viewer: in Figure 8-2, the filename `2010 May 11 13_13_49.raw` is displayed. If there is a filename, click on the camera icon. The file data will be cleared from the viewer and the live data will then be displayed.

Figure 8-2: Acquisition Display



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8.3 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 Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 160 for complete information.

8.4 Camera Not Found

This message will be displayed if no camera is detected when you launch the WinX application. See Figure 8-3.

Figure 8-3: Typical WinX/32 Camera Not Found Dialog

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/32 application opens, launch the Camera Detection Wizard (button located on the Hardware Setup dialog).
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.
   - 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 Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 160 for complete information.

8.5 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 Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 160 for complete information.

8.6 Camera1 (or similar name) in Camera Name field

Figure 8-4: 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. 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** ► **Princeton Instruments** menu or from the directory where you installed WinView/32, WinSpec/32, or WinXTest/32.
3. Edit the name.
4. Click on the **Done** button.
5. The next time you start the WinX/32 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).

8.7 Cooling Troubleshooting

8.7.1 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.
- $\text{CoolCUBE}_{\text{II}}$: The $\text{CoolCUBE}_{\text{II}}$ 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.

8.7.2 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.

8.8 Data Overrun Due to Hardware Conflict message

Figure 8-5: Data Overrun Due to Hardware Conflict dialog

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If this dialog 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 2048 x 2048 array), requires a larger DMA buffer larger setting than that for a smaller array (for example, a 512 x 512 array).

To change the DMA buffer setting:

1. Note the array size (on the **Setup** ► **Hardware** ► **Controller/CCD** tab or the **Acquisition** ► **Experiment Setup** ► **Main** tab Full Chip dimensions).
2. Open **Setup** ► **Environment** ► **Environment** dialog.
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/32 application (WinView/32 or WinSpec/32).
4. Reboot your computer.
5. Restart the WinX/32 application and begin acquiring data or focusing. If you see the message again, increase the DMA buffer size.

8.9 Device Is Not Found

When LightField is started, it looks for devices (cameras, spectrographs, and filters) that are powered on and connected via a communications interface to the host computer. If it cannot find a device that was used in the last experiment, it will continue to look for it. See Figure 8-6.

Figure 8-6: Devices Missing dialog

- Make sure the device is connected and powered on. If LightField cannot find a spectrograph that is connected and powered on, turn the spectrograph off and back on. LightField should now find it.
- Make sure the device is connected and powered on. If WinX/32 or LightField is not able to detect a camera that is powered on and connected via the GigE interface, UDP ports 20200-20202 may need to be opened. These ports must be open before WinX/32 or LightField can detect a Teledyne Princeton Instruments GigE camera, but they may have been closed as part of your computer security (such as an anti-virus program or a firewall). Contact your Information Technology specialist for assistance.
- Cancel the load. Canceling a load means that the last used experiment will not be loaded automatically when LightField opens. However, you can load the experiment after all the devices are available, you can start a new experiment design, or you can load a different experiment that matches the devices you are using.

8.10 Device is Occupied

Multiple instances of LightField can be running at the same time. However, a device currently being used by one instance of LightField will be shown in the Available Devices area as **Occupied** for all other instances of LightField. See Figure 8-7.

Figure 8-7: Typical Occupied Device Indicator

4411-0126_0085

To make a device available to the current instance of LightField, either remove it from the Experiment Devices area in the other instance or close the instance that is using the device.

8.11 Ethernet Network is Not Accessible

When the Teledyne 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:

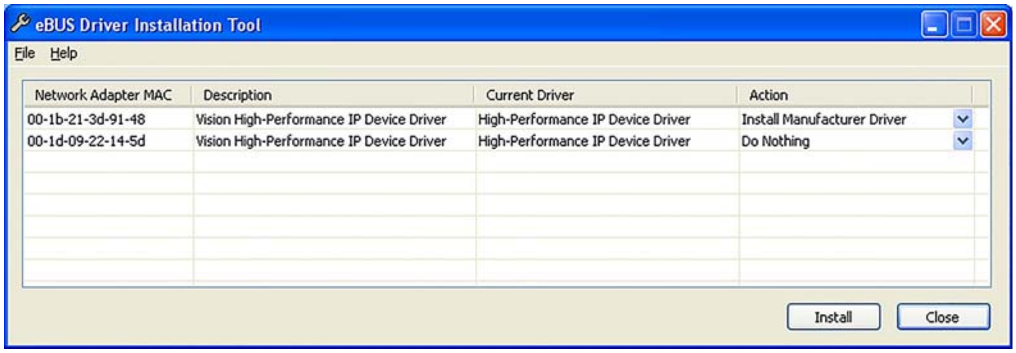
1. Locate the `EbDriverTool.exe` file.
   - Download the `EbDriverTool.exe` file to your computer from:

     ftp://ftp.princetoninstruments.com/public/software/official/winx32/v2525/patches
   - Or open the default Pleora directory. Typically its path is:

     `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 pull-down menu. See Figure 8-8.

Figure 8-8: Typical eBUS Driver Installation Tool Dialog



4411-0126_0086

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.

8.12 Program Error Message

The dialog illustrated in Figure 8-9 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 2048 x 2048 array,) requires a larger setting than that for a smaller array (for example, a 512 x 512 array.)

Figure 8-9: Typical WinX/32 Program Error Dialog

4411-0126_0087

To correct the problem:

1. Click on **OK**.
2. Reboot WinView/32.
3. Note the array size (on the **Setup** ► **Hardware** ► **Controller/CCD** tab or the **Acquisition** ► **Experiment Setup** ► **Main** tab **Full Chip** dimensions.) If your camera contains a large array (such as a 2048 x 2048 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.
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/32.
6. Reboot your computer.
7. Restart WinView/32 and begin acquiring data or focusing. If you see the message again, increase the DMA buffer size.

8.13 Serial Violations Have Occurred. Check Interface Cable.

The error message shown in Figure 8-10 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.

Figure 8-10: Typical WinX/32 Serial Violations Have Occurred Dialog

4411-0126_0088

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.

8.14 Smeared Images

ProEM frame-transfer CCDs allow simultaneous exposure-readout operations (refer to Section 5.4.6, Exposure – Readout Modes, on page 82 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:

- Use a longer exposure time, or
- 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.

8.15 TEC Fault LED Comes On

There are two possible reasons for the **TEC Fault** to come on:

- The **TEC Fault** LED might come on if the power supply on/off state is switched too quickly. When turning off and on the power supply, wait at least 10 seconds while the power supply is in its off state before switching it back on.
- The **TEC Fault** LED will come on if there is problem with the cooling system. Contact Teledyne Princeton Instruments Customer Service. Refer to Contact Information on page 160 for complete information.

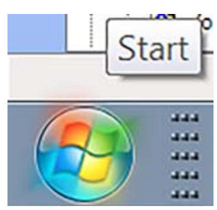
8.16 WinX/32 or LightField Crashes When Adding GigE Camera to System

If you have a dual port Intel Pro/1000 Ethernet card and WinX/32 or LightField crashes when trying to add a GigE camera to the system, you will need to modify the default IP address for one of the ports.

To Modify the Default IP Address for a Port:

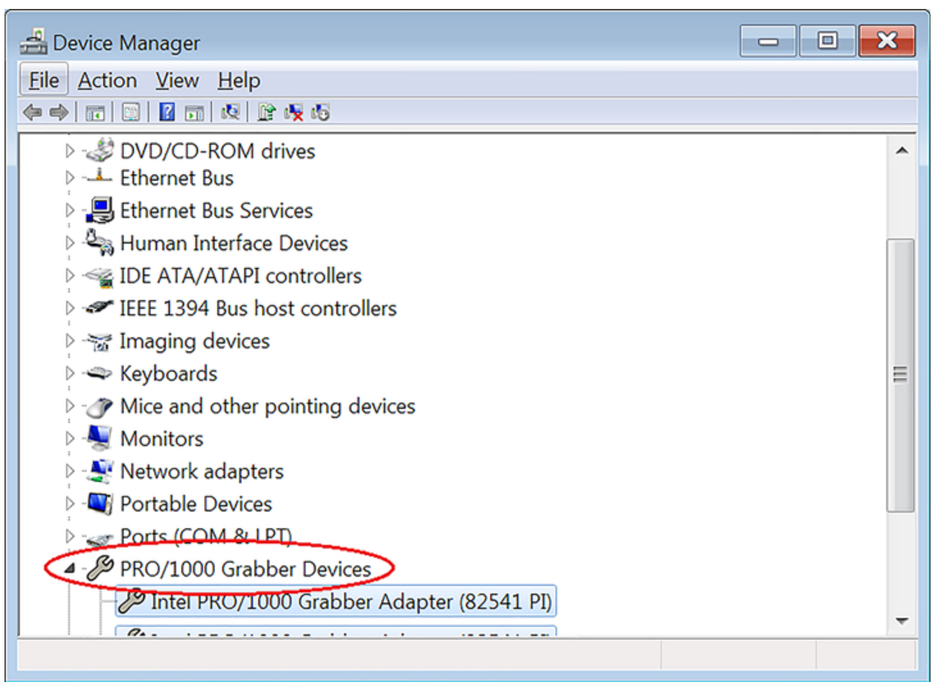
1. Click on the Windows **Start** button and click on **Control Panel**. See Figure 8-11.

Figure 8-11: Typical Windows Start button



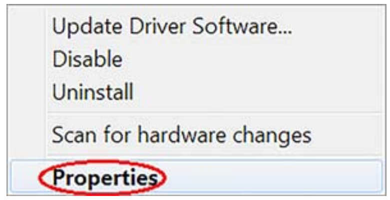
2. On the **Control Panel**, click on **Device Manager**.
3. After the **Device Manager** opens, scroll down until **PRO/1000 Grabber Devices** (or similar label) is displayed. See Figure 8-12.

Figure 8-12: Typical Device Manager Dialog



4. Click on that label to expand it and then right-click on one of the ports. On the popup menu, click on **Properties**. See Figure 8-13.

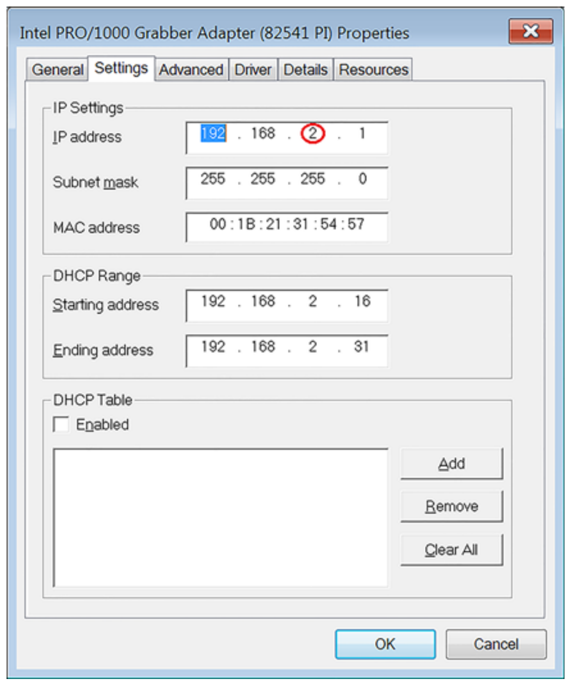
Figure 8-13: Typical Device Pop-Up Menu



4411-0126_0091

5. On the **Settings** tab, change the third number from the left in the **IP Address**. For example, replace the **2** in the IP Address **192.168.2.1** with **4** so the IP Address becomes **192.168.4.1**. See Figure 8-14.

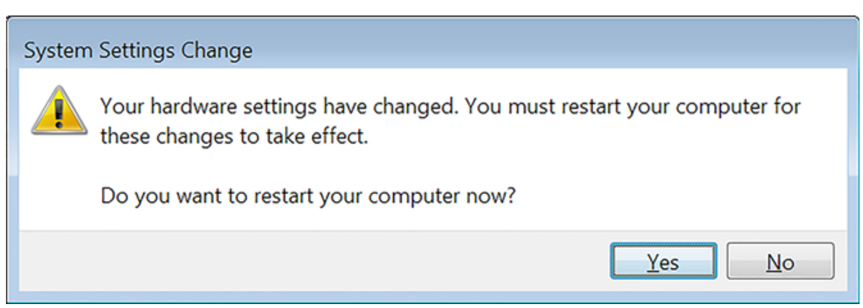
Figure 8-14: Typical Adapter Properties: Settings tab



4411-0126_0092

6. Click on **OK**.
7. When the **System Settings Change** dialog appears, click **Yes** to restart your computer now or click **No** to restart it later. See Figure 8-15.

Figure 8-15: Typical System Settings Change Dialog



4411-0126_0093

The change will not take place until you restart the computer.

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Appendix A: Technical 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, on page 141, or on the appropriate data sheet. Data sheets can be downloaded from the Teledyne Princeton Instruments website (www.princetoninstruments.com).

A.1 Window

UV grade fused-silica (0.125"/ 3.18 mm thick). Teledyne 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, proprietary Unichrome™ coating of the CCD is available. For broadband applications, a choice of $MgFl_2$ or broadband AR coating is available upon request.

A.2 CCD Arrays

Table A-1: CCD Specifications by ProEM Model (Sheet 1 of 2)

Parameter	ProEM:512B	ProEM:512BK	ProEM:1024B	ProEM:1600[2]	ProEM:1600[4]
CCD	e2v CCD97B	PI Proprietary	e2v CCD201B	PI Proprietary	PI Proprietary
Image Type	Monochrome	Monochrome	Monochrome	Monochrome	Monochrome
Resolution	512 x 512	512 x 512	1024 x 1024	1600 X 200	1600 X 400
Pixel Size	16 µm x 16 µm	16 µm x 16 µm	13 µm x 13 µm	16 µm x 16 µm	16 µm x 16 µm
Active Area	8.2 mm x 8.2 mm	8.2 mm x 8.2 mm with on-chip mask	13.3 mm x 13.3 mm	25.6 mm x 3.2 mm	25.6 mm x 6.4 mm
Peak Q.E.	95%	92%	95%	92%	92%
Frame Rate	> 33 fps (full frame)	> 33 fps (full frame)	> 8.5 fps (full frame)		
Spectral Rate (at 6.67 MHz)				> 1500 fps (full vertical binning)	> 1000 fps (full vertical binning)
Readout Amplifiers (Ports)	2	2	2	2	2

Table A-1: CCD Specifications by ProEM Model (Sheet 2 of 2)

Parameter	ProEM:512B	ProEM:512BK	ProEM:1024B	ProEM:1600[2]	ProEM:1600[4]
EM Digitization (Readout) Rate	10 MHz, 5 MHz	10 MHz, 5 MHz	10 MHz, 5 MHz	6.67 MHz, 4 MHz, 1 MHz	6.67 MHz, 4 MHz, 1 MHz
Low Noise Digitization (Readout) Rate	5 MHz, 1 MHz, 100 kHz	5 MHz, 1 MHz, 100 kHz	5 MHz, 1 MHz, 100 kHz	5 MHz, 1 MHz, 100 kHz	5 MHz, 1 MHz, 100 kHz

NOTE:

The arrays listed and the specifications provided are those that were available at the time that the manual was written. For current arrays and specifications, refer to ProEM data sheets which can be downloaded from the Teledyne Princeton Instruments website (www.princetoninstruments.com).

A.3 Mounts

- C-mount: Standard threaded video mount.
- Spectroscopy-mount: 3.60" and 3.88" bolt circles
- C- to Spectroscopy-mount adapter: Optional
- Adjustable C- to Spectroscopy-mount adapter: Optional

A.4 Focal Distance (Optical)

- C-mount, Front Surface to Focal Plane: 0.690" (17.53 mm)
- Spectroscopy-mount, Front Surface to Focal Plane: 0.590" (14.99 mm)

A.5 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:

Table A-2: Default Operating Temperature

CCD Size	Default
512 x 512	-70°C
1024 x 1024	-55°C
1600 x 200	-55°C
1600 x 400	-55°C

- Temperature Stability: ±0.05°C; closed-loop stabilized-temperature control
- Gain: Software-selectable [1 (low), 2 (medium), 3 (high)]
- Dimensions: Refer to Appendix B, Outline Drawings, on page 141
- Connectors:
  - Gig-E: Gigabit Ethernet connector.
  - Shutter: LEMO® connector provides the shutter drive pulses for driving a Teledyne 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.
- 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, Advanced Topics. MCX-to-BNC adapter cable is supplied with system.
- Logic Out: 0 to +3.3 V programmable logic level output (TTL-compatible). The output of this connector can be programmed and can also be inverted via the application software. For detailed information about each output signal, refer to Section 6.3, LOGIC OUT Control, on page 97.
- Power Connector:

  Figure A-1 shows the Power Connector on the rear panel of the ProEM camera, including the pinout diagram. Refer to Table A-3, Power Connector Pinout, for pin assignment information.

Figure A-1: Rear of ProEM Camera

Table A-3: Power Connector Pinout (Sheet 1 of 2)

Pin #	Signal
A1	TEC Return

Table A-3: Power Connector Pinout (Sheet 2 of 2)

Pin #	Signal
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.

A.6 Options

A partial listing of options includes the WinView/32 and WinSpec/32 application software and manual, Scientific Imaging ToolKit™ (SITK™) for LabVIEW, C-mount to spectroscopy mount adapter, adjustable C- to spectroscopy-mount adapter, and the CoolCUBE$_{II}$ coolant circulator. Contact Teledyne Princeton Instruments Customer Service for more information regarding options available for your system. Refer to Contact Information on page 160 for complete information.

Appendix B: Outline Drawings

NOTE:

All dimensions are in inches [mm].

Figure B-1: Outline Drawing: ProEM:512B-1024B Camera, Standard Mount

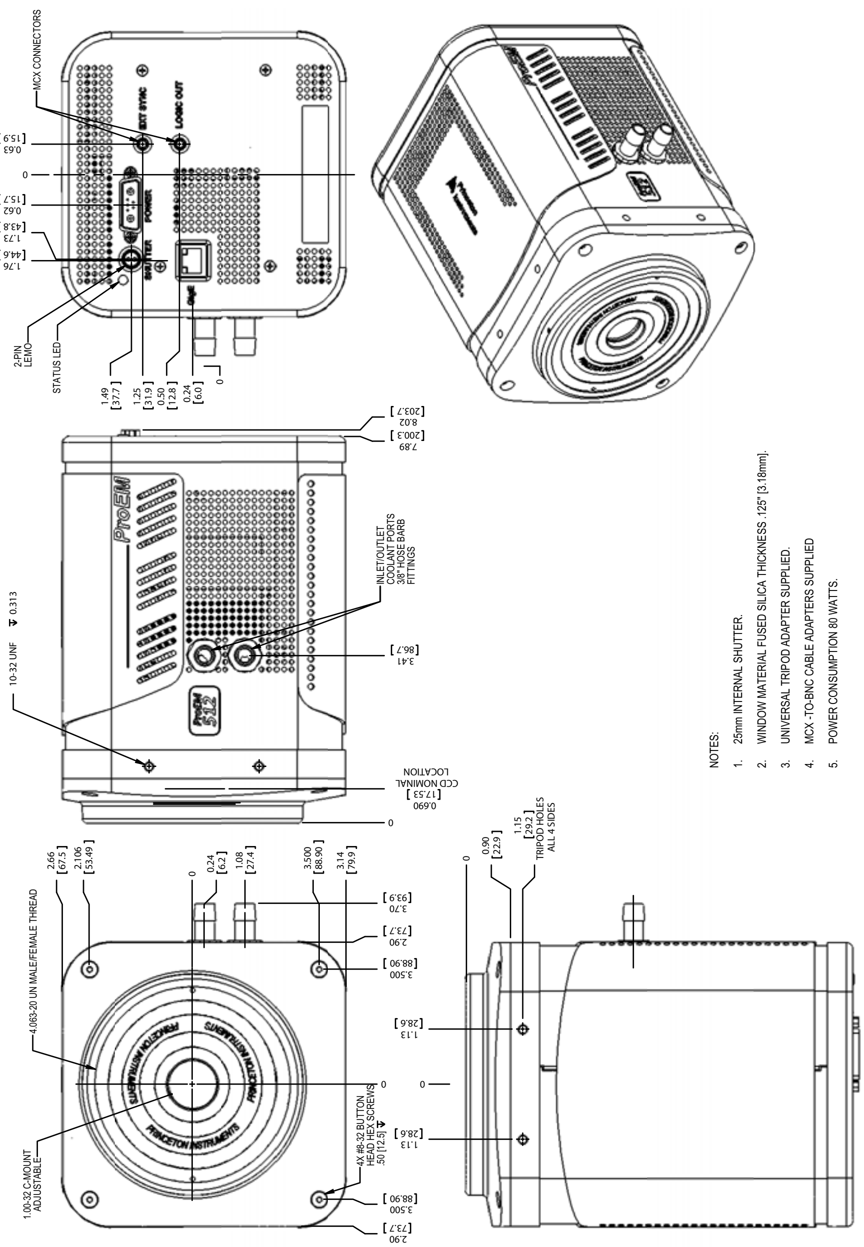


Figure B-2: Outline Drawing: ProEM:512BK - Kinetics

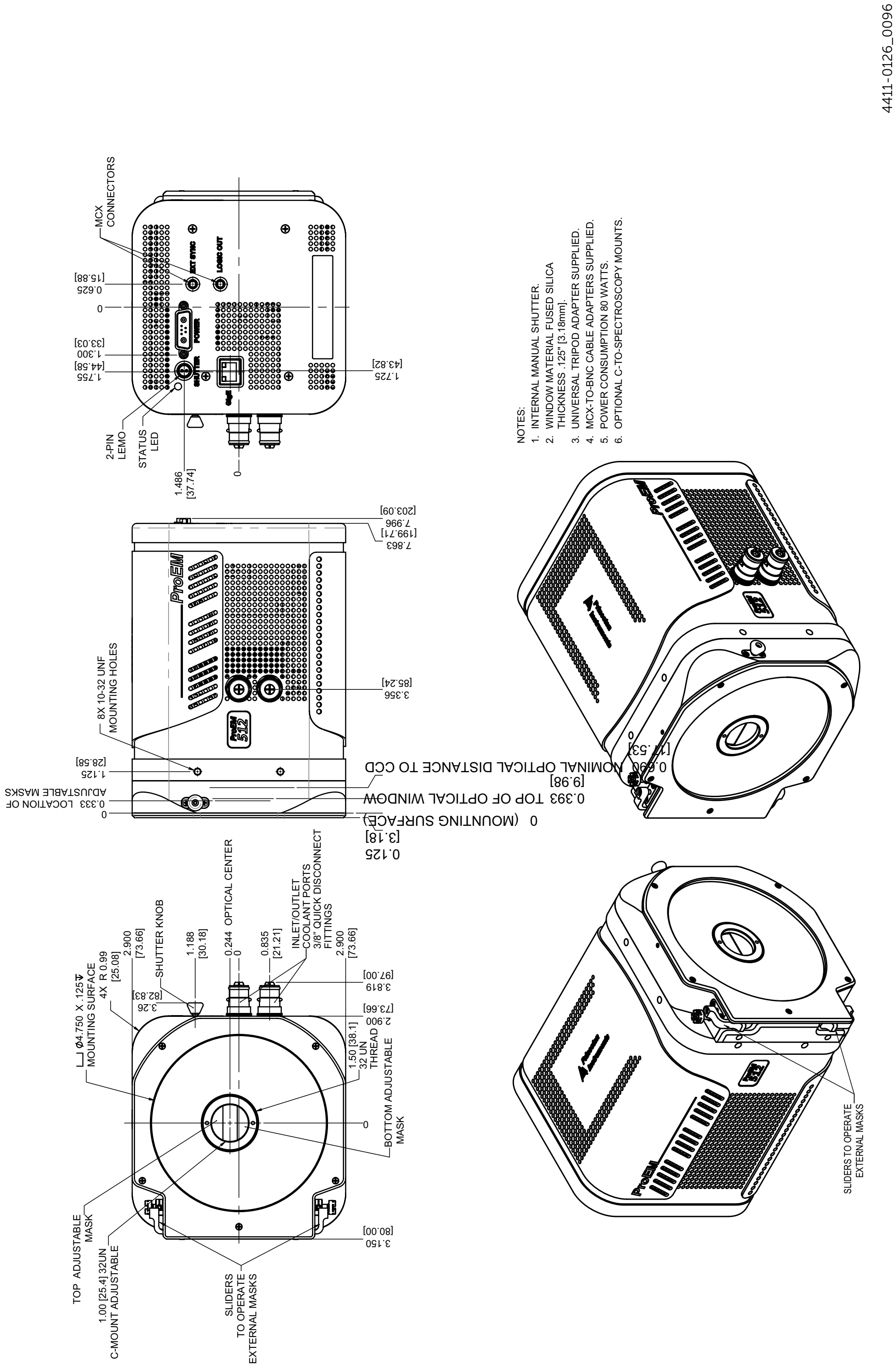


Figure B-3: Outline Drawing: ProEM:1600 Series, Full Frame Spectroscopy

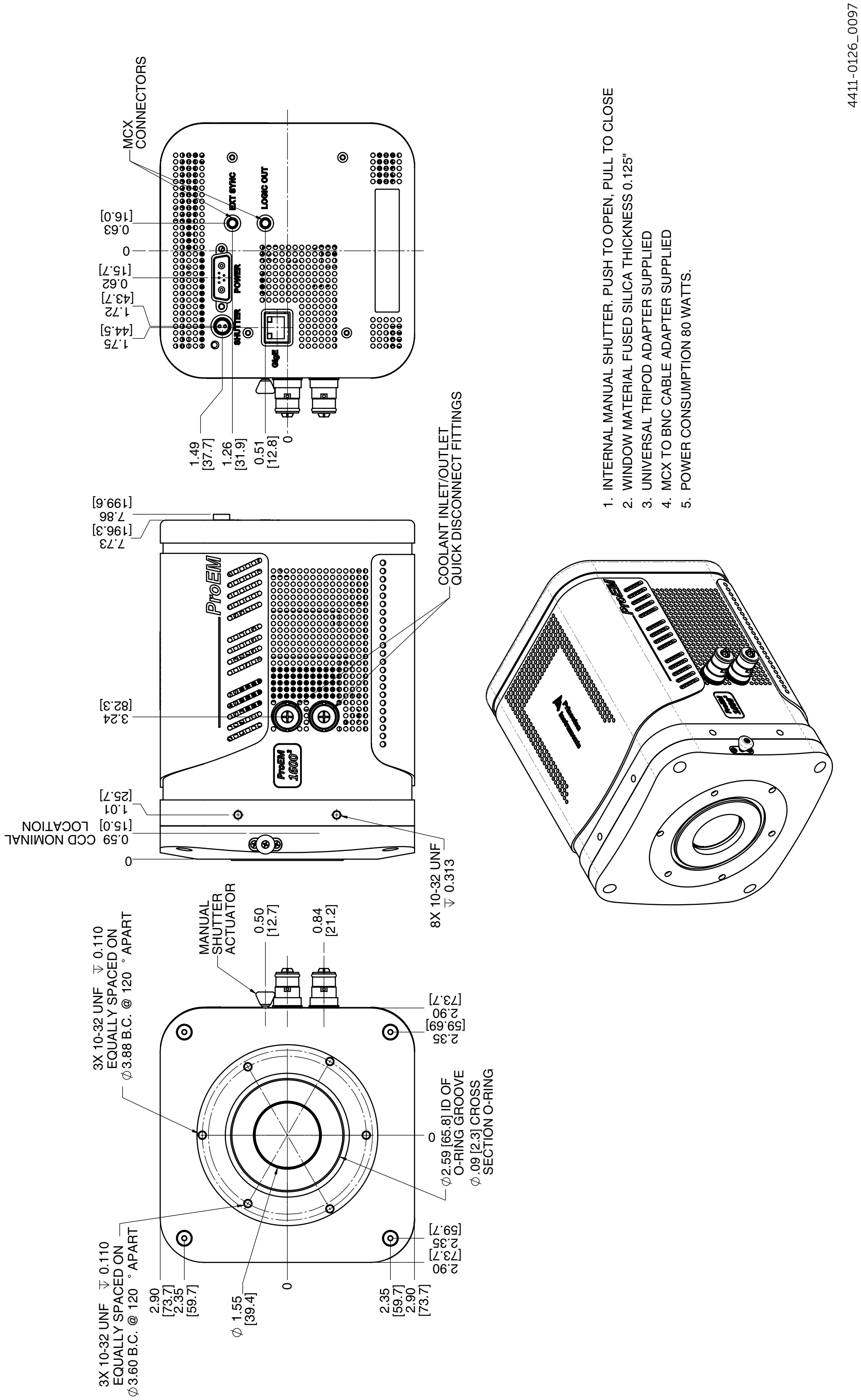


Figure B-4: Outline Drawing: ProEM Power Supply

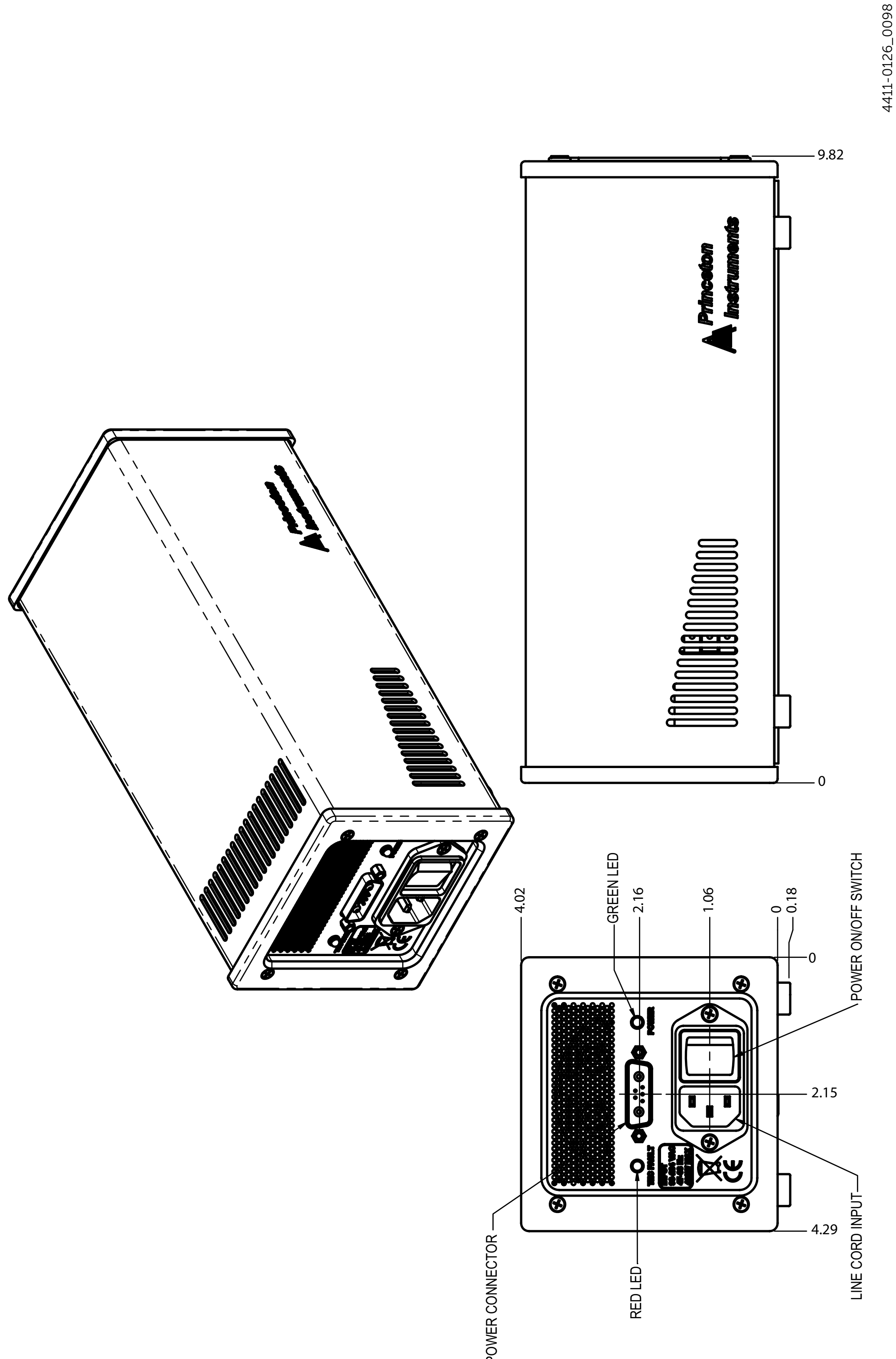
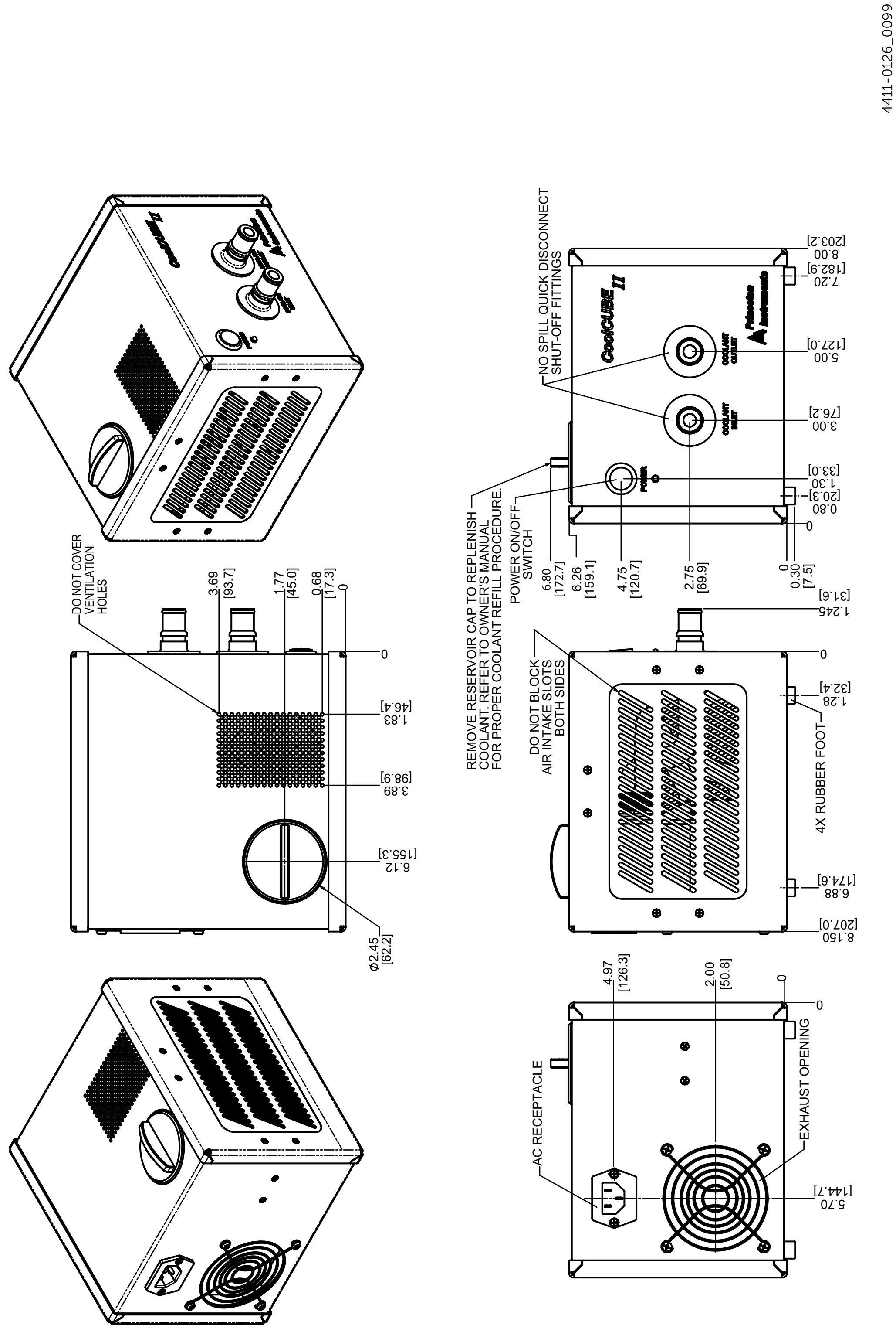


Figure B-5: Outline Drawing: CoolCUBE$_{II}$



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Appendix C: Spectrograph Adapters

ProEM cameras for imaging are designed with a C-mount adapter to accommodate C-mount lenses. Cameras for spectroscopy applications are designed with two different bolt circle patterns to accommodate Teledyne Acton Research sliding tubes. Before mounting your camera to a Teledyne Acton Research Series spectrograph, you should follow the instructions in this appendix for attaching the appropriate spectrograph kit and sliding tube.

NOTE:

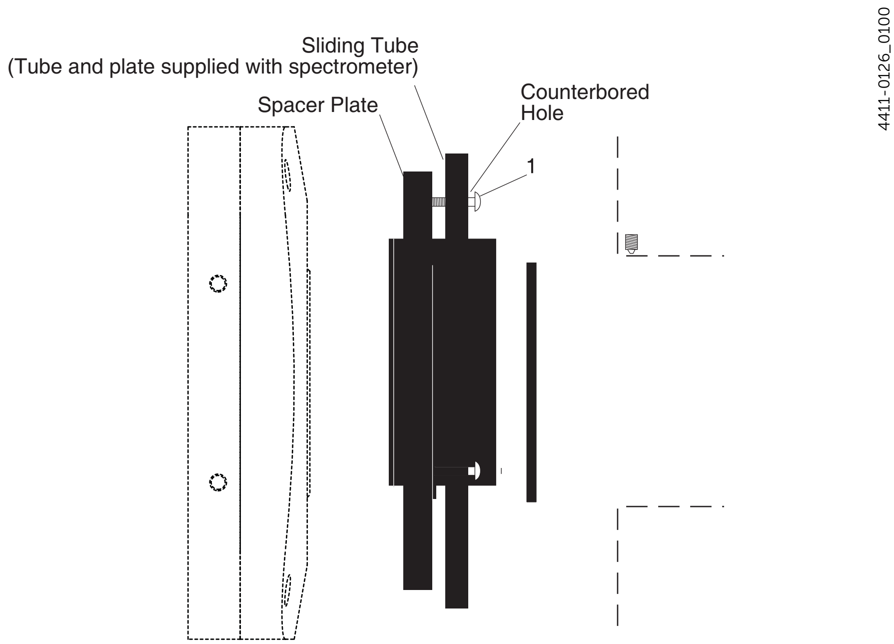
When mounted to a spectrograph, the text on the back of the ProEM should be right side up.

Table C-1 cross-references the adapter kits with the page number for the appropriate instruction set.

Table C-1: ProEM-Spectrograph Adapter Kit Cross Reference

Spectrograph	Adapter Kit Number	Information begins on…
Teledyne Acton Research (ProEM with 3.60"/3.88" Bolt Circles)		page 148
Teledyne Acton Research (ProEM with C-Mount)		page 149
Teledyne Acton Research SP-2350/SP-2550 (ProEM with adjustable C- to spectroscopy-mount)	7050-0104	page 150
Teledyne Acton Research SP-2150/SP-2750 (ProEM with adjustable C- to spectroscopy-mount)	7050-0107	page 151

C.1 ProEM:1600 Series with 3.60"/3.88" Bolt Circles



Item	Qty	P/N	Description
1	3	2826-0584	Screw, 10-32 x 9/16", Pan Head Phillips, Stainless Steel

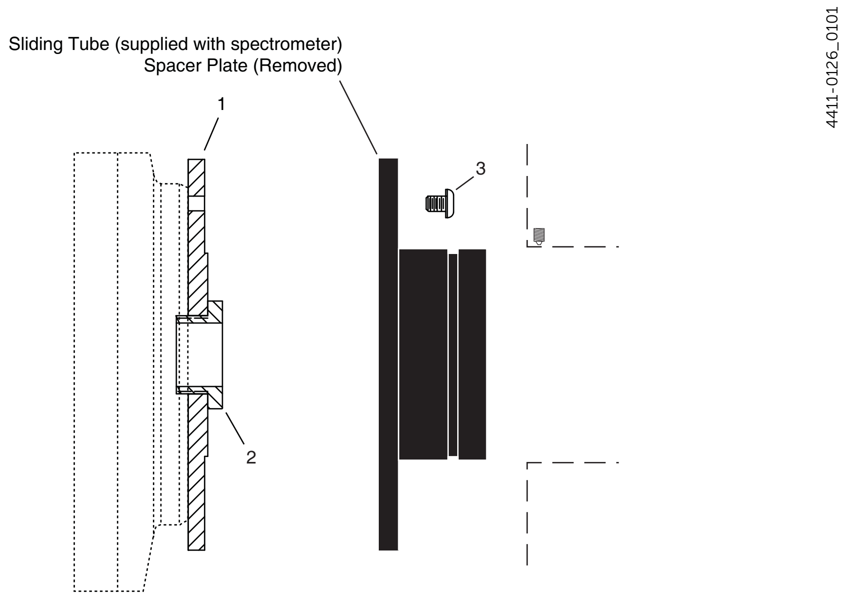
C.1.1 Assembly Instructions

1. Verify the shipping cover has been removed from the spectrograph's camera port.
2. Loosen the two setscrews holding the sliding tube in the spectrograph
3. Rotate the sliding tube as you remove it from the spectrograph.
4. If the spacer plate is mounted to the sliding tube, remove the three (3) socket head screws securing it to the tube.
5. Insert the three (3) 9/16" long pan head screws into the counterbored holes on the sliding tube (as shown above) and through the matching holes on the spacer.
6. Position the sliding tube and spacer on the face of the camera and secure them to the camera nose with the screws.
7. Rotate the camera and sliding tube assembly as you gently insert it into the spectrograph.
8. Secure the sliding tube with the two setscrews.

NOTE:

Adapter parts are machined to provide a tight fit. If you need to remove the sliding tube from the spectrograph, first loosen the two setscrews that secure it, and then rotate the tube as you pull it out. If you have removed the sliding tube from the spectrograph, rotate the sliding tube as you re-insert it, and tighten the setscrews afterwards to secure it. Forcing the tube into the spectrograph may permanently damage the tube and the spectrograph opening.

C.2 C- to Spectroscopy-Mount Adapter



Item	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 x ¼ Button Head Allen Hex, Stainless Steel

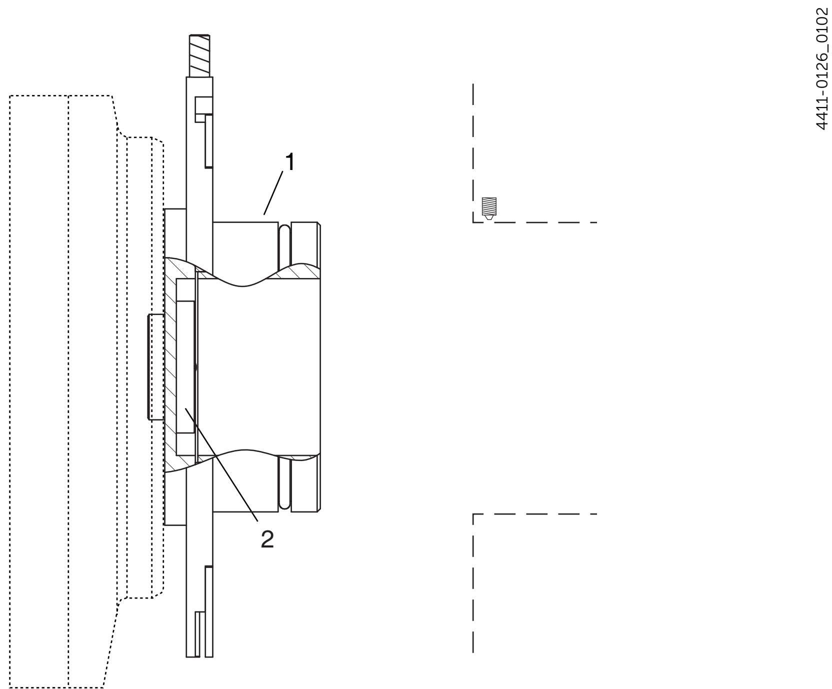
C.2.1 Assembly Instructions

1. Verify the shipping cover has been removed from the spectrograph's camera port.
2. Loosen the two setscrews holding the sliding tube in the spectrograph and rotate the sliding tube as you remove it from the spectrograph. If there is a spacer plate mounted to the sliding tube, remove it.
3. Place the flat side of the adapter plate against the face of the camera.
4. Insert the threaded C-mount adapter through the center hole in the plate and screw the adapter into the camera's C-mount.
5. Using three (3) ¼" button head screws, secure the sliding tube to the adapter plate.
6. Gently rotate the camera and sliding tube assembly as you insert it into the spectrograph.
7. Secure the sliding tube with the two setscrews.

NOTE:

Adapter parts are machined to provide a tight fit. If you need to remove the sliding tube from the spectrograph, first loosen the two setscrews that secure it, and then rotate the tube as you pull it out. If you have removed the sliding tube from the spectrograph, rotate the sliding tube as you re-insert it, and tighten the setscrews afterwards to secure it. Forcing the tube into the spectrograph may permanently damage the tube and the spectrograph opening.

C.3 Adjustable C- to Spectroscopy-Mount Adapter (7050-0104 for SP2350/SP-2550)



Item	Qty	P/N	Description
1	1		Adapter Plate
2	1	2518-1284	1.25"-32 Threaded Insert

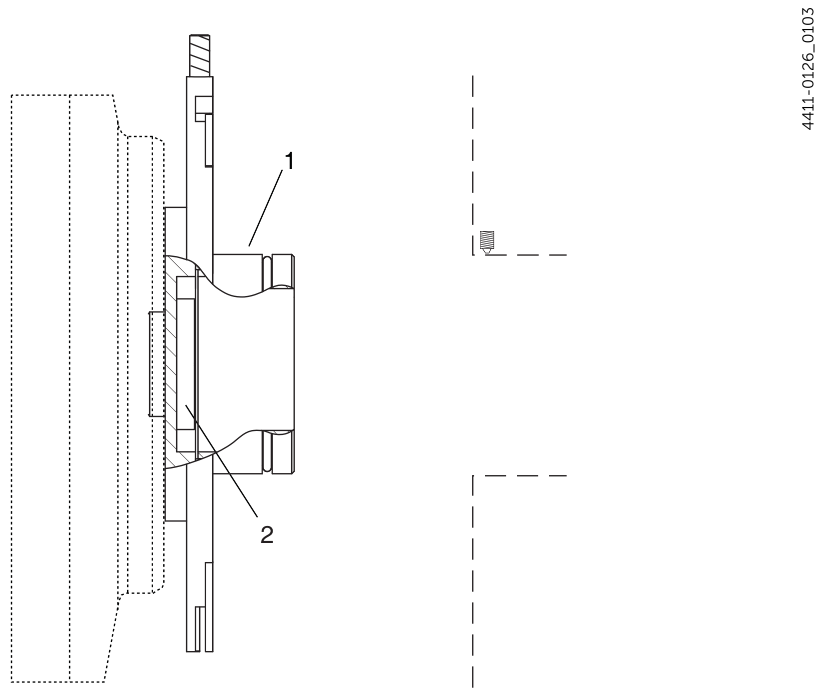
Assembly Instructions

1. Verify the shipping cover has been removed from the spectrograph's camera port.
2. Place the flat side of the adapter plate against the face of the camera.
3. Insert the threaded insert through the center hole in the plate and screw the adapter into the camera's C-mount.
4. Gently rotate the camera and sliding tube assembly as you insert it into the spectrograph.

NOTE:

5.Secure the sliding tube with the two spectrograph setscrews (one coming down from Adapter parts are machined to provide a tight fit. If you need to remove the sliding tube from the spectrograph, first loosen the two setscrews that secure it, and then rotate the tube as you pull it out. If you have removed the sliding tube from the spectrograph, rotate the sliding tube as you re-insert it, and tighten the setscrews afterwards to secure it. Forcing the tube into the spectrograph could permanently damage the tube and the spectrograph opening.

C.4 Adjustable C- to Spectroscopy-Mount Adapter (7050-0107 for SP2150/SP-2750)



Item	Qty	P/N	Description
1.	1	Adapter Plate	
2.	1	2518-1284	1.25"-32 Threaded Insert

C.4.1 Assembly Instructions

1. Verify the shipping cover has been removed from the spectrograph's camera port.
2. Place the flat side of the adapter plate against the face of the camera.
3. Insert the threaded insert through the center hole in the plate and screw the adapter into the camera's C-mount.
4. Gently rotate the camera and sliding tube assembly as you insert it into the spectrograph.
5. Secure the sliding tube with the two spectrograph setscrews (one coming down from the top and the other from the side).

NOTE:

Adapter parts are machined to provide a tight fit. If you need to remove the sliding tube from the spectrograph, first loosen the two setscrews that secure it, and then rotate the tube as you pull it out. If you have removed the sliding tube from the spectrograph, rotate the sliding tube as you re-insert it, and tighten the setscrews afterwards to secure it. Forcing the tube into the spectrograph may permanently damage the tube and the spectrograph opening.

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Appendix D: WinSpec/32/LightField Cross Reference

This appendix provides cross reference information for terminology used within the WinSpec/32 and LightField application software packages.

D.1 WinSpec/32-to-LightField Terminology

Refer to Table D-1 for a list of WinSpec/32 terms and their corresponding LightField terms.

Table D-1: WinSpec/32-to-LightField Cross Reference (Sheet 1 of 2)

WinSpec/32 Term	LightField Term
Active Rows Parallel to Shift Register	Active Height
Active Shift Register Columns	Active Width
ADC Rate	Speed
ADC Resolution	Bit Depth
Continuous Cleans	Clean Until Trigger
Controller Gain	Analog Gain
Custom Chip	Custom Sensor
Custom Timing	Custom Timing
Disabled Closed (Shutter)	Always Closed (Shutter)
Disabled Open (Shutter)	Always Open (Shutter)
Dual Trigger Mode	Shift Per Trigger
Easy Bin	Sensor Readout Region expander functions
Edge Trigger	Trigger Determined By
External Sync	Readout Per Trigger
F.T. Dummies or Frame Transfer Dummies	Active Area: Top Margin
Focus	Preview or Run
Free Run	No Response
Logic Out	Output Signal
Logic Out: Logic 0	Output Signal: Always Low
Logic Out: Logic 1	Output Signal: Always High
Logic Out: Not Ready	Output Signal: Busy
Logic Out: Not Scan	Output Signal: Not Reading Out

Table D-1: WinSpec/32-to-LightField Cross Reference (Sheet 2 of 2)

WinSpec/32 Term	LightField Term
Logic Out: Shutter	Output Signal: Shutter Open
Minimum Block Size	Final Section Height
Normal Shutter	Normal (Shutter)
Number of Blocks	Final Section Count
Number of Cleans	Number of Clean Cycles
Number of Strips per Clean	Clean Cycle Height
Post-Dummy Rows Parallel to Shift Register	Active Area: Bottom Margin
Post-Dummy Shift Register Columns	Active Area: Right Margin
Pre-Dummy Rows Parallel to Shift Register	Active Area: Top Margin
Pre-Dummy Shift Register Columns	Active Area: Left Margin
PreOpen (Shutter)	Open Before Trigger (Shutter)
Readout Port	Quality
Shutter Close Compensation Time	Closing Delay
Shutter Control	Shutter Mode
Shutter Open Compensation Time	Opening Delay
Single Trigger Mode (DIF)	Readout Per Trigger
Skip Serial Register Clean (deselected)	Clean Serial Register
Target Temperature	Temperature Setpoint
Timing Mode	Trigger Response

D.2 LightField to WinSpec/32

Refer to Table D-2 for a list of LightField terms and their corresponding WinSpec/32 terms.

Table D-2: LightField-to-WinSpec/32 Cross Reference (Sheet 1 of 2)

LightField Term	WinSpec/32 Term
Active Area: Bottom Margin	Post-Dummy Rows Parallel to Shift Register
Active Area: Left Margin	Pre-Dummy Shift Register Columns
Active Area: Right Margin	Post-Dummy Shift Register Columns
Active Area: Top Margin	F.T. Dummies or Frame Transfer Dummies
Active Area: Top Margin	Pre-Dummy Rows Parallel to Shift Register
Active Height	Active Rows Parallel to Shift Register
Active Width	Active Shift Register Columns
Always Closed (Shutter)	Disabled Closed (Shutter)
Always Open (Shutter)	Disabled Open (Shutter)
Analog Gain	Controller Gain
Bit Depth	ADC Resolution
Clean Cycle Height	Number of Strips per Clean
Clean Serial Register	Skip Serial Register Clean (deselected)
Clean Until Trigger	Continuous Cleans
Closing Delay	Shutter Close Compensation Time
Custom Sensor	Custom Chip
Custom Timing	Custom Timing
Final Section Count	Number of Blocks
Final Section Height	Minimum Block Size
No Response	Free Run
Normal (Shutter)	Normal Shutter
Number of Clean Cycles	Number of Cleans
Open Before Trigger (Shutter)	PreOpen (Shutter)
Opening Delay	Shutter Open Compensation Time
Output Signal	Logic Out
Output Signal: Always High	Logic Out: Logic 1
Output Signal: Always Low	Logic Out: Logic 0
Output Signal: Busy	Logic Out: Not Ready
Output Signal: Not Reading Out	Logic Out: Not Scan
Output Signal: Shutter Open	Logic Out: Shutter

Table D-2: LightField-to-WinSpec/32 Cross Reference (Sheet 2 of 2)

LightField Term	WinSpec/32 Term
Preview	Focus
Quality	Readout Port
Readout Per Trigger	External Sync
Readout Per Trigger (DIF)	Single Trigger (DIF)
Sensor Readout Region expander functions	Easy Bin
Shift Per Trigger (DIF)	Dual Trigger Mode (DIF)
Shutter Mode	Shutter Control
Speed	ADC Rate
Temperature Setpoint	Target Temperature
Trigger Determined By	Edge Trigger
Trigger Response	Timing Mode

Warranty and Service

Limited Warranty

Teledyne 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

Teledyne 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, Teledyne 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 Teledyne 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 Teledyne 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

Teledyne 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, Teledyne 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 Teledyne Princeton Instruments factory or, at our option, a factory-authorized service center. You are responsible for the shipping costs to return the product to Teledyne Princeton Instruments. International customers should contact their local Teledyne 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

Teledyne 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 Teledyne 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

Teledyne 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

Teledyne 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. Teledyne 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. *Refer to 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

Teledyne 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. *Refer to 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

Teledyne 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. Teledyne 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 CDROM from our factory for an incidental shipping and handling charge. *Refer to Item 12 in Your Responsibility of this warranty 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 Teledyne 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 Teledyne Princeton Instruments technical support staff or our authorized service representative. *Refer to Item 12 in Your Responsibility of this warranty 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 Teledyne Princeton Instruments.
2. You must notify the Teledyne 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 Teledyne 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 Teledyne 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 Teledyne Princeton Instruments factory or one of our authorized manufacturer's representatives or distributors.
6. Unless specified in the original purchase agreement, Teledyne 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;
   - has been damaged as a result of misuse, improper installation, faulty or inadequate maintenance, or failure to follow instructions furnished by us;
   - has had serial numbers removed, altered, defaced, or rendered illegible;
   - has been subjected to improper or unauthorized repair;
   - has been damaged due to fire, flood, radiation, or other "acts of God," or other contingencies beyond the control of Teledyne Princeton Instruments; or
   - is a shutter which is a normal wear item and as such carries a onetime only replacement due to a failure within the original 1 year Manufacturer warranty.
8. After the warranty period has expired, you may contact the Teledyne Princeton Instruments factory or a Teledyne 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 Teledyne 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 Teledyne Princeton Instruments factory of purchase, contact your authorized Teledyne Princeton Instruments representative or reseller, or visit our technical support page at www.princetoninstruments.com.

Contact Information

Teledyne Princeton Instruments' manufacturing facility for this product is located at the following address:

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

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

Customer Support E-mail: techsupport@princetoninstruments.com

Refer to http://www.princetoninstruments.com/support for complete support and contact information, including:

- Up-to-date addresses and telephone numbers;
- Software downloads;
- Product manuals;
- Support topics for Teledyne Princeton Instruments' product lines.

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