Quad-RO System

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Princeton Instruments

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Chapter 1
Introduction

When Flexibility Counts

Princeton Instruments knows that a camera designed to detect x-ray photons for scientific research needs to be flexible. X-ray scattering from complex crystals such as proteins requires high dynamic range and low-noise readout, whereas scattering from materials like polymers, fibers, and powders requires deep cooling and rapid imaging to capture phase or morphological changes during thermal or mechanical processing. Shutterless operation, low noise, and the ability to select a fiber ratio up to 5:1 make the Princeton Instruments Quad-RO system an ideal choice for both of these applications.

In fact, Quad-RO high-performance systems are designed specifically for applications like x-ray tomography, x-ray topography, x-ray diffraction, x-ray crystallography, medical x-ray imaging, nondestructive testing (NDT), streak tube readout, and image intensifier readout.

When a 1:1 fiberoptic-coupling configuration is chosen, these cameras are well suited for streak tube and image intensifier readout or low x-ray flux imaging.

Fiberoptic Expertise

The Quad-RO camera system utilizes Princeton Instruments' fiberoptic-coupling technology to ensure the highest possible resolution. This process eliminates any intermediate fiberoptic faceplate or unreliable oil layer between surfaces. An optional phosphor screen (GdOS:Tb) that absorbs x-rays and emits visible light (~550 nm) can also be coupled to the CCD with a fiberoptic in order to detect x-rays. When the highest sensitivity is required, such as when detecting low flux or lower x-ray energies (~5 keV), smaller taper ratios and back-illuminated CCDs are offered. For distortion-free imaging, a 1:1 fiberoptic system is recommended, while for maximum field of view—ideal for high-brilliance sources like third-generation synchrotrons—tapers with diameters as large as 165 mm are recommended.

Shuttering and Synchronization

Electrical timing signals are available from the camera controller for synchronization with a customer-provided x-ray shutter. The CCD can be continuously cleared of dark charge while waiting for an exposure to begin. Exposures that are much longer than the CCD readout time can be performed without a shutter, as the amount of smearing (due to continued exposure during readout) will be low.

Noise Reduction

The Quad-RO system uses liquid-cooling (50:50 ethylene glycol-water) to reduce dark current. The thermoelectric (Peltier) design and precision electronics provide very high precision, vibration-free operation, as well as the capability to set the required temperature.

Software Solutions

The Quad-RO camera runs under WinView and WinSpec, Princeton Instruments' 32-bit Windows® software packages designed for imaging and spectroscopy, respectively. They provide comprehensive image or spectra capture and display functions, so you can perform data acquisition without having to rely on third-party software. The packages also facilitate snap-ins to permit easy user customization of any function or sequence. The PVCAM library, LabVIEW® VIs, and a Linux driver are available, which allows you to write your own software. This makes integrating the system into larger experiments or instruments a straightforward endeavor.

Quad-RO System Components

The Princeton Instruments Quad-RO system normally contains the major components shown in Figure 1 and described below. Actual system components will depend on the system configuration ordered.

- **Fiberoptic Taper CCD Camera:** X-rays pass through the Beryllium window and are absorbed by a phosphor screen that emits visible light. This light is coupled to the CCD by a reducing fused fiber optic taper. The CCD detects one or more visible photons per X-ray photon absorbed. Detected photons are converted to electrical signals. The data is then transferred to the computer for further processing.

WARNING!

1. Do not touch the Beryllium window at the front of the camera.
2. Avoid abrasion of the Beryllium window since powdered Beryllium is highly toxic if ingested. Beryllium should never be handled in a way that places personnel at risk.
3. Units are shipped with a protective label over the Beryllium window. This label should be removed and discarded. Damage to the Beryllium window may result in loss of vacuum and improper camera operation.

- **External Power Supply and Camera Power Cable:** Provide the voltages required for camera operation.
- **User Manuals:** Quad-RO System and WinView/32 Imaging Software. The Quad-RO manual contains the basic setup and operation information for Quad-RO camera systems. For information about WinView/32, refer to its manual and to the on-line help supplied with the program.

  Note: The system and software manuals may be provided on the software CD supplied with your system.

- **WinView/32 CD-ROM:** This CD contains the WinView/32 imaging software and related manuals in PDF format.
- **Interface Card:** User-supplied FireWire™ (IEEE 1394a) Interface Card.
- **Interface Cable:** FireWire (IEEE 1394a) cable: 14.7' (4.5m) cable (6050-0558 is standard)

Figure 1. Standard System Components

About this Manual

Manual Organization

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

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

Chapter 1, Introduction, briefly describes the Quad-RO family of cameras; details the structure of this manual; and documents environmental, storage, and cleaning requirements.

Chapter 2, Component Descriptions, provides descriptions of each system component.

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

Chapter 4, System Setup, provides detailed directions for interconnecting the system components.

Chapter 5, Operation, includes a simple procedure for verifying system operation and discusses operational considerations associated with exposure, readout, and digitization.

Chapter 6, Advanced Topics, discusses standard timing modes (Free Run, External Sync, and Continuous Cleans), Fast and Safe, and TTL control.

Chapter 7, Distortion Correction, provides instructions on applying the distortion correction for tapers with fiberoptic ratios other than 1:1.

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

Declaration of Conformity contains the Declaration of Conformity for Quad-RO systems.

Appendix A, Specifications, includes Quad-RO camera.

Appendix B, Outline Drawings, includes outline drawings of the Quad-RO cameras.

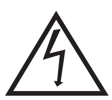
Appendix C, Swagelok Fittings, includes instructions for assembling Swagelok® tube fittings.

Appendix D, Repumping the Vacuum, explains how to restore the camera's vacuum if that vacuum has deteriorated over time.

Warranty & Service provides warranty and customer support contact information.

Safety Related Symbols Used in this Manual

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



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

Environmental Conditions

- Storage temperature < 50°C
- Operating environment 0°C < T< 40°C
- Operating temperature range over which specifications can be met is 0° C to 25° C
- Relative humidity ≤50%, noncondensing.

Grounding and Safety

The Quad-RO power supply is designed for indoor operation only. Before turning on the power supply, the ground prong of the powercord plug must be properly connected to the ground connector of the wall outlet. The wall outlet must have a third prong or must be properly connected to an adapter that complies with these safety requirements.

WARNING! If the equipment 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 powercord. If it is not compatible with the power socket, replace the cord with one that has suitable connectors on both ends.

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

Repairs

Repairs must be done by Princeton Instruments. If your system hardware needs repair, contact Princeton Instruments Customer Service. Please save the original packing material so you can safely ship the system to another location or return it for repairs.

Warnings

To prevent injury, please observe the following warnings:

Beryllium

- Do not touch the Beryllium window at the front of the camera.
- Avoid abrasion of the Beryllium window since powdered Beryllium is highly toxic if ingested. Beryllium should never be handled in a way that places personnel at risk.
- Units are shipped with protective label over the Beryllium window. This label should be removed and discarded. Damage to the Beryllium window may result in loss of vacuum and improper camera operation.
- For additional information on safe handling practices or technical data on Beryllium, contact Brush Wellman Inc. at www.brushwellman.com

Coolant

- COOLANT IS HARMFUL IF SWALLOWED. Store coolant securely and keep it out of the reach of children.

Precautions

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

- Never operate the camera cooled without proper evacuation or backfill. This could damage the CCD!
- Never operate a Quad-RO camera without coolant circulating at the specified rate properly.
- Never operate a Quad-RO camera with coolant at a temperature below that specified for it.
- Never prevent the free flow of air through the equipment by blocking the air vents.

Cleaning

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

Camera

Although there is no periodic maintenance that *needs* to be performed on a Quad-RO camera, users are advised to wipe it down with a clean damp cloth from time to time -- **Do not wipe the Beryllium window.** 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.

Beryllium Window

Cleaning may be necessary to remove oil or other contaminants from the surface of the window. Because a fingerprint left on the surface will disrupt the effectiveness of the final etch or coating and because of the potential toxicity, protective gloves should be worn when cleaning the window. To clean the window, wipe it down with isopropanol and a lintless cloth. DO NOT use water. Beryllium is highly susceptible to localized pitting when in contact with the chloride and sulfate ions contained in ordinary water.

Princeton Instruments Customer Service

Refer to the contact information located on page 82 of this manual.

Chapter 2
System Component Descriptions

Quad-RO Camera

CCD Array: Quad-RO currently offers two scientific grade full-frame CCD formats: 2084x2084 array with 24x24 µm pixels and 4096x4096 array with 15x15 µm pixels. Systems can effectively provide x-ray photon-counting capability with up to 16-bit dynamic range.

CCD Chamber: The vacuum-sealed CCD chamber protects the CCD from contamination as well as insulates it from the warmer air in the camera body. The inherent low humidity prevents condensation on the cooled surface of the array. The thermal barrier provided by the fiberoptic prevents the condensation from forming on the front of the fiberoptic.

Quad-RO cameras are normally shipped with a vacuum level of ~0.01 mTorr or better. Because this vacuum may deteriorate over time due to outgassing of electrical components, Quad-RO cameras are designed with a built-in vacuum port that can be used to restore the vacuum to its original level. Instructions for repumping the vacuum are provided in Appendix D.

Fiber Optic: The Quad-RO fiberoptic tapers are bonded to the face of the CCD arrays with Princeton Instruments' proprietary fiberoptic-coupling technology. The direct bonding to the face of the array eliminates the need for an intermediate fiberoptic faceplate or an oil layer between surfaces, thereby increasing sensitivity and resolution. Currently, the Quad-RO is bonded to either a 1:1 fiberoptic taper (extending outside the vacuum), which gives a maximum resolution of approximately 33 lp/mm with the 4k×4k CCD installed in the camera, or to a 2.67:1 taper, which gives a maximum resolution of approximately 12.5 lp/mm.

Thermoelectric Cooler: While the CCD accumulates charge, thermal activity releases electrons, generating dark current. Cooling the CCD enhances the low-light sensitivity by reducing thermally generated charge. With +5°C water for water-assisted cooling, the 1:1 fiberoptically coupled Quad-RO camera can reach –40°C.

Cooling is accomplished by mounting the CCD on a cold finger, which in turn is seated on a thermoelectric (Peltier-effect) cooler. With water-cooling, a 50:50 ethylene glycol-water coolant is circulated through a heatsink thermally connected to the Peltier. CCD temperature is controlled by the camera electronics and may be monitored from the host computer.

Electronics: The camera electronics enclosure contains array driver, preamplifiers, ADCs and all control logic for a fully self-contained electronic solution.

The speed of data acquisition is determined primarily by the A/D converter used, the selected readout rate (1 MHz or 500 kHz), and the mode (four-port or single-port). Binning on the array is also a factor.

Connectors:

All of the camera's electrical connections are located on the control panel (Figure 2) and are described below.

IEEE 1394: Control signals and data are transmitted between the camera and the host computer via the FireWire™ port located on the rear of the camera. This port has a single 6-pin 1394a connection (400 Mbps).

EXT SYNC: 0-+3V logic level input (TTL-compatible) that has a 10 kΩ pullup resistor. Allows data acquisition and readout to be synchronized with external events. Through software, positive or negative (default) edge triggering can be selected.

Figure 2. Control Panel Connectors

SCAN: 0-+3V logic level output (TTL-compatible) provides a 50 mA closure to ground when active, open when inactive. Allows data acquisition and readout to be synchronized with external events or may be used as to control an external shutter. Software-selectable positive or negative (default) edge triggering. Software functionality allows for choice of NOTSCAN or Shutter control.

$\overline{\text{READY}}$: 0-+3V logic level output (TTL-compatible) provides a 50 mA closure to ground when active, open when inactive. Allows data acquisition and readout to be synchronized with external events.

Power: Depending on operating conditions, approximately 200 W maximum total power is drawn from the Quad-RO power supply.

Mounting Holes: The Quad-RO camera has three threaded holes on the underside of the camera body (two are M8 x 1.25 tap, 19.1 mm deep; and one is 1/4"-20 tap, .50" deep).

Coolant Ports: There are two coolant ports for water-cooling. The Inlet and Outlet ports are interchangeable, are barbed (straight or right-angled), and will accommodate 3/8" ID Tygon tubing.

Power Supply

Figure 3. Quad-RO Power Supply

POWER Switch: The power switch is located on the front panel. The LED located above the power switch lights whenever the Quad-RO power supply is powered.

Power Module: Contains the powercord socket and two fuses. 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.

Fuse/Voltage Label: Displays the power supply's power and fuse requirements at 100/120 VAC and 220/240 VAC.

Cables

FireWire™ (IEEE 1394a) Cable: The standard 14.7' (4.5 m) cable (6050-0558) has 6-pin IEEE 1394a connectors on each end. The cable is intended to connect the "IEEE 1394" connector of the Quad-RO with a FireWire (IEEE 1394a) interface on the host computer.

Camera Power Cable: The standard 15' (3.7 m) cable (6050-0587) 37-pin DB connector at each end. The cable connects the power supply to the camera.

Application Software

The Princeton Instruments WinView/32 software package provides comprehensive image acquisition, display, processing, and archiving functions so you can perform complete data acquisition and analysis without having to rely upon third-party software. WinView/32 provides reliable control over all Princeton Instruments cameras, regardless of array format and architecture, via an exclusive universal programming interface (PVCAM®). WinView/32 also features snap-ins and macro record functions to permit easy user customization of any function or sequence.

PVCAM is the standard software interface for cooled CCD cameras from Princeton Instruments. It is a library of functions that can be used to control and acquire data from the camera when a custom application is being written. For example, in the case of Windows, PVCAM is a dynamic link library (DLL). Also, it should be understood that PVCAM is solely for camera control and image acquisition, not for image processing, display, or storage. 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.

On the CD you will also find PVCAM V2.# for Linux® (in the SOFTWARE/LINUX subdirectory). Note that PVCAM V2.7.1.7 and later provide support for the Quad-RO cameras.

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

User Manuals

Quad-RO System User Manual: This manual describes how to install and use the Quad-RO system components.

WinView/32 User Manual: This manual describes how to install and use the application program. A PDF version of this manual is provided on the installation CD. Additional information is available in the program's on-line help.

Chapter 3
Installation Overview

The list and diagrams below briefly describe the sequence of actions required to hookup your system and prepare to gather data. Refer to the indicated references for more detailed information. This list assumes that the application software is Princeton Instruments WinView/32.

Action	Reference
1. If the system components have not already been unpacked, unpack them and inspect their carton(s) and the system components for in-transit damage. Store the packing materials.	Chapter 4 System Setup, page 19
2. Verify that all system components have been received.	Chapter 4 System Setup, page 19
3. If the WinView/32 software is not already installed in the host computer, install it. This will install the appropriate drivers for the camera interface.	WinView/32 manual
4. If the camera is water-cooled, make the tubing connections between the circulator and the camera. Fill the circulator with the required mixture, turn on the circulator, turn on the refrigeration, and set the coolant temperature.	Chapter 4 System Setup, page 23 Chapter 5 Operation, page 27
5. Connect the camera power supply to the camera.	
6. Connect the camera power supply to an AC power source and turn the power supply ON.	
7. Connect the interface cable to the interface card in the host computer.	Chapter 4 System Setup, page 23
8. Turn on the computer.	
9. After the computer boots, connect the other end of the interface cable to the camera. After a few moments, the camera should be detected and you may be asked for the location of the interface drivers. **Note: the interface drivers must be installed and loaded before starting WinView/32 or the camera will not be recognized by the software.**	WinView/32 manual
10. When the drivers have been installed and camera is connected, begin running WinView/32.	WinView/32 manual
11. Complete the Camera Detection Wizard for the camera. This enters the default hardware settings for the Quad-RO system into WinView/32.	Chapter 5 Operation, page 27

Action	Reference
12. Set the target array temperature.	Chapter 5 Operation, page 27
13. When the system reaches temperature lock, begin acquiring data in focus mode.	Chapter 5 Operation, page 28

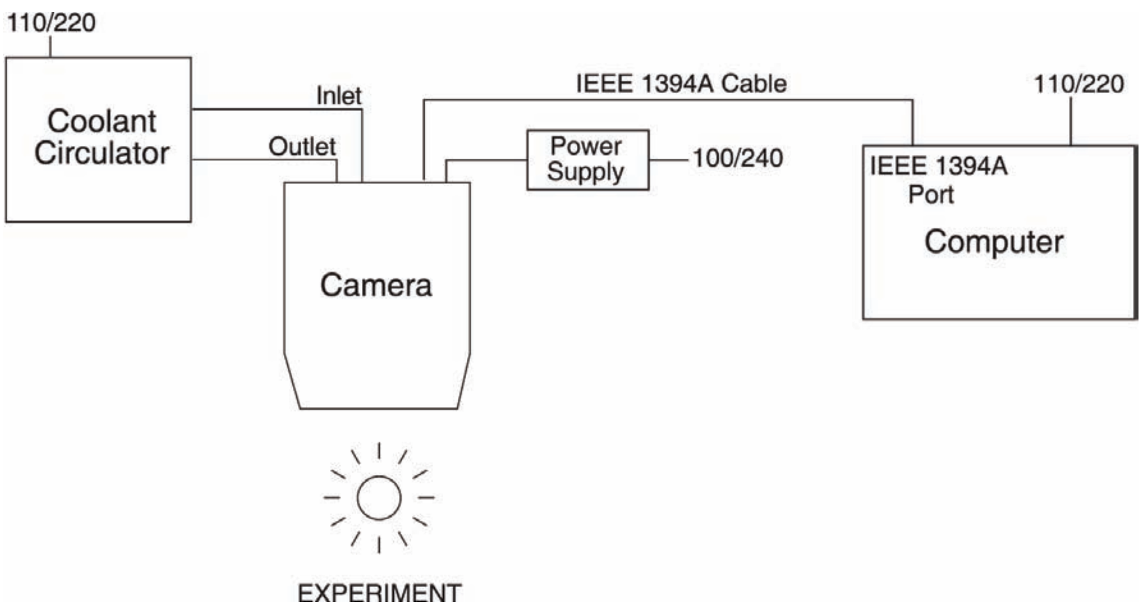


Figure 4. Quad-RO System Diagram

Chapter 4
System Setup

Unpacking the System

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

Checking the Equipment and Parts Inventory

Confirm that you have all of the equipment and parts required to set up the system. A complete Quad-RO system consists of

- **Camera:** Quad-RO.
- **Computer Interface:**
  - FireWire (IEEE 1394a) cable: 14.7' (4.5m) meter cable (6050-0558) is standard
- **WinView/32 CD-ROM:** This CD contains the WinView/32 imaging software and related manuals in PDF format.
- **Camera Power Cable***:* The standard 15' (3.7 m) cable (6050-0587) 37-pin DB connector at each end. .
- **User Manuals**: Quad-RO System and WinView/32 Imaging Software. These manuals are supplied on the CD shipped with your system.
- **Host Computer:** Typically, the computer is user-supplied.
- **Coolant Circulator:** Typically, the coolant circulator and hoses are user-supplied.

System Requirements

Environmental

Operating temperature: 0ºC to +40ºC;

Operating temperature range over which system specifications can be met: 0ºC to +25ºC

Relative humidity ≤50% noncondensing.

Ventilation

Camera: Allow at least one inch of clearance for side and rear air vents.

Vacuum

The CCD is housed in the vacuum with the fiberoptic taper extending beyond the vacuum chamber with a thin Beryllium window to block visible light and to admit X-rays. The camera is shipped with a vacuum quality superior to the minimum required to assure proper operation of the system for an extended period of time without concern for the quality of the vacuum. *See Appendix D for additional information.*

Coolant

WARNING!

COOLANT IS HARMFUL IF SWALLOWED.

KEEP OUT OF REACH OF CHILDREN.

Quad-RO cameras require circulating coolant (50:50 mixture of ethylene glycol and water) for proper operation. All hose connections should be secured with good quality hose clamps.

Flow Rate: Users are advised to install a flow meter to monitor the rate.
Quad-RO:4320 and Quad-RO:4096 3 liters/minute (minimum).

Fluid Pressure: 25 psig (maximum).

Inlet/Outlet Port Locations: Two barbed coolant ports are supplied with a water-cooled system and are mounted at the back of the camera. Use 3/8" ID tubing.

CAUTION **Coolant Temperature:** Coolant should be no colder than the following temperatures:

Quad-RO:4320 and Quad-RO:4096 +5°C. Operating one of these cameras with coolant at a colder temperature could cause induced condensation in the electronics enclosure and possible catastrophic damage to the camera. ***Damage resulting from this type of operation may void the warranty.***

Power

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

Caution The plug on the line cord supplied with the system should be compatible with the line-voltage outlets in common use in the region to which the system is shipped. If the line cord plug is incompatible, a compatible plug should be installed, taking care to maintain the proper polarity to protect the equipment and assure user safety.

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.

FireWire Protocol:

- Pentium 3 or better processor running at 1 GHz or better.
- Windows 2000 (with Service Pack 4), Windows XP (with Service Pack 2) or later operating system.
- Native FireWire (IEEE 1394a) support on the mother board or plug-in interface card.
- Minimum of 512 Mbytes of RAM.
- CD-ROM drive.
- Hard disk with a minimum of 1-2 Gbytes available. A complete installation of the program files takes about 25 Mbytes and the remainder is required for data storage, depending on the number and size of images collected (up to 64 MBytes

per image depending on the array size). Disk level compression programs are not recommended.

- Super VGA monitor and graphics card supporting at least 256 colors with at least 1 MByte of memory. Memory requirement is dependent on desired display resolution.
- Two-button Microsoft compatible serial mouse or Logitech three-button serial/bus mouse.

Mounting the Camera

For the square case camera, there are three threaded camera mounting holes on the bottom of the camera, toward the rear. Two of the holes are M8 × 1.25 tap (0.75″ deep) and the third one is 1/4″–20 tap (0.50″ deep). Figure 5 shows the location of the mounting holes and their distance from the front of the camera.

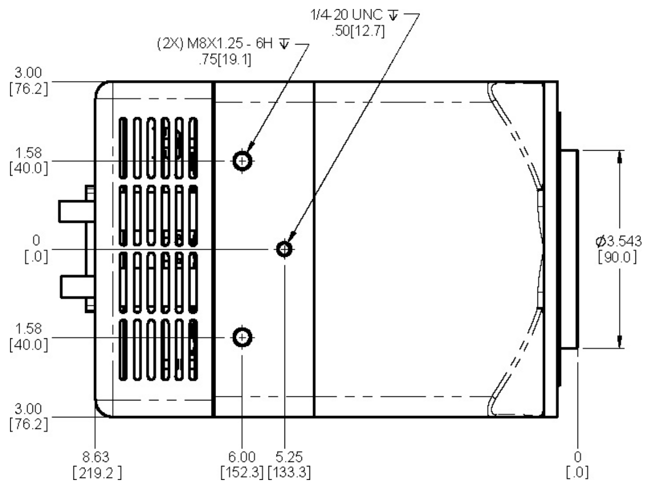


Figure 5. Mounting Holes on Bottom of Camera (90 mm)

For the cylindrical case camera there are two sets of mounting holes: 8–32 tap (0.420″ deep) and 1/4″–20 tap (0.400″ deep) on opposite sides of the camera. Figure 6 shows the locations of the mounting holes and their distance from the back of the camera. Also shown is the mounting adapter with its mounting hole configuration of two M8 × 1.25 tap (0.500″ deep) holes and one that is 1/4″–20 tap (0.500″ deep).

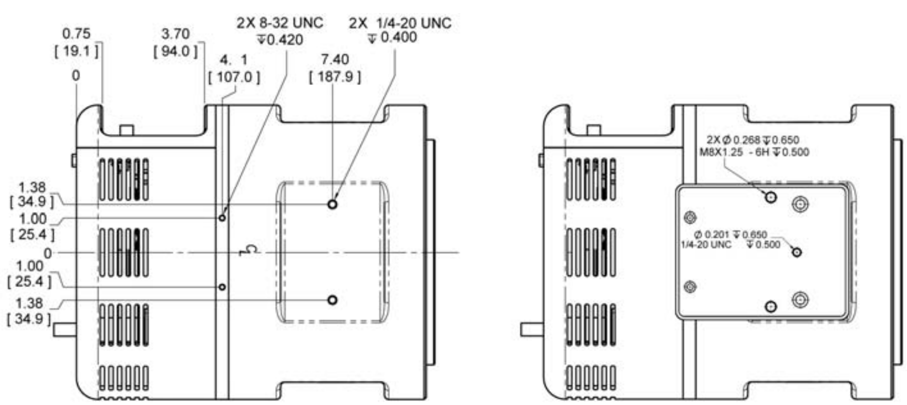


Figure 6. Mounting Holes on 165 mm Camera (left); Mounting Adapter (right)

Installing the Application Software

Installation is performed via the WinView/32 installation process. If you are installing WinView for the first time, you should run the installation before the interface card is installed in the host computer. On the **Select Components** dialog box (see Figure 7), click on the **AUTO PCI** button to install the interface card drivers (the Princeton Instruments PCI, USB, or FireWire drivers) and the most commonly installed program files. Select the **Custom** button if you would like to choose among the available program files or do not want to install the PCI driver.

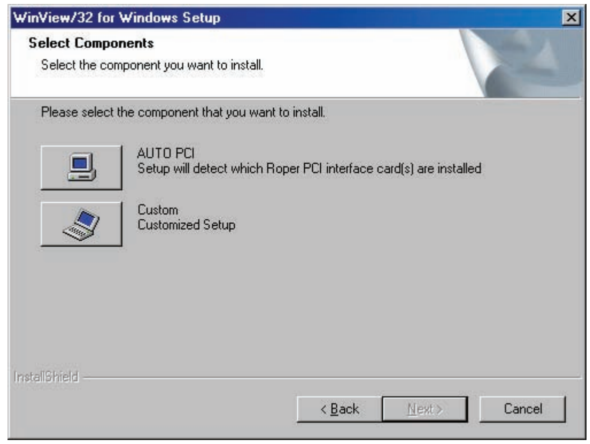


Figure 7. WinView Installation: Interface Card Driver Selection

Setting up a FireWire (IEEE 1394a) Interface

Administrator privileges are required under Windows® 2000 and Windows® XP to install software and hardware.

Check your computer for an existing FireWire (IEEE1394a) port:

The Quad-RO camera connects to your Windows® PC via a 1394a port. Check the connectors at the front or back of your PC for a port that matches the 1394a port on your camera (see Figure 8).

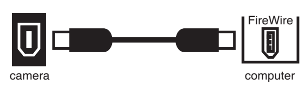


Figure 8. 6-Pin FireWire (IEEE 1394a) Port

If your PC does not have a functioning FireWire (1394a) port, you must install a FireWire (IEEE 1394a) interface card. Refer to the manufacturer's documentation for instructions. The small connector on a laptop computer will work with the appropriate cable.

To Connect the Interface (Camera-Computer) Cable:

FireWire (IEEE 1394a) Cable (6050-0558)

To Connect the FireWire (IEEE 1394a) Cable:

1. Connect one end of the cable to the FireWire (IEEE 1394a) port on the host computer.
2. Connect the other end of the cable to the FireWire (IEEE 1394a) port on the side of the camera.

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

The following instructions assume that you have performed the computer interface installation.

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

Figure 9. Camera Detection Wizard - Welcome dialog box

4. Follow the instructions on the dialog boxes to perform the initial hardware setup: this wizard enters default parameters on the **Hardware Setup** dialog box tab pages and gives you an opportunity to acquire a single test image to confirm the system is working. Note that this is a test image and it is not acquired using the settings needed for true data acquisition.

Making the Circulator-Camera Connections

1. Set up the coolant circulator according to the directions in the user manual for that equipment. Do not apply power to the circulator until directed to do so.
2. Make the hose connections between the circulator and the camera. For best cooling performance, the tubing should be no longer than necessary.

   Use 3/8″ I.D. plastic tubing. Be sure the tubing is properly secured with hose clamps at both ends. Note that either of the camera's coolant ports can function as the inlet or outlet. We advise installing an in-line flow meter so that the flow rate can be monitored.

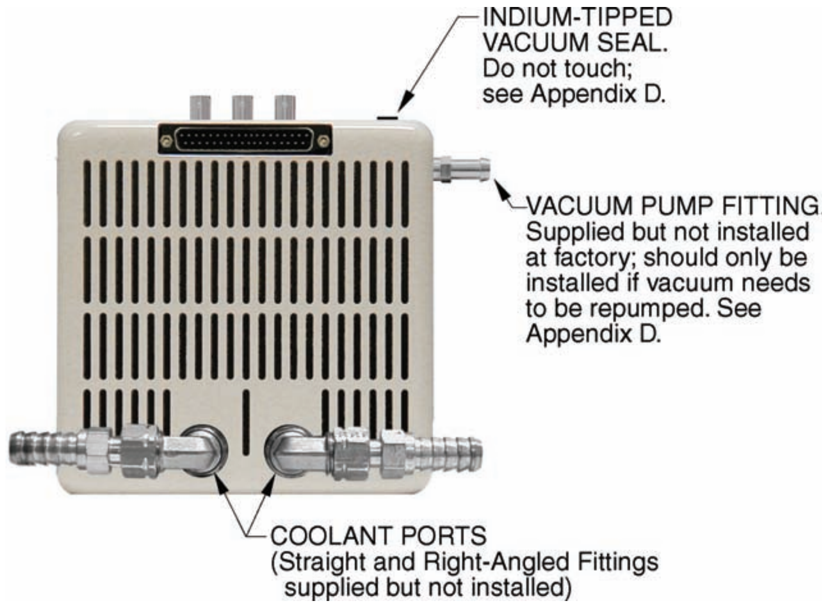


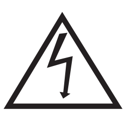
Figure 10. Quad-RO Camera Back Panel

CAUTION

Do not disturb the Vacuum Pumping fitting or the Indium-tipped Vacuum Seal. Damage to the vacuum fittings and seals could void your warranty. Refer servicing to qualified personnel and contact the factory Customer Support for guidance. Detailed information about the vacuum system is provided in Appendix D.

3. Fill the circulator with a mixture of 50% ethylene glycol and 50% water.

Service Notes



There are no user-serviceable components inside the fiberoptic taper camera. Refer servicing to qualified personnel and contact the factory Customer Support for guidance. Contact information is provided in the ***Warranty & Service*** section of the manual.

Chapter 5

Operation

Introduction

Once the Quad-RO camera has been installed, camera operation is basically straightforward. In most applications you simply establish the optimum setup using the **Focus** mode (WinView/32), set the target detector temperature, wait until the temperature has stabilized at the set temperature (see the "Setting the Temperature" section in this chapter), 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 an illumination source and charge accumulates in the pixel wells. After the defined exposure time, the accumulated signal is readout of the array, digitized, and then transferred to the host computer. Upon data transfer, the data is displayed and/or stored via the application software. This sequence is illustrated by the block diagram shown in Figure 11.

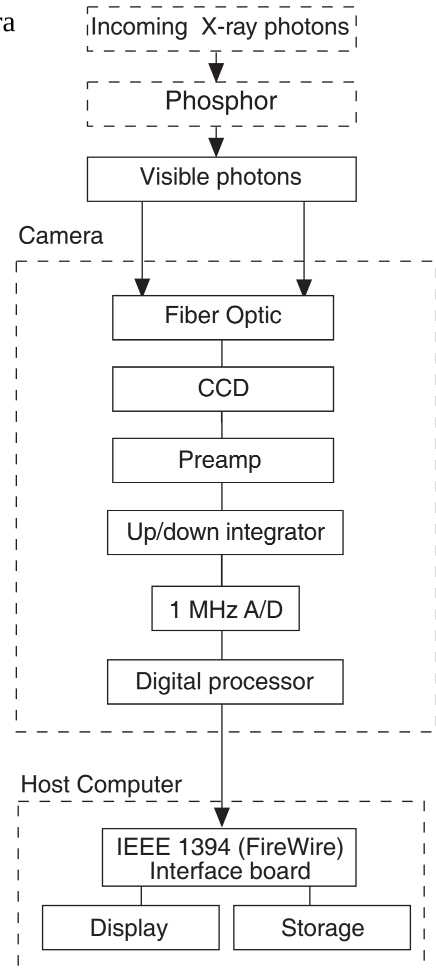


Figure 11. Block Diagram of Light Path in System

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

- In **Focus** mode, the number of frames and accumulations settings are ignored. A single frame is acquired and displayed, another frame is acquired and overwrites the currently displayed data, and so on until Stop is selected. Only the last frame acquired before Stop is selected can be stored. When Stop is selected, the File Save function can be used to save the currently displayed data. This mode is particularly convenient for familiarization and setting up. For ease in focusing, the screen refresh rate should be as rapid as possible, achieved by operating with axes and cross-sections off, and with Zoom 1:1 selected.

- In **Acquire** mode, every frame of data collected can be automatically stored (the completed dataset may include multiple frames with one or more accumulations). This mode would ordinarily be selected during actual data collection. One limitation of Acquire mode operation is that if data acquisition continues at too fast a rate for it to be stored, data overflow will eventually occur. This could only happen in Fast Mode operation.

The remainder of this chapter is organized to first talk about the system on/off sequences. Then "First Light" procedures for imaging and spectroscopy applications follow: these procedures provide step-by-step instruction on how to initially verify system operation. The last three sections discuss factors that affect exposure, readout, and digitization of the incoming signal. By understanding these factors and making adjustments to software settings you can maximize signal-to-noise ratio. For information about synchronizing data acquisition with external devices, please refer to ***Chapter 6, Advanced Topics***.

System On/Off Sequences

For best results, follow the system on/off sequences as stated below. These sequences ensure that communication is established and maintained between the camera and the host computer:

1. Connect and start the liquid coolant circulator. If the circulator is not connected (or not available), you can still familiarize yourself with the camera functions by setting the CCD temperature to +25 deg C.
2. The Quad-RO camera must be powered ON and recognized by Windows as an attached peripheral before WinView/32 or WinSpec/32 is opened to ensure communication between the camera and the computer. If WinView or WinSpec is opened and the camera is not powered ON, many of the functions will be disabled and you will only be able to retrieve and examine previously acquired and stored data. You must close WinView or WinSpec, power the camera ON, and reopen WinView or WinSpec before you can set up experiments and acquire new data.
3. WinView/32 or WinSpec/32 must be closed before powering the camera OFF. If you power the camera OFF before closing WinView or WinSpec, the communication link with the camera will be broken. You should close WinView or WinSpec immediately. If the camera is disconnected and then reconnected, it is not safe to continue running the WinView or WinSpec software. You should close the software and restart it.

First Light

The following paragraphs provide step-by-step instructions for verifying the operation of your Quad-RO system. 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. *The procedure does not require an X-ray source.* Once basic familiarity has been established, then operation with other configurations and those with more complex timing modes, will be easier to understand and perform.

Once the Quad-RO system has been installed, operation of the camera is basically straightforward. In most applications you simply establish optimum setup using the **Focus** mode (WinView/32), select full frame, set the target camera temperature, and watch the dark charge decrease as the CCD temperature approaches the set temperature.

Cabling

- If the system cables haven't been installed, connect them as instructed in Chapter 4.

Getting Started

1. Follow the steps in Chapter 4 to connect the camera and start the software.
2. Double check that the circulator is filled with a 50:50 mixture of ethylene glycol and water and that the hose connections are secure. When satisfied that these requirements are met, do the following.
    - Turn on the circulator. The circulator will power up and begin pumping coolant through the camera. *See the circulator instruction manual for detailed information.*
    - Inspect the coolant hose connections to be sure there are no leaks.
    - Turn on the refrigeration, if this feature is available, and set the coolant temperature (+5° for Quad-RO:4320 and Quad-RO:4096, unless otherwise specified). The compressor will start and cooldown will begin.

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:

Environment dialog (Setup|Environment): Verify that the DMA Buffer size is initially set to 128 Mbytes. The amount of memory required will depend on the size and number of images that you wish to acquire at one time. WinView/32 will automatically increase the memory usage as needed. However, you will want to ensure that your host computer has enough memory available for the task. It is recommended that your host computer have a minimum of 512 Mbytes of physical memory. Note that each 4k×4k non-corrected full frame image occupies 32 Mbytes of memory and, under the same conditions, each 2kx2k image occupies 8 Mbytes of memory.

Controller/Camera tab page (Setup|Hardware): Controller and Camera parameters should be set automatically to the proper values for your system. However, you can click on the **Load Defaults From Controller** button on this tab page to load the default settings.

- **Camera Type:** The array for your camera will either be FCD 4096x4096F MT or KAF 2084x2084 MT
- **Shutter type:** Custom. See Figure 20, page 41, for shutter capabilities and maximum delay time.
- **Readout mode:** Full frame.

- **Cleans and Skips tab page (Setup|Hardware):** Default
- **Camera Temperature (Setup|Detector Temperature…):**
    - The default is –25ºC for Quad-RO:4320 or Quad-RO:4096 with +10° water unless otherwise specified at the time of the customer order.

- The temperature should drop steadily, reaching the set temperature in about 60 minutes (typical). At that point there will be a **locked** indication at the computer monitor, indicating that temperature lock has been established. Some overshoot may occur that may cause temperature lock to be briefly lost and then 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 ±0.10°C (because of analog to digital conversion, the software reports stability to within ±0.20°C).

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

- **Experiment Setup Main tab page (Acquisition|Experiment Setup…):**
  - **Exposure Time:** 100 ms
  - **Accumulations & Number of Images:** 1
  - **CCD Readout:** Use Full Chip
- **Experiment Setup Timing tab page (Acquisition|Experiment Setup…):**
  - **Timing Mode:** Free Run
  - **Shutter Control:** Normal
  - **Safe Mode vs. Fast Mode: Fast Mode**
- **General tab page (Display|Layout…):** Select **Horizontal** and **Vertical** Cross Sections.

Acquiring Data

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. Since no X-ray source is being used, the acquired images will be of the camera's dark charge. As the CCD temperature decreases, the image will get darker as the dark charge decreases. Signal changes may be more easily seen on the cross-section views.

Figure 12 shows the kind of image data you might see in WinView. The horizontal and vertical cross sections have been turned on via the **General** tab card (**Display|Layout**).

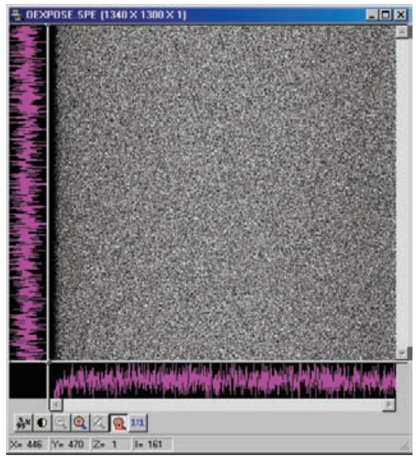


Figure 12. Example of WinView Data Acquired from First Light Procedure

Because the time to acquire and read out an image varies directly with the size of the CCD, the observed frame rate will vary greatly depending on the CCD installed. With a short exposure time, it is not uncommon for the frame readout time to be significantly longer than the exposure time: for an FCD 4096x4096 array, a full frame readout at 1 MHz takes approximately 5 seconds; for a KAF 2084x2084 array, it takes approximately 1.4 seconds.

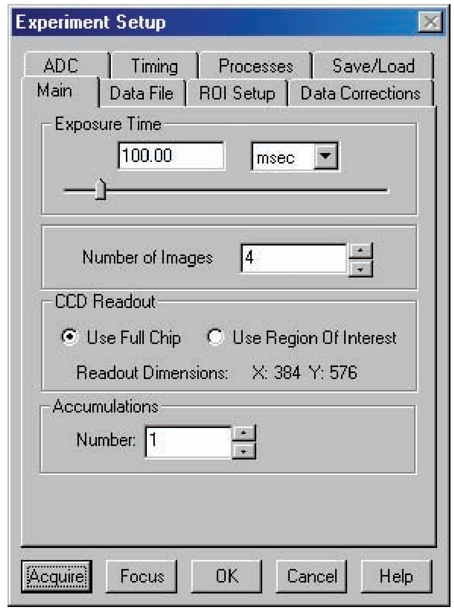
This completes *First Light*. If the system functioned as described, you can be reasonably sure it has arrived in good working order. In addition, you should have a basic understanding of how the system hardware is used. A recommended procedure for powering down the camera is provided in the next section. Other topics, which could be quite important in certain situations, are discussed in the following chapters. See the appropriate application software manual for information on using the software to control the system.

Circulator Power Down Procedure

It is recommended that the camera warm-up be carefully controlled. Proper warm-up will be achieved by proceeding as follows:

1. While running WinView, allow the camera to warm up from its current locked temperature to ambient temperature. To accomplish this, open the **Detector Temperature** dialog box, set the target temperature to ambient and wait until lock is reached.
2. Turn off the Quad-RO power supply.
3. Set the circulator's refrigeration On/Off switch to OFF.
4. Set the circulator's main power switch to OFF. This completes the warm-up procedure.

Exposure and Signal



Introduction

The following topics address factors that can affect the signal acquired on the CCD array. These factors include array architecture, exposure time, CCD temperature, dark charge, and saturation.

CCD Array Architecture

Charge coupled devices (CCDs) can be roughly thought of as a two-dimensional grid of individual photodetectors (called pixels), each connected to its own charge storage "well." Each pixel accumulates photons on its collection area, and stores a proportional amount of charge in its associated "well." Once charge accumulates for the specified exposure time (set in the software), the pixels are read out serially.

CCDs are rugged and compact: unintensified, uncoated CCDs can withstand direct exposure to relatively high light levels, magnetic fields and RF radiation. They are easily cooled and can be precisely temperature controlled to within millidegrees.

Because CCD arrays, like film and other media, are always sensitive to light, light must not be allowed to fall on the array during readout (with a few exceptions). Unintensified full-frame CCD cameras like the QUAD-RO cameras may require a customer-provided X-ray shutter to prevent light from reaching the CCD during readout.

Exposure Time

Exposure time (set on the **Experiment Setup|Main** tab page) is the time between Start Acquisition and Stop Acquisition commands sent by the application software to the camera. In combination with triggers, these commands control when continuous cleaning of the CCD stops and when the accumulated signal will be readout. The continuous cleaning prevents buildup of dark current and unwanted signal prior to the X-ray pulse. At the end of the exposure time, the CCD is readout and cleaning starts again.

Because Quad-RO cameras do not incorporate an internal shutter, some signal may accumulate on the array while it is being readout. This continuous exposure of the array during readout may result in some smearing. However, exposures that are significantly longer than the readout time can be performed without a shutter, as the amount of smearing will be low.

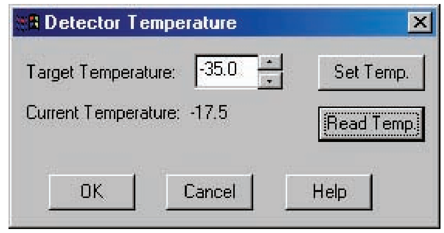
If smearing or other factors require a shutter, the **NOT SCAN** or the **SHUTTER** signal at the camera's **SCAN** output can be used to control a customer-supplied external X-ray shutter. By using one of the signals to synchronize the shutter operation with exposure, the CCD can be read out in darkness. Alternatively, the X-ray source can be interrupted elsewhere in the system while readout is taking place.

CCD Temperature

Each Quad-RO camera contains a Peltier-effect thermoelectric cooler that cools the CCD. This cooling, assisted by liquid coolant circulation, reduces the amount of dark charge that is generated on the array. A thermal sensor attached to the cooling block of the camera monitors the array temperature and the current temperature is reported back to the operating software. The operating (or target) temperature is settable in software. Ambient temperature, cooling type, and CCD array size all affect the time required to reach and stabilize at the appropriate operating temperature (see Table 2, page 65, for typical cooldown temperatures).

Setting the Temperature

The temperature of the CCD array is set through software. With WinView/32, you enter and set the target temperature after selecting **Detector Temperature** from the **Setup** menu.



Temperature Stabilization

After the system begins cooling, it takes about 60 minutes for the CCD to reach its preset temperature. Because the control loop is designed to achieve temperature lock as quickly as possible, overshoot may occur. If this happens, temperature lock will be briefly indicated and then discontinue during the overshoot. However, the lock indication will be quickly restored as stable control is re-established. This is normal behavior and should not be a cause for concern. Once temperature lock is established, the temperature is stable to within ±0.10°C (because of analog to digital conversion, the software reports stability to within ±0.20°C).

Notes:

1. The time to reach temperature lock is affected by CCD array size and the ambient temperature. Typically, the larger the array or the warmer the ambient temperature, the longer the time to reach lock. If the ambient temperature is above +23°C, temperature lock may not be achievable at the lowest specified temperature for your camera. Temperature regulation does not reach its ultimate stability for at least 30 minutes after lock is established.
2. The Detector Temperature dialog box will not display temperature information while you are acquiring data.

Dark Charge

Dark charge (or dark current) is the thermally induced buildup of charge in the CCD over time. Even with the light into the camera completely blocked, the CCD will collect a dark charge pattern, dependent on the exposure time and camera temperature. The longer the exposure time and the warmer the camera, the larger and less uniform this background will appear. Thus, to minimize dark-charge effects, you should set the camera temperature at the lowest CCD temperature within the recommended range for your camera (see Table 2, on page 65).

The statistical noise associated with dark charge is known as dark noise. Dark charge values vary widely from one CCD array to another and are exponentially temperature dependent. At the typical operating temperature of a thermoelectrically-cooled camera, dark charge is approximately cut in half for every 6-7 degree reduction in temperature. In the case of cameras such as the QUAD-RO cameras, which have MPP type arrays, the average dark charge is extremely small. However, the dark-charge distribution is such that a significant number of pixels may exhibit a much higher dark charge, limiting the maximum practical exposure.

Note: Do not be concerned about either the DC level of this background or its shape unless it is very high, i.e., >1000 counts with 16-bit ADC. What you see is not noise. It is a fully subtractable readout pattern. Each CCD has its own dark charge pattern, unique to that particular device. 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.

WARNING!

If you observe a sudden change in the baseline signal you may have excessive humidity in the camera's vacuum enclosure. Immediately turn off the system. *Refer to Appendix C and contact Princeton Instruments Customer Support for information on how to refresh the vacuum.* *See page 82 for contact information*.

Saturation

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 more frequent readout 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 averaging, determined by either the saturation of the CCD pixels by the signal or the loss of dynamic range due to the buildup of dark charge in the pixels

Readout

Introduction

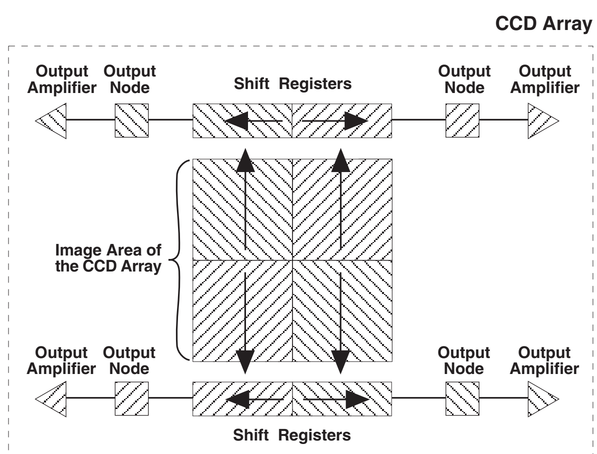


Figure 13. Array Terms for a CCD with Four Output Amplifiers

After the exposure time has elapsed, the charge accumulated in the pixels needs to be read out of the array, digitized, and transmitted to the application software where it can be displayed and/or stored. Readout begins by moving charge from the CCD image area to the shift register(s): charge from the array will be read out from four ports simultaneously or, in the case of the Quad-RO:4096, it may be read out from a single factory-selected port (four-port or single-port readout for Quad-RO:4096 cameras depends on the defined region of interest).The charge in the shift register pixels, which typically have twice the capacity of the image pixels, is then shifted into the output node(s) and then to the output(s). The signal level, which is proportional to the number of electrons collected, leaves the CCD and goes to the preamplifier(s) where gain is applied. After processing by the preamplifier(s), the signal is digitized into a numeral count that can be converted into the number of electrons collected at the pixel.

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

In WinView and WinSpec, four-port readout mode is selected whenever full image readout is selected or when the region of interest (ROI) is defined to be both vertically and horizontally symmetrical and centered.

Single-port readout is only supported for the Quad-RO:4096 cameras and is activated when the ROI is not both vertically and horizontally symmetrical and centered. The same rules apply whether or not binning is utilized. Readout in single-port mode may be significantly slower than four-port mode. The port used for single-port mode is selected at the factory because it had the lowest noise performance of the four ports.

Full Frame Readout

In this section, a simple 16 × 16 pixel CCD is used to demonstrate how charge is shifted and digitized using four-port operation. Full frame readout, for full frame CCDs, reads out the entire CCD surface at the same time.

The drawing in Figure 14 represents a CCD after exposure and shows pixels being read out of the shift registers. 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.

Readout of the CCD begins with the simultaneous shifting of all pixels toward the shift registers located along the top and bottom of the array. Each shift register is a single line of pixels along one edge of the CCD, not sensitive to light and used for readout only. Typically the shift register pixels hold twice as much charge as the pixels in the imaging area of the CCD.

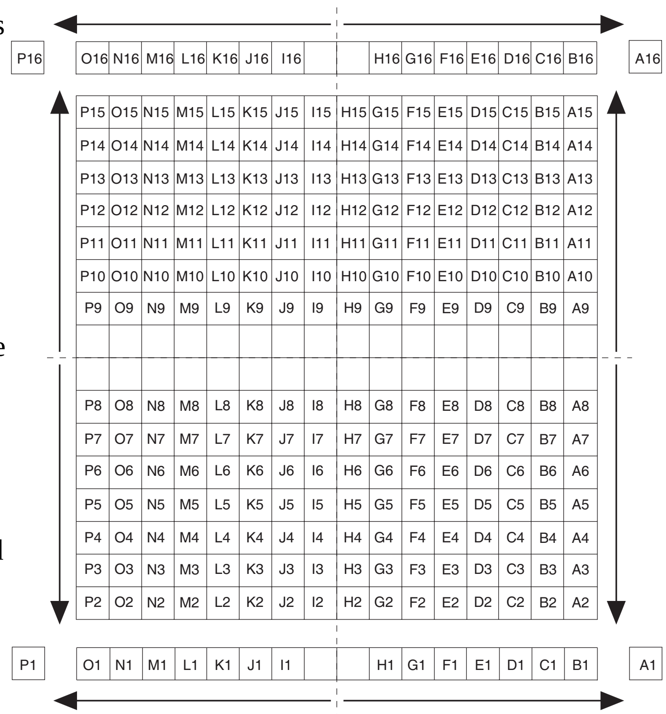


Figure 14. Full Frame at Full Resolution

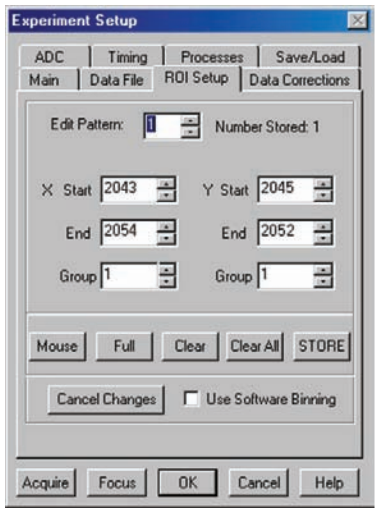
After one row from each half (top and bottom) of the array is moved into the shift registers, the charge is shifted toward the output nodes, located at each end of each shift register. As each value is “emptied” into the output it is digitized. Only after all pixels in the first pair of rows are digitized is the second pair of rows moved into the shift registers.

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). Note that some overhead time is required to shift out and discard the unwanted pixels.

Partial Frame ROI with Four-Port Readout

In WinView, four-port readout mode is selected whenever full image readout is selected or when the region of interest (ROI) is defined to be both vertically and horizontally symmetrical and centered. Figure 15 shows a 12 x 8 ROI. Because the ROI is symmetrical about the center and the middle (dashed lines) all four ports will be used during the readout.



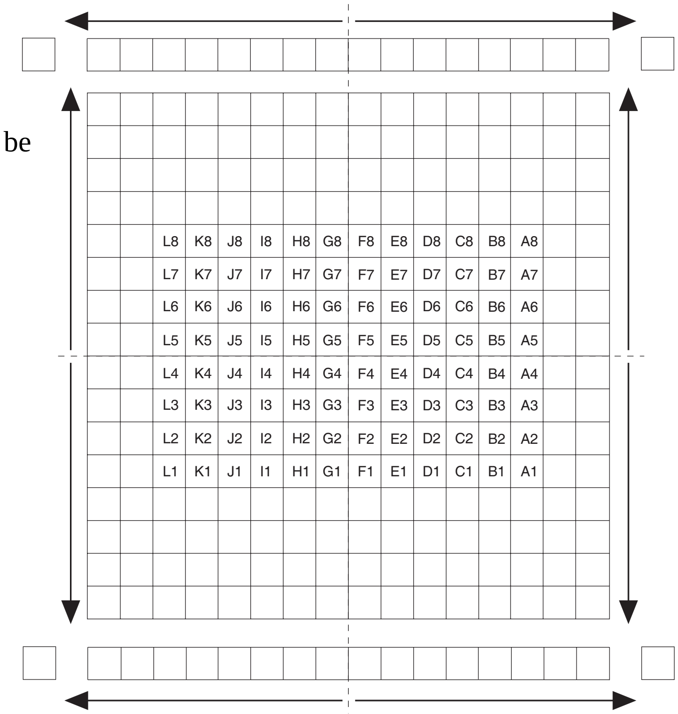


Figure 15. Symmetrical 12 x 8 Region of Interest (ROI)

Defining a Partial Frame ROI for Four-Port Readout

The following shows you how to calculate the XY Start and End coordinates for an ROI that is symmetrical about the center of the CCD.

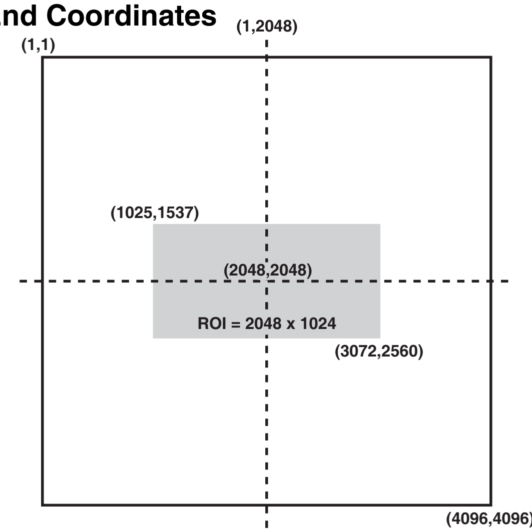
Equations for Calculating XY Start and End Coordinates

$$\text{X Start} = \left(\frac{C_x - R_x}{2}\right) + 1 \qquad \text{Y Start} = \left(\frac{C_y - R_y}{2}\right) + 1$$

$$\text{X End} = \left(\frac{C_x + R_x}{2}\right) \qquad \text{Y End} = \left(\frac{C_y + R_y}{2}\right)$$

Where:

C_x = x dimension of CCD
C_y = y dimension of CCD
R_x = x dimension of ROI
R_y = y dimension of ROI



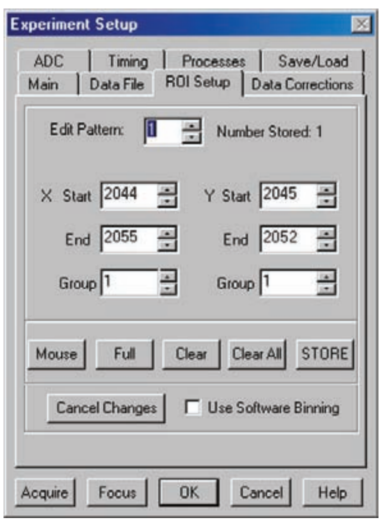
Example: 4096 x 4096 CCD, 2048 x 1024 ROI

$$\text{X Start} = \left(\frac{4096-2048}{2}\right)+1 = 1025 \quad \text{Y Start} = \left(\frac{4096-1024}{2}\right)+1 = 1537$$

$$\text{X End} = \left(\frac{4096+2048}{2}\right) = 3072 \quad \text{Y End} = \left(\frac{4096+1024}{2}\right) = 2560$$

Partial Frame ROI with Single-Port Readout (Quad-RO:4096 only)

For Quad-RO:4096 cameras, single-port readout will be used whenever an ROI does not meet the symmetrical and centered rules. Figure 16 also shows a 12 x 8 ROI, but in this case the ROI is not symmetrical about the center and the middle (dashed lines). Therefore, the image will be read out through the single port. Readout in single-port mode may be significantly slower than four-port mode. The port used for single-port mode is selected at the factory.



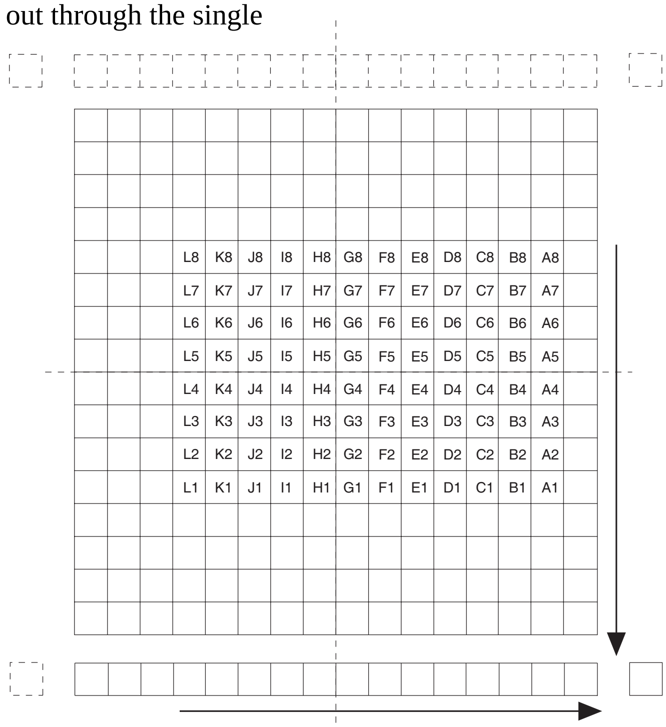


Figure 16. Asymmetrical 12 x 8 ROI

Binning

Binning is the process of adding the data from adjacent pixels together to form a single pixel (sometimes called a super pixel), and it can be accomplished in either hardware or software (on the **Experiment Setup|ROI Setup** tab page in WinView). Rectangular groups of pixels of any size may be binned together, subject to some hardware and software limitations. However, if you want to take advantage of four-port readout, you must correctly define the binned ROI. For information on the constraints and equations for this purpose, refer to ***"Defining a Binned ROI for Four-Port Readout"***, page 37.

Hardware Binning

Hardware binning is performed on the CCD array *before* the signal is read out of the output amplifier. For signal levels that are readout noise limited this method improves S/N ratio linearly with the number of pixels grouped together. For signals large enough to render the camera photon shot noise limited, the S/N ratio improvement is roughly proportional to the square root of the number of pixels binned.

Binning also reduces readout time and the burden on computer memory, but at the expense of resolution. Since horizontal shift register pixels typically hold only twice as much charge as image pixels, the binning of large sections in the column may result in saturation and "blooming", or spilling of charge back into the image area.

Note: In the case of the Quad-RO:4320, the output amplifier capacity is equivalent to the capacity of a single pixel.

Software Binning

One limitation of hardware binning is that the shift register pixels and the output node are typically only 2-3 times the size of imaging pixels. Consequently, if the total charge binned together exceeds the capacity of the shift register or output node, data accuracy will be lost.

This restriction strongly limits the number of pixels that may be binned in cases where there is a small signal superimposed on a large background, such as signals with a large fluorescence. Ideally, one would like to bin many pixels to increase the S/N ratio of the weak peaks but this cannot be done because the fluorescence would quickly saturate the CCD.

The solution is to perform the binning in software. In WinView, software binning is specified on the **Experiment Setup|ROI Setup** tab page (Figure 17). Limited hardware binning may be used when reading out the CCD. Additional binning is accomplished in software, producing a result that represents many more photons than was possible using hardware binning.

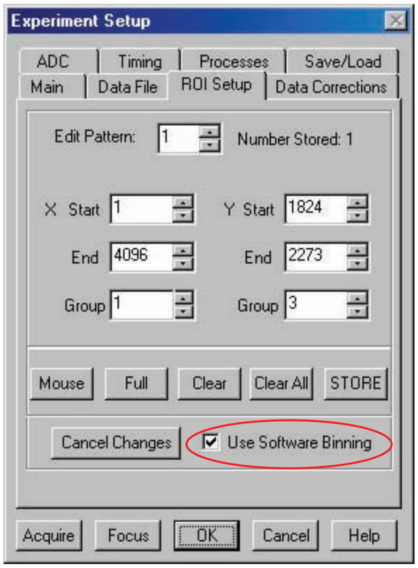


Figure 17. Software Binning Selected in WinView

Software averaging can improve the S/N ratio by as much as the square root of the number of scans. Unfortunately, with a high number of scans, i.e., above 100, camera 1/f noise may reduce the actual S/N ratio to slightly below this theoretical value. Also, if the light source used is photon-flicker (1/f noise) limited rather than photon shot-noise limited, this theoretical signal improvement cannot be fully realized. Again, background subtraction from the raw data is necessary.

This technique is also useful in high light level experiments, where the camera is again photon shot-noise limited. Summing multiple pixels in software corresponds to collecting more photons, and results in a better S/N ratio in the measurement.

Defining a Binned ROI for Four-Port Readout

To ensure four-port readout, you must adhere to the following rules when setting up for binning (hardware or software):

The binned ROI must be centered horizontally and vertically on the CCD and it must have an even number of pixels or superpixels in the X and Y dimensions.

Equations for Calculating XY Start and End Coordinates for Binned ROI

X Start = $\left(\frac{C_x}{2}+1\right)-\left(\frac{R_{xb}}{2}\times G_x\right)$ Y Start = $\left(\frac{C_y}{2}+1\right)-\left(\frac{R_{yb}}{2}\times G_y\right)$

X End = $\frac{C_x}{2}+\left(\frac{R_{xb}}{2}\times G_x\right)$ Y End = $\frac{C_y}{2}+\left(\frac{R_{yb}}{2}\times G_y\right)$

Where:

C_x = x dimension of CCD
C_y = y dimension of CCD
R_{xb} = x dimension of binned ROI
R_{yb} = y dimension of binned ROI
G_x = x dimension Group size (binning factor)
G_y = y dimension Group size (binning factor)

Example: 4096 x 4096 CCD, 4096 x 150 ROI (Y group size = 3)

X Start = 1 Y Start = $\left(\frac{4096}{2}+1\right)-\left(\frac{150}{2}\times 3\right)=1824$

X End = 4096 Y End = $\frac{4096}{2}+\left(\frac{150}{2}\times 3\right)=2273$

Analog Gain Control

Analog gain control (a function of the preamplifier) is used to change the relationship between the number of electrons acquired on the CCD and the Analog-to-Digital Units (ADUs or counts) generated. In WinView/32 and WinSpec/32, the analog gain choices vary depending on the CCD array and the number of output amplifiers (Quad-RO:4320 and Quad-RO:4096 have a single amplifier per readout port.).

In most instances, the analog gain should be set to **Medium (1x)**. In situations where the A/D range exceeds that of the array, it will generally be better to set the Analog Gain to **High** so that the signal can be spread over as much of the A/D range as possible. This is a particularly important consideration in absorbance measurements. Users who consistently measure low-level signals or run the detector in binned mode may wish to select **High (1/2x)**. Users who measure high-level signals may wish to select **Low (2x)** to allow digitization of larger signals.

Example: The following descriptions assume that the actual incoming light level is identical in all three instances. ***The numbers used illustrate the effect of changing an analog gain setting and may not reflect actual performance: gain at the Low, Medium, and High settings depends on the CCD installed and the amplifier selected.***

Low requires eight electrons to generate one ADU. Strong signals can be acquired without flooding the image. If the gain is set to **Low** and the images or spectra appear weak, you may want to change the gain setting to **Medium** or **High**.

Medium requires four electrons to generate one ADU. If the gain is set to **Medium** and the images or spectra do not appear to take up the full dynamic range of the CCD array, you may want to change the gain setting to **High**. If the image appears to be flooded with light, you may want to change the setting to **Low**.

High requires two electrons to generate one ADU. Because fewer electrons are needed to generate an ADU, weaker signals can be more readily detected. If the image appears to be flooded with light, you may want to change the setting to **Medium** or **Low**.

Digitization

Introduction

After gain has been applied to the signal, the Analog-to-Digital Converter (ADC) converts that analog information (continuous amplitudes) into a digital data (quantified, discrete steps) that can be read, displayed, and stored by the application software (see ***"Readout",*** page 32).

Digitization Rate

The Quad-RO camera has two readout rates (500 kHz/1 MHz). Because the readout noise of CCD arrays increases with the readout rate, it is sometimes necessary to trade off readout speed for high dynamic range. The 1 MHz conversion speed is used for the fastest possible data collection and the 500 kHz conversion speed is used where noise performance is the paramount concern. Switching between the conversion speeds is completely under software control for total experiment automation.

Note: The ADC rate can be changed on the **Experiment Setup|ADC** tab page.

WARNING! If you observe a sudden change in the baseline signal and readout speed has not been changed, you may have excessive humidity in the camera's vacuum enclosure. ***TURN OFF THE SYSTEM IMMEDIATELY.*** *Contact Princeton Instruments Customer Support for information on how to refresh the vacuum. See page 82 for contact information*.

Chapter 6

Advanced Topics

Introduction

Previous chapters have discussed setting up the hardware and the software for basic operation. This chapter discusses topics associated with experiment synchronization (set up on the **Experiment Setup|Timing** tab page in WinView and WinSpec).With the exception of Edge Trigger, the topics are addressed in order of their appearance on the Timing tab page (see Figure 18).

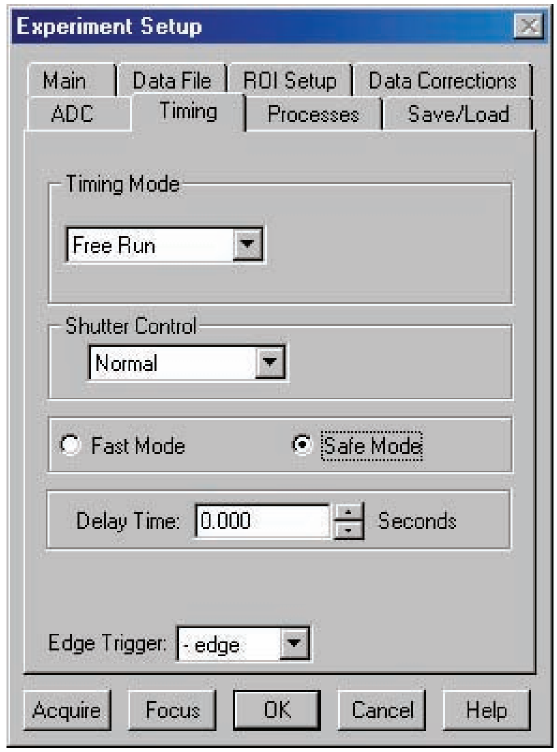


Figure 18. Timing tab page

"Timing Modes", the first topic, discusses Timing Modes, Shutter Control, and Edge Trigger. Also included under this topic is a discussion of the **EXT SYNC** connector, the input connector for a trigger pulse.

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

"Logic Out Control", the final topic, discusses the **SCAN** and **READY** output connectors on the Quad-RO. The levels at these connectors can be used to monitor camera operation or synchronize external equipment.

Standard Timing Modes

The chart to the right lists the timing mode combinations (selected on the **Experiment Setup|Timing** tab page). Use this chart in combination with the detailed descriptions in this chapter to determine the optimal timing configuration.

Mode	Shutter
Free Run	Normal
External Sync	Normal
External Sync	PreOpen
External Sync with Continuous Cleans	Normal
External Sync with Continuous Cleans	PreOpen

Table 1. Camera Timing Modes

The basic timing modes are Free Run, External Sync, and External Sync with Continuous Cleans. These modes are combined with the Shutter options to provide the widest variety of timing modes for precision experiment synchronization.

The shutter options available include Normal, PreOpen, Disable Opened or Disable Closed. Disable Open simply means that the shutter will not operate during the experiment. Disable Closed is useful for making dark charge measurements or when no shutter is present. PreOpen, available in the External Sync and External Sync with Continuous Cleans modes, opens the shutter as soon as the camera is ready to receive an External Sync pulse. This is required if the time between the External Sync pulse and the event is less than a few milliseconds, the time it takes the shutter to open.

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

The timing diagrams are labeled indicating the exposure time (t_{exp}), shutter compensation time (t_c), and readout time (t_R). Note that if no shutter is selected in the software, the shutter compensation time (the time allowed for a mechanical shutter to close) will be approximately 0 ms.

Free Run

In the Free Run mode the controller does not synchronize with the experiment in any way. The shutter opens as soon as the previous readout is complete, and remains open for the exposure time, t_{exp}. Any External Sync signals are ignored. This mode is useful for experiments with a constant light source. Other experiments that can utilize this mode are high repetition studies, where the number of shots that occur during a single shutter cycle is so large that it appears to be continuous illumination.

Other experimental equipment can be synchronized to the camera by using the output signal (software-selectable **SHUTTER** or **NOT SCAN** on the **Hardware Setup|Controller Camera** tab page) from the $\overline{\textbf{SCAN}}$ connector. Shutter operation and the NOT SCAN output signal are shown in Figure 20.

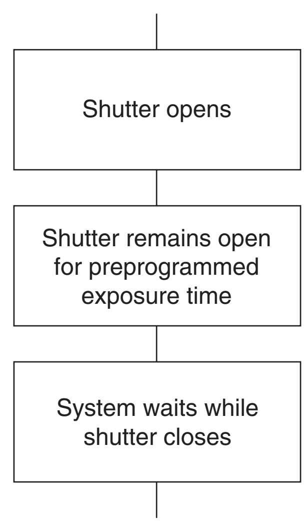
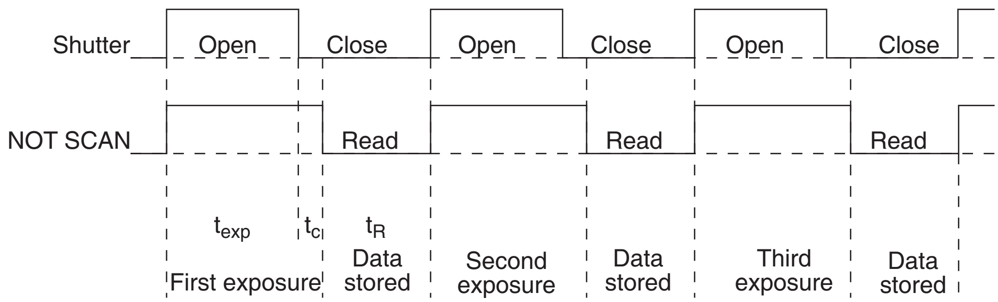


Figure 19. Free Run Timing Chart, part of the chart in Figure 25



t_{exp} = Exposure Time
t_R = Readout Time
t_c = Shutter Compensation Time*

Shutter Type	* Shutter Compensation Time
Custom	0-21 sec (0-21,000 ms in 1 ms increments)

Figure 20. Free Run Timing Diagram

To accommodate the range of timings required by x-ray diffraction studies, WinView and WinSpec provide a programmable shutter compensation time of up to 21 seconds in increments of 1 millisecond. The factory default is zero seconds. To set the compensation time, open the **Controller/Camera** tab panel on the **Setup|Experiment** dialog box and enter the desired value (in milliseconds) in the text box below **Shutter Type**.

External Sync

In this mode all exposures are synchronized to an external source via signal input to the Ext Sync BNC on the back of the camera. To ensure synchronization, the trigger edge (negative- or positive-going) of the Ext Sync signal must be identified in the application software (in WinView and WinSpec, this is done on the **Experiment Setup|Timing** tab page). As shown in the flowchart, Figure 21, External Sync mode can be used in combination with Normal or PreOpen Shutter operation. In Normal Shutter mode, the controller waits for an External Sync pulse and then opens the shutter for the programmed exposure period. As soon as the exposure is complete, the shutter closes and the CCD array is read out.

Because the external shutter requires a finite amount of time to open completely (shutter open time may be 5–28 msec depending on the shutter), the External Sync pulse trigger edge provided by the experiment should precede the actual signal by at least that much time. If not, the shutter will not be open for the duration of the entire signal, or the signal may be missed completely.

Also, since the amount of time from initialization of the experiment to the first External Sync pulse trigger edge is not fixed, an accurate background subtraction may not be possible for the first readout. In multiple-shot experiments this is easily overcome by simply discarding the first frame.

In the PreOpen Shutter mode, on the other hand, shutter operation is only partially synchronized to the experiment. As soon as the controller is ready to collect data, the shutter opens. Upon arrival of the first External Sync pulse trigger edge, the shutter remains open for the specified exposure period, closes, and the CCD is read out. As soon as readout is complete, the shutter reopens and waits for the next frame.

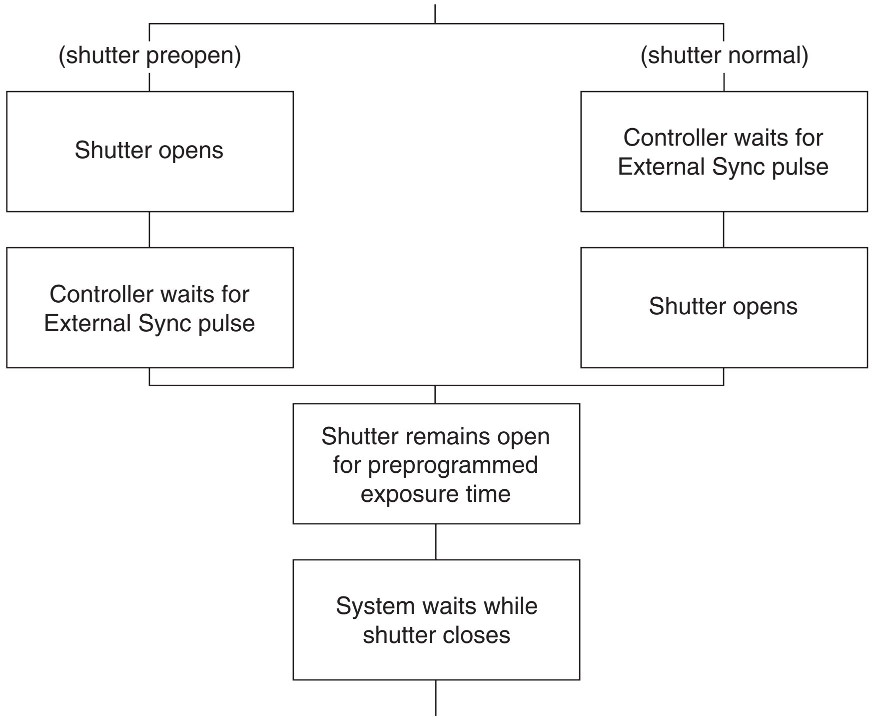


Figure 21. Chart Showing Two External Sync Timing Options

The PreOpen mode is useful in cases where an External Sync pulse trigger edge cannot be provided 5–28 msec (shutter open time) before the actual signal occurs. Its main drawback is that the CCD is exposed to any ambient light while the shutter is open between frames. If this ambient light is constant and the triggers occur at regular intervals, this background can also be subtracted, providing that it does not saturate the CCD. As with the Normal Shutter mode, accurate background subtraction may not be possible for the first frame.

Also note that, in addition to signal from ambient light, dark charge accumulates during the “wait” time (t_w). Any variation in the external sync frequency also affects the amount of dark charge, even if light is not falling on the CCD during this time.

Note: If EXT SYNC is still active (in Figure 22, this means that if it is still LOW) at the end of the readout, the hardware may interpret this as a second sync pulse, and so on.

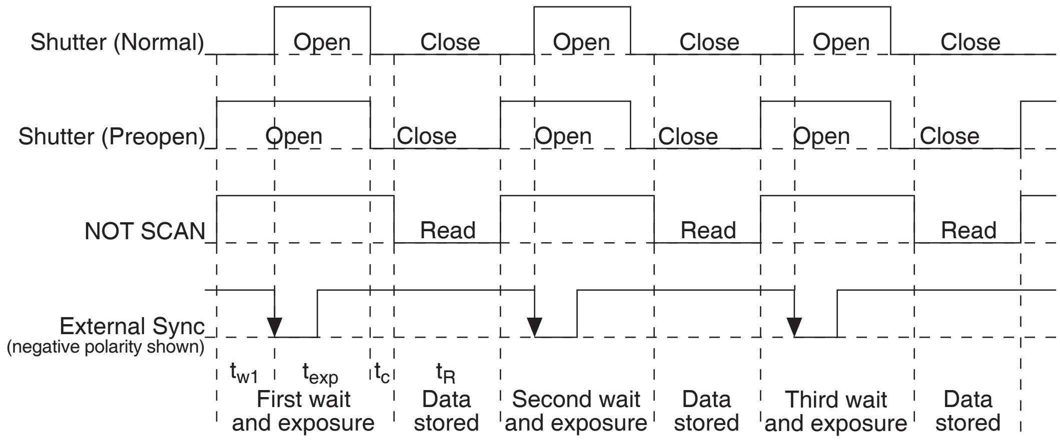


Figure 22. Timing Diagram for the External Sync Mode (- edge trigger)

External Sync with Continuous Cleans

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

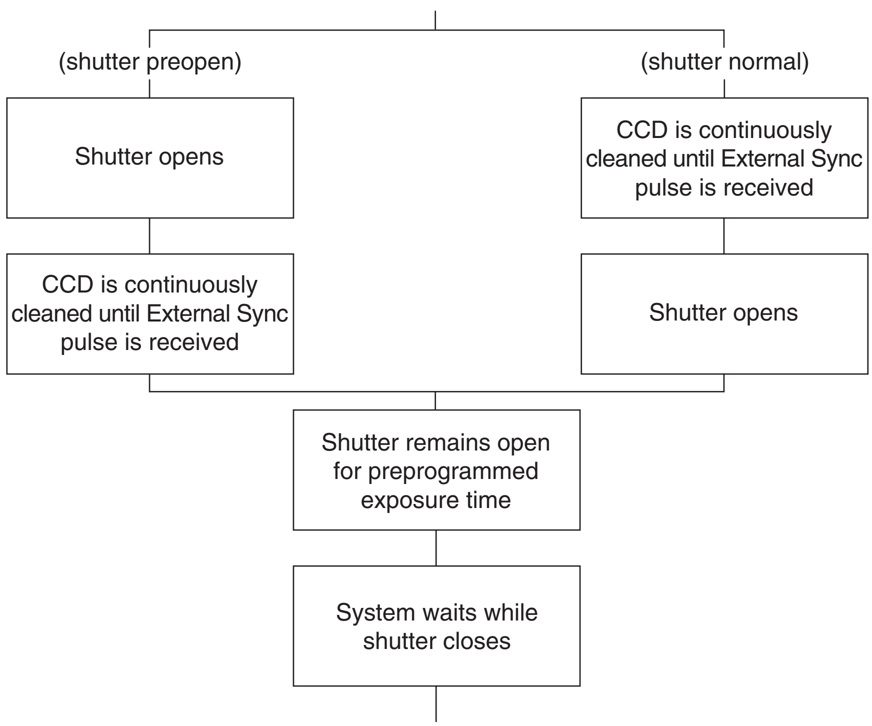


Figure 23. Continuous Cleans Operation Flowchart

Once the External Sync pulse trigger edge is received, cleaning of the array stops as soon as the current cleaning cycle is complete, and frame collection begins: a maximum time delay equal to the cleaning cycle time can be expected (a cleaning cycle can be defined through software). With Normal Shutter operation the shutter is opened for the set exposure time. With PreOpen Shutter operation the shutter is open during the continuous cleaning, and once the External Sync pulse trigger edge is received, the shutter remains open for the set exposure time, then closes. If the cleaning is in mid-cycle when the External Sync pulse trigger edge arrives, the exposure is delayed until the cleaning cycle is complete, to prevent the CCD from getting "out of step." As expected, the response latency is determined by the defined cleaning cycle and may be estimated as approximately 2 msec per row. 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 arrives before the clean cycle is complete, image smearing is possible. The amount of smearing is a function of the signal duration compared to the cleaning cycle time.

Notes:

1. For minimum delay, set **Number of Cleans** = 1 and **Number of Strips per Clean** = 1 on the **Hardware Setup|Cleans/Skips** tab.
2. If EXT SYNC is still active (in Figure 24, this means that if it is still LOW) at the end of the readout, the hardware may interpret this as a second sync pulse, and so on.

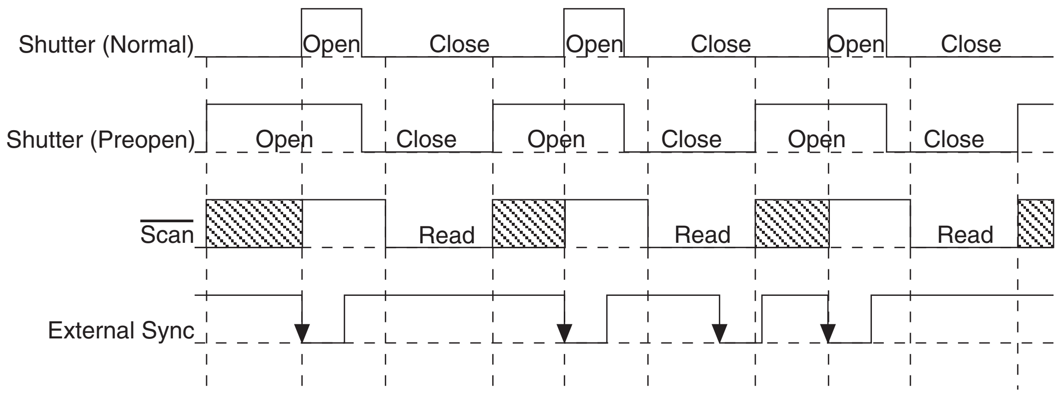


Figure 24. Continuous Cleans Timing Diagram (-edge trigger)

Fast Mode and Safe Mode

The **Experiment Setup|Timing** tab page allows you to choose **Fast Mode** or **Safe Mode**. Figure 25 is a flowchart comparing the two modes. In Fast Mode operation, the camera runs according to the timing of the experiment, with no interruptions from the computer. In Safe Mode operation, the camera will not begin collection of the next frame until commanded to do so by the software.

Fast Mode operation is primarily for collecting "real-time" sequences of experimental data, where timing is critical and events cannot be missed. Once the camera is sent the Start Acquisition 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: WinView/32 will automatically allocate enough memory to hold all of the images collected in one acquisition pass. In fast mode, the “Number of images” is set in the “Experiment Setup” dialog. The amount of memory required expressed in bytes for one image frame is determined by, *frame memory = rows X columns X 2*. For a 4096x4096 full frame image *frame memory* = 32Mbytes. The total memory required in fast mode is, *total required memory = frame memory X number of frames*.

Safe Mode operation is primarily useful for experiment setup, including alignment and focusing, when it is necessary to have the most current image displayed on the screen. It is also useful when data collection must be coordinated through software with external devices such as external shutters and filter wheels. As seen in Figure 25, in Safe Mode operation, the computer controls when each frame is taken. After each frame is received, the camera sends the Stop Acquisition command to the camera, instructing it to stop acquisition. Once that frame is completely processed and displayed, another Start Acquisition 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 internal controller is disabled for a short time after each frame.

Note: WinView/32 will automatically allocate enough memory to hold all of the images collected in one acquisition pass. The amount of memory required expressed in bytes for one image frame is determined by, *frame memory = rows X columns X 2*. For a full frame image *frame memory* = 32Mbytes. The total memory required in safe mode is equal to the memory required for one frame.

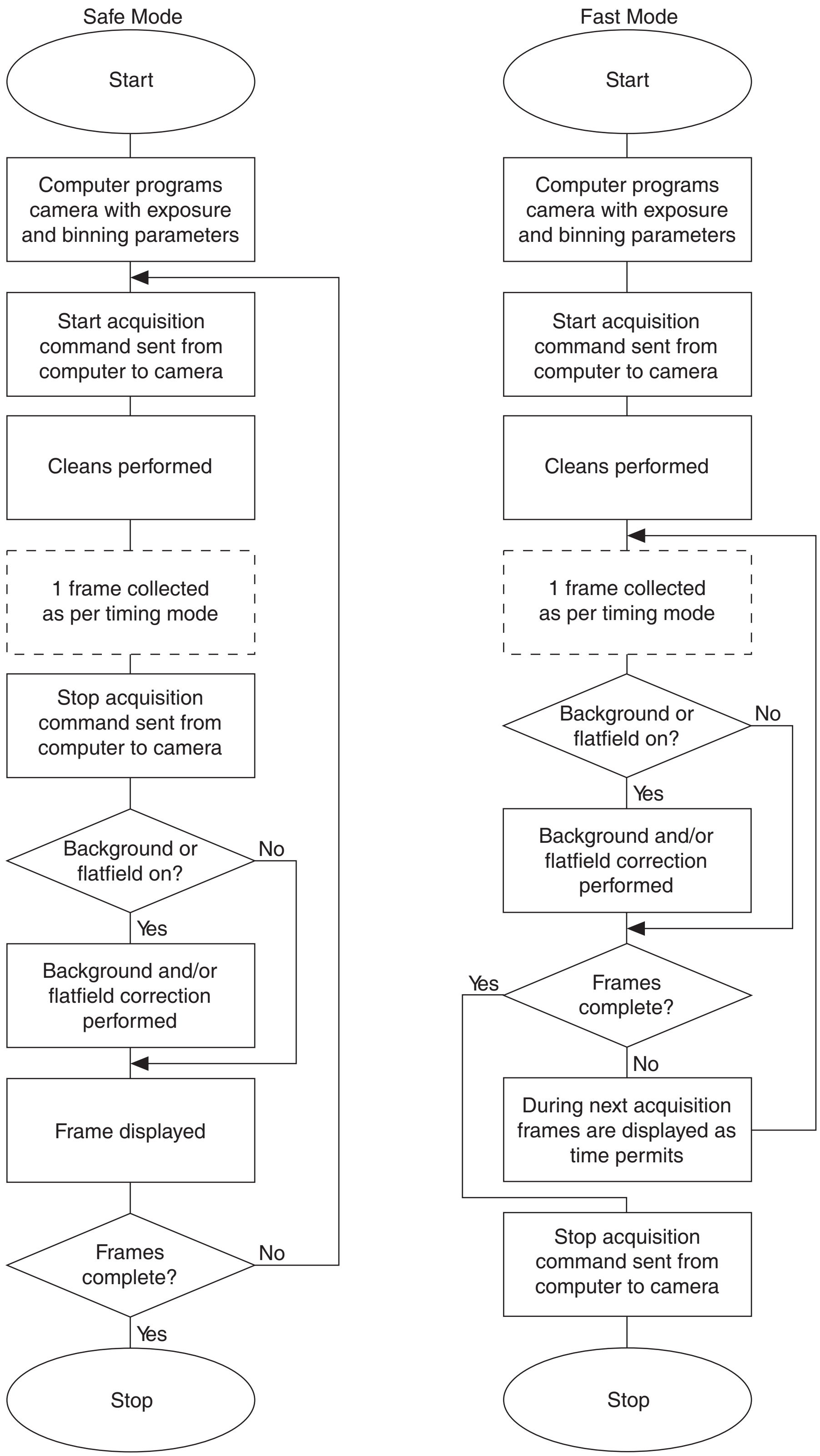


Figure 25. Chart of Safe Mode and Fast Mode Operation

LOGIC OUT Control

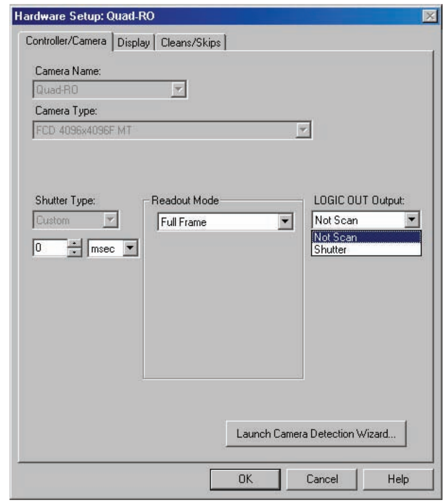


Figure 26. Hardware Setup| Controller/Camera tab page

The TTL-compatible logic level output (0 to +3 V) from the **SCAN** and **READY** connectors on the camera can be used to monitor camera status and control external devices.

- **SCAN:** It is at a logic low when CCD is being read; otherwise high. The timing of level changes depends on the output type selected on the **Hardware Setup|Controller/Camera** tab page: *Not Scan* or *Shutter*.
- **READY:** After a start acquisition command, this output changes state when the camera is ready to begin the first exposure or is ready to receive an **EXT TRIG** signal. Initially high, it goes low to mark the beginning of the first exposure. In free run operation it remains low until the system is halted. If a specific number of frames have been programmed, it remains low until all have been taken and then returns high. Figure 27 assumes 2 frames have been programmed.

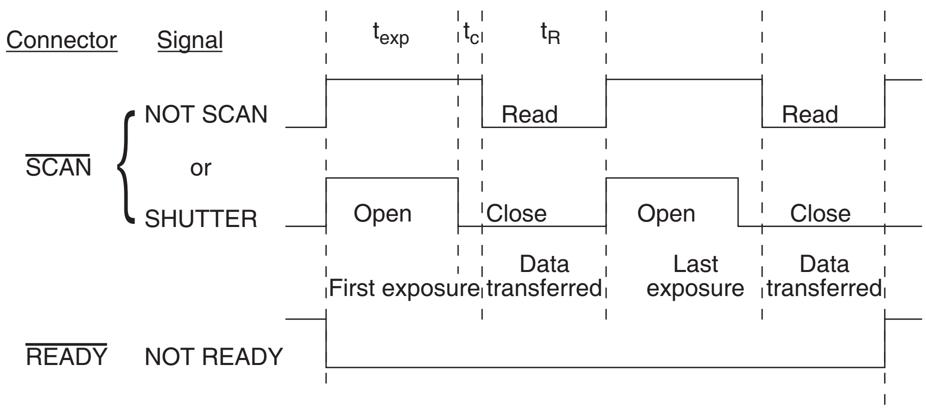


Figure 27. Comparison of NOT SCAN, SHUTTER, and NOT READY Logic Output Levels

Since the **SCAN** connector can have one of two different signals, the figure above shows three different timing diagrams. The difference between the two **SCAN** connector signals is that **SHUTTER** goes low at the end of the exposure time while **NOT SCAN** goes low after the shutter compensation time has elapsed. The shutter compensation time compensates for the time that it actually takes a shutter to fully close.

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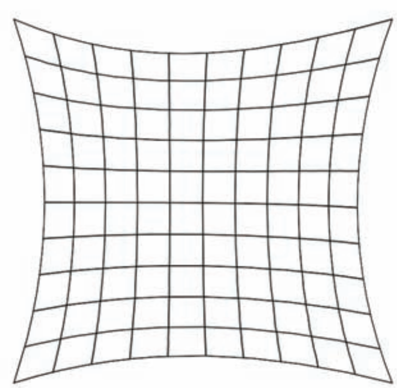
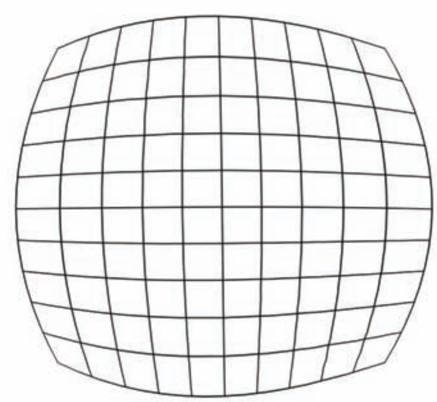
Chapter 7
Distortion Correction

Introduction

Imperfections in fiberoptic tapers can result in various geometric distortions of the image. Such distortions are commonly of the “pin-cushion” type, which give concave sides to a rectangular grid, or of the “barrel” type, which give convex sides to a rectangular grid, or a combination of these two types.



Pin-cushion distortion



Barrel distortion

The mapping of a regular grid at the image plane at the top of the fiberoptic taper to a distorted grid at the bottom of the taper (near the surface of the CCD) can be obtained, and an inverse transform can be developed and applied to the raw data to correct for such distortions in all images acquired with that taper.

For tapers having a 1:1 ratio, this correction is not necessary. For tapers having other ratios, including the 165-mm taper (2.7:1 ratio) of some Quad-RO:4096 models, a WinView/WinSpec snap-in is now available that performs this correction.

The Distortion Correction Snap-in

The snap-in is described in this section; its installation and use are described in the next two sections. The **Distortion Correction** dialog box is shown to the right.

The experimental conditions are set up using the **Experiment Setup** dialog box. The **Exposure** time can also be changed from the snap-in. The correction is valid only for full-frame images with binning factors of 1, 2, 4, 8, and 16, and both directions must have the same binning values.

The **Distortion correction** check box is active only when the **Background** and **Flat Field** check boxes are selected and appropriate image files are selected in the **Data Corrections** tab panel of the **Experiment Setup** dialog box.

While the **Distortion Correction** dialog box is open, any changes made in the **Experiment Setup** dialog box are not automatically updated in the correction dialog. Press **Sync to Exp Setup** after exiting **Experiment Setup** to show the changes in the correction dialog.

When the distortion correction is performed, the uncorrected raw data is not saved. If the **Output File** text box (to the right) is left blank, an output filename is created by appending "_xdc" to the source window name.

The distortion correction requires calibration files unique to each camera that are provided by the factory along with the snap-in. An error message is displayed when the snap-in cannot find the calibration files in the predefined folder. Make sure the folder "xdctables" is in the same directory as the snap-in.

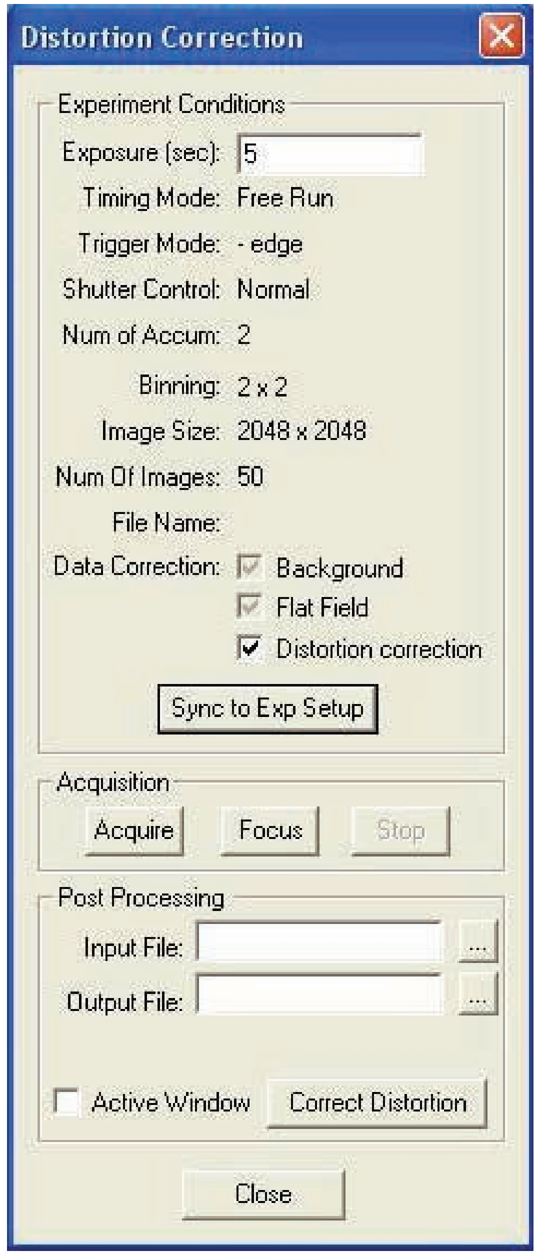


Figure 28. Distortion Correction dialog box

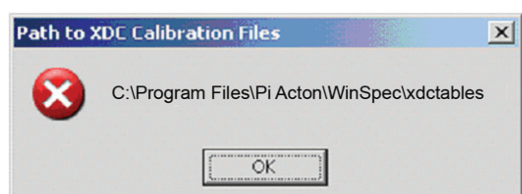


Figure 29. Distortion Correction error message

Installing the Distortion Correction Snap-in

To install the distortion correction snap-in:

1. Close WinView32 or WinSpec32 if it is running.
2. Copy the DLL (DistortionCorrection.dll) to the WinView32 or WinSpec32 folder (C:\Program Files\PI Acton\WinView)
3. Click on **Start**, then **Run**, and type **cmd** and click **OK** to get the command prompt.
4. Navigate to the WinView32 or WinSpec32 directory (\Program Files\PI Acton\WinView)
5. Type **regsvr32** followed by a space and the DLL name (i.e., regsvr32 DistortionCorrection.dll), press enter, and a message of successful DLL registration should pop-up.
6. Restart WinView32 or WinSpec32 and an icon for the snap-in should appear on the Snap-In tool bar.

Applying the Distortion Correction

To perform an acquisition that applies the distortion correction:

1. A background subtraction file must be acquired or loaded. If the flat field correction is to be applied, an appropriate flat field file must be acquired or loaded.
2. Click on the distortion correction snap-in button on the Snap-In toolbar.
3. If experimental settings are changed after opening the **Distortion Correction** dialog box, press **Sync to Exp Setup** to have the current settings appear in the **Distortion Correction** dialog box.
4. Select **Focus** or **Acquire** to begin obtaining data.

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Chapter 8

Troubleshooting

Introduction

The Quad-RO system is designed to be highly reliable. Nevertheless, problems could develop. In most instances, the best recourse will be to contact the factory for guidance. Most often the system will be most reliably and quickly restored to service by identifying the faulty component and returning it to the factory for service. The information in this chapter is provided as an aid for gathering information that will assist in identifying the source of the problem. The most likely problem with the camera would be gradual deterioration of the vacuum to where temperature lock can no longer be achieved.

WARNING! Do ***NOT*** attempt any disassembly of the camera. The camera sections have Indium vacuum seals where they join. Attempting to disassemble the camera would damage these seals. Once the integrity of a seal is compromised, there would be no alternative but to return the camera to the factory for repair. Such a repair would ***not*** be covered by the equipment Warranty.

The following issues have corresponding troubleshooting sections in this chapter.

Baseline Signal Suddenly Changes	Page 54
Camera not found	Page 54
Camera is not detected by the Camera Detection Wizard	Page 54
Camera Stops Working	Page 56
Changing the Power Supply Line Voltage and Fuses	Page 56
Controller Is Not Responding	Page 57
Cooling Troubleshooting	Page 58
Data Loss or Serial Violation	Page 59
Editing PVCAM.INI	Page 59
Error Creating Controller message	Page 60

Baseline Signal Suddenly Changes

If you observe a sudden change in the baseline signal, you may have excessive humidity in the vacuum enclosure of the camera. Turn off the controller and have the camera repumped before resuming normal operation. *Contact the factory Customer Support Dept. for information on how to refresh the vacuum. See page 82 for contact information.*

Camera not found

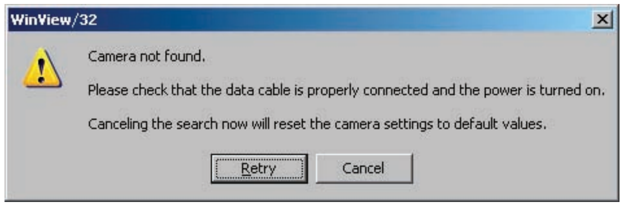


Figure 30. Camera not found dialog box

If you see this dialog box when you start WinView, click on the **Cancel** button, WinView will open but you will not be able to acquire data until the camera is detected. Close WinView and check that the camera is properly connected to the host computer and that the host computer recognizes the camera as a peripheral. If the camera is connected and powered on, but not recognize as a peripheral, disconnect the interface cable at either end. Wait approximately 10 seconds and then reconnect the camera. Once the camera is properly connected and recognized, restart WinView.

Camera is not detected by the Camera Detection Wizard

Figure 31. Camera Detection Wizard - Detected Hardware dialog box

1. Click Cancel, then close WinView.
2. Verify that the FireWire (1394a cable) is plugged into the host computer and the camera.
3. Verify that the camera has power.
4. Verify that the host computer recognizes the camera as a peripheral.
5. Click on the **Back** button to return to the Welcome dialog box.
6. Click on the **Next** button.

7. If the camera is still not detected, exit WinView.
8. Run RSConfig from the **Windows|Start|Programs|PI Acton** menu or from the directory where you installed WinView.
9. When the RSConfig dialog box (Figure 32) appears, confirm that the camera is listed.

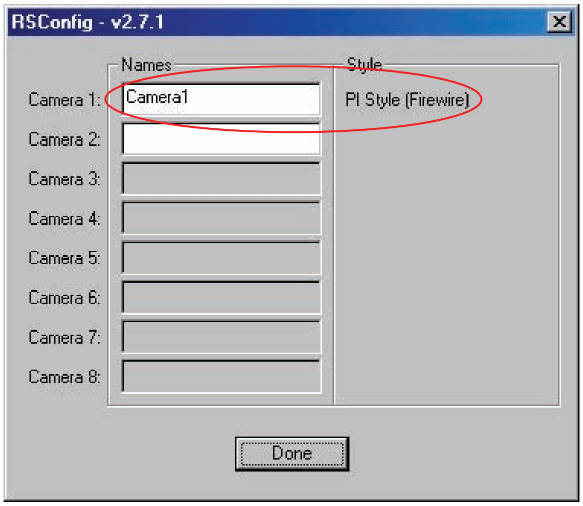


Figure 32. RSConfig dialog box

10. Start WinView, select Setup from the Hardware menu and rerun the Camera Detection Wizard. You should now see the camera listed on the Detector Hardware dialog box as shown in Figure 33 below.

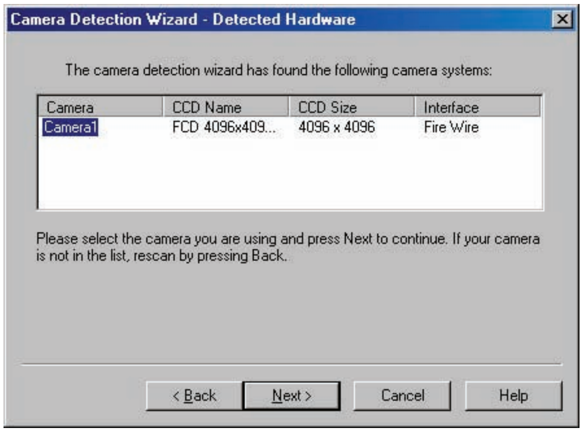


Figure 33. Camera Detection Wizard - Detected Hardware dialog box

11. If more than one camera is listed, select the camera shown above and then click on the **Next** button to continue.

Note: You can change the camera name to one that is more specific or you can keep the default name "Camera1". To change the name, you will need to edit the PVCAM.INI file. Instructions for that operation are included in ***"Editing PVCAM.INI"*** on page 59.

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 QUAD-RO system hardware, begin with these simple checks:

- Turn off all AC power.
- Verify that all cables are securely fastened and that all locking screws are in place.
- Correct any apparent problems and turn the system on.

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

Changing the Power Supply Line Voltage and Fuses

The appropriate voltage setting for your country is set at the factory and can be seen on the back of the power module. If your voltage source changes, you will need to change the voltage setting and you may need to change the fuse configuration.

WARNING! Use proper fuse values and types for the power supply and camera to be properly protected.

To Change Voltage and Fuse Configuration:

WARNING! Before opening the power module, turn the power supply OFF and unplug the powercord.

1. As shown in Figure 34, place the flat side of a flat bladed screwdriver parallel to the back of the power supply and behind the small tab at the top of the power module, and twist the screwdriver slowly but firmly to pop the module open.
2. To change the voltage setting, roll the selector drum until the setting that is closest to the actual line voltage is facing outwards.
3. Confirm the fuse ratings by removing the two white fuse holders. To do so, simply insert the flat blade of the screwdriver behind the front tab of each fuse holder and gently pry the assembly out.

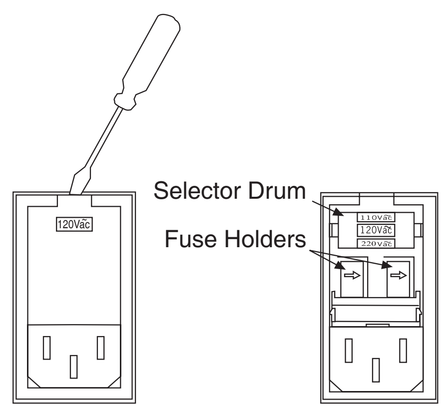


Figure 34. Power Input Module

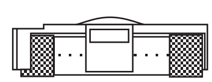


Figure 35. Fuse Holder

4. Refer to the Fuse/Voltage label to see which fuses are required by the selected voltage.
5. After inspecting and if necessary, changing the fuses to those required by the selected voltage, reinstall the holders with the arrow facing to the right.

6. Close the power module and verify that the correct voltage setting is displayed.
7. Verify that the Power Supply power switch is in the OFF position and then plug the powercord back into the power module.

Controller Is Not Responding

If this message pops up when you click on **OK** after selecting the "Interface Type" during **Hardware Setup** (under the WinView/32 **Setup** menu), the system has not been able to communicate with the camera. Check to see if camera has been turned ON and if the interface card, its driver, and the interface cable have been installed.

1. Close WinView.
2. Check power connection to camera.
3. Check FireWire (1394a) cable connections at the camera and the computer.
4. Disconnect one end of the cable and verify that the camera is not recognized by the computer.
5. Reconnect the cable and verify that the computer recognizes it. This may take a few seconds.
6. Restart WinView.

If the system is still not able to communicate with the camera:

1. Verify that the following INF and SYS files have been installed on your computer:

Windows Version	FireWire INF Filename Located in "Windows"\INF directory*	USB Device Driver Name Located in "Windows"\System32\Drivers directory
Windows® 2000 and XP	pi1394.inf (in WINNT\INF, for example)	pi1394.sys (in WINNT\System32\Drivers, for example)

* The INF directory may be hidden.

2. If these files are not installed, you are probably running an older version of WinX software. Quad-RO support was added with Version 2.5.20.2. To check the software version, open WinView and select **About WinView** from the **Help** menu. If your software is not 2.5.20.2 or higher, contact *Customer Support* for information on updating your software.

Cooling Troubleshooting

Temperature Lock Cannot be Achieved or Maintained.

CAUTION

Operating a Quad-RO camera with coolant at a temperature colder than specified could cause induced condensation in the electronics enclosure and possible catastrophic damage to the camera. ***Damage resulting from this type of operation may void the warranty.***

Possible causes could include:

- Ambient temperature greater than +23°C. If it is greater than +23°C, you will need to cool the camera environment or raise the set temperature.
- The vacuum has deteriorated and needs to be refreshed.
- The target array temperature is not appropriate for your particular camera and CCD array.
- The coolant flow rate may be insufficient due to a pinched coolant line, blockages, circulator power problem, or pump failure. Check the flow rate and coolant temperature.

Over-temperature Failsafe

The Quad-RO has built-in failsafe temperature control. This mechanism monitors the wet plate temperature and controls the Peltier cooler drive to prevent overheating. The Quad-RO will begin to allow the CCD to warm in order to prevent overheating. If left uncorrected, cooler power will eventually be shut down completely.

Overheating is usually the result of loss of coolant or coolant flow restriction. Check the coolant level in your circulator, ensure that your coolant pump is running and check for obstructions or pinching of the coolant hoses. Once coolant flow is restored and the wet plate temperature drops below the safe limit, the Quad-RO will automatically resume cooling the CCD.

Camera loses Temperature Lock

The internal temperature of the camera is too high. This might occur if the operating environment is particularly warm or if you are trying to operate at a temperature colder than the specified limit. If this happens, the Quad-RO may not be able to achieve the desired CCD temperature or may not be able to hold the temperature constant.

Check for:

- proper coolant flow,
- sufficient coolant level, and (if applicable)
- check that the coolant chiller is turned on.

If you are operating in high ambient temperatures, you can try increasing your CCD temperature setting to a value that can be more easily maintained.

If conditions are nominal and the coolant flow is proper, you may be experiencing vacuum loss. See the next section for more information.

Gradual Deterioration of Cooling Capability

With time, there may be a gradual deterioration of the camera's 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.

Vacuum deterioration occurs primarily as a result of material outgassing in the vacuum chamber. Because outgassing normally diminishes with time, the rate of vacuum deterioration in new cameras may be faster than in old ones. For example, a camera that has to be repumped after perhaps a year of operation, may not have to be pumped again for several years. In any case you may notice a gradual deterioration in temperature control performance indicative of vacuum deterioration. If this happens, the camera will have to be repumped. Appendix D provides directions for repumping the vacuum. If you have the appropriate equipment and personnel with the necessary expertise available, you may wish to pump down the camera at your facility by following the procedure outlined in Appendix D. If the necessary equipment and expertise isn't available, simply contact the factory to make arrangements for returning the camera to the support facility nearest to you to have the vacuum restored.

Data Loss or Serial Violation

You may experience either or both of these conditions if the host computer has been set up with Power Saving features enabled. This is particularly true for power saving with regard to the hard drive. Make sure that Power Saving features are disabled while you are running WinView/32.

Editing PVCAM.INI

When a PVCAM-based camera is detected/selected during the Camera Detection wizard, a default name such as Camera1 will be shown in the Detected Hardware table and will be entered in the **Camera Name** field on the **Setup|Hardware|Controller/CCD** tab page and in the Hardware Setup title bar. Because this name is not particularly descriptive, you may want to change it. Such a change is made by editing the PVCAM.INI file that is generated by Camera Detection wizard.

To change the default Camera Name:

1. Using **Notepad** or a similar text editor, open **PVCAM.INI**, which is located in the Windows directory (C:\WINNT, for example). You should see entries like the ones below.

   [Camera_1]
   Type=1
   Name=Camera1
   Driver=pi1394.sys
   Port=0
   ID=523459

2. Change the "Name=" entry to something more meaningful for you (for example, QuadRO:4096 - to indicate that this is a PVCAM-based system using a QuadRO:4096 camera). Then save the edited file.

   [Camera_1]
   Type=1
   Name=QuadRO:4096

Driver=pi1394.sys
Port=0
ID=523459

3. The new camera name will now appear in the **Camera Name** field and in the title bar for the Hardware Setup dialog box.

Error Creating Controller message

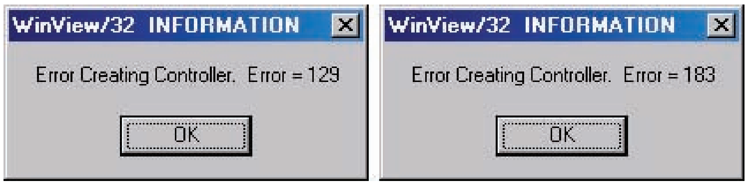


Figure 36. Error Creating Controller dialog box

This message may appear if the PVCAM.INI file has become corrupted or if the camera was not turned on before you started WinView and began running the Camera Detection wizard. If one of these dialog boxes pops up:

1. See ***"Controller Is Not Responding"***, page 57.
2. Run the Camera Detection Wizard.

Declaration of Conformity

This section of the Quad-RO system manual contains the declaration(s) of conformity for Quad-RO systems.

DECLARATION OF CONFORMITY

We

ROPER SCIENTIFIC

(PRINCETON INSTRUMENTS)

3660 QUAKERBRIDGE ROAD

TRENTON, NJ 08619

Declare under our sole responsibility, that the product

Quad-RO CAMERA SYSTEM

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

IEC 1010-1:1990, EN 61010-1:1993/A2:1995,

EN 61326 for Class A:1997 incorporating A1:1998, A2:2001, and A3:2003 (IEC 61000-3-2:2000, IEC 61000-3-3:1995 (A1:2001), IEC 61000-4-2, IEC 61000-4-3, IEC 61000-4-4, IEC 61000-4-5,

IEC 61000-4-6, IEC 61000-4-11)

Which follow the provisions of the

CE LOW VOLTAGE DIRECTIVE 73/23/EEC

And

EMC DIRECTIVE 89/336/EEC.

Date: March 26, 2007
TRENTON, NJ

William Asher
Vice President of New Product Development

Appendix A
Specifications

CCD Arrays

Types

The following list is not necessarily current. Other chips may also be available. Contact the factory for up-to-date information.

Model	WinView/32 Name	Pixel Format	Pixel Size	CCD Type
4320	KAF 2084×2084 MT	2084 × 2084	24 × 24 µm	16 bits, 1 MHz/500 kHz per output amplifier, Full Frame
4096	FCD 4096×4096F MT	4096 × 4096	15 × 15 µm	16 bits, 1 MHz/500 kHz per output amplifier, Full Frame, MPP

Quad-RO:4096

Array Size: 4096×4096
Pixel Size: 15×15 µm
Image Area: 61.44 × 61.44 mm
Port Readout: Four port or single port
Output Amplifier (MPP): 400 ke$^-$ typical
Read Noise: Single pixel = 12 e$^-$ (typical) / 16 e$^-$ (max) @ 1 MHz
Grade: Grade 1
Parallel Shift Time: 180 µs
Pixel Well: 80 ke$^-$ typical

Quad-RO:4320

Array Size: 2084×2084
Pixel Size: 24×24 µm
Image Area: 50.02 × 50.02 mm
Port Readout: Four port
Output Amplifier: 500 ke$^-$ typical
Read Noise: Single pixel = 10 e$^-$ (typical) / 14 e$^-$ (max) @ 1 MHz
Grade: Grade 1
Parallel Shift Time: 120 µs
Pixel Well: 500 ke$^-$ typical

Camera Window

Beryllium (Be); 20 mil (500 µm) thick

Camera Connector

6-pin FireWire (IEEE 1394a)

Pin	Name	Notes
1	Power	Power (18–25 V, 15 W)
2	GND	Ground
3	TPB-	Pair B-
4	TPB+	Pair B+
5	TPA-	Pair A-
6	TPA+	Pair A+

4-pin FireWire (IEEE 1394a)

Pin	Name	Notes
1	TPB–	Pair B–
2	TPB+	Pair B+
3	TPA–	Pair A–
4	TPA+	Pair A+
(Shell)	GND	Ground

Camera Cooling

Quad-RO:4320 and Quad-RO:4096 -40°C with +5°C water

Water Cooling: Mixture of 50% ethylene glycol and 50% water pumped through coolant ports at the rear of the camera.

Gain

Software selectable (high, medium, low)

Temperature Control

Setting Mechanism: Temperature is set by the application software.

Display: The actual temperature can be displayed at the computer by the application software.

Control Precision: ±0.10°C; closed-loop stabilized-temperature control

Cooldown Temperature (typical): As long as the ambient temperature is between +0°C and +25°C and the humidity is <50%, Quad-RO CCDs can typically be cooled down to the following temperatures:

Camera	Cooldown Temperature
Quad-RO:4320	–40°C with +5°C circulating water
Quad-RO:4096	–40°C with +5°C circulating water

Table 2. Camera vs. Approximate Cooldown Temperature

If the ambient temperature is greater than +23°C, temperature lock may not be achievable at the above temperatures

Power Supply

Input Voltage	*Fuse*
100/120	5A
220/240	2.5A

Power: 50/60 Hz, 200 W maximum

Dimensions

All dimensions are approximate and subject to change. Refer also to the outline drawings in Appendix B.

Quad-RO:4320 (75 mm)

Width: 6.00 in (16.92 cm)

Length: 9.60 in (24.38 cm)

Height: 6.66 in (16.92 cm)

Weight: 23 lb (10.43 kg)

Quad-RO Power Supply

Width: 13.00 in (33.0 cm)

Length: 17.04 in (43.3 cm)

Height: 6.99 in (17.7 cm)

Weight: 30 lb (13.6 kg)

Quad-RO:4096 (90 mm)

Width: 6.0 in (15.24 cm)

Length: 9.32 in (23.67 cm)

Height: 6.66 in (16.92 cm)

Weight: 23 lb (10.43 kg)

Quad-RO:4096 (165 mm)

Width: 8.50 in (21.59 cm)

Length: 11.0 in (27.9 cm)

Height: 8.50 in (21.59 cm)

Weight: 43.5 lb (19.75 kg)

FireWire (IEEE 1394a)

Supports data transfer rates of up to 400 Mbps.

TTL I/O

Input:
 External Sync
Outputs:
 $\overline{\text{READY}}$: frame start
 $\overline{\text{SCAN}}$: shutter/readout status

Mounting

Square case camera

Mounting holes (bottom of camera):	two M8 × 1.25 tap (0.75″ deep) and one 1/4″–20 tap (0.50" deep)

Cylindrical case camera

Mounting holes (side of camera):	two 8–32 tap (0.420″ deep)
Mounting holes (opposite side of camera):	two 1/4″–20 tap (0.400″ deep)

Mounting adapter

Mounting holes:	two M8 × 1.25 tap (0.500″ deep) and one 1/4″–20 tap (0.500″ deep)

Fiber Ratios*

1:1 option	Distortion and vignetting-free optical coupling
2.67:1 option	Large field of view (160+ dia.)

Custom Phosphors*

Gd_2O_2S:Tb	Available for 8 keV, 12 keV, and 17 keV; resolution of 60 to 80 µm; emission wavelength ~550 nm
CsI:TI	Available for 8–25 keV and 80 keV; resolution of 20 to 40 µm; emission wavelength ~550 nm

* Contact Princeton Instruments for information about additional fiber ratios and phosphors

Appendix B
Outline Drawings

Note: All dimensions are in inches [mm] unless otherwise noted.

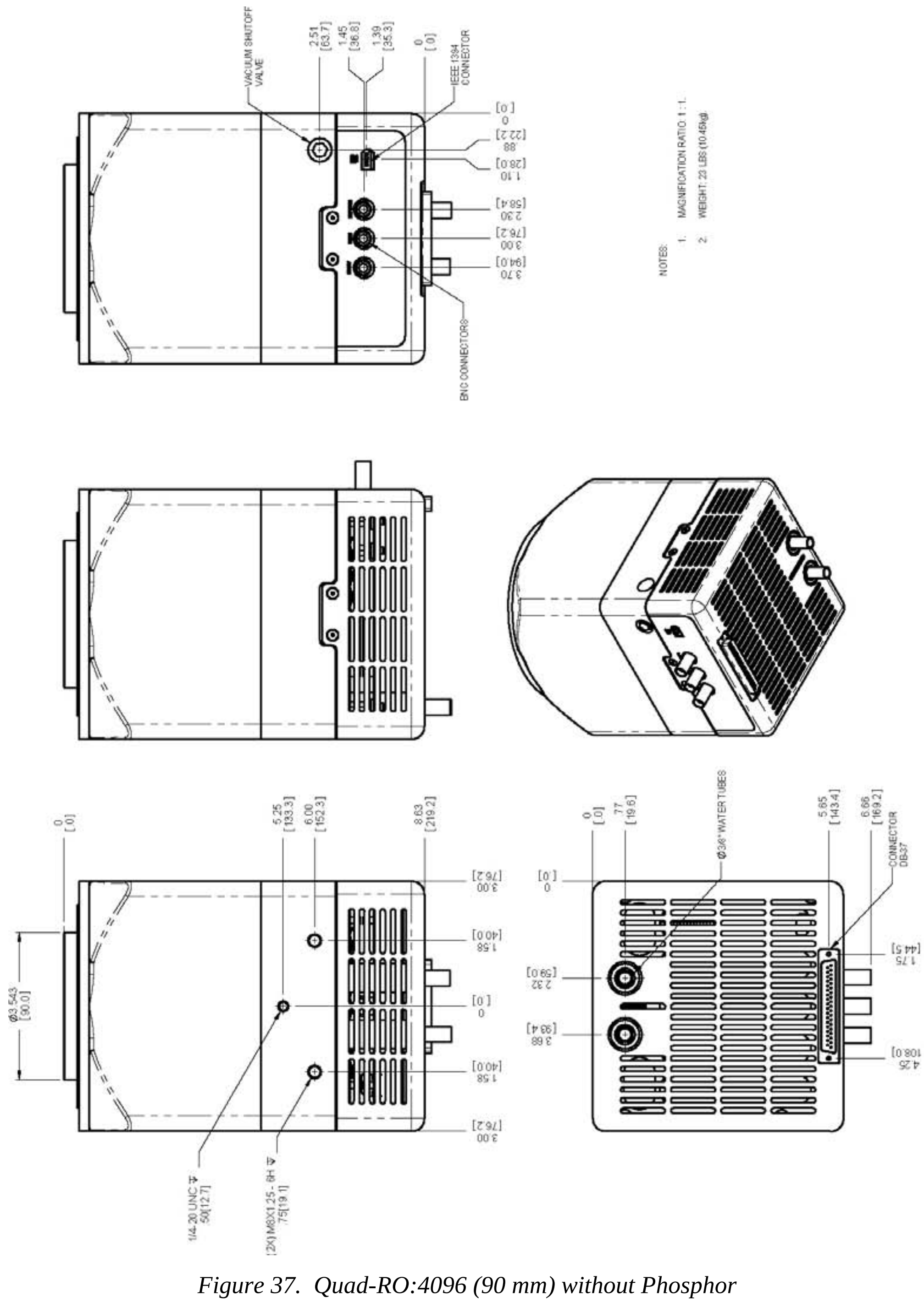


Figure 37. Quad-RO:4096 (90 mm) without Phosphor

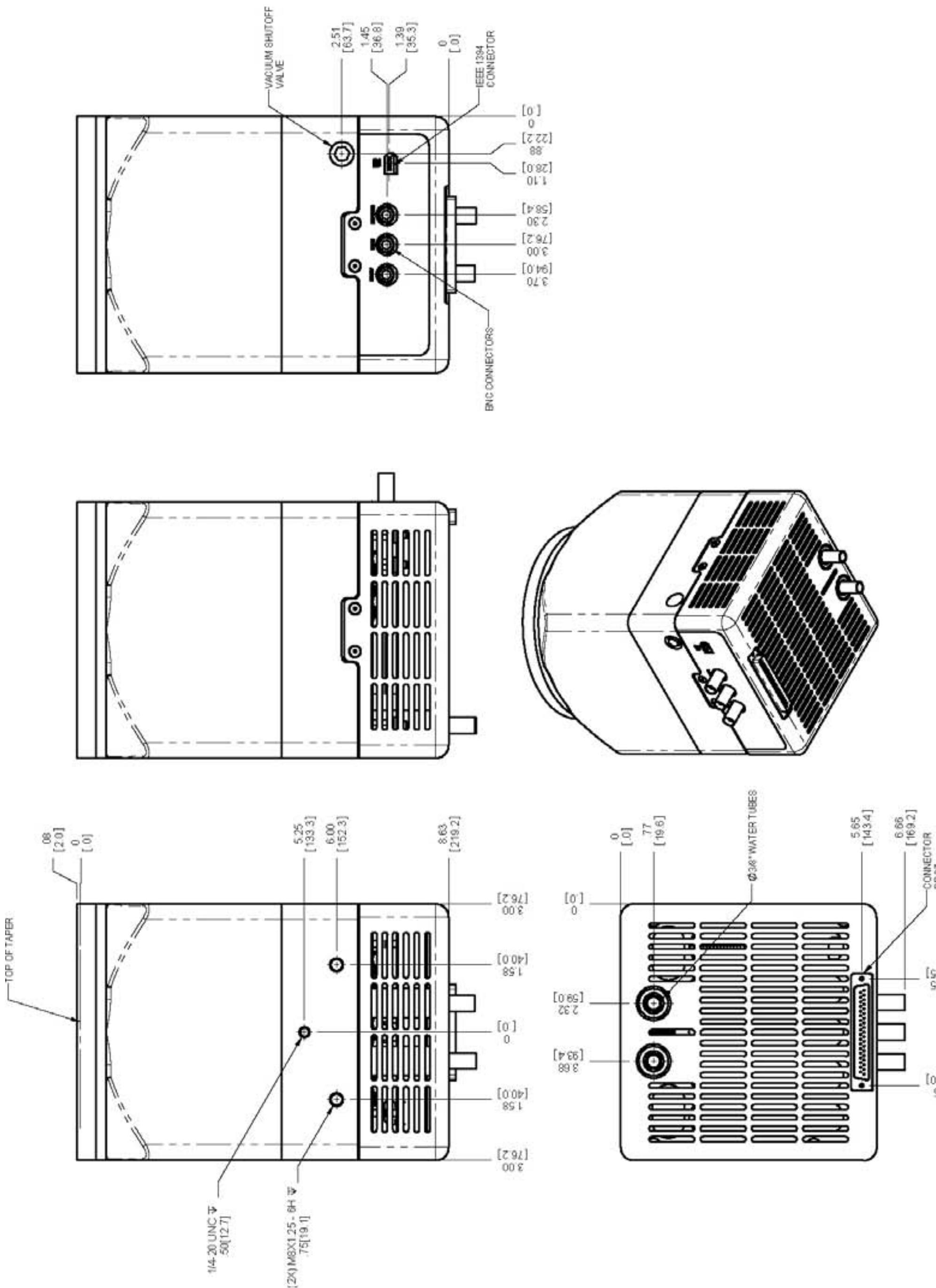


Figure 38. Quad-RO:4096 (90 mm) with Phosphor

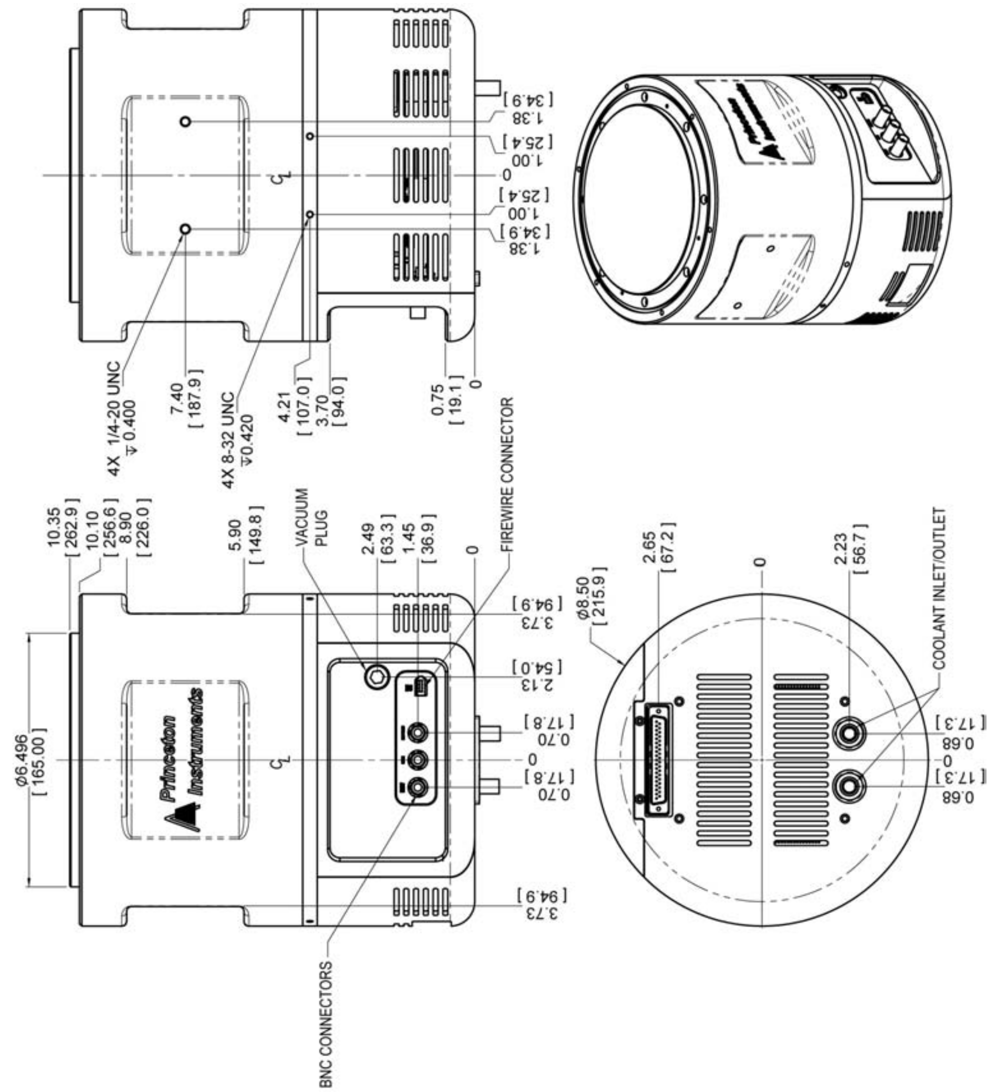


Figure 39. Quad-RO:4096 (165 mm) without Phosphor

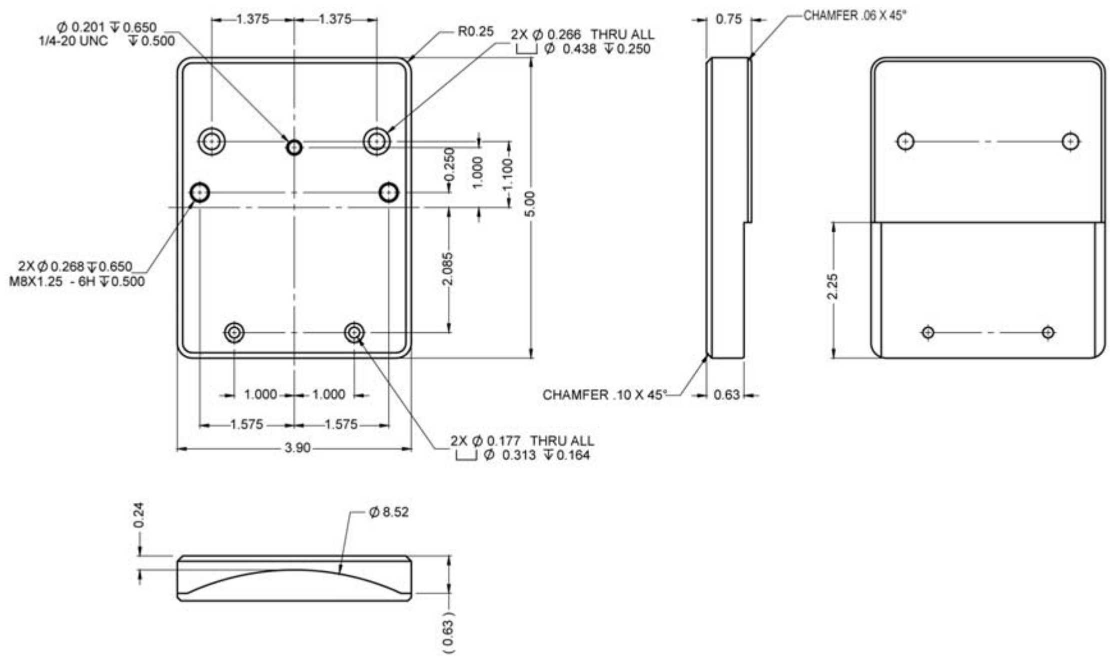


Figure 40. Quad-RO:4096 (165 mm) Camera Mount

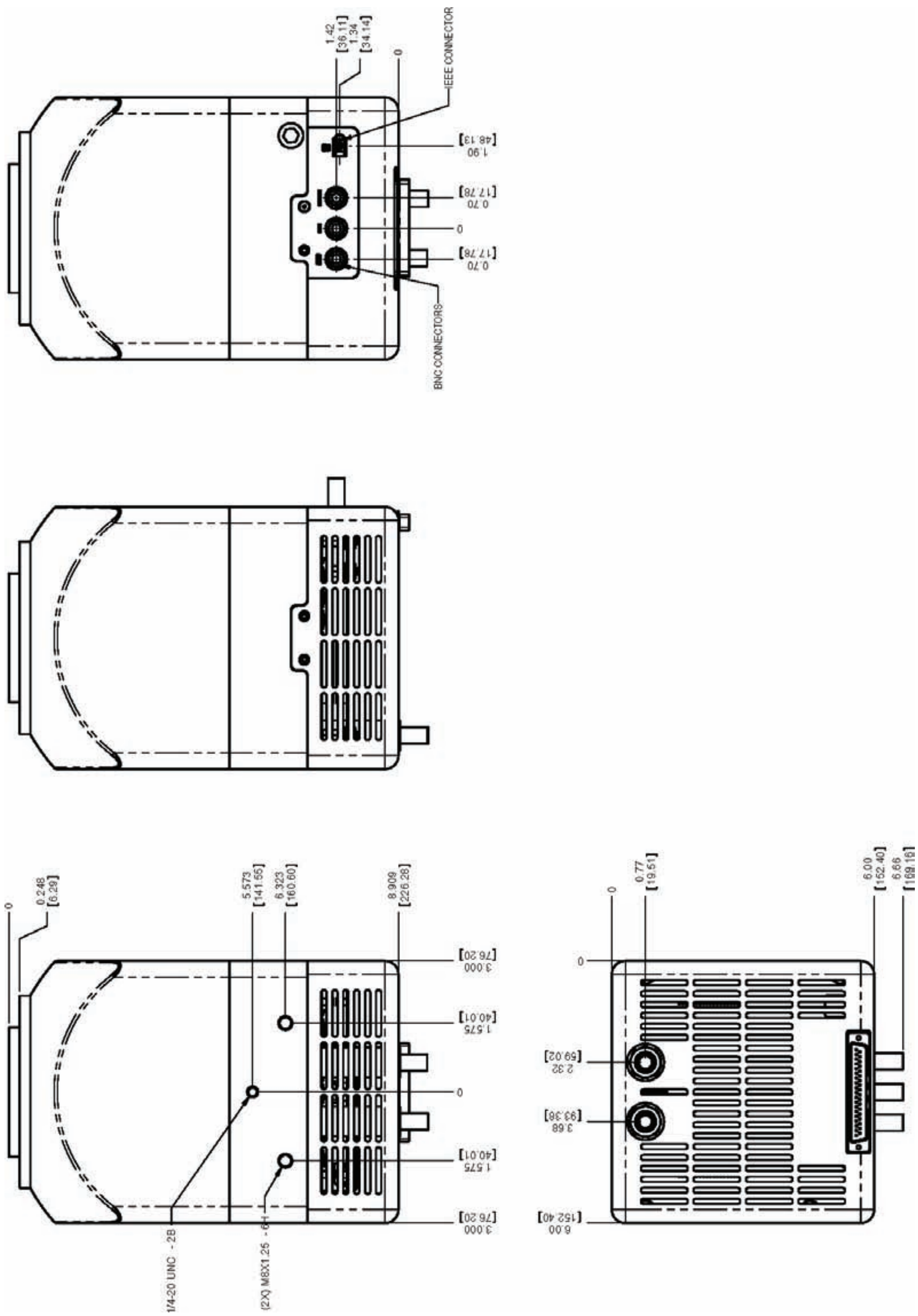


Figure 41. Quad-RO:4320 without Phosphor

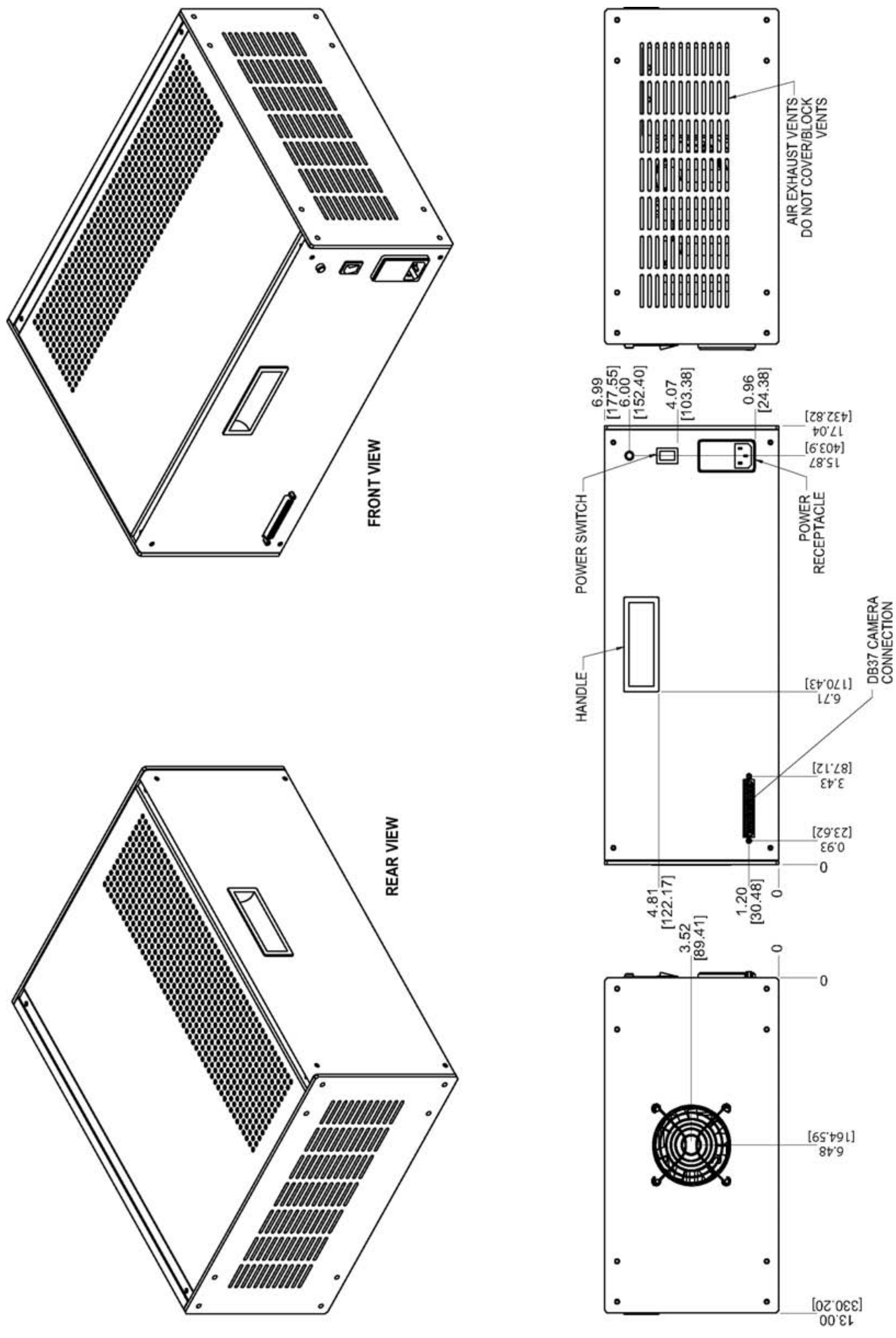


Figure 42. Quad-RO Power Supply

Appendix C
Swagelok Fittings

Installation

Swagelok Tube Fittings come completely assembled, finger-tight, and are ready for immediate use. Disassembly before use is unnecessary and could result in dirt or foreign material getting into the fitting and causing leaks.

Swagelok Tube Fittings are installed in three (3) easy steps, as follows.

Step 1
Simply insert the tubing into the Swagelok Tube Fitting. Make sure that the tubing rests firmly on the shoulder of the fitting and that the nut is finger-tight.

Step 2
Before tightening the Swagelok nut, scribe the nut at the 6 o’clock position.

Step 3
Hold the fitting body steady with a backup wrench and tighten this nut 1¼ turns. Watch the scribe mark, making one complete revolution and continue to the 9 o’clock position

By scribing the nut at the 6 o’clock position as it appears to you, there will be no doubt as to the starting position. When the nut is tightened 1¼ turns to the 9 o’clock position, you can easily see that the fitting has been properly tightened.

Use of the Gap Inspection Gauge (1¼ turns from finger-tight) ensures sufficient pull-up.

Notes:

For 1/16″, 1/8″, 3/16″, 2 mm, 3 mm and 4 mm size tube fittings, only ¾ turn from finger tight is necessary.

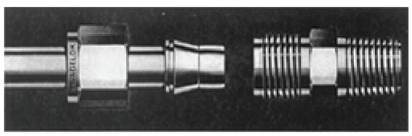
A Swagelok Hydraulic Swaging unit must be used for assembly of Swagelok Tube Fittings onto 1¼″, 1½″, 2″, 28 mm, 32 mm, and 38 mm outside diameter steel and stainless steel tubing.

High Pressure Applications or High-Safety-Factor Systems

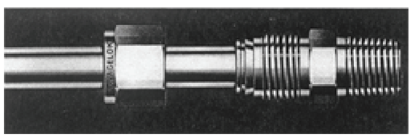
Due to variations in tubing diameters, a common starting point is desirable. Using a wrench, tighten the nut to the SNUG position. Snug is determined by tightening the nut until the tubing will not rotate freely (by hand) in the fitting. *If tube rotation is not possible, tighten the nut approximately 1/8 turn from the finger-tight position.* At this point, scribe the nut at the 6 o'clock position and tighten the nut 1¼ turns. The fitting will now hold pressures well above the rated working pressure of the tubing.

Retightening Instruction

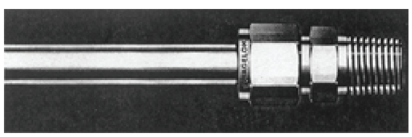
Connections can be disconnected and retightened many times. The same reliable leak-proof seal can be obtained every time the connection is remade. Directions follow.



Fitting shown in the disconnected position.



Insert tubing with preswaged ferrules into fitting body until front ferrule seats.



Tighten nut by hand. Rotate nut to the original position with a wrench. *An increase in resistance will be encountered at the original position.*

Then tighten slightly with the wrench. Smaller tube sizes will take less tightening to reach the original position, while larger tube sizes will require more tightening. The wall thickness will also have an effect on tightening.

Appendix D
Repumping the Vacuum

Introduction

Fiberoptic taper CCD cameras are shipped with a vacuum level below 10^{-5} Torr to assure proper cooling performance and to prevent condensation from collecting on the CCD. In time, the vacuum level could deteriorate to where achieving temperature lock will no longer be possible. If this happens, it will be necessary to restore the vacuum.

A ¼″ Vacuum Pumping fitting (Figure 43) is supplied with the camera but is not factory installed. The access port, located at the top of the camera, is capped. The cap can easily be removed, allowing the vacuum pumping fitting to be installed.

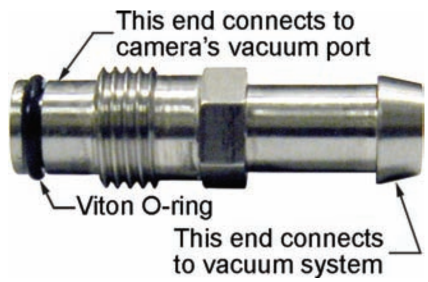


Figure 43 Vacuum Pumping Fitting

A special Indium-tipped Vacuum Seal (Figure 44) is installed in the side of the camera (see Figure 10). At installation, the Vacuum Seal's Indium tip is crushed to provide a metal-to-metal seal in the vacuum chamber. The number of times this can be done before a new Vacuum Seal is required is limited. Typically, an Indium tip can be crushed up to ten times before the Vacuum Seal must be replaced to assure a good vacuum seal. Because the tip is crushed only once at the factory, it can be successfully used again numerous times in the field. With repeated repumpings, however, it will eventually be necessary to replace the Indium-tipped Vacuum Seal (PI #2550-0352).

Note: The required seating torque for successful vacuum sealing is 28 in. lb. (3.2 Nm).

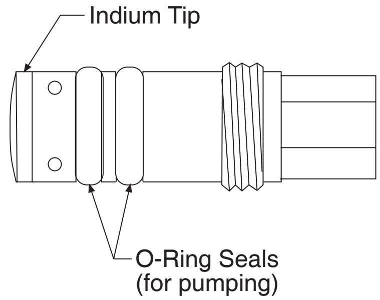


Figure 44. Indium-tipped Vacuum Valve

Requirements

- A molecular drag pump of better (Varian or equivalent) capable of achieving absolute pressures below 0.01 mTorr.

CAUTION

> Your vacuum system *must* have a trap (ideally cryogenic) placed between the camera and the pump to prevent contamination due to oil backstreaming from the pump.

- 5/16″ hex torque wrench for tightening the Indium-tipped Vacuum Seal.
- A new Indium-tipped Vacuum Seal (PI #2550-0352). A new seal will only be required if the camera has been repumped a number of times and the original seal is no longer able to maintain vacuum.

Pumping Procedure

WARNING!

> Wait at least two hours after the camera was last operated before proceeding. This is necessary so that the CCD can warm to ambient before being opened to the atmosphere. If opened when still cold, potentially harmful condensation could form on the CCD.

Preliminary Steps

1. Turn off the system power and disconnect all cables.
2. Apply a light coating of high-quality vacuum grease such as Apiezon M to the O-ring on the Vacuum Pumping Fitting supplied with the system.
3. Remove the cap from the vacuum access port at the top of the camera.
4. Insert the end of the Vacuum Pumping Fitting into the port at the top of the camera to where the threads can be engaged. Then tighten it down. *Finger tight is sufficient. The greased O-ring makes the seal.*
5. Connect the vacuum hose from the pump to the ¼″ fitting at the end of the Vacuum Pumping fitting and clamp the hose connection securely.
6. ***If you are going to reuse the currently installed Indium-tipped Vacuum Seal***, turn on the vacuum pump. Then:
   - Using the 5/16″ hex torque wrench, rotate the Indium-tipped Vacuum Seal two full revolutions counterclockwise, *just enough* to unseal the vacuum.
   - Perform the steps outlined in the ***"Pumping Down"*** section, located on the following page.

7. ***If you are going to install a new Indium-tipped Vacuum Seal***, do not turn on the pump. Instead, perform the steps outlined in the section titled ***"Installing a New Vacuum Seal"***, which follows the ***"Pumping Down"*** section.

Pumping Down

1. Do not bake during pumping. Maintain ambient temperature (≈25°C).
2. Continue pumping for 48 hr. The final vacuum must be below 0.01 mTorr. *At the factory, a much higher initial vacuum level is generated using a turbo pump. Although this is desirable, it is not necessary and may be cost prohibitive for the user to purchase similar equipment; 0.01 mTorr is sufficient to assure normal operation of the unit.*
3. When the required vacuum level has been achieved, tighten down the Indium-tipped Vacuum Seal with the 5/16″ torque wrench to crush the Indium tip and reseal the vacuum. A sealing torque of 28 in. lb. or 3.2 Nm is required.
4. Shut down the pump and remove the vacuum hose from the Vacuum Pumping fitting. Although it shouldn't be required, a 7/16″ nut driver may prove helpful in removing the fitting.
5. Replace the vacuum port cap.

Installing a New Vacuum Seal

CAUTION

Preventing atmospheric contamination of the vacuum chamber is imperative to the operation and longevity of the camera.

- Placing the camera inside a plastic bag filled with dry nitrogen gas prior to removing the Vacuum Seal will backfill the camera when the Vacuum Seal is removed and help prevent contamination. *Consult the factory.*
- Alternatively, a dry nitrogen pressure may be applied to the vacuum pumping fitting before removing the vacuum valve. Pressure should be 3 psig or less. Maintain a flow of nitrogen until the valve is replaced in Step 3. *Consult the factory.*

1. Using the 5/16" hex torque wrench, rotate the Indium-tipped Vacuum Seal counterclockwise to where the threads completely disengage and then remove it from the vacuum block.
2. Lightly grease the Viton O-ring on the new Indium-tipped Vacuum Seal. Use a high-quality grade of vacuum grease such as Apiezon M.
3. Carefully insert the new Indium-tipped Vacuum Seal into the corresponding opening on the camera vacuum block to where the threads can be engaged – a turn or two is sufficient. ***Do not rotate the plunger to where it bottoms out. The Indium tip should not be disturbed until the new vacuum has been established.***
4. Turn on the pump and follow the ***"Pumping Down"*** instructions.

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Warranty & Service

Limited Warranty

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

Basic Limited One (1) Year Warranty

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

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

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

XP Vacuum Chamber Limited Lifetime Warranty

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

Sealed Chamber Integrity Limited 12 Month Warranty

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

Vacuum Integrity Limited 12 Month Warranty

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

Image Intensifier Detector Limited One Year Warranty

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

X-Ray Detector Limited One Year Warranty

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

Software Limited Warranty

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

Owner's Manual and Troubleshooting

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

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Your Responsibility

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

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

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

Contact Information

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

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

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

Customer Support E-mail: techsupport@princetoninstruments.com

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

America	1.877.4.PIACTON (877.474.2286)
Benelux	+49 (0) 89.660.7793
France	+33 (1) 60.86.03.65
Germany	+49 (0) 89.660.7793
Japan	+81 (3) 5639.2741
UK & Ireland	+44 (0) 28.3831.0171

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

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