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Part of the Teledyne Imaging Group

PIXIS-XF System Manual

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Revision History

Issue	Date	List of Changes
Issue 5	January 9, 2020	Issue 5 of this document incorporates the following changes: • Rebranded as Teledyne Princeton Instruments; • Converted to standard FrameMaker template.
Issue 4	April 20, 2016	Issue 4 of this document incorporates the following changes: • Removed the Declaration of Conformity.
Issue 3	October 19, 2015	Issue 3 of this document incorporates the following changes: • Updated the Declaration of Conformity.
Issue 2	January 24, 2014	Issue 2 of this document incorporates the following changes: • Added information about the large format power supply; • Updated the Declaration of Conformity.
Issue 1.E	March 21, 2012	Issue 1.E of this document incorporates the following changes: • Updated LightField images; • Updated Contact Information; • Global terminology updates.
Issue 1.D	January 4, 2011	Issue 1.D of this document incorporates the following changes: • Added support for LightField; • Global update of voltage range to: 100−240; • Added support for 1024B and 2048B CCDs; • Global terminology updates.
Issue 1.C	February 9, 2009	Issue 1.C of this document incorporates the following changes: • Updated Warranty information.
Issue 1.B	June 4, 2008	Issue 1.B of this document incorporates the following changes: • Updated Air-cooled outline drawings; • Updated dimension information for Berillium and non-Berillium cameras; • Added support for PIXIS-XF 2k.
Issue 1.A	November 16, 2006	This is the initial release of this document.

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Chapter 1:   Introduction

1.1   When Flexibility Counts

Teledyne 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 3:1 make the Teledyne Princeton Instruments' PIXIS-XF system an ideal choice for both of these applications.

In fact, PIXIS-XF high-performance systems are designed specifically for applications like X-ray tomography, X-ray topography, 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.

1.2   Fiberoptic Expertise

The PIXIS-XF camera system utilizes Teledyne 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 (with other high resolution CCDs) are recommended. Contact the factory for further information.

1.3   Shuttering and Synchronization

Electrical timing signals are available from the back panel of the camera 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.

1.4   Low-Noise Configurations

The PIXIS-XF system provides either a forced-air or liquid-cooling option to reduce dark current. The thermoelectric (Peltier) design and precision electronics provide very high precision as well as the capability to set the required temperature.

For flexibility, the fiberoptic extends outside the vacuum, allowing you to change scintillators/phosphors for specific X-ray energy without breaking vacuum or coupling the camera system to streak tubes or image intensifiers.

1.5   Software Solutions

The PIXIS-XF camera runs under WinView/32 and WinSpec/32, Teledyne Princeton Instruments' 32-bit Windows$^®$ software packages and LightField$^®$, Teledyne Princeton Instruments 64-bit Windows software package. These applications provide comprehensive image capture and display functions, so you can perform data acquisition without having to rely on third-party software. Windows-compatible PVCam$^®$ (32-bit) and PICam (64-bit) are also available. These applications allow you to write your own software for integrating the system into larger experiments or instruments.

1.6   Environmental Conditions

- Storage temperature < 50°C.
- Operating environment 5°C < T< 30°C.
- Operating temperature range over which specifications can be met is 18°C to 20°C.
- Relative humidity 50%, non-condensing.

1.7   Beryllium Warnings

To prevent injury, please observe the following warnings:

- 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.
- For additional information on safe handling practices or technical data on Beryllium, contact Brush Wellman Inc. at www.brushwellman.com.

1.8   Precautions

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

- Always switch off and unplug the PIXIS-XF camera before changing your system configuration in any way.
- Never operate the camera cooled without proper evacuation or backfill. This could damage the CCD!
- Never connect or disconnect any cable while the PIXIS-XF system is powered on. Reconnecting a charged cable may damage the CCD.
- Never prevent the free flow of air through the equipment by blocking the air vents.
- If the system is liquid-cooled, make sure that the 50:50 ethylene-glycol and water mixture is circulating freely through the camera.

1.9 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.

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1.9.1 Camera

Although there is no periodic maintenance that must be performed on the camera, you may clean the camera from time to time by wiping it down with a clean damp cloth. 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.

1.9.2 Beryllium Window

Cleaning may be necessary to remove oil or other contaminants from the surface of the Beryllium window. 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 lint free 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.

🔍 **NOTE:** ─────────────────

There are no user-serviceable components inside the fiberoptic taper camera. Refer servicing to qualified personnel and contact the factory Customer Support for guidance. Refer to Contact Information on page 114 for complete information.

Please save the original packing material so you can safely ship the system to another location or return it for repairs.

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1.10 Conventions Used In this Document

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

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

Table 1-1:   Terminology Conventions Used

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

1.11   Document Organization

This manual includes the following chapters and appendices:

- **Chapter 1, About this Manual**

  This chapter provides information about the organization of this document, as well as related documents, safety information, and conventions used throughout the manual.

- **Chapter 2, PIXIS-XF Camera System**

  This chapter provides information about the camera, cables, and application software.

- **Chapter 3, Initial System Verification**

  This chapter cross-references system setup actions with the relevant manuals and/or manual pages. It also contains system layout diagrams.

- **Chapter 4, System Setup**

  This chapter provides detailed directions for interconnecting the system components.

- **Chapter 5, Operation**

  This chapter includes a simple procedure for verifying system operation and discusses operational considerations associated with exposure, readout, and digitization.

- **Chapter 6, Advanced Topics**

  This chapter discusses standard timing {Trigger Response} modes (Free Run {No Response}, External Sync {Readout Per Trigger}, and Continuous Cleans {Clean Until Trigger}), Fast and Safe modes, Logic Output control, Kinetics mode, and Custom modes.

- **Chapter 7, Troubleshooting**

  This chapter provides recommended troubleshooting procedures if there are problems with the system.

- **Appendix A, Technical Specifications**

  This appendix provides system specifications.

- **Appendix B, Outline Drawings**

  This appendix provides outline drawings for the cameras.

- **Appendix C, Gd_2O_2S Phosphor Replacement**

  This appendix describes how to change a Gd_2O_2S phosphor mounted on the fiber optic taper.

- **Appendix D, WinSpec/32/LightField Cross Reference**

  This appendix provides two alphabetically sorted tables (WinX to LightField and LightField to WinX) that cross reference terms used by the two applications.

- **Warranty and Service**

  Provides warranty information for the PIXIS-XF system. Contact information is also included.

1.12   Safety Related Symbols Used in this Manual

⚠️ **CAUTION!** ────────────────────────────────

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

⚡ **WARNING!** ────────────────────────────────

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

⚡ **WARNING! RISK OF ELECTRIC SHOCK!** ──────

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

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Chapter 2: PIXIS-XF Camera System

A typical air-cooled PIXIS-XF system consists of the camera with a Certificate of Performance, a power supply, a USB 2.0 interface cable for your computer system, MCX to BNC adapter cables, and the user manual. A typical liquid-cooled PIXIS-XF system consists of the camera with a Certificate of Performance, a CoolCUBE$_{II}$ circulator with hoses, a USB 2.0 interface cable for your computer system, MCX to BNC adapter cables, and the user manual.

Figure 2-1 shows those items that are typically included as part of a standard air-cooled PIXIS-XF Camera system.

Figure 2-1:   Typical Air-Cooled PIXIS-XF System Components
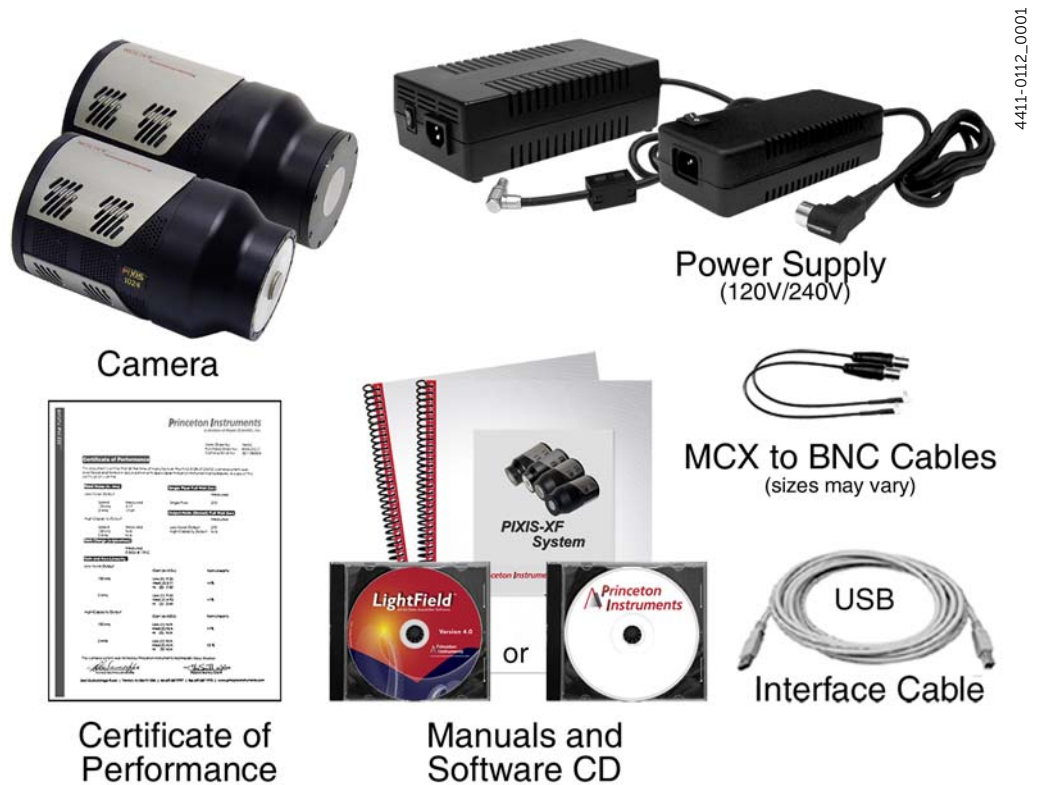
Optional items include the WinX application software and manual, LightField application software, and Scientific Imaging ToolKit™ (SITK™) for LabVIEW®.

2.1   PIXIS-XF Camera

A typical PIXIS-XF camera is illustrated in Figure 2-2.

Figure 2-2:   Typical PIXIS-XF Camera

- CCD Array

  PIXIS-XF currently offers a 1024 x 1024 array with 13 μm x 13 μm pixels or a 2048 x 2048 array with 13.5 μm x 13.5 μm pixels. When used with an X-ray scintillator screen and a 1:1 fiber optic, this system 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 condensation and contamination.

- Fiber Optic

  The PIXIS-XF fiberoptic tapers are bonded to the face of the CCD arrays with Teledyne Princeton Instruments' 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.

- Cooling

  Dark current is reduced in PIXIS-XF camera systems through thermoelectric cooling of the CCD arrays. Cooling by this method uses a multi-stage Peltier cooler in combination with circulating air or coolant. Due to CCD size/packaging differences, the lowest achievable temperature can vary from one PIXIS-XF model to the next. Please refer to the specific system's data sheet for cooling performance.

- Fan

  Air-cooled cameras contain an internal fan. Its purpose is to:
  — Remove heat from the Peltier device that cools the CCD array, and
  — Cool the electronics.

  An internal Peltier device directly cools the cold finger on which the CCD is mounted. The air drawn into the camera by the internal fan through the back slots on the side panels and exhausted through the front slots on the side panels then removes the heat produced by the Peltier device. The fan is always in operation and air-cooling of both the Peltier and the internal electronics takes place continuously. The fan is designed for low-vibration and does not adversely affect the image. For the fan to function properly, free circulation must be maintained between the sides of the camera and the laboratory atmosphere.

- Coolant Ports

  Liquid-cooled cameras have internal hoses that can be connected to the CoolCUBE$_{II}$ circulator via the coolant ports on the side of the camera (either port can be the input). As is the case with circulating air (see above), circulating coolant removes the heat produced by the Peltier device. This means of heat removal is designed for vibration-free data acquisition. For the circulating coolant to function properly, free air circulation must be maintained between the sides of the CoolCUBE$_{II}$ and the laboratory atmosphere.

  ⚠ **CAUTION!**

  Use only the hoses and circulator shipped with your system.
  Attaching any other hoses or circulator voids the warranty.

2.1.1   PIXIS-XF Rear-Panel Connectors and Indicators

Figure 2-3 illustrates the rear-panel connectors and indicators on a PIXIS-XF camera.

Figure 2-3:   PIXIS-XF Rear-Panel Connectors
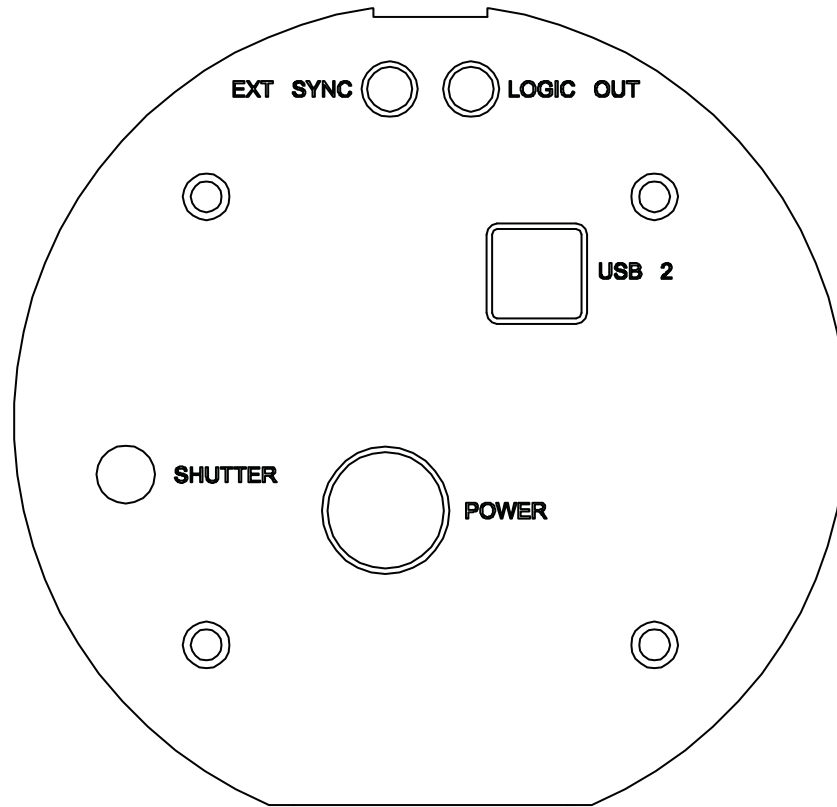
Refer to Table 2-1 for information about each rear-panel connector and indicator.

Table 2-1:   PIXIS-XF Rear-Panel Connectors and Indicators

Label	Description
EXT SYNC	0 to +3.3-5V_{DC} logic level input (TTL-compatible) that has a 10 kΩ pull-up resistor. Allows data acquisition and readout to be synchronized with external events. Through software, positive or negative (default) edge triggering can be selected.
LOGIC OUT	0 to +3.3V_{DC} programmable logic level output (TTL-compatible). The output of this connector can be programmed and also inverted via the application software. For additional information, refer to Section 6.3, LOGIC OUT Control, on page 67.
USB 2.0	Control signals and data are transmitted between the camera and the host computer via the USB port located on the rear of the camera. You can hot plug the PIXIS-XF camera whenever the WinX application is not running (i.e., connect or disconnect from the camera or the host computer while the camera is on).
POWER	12 V_{DC} (6.6A max) input from power supply.
SHUTTER	LEMO® connector provides the shutter drive pulses for driving an optional Teledyne Princeton Instruments-supplied 25 mm external slit shutter. Camera power must be off before connecting to or disconnecting from this connector.

2.1.2   PIXIS-XF Power Supply (Air/Liquid-Cooled Systems)

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.

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Small Format PIXIS-XF: 1024

- Maximum Power Output: 80 W
- Input: 100-240 V_{AC}, 47-63 Hz, 1.9 A
- Output: 12 V_{DC} at 6.6 A maximum

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Large Format PIXIS-XB: 2048

- Maximum Power Output: 150 W
- Input: 100-240 V_{AC}, 50/60 Hz, 2 A
- Output: 12 V_{DC} at 12.5 A maximum

2.1.3   Coolant Hoses

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Quick-disconnects that mate to the PIXIS-XF's coolant ports have been installed on one end of each hose. Refer to your coolant circulator's specifications regarding circulator-compatible hose fittings. If a Teledyne Princeton Instruments CoolCUBE$_{II}$ circulator is ordered with the camera, hoses are supplied with appropriate connectors on both ends.

NOTE:

Part numbers for the hose, PIXIS-XF fittings, and CoolCUBE$_{II}$ fitting are: McMaster# MCM 5238K748; CPC# MCD1004 and McMaster# MCM 5346K35; and CPC# NS6D17006, respectively.

2.1.4   Cables

USB 2.0 Cable

The standard 16.4' (5 m) cable (6050-0494) has USB connectors that interconnect the "USB 2.0" connector on the rear of the PIXIS-XF with a USB 2 connector on the host computer.

4411-0112_0007

MCX to BNC Adapter Cables

Two MCX to BNC adapter cables are provided with the PIXIS-XF system. These mount to the EXT SYNC and the LOGIC OUT connectors on the rear of the PIXIS-XF.

4411-0112_0008

2.2   Certificate of Performance

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

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

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

2.2.1   User Manuals

PIXIS-XF System Manual

This manual describes how to install and use the PIXIS-XF system components.

WinView/32 or WinSpec/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 Teledyne Princeton Instruments maintains updated documentation and user manuals on their FTP site. Visit the Teledyne Princeton Instruments FTP Site to verify that the most recent user manual is available and being referenced:

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

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

2.3   Application Software

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

- LightField

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

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

- WinX

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

- PVCAM

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

- PICam

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

  Refer to the PICam Programmer's Manual for the list of supported operating systems.

- Scientific Imaging ToolKit (SITK)

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

> **NOTE:**
>
> PIXIS-XF cameras may be operated by third-party software packages. Please check with the providers of the packages for compatibility and support information.

2.4   Accessories

Teledyne Princeton Instruments offers a number of optional accessories that are compatible with PIXIS-XF.

For ordering information, contact Teledyne Princeton Instruments. Refer to Contact Information on page 114 for complete information.

2.4.1   Fiber Optic Extender

The specially designed fiber optic data interface kit allows the computer and the USB 2.0 camera head to be separated by up to 500 meters without the loss of data.

The kit consists of two compact, high speed transceivers (interface modules) for completely transparent operation between the host computer and the camera and is ideal for hazardous or high EMI environment applications.

This optional kit supports PIXIS-XF, Spec-10, VersArray and PI-MAX family of products as well Teledyne Acton Research Series spectrometers with a USB 2.0 data interface.

2.4.2   CoolCUBE$_{II}$ with PIXIS-XF-Compatible Hoses

Liquid-cooled PIXIS-XF cameras provide a low vibration system for data acquisition. Instead of using a fan to remove heat, these cameras incorporate a closed loop system of circulating fluid. The CoolCUBE$_{II}$ circulator unit [P/N: 7567-0002] continuously pumps a 50:50 mixture of room temperature (23°C) water and ethylene glycol.

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

Chapter 3:   Initial System Verification

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

Refer to Section 3.1, System Block Diagrams, on page 24 for high-level block diagrams of typical system configurations.

Table 3-1:   PIXIS-XF **Installation Actions (Sheet 1 of 2)**

Action	Refer to...
1. If the system components have not already been unpacked, unpack them and inspect their carton(s) and the system components for in transit damage.	Section 4.1, Unpack the System, on page 27.
2. Verify that all system components have been received.	Section 4.2, Verify Equipment and Parts Inventory, on page 28.
3. If the components show no signs of damage, verify that the appropriate power cord has been supplied with the power supply.	Section 4.2, Verify Equipment and Parts Inventory, on page 28.
4. If the application software is not already installed on the host computer, install it.	Section 4.4, Install the Application Software, on page 30 Software manual
5. If the USB 2.0 interface card is not already installed in the host computer, install it.	Host computer manufacturer's instructions
6. With the power supply disconnected from the camera, connect the USB cable to the USB port at the rear of the camera and to the USB port at the computer.	—
7. Air-Cooled System: Plug the power supply into the rear of the camera and plug the power supply into the power source. Liquid-Cooled System: Plug the power supply into the rear of the camera and plug the power supply into the power source. Make the hose connections to the camera. Plug the circulator into the power source. Add coolant if necessary. Turn on the circulator.	— Section 4.5, Make Camera-Circulator Connections for a CoolCUBE$_{II}$, on page 32
8. Turn the Camera on.	—
9. Turn on the computer and begin running the application software.	Software Manual/Online Help
10. Enter the hardware setup information or load the default parameter settings from the camera.	Software Manual/Online Help
11. Set the target array temperature.	Section 5.4.3, CCD Temperature, on page 46

Table 3-1:   PIXIS-XF **Installation Actions (Sheet 2 of 2)**

Action	Refer to...
12. Once the system reaches temperature lock, wait an additional 20 minutes and then begin acquiring data in focus/preview mode.	Section 5.2, WinX/32 First Light on page 39. Section 5.3, LightField First Light on page 42..

3.1   System Block Diagrams

This section provides typical system-level block diagrams.

Figure 3-1:   **Block Diagram: Typical Air-Cooled** PIXIS-XF System
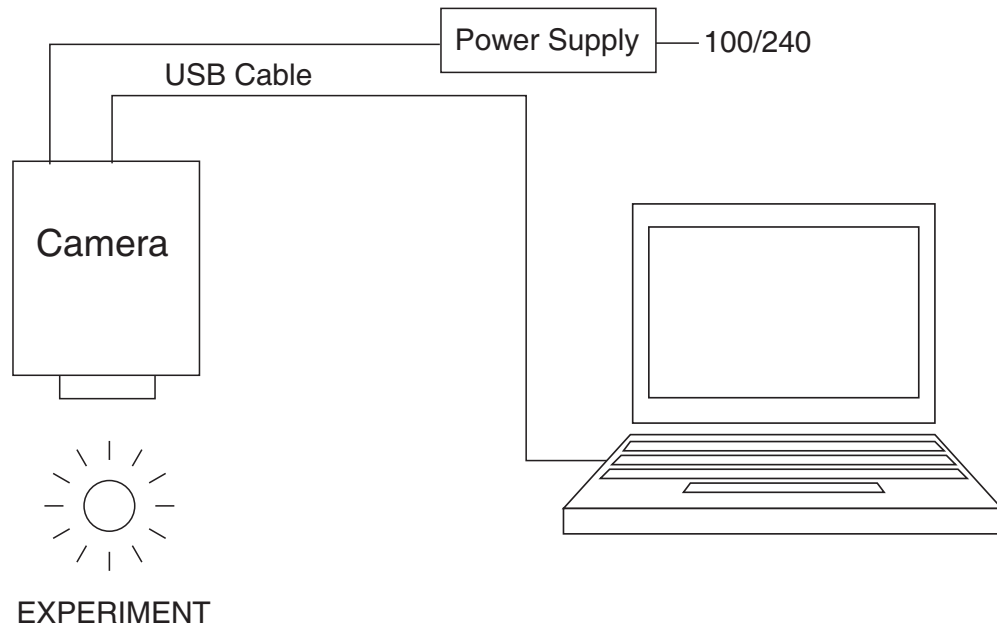
Figure 3-2: Block Diagram: Typical Liquid-Cooled PIXIS-XF System
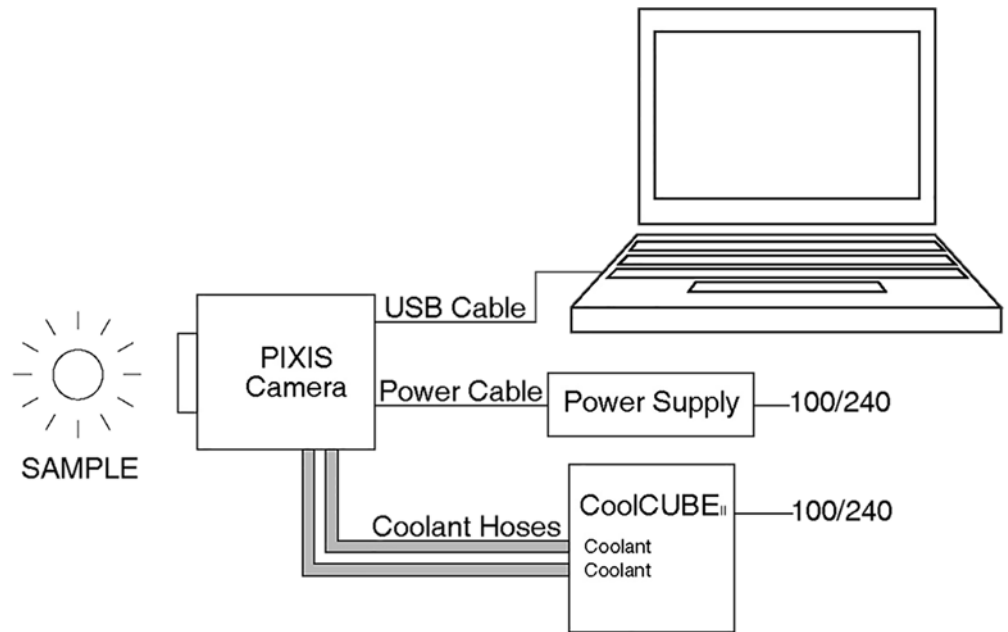
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Chapter 4:   System Setup

⚠ **WARNING!** ———————————————————————
    To minimize risk to users or to system equipment, turn the
    system off before any cables are connected or
    disconnected.
——————————————————————————————

A PIXIS-XF camera system consists of three or four hardware components:

- Camera head;
- Cables;
- Power supply;
- CoolCUBE$_{II}$ (shipped with the water-cooled camera.)

All of the components and cables required for your configuration are included with your shipment. Your PIXIS-XF system has been specially configured and calibrated to match the camera options specified at the time of purchase.

Keep all of the original packing materials so you can safely ship the PIXIS-XF system to another location or return it for service if necessary. If you have any difficulty with any step of the instructions, call Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 114 for complete information.

Hardware installation may consist of:

- Installing a USB 2 interface card, if one is not already installed in the host computer;
- Connecting the camera to external triggering or monitoring equipment.

Software installation depends on the application software you will be using to run the system. Refer to the manual supplied with the software for information about installing and setting it up.

4.1   Unpack the System

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

4.2   Verify Equipment and Parts Inventory

Confirm that you have all of the equipment and parts required to set up the PIXIS-XF system.

A standard system consists of:

- Camera and Power Supply
- CoolCUBE$_{II}$ Circulator and hoses (for liquid-cooled system)
- Host Computer

  Can be purchased from Teledyne Princeton Instruments or provided by user. For enhanced performance, a fast hard drive (10,000 rpm) and 2 GB RAM is recommended.
- Operating System:
  — WinView/32 or WinSpec/32: Windows XP (32-bit, SP3 or later) or Vista (32-bit required)
  — LightField: Windows Vista (64-bit) or Windows 7 (64-bit)
- USB cable: Five (5) meter cable (6050-0494) is standard.
- PIXIS-XF System Manual

Available options include:

- Application Software:
  — WinView/32 or WinSpec32 (Version 2.5.25 or later) CD-ROM and User Manual
  — LightField CD-ROM and User Manual
- Shutter connector and Teledyne Princeton Instruments 25 mm external shutter
- Fiber Optic Extender Kit

4.3   System Requirements

Environmental Requirements

- Storage temperature: ≤55°C
- Operating environment temperature: +5°C to +30°C; the environment temperature range over which system specifications can be guaranteed is +18°C to +20°C
- Relative humidity 50%; non-condensing

> **NOTE:**
>
> The cooling performance may degrade if the room temperature is above +20°C.

Ventilation

Allow at least one inch clearance for the side air vents. Where the camera is inside an enclosure, < 30 cfm air circulation and heat dissipation of 100 W is required.

Power:

The PIXIS-XF camera receives its power from the supplied power supply, which in turn plugs into an AC power source.

Host Computer

Computers and operating systems undergo frequent revision. The following information is intended to specify minimum computer requirements. Please contact the factory to determine your specific needs.

> **NOTE:**
>
> The following requirements are the minimum for operating a PIXIS-XF camera. A faster computer with 5 GB or more memory (RAM) will significantly enhance software performance during live mode operations.

- WinX Requirements
  — Windows XP (32-bit with SP3 or later) or Vista (32-bit)
  — 2 GHz Pentium 4 (or greater).
  — Native USB 2.0 support on the mother board or USB 2.0 Interface Card (Orange Micro 70USB90011 USB2.0 PCI is recommended for desktop; SIIG, Inc. USB 2.0 PC Card, Model US2246 for laptop)
  — Minimum of 1 GB RAM (or greater).
  — CD-ROM drive.
  — Hard disk with a minimum of 1 GB available.
    A complete installation of the program files takes about 17-50 MB and the remainder is required for data storage, depending on the number and size of images/spectra collected.
    Disk level compression programs are not recommended.
    Drive speed of 10,000 RPM recommended.
  — Super VGA monitor and graphics card supporting at least 65,535 colors with at least 128 MB of memory. Memory requirement is dependent on desired display resolution.
  — Mouse or other pointing device.
- LightField Requirements
  — Windows Vista (64-bit) or Windows 7 (64-bit)
  — 2 GHz dual core processor
  — 4 GB RAM (or greater)
  — CD-ROM drive
  — Super VGA monitor and graphics card supporting at least 65535 colors with at least 128 MB of memory. Memory requirement is dependent on desired display resolution.
  — Hard disk with a minimum of 1 GB available for installation.
    Additional space is required for data storage: the amount of space required depends on the number and size of images/spectra collected.
    Disk level compression programs are not recommended.
    Drive speed of 10,000 RPM recommended.
  — Mouse or other pointing device.

4.4   Install the Application Software

This section provides information about installing image acquisition software.

4.4.1   Install WinX/32

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

1. On the Select Installation Type dialog illustrated in Figure 4-1, select:
   * **Typical** to install the required drivers and the most commonly installed program files;
   * **Custom** to select among the available program files or do not want to install the drivers;
   * **Complete** to install all application features.

Figure 4-1:   Typical WinView Installation Dialog: Select Installation Type
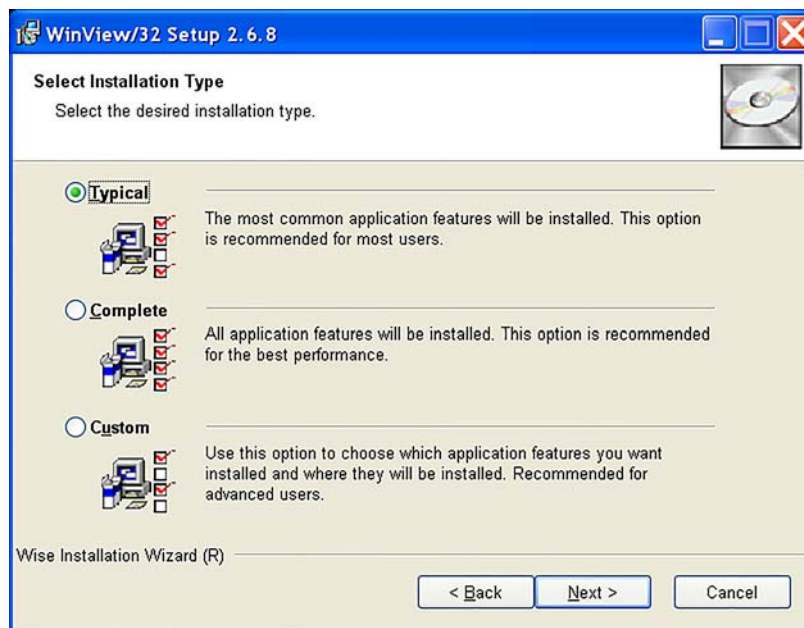
The required INF, DLL, and USB driver files will be placed in the appropriate `Windows` directories. Refer to Table 4-1.

Table 4-1:   USB Driver Files and Locations

Windows Version	INF File, Located in "Windows"/INF[a]	Properties DLL, Located in "Windows"/System32	Device Driver, Located in "Windows"/System32/
Windows XP Vista (32-bit)	`rsusb2k.inf`	`apausbprop.dll`	`apausb.sys`

a. The INF directory may be hidden.

2. Make sure the camera is connected to the host computer and that the camera power supply is turned on.
3. Reboot the computer.
4. At boot up, Windows will detect the Teledyne Princeton Instruments USB2 Interface hardware in the PIXIS-XF.

4.4.2   Install LightField

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

1. Before starting the installation:
    • Verify that the computer operating system is Windows Vista (64-bit) or Windows 7 (64-bit).
    • Confirm that your computer supports USB 2.0. If it does not, please refer to the manufacturer's instructions for installing a USB 2.0 interface card.
    • Verify that your computer is connected to the Internet. Internet connection is required for product activation.
2. Insert the CD and follow the installation wizard prompts.

Figure 4-2:   Typical LightField Installation Wizard Dialog

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

4.5   Make Camera-Circulator Connections for a CoolCUBE$_{II}$

For liquid-cooled cameras, the CoolCUBE$_{II}$ circulator provides a vibration-free method of heat removal. Figure 4-3 illustrates a typical CoolCUBE$_{II}$ circulator.

Figure 4-3:   Typical CoolCUBE$_{II}$
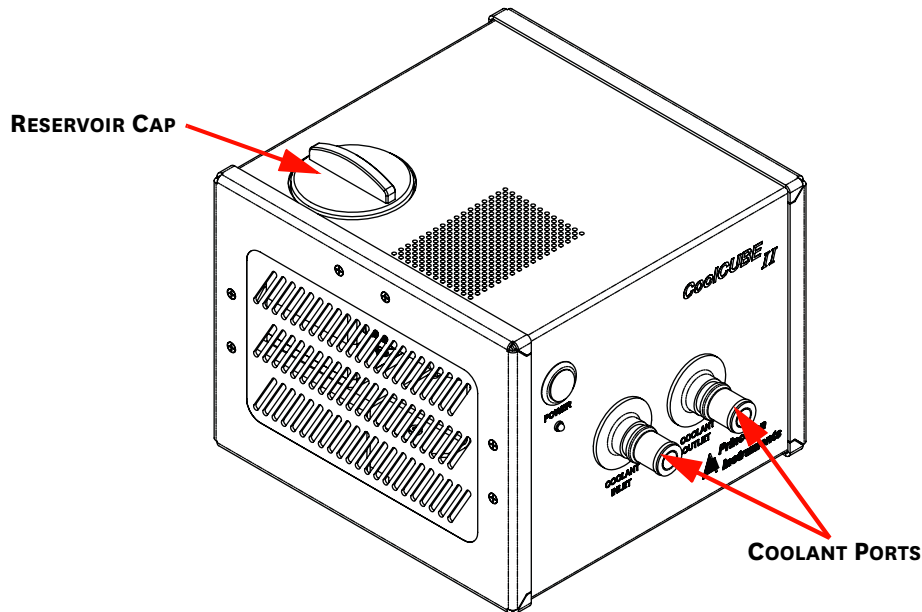
1. Make sure the camera and the circulator power switches are turned off.
2. Make sure the circulator is 6 inches (150 mm) or more below the camera. The vertical distance should not exceed 10 feet (3 m). Typically, the camera is at table height and the circulator is on the floor.
3. Make the coolant connections between the circulator and the camera. It does not matter which hose from the circulator is plugged into a coolant port on the camera.
4. It is recommended that hoses be secured to the camera hose barbs with the clamp supplied.

NOTES:

1. Make sure that there are no kinks in the hoses that impede the coolant flow. Lack of sufficient flow can seriously harm the detector and any resulting damage is not covered under warranty.
2. Damage caused by water leaking into the PIXIS-XF voids the warranty.

5. Unscrew the reservoir cap located on top of the CoolCUBE$_{II}$ and make sure that the coolant reservoir contains coolant. If additional coolant is required, fill with a 50:50 mixture of water and ethylene glycol.
6. Screw the reservoir cap back in.
7. Plug the circulator into a 100-240 V$_{AC}$, 47-63 Hz power source.

8. Turn the circulator on. Make sure there are no leaks or air bubbles in the hoses.

NOTE:

Small air bubbles (about the size of bubbles in soda) are common in the CoolCUBE$_{II}$ especially at start up and do not prevent proper operation.

- If there are no problems, proceed to step 9.
- If there are leaks or air bubbles, turn the circulator off and correct the problem(s) by securing the hoses or adding more coolant to the reservoir.
  Turn the circulator back on. Recheck and if there are no problems, proceed to step 9.

9. Turn the camera on.
10. Start the application software.

4.6 Configure Default Camera System Parameters

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

4.6.1 Configure Default WinX/32 Parameters

1. Make sure the PIXIS-XF is connected to the host computer and that it is turned on.
2. Run the WinX/32 application.
   The Camera Detection wizard will automatically run if this is the first time you have installed a Teledyne Princeton Instruments WinX application (WinView/32, WinSpec/32, or WinXTest/32) and a supported camera. Otherwise, if you installing a new camera type, click on the Launch Camera Detection Wizard... button on the Controller/CCD tab to start the wizard.
3. On the Welcome dialog, shown in Figure 4-4, leave the checkbox unselected and click Next.

Figure 4-4: Typical WinX/32 Camera Detection Wizard: Welcome Dialog
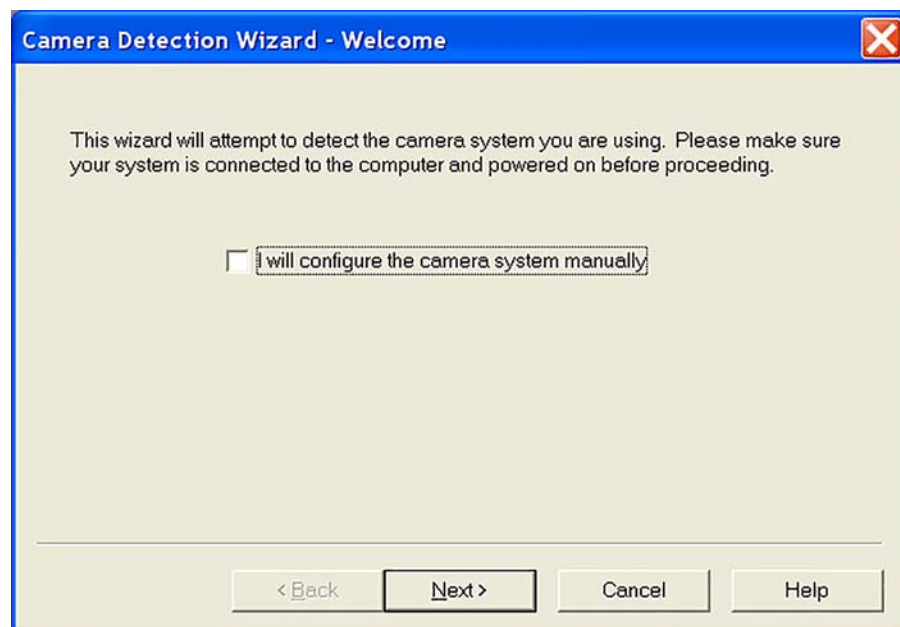
4. Follow the instructions on the dialogs to perform the initial hardware setup: this wizard enters default parameters on the Hardware Setup dialog tabs and gives you an opportunity to acquire a test image to confirm the system is working.

NOTE:

For step-by-step instructions about basic system operation, refer to Section 5.2, WinX/32 First Light, on page 39.

4.6.2 Configure Default LightField Parameters

1. Verify the PIXIS-XF is connected to the host computer and that the camera power supply is turned on.
2. Start LightField.
3. While LightField is starting up, it will detect the available device(s) and load the appropriate icons into the Available Devices area in the Experiment workspace.
4. When you drag an icon into the Experiment Devices area, the appropriate expanders will be loaded into the Experiment Settings stack on the left-hand side of the window. See Figure 4-5.

Figure 4-5: Typical LightField Experiment Workspace
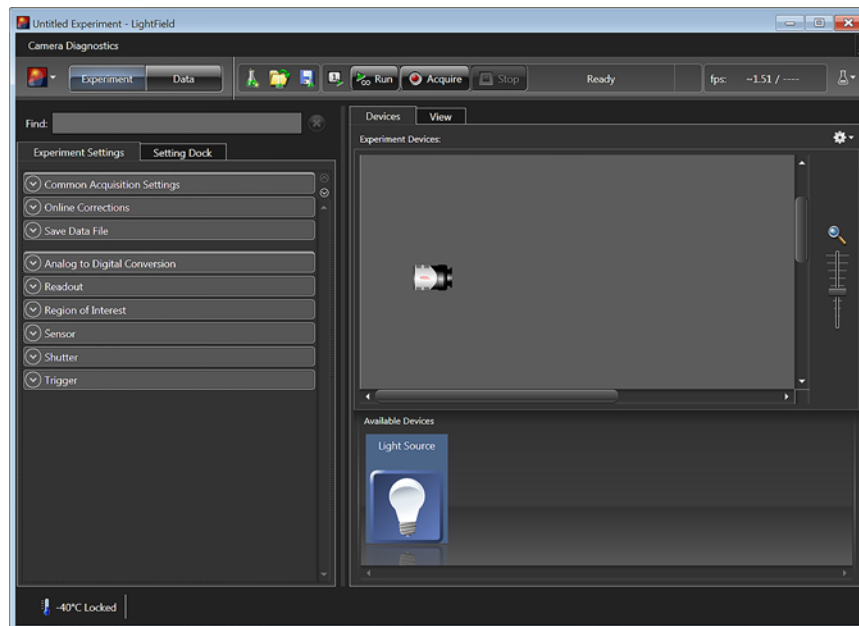
5. Because this is a new experiment, the default settings will automatically be entered for the experiment device(s). These settings will allow you to begin previewing (Run button) or acquiring (Acquire button) data.

NOTE:

For step-by-step instructions about basic system operation, refer to Section 5.3, LightField First Light, on page 42.

4.7   Connect an External Shutter

⚠ **CAUTION!** ─────────────────────────────────
Disconnecting or connecting the shutter cable to the
camera while the camera is on can destroy the shutter or
the shutter driver in the camera!
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While PIXIS-XF cameras do not have an internal shutter, there is provision for
connecting only a Teledyne Princeton Instruments-supplied 25 mm external slit shutter
at the optional Shutter connector on the rear of the PIXIS-XF.

Electromechanical shutters typically have a lifetime of about a million cycles. Avoid
running the shutter unnecessarily. Also avoid using shorter exposure times and higher
repetition rates than are required.

Perform the following procedure to connect an external shutter:

1. Verify that the PIXIS-XF camera is turned off (i.e., the power supply is switched off).
2. Connect the shutter cable from the Teledyne Princeton Instruments-supplied
   25 mm external slit shutter to the LEMO connector on the rear of the camera.
3. Power the PIXIS-XF camera on.

4.8   Connect/Disconnect the PIXIS-XF USB Cable

As of November 1, 2005, you can hot plug the PIXIS-XF camera whenever the WinX/32
application is not running (i.e., connect or disconnect from the camera or the host
computer while the camera is powered on.)

For cameras built before November 1, 2005, you must exit the WinX/32 application and
turn the camera power off before connecting the USB cable to, or disconnecting it
from, the camera or host computer.

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Chapter 5: Operation

Once the PIXIS-XF system has been set up, camera operation is basically straightforward. In most applications you simply establish optimum performance using the Focus mode (e.g., in WinX/32,) set the target detector temperature, wait until the temperature has stabilized at the set temperature and then do actual data acquisition in the Acquire mode. Additional considerations regarding experiment setup and equipment configuration are addressed in the software manual.

During data acquisition, the CCD array is exposed to a source and charge accumulates in the pixels. After the defined exposure time, the accumulated signal is readout of the array, digitized, and then transferred to the host computer. Upon data transfer, the data is displayed and/or stored via the application software. This sequence is illustrated by the block diagram shown in Figure 5-1.

Figure 5-1:   Block Diagram of Light Path in System
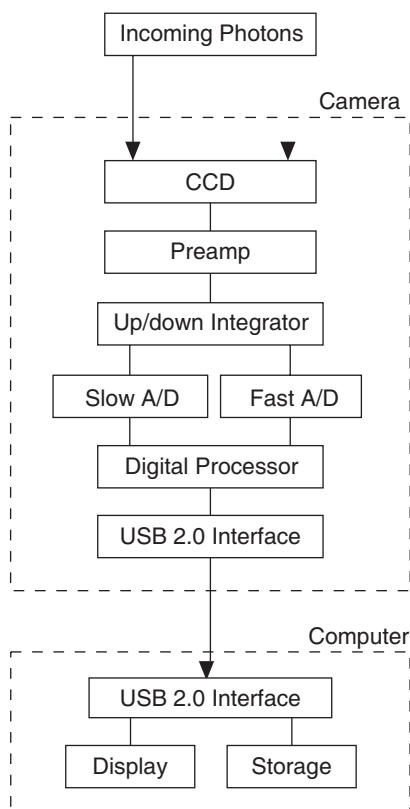
Whether or not the data are displayed and/or stored depends on the data collection operation that has been selected in the application software.

In WinX/32 and LightField, these operations use the Experiment Setup parameters to establish the exposure time (i.e., the period when signal of interest is allowed to accumulate on the CCD.) **Focus** {**Preview**} is more likely to be used in setting up the system (refer to Section 5.2, WinX/32 First Light on page 39, and Section 5.3, LightField First Light, on page 42, for more information,) and **Acquire** is then used for the collection and storage of data.

Briefly:

- In **Focus** {**Preview**} 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.
  - In WinX/32, the last frame acquired before **Stop** is selected can be stored.
  - In LightField, this frame cannot be stored.

  Focus {**Preview**} mode is particularly convenient for familiarization and setting up.

- 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. In WinX/32, this could only happen in Fast Mode operation.

The remainder of this chapter is organized to first talk about the system on/off sequences. Next First Light procedures follow which provide step-by-step information about how to verify initial 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.

📖 REFERENCES:

For information about synchronizing data acquisition with external devices, refer to Chapter 6, Advanced Topics, on page 57.

5.1 System On/Off Sequences

For WinView/32 and WinSpec/32, the following on/off sequences must be followed to establish and maintain the communication link between the camera and the host computer:

- The PIXIS-XF camera must be powered ON before the WinX/32 application software (e.g., WinView/32,) is launched to ensure communication between the camera and the computer. If the application software is opened and the PIXIS-XF 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 the application software, power the camera on, and reopen the application software before you can set up experiments and acquire new data.
- The WinX application software must be closed before powering the camera off. If you power the camera off before closing the application software, the communication link with the camera will be broken. You can operate the program in a playback mode (i.e., examine previously acquired data,) but will be unable to acquire new data until you have closed the application software, powered the camera on, and then relaunched the application software.

5.2   WinX/32 First Light

This section provide step-by-step information about verifying the operation of your PIXIS-XF 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 operating configurations, ones with more complex timing modes, can be performed.

Once the PIXIS-XF system has been set up, operation of the camera is basically straightforward. In most applications you simply establish optimum performance using the Focus mode, select full frame, set the target camera temperature, and watch the dark charge decrease as the CCD temperature approaches the set temperature.

The following procedure assumes:

- You have already set up your system in accordance with the instructions in Chapter 4, System Setup, on page 27 and are verifying the camera system operation.
- You have read the previous sections of this chapter.
- You are familiar with the application software.
- The system is being operated in imaging mode.

Perform the following procedure to verify initial system operation:

NOTE:
> The following procedure is based on WinView/32. You will need to modify it if you are using a different application (e.g., set up WinSpec/32 in imaging mode.) Basic familiarity with the WinX/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.

1. Power on the camera (i.e., switch the power supply on.)

NOTE:
> The camera must be turned on before WinX/32 is launched, and WinX/32 must be closed before the camera is turned off.

2. Turn on the host computer power.
3. Launch the application software.
4. Configure the parameters as indicated:

- **Environment** dialog (**Setup ► Environment**)

  Set the DMA Buffer size to 32 MB, reboot the computer for this memory allocation to be activated, and then relaunch WinView/32.

- **Controller/Camera** tab (**Setup ► Hardware**)

  Controller and Camera parameters should be set automatically to the proper values for your system.
  — **Camera name**: This information is read from the camera.
  — **Controller type**: This information is read from the camera.
  — **Shutter type**: None.
  — **Readout mode**: Select Full frame.

- **Cleans and Skips** tab (**Setup ► Hardware**): Default

- **Camera Temperature** (**Setup ► Detector Temperature…**)

  -40°C for air-cooled or liquid-cooled PIXIS-XF:1024.

  The temperature should drop steadily, typically reaching the programmed temperature in about 15 minutes. When the array temperature reaches the programmed temperature, the **Detector Temperature** dialog will report that the temperature is **LOCKED**. Note that some overshoot may occur. This could cause temperature lock to be briefly lost and then quickly re-established. If you are reading the actual temperature reported by the application software, there may be a small difference between the programmed 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 $\pm$0.05°C.

  🔍 **NOTE:** ───────────────────────

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

- **Experiment Setup Main** tab (**Acquisition ► Experiment Setup…**)
  - **Exposure Time**: 100 ms
  - **Accumulations & Number of Images**: 1
  - **CCD Readout**: Select **Use Full Chip**

- **Experiment Setup Timing** tab (**Acquisition ► Experiment Setup…**)
  - **Timing Mode**: Select **Free Run**
  - **Shutter Control**: Select **Normal**

- **Safe Mode vs. Fast Mode**

  Select **Fast Mode**

- **General** tab (**Display ► Layout…**)

  Select **Horizontal and Vertical Cross Sections**

5. Select **Focus** from the **Acquisition** menu to view successive images on 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. When you stop the acquisition, you will be given the opportunity to save the last displayed image.

   Figure 5-2 illustrates typical image data you might see in WinView/32. The horizontal and vertical cross sections have been turned on via the **General** tab (**Display ► Layout**).

Figure 5-2:   Typical WinView/32 First Light Acquired Data
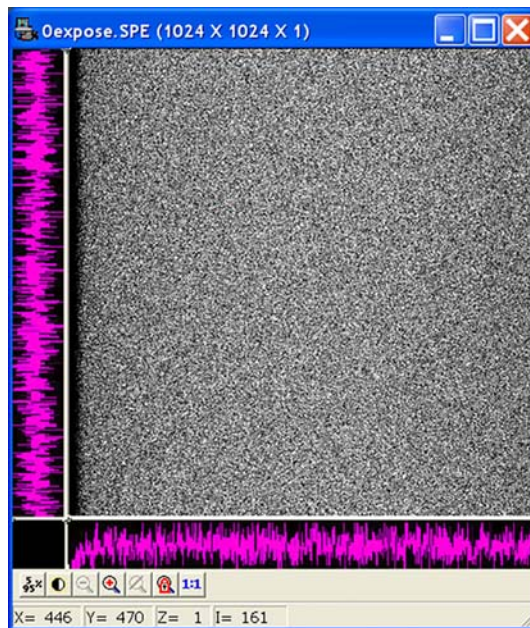
Because the time to acquire and read out an image varies directly with the size of the CCD, the observed frame rate will vary greatly depending on the CCD installed. With a short exposure time, it is not uncommon for the frame readout time to be significantly longer than the exposure time.

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.

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5.3 LightField First Light

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

The following procedure assumes:

- You have already set up your system in accordance with the instructions in Chapter 4, System Setup, on page 27 and are verifying the camera system operation.
- You have read the previous sections of this chapter.
- You are familiar with the application software.
- The system is being operated in imaging mode.

Perform the following procedure to verify initial system operation:

NOTE:

This procedure is based on LightField. Basic familiarity with the LightField software is assumed. If this is not the case, you may want to review the software manual or have it available while performing this procedure.

1. Power on the camera (i.e., switch the power supply on.)
2. Turn on the host computer power.
3. Launch LightField.

   Once LightField is running, you should see an icon representing your camera in the **Available Devices** area. Figure 5-3 illustrates a PIXIS-XF:1024F.

Figure 5-3: Typical LightField Available Devices Area
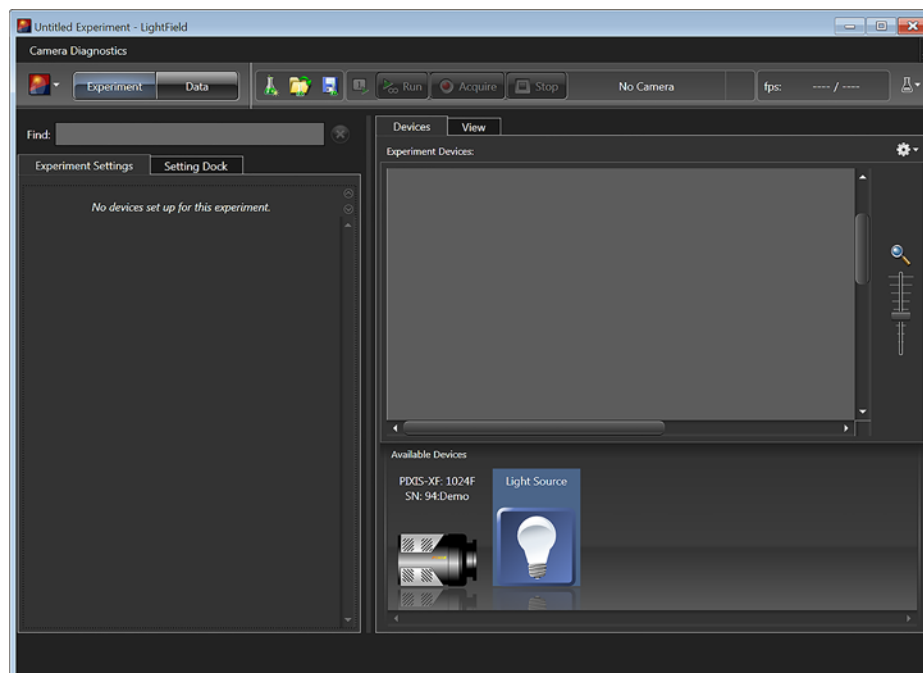
4. Drag the camera icon into the **Experiment Devices** area. See Figure 5-4.

Figure 5-4:   Typical LightField Experiment Devices Area
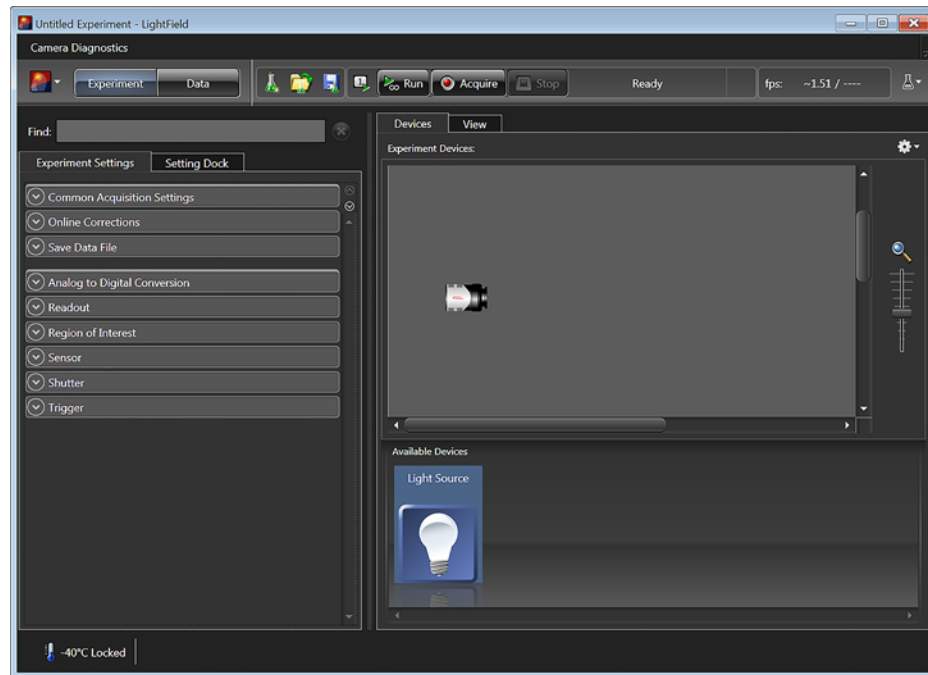
The **Experiment Settings** stack on the left displays several expanders. Since this is a new experiment, the default settings for the camera will be programmed.

5. The **Status** bar at the bottom of the window displays an icon for temperature status. Temperature status reports the current temperature and whether the set temperature has been reached. Clicking on the icon opens the **Sensor** expander where the set temperature can be changed.

6. Click on the **View** tab above **Experiment Devices**, to change to the Display area.

Figure 5-5:   Typical LightField View Area
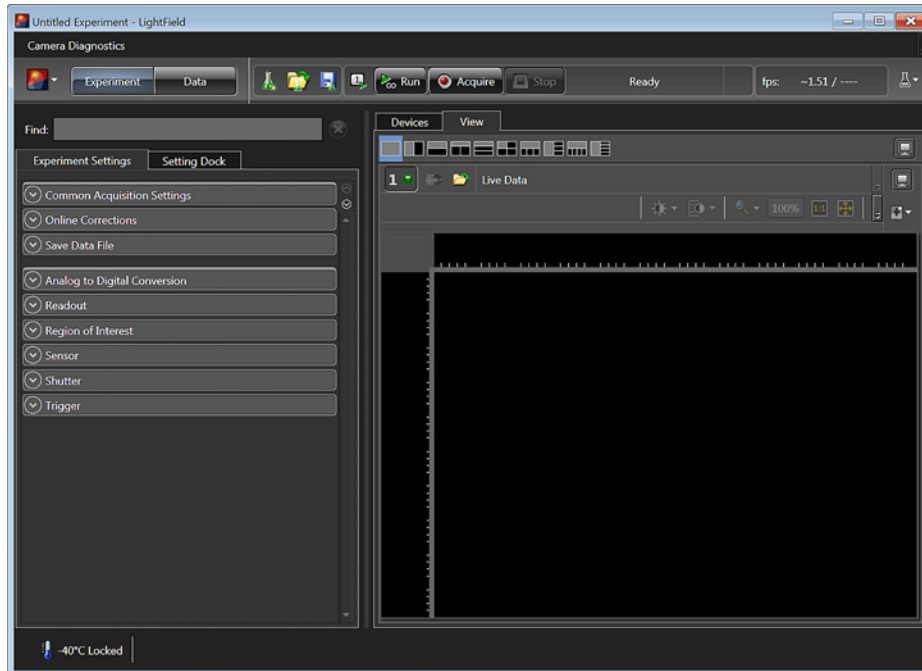
7. Click on **Run** [Run icon] to start **Preview** mode.

In this mode, images will be continuously acquired and displayed. Because no X-ray source is being used, the images you see will be of the camera's dark charge. As the CCD temperature decreases, the image will get darker as the dark charge decreases

Figure 5-6:   Typical LightField View Area Displaying an Image
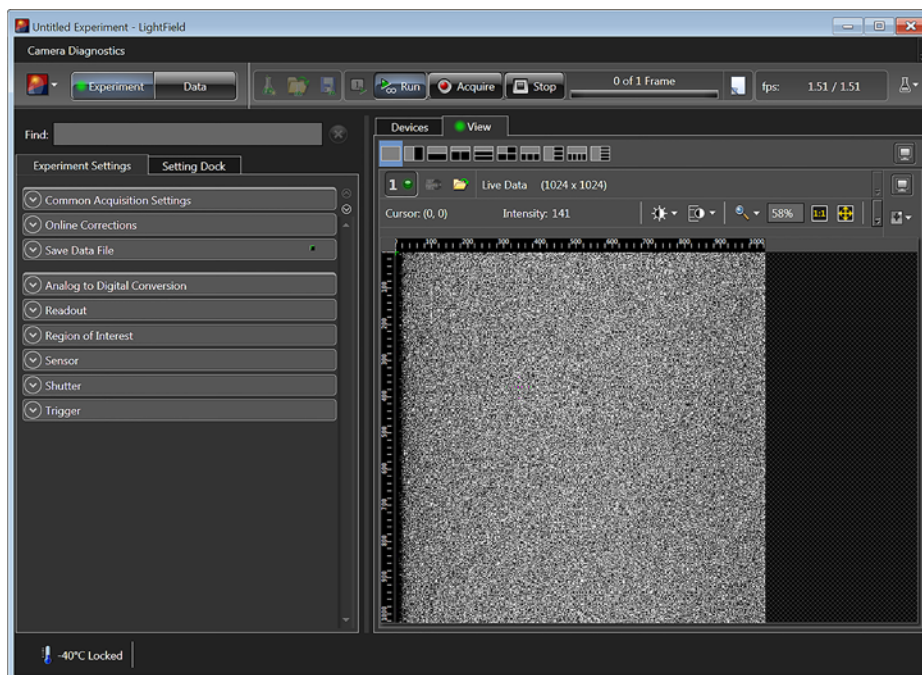
When using an X-ray source, you might run in **Preview** mode while positioning the camera or the subject of the experiment. Then either:

- Stop **Preview** mode;
- Continue running in **Preview** mode;
- Begin **Acquire** mode;
- Wait for the CCD to reach the operating temperature before beginning **Acquire** mode.

5.4 Exposure and Signal

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

5.4.1 CCD Array Architecture

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

CCDs are rugged and compact: unintensified CCDs can withstand direct exposure to relatively high light levels, magnetic fields and RF radiation. They are easily cooled and can be precisely thermally controlled to within ± 50 millidegrees.

Because CCD arrays 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 PIXIS-XF cameras may require a customer-provided X-ray shutter to prevent light from reaching the CCD during readout.

5.4.2 Exposure Time

Exposure Time, which is set on the **Experiment Setup ► Main** tab {**Common Acquisition Settings** expander}, 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 before the start of the exposure time. At the end of the exposure time, the CCD is readout and cleaning starts again.

Because PIXIS-XF 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** {**Not Reading Out**} or the **SHUTTER** {**Shutter Open**} signal on the **LOGIC OUT** connector on the rear of the PIXIS-XF 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.

5.4.3 CCD Temperature

As stated before, lowering the temperature of the CCD will generally enhance the quality of the acquired signal.

- When WinX/32 is the controlling software, temperature control is done via the Detector Temperature dialog accessed from the Setup menu. See Figure 5-7.
- When LightField is being used, temperature control is done on the Sensor expander.

Figure 5-7: Typical WinX Detector Temperature Dialog
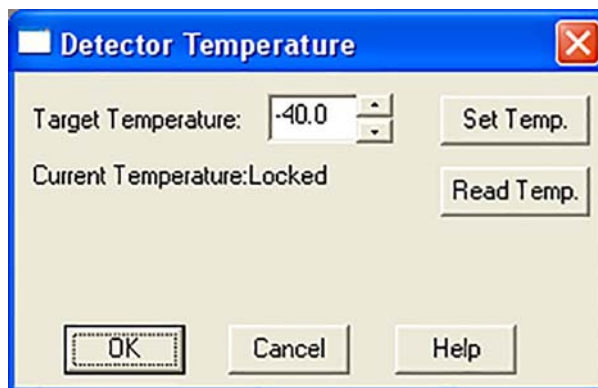
Once the target array temperature {Temperature Setpoint} has been set, the software controls the camera's cooling circuits to reach set array temperature. On reaching that temperature, the control loop locks to that temperature for stable and reproducible performance. When temperature lock has been reached (temperature within 0.05°C of set value), the current temperature is **Locked**. The on-screen indication allows easy verification of temperature lock.

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

The deepest operating temperature for a system depends on the CCD array size and packaging. Refer to Table A-2, Typical Deepest Operating Temperature, on page 91 for complete information.

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 greater than +20°C, temperature lock may not be achievable at the lowest specified temperature for your camera. Temperature regulation may not reach its ultimate stability for at least 30 minutes after lock is established.

2. In WinX, the Detector Temperature dialog will not display temperature information while you are acquiring data.

5.4.4   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. Refer to Table A-2, Typical Deepest Operating Temperature, on page 91 for complete information.

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 reduced by a factor of ~2 for every 6-7 degree reduction in temperature. In the case of cameras such as the PIXIS-XF 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.

⚠ CAUTION!

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. Contact Teledyne Princeton Instruments Customer Support for information about how to refresh the vacuum. Refer to Contact Information on page 114 for complete information.

🔍 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.

5.4.5   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.

5.5 Readout

After the exposure time has elapsed, the charge accumulated in the array pixels needs to be read out of the array, converted from electrons to digital format, 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. The charge in the shift register pixels, which typically have twice the capacity of the image pixels, is then shifted into the output node and then to the output amplifier where the electrons are grouped as electrons/count. This result leaves the CCD and goes to the preamplifier where gain is applied. See Figure 5-8.

Figure 5-8: Array Terms for a CCD with a Dual Output Amplifier
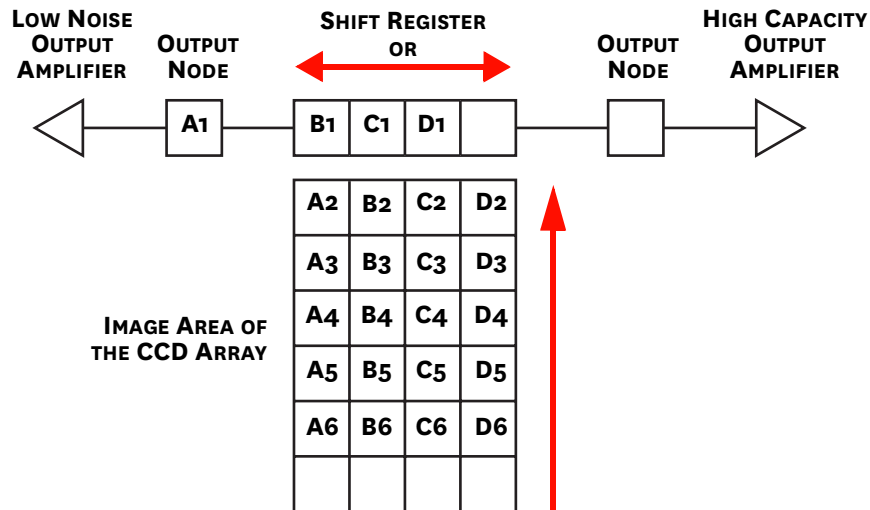
WinX/32 and LightField allow you to specify the type of readout (full frame or binned), the output amplifier, and the gain (i.e., the number of electrons required to generate an ADU).

5.5.1 Full Frame Readout

In this section, a simple 6 x 4 pixel CCD is used to demonstrate how charge is shifted and digitized. Full frame readout, for full frame CCDs, reads out the entire CCD surface at the same time.

Region 1 in Figure 5-9 represents a CCD after exposure but before the beginning of readout. The capital letters represent different amounts of charge, including both signal and dark charge. This section explains readout at full resolution, where every pixel is digitized separately.

Figure 5-9:   Full Frame at Full Resolution
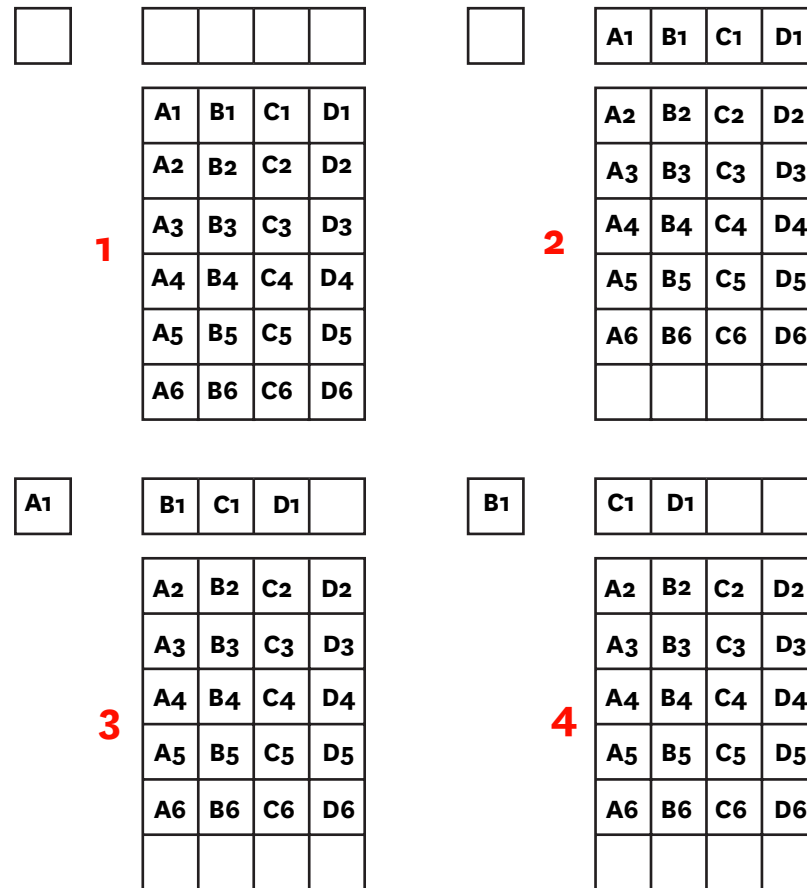
CCD Readout begins with the simultaneous shifting of all pixels one row toward the shift register, in this case the row at the top. The shift register is a single line of pixels along one edge of the CCD, not sensitive to light and used for readout only. Typically the shift register pixels hold twice as much charge as the pixels in the imaging area of the CCD.

After the first row is moved into the shift register, the charge now in the shift register is shifted toward the output node, located at one end of the shift register. As each value is emptied into the output it is digitized. Only after all pixels in the first row are digitized is the second row moved into the shift register. The order of shifting in our example is therefore A1, B1, C1, D1, A2, B2, C2, D2, A3, ...

After charge is shifted out of each pixel the remaining charge is zero, meaning that the array is immediately ready for the next exposure.

A subsection of the CCD can be read out at full resolution, sometimes dramatically increasing the readout rate while retaining the highest resolution in the Region Of Interest (ROI). Some overhead time is required to shift out and discard unwanted pixels.

5.5.2   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. Rectangular groups of pixels of any size may be binned together, subject to some hardware and software limitations.

5.5.2.1 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 shift register pixels typically hold only twice as much charge as image pixels, the binning of large sections may result in saturation and blooming, or spilling of charge back into the image area.

Figure 5-10 shows an example of 2 x 2 binning. Each pixel of the image displayed by the software represents 4 pixels of the CCD array. Rectangular bins of any size are possible. Binning also reduces readout time and the burden on computer memory, but at the expense of resolution. Since shift register pixels typically hold only twice as much charge as image pixels, the binning of large sections may result in saturation and blooming, or spilling of charge back into the image area.

Figure 5-10: Diagram of 2 x 2 Binning
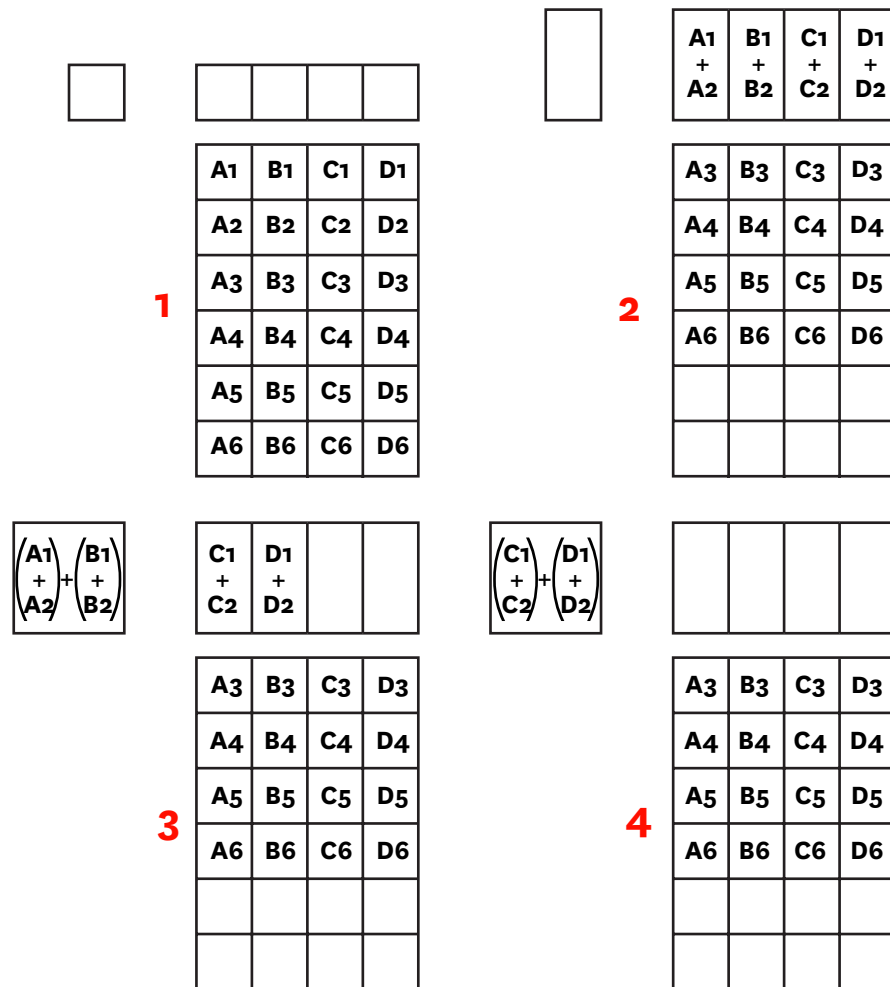
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The readout rate for n x n binning is approximated using a more general version of the full resolution equation. The modified equation is:

$$t_r - \left[N_x \cdot N_y \cdot \left(\frac{t_{sr}}{n} + \frac{t_v}{n^2} \right) \right] + (N_x \cdot t_i)$$

5.5.2.2   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, the data 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. 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.

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., more than 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.

5.5.3   Output Amplifier {Quality} Selection

The output amplifier amplifies the collected charge from the output node and outputs it as electrons/count. Although Figure 5-11 shows an array with dual output nodes and amplifiers (one set at each end of the shift register), some PIXIS-XF systems are available with a single output node and amplifier.

Figure 5-11: Array Terms for a CCD with a Dual Output Amplifier
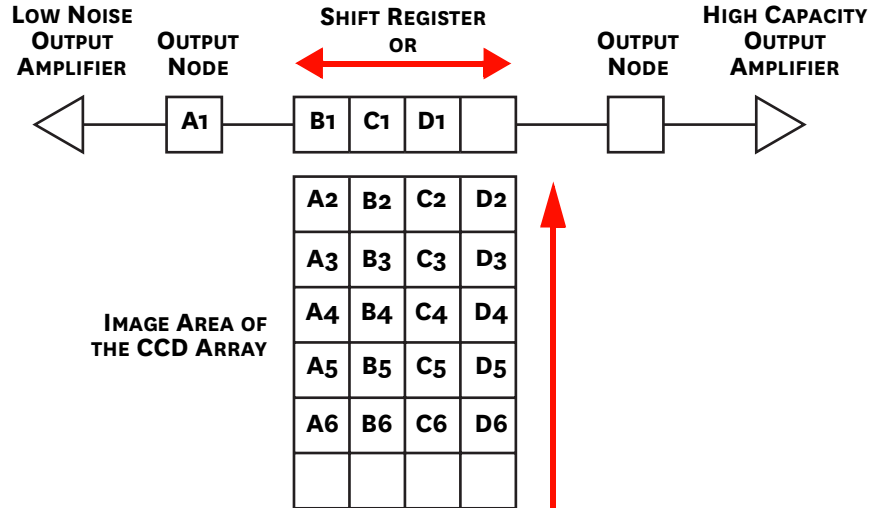
If your system has dual output amplifiers, you can choose the output amplifier to be used (i.e., High Capacity or Low Noise,) via the **Acquisition ► Experiment Setup... ► ADC** tab {**Quality** on the **Analog to Digital Conversion** expander}:

- **High Capacity Amplifier**

  Provides a spectrometric well capacity that is approximately 3 times the well capacity for the Low Noise amplifier selection. High Capacity is suitable when you have intense light signals or signals with high dynamic range.

- **Low Noise Amplifier**

  Provides the highest sensitivity performance and is suitable when you have weak signals.

> **NOTE:**
>
> The choice of **Output Amplifier** {**Quality**} and **Controller Gain** {**Analog Gain**} settings should be considered together for the best signal capture. Examples of the interaction of output amplifier and controller gain selections are provided in Table 5-1, Typical Controller Gain {Analog Gain} vs. Readout Port, on page 53.

5.5.4 Controller Gain

Controller Gain is software-selectable and is used to change the relationship between the number of electrons acquired on the CCD and the Analog-to-Digital Units (ADUs or counts) generated.

In WinX/32, gain selection is made on the **Acquisition ► Experiment Setup... ► ADC** tab. The choices are

- **1 (Low)**
  Users who measure high-level signals may wish to select Low to allow digitization of larger signals.
- **2 (Medium)**
  Medium is suitable for experiments within the mid-level intensity range.
- **3 (High)**
  Users who consistently measure low-level signals may wish to select High, which requires fewer electrons to generate an ADU and reduces some sources of noise.

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

Example

The following descriptions assume the Low Noise Readout Port has been selected and that the actual incoming light level is identical in all three instances.

> **NOTE:**
>
> The numbers used illustrate the effect of changing a controller gain setting and may not reflect actual performance: gain at the 1, 2, and 3 settings depends on the CCD installed.

Table 5-1: Typical Controller Gain {Analog Gain} vs. Readout Port

Readout Port {Quality}	Controller Gain {Analog Gain} Selection		
	1 {Low}	2 {Medium}	3 {High}
Low Noise	4 e-/count	2 e-/count	1 e-/count
High Capacity	16 e-/count	8 e-/count	4 e-/count

- **1 (Low)** requires four electrons to generate one ADU. Strong signals can be acquired without flooding the CCD array. 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.
- **2 (Medium)** requires two 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 CCD array appears to be flooded with light, you may want to change the setting to Low.
- **3 (High)** requires one electron to generate one ADU and some noise sources are reduced. Because fewer electrons are needed to generate an ADU, weaker signals can be more readily detected. Lower noise further enhances the ability to acquire weak signals. If the CCD array appears to be flooded with light, you may want to change the setting to Medium or Low.

5.6   Digitization (Rate)

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. The number of bits per pixel is based on both the hardware and the settings programmed into the camera through the software. Refer to Section 5.5, Readout, on page 48 for additional information.

Factors associated with digitization include the digitization rate and baseline signal. Because the PIXIS-XF cameras have dual digitizers, you can change the speed at which digitization occurs. ADC offset of the baseline, however, is set at the factory and is not user-changeable. These factors are discussed in the following paragraphs.

5.6.1   Digitization Rate

The PIXIS-XF camera has been designed with dual digitizers (i.e., 100 kHz and 2 MHz). Dual digitization allows you to choose how quickly the data will be digitized with optimal signal-to-noise ratios achieved at both readout speeds. 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 2 MHz conversion speed is used for the fastest possible data collection and the 100 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:**
>
> In WinX/32, the ADC rate can be changed on the **Experiment Setup ▶ ADC** tab.
>
> In LightField, the speed is changed on the **Analog to Digital Conversion** expander.

5.6.2 ADC Offset (Bias)

ADC offset, which is also known as Baseline Offset, provides another way of dealing with dark charge.

REFERENCES:

Refer to Section 5.4.4, Dark Charge, on page 47 for additional information.

By offsetting the baseline signal, much of the background is ignored during conversion.

Offsetting the baseline is accomplished by adding a voltage to the signal to bring the A/D output to a non-zero value, typically 50-100 counts. This offset value ensures that all the true variation in the signal can really be seen and not lost below the A/D 0 value. Since the offset is added to the signal, these counts only minimally reduce the range of the signal from 65535 (16-bit A/D) to a value in the range of 50-100 counts lower.

⚠ CAUTION!

If you observe a sudden change in the baseline signal you may have excessive humidity in the camera's vacuum enclosure. TURN OFF THE SYSTEM IMMEDIATELY. Contact Teledyne Princeton Instruments Customer Support for information on how to refresh the vacuum. See page 98 for contact information.

NOTE:

Do not be concerned about either the DC level of the baseline signal or its shape unless it is very high (i.e., > 1000 counts with 16-bit ADC).

The ADC Offset is pre-set at the factory and is not user-changeable.

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Chapter 6: Advanced Topics

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

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

The following topics are discussed:

- **Section 6.1, Timing Modes**, on page 58

  Discusses Timing Modes {Trigger Response}, Shutter Control {Shutter Mode}, and Edge Trigger.

  Also included under this topic is a discussion of the EXT SYNC connector, the input connector for a trigger pulse.

- **Section 6.2, Fast and Safe Modes**, on page 65

  Discusses the Fast and the Safe modes.

  — Fast is used for real-time data acquisition.

  — Safe is used in WinX/32 when coordinating acquisition with external devices or when the computer speed is not fast enough to keep pace with the acquisition rate.

- **Section 6.3, LOGIC OUT Control**, on page 67

  Discusses the EXT SYNC and LOGIC OUT output connectors on the rear of the PIXIS-XF. The levels at this connector can be used to monitor camera operation or synchronize external equipment.

- **Section 6.4, Kinetics Mode**, on page 68

  Describes how to set up and acquire data with the Kinetics Mode (a WinX/32 option, standard with LightField), which allows full-frame CCDs to take time-resolved images/spectra.

  > **NOTE:**
  >
  > Full-frame CCDs require mechanical or optical masking of the CCD array.

- **Section 6.5, Custom Modes**, on page 72

  Discusses the following modes:

  — Custom Chip {Custom Sensor}

  — Custom Timing

  These modes allow you to specify an active sub-area of the CCD array and/or a faster vertical shift rate for the purpose of increased frame rate (pixels outside of the area are not read).

  > **NOTE:**
  >
  > Custom Chip {Custom Sensor} mode requires mechanical or optical masking of the array to prevent smearing.

6.1 Timing Modes

The basic PIXIS-XF timing modes are:

- Free Run {No Response}
- External Sync {Readout Per Trigger}
- External Sync {Readout Per Trigger} with Continuous Cleans {Clean Until Trigger}.

Timing modes are combined with Shutter options to provide the widest variety of timing modes for precision experiment synchronization. Refer to Table 6-1.

Table 6-1:   Camera Timing Modes

Mode	Shutter Condition
Free Run {No Response}	Normal
External Sync {Readout Per Trigger}	Normal
External Sync {Readout Per Trigger}	PreOpen {Open Before Trigger}
External Sync {Readout Per Trigger} with Continuous Cleans {Clean Until Trigger}	Normal
External Sync {Readout Per Trigger} with Continuous Cleans {Clean Until Trigger}	PreOpen {Open Before Trigger}

> **NOTE:**
>
> Since PIXIS-XF cameras do not use shutters, the **Shutter Type** parameter on the **Hardware Setup ► Controller/ Camera** tab should be set to **None**.

Available shutter options include Normal, PreOpen {Open Before Trigger}, Disable Opened {Always Open} or Disable Closed {Always Closed}. Disable means that the shutter will not operate during the experiment. Disable Closed {Always Closed} is useful for making dark charge measurements. PreOpen {Open Before Trigger}, available in the External Sync {Readout Per Trigger} and External Sync {Readout Per Trigger} with Continuous Cleans {Clean Until Trigger} modes, opens the shutter as soon as the PIXIS-XF 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 included in the following sections. With the exception of Free Run where the modes of shutter operation are identical, both Normal and PreOpen lines are illustrated in the timing diagrams and flow chart.

The timing diagrams are labeled with:

- Exposure Time (t_{exp});
- Shutter Compensation Time (t_c);
- Readout Time (t_R).

Exposure time and readout are discussed in greater detail in Chapter 5, Operation.

> **NOTE:**
>
> When no shutter is configured, the shutter compensation time (the time required to close a mechanical shutter) will be approximately 0 ms.

6.1.1   Free Run {No Response}

In Free Run {No Response} mode the camera 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. See Figure 6-1.

Figure 6-1:   High-Level Block Diagram: Free Run {No Response}
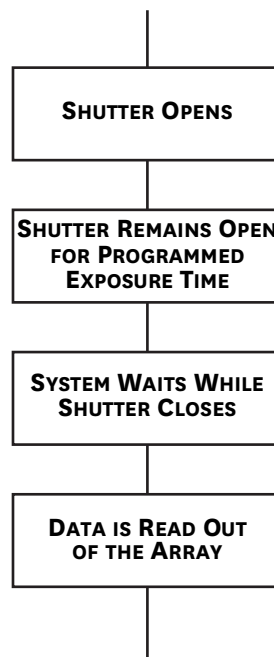
This mode is useful for experiments with a constant light source, such as a CW laser, an X-ray source, or a DC lamp. Other experiments that can utilize this mode are high repetition studies, where the number of shots that occur during a single shutter cycle is so large that it appears to be continuous illumination.

Other experimental equipment can be synchronized to the camera by using the software-selectable output signal **SHUTTER {Normal}** or **NOT SCAN {Not Reading Out}** on the **Hardware Setup ► Controller Camera** tab {**Trigger/Shutter** expander} from the **LOGIC OUT** connector. Shutter operation and the NOT SCAN {Not Reading Out} output signal are illustrated in Figure 6-2.

Figure 6-2:   Timing Diagram: Free Run {No Response}
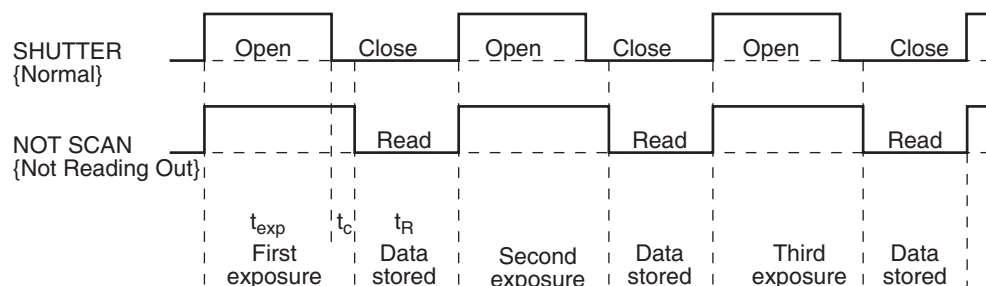
t_{exp} = Exposure Time

t_R = Readout Time

t_c = Shutter Compensation Time* {Closing Delay}

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

6.1.2   External Sync {Readout Per Trigger}

In this mode all exposures are synchronized to an external source. As illustrated in Figure 6-3, this mode can be used in combination with Normal or PreOpen {Open Before Trigger} shutter operation.

Figure 6-3:   High-Level Block Diagram: External Sync, Shutter Preopen vs. Normal
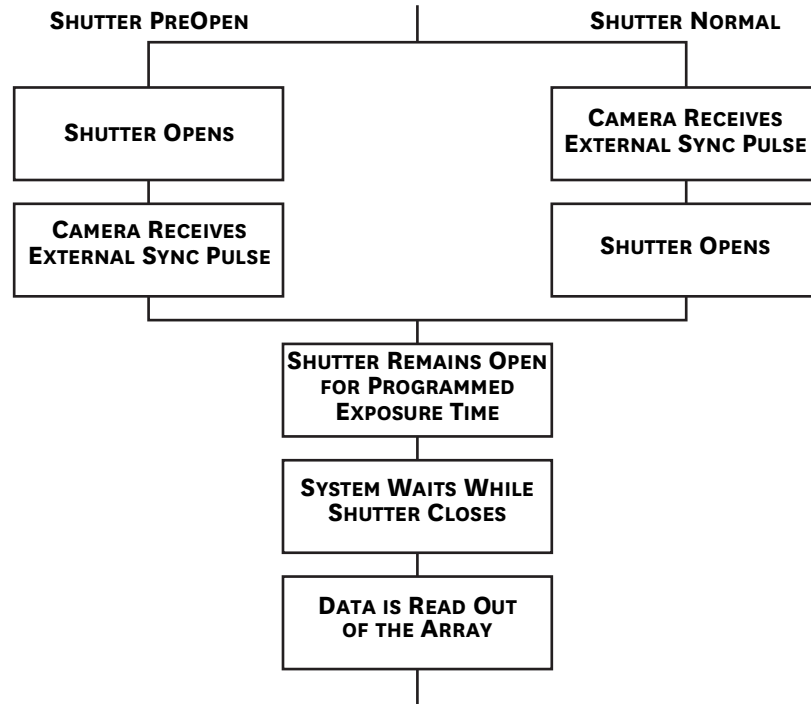
In Normal Shutter {Normal} mode, the camera waits for an External Sync pulse and then opens the shutter for the programmed exposure period. As soon as the exposure is complete, the shutter closes and the CCD array is read out. The shutter requires up to 8 ms or more to open completely, depending on the shutter model.

External synchronization depends on an edge trigger (negative- or positive-going) which must be supplied to the **EXT SYNC** connector on the back of the camera. The type of edge must be identified in the application software to ensure that the shutter opening is initiated by the correct edge (in WinX/32, this is done on the **Experiment Setup ► Timing** tab, in LightField on the **Trigger/Shutter** expander). Since the shutter requires up to 8 ms to fully open, the External Sync pulse provided by the experiment must 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 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 PreOpen Shutter {Open Before Trigger} mode shutter operation is only partially synchronized to the experiment. As soon as the camera is ready to collect data, the shutter opens. Upon arrival of the first External Sync pulse at the **EXT SYNC** connector, 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.

The PreOpen {Open Before Trigger} mode is useful in applications where an External Sync pulse cannot be provided 8 ms (or the length of time a mechanical shutter takes to open) 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 {Normal} 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.

Figure 6-4 illustrates the timing diagram for External Sync mode.

Figure 6-4:　Timing Diagram: External Sync Mode (+ edge trigger)
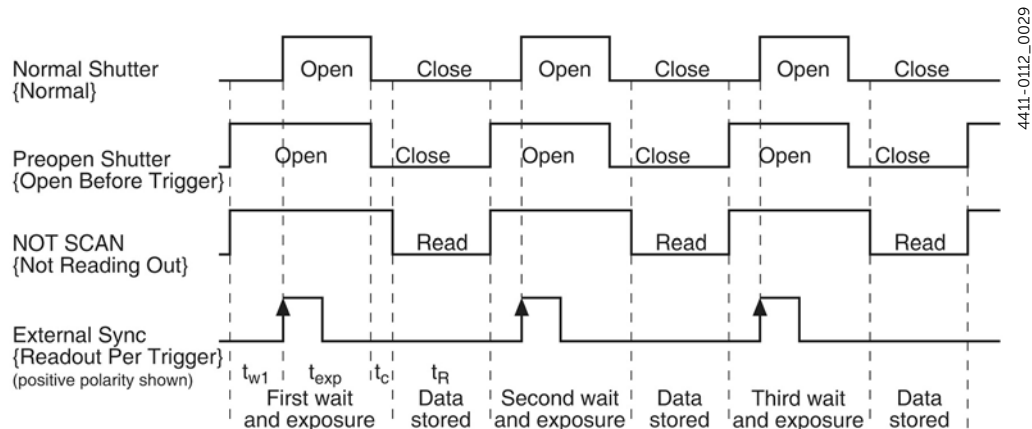
NOTE:

If EXT SYNC is still active at the end of the readout (i.e., it is still HIGH in Figure 6-4,) the hardware may interpret this as a second sync pulse, and so on.

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

Another timing mode available with the PIXIS-XF is Continuous Cleans {Clean Until Trigger}. In addition to the standard cleaning of the array which occurs after the camera is enabled, this mode removes any charge from the array until the moment the External Sync pulse trigger edge is received. See Figure 6-5 for a high-level block diagram of this process.

Figure 6-5:   High-Level Block Diagram: Continuous Cleans {Clean Until Trigger}
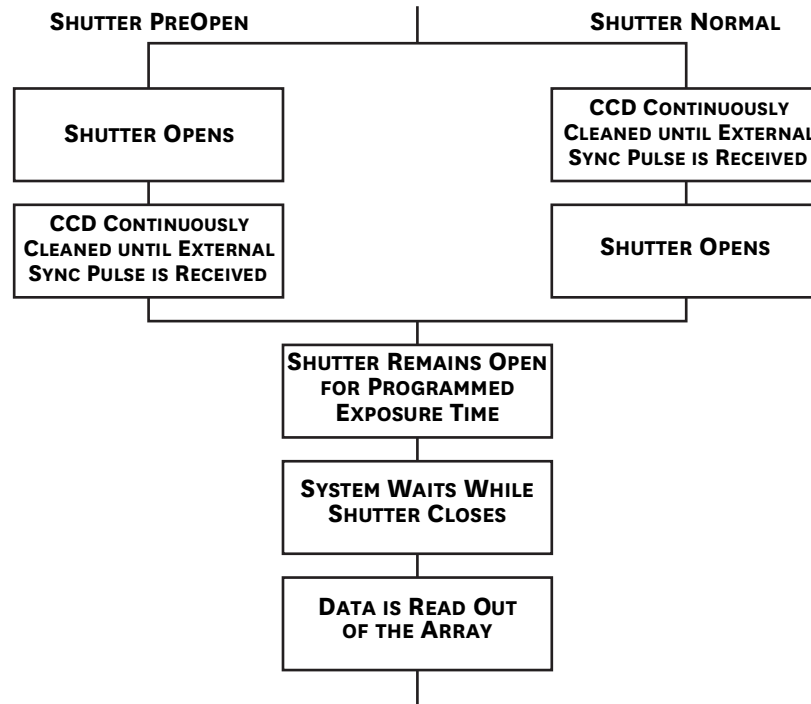
Once the External Sync pulse trigger edge is received, cleaning of the array stops as soon as the current row is shifted, and frame collection begins. A time delay of up to one row shift can be expected. With Normal Shutter {Normal} operation the shutter is opened for the set exposure time. With PreOpen Shutter {Open Before Trigger} 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 vertical rows are shifted midway when the External Sync pulse trigger edge arrives, the pulse is saved until the row shifting is completed, to prevent the CCD from getting out of sync. As expected, the response latency is on the order of one vertical shift time, from 1-30μs depending on the array. This latency does not prevent the incoming signal from being detected since photo generated electrons are still collected over the entire active area. However, if the signal arrival is coincident with the vertical shifting, image smearing of up to one pixel is possible. The amount of smearing is a function of the signal duration compared to the single vertical shift time.

Figure 6-6 and Figure 6-7 illustrate the timing diagrams for this mode for WinX/32 and LightField, respectively.

NOTE:

If EXT SYNC is still active at the end of the readout (i.e., it is still HIGH in Figure 6-6,) the hardware may interpret this as a second sync pulse, and so on.

Figure 6-6: Timing Diagram: WinX/32 Continuous Cleans
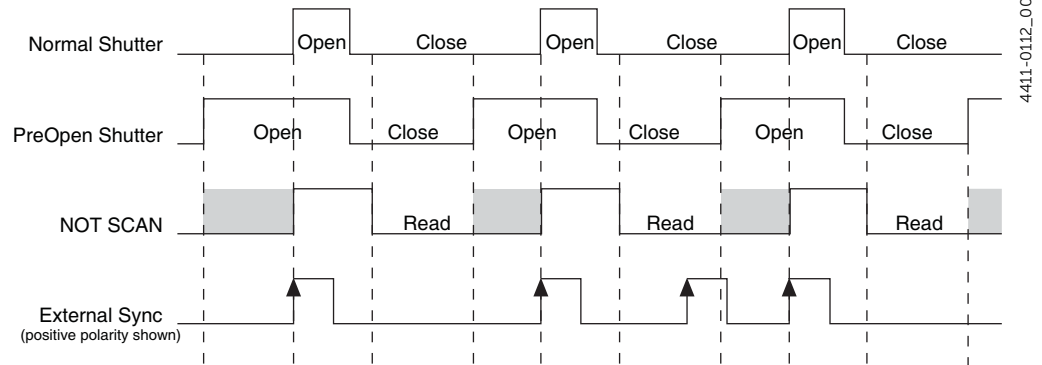
Figure 6-7: Timing Diagram: LightField Clean Until Trigger
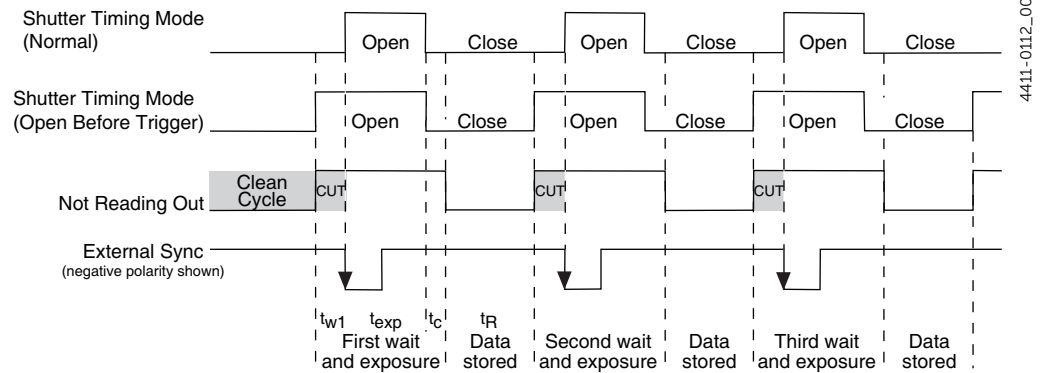
6.1.4   EXT SYNC Trigger Input

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

- Pulse Height

  0 to +3.3-5 V_{DC} logic levels (TTL-compatible)

- Pulse Width (trigger edge frequency)

  The time between trigger edges.

- EXT SYNC Connector Impedance

  High impedance

- Trigger Edge

  + (rising) or – (falling) edge must be indicated on the Experiment Setup ▶ Timing tab {Trigger/Shutter expander}

Figure 6-8 illustrates the rear panel connectors on the PIXIS-XF.

Figure 6-8:   Rear View of PIXIS-XF Camera

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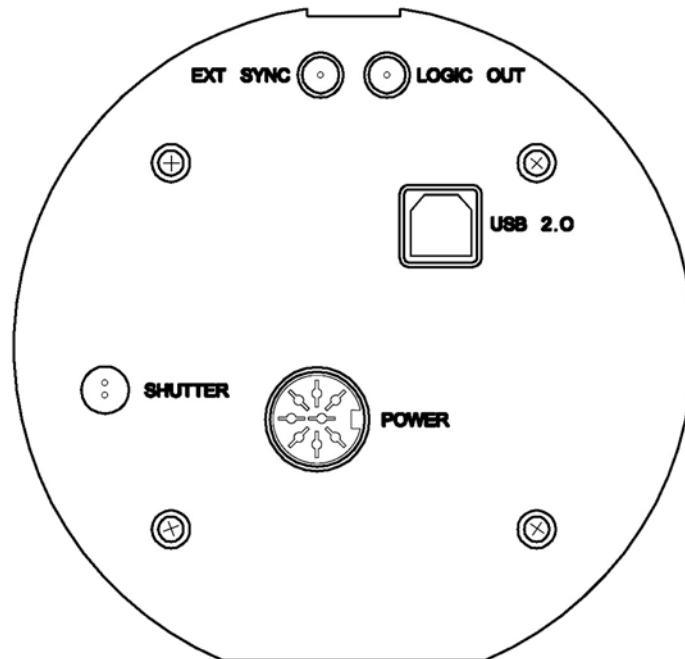
6.2 Fast and Safe Modes

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

In WinX, the choice of Fast or the Safe data collection is made on the **Experiment Setup ► Timing** tab. The flowcharts illustrated in Figure 6-9 show the differences between the two modes. In LightField, Fast data collection is always used.

6.2.1 Fast Mode (WinX/32 and LightField)

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

NOTE: ─────────────────────────

LightField always uses Fast Mode.

6.2.2 Safe Mode (WinX/32)

Safe Mode operation is useful when the camera is operated from a slower computer that cannot process the incoming data fast enough. It is also useful when data collection must be coordinated with external devices such as external shutters and filter wheels. As shown in Figure 6-9, 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 PIXIS-XF is disabled for a short time after each frame.

NOTE: ─────────────────────────

When running WinX/32, Safe Mode must be used whenever the system is set up for the optional Kinetics Mode. Refer to Section 6.4, Kinetics Mode, on page 68 for complete information about this type of image acquisition and readout.

Figure 6-9:   Flowcharts Comparing Safe and Fast Mode Operation

Safe Mode

Start

Computer programs camera with exposure and binning parameters

Start acquisition command sent from computer to camera

Cleans performed

1 frame collected as per timing mode

Stop acquisition command sent from computer to camera

Background or flatfield on? — No

Yes

Background and/or flatfield correction performed

Frame displayed

Frames complete? — No

Yes

Stop

Fast Mode

Start

Computer programs camera with exposure and binning parameters

Start acquisition command sent from computer to camera

Cleans performed

1 frame collected as per timing mode

Background or flatfield on? — No

Yes

Background and/or flatfield correction performed

Frames complete? — Yes

No

During next acquisition frames are displayed as time permits

Stop acquisition command sent from computer to camera

Stop

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6.3 LOGIC OUT Control

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

- **NOT SCAN {Not Reading Out}**

  Logic low when CCD is being read; otherwise high.

- **SHUTTER {Shutter Open}**

  Logic high when the shutter is open. The output precisely brackets shutter-open time (exclusive of shutter compensation, tc) and can be used to control an external shutter or to inhibit a pulser or timing generator.

- **NOT READY {Busy}**

  After a start acquisition command, this output changes state on completion of the array cleaning cycles that precede the first exposure. 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 3 frames have been programmed.

- **LOGIC 0 {Always Low}**

  The level at the connector is low.

- **LOGIC 1 {Always High}**

  The level at the connector is high.

Figure 6-10 illustrates the timing diagram for these key LOGIC OUT control signals.

Figure 6-10: Timing Diagram: LOGIC OUT Control Signals
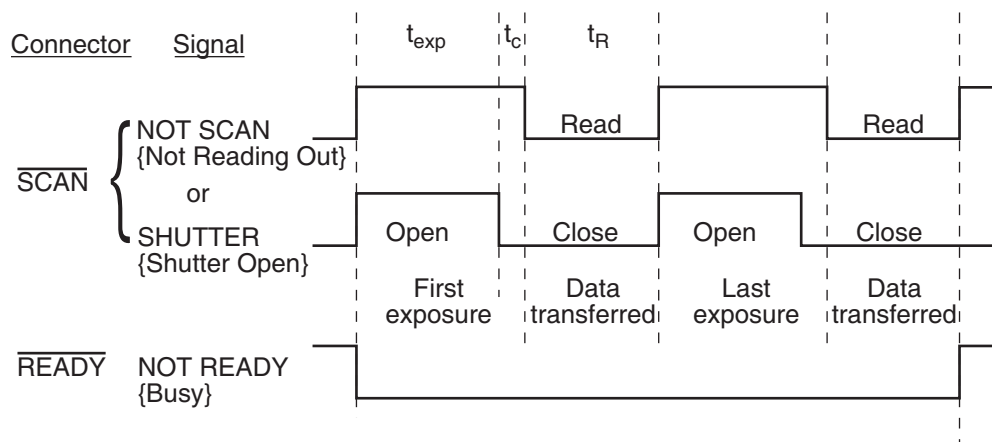
6.4 Kinetics Mode

> **NOTE:**
>
> Kinetics Mode is:
> - A purchased option for WinX/32 applications;
> - Included in the standard LightField application.

Kinetics mode uses the CCD to expose and store a limited number of images in rapid succession. The time it takes to shift each line (or row) on the CCD is as short as a few hundred nanoseconds to few microseconds, depending on the CCD. Therefore the time between images can be as short as a few microseconds. Kinetics mode allows frame transfer CCDs to take time-resolved images/spectra.

> **NOTE:**
>
> In WinX/32, if the Kinetics option has been installed in the PIXIS-XF, this readout mode will be made available when you select the appropriate camera type on the Hardware Setup dialog.

Figure 6-11 illustrates a high-level diagram of kinetics mode. Returning to the 4 x 6 CCD example, in this case 2/3 of the array is masked, either mechanically or optically. The shutter opens to expose a 4 x 2 region. While the shutter remains open, charge is quickly shifted just under the mask, and the exposure is repeated. After a third image has been collected the shutter is closed and the CCD is read out. Since the CCD can be read out slowly, very high dynamic range is achieved. Shifting and readout are shown Figure 6-11.

Figure 6-11: High-Level Diagram: Kinetics Readout
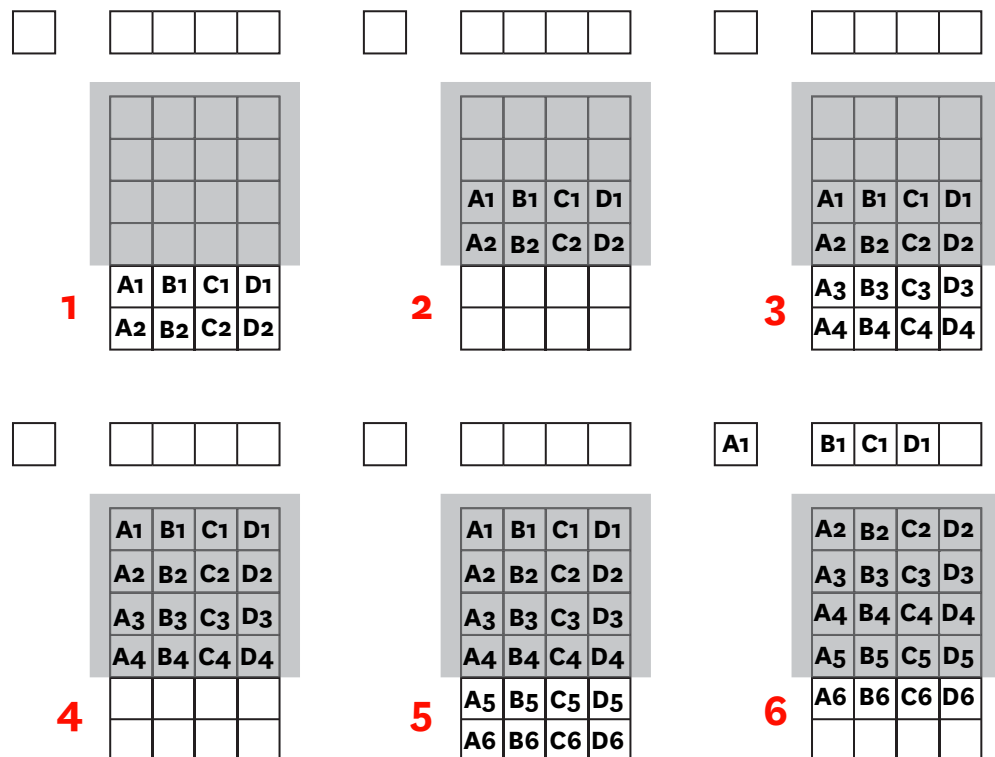
6.4.1   Kinetic Timing Modes

Kinetics Mode operates with three timing modes: Free Run {No Response}, Single Trigger {Readout Per Trigger}, and Multiple Trigger {Shift Per Trigger}. Free run {No Response} mode is used for experiments that do not require any synchronization with the experiments. The other two modes (i.e., Single Trigger and Multiple Trigger,) require that an external TTL pulse be applied to the camera via the **EXT SYNC** connector on the rear of the camera. See Figure 6-12, Figure 6-13, Figure 6-14, and Figure 6-15.

Figure 6-12: Typical WinX/32 Hardware Setup Dialog
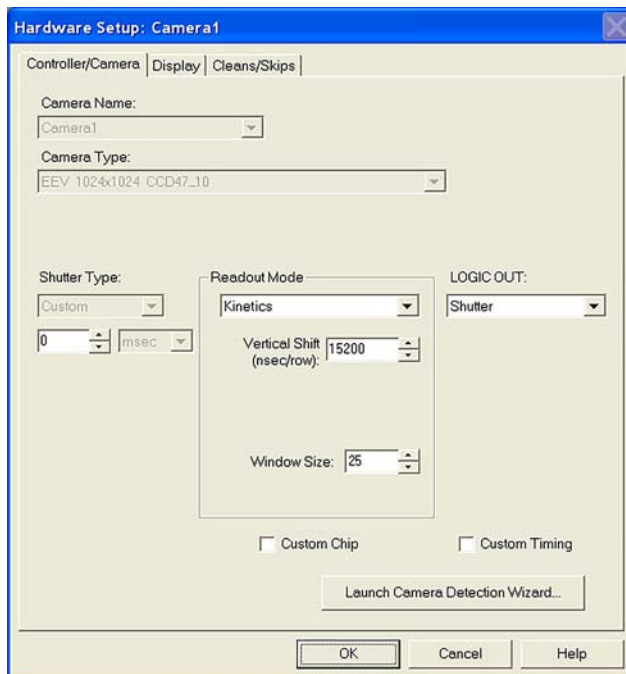
Figure 6-13: Typical WinX/32 Experiment Setup Dialog
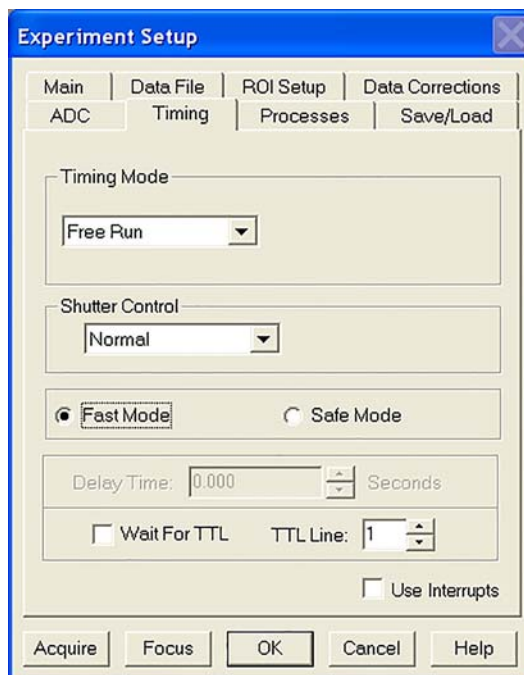
Figure 6-14: Typical LightField Readout Expander: Kinetics Mode
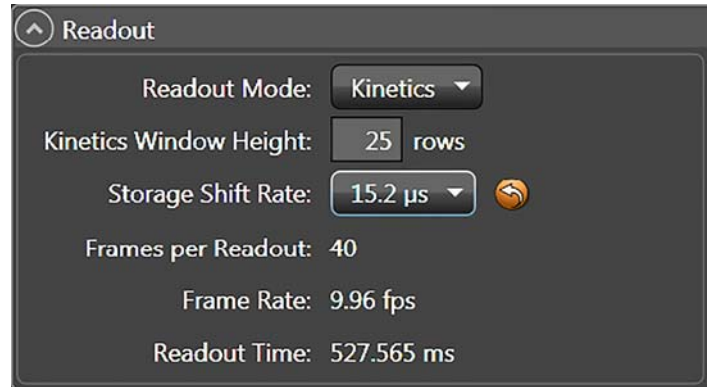
4411-0112_0038

Figure 6-15: Typical LightField Shutter and Trigger Expanders: Normal, No Response
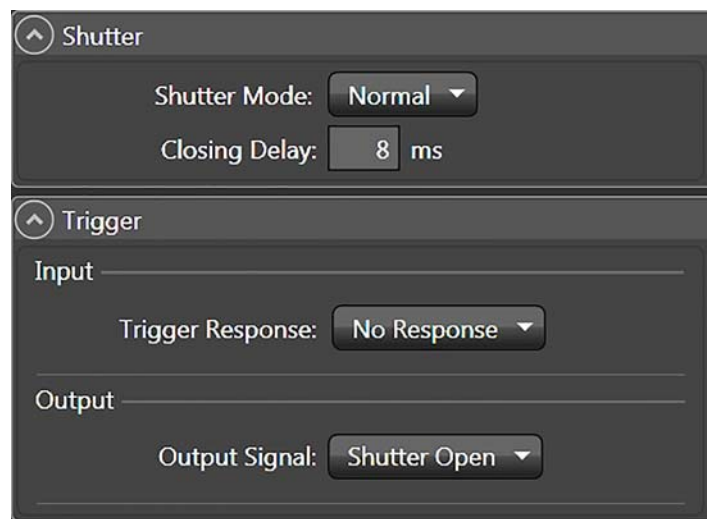
4411-0112_0039

6.4.1.1 Free Run (Non-Triggered Mode)

In Free Run {No Response} Kinetics mode, the PIXIS-XF takes a series of images, each with the Exposure time set through the software (in WinX/32, the exposure time is set on the **Experiment Setup ► Main** tab; in LightField on the **Common Acquisition Settings** expander.) The time between image frames, which may be as short as a few microseconds, is limited by the time required to shift an image under the mask: this inter-image time equals the Vertical Shift rate (specified in ns/row) multiplied by the Window Size (the number of rows allocated for an image frame). The exact number of frames depends on the selected Window Size and is equal to the number of pixels perpendicular to the shift register divided by the Window Size. Integrate signals (SHUTTER {Shutter Open}) or Readout signals (NOT SCAN {Not Reading Out}) are provided at the **LOGIC OUT** connector for timing measurements.

For example, returning to Figure 6-11, there are 6 pixels perpendicular to the shift register and the Window Size is 2 pixels high. The number of frames is 3. If the Vertical Shift rate for the CCD is 1600 ns/row, the Shift time will be 3200 ns per frame.

Figure 6-16 illustrates the timing diagram for Free Run Kinetics mode.

Figure 6-16: Timing Diagram: Free Run
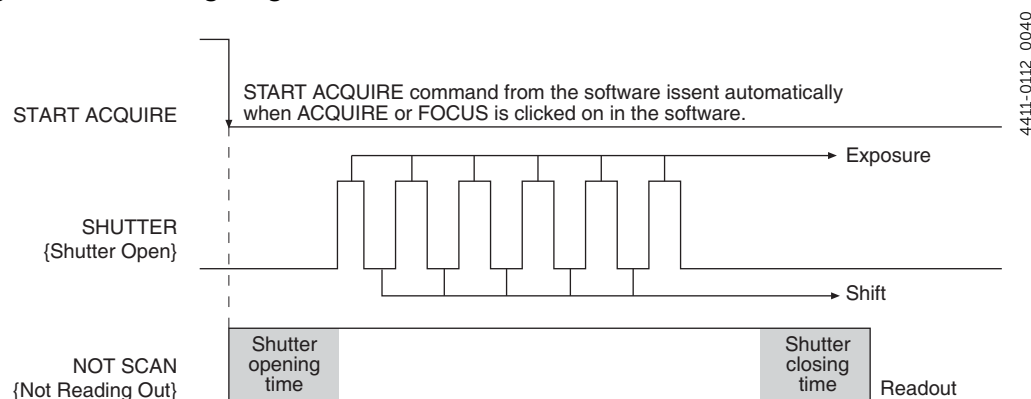
6.4.1.2   Triggered Modes

In Single Trigger mode, the camera requires only one trigger to initiate an entire series of exposure-shift cycles as illustrated in Figure 6-17.

Figure 6-17: Timing Diagram: Single Trigger
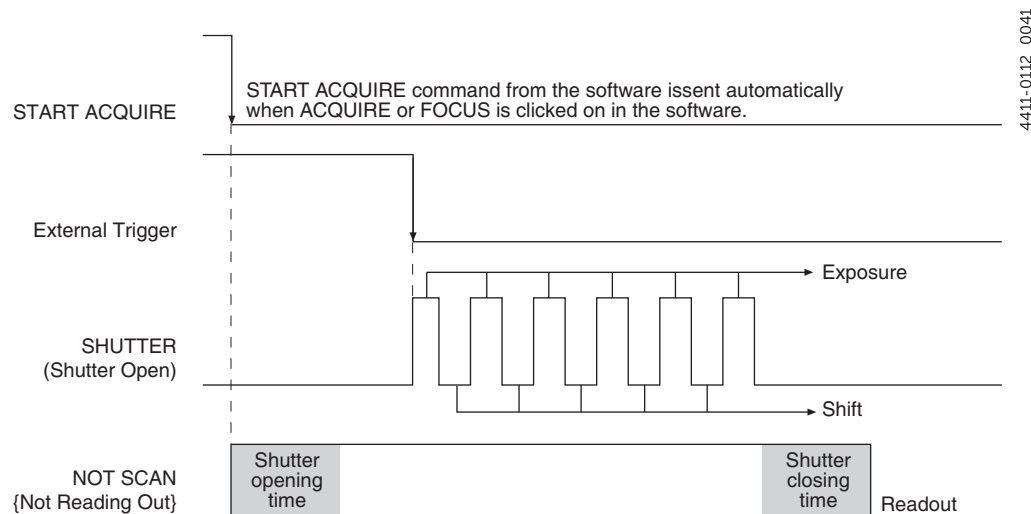
When Acquire or Focus {Run} is clicked, the shutter (if there is an external X-ray shutter) is opened and the camera uses the exposure time as entered in the software. The trigger is applied at the Ext Sync connector on the rear of the PIXIS-XF. After the series is complete, the shutter closes and the CCD is read out at normal speeds. Once the readout is complete, the camera is ready for the next series of exposures. This timing is shown in Figure 6-17, where a single External trigger pulse is used to collect a burst of 6 frames.

In multiple trigger mode, the shutter (if there is an external X-ray shutter) is opened when Acquire or Focus {Run} is clicked and each exposure-shift cycle in the acquisition is triggered independently by a pulse applied at the EXT SYNC connector. This mode is useful when each subframe needs to be synchronized with a pulsed external light source such as a laser. Once the series is complete, the shutter closes and readout begins. Since the shutter is open during the entire series of images, irregularly spaced external pulses will result in exposures of different lengths. Once the series has been read out the camera is ready for the next series. This timing is shown in Figure 6-18, where a series of 6 frames is collected with 6 External Sync pulses.

Figure 6-18: Timing Diagram: Multiple Trigger
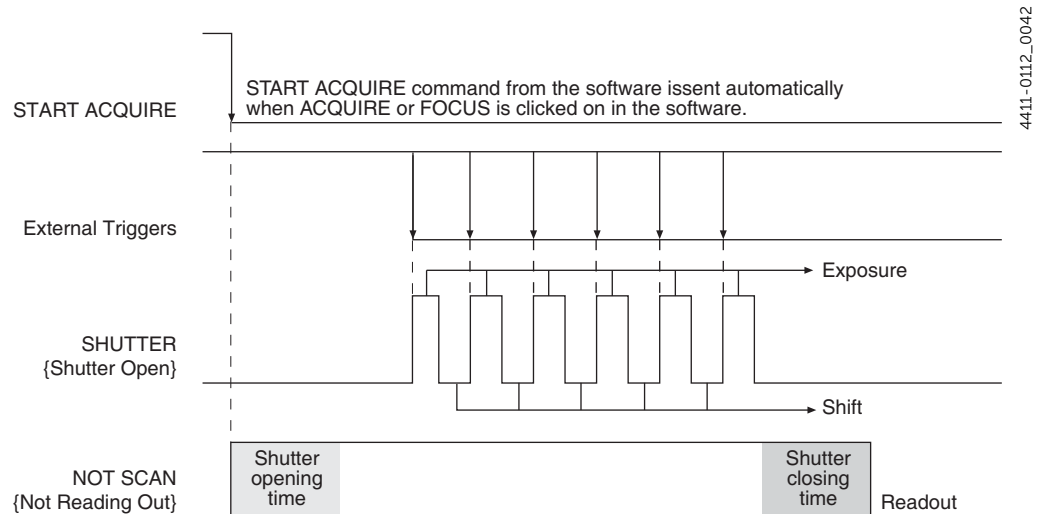
6.5   Custom Modes

Custom Chip and Custom Timing modes are available as an option for WinX/32. {Custom Sensor} and Custom Timing are standard in LightField (sensor and readout mode dependent.) These modes are intended to allow data acquisition at the fastest possible rates for your camera. Custom Chip {Custom Sensor} allows you to reduce the apparent size of the CCD array and Custom Timing allows you to select a faster vertical shift time.

6.5.1   Custom Chip

In addition to Binning and Regions of Interest, there is a third way to reduce Readout Time: Custom Chip {Custom Sensor}. This feature allows you to redefine the size of the CCD's active area via software. Unlike setting a smaller Region Of Interest (ROI), which also involves reading out fewer pixels, this mode does not incur overhead from discarding or skipping the rest of the rows. And, unlike both Binning and ROI, Custom Chip {Custom Sensor} relies on a form of array masking to ensure that no light falls outside the currently set active area.

> 🔍 **NOTE:** ────────────────────────────
>
> Custom Chip is a WinX option. Custom Sensor is standard with LightField: availability is sensor-dependent.

6.5.1.1 Software Settings

⚠️ **CAUTION!** ————————————

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

In WinX/32, if Custom Chip has been installed, selecting **Show Custom Chip** check box
on the **Controller/Camera** tab adds the **Custom Chip** tab to the **Hardware Setup** dialog.
The Custom Chip parameters are shown in Figure 6-19. The default values conform to
the physical layout of the CCD array and are optimum for most measurements.

Figure 6-19: Typical WinX/32 Hardware Setup Dialog: Custom Chip Tab
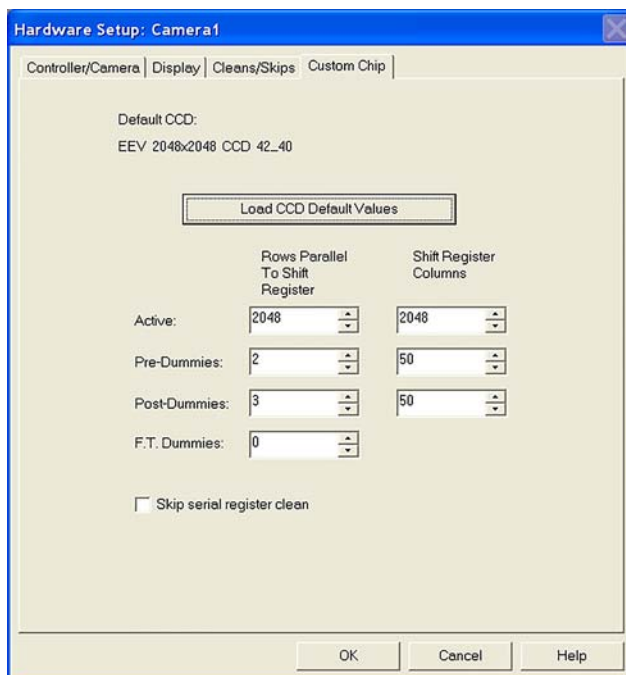
In LightField, the Custom Sensor pane, which is illustrated in Figure 6-20, is accessed by
opening the Sensor expander and clicking on the Custom Sensor button.

Figure 6-20: Typical LightField Custom Sensor Pane
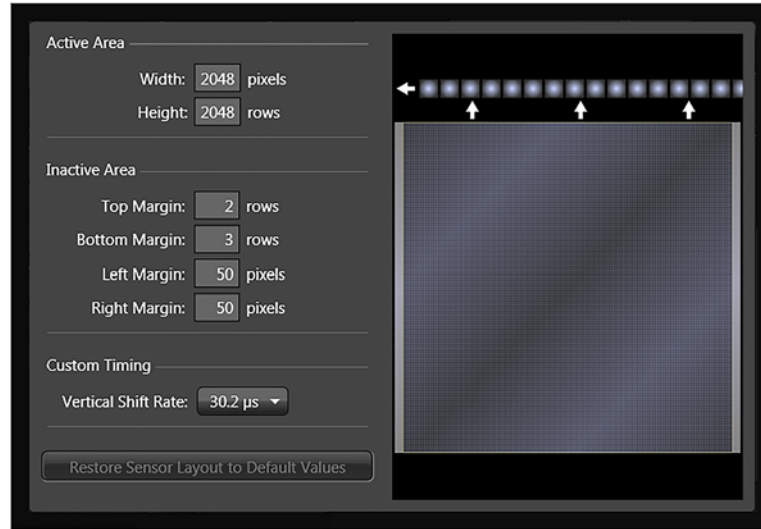
By changing the values in the Active fields, you can increase image acquisition speed by reducing the size of the active area in the definition. The result will be faster but lower resolution data acquisition. Operating in this mode would ordinarily require that the chip be masked so that only the reduced active area is exposed. This will prevent unwanted charge from spilling into the active area or being transferred to the shift register.

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

NOTE:

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

6.5.2   Custom Timing

In LightField, Custom Timing is accessed via the Custom Sensor button on the Sensor expander.

NOTE:

Custom Timing is standard with LightField for full frame CCD cameras.

Vertical Shift Rate is the time required to shift one row into the serial register. The smaller this value, the faster charge will be shifted up one row at a time toward the serial register.

On the **Custom Timing** panel you can select from among the **Vertical Shift Rate** options illustrated in Figure 6-21.

Figure 6-21: Typical LightField Custom Timing Dialog
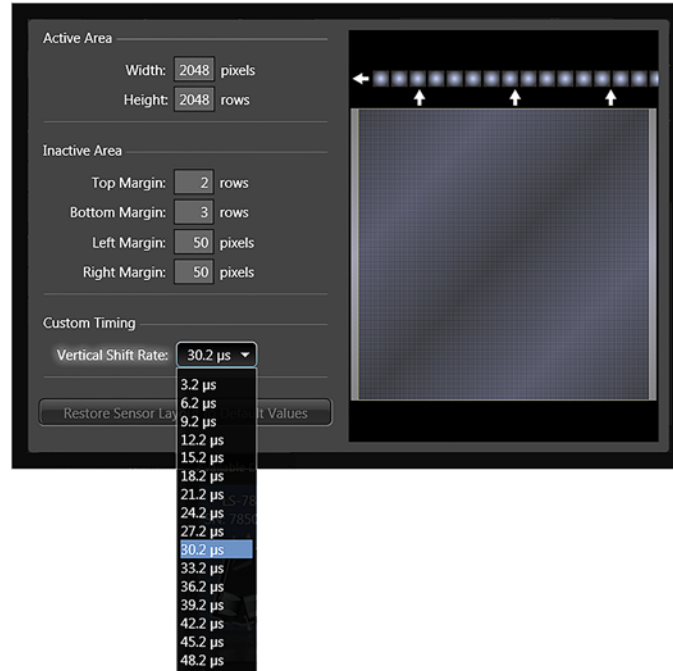
4411-0112_0045

In WinX/32, if Custom Timing is supported and selected, **Vertical Shift** is configured on the **Hardware Setup** dialog, **Custom Timing** tab. See Figure 6-22.

> 📖 **NOTE:** ———————————————————————————
>
> Custom Timing fully supported by WinX/32 Versions 2.5.18.1 and higher.

Figure 6-22: Typical WinX/32 Hardware Setup Dialog, Custom Timing Tab
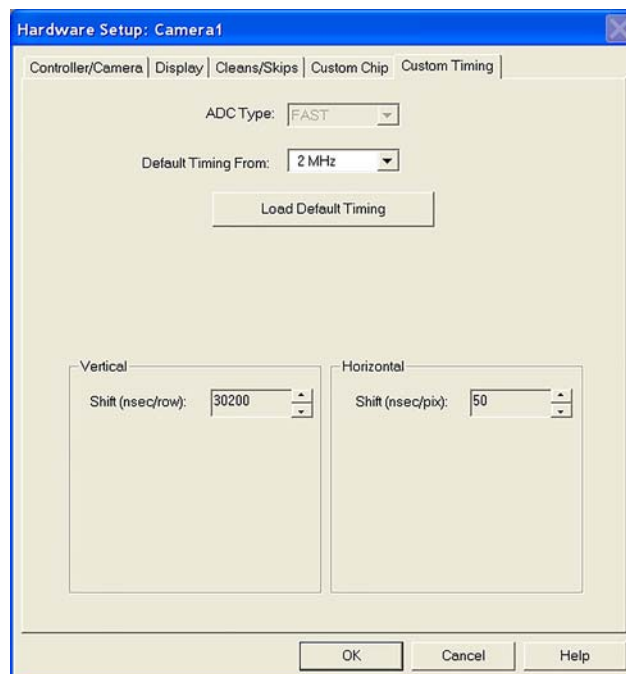
4411-0112_0046

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Chapter 7: Troubleshooting

⚠️ **WARNING!** ————————————————————————————

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

————————————————————————————

Refer to Table 7-1 for issues which have recommended troubleshooting procedures in this chapter.

Table 7-1: List of Recommended Troubleshooting Procedures

Issue	Information begins on...
Acquisition Started but Viewer Contents Do Not Update	page 78
Baseline Signal Suddenly Changes	page 78
Camera Stops Working	page 78
Camera1 (or Similar Same) in Camera Name Field	page 79
Controller Is Not Responding	page 80
CoolCUBE$_{II}$: Low Coolant (Air in the Hoses)	page 81
Temperature Lock Cannot be Achieved or Maintained	page 81
Camera loses Temperature Lock	page 82
Gradual Deterioration of Cooling Capability	page 82
Data Loss or Serial Violation	page 82
Data Overrun Due to Hardware Conflict Message	page 83
Data Overrun Has Occurred Message	page 83
Device Is Not Found	page 84
Device is Occupied	page 85
Error Creating Controller Message	page 85
Program Error Message	page 86
Serial Violations Have Occurred. Check Interface Cable.	page 86

7.1　Acquisition Started but Viewer Contents Do Not Update

In LightField, live data is normally displayed in the Experiment workspace viewer as it is being acquired (Preview or Acquire mode). If the viewer is not being updated and acquisition is occurring, check to see if there is a filename in the top row of the viewer. In Figure 7-1, the filename `2010 May 11 13_13_49.raw` is displayed. If there is a filename, click on the camera icon. The file data will be cleared from the viewer and the live data will then be displayed.

Figure 7-1:　Typical LightField Acquisition Display
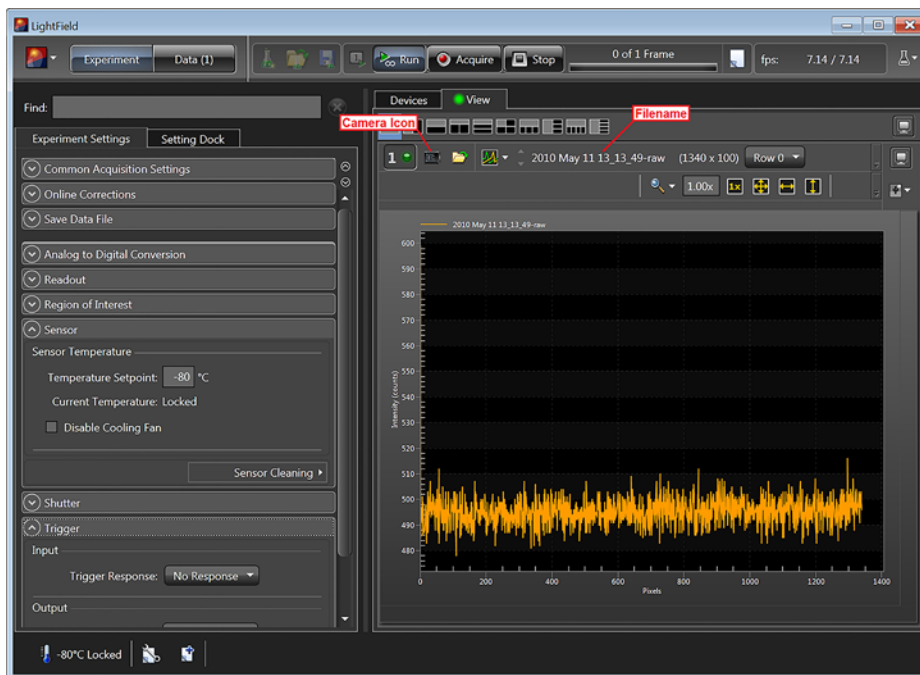
7.2　Baseline Signal Suddenly Changes

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 Teledyne Princeton Instruments Customer Support for information about how to refresh the vacuum. Refer to Contact Information on page 114 for complete information.

7.3　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 PIXIS-XF 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 Teledyne Princeton Instruments Customer Support for information about how to refresh the vacuum. Refer to Contact Information on page 114 for complete information.

7.4　Camera1 (or Similar Same) in Camera Name Field

When the Camera Detection Wizard installs a new camera, the camera is automatically named **Camera#** (where # = 1, 2, or 3, depending on the number of cameras detected) This name will appear in the Hardware Setup title bar and as the active camera on the **Hardware Setup ► Controller/Camera** tab. See Figure 7-2.

Figure 7-2:　Camera1 in Camera Name Field

If you would prefer a more specific name, you can edit `PVCAM.INI` (located in the Windows directory) and rename the camera. The new name will then be used by the system until the Camera Detection Wizard is run again.

Perform the following procedure to change the default Camera Name:

1. Close the application program if it is running.
2. Using Notepad.exe, open `PVCAM.INI` from the Windows directory.
3. Edit the Name. See Figure 7-3.

Figure 7-3:　Editing Camera Name
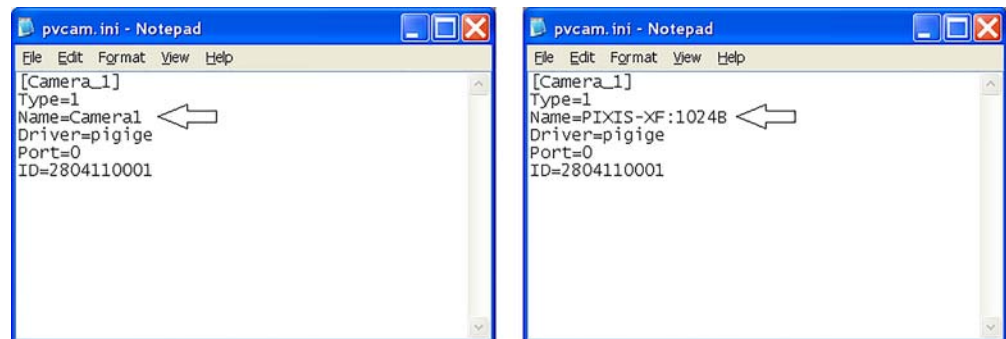
4. Save the edited file.

5. The next time you start the WinX/32 application, the new name will be displayed on the Hardware Setup dialog. See Figure 7-4.

Figure 7-4:　Camera Name on Hardware Setup Dialog
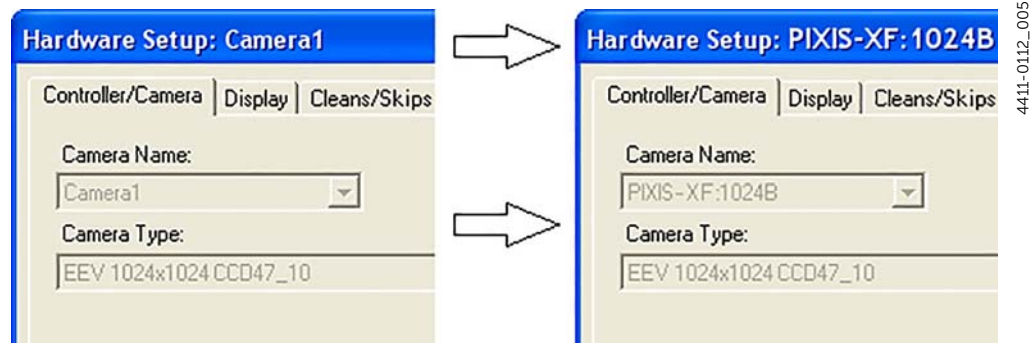
6. If you later re-run the Camera Detection Wizard, the name will be changed back to the default name (i.e., Camera1).

7.5　Controller Is Not Responding

If this message pops up when you click on **OK** after selecting the **Interface Type** during **Hardware Setup** on the WinX/32 **Setup** menu, the system has not been able to communicate with the camera. Check to see if camera has been turned ON (i.e., is connected to the switched on power supply) and if the USB 2.0 interface card, its driver, and the USB cable have been installed.

- If the camera is ON, the problem may be with the USB 2 card, its driver, or the cable connections.
- If a USB 2 interface card is not installed, close the WinX application program and turn the camera OFF. Follow the installation instructions in provided with your interface card, and cable the card to the USB 2 port on the rear of the camera. Then do a **Custom** installation of WinX/32 with the appropriate interface component selected. Be sure to deselect the interface component that does not apply to your system.
- If a USB 2 interface card is installed in the computer and is cabled to the USB 2 port on the rear of the camera, close the application program and turn the camera OFF. Check the cable connections.
- If the USB 2 interface card was installed after the application program was installed, close the application program and do a **Custom** installation of WinX/32 with the appropriate interface component selected. Be sure to deselect the interface component that does not apply to your system.

7.6   CoolCUBE$_{II}$: Low Coolant (Air in the Hoses)

⚠️ **CAUTION!** ────────────────────────────────

If more than two inches (50.8 mm) of the coolant line is filled with air, the pump will stop working and may be damaged. If flow stops while the pump is on, turn off the CoolCUBE$_{II}$ and add coolant.

──

1. Unscrew the reservoir cap (on top of the CoolCUBE$_{II}$) and make sure that the coolant reservoir contains coolant. If additional coolant is required, fill with a 50:50 mixture of water and ethylene glycol.
2. Screw the reservoir cap back in.
3. Make sure the power switch is turned off before plugging the circulator in.
4. Plug the circulator into a 100-240 V$_{AC}$, 47-63 Hz power source.
5. Turn the circulator on. Make sure there are no leaks or air bubbles in the hoses.

🔍 **NOTE:** ────────────────────────────────

Small air bubbles (about the size of bubbles in soda) are common in the CoolCUBE$_{II}$ especially at start up and do not prevent proper operation.

──

- If there are no problems, continue to step 6.
- If there are leaks or air bubbles, turn the circulator off and correct the problem(s) by securing the hoses or adding more coolant to the reservoir. Turn the circulator back on. Recheck and if there are no problems, continue to step 6.
6. Turn the camera on.
7. Start the application software.

7.7   Cooling Troubleshooting

This section provides information about troubleshooting cooling-related issues.

7.7.1   Temperature Lock Cannot be Achieved or Maintained

Possible causes may include:

- Ambient temperature greater than +20°C. If it is greater than +20°C, you will need to cool the camera environment or raise the set temperature.
- Airflow through the camera and/or circulator is obstructed. The camera needs to have approximately two (2) inches (50 mm) clearance around the vented covers. If there is an enclosure involved, the enclosure needs to have unrestricted flow to an open environment. The camera vents its heat out the vents near the nose. The air intake is near the rear of the camera.
- A hose is kinked. Unkink the hose.
- Coolant level is low. Add coolant. Refer to Section 7.6, CoolCUBE$_{II}$: Low Coolant (Air in the Hoses), on page 81.
- There may be air in the hoses. Refer to Section 7.6, CoolCUBE$_{II}$: Low Coolant (Air in the Hoses), on page 81.

- The circulator is higher than the camera. Reposition the circulator so that it is 6 inches [150 mm] or more below the camera. The vertical distance should not exceed 10 feet [3 m]. Typically, the camera is at table height and the circulator is on the floor.
- The vacuum has deteriorated and needs to be refreshed. Contact Teledyne Princeton Instruments Customer Support for information about how to refresh the vacuum. Refer to Contact Information on page 114 for complete information.
- The connectors of the cable that interconnects the controller and the camera need to be secured.
- The target array temperature is not appropriate for your particular camera and CCD array.
- For a TE-cooled camera, the camera's internal temperature may be too high, such as might occur if the operating environment is particularly warm or if you are attempting to operate at a temperature colder than the specified limit. TE-cooled cameras are equipped with a thermal-protection switch that shuts the cooler circuits down if the internal temperature exceeds a preset limit. Typically, camera operation is restored automatically in about ten minutes. Although the thermo-protection switch will protect the camera, you are nevertheless advised to power down and correct the operating conditions that caused the thermal-overload to occur.

7.7.2   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, an internal thermal overload switch will disable the cooler circuits to protect them. Typically, camera operation is restored in about ten minutes. Although the thermal overload switch will protect the camera, users are advised to power down and correct the operating conditions that caused the thermal overload to occur.

7.7.3   Gradual Deterioration of Cooling Capability

While unlikely with the PIXIS-XF camera (guaranteed permanent vacuum for the life of the camera), if you see a gradual deterioration of the cooling capability, 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. Contact Teledyne Princeton Instruments Customer Support for information about returning the camera for service. Refer to Contact Information on page 114 for complete information.

7.8   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 the WinX/32 application.

7.9   Data Overrun Due to Hardware Conflict Message

If this dialog illustrated in Figure 7-5 appears when you try to acquire a test image, acquire data, or run in focus mode, check the CCD array size and then check the DMA buffer size.

Figure 7-5:   Typical WinSpec/32 Data Overrun Due to Hardware Conflict Dialog

Perform the following procedure to change the DMA buffer setting:

1. Note the array size on the **Setup ► Hardware ► Controller/CCD** tab or the **Acquisition ► Experiment Setup ► Main** tab, **Full Chip** dimensions.
2. Open **Setup ► Environment ► Environment** dialog.
3. Increase the DMA buffer size to a minimum of 32 MB (64 MB if it is currently 32 MB or 128 MB if it is currently 64 MB,) click on **OK**, and close the WinX/32 application.
4. Reboot your computer.
5. Restart the WinX/32 application and begin acquiring data or focusing. If you see the message again, increase the DMA buffer size.

7.10   Data Overrun Has Occurred Message

Because of memory constraints and the way that USB transfers data, a **Data overrun has occurred** message may be displayed during data acquisition. If this message is displayed, take one or more of the following actions:

- Minimize the number of programs running in the background while you are acquiring data with the WinX/32 application.
- Run data acquisition in Safe Mode.
- Add memory.
- Use binning.
- Increase the exposure time.
- Defragment the hard disk.
- Update the USB2 driver.

If the problem persists, your application may be USB 2.0 bus limited. Since the host computer controls the USB 2.0 bus, there may be situations where the host computer interrupts the USB 2.0 port. In most cases, the interrupt will go unnoticed by the user. However, there are some instances when the data overrun cannot be overcome because USB 2.0 bus limitations combined with long data acquisition times and/or large data sets increase the possibility of an interrupt while data is being acquired. If your experiment requirements include long data acquisition times and/or large data sets, your application may not be suitable for the USB 2.0 interface. If this is not the case and data overruns continue to occur, contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 114 for complete information.

7.11 Device Is Not Found

When LightField is launched, it looks for devices (i.e., cameras, spectrometers, and filters,) that are powered on and connected via a communications interface to the host computer. If LightField cannot find a device that was used in the last experiment, it will display the dialog showin in Figure 7-6 as it continues searching for it until you connect and power the device on or you cancel the load.

Figure 7-6:   Typical LightField Devices Missing Dialog
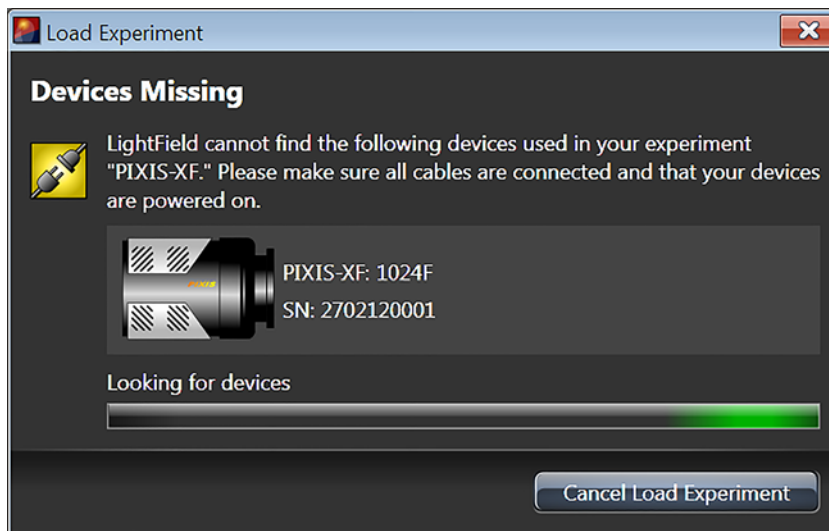
- Verify that the device is connected and powered on. If the device is connected but turned off, switch it on. LightField should now find the device. If it does not, cancel the load and restart LightField.
- Cancel the load. Canceling a load means that the last used experiment will not be loaded automatically when LightField opens. However, you can load the experiment after all the devices are available, you can start a new experiment design, or you can load a different experiment that matches the devices you are using.

7.12   Device is Occupied

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

Figure 7-7:   Typical LightField Occupied Device Icon
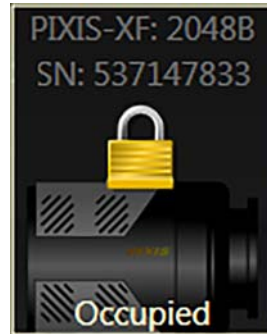
To make a device available to the current instance of LightField, either remove it from the **Experiment Devices** area in the other instance or close the instance that is using the device.

7.13   Error Creating Controller Message

Figure 7-8:   Typical WinSpec/32 Error Creating Controller Dialog

This message may appear if the `PVCAM.INI` file has become corrupted or if the camera was not turned on before you started the WinX/32 application and began running the Camera Detection wizard. If one of these dialogs pops up:

1. Refer to Section 7.5, Controller Is Not Responding, on page 80.
2. Run the Camera Detection Wizard.

7.14   Program Error Message

The error dialog illustrated in Figure 7-9 may appear if you have tried to acquire a test image, acquire data, or run in focusing mode and the DMA buffer size is too small.

Figure 7-9:   Typical WinSpec/32 Program Error Dialog

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Perform the following procedure to correct the problem:

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

7.15   Serial Violations Have Occurred. Check Interface Cable.

This error dialog shown in Figure 7-10 will appear if you try to acquire an image or focus the camera and either (or both) of the following conditions exists:

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

Figure 7-10: Typical WinSpec/32 Serial Violations Have Occurred Dialog
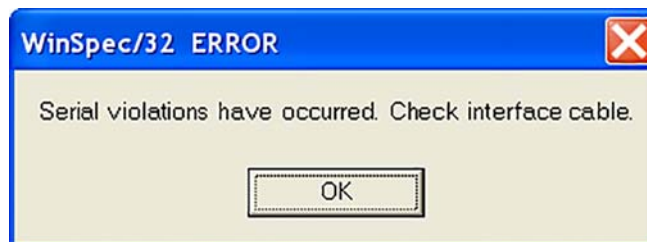
4411-0112_0056

NOTE:

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

Perform the following procedure to correct the problem:

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

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Appendix A: Technical Specifications

⚠ **CAUTION!**
All specifications are subject to change.

This appendix provides some technical information and specifications for PIXIS-XF cameras and optional accessories. Additional information may be found on data sheets available on the Teledyne Princeton Instruments website (www.princetoninstruments.com).

A.1 CCD Arrays

The information in Table A-1 is not necessarily current. Other chips may be available. Contact Teledyne Princeton Instruments for up-to-date information. Refer to Contact Information on page 114 for complete information.

Table A-1: CCD Information

Model	CCD (WinX/32 Name)	Pixel Format	Pixel Size	CCD Type
1024F	EEV CCD47-10 (EEV 1024x1024F)	1024 × 1024	13 μm × 13 μm	100 kHz/2 MHz Full Frame
1024B	EEV CCD47-10B (EEV 1024x1024B)	1024 × 1024	13 μm × 13 μm	100 kHz/2 MHz Full Frame
2048F	E2V CCD42-40 (EEV 2048x2048F)	2048 × 2048	13.5 μm × 13.5 μm	100 kHz/2 MHz Full Frame
2048B	E2V CCD42-40 (EEV 2048x2048B)	2048 × 2048	13.5 μm × 13.5 μm	100 kHz/2 MHz Full Frame

For detailed system specifications, refer to the latest data sheet. PIXIS-XF data sheet(s) are available on the Teledyne Princeton Instruments website (www.princetoninstruments.com).

A.2 Camera

Window

Beryllium (Be); 10 mil (250 μm) thick

Cooling

Thermoelectric, PIXIS-XF:1024F/B (air or liquid), PIXIS-XF:2048F/B (air or liquid)

Gain

Software-selectable (high, medium, low)

Dimensions

Refer to Appendix B, Outline Drawings, on page 93.

Connectors

- **EXT SYNC (MCX)**

  0 to +3.3-5 V_{DC} logic level input to allow data acquisition to be synchronized with external events. Trigger edge can be positive- or negative-going as set in software. Synchronization and Timing Modes are discussed in Section 6.1, Timing Modes, on page 58. MCX-to-BNC adapter cable supplied with system.

- **LOGIC OUT (MCX)**

  0 to +3.3-5 V_{DC} logic level output for monitoring camera status. Logic output is software-selectable. Logic Out Control is discussed in Section 6.3, LOGIC OUT Control, on page 67. MCX-to-BNC adapter cable is supplied with system.

  — **NOT SCAN {Not Reading Out}**

    Logic low when CCD is being read; otherwise high.

  — **SHUTTER {Shutter Open}**

    The output precisely brackets shutter-open time (exclusive of shutter compensation) and can be used to control an external shutter or to inhibit a pulser or timing generator.

  — **NOT READY {Busy}**

    The output changes state on completion of the array cleaning cycles that precede the first exposure. Initially high, it goes low to mark the beginning of the first exposure. In free run operation it remains low until the system in halted. If a specific number of frames have been programmed, it remains low until all have been taken, then returns high.

  — **LOGIC 0 {Always Low}**

    Logic Low

  — **LOGIC 1 {Always High}**

    Logic High

- **Shutter (LEMO)**

  Optional. Used for connecting to a Teledyne Princeton Instruments-supplied 28 mm external shutter. Cable not supplied.

- **USB 2.0 (USB B Female)**

  Data link to computer via USB cable inserted at this connector. Cable length of 5 meters is standard. Other lengths may be available. Contact Teledyne Princeton Instruments Customer Support for more information. Refer to Contact Information on page 114 for complete information. USB A/B cable supplied with system.

- **Power (DIN)**

  12 V_{DC} (6.6 A max) input from power supply.
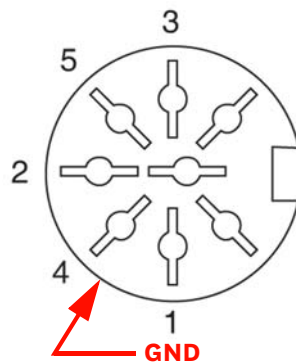
Pin 3, 5: 12 V_{DC}

Pin 1, 2, 4: Return

Shell: Ground

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Fan

> (Air-cooled systems only)
>
> 24 CFM fan capacity at full power.

Coolant Ports

> (Liquid-cooled systems only)
>
> Two interchangeable ¼" CPC valved quick disconnect fittings for connection to the CoolCUBE$_{II}$ circulator hoses.

Deepest Operating Temperature

> Refer to Table A-2.

Table A-2:   Typical Deepest Operating Temperature

CCD Size	Typical
1024 x 1024	−40°C
2048 x 2048	−40°C with +10°C water

> If the ambient temperature is greater than +20°C, temperature lock may not be achievable at the above temperatures.

Temperature Stability

> ±0.05°C; closed-loop stabilized-temperature control

Power Input

> 100-240 V$_{AC}$; 47 to 63 Hz, 1.9 A.
>
> DC power to camera is provided by the self-switching power supply.

Tripod Mount

> ¼-20 x 0.25" mounting hole at bottom of camera.
>
> M6 threaded adapter supplied with system.

A/D Converters

> Dual digitizers with 100 kHz/2 MHz readout rates. Software selectable. Low-speed operation gives better noise performance; high-speed operation allows faster data acquisition.

A.3   Options

Contact Teledyne Princeton Instruments for information regarding options available for your system. Refer to Contact Information on page 114 for complete information.

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Appendix B: Outline Drawings

> 🔍 **NOTE:** ——————————————————————————————
>
> All dimensions are in inches [mm] unless otherwise noted.

B.1   PIXIS-XF (Air-Cooled)

Figure B-1:   Outline Drawing: Air-Cooled PIXIS-XF: 1024F/B
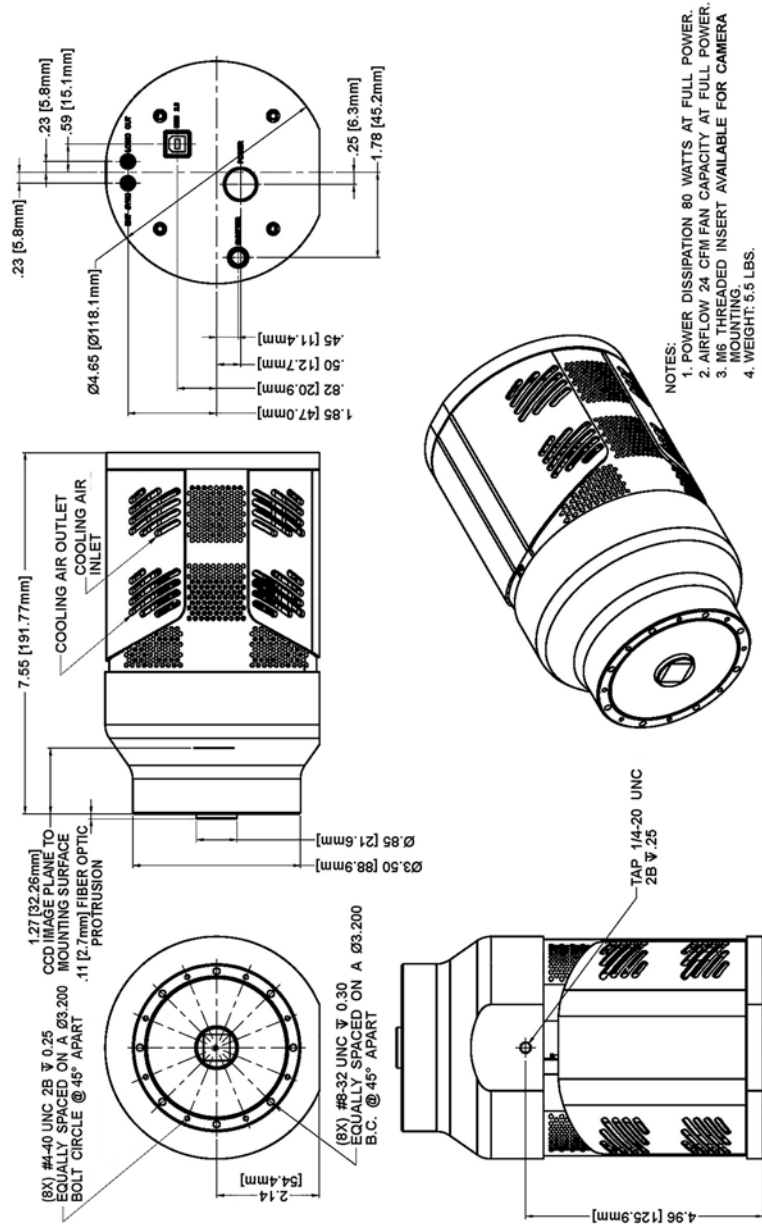
Figure B-2:   Outline Drawing: Air-Cooled PIXIS-XF: 1024F/B (Beryllium Window)
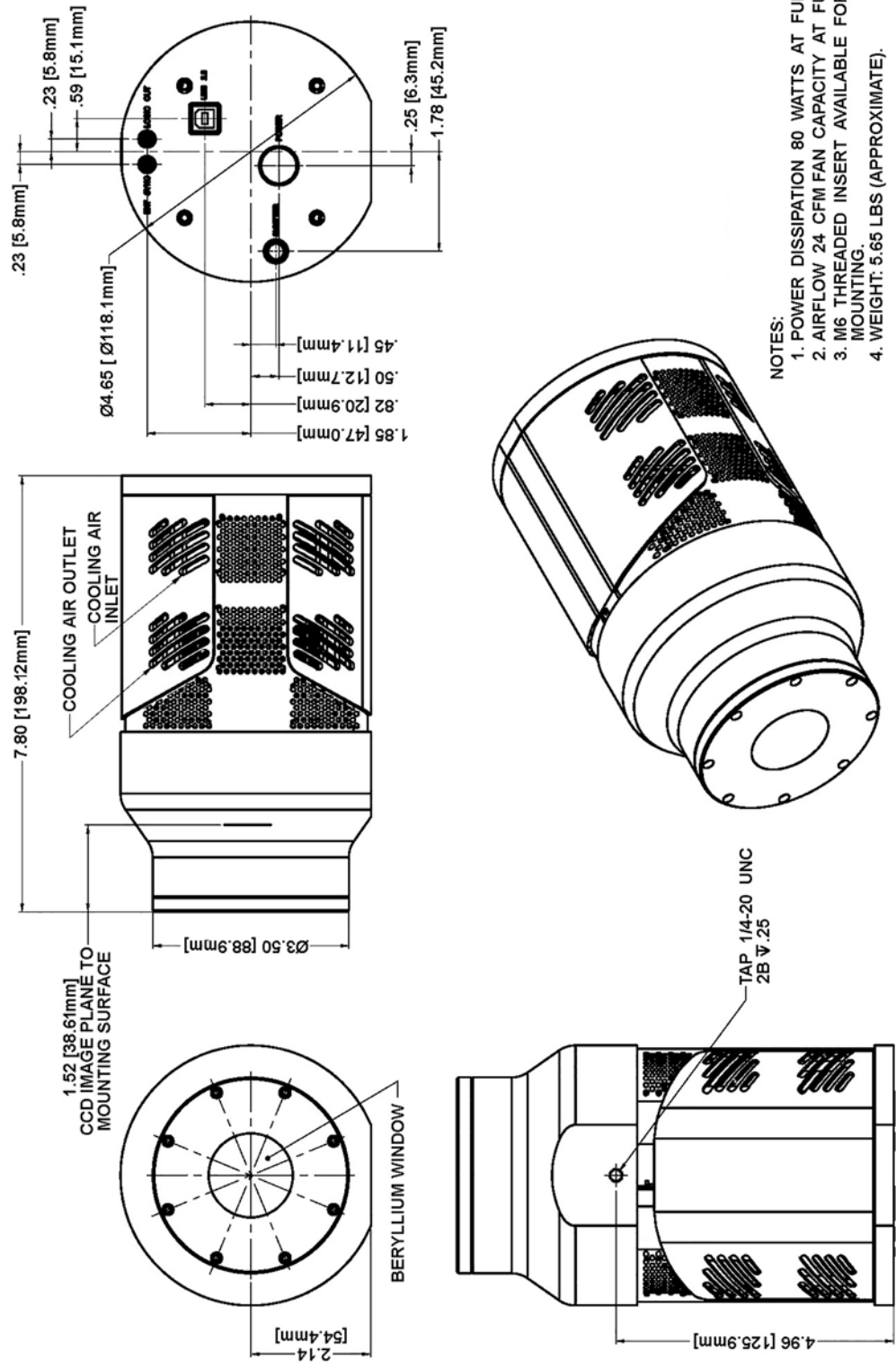
NOTES:
1. POWER DISSIPATION 80 WATTS AT FULL POWER.
2. AIRFLOW 24 CFM FAN CAPACITY AT FULL POWER.
3. M6 THREADED INSERT AVAILABLE FOR CAMERA MOUNTING.
4. WEIGHT: 5.65 LBS (APPROXIMATE).

Figure B-3:   Outline Drawing: Air-Cooled PIXIS-XF: 2048F/B

Figure B-4:   Outline Drawing: Air-Cooled PIXIS-XF: 2048F/B (Beryllium Window)

NOTES:
1. POWER DISSIPATION 80 WATTS AT FULL POWER
2. AIRFLOW 24 CFM FAN CAPACITY AT FULL POWER
3. (2X) M6 THREADED INSERTS INCLUDED FOR CAMERA MOUNTING
4. WEIGHT 6.15 LBS.

B.2   PIXIS-XF (Liquid-Cooled)

Figure B-5:   Outline Drawing: Liquid-Cooled PIXIS-XF: 1024F/B
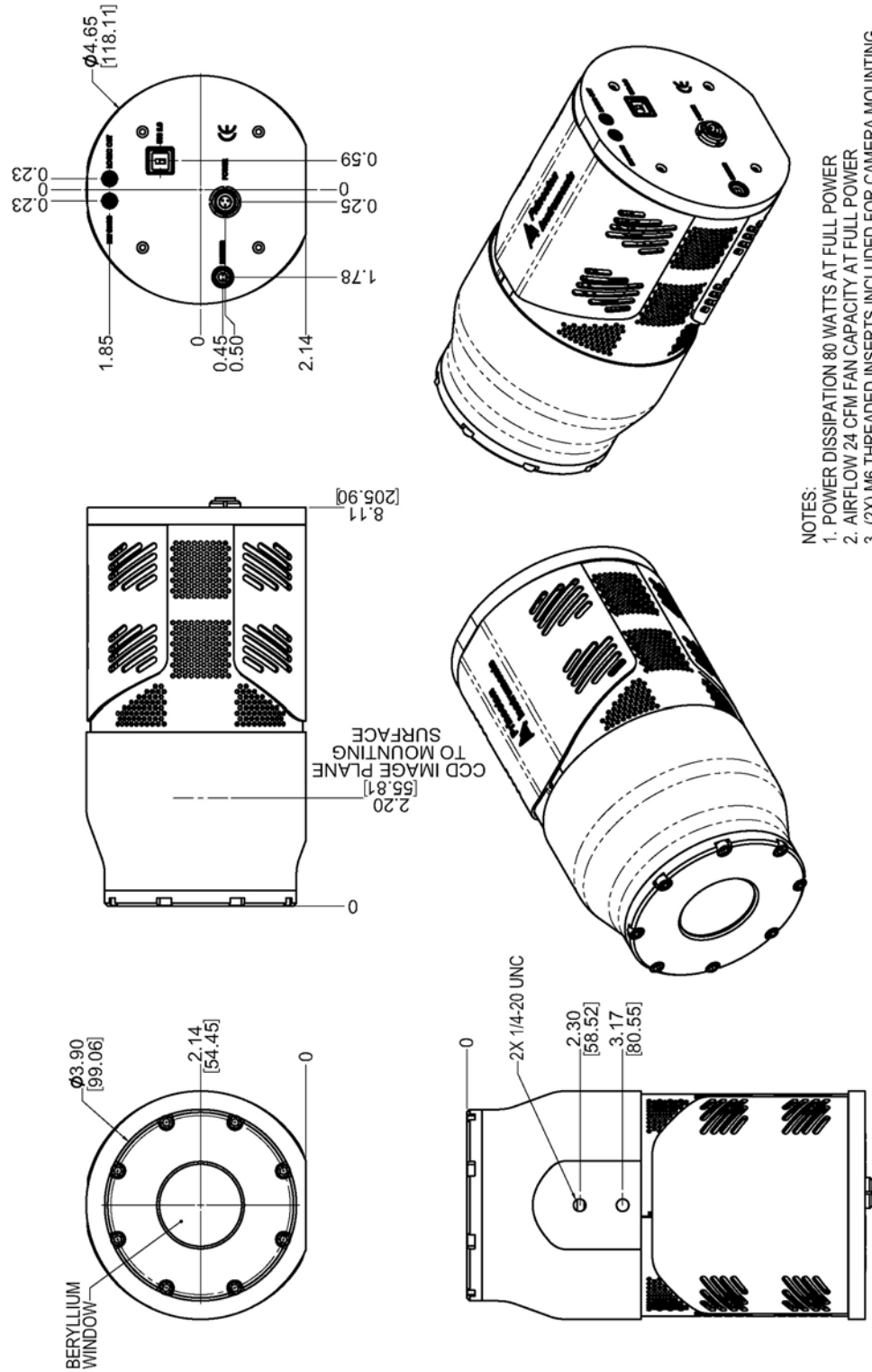
Figure B-6:   Outline Drawing: Liquid-Cooled PIXIS-XF: 1024F/B (Beryllium Window)
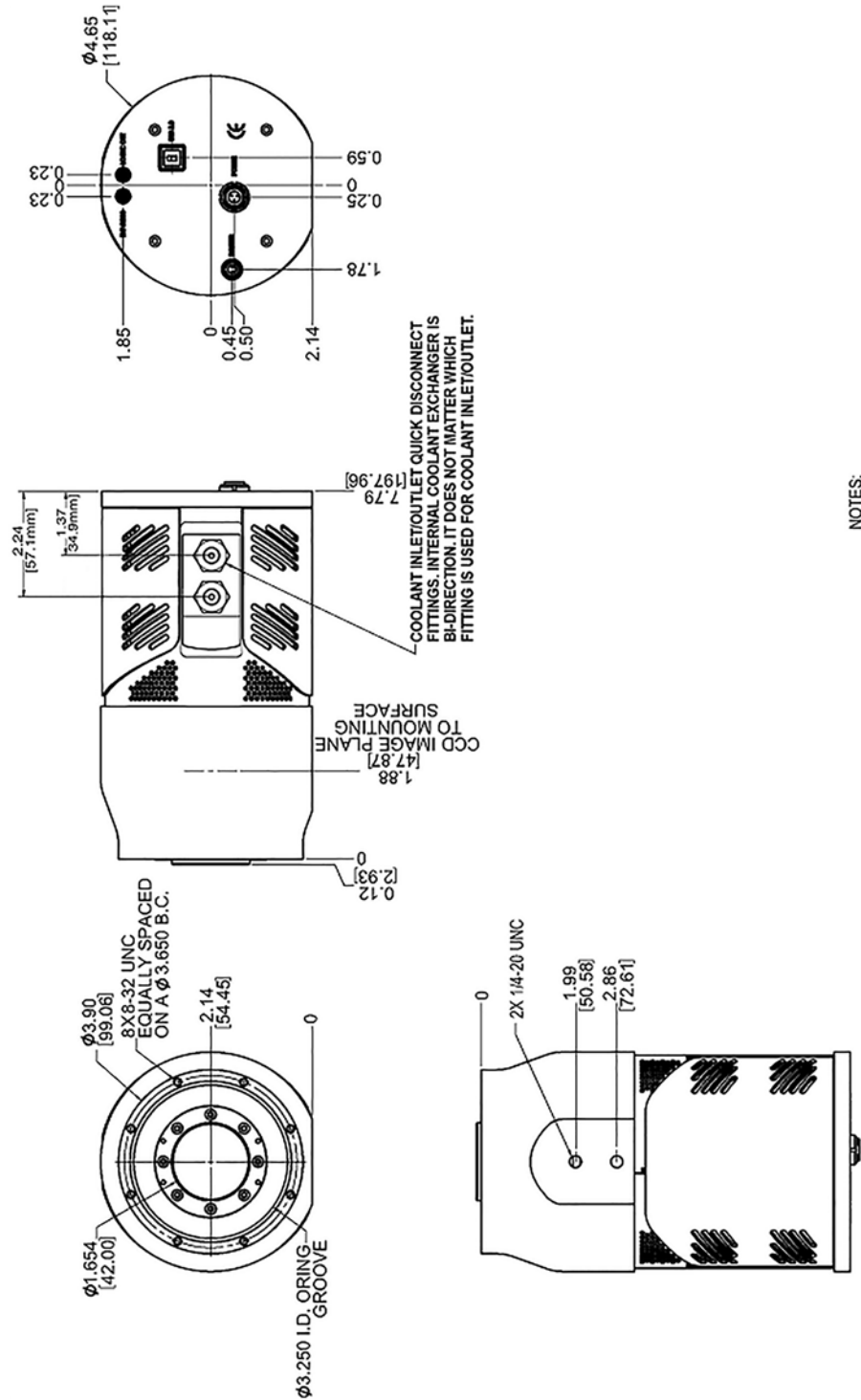
NOTES:
1. POWER DISSIPATION 80 WATTS AT FULL POWER
2. (2X) M6 THREADED INSERTS
3. INCLUDED FOR CAMERA MOUNTING
   WEIGHT 6.00 LBS.

Figure B-7:   Outline Drawing: Liquid-Cooled PIXIS-XF: 2048F/B
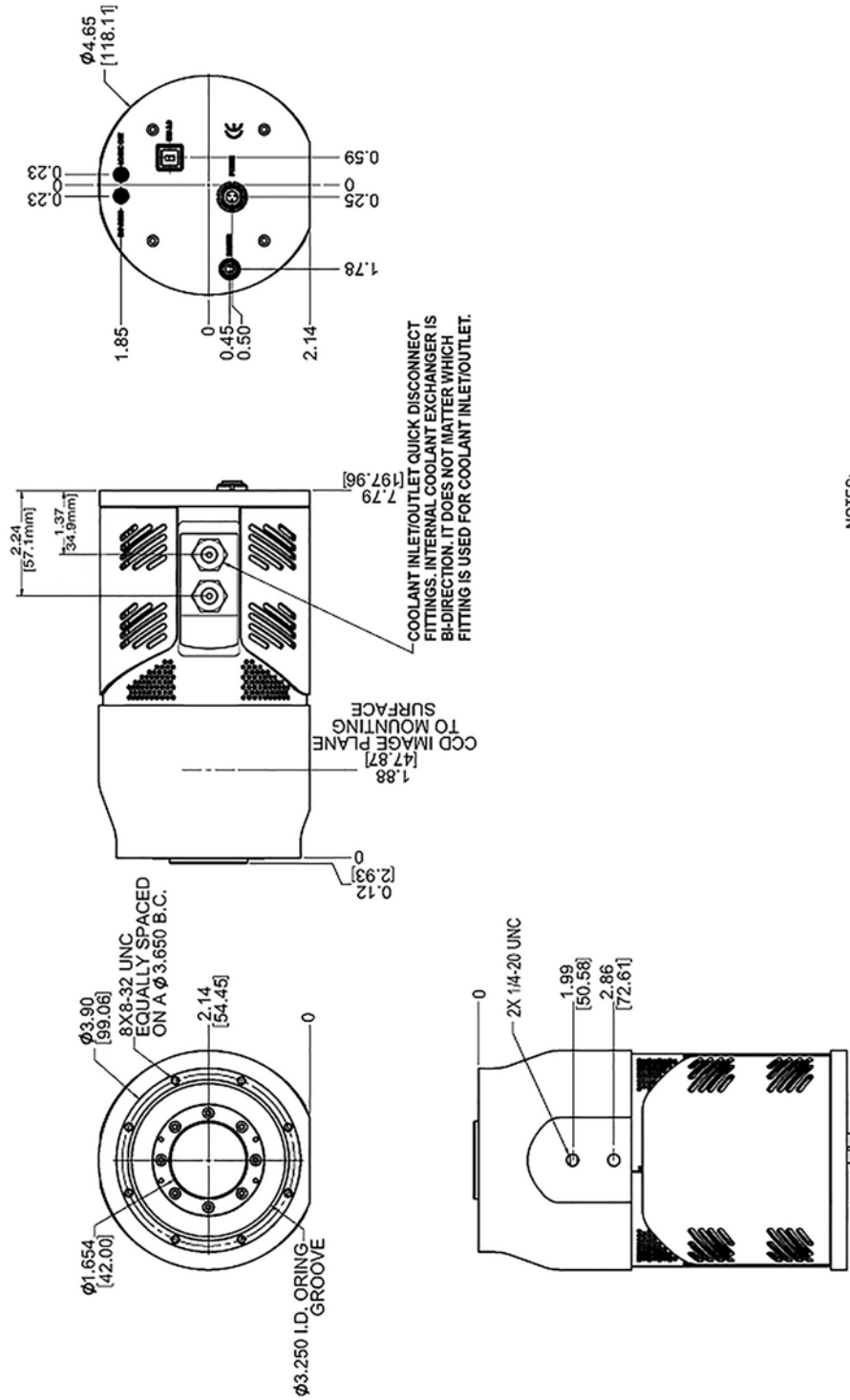
NOTES:
1. POWER DISSIPATION 80 WATTS AT FULL POWER
2. (2X) M6 THREADED INSERTS
3. INCLUDED FOR CAMERA MOUNTING
    WEIGHT 6.00 LBS.

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Figure B-8:   Outline Drawing: Liquid-Cooled PIXIS-XF: 2048F/B (Beryllium Window)

NOTES:
1. POWER DISSIPATION 80 WATTS AT FULL POWER
2. (2X) M6 THREADED INSERTS INCLUDED FOR CAMERA MOUNTING
3. WEIGHT 6.15 LBS.

B.3   CoolCUBE_{II} Circulator

Figure B-9:   Outline Drawing: CoolCUBE_{II} Circulator
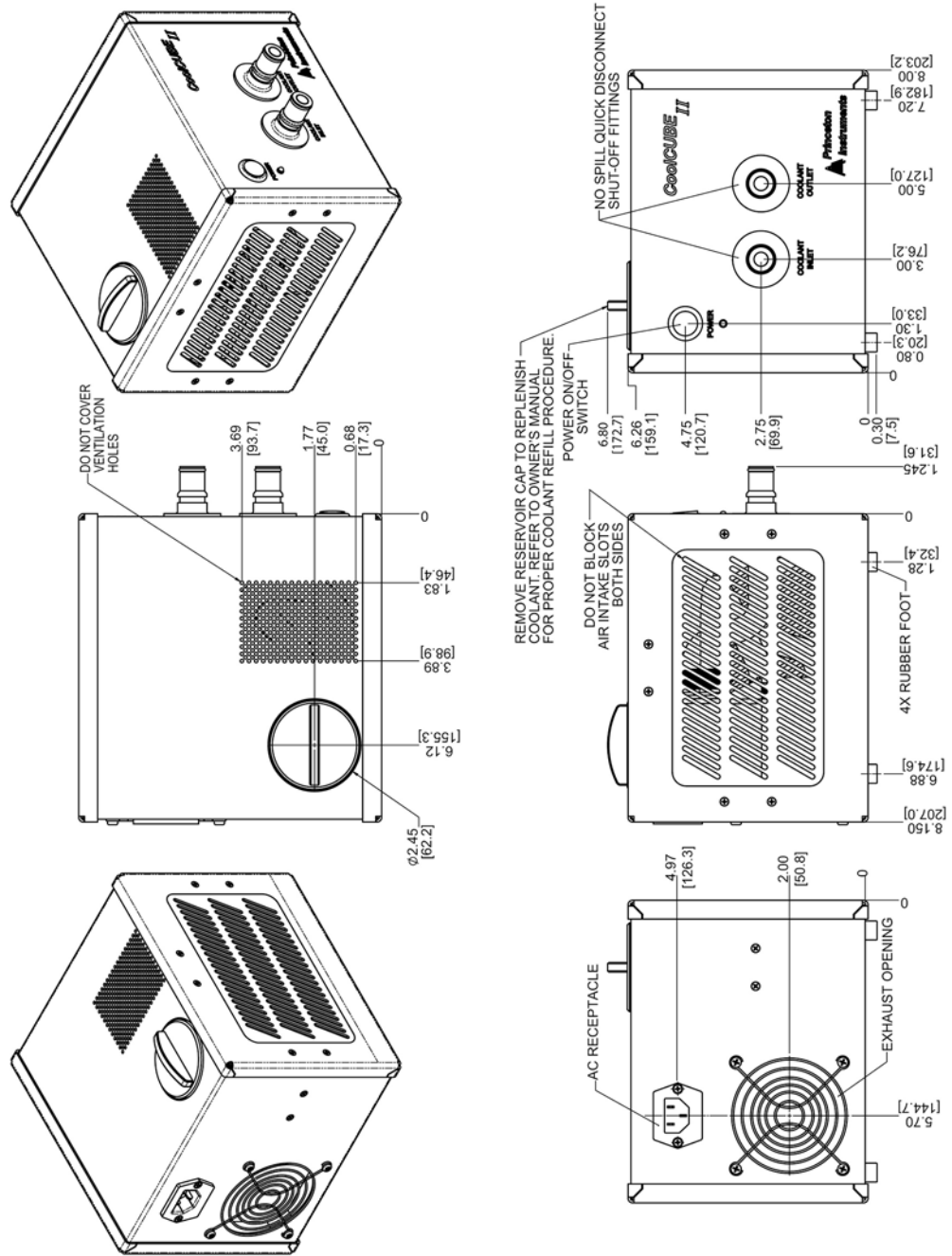
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Appendix C: Gd$_2$O$_2$S Phosphor Replacement

In some instances, it may become desirable to change the phosphor mounted on the fiber optic taper.

⚠ **CAUTION!** ————————————————————
Observe the following cautions when handling Beryllium:
- To avoid oil transfer from your fingers, do not touch the Beryllium window at the front of the camera without vinyl gloves.
- 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.
- For additional information about safe handling practices or technical data on Beryllium, visit the Materion website at https://materion.com/.

C.1   Required Items

The following tools are required to perform procedures in this appendix:
- Thin, non-powdered, vinyl gloves;
- 3/32" Hex key;
- Acetone
- Lens tissue or lint free cloth;
- Torque driver with 3/32" bit.

C.2   Remove the Beryllium Window Assembly

Perform the following procedure to safely remove the Beryllium window assembly:

⚠ **CAUTION!** ————————————————————
If the camera has been in use, allow a minimum of 1 hour warm-up time to avoid thermal shock while handling the phosphor plate.

1. Put on vinyl protective gloves.
2. Disconnect any cables and hoses from the camera.
3. Position the camera with its nose pointing up.

4. Use the 3/32" hex key to unscrew the eight (8) 4-40 x 3/8" socket head screws securing the Beryllium window assembly to the nose of the camera.

⚠ **CAUTION!**
DO NOT LOOSEN ANY OTHER SCREWS.

See Figure C-1.

Figure C-1:   PIXIS-XF:1024 Phosphor Assembly Drawing

4-40 X 3/8" SOCKET HEAD SCREWS (QTY. 8)

BERYLLIUM WINDOW ASSEMBLY

FOAM DISK (NOT REUSABLE)

Gd$_2$O$_2$S PHOSPHOR (SHINY SIDE UP, MATTE SIDE ON FIBER OPTIC)
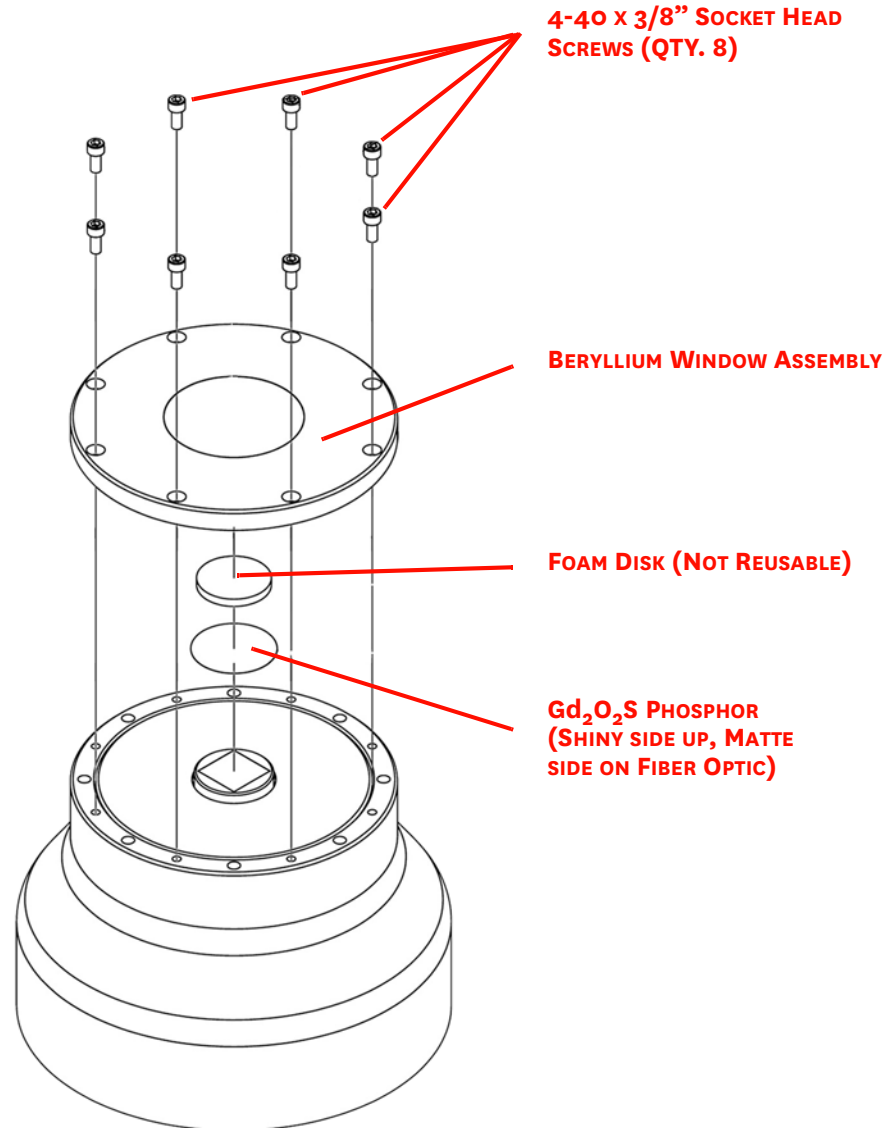
4411-0112_0067

5. Carefully lift the Beryllium window assembly with the eight (8) screws up and off of the camera. Set this assembly in a safe location.
6. If there is an O-ring, set it aside with the Beryllium window assembly.
7. Proceed to Section C.3, Remove and Replace the Phosphor, on page 105.

C.3   Remove and Replace the Phosphor

Perform the following procedure to remove and replace the phosphor:

1. Remove the foam disk and throw it away. This foam disk is NOT reusable.
2. Slide the phosphor disk off of the fiber optic. Sliding is easier and less likely to damage the disk than trying to lift the phosphor plate from the fiber optic.
3. Place the phosphor disk in a clean, dry container and store it in a secure location.
4. Using a lens tissue or a lint free cloth moistened with acetone, clean the top of the fiber optic.
5. Position the new phosphor disk so the matte side is on the fiber optic and the shiny side is facing away from the fiber optic. See Figure C-1.
6. Gently place the NEW foam disk on top of the shiny side of the phosphor.

C.4   Install the Beryllium Window Assembly

Perform the following procedure to install the Beryllium window assembly:

1. If an O-ring was removed and set aside in step 6 of Section C.2, Remove the Beryllium Window Assembly, reinstall it.
2. Reinstall the Beryllium window assembly.
3. Using the torque driver and 3/32" hex tip, tighten the mounting screws to **6 inch-pounds**.
4. If the image quality is good, you have successfully completed the phosphor disk replacement operation.

   If there appears to be an optical interface issue, you can turn off the camera, disconnect the detector cable, perform the disassembly, and reposition the phosphor as required to obtain optimum images.

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Appendix D: WinSpec/32/LightField Cross Reference

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

D.1 WinSpec/32-to-LightField Terminology

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

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

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

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

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

D.2   LightField to WinSpec/32

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

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

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

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

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

Warranty and Service

Limited Warranty

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

Basic Limited One (1) Year Warranty

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

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

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

XP Vacuum Chamber Limited Lifetime Warranty

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

Sealed Chamber Integrity Limited 12 Month Warranty

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

Vacuum Integrity Limited 12 Month Warranty

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

Image Intensifier Detector Limited One Year Warranty

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

X-Ray Detector Limited One Year Warranty

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

Software Limited Warranty

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

Owner's Manual and Troubleshooting

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

Your Responsibility

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

1. You must retain your bill of sale (invoice) and present it upon request for service and repairs or provide other proof of purchase satisfactory to Teledyne Princeton Instruments.

2. You must notify the Teledyne Princeton Instruments factory service center within (30) days after you have taken delivery of a product or part that you believe to be defective. With the exception of customers who claim a "technical issue" with the operation of the product or part, all invoices must be paid in full in accordance with the terms of sale. Failure to pay invoices when due may result in the interruption and/or cancellation of your one (1) year limited warranty and/or any other warranty, expressed or implied.

3. All warranty service must be made by the Teledyne Princeton Instruments factory or, at our option, an authorized service center.

4. Before products or parts can be returned for service you must contact the Teledyne Princeton Instruments factory and receive a return authorization number (RMA.) Products or parts returned for service without a return authorization evidenced by an RMA will be sent back freight collect.

5. These warranties are effective only if purchased from the Teledyne Princeton Instruments factory or one of our authorized manufacturer's representatives or distributors.

6. Unless specified in the original purchase agreement, Teledyne Princeton Instruments is not responsible for installation, setup, or disassembly at the customer's location.

7. Warranties extend only to defects in materials or workmanship as limited above and do not extend to any product or part which:
   - has been lost or discarded by you;
   - has been damaged as a result of misuse, improper installation, faulty or inadequate maintenance, or failure to follow instructions furnished by us;
   - has had serial numbers removed, altered, defaced, or rendered illegible;
   - has been subjected to improper or unauthorized repair;
   - has been damaged due to fire, flood, radiation, or other "acts of God," or other contingencies beyond the control of Teledyne Princeton Instruments; or
   - is a shutter which is a normal wear item and as such carries a onetime only replacement due to a failure within the original 1 year Manufacturer warranty.

8. After the warranty period has expired, you may contact the Teledyne Princeton Instruments factory or a Teledyne Princeton Instruments-authorized representative for repair information and/or extended warranty plans.

9. Physically damaged units or units that have been modified are not acceptable for repair in or out of warranty and will be returned as received.

10. All warranties implied by state law or non-U.S. laws, including the implied warranties of merchantability and fitness for a particular purpose, are expressly limited to the duration of the limited warranties set forth above. With the exception of any warranties implied by state law or non-U.S. laws, as hereby limited, the forgoing warranty is exclusive and in lieu of all other warranties, guarantees, agreements, and similar obligations of manufacturer or seller with respect to the repair or replacement of any parts. In no event shall Teledyne Princeton Instruments' liability exceed the cost of the repair or replacement of the defective product or part.

11. This limited warranty gives you specific legal rights and you may also have other rights that may vary from state to state and from country to country. Some states and countries do not allow limitations on how long an implied warranty lasts, when an action may be brought, or the exclusion or limitation of incidental or consequential damages, so the above provisions may not apply to you.

12. When contacting us for technical support or service assistance, please refer to the Teledyne Princeton Instruments factory of purchase, contact your authorized Teledyne Princeton Instruments representative or reseller, or visit our technical support page at www.princetoninstruments.com.

Contact Information

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

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

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

Customer Support E-mail: techsupport@princetoninstruments.com

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

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

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