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Part of the Teledyne Imaging Group

PIXIS System Manual

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Revision History

Issue	Date	List of Changes
Issue 5	May 22, 2019	Issue 5 of this document incorporates the following changes: • Updated to standard document template; • Rebranded as Teledyne Princeton Instruments.
Issue 4	April 20, 2016	Issue 4 of this document incorporates the following changes: • Removed Declaration of Conformity.
Issue 3	October 16, 2015	Issue 3 of this document incorporates the following changes: • Updated the Declaration of Conformity.
Issue 2	March 14, 2013	Issue 2 of this document incorporates the following changes: • Added LightField; • Added CoolCUBEII; • Added eXcelon; • Updated Warranty; • Removed Appendix E, USB 2.0 Card Installation; • Cumulative editorial corrections and updates.
Issue 1	February, 2008	This is the initial release of this document.

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Chapter 1:   About this Manual

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

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

If you have any questions about the information contained in this manual, contact the Teledyne Princeton Instruments customer service department. Refer to Contact Information on page 154 for complete contact information.

1.1   Intended Audience

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

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

1.2   Related Documentation

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

Table 1-1:   Related Documentation

Document Number	Document Title
–	LightField 6 Online Help
–	PIXIS Camera System Data Sheet

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

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

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

1.3   Document Organization

This manual includes the following chapters and appendices:

- **Chapter 1, About this Manual**

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

- **Chapter 2, System Component Descriptions**

  This chapter provides information about the components included with a standard PIXIS camera system, as well as options that are available for purchase from Teledyne Princeton Instruments.

- **Chapter 3, Install Data Acquisition Software**

  This chapter provides information about the installation of Teledyne Princeton Instruments' WinSpec/32, WinView/32, and LightField image acquisition software.

- **Chapter 4, System Block Diagrams**

  This chapter provides information about integrating the PIXIS into a user's experiment.

- **Chapter 5, Hardware Installation**

  This chapter provides information about the installation and configuration of the system hardware.

- **Chapter 6, First Light**

  This chapter provides step-by-step procedures for placing a PIXIS camera system in operation for the first time when using Teledyne Princeton Instruments' WinSpec/32, WinView/32, and LightField image acquisition software.

- **Chapter 7, Exposure**

  This chapter discusses the various factors that affect the signal acquired on the array, including array architecture, exposure time, temperature, and saturation.

- **Chapter 8, Analog to Digital Conversion**

  This chapter discusses the configuration of the Analog to Digital Conversion configuration parameters.

- **Chapter 9, Full Frame Readout**

  This chapter discusses Full Frame Readout operation and related parameter configuration.

- **Chapter 10, Binning**

  This chapter discusses of the configuration of hardware and software binning.

- **Chapter 11, Advanced Topics**

  This chapter discusses topics associated with experiment synchronization, including Timing Modes, Fast and Safe Modes, LOGIC OUT Control, Kinetics Mode, and Custom Modes.

- **Appendix A, Technical Specifications**

  This appendix provides CCD, system and other technical specifications for a PIXIS system.

- **Appendix B, Outline Drawings**

  This appendix provides outline drawings of the PIXIS family of cameras and accessories.

- **Appendix C, Adapter Adjustment and Focusing Procedures**

  This appendix provides procedures to adjust and focus Adjustable C-mount and F-mount adapters when using them with a PIXIS camera.

- Appendix D, Spectrograph Adapters

  This appendix provides installation procedures and information necessary to install supported spectroscopic adapters.

- Appendix E, Troubleshooting

  This appendix provides recommended troubleshooting information for issues which may be encountered while working with a PIXIS camera system.

- Appendix F, WinSpec/32/LightField Cross Reference

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

- Warranty and Service

  This chapter provides warranty information for the PIXIS. Contact information is also provided.

1.3.1   Conventions Used In this Document

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

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

Table 1-2:   Terminology Conventions Used

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

1.4   Safety Related Symbols Used in this Manual

⚠ **CAUTION!**

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

⚠ **WARNING!**

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

⚠ **WARNING! RISK OF ELECTRIC SHOCK!**

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

1.5   PIXIS Safety Information

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

⚡ WARNINGS!

1. If the PIXIS camera system is used in a manner not specified by Teledyne Princeton Instruments, the protection provided by the equipment may be impaired.

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

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

⚡ WARNING!

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

1.6   Precautions

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

⚠ CAUTION!

1. The CCD array is very sensitive to static electricity. Touching the CCD can destroy it. Operations requiring contact with the device can only be performed at the factory.

2. When using high-voltage equipment (e.g., an arc lamp,) with the camera system, be sure to turn the camera power ON LAST and turn the camera power OFF FIRST.

3. Use caution when triggering high-current switching devices near the system (e.g., an arc lamp.) The CCD can be permanently damaged by transient voltage spikes. If electrically noisy devices are present, an isolated, conditioned power line or dedicated isolation transformer is highly recommended.

4. Do not block air vents on the camera. Preventing the free flow of air overheats the camera and may damage it.

5. If the PIXIS camera system is used in a manner not specified by Teledyne Princeton Instruments, the protection provided by the equipment may be impaired.

1.6.1   UV Coatings

⚠ **CAUTION!**

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

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Chapter 2:   System Component Descriptions

This chapter provides an introduction to, and overview information about, Teledyne Princeton Instruments's PIXIS camera system. Figure 2-1 shows those items that are typically included as part of a standard PIXIS Camera system.

Figure 2-1:   Typical System Components

A typical air-cooled PIXIS 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 system consists of the camera with a Certificate of Performance, a CoolCUBEII circulator with hoses, a USB 2.0 interface cable for your computer system, MCX to BNC adapter cables, and the user manual.

Optional items include the WinX application software and manual, LightField® application software and manual, Scientific Imaging ToolKit™ (SITK™) for LabVIEW®, internal 25 mm or 45 mm shutter (dependent on CCD array size), an F-mount adapter, an adjustable C- to Spectroscopy-mount kinetics adapter, and a fiber optic extender kit.

2.1 PIXIS Camera

PIXIS is a fully integrated camera system. The camera contains all of the electronics necessary to read out and control the CCD device. For instance, it houses precision analog-to-digital converters (ADCs) positioned close to the CCD for lowest noise and has USB 2.0 electronics to interface with the host computer.

The easy-to-use PIXIS camera system offers all basic CCD camera functions, such as region-of-interest (ROI) selection and binning, all under software control. It also provides advanced triggered operation as well as programmable TTL output.

Figure 2-2 illustrates a typical PIXIS camera.

Figure 2-2:   Typical PIXIS Camera

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2.1.1 eXcelon®

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

- Improved Sensitivity
  Improved QE over broader wavelength region compared to back-illuminated sensors;
- Reduced Etaloning
  Up to 10 times lower etaloning or unwanted fringes in near infrared (NIR) region compared to standard back-illuminated CCDs;
- Lower Dark Current
  Similar to back-illuminated CCDs or 100 times lower than deep depletion CCDs.

2.1.2   CCD Array

The PIXIS camera system offers both front- and back-illuminated CCDs in a variety of array sizes that allow you to precisely match the sensor to your application. Only scientific-grade devices are used in order to ensure the highest image fidelity, resolution, and acquisition flexibility required for scientific imaging. Teledyne Princeton Instruments has developed exclusive CCDs with unmatched quantum efficiency and low noise to offer the utmost in sensitivity. Large full wells, square pixels, and 100% fill factors provide high dynamic range and excellent spatial resolution. Unichrome (exclusive Teledyne Princeton Instruments technology) and other UV-enhancement coatings can be used to further improve the quantum efficiency of these CCDs in the ultraviolet. Your choice of CCD is already installed in the camera that you received and has been individually tested.

2.1.3   Rear Panel Connectors

Figure 2-3 shows the rear panel connectors on a typical PIXIS camera.

Figure 2-3:   PIXIS Rear Connector Panel
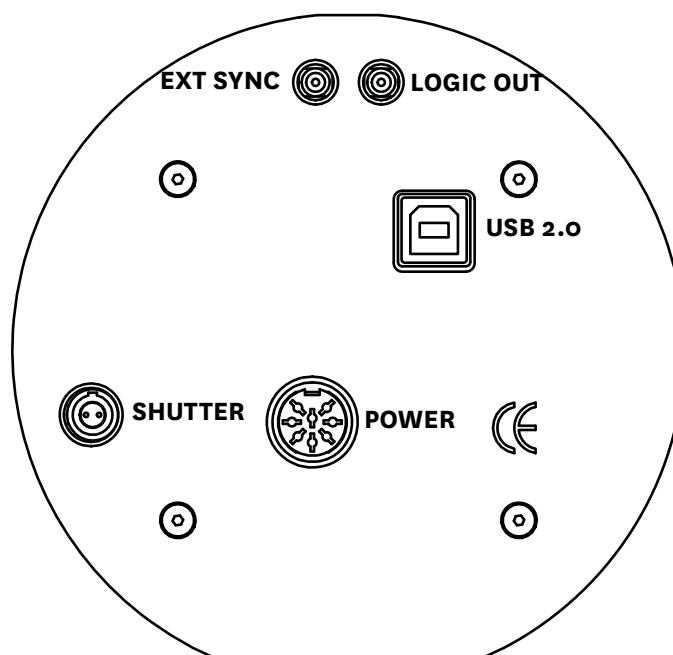
4411-0106_0003

Refer to Table 2-1 for information about each rear panel connector.

Table 2-1:   PIXIS Rear Panel Connector Information (Sheet 1 of 2)

Label	Description
EXT SYNC	0-+3.3V logic level input (TTL-compatible) that has a 10 kΩ pull-up resistor. Allows data acquisition and readout to be synchronized with external events. Through software, positive or negative (default) edge triggering can be selected.
LOGIC OUT	0 to +3.3 V_{DC} programmable logic level output (TTL-compatible). The output of this connector can be programmed and can also be inverted via the application software For additional information, refer to Section 11.3, LOGIC OUT Control, on page 93.

Table 2-1:   PIXIS Rear Panel Connector Information (Sheet 2 of 2)

Label	Description
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. As of this printing, you can hot plug the PIXIS camera whenever the WinX application is not running (i.e., connect or disconnect from the camera or the host computer while the camera is powered ON). In the case of cameras built before November 1, 2005, you must exit the WinX application and turn the camera power OFF before connecting the USB cable to or disconnecting it from the camera or host computer.
SHUTTER	LEMO® connector provides the shutter drive pulses for driving a Teledyne Princeton Instruments-supplied external shutter (for example, a shutter at the entrance slit of a spectrograph). Camera power must be OFF before connecting to or disconnecting from this connector. ***NOTE:*** When there is an installed internal shutter, this connector cannot drive an external shutter.
POWER	12 V_{DC} (6.6A max) input from power supply.

2.1.4   Power

All voltages required by PIXIS camera systems are generated and delivered by an external power supply included with each PIXIS camera.

⚠ **CAUTION!** ────────────────
Use of a power supply other than that provided with the PIXIS camera will void the camera warranty. For specific power supply requirements, contact Teledyne Princeton Instruments. Refer to Contact Information on page 154 for complete information.

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.

📖 **REFERENCES:** ────────────────
Refer to Section A.4, Power Specifications, on page 106 for detailed voltage specifications.

2.1.5   Cooling

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

2.1.5.1   Internal Fan

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

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

An internal Peltier device directly cools the cold finger on which the CCD is mounted. 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.

2.1.5.2   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, 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.

⚠ **WARNING!** ─────────────────────────

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

2.1.5.3   Coolant Hoses (Liquid-Cooled Systems)

4411-0106_0004

Quick-disconnects that mate to the PIXIS' 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 (P/N: 7567-0002).

Part numbers for the hose, PIXIS fittings, and CoolCUBE$_{II}$ fitting are:

- McMaster# MCM 5238K748 (3/8 ID, 5/8 OD tubing);
- CPC# MCD1004 (1/4 NPT Valved Coupling Body) and McMaster# MCM 5346K35 (barbed hose fitting adapter for 3/8" hose ID X ¼" NPTF female pipe) at PIXIS end; and
- CPC# NS6D17006 (3/8 hose barb valved in-line coupling body) at CoolCUBE$_{II}$ end.

2.2   Cables

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

Table 2-2:   Standard PIXIS Camera System Cables

Cable	Part Number	Description/Purpose	Length
USB 2.0	6050-0494	Connects the USB 2.0 connector on the rear of the PIXIS with a USB card installed in the host computer. 4411-0106_0005	5 m [16.4 ft]
MCX to BNC	6050-0540	Two MCX to BNC adapter cables are included. These connect to the EXT SYNC and the LOGIC OUT connectors on the rear of the PIXIS 4411-0106_0006	Varies

2.3   Certificate of Performance

Each PIXIS 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 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.

2.4   PIXIS System User Manuals

The PIXIS System User Manual describes how to install, configure, and use a PIXIS camera and its components.

2.5   Application Software

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

- LightField®

    The PIXIS camera can be operated using LightField, Teledyne Princeton Instruments' 64-bit Windows® 7 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.

    A PDF version of the LightField User Manual is provided on the installation CD. The manual describes how to install and use the LightField application program. Additional information is available in the program's online help.

- 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. Currently, the interface supports Windows Vista and Windows 7.

- 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.

- WinX

    The PIXIS 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 camera and even enhance it by making integration of the detection system into larger experiments or instruments an easy, straightforward endeavor.

    The WinX User Manual describes how to install and use the application program. A PDF version of the manual is provided on the installation CD. Additional information is available in the program's online help.

- PVCAM®

  A standard software interface for cooled PDA, FPA, and CCD detectors from Teledyne Princeton Instruments. It is a library of functions that can be used to control and acquire data from the detector 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 detector 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.

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

2.6   Accessories

Teledyne Princeton Instruments offers a number of optional accessories that are compatible with PIXIS. This section provides information about each of them. For complete ordering information, contact Teledyne Princeton Instruments.

4411-0106_0007

Internal Shutter

Optional 25 or 45 mm internal shutter (dependent on CCD array size). Shutters are mechanical devices with a finite lifetime, typically of the order of a million cycles, although some individual shutters may last a good deal longer. How long a shutter lasts in terms of experimental time will, of course, be strongly dependent on the operating parameters. High repetition rates and short exposure times will rapidly increase the number of shutter cycles and hasten the time when the shutter will have to be replaced.

4411-0106_0008

F-Mount Adapter

An F-mount adapter (P/N: 7050-0009) is available for modifying a spectroscopy-mount PIXIS with internal shutter.

4411-0106_0009

Adjustable C- to Spectroscopy-Mount Kinetics Adapter

An adjustable C- to Spectroscopy-mount kinetics adapter is available for modifying a C-mount PIXIS for mounting to a Teledyne Acton Research spectrograph. The adapter allows you to move the camera vertically at the exit plane of a Teledyne Acton Research Series spectrograph in order to align kinetics rows at the middle of the focal plane for the best spectral quality. Two versions are available: Model 7050-0104 for SP-2350 and SP-2550 spectrographs and Model 7050-0107 for SP-2150 and SP-2750 spectrographs.

Fiber Optic Extender Kit

4411-0106_0010

The specially designed fiber optic data interface kit allows the computer and the USB2.0 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. The FO kit is ideal for hazardous or high EMI environments. This optional kit supports PIXIS, Spec-10, VersArray and PIMAX family of products as well Teledyne Acton Research Series spectrographs with USB2.0 data interface.

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

4411-0106_0011

P/N: 7567-0002

Liquid-cooled PIXIS cameras can cool to a lower temperature (typically -35° C) than air cooling. Instead of using a fan to remove heat, these cameras incorporate a closed loop system of circulating fluid. The CoolCUBEII circulator unit continuously pumps the 50:50 mixture of room temperature (23ºC) water and ethylene glycol. To prevent voiding the warranty, use only the circulator and hoses shipped with your system.

2.7   Unpack the System

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

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

Retain all original packing materials so that the PIXIS system can be easily and safely packaged and shipped to another location or returned for service if necessary. If assistance is required at any time, contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for complete information.

2.7.1   Verify Equipment and Parts Inventory

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

A typical system consists of:

- PIXIS Camera;
- Power Supply and Cable;
- CoolCUBE$_{II}$ Circulator and hoses (for liquid-cooled system);
- Host Computer;
  May be purchased from Teledyne Princeton Instruments or provided by user. Refer to Section A.9, Minimum Host Computer Specifications, on page 109 for minimum specifications.
- USB cable;
  Five (5) meter cable (6050-0494) is standard.
- PIXIS System User Manual.

Options that may have been purchased include:

- F-mount adapter;
- Adjustable C- to Spectroscopy-mount kinetics adapter;
- 25 mm or 45 mm Internal Shutter (as appropriate for the CCD size);
- Application Software, including User Manual:
  — WinView/32 or WinSpec32 (Version 2.5.25 or later);
  — LightField CD-ROM;
- Fiber Optic Extender Kit.

2.8 PIXIS Camera and System Maintenance

⚠️ **WARNING!** ————————————————

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

2.8.1 Camera

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

2.8.2 Optical Surfaces

As a good practice, the camera must be closed/capped off with the supplied dust cover or lens cap when not in use. Should a need to clean the optical window arise due to the accumulation of atmospheric dust, we advise that the drag-wipe technique be used. This involves dipping a clean cellulose lens tissue into clean anhydrous methanol, and then dragging the dampened tissue over the optical surface to be cleaned. Do not allow any other material to touch the optical surfaces.

2.8.3 Repairs

Because the PIXIS camera system contains no user-serviceable parts, repairs must be performed by Teledyne Princeton Instruments. Should the system need repair, contact Teledyne Princeton Instruments customer support for instructions. Refer to Contact Information on page 154 for complete information.

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

Chapter 3:   Install Data Acquisition Software

This chapter provides information about installing the following data acquisition software:

- LightField;
- WinX.

> 🔍 **NOTE:** ────────────────────
> If application software is already installed on the host computer, this chapter may be skipped.

Prior to installing the desired data acquisition software, verify that the host computer satisfies the minimum system requirements listed in Section A.9, Minimum Host Computer Specifications, on page 109.

3.1   LightField

Perform the following procedure to install LightField on the host computer:

1. Insert the LightField Installation CD into the CD drive on the host computer and follow the on-screen prompts.
2. After the installation has been completed, reboot the host computer.
3. Connect the PIXIS system components to your computer and apply power.
4. Launch LightField, activate it, and begin experiment configuration.

3.2   WinX

This section provides information about installing WinView/32 and WinSpec 32 data acquisition software.

NOTES:
1. Before proceeding, please check to see if your computer supports USB 2.0. If it does not, install a USB 2.0 interface card. Follow the manufacturer's instructions.
2. Leave the USB cable disconnected from the camera until you have installed WinView/32 or WinSpec/32.

Perform the following procedure to install WinX on the host computer:
1. Insert the WinView/32 or WinSpec/32 installation CD into the CD drive on the host computer. The installation wizard will automatically launch.
2. From the Select Installation Type dialog select the desired type of installation:
    *   Typical
        Installs the required drivers and the most commonly installed program files.
    *   Custom
        Allows the specific set of program files to be selected for installation.
        Select this option if the drivers are not to be installed.
    *   Complete
        Installs all application features.
        See Figure 3-1.

Figure 3-1:   Typical WinView Select Installation Type Dialog
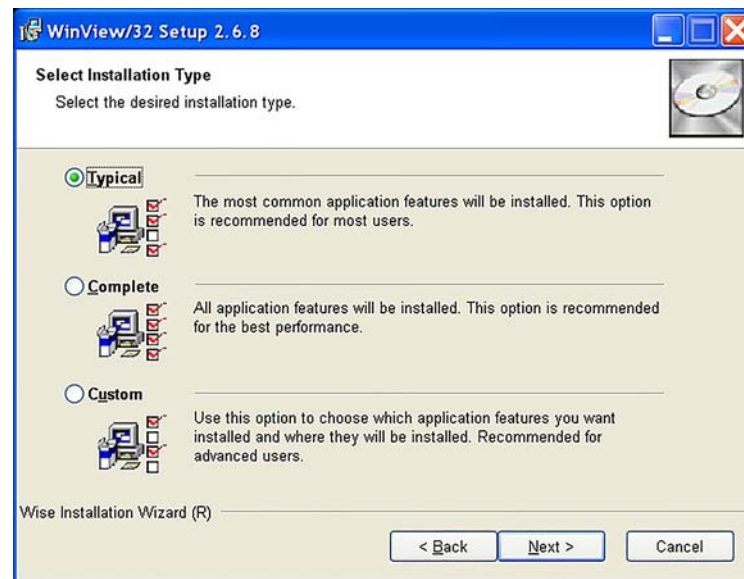
3. Click <u>N</u>ext > to proceed with the installation.

The required INF, DLL, and USB driver files will be placed in the appropriate Windows directory as specified in Table 3-1.

Table 3-1:   USB Driver Files and Locations

Windows® Version	USB INF File Located in `Windows/INF` directory[a]	USB Properties DLL Located in `Windows/System 32` directory	USB Device Driver Name Located in `Windows/System32/Drivers` directory
Windows XP Vista (32-bit) Windows 7 (32-bit)	rsusb2k.inf	apausbprop.dll	apausb.sys (in WINDOWS/ System32/Drivers, for example)

a. The INF directory may be hidden.

4. Verify the camera is connected to the host computer and that the camera power supply is turned on.

5. Reboot the host computer.

Windows will detect the Teledyne Princeton Instruments USB2 Interface hardware in the PIXIS.

6. If prompted, enter the directory path(s) for the following files by either manually typing them in or browsing to their locations:

• `apausbprop.dll`
• `apausb.sys.`

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Chapter 4: System Block Diagrams

This chapter provides block diagrams of typical system configurations.

Figure 4-1: Block Diagram: Typical Air-Cooled Imaging Experiment
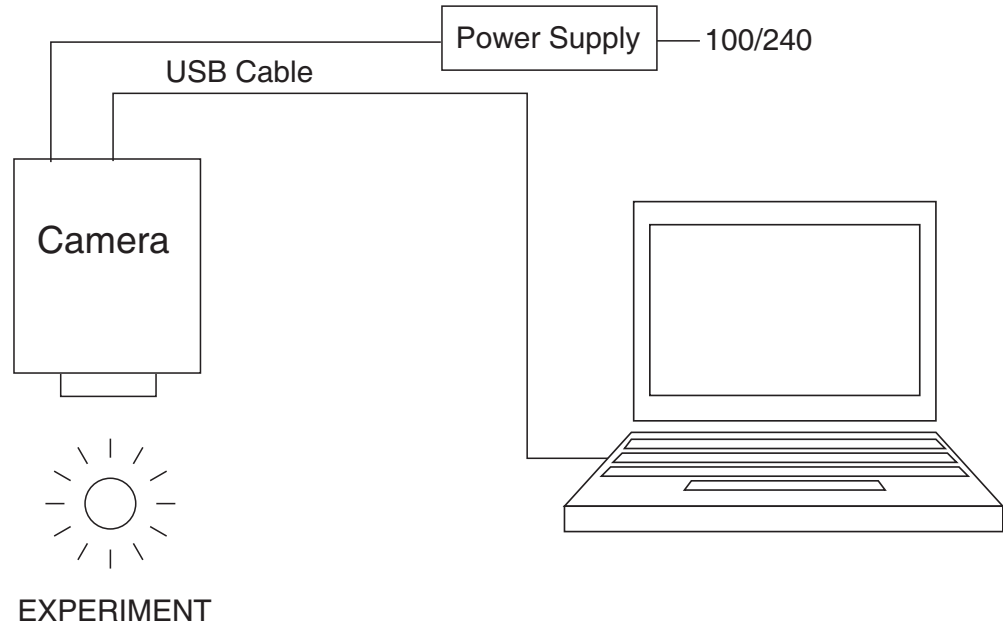
Figure 4-2: Block Diagram: Typical Air-Cooled Spectroscopy Experiment
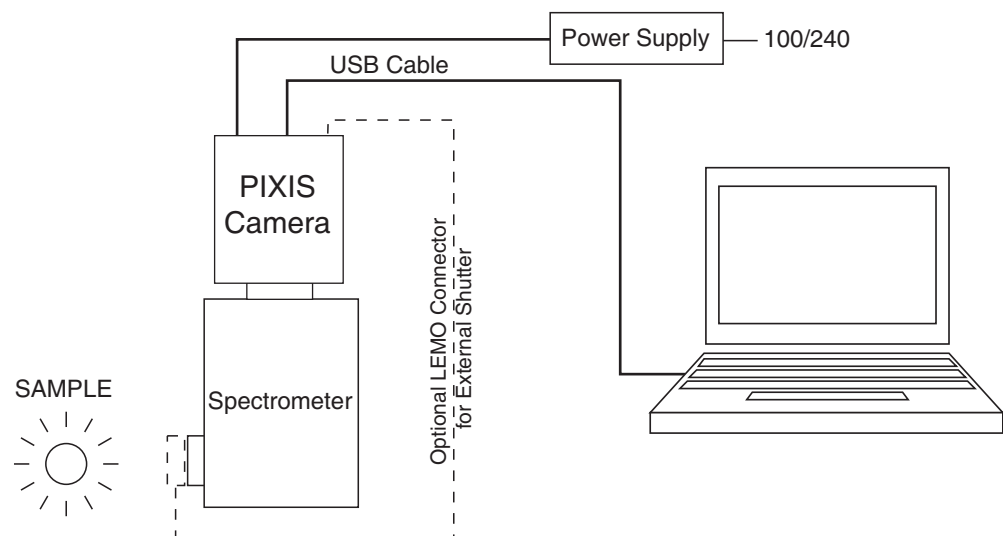
Figure 4-3:   Block Diagram: Typical Liquid-Cooled Imaging Experiment
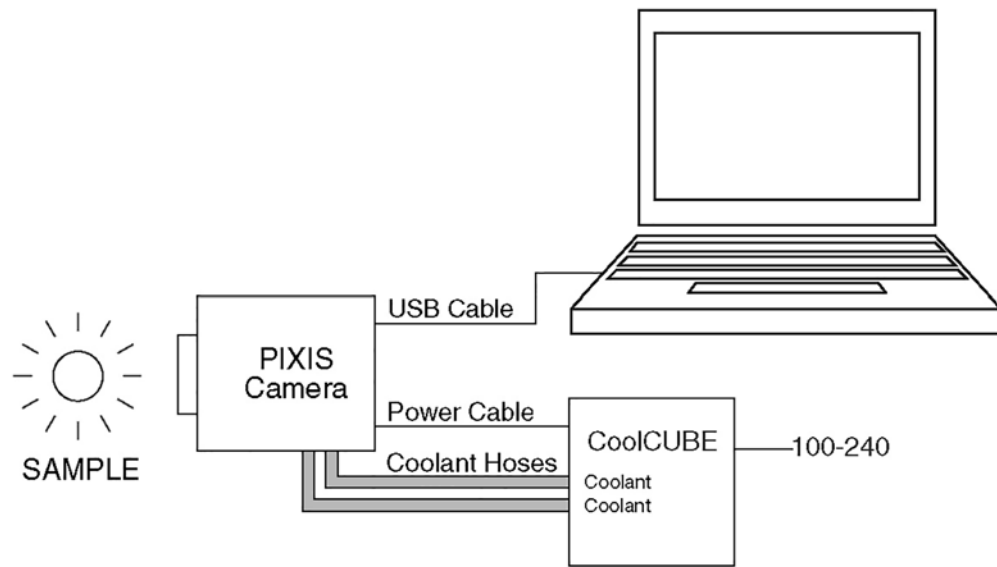
Figure 4-4:   Block Diagram: Typical Liquid-Cooled Spectroscopy Experiment
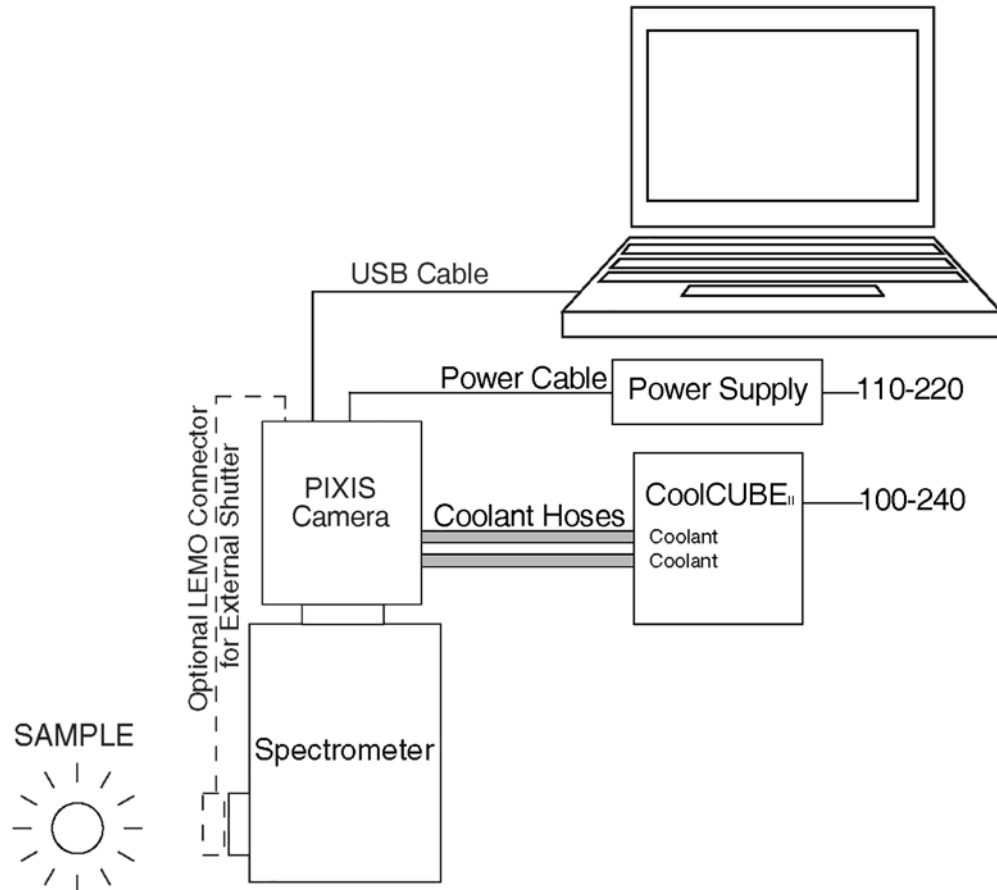
Chapter 5:   Hardware Installation

This chapter provides information about the installation of hardware that may be used with a PIXIS camera.

- Connect a CoolCUBEII Liquid Circulator;
- Install a Lens on a C-Mount Adapter, on page 35;
- Install a Lens on an Integral F-Mount Adapter, on page 35;
- Install Adjustable C- to Spectroscopy-Mount Kinetics Adapter, on page 36;
- Mount the PIXIS on a Spectrograph, on page 38;
- Connect an External Shutter, on page 38.

5.1   Connect a CoolCUBE$_{II}$ Liquid Circulator

For liquid-cooled cameras, the CoolCUBE$_{II}$ circulator, illustrated in Figure 5-1, provides a vibration-free method of heat removal.

Figure 5-1:   Typical CoolCUBE$_{II}$ Circulator
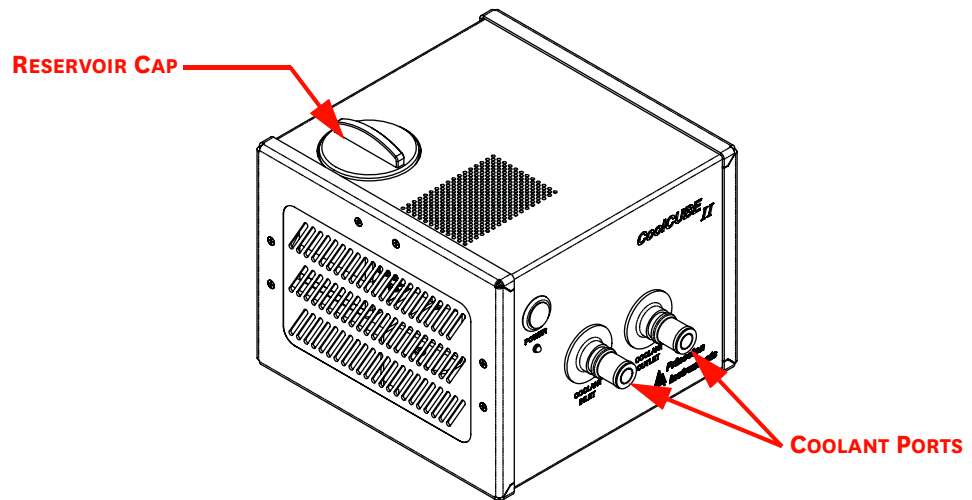
Perform the following procedure to connect a liquid-cooled PIXIS to an external CoolCUBE$_{II}$ liquid circulator:

1. Verify the power to both the PIXIS and the circulator is turned off.
2. Verify the circulator is placed a minimum of 6 inches [15.0 cm] below the PIXIS. This vertical distance should not exceed 10 feet [3 m.]

   Typically, the PIXIS is at table height and the circulator is on the floor.

3.   Connect the PIXIS to the circulator using the respective coolant ports on both pieces of equipment.

> **NOTES:**
> 1.   It does not matter which hose from the circulator is connected to which coolant port on the PIXIS.
> 2.   It is recommended that hoses be secured to the camera hose barbs with the clamp supplied.
> 3.   Verify that there are no kinks in the hoses that may impede the coolant flow. Lack of sufficient flow can seriously harm the detector and any resulting damage is not covered under warranty.
> 4.   Damage caused by water leaking into the PIXIS voids the warranty.

4.   Unscrew the reservoir cap located on the top of the CoolCUBE$_{II}$. Verify that the coolant reservoir contains coolant. If additional coolant is required, fill with a 50:50 mixture of water and ethylene glycol.
5.   Replace the reservoir cap.
6.   Plug the circulator into a 100-240 V_{AC}, 47-63 Hz power source.
7.   Turn the circulator on. Verify there are no leaks or air bubbles in the hoses.

> **NOTE:**
> Small air bubbles that are approximately the size of bubbles in soda are common in the CoolCUBE$_{II}$ particularly immediately following start up. These will not prevent proper operation.

   •   If there are no problems, proceed to step 8.
   •   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 8.

8.   Turn on the PIXIS.
9.   Launch the application software.

5.2   Install a Lens on a C-Mount Adapter

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

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

🔍 **NOTE:** ─────────────────────────

PIXIS cameras for imaging applications may incorporate an integral C-mount or adjustable C-mount adapter. Other mounts may be available. Contact Teledyne Princeton Instruments Customer Service for assistance. Refer to Contact Information on page 154 for complete information.

C-mount lenses simply screw into the front of these cameras. Tighten the lens by hand only. An optional C-to-F-mount adapter, which uses the Nikon bayonet format, can be ordered. Refer to Appendix C, Adapter Adjustment and Focusing Procedures, on page 123 for information about adjusting the focal distance for an adjustable C-mount adapter.

🔍 **NOTE:** ─────────────────────────

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

5.3   Install a Lens on an Integral F-Mount Adapter

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

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

🔍 **NOTE:** ─────────────────────────

PIXIS cameras for imaging applications may incorporate an integral F-mount adapter. Other mounts may be available. Contact Teledyne Princeton Instruments Customer Service for assistance. Refer to Contact Information on page 154 for complete information.

F-mount adapters incorporate the Nikon bayonet format.

Perform the following procedure to mount a lens on a PIXIS which includes an integral F-Mount Adapter:

1. Locate the large indicator dot on the side of the lens.
2. Note the corresponding dot on the front side of the adapter.
3. Line up these dots and slide the lens onto the adapter.
4. Turn the lens counterclockwise until a click is heard. The lens is now locked in place.

> 🔍 **NOTE:** —————————————————————————————
>
> In addition to the focus ring on the lens, the adapter is also capable of being focused. This adjustment is secured by set screws on the side of the adapter's adjustment ring.
>
> Refer to Section C.2, F-Mount Adapter Focusing Procedure, on page 124 for complete information.

5.4 Install Adjustable C- to Spectroscopy-Mount Kinetics Adapter

The adjustable spectroscopy-mount kinetics adapter allows the PIXIS to move vertically at the exit plane of a Teledyne Acton Research Series spectrograph. This vertical adjustment aligns the PIXIS' kinetics rows with the middle of the focal plane for the best spectral quality.

The adapter is mounted to the front of a PIXIS camera and secured by a threaded insert screwed into the camera's C-mount opening.

Figure 5-2 identifies key components of the adapter.

Figure 5-2:   Key Components: Adjustable C- to Spectroscopy-Mount Kinetics Adapter

VERTICAL ADJUSTMENT SET SCREW

SLIDING TUBE

RECESSED LOCKING SET SCREW

THREADED INSERT

ADAPTER FLANGE

RECESSED LOCKING SET SCREW

CAMERA BOTTOM

4411-0106_0018
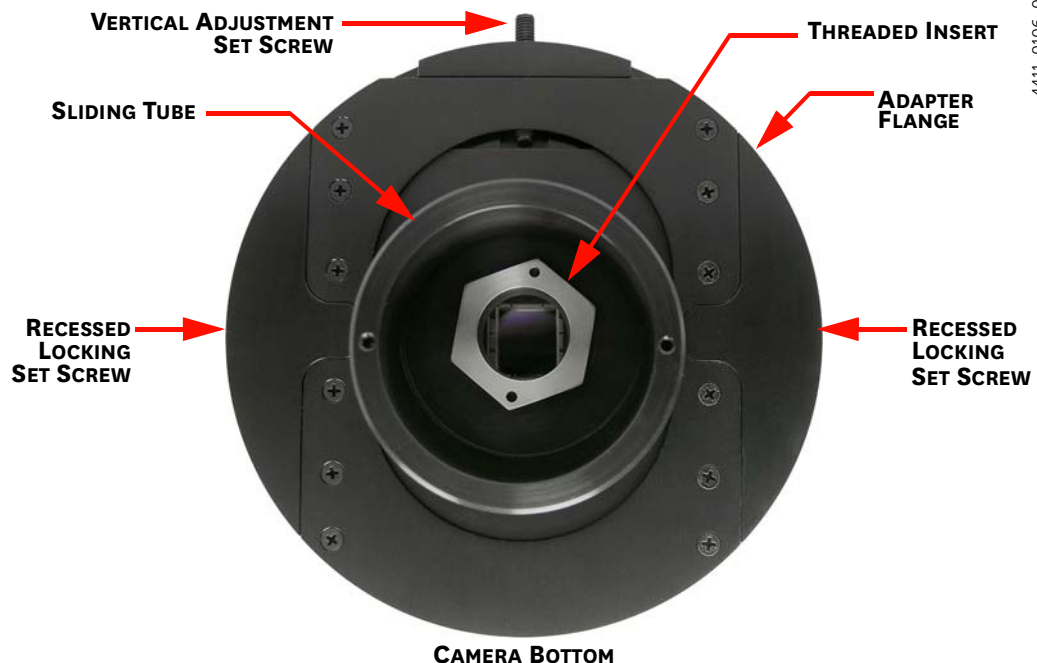
Required tools and equipment include:

- 0.050" Hex Wrench;
- 3/32" Hex Wrench;
- Blade screwdriver;
- Spanner wrench (1.17"/29.7 mm between 0.094"/2.38 mm diameter holes);
- Teledyne Acton Research Series Spectrograph with light source at entrance port
- Kinetics Adapter
- SP-2150 and SP-2750 Spectrographs: Use the Model 7050-0107 adapter
- SP-2350 and SP-2550 Spectrographs: Use the Model 7050-0104 adapter
- Camera with C-mount nose

Perform the following procedure to install the adjustable C-to-Spectroscopy Mount Kinetics adapter:

1. If a light baffle is mounted to the front of the adapter, remove the two 2-56 screws securing it and set the baffle aside.
2. Orient the adapter with the Vertical Adjustment Set Screw positioned at the top. See Figure 5-2.
3. Using a spanner wrench (or equivalent), tighten the threaded insert into the C-mount opening on the camera.
4. When using a light baffle, mount the light baffle to the front of the adapter.
5. Rotate the sliding tube while gently inserting it into the spectrograph's exit port.
6. With the spectrograph, PIXIS, and light source powered on and connected to the host computer (as required,) launch the desired image acquisition software.

   Refer to the following application-specific sections for information about focusing and rotationally aligning the PIXIS to the spectrograph's optics:

   - WinX Procedures:
     — Section 6.1.2.1, Focus and Rotational Alignment, on page 50.
   - LightField Procedures:
     — Section 6.2.2.1, Focus and Rotational Alignment, on page 62.

7. Once the PIXIS has been focused and rotationally aligned, secure the sliding tube in place using the spectrograph set screws.
8. If already installed, use the 0.050" Hex Wrench to loosen the adapter's two recessed locking set screws.

   If not installed, insert the set screws into the appropriate holes on the sides of the adapter and use the 0.050" Hex Wrench to secure them with a couple of turns.

9. When the PIXIS' opening is centered within the sliding tube, adjust the camera vertically by up to 0.4" (4.06 mm) by tightening or loosening the vertical adjustment set screw with the 3/32" Hex Wrench.
10. Once the adjustments are complete, tighten the recessed locking set screws in the adapter flange to lock into place.

5.5   Mount the PIXIS on a Spectrograph

The PIXIS must be properly mounted to the spectrograph in order to achieve proper focus. Additional precautions must also be taken to prevent overexposure of the camera.

The distance to the focal plane from the front of the mechanical assembly depends on the specific camera's configuration. Refer to Section A.3, Focal Distance (Optical), on page 105 for complete information.

5.5.1   Spectrograph Adapters

Refer to Appendix D, Spectrograph Adapters, on page 127 for complete information about available adapters. Contact Teledyne Princeton Instruments Customer Support for assistance when assessing system requirements. Refer to Contact Information on page 154 for complete information.

5.6   Connect an External Shutter

⚡ WARNING! ─────────────────────

Disconnecting or connecting the shutter cable to the PIXIS while the camera is turned on can destroy the shutter or the shutter driver in the camera!

Typically, PIXIS cameras for imaging applications are shipped with an internal shutter. Depending on the CCD array size, the 25 mm or 45 mm internal shutter is housed in the main body. Typically, cameras for spectroscopy applications do not incorporate an internal shutter. However, for cameras without an internal shutter, an external Teledyne Princeton Instruments-supplied 25 mm or 45 mm shutter can be connected to the Shutter connector on the rear of the PIXIS.

⚠ CAUTION! ─────────────────────

DO NOT connect a Teledyne Princeton Instruments-supplied external shutter when there is an internal shutter already installed. Permanent damage to the shutter driver may occur.

Electromechanical shutters typically have a lifetime of about one million cycles. Avoid running the shutter unnecessarily.

A shutter can become overheated when short, rapidly repeated exposures are used or if the shutter is held open for an extended period of time. Newer versions of the WinView/WinSpec software and camera hardware monitor the temperature of 45 mm internal shutters to prevent overheating conditions. The temperature of external shutters is NOT monitored!

5.6.1   External Shutter

A Teledyne Princeton Instruments-supplied external shutter may be used with a PIXIS camera that does not have an internal shutter. In most situations, the external shutter is mounted on the entrance slit of a spectrograph. The shutter mount used with all Teledyne Acton Research Series spectrographs requires no disassembly. Mount it to the spectrograph as shown in Figure 5-3.

Figure 5-3:   Teledyne Acton Research Series Spectrograph Entrance Slit Mount
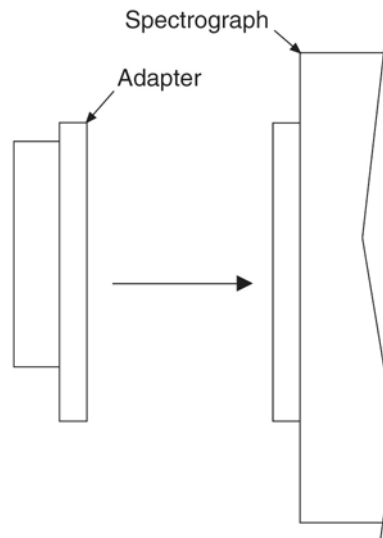
> 📑 **NOTE:** —————————————————————————
>
> When using an IsoPlane SCT-320 spectrograph, the shutter assembly is mounted internally. Refer to the information provided in the IsoPlane manual.

Perform the following procedure to connect the shutter cable:

1. Verify that the PIXIS camera is turned OFF.
2. Verify that there is no internal shutter.

> ⚠ **CAUTION!** ————————————————————
>
> If the camera is equipped with an internal shutter, DO NOT USE the Shutter connector to drive an external (second) shutter. Doing so will result in under-powering both shutters and may cause damage to the system.

3. Connect the shutter cable to the LEMO® connector at the rear of the camera.
4. Turn the PIXIS camera ON.

5.6.1.1   Overexposure Protection

Cameras that are exposed to room light or other continuous light sources will quickly become saturated. This most often occurs when operating without a shutter. If the camera is mounted to a spectrograph, close the entrance slit of the spectrograph to reduce the incident light.

NOTE:

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

Chapter 6: First Light

Once the PIXIS camera has been configured as described in Chapter 5, Hardware Installation, acquiring data using image acquisition software is straightforward. For most applications simply:

- Establish optimum performance (e.g., in WinX use Focus mode);
- Set a target camera temperature;
- Wait until the system's temperature has stabilized;
- Acquire live data in Acquire mode.

Additional considerations regarding experiment setup and equipment configuration are addressed in the associated software manual.

During data acquisition, the CCD array is exposed to a source and charge accumulates in the pixels. After the defined exposure time, the accumulated signal is readout of the array, digitized, and then transferred to the host computer. Upon data transfer, the data are displayed and/or stored via the application software. This sequence is illustrated by the block diagram shown in Figure 6-1.

Figure 6-1:   Block Diagram for PIXIS Systems
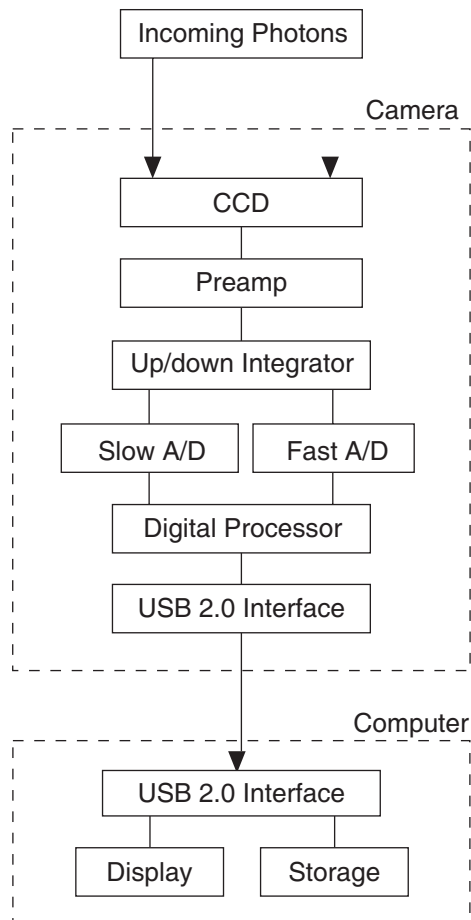
Whether or not the data are displayed and/or stored depends on the data collection operation that has been selected in the application software.

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

- Focus {Preview}

  Focus {Preview} is typically used when setting up the system/experiment.

  In Focus {Preview} mode, the number of frames is ignored. A single frame is acquired and displayed, another frame is acquired and overwrites the currently displayed data, and so on until Stop is selected.

  NOTE:

  > In WinX, the last frame acquired before Stop is selected can be stored.
  > In LightField, this frame cannot be stored.

  Focus {Preview} mode is particularly convenient for familiarization and configuration. For ease in focusing, the screen refresh rate should be as quick as possible, achieved by operating with axes and cross-sections off, and with Zoom 1:1 selected.

- Acquire

  Acquire is typically used for the collection and storage of data.

  In Acquire mode, every frame of data collected can be automatically stored, so the completed dataset may include multiple frames with one or more accumulations. This mode is typically selected during actual data collection.

  One limitation of Acquire mode operation is that if data acquisition continues at too fast a rate for it to be stored, data overflow may occur.

  NOTE:

  > In WinX, this could only happen in Fast Mode operation.

6.1   WinX First Light Procedure

This section provides information necessary to acquire image and spectroscopic data for the first time using WinView/32 and WinSpec/32 respectively. The purpose of this section is to gain familiarity with the operation of the system and to show that it is functioning properly. Once basic familiarity has been established, additional, more complex configurations can be implemented.

The procedures within this section assume:

- The system has been set up in accordance with instructions in previous chapters;
- Familiarity with WinView/32 and WinSpec/32;
  If this is not the case, refer to the appropriate User's Manual and/or online help.

When using WinX to acquire data, the following power sequences must be followed:

- The PIXIS camera must be powered on prior to launching WinX.
  In order to ensure communication between the PIXIS and the host computer, the PIXIS must be powered on before launching the WinX application.
  If WinX is launched and the PIXIS has not already been powered on, many functions will be disabled and you will only be able to retrieve and examine previously acquired and stored data.
  To resolve this, WinX must be closed, the PIXIS turned on, and finally WinX launched before new experiment configuration and data acquisition can begin.
- WinX must be closed prior to powering off the PIXIS.
  If the PIXIS is powered off prior to closing WinX, the communication link with the camera will be broken. WinX can be operated in a playback mode (i.e., examine previously acquired data,) but the acquisition of new data will be disabled until WinX has been closed, the PIXIS has been turned on, and finally WinX launched again.

6.1.1   Imaging Applications

The following procedure assumes that:

- The system is being operated in imaging mode.
- The target is a sharp image, text, or a drawing that can be used to verify that the camera is seeing and can be used to maximize focus.

> **NOTE:**
> This procedure uses WinView/32-specific terminology. Basic familiarity with WinView/32 is assumed. If this is not the case, review the software manual or have it available while performing this procedure.
> When using different data acquisition software, appropriate changes to this procedure must be made.

Perform the following procedure to configure the PIXIS to acquire image data:

1. Mount a test target in front of the PIXIS.
2. Turn on the PIXIS.

> **NOTE:**
> The camera must be turned on prior to launching WinView/32.

3. Turn on the host computer and allow it to boot up.
4. Once the host computer has finished booting up, launch WinView/32.
5. Configure the following parameters as indicated:

- Environment dialog (Setup ► Environment)
  Check the DMA Buffer size.
  Large arrays (e.g., 2048 x 2048,) require a buffer size on the order of 32 MB.
  If the buffer size is changed, the host computer must be rebooted for this memory allocation to be activated. WinView/32 must be relaunched.

- Controller ► Camera tab (Setup ► Hardware)
  The following parameters should automatically be configured for the system:
  — Controller type
    This information is read from the camera.
  — Camera type
    This information is read from the camera.
  — Shutter type
    None or Small (System dependent).
  — Readout mode
    Available modes are read from the camera. Select Full frame.

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

NOTE:
> The Detector Temperature dialog will not display temperature information during data acquisition.

- Cleans and Skips tab (Setup ► Hardware)
  Click on Load Default Values and click Yes.

- Experiment Setup Main tab (Acquisition ► Experiment Setup...)
  — Exposure Time
    100 ms
  — Accumulations & Number of Images
    1

- Experiment Setup ROI tab (Acquisition ► Experiment Setup...)
  Use this function to define the region of interest (ROI).
  — Imaging Mode
    Select this mode if using WinSpec./32
  — Clicking on Full loads the full size of the chip into the edit boxes.

- Experiment Setup Timing tab (Acquisition ► Experiment Setup...)
  — Timing Mode
    Free Run
  — Shutter Control
    Normal
  — Safe Mode vs. Fast Mode
    Fast

6. If using WinView/32 and the host computer monitor to focus the system, select Focus from the Acquisition menu.

   Successive images will be displayed on the monitor as quickly as they are acquired.

7. Adjust the lens aperture, intensity scaling, and focus for the best image as viewed on the host computer monitor.

   Imaging tips include:

   - Begin with the lens blocked off and set the lens at the smallest possible aperture (i.e., the largest f-stop number).
   - Verify there is a suitable target in front of the lens. An object with text or graphics works best.
   - Adjust the intensity scaling using the 5%-95% button in the bottom left corner of the data window. Adjust the lens aperture until a suitable setting is found.

     Once determined that the image is present, select a lower setting for better contrast.

     Check the brightest regions of the image to determine if the A/D converter is at full-scale. A 16-bit A/D is at full scale when the brightest parts of the image reach an intensity of 65535. Adjust the aperture so that it is just slightly smaller (i.e., larger f-stop,) than the setting where maximum brightness on any part of the image occurs.
   - Set the focus adjustment of the lens for maximum sharpness in the viewed image.
   - In the case of a camera with an F-mount, the camera lens adapter itself also has a focus adjustment.

     If necessary, this focus can be adjusted to bring the image into range of the lens focus adjustment. Refer to Section C.2, F-Mount Adapter Focusing Procedure, on page 124 for complete information.

8. Once the camera has been focused, either:

   - Stop Focus mode;
   - Continue Focus mode;
   - Begin Acquire mode; or
   - Wait for the CCD to reach the operating temperature before beginning Acquire mode.

6.1.2   Spectroscopy Applications

The following procedure assumes that:

- The PIXIS is to be operated with, and has been properly installed on, a spectrograph (e.g., Teledyne Acton Research Series 2300 spectrograph,) and is being operated in spectroscopy mode.

  Refer to Section D, Spectrograph Adapters, on page 127, for complete installation procedures.

- A suitable light source (e.g., mercury pen-ray lamp,) has been mounted in front of the entrance slit of the spectrograph.

  Any light source with line output can be used. Standard fluorescent overhead lamps have good calibration lines as well.

  If no line source is available, use a broadband source (e.g., tungsten,) for the alignment using a wavelength setting of 0.0 nm for alignment purposes.

- The spectrograph has an entrance slit shutter that is being controlled by the PIXIS via the Shutter connector.

⚠ **CAUTION!**

If the PIXIS is equipped with an internal shutter, DO NOT USE the Shutter connector to drive a spectrograph entrance slit shutter.

If both the PIXIS and the spectrograph have shutters, the entrance slit shutter must be removed.

Alternatively, a Teledyne Princeton Instruments SHC-EXT Shutter Control Box may be used to control the opening and closing of the entrance slit shutter. Refer to the spectrograph manual for additional information.

🔍 **NOTE:**

This procedure uses WinSpec/32-specific terminology. Basic familiarity with WinSpec/32 is assumed. If this is not the case, review the software manual or have it available while performing this procedure.

When using different data acquisition software, appropriate changes to this procedure must be made.

Perform the following procedure to configure the PIXIS to acquire image data:

1. Set the spectrograph entrance slit width to a minimum (i.e., 10 μm if possible).
2. Turn on the spectrograph (if applicable.)
3. Mount a light source at the spectrograph's entrance slit.
4. Mount the PIXIS to the spectrograph's exit port.
5. Connect the shutter cable between the entrance slit shutter and the PIXIS Shutter connector.

- External Slit Shutter

  A shutter assembly mounted externally to the spectrograph has shutter cable that plugs into the Shutter connector.

- Internal Slit Shutter

  A shutter mounted internally has an external shutter connector in the sidewall of the spectrograph. Connect a shutter cable from the PIXIS Shutter connector to that connector.

6. Turn on the PIXIS camera.

> 🔍 **NOTE:** _____
>
>   The PIXIS must be turned on prior to launching WinSpec/32.

7. Turn on the host computer and allow it to boot up.
8. Once the host computer has finished booting up, launch WinSpec/32.
9. Configure the following parameters as indicated:

- Environment dialog (Setup ► Environment)

  Check the DMA Buffer size.

  Large arrays (e.g., 2048 x 2048,) require a buffer size on the order of 32 MB.

  If the buffer size is changed, the host computer must be rebooted for this memory allocation to be activated. WinSpec/32 must be relaunched.

- Controller ► Camera tab (Setup ► Hardware)

  The following parameters should automatically be configured for the system:
  — Controller type

    This information is read from the camera.
  — Camera type

    This information is read from the camera.
  — Shutter type

    Remote (entrance slit shutter).

    Select None if the PIXIS has no shutter and is not controlling an entrance slit shutter.
  — Readout mode

    Available modes are read from the camera.

    Select Full frame.

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

  The default temperature setting is read from the camera. When the array temperature reaches the set temperature, the Detector Temperature dialog will report that the temperature is LOCKED.

  Note that some overshoot may occur. This could cause temperature lock to be briefly lost and then quickly re-established. If you are reading the actual temperature reported by the application software, there may be a small difference between the set and reported temperature when lock is established. This is normal and does not indicate a system malfunction. Once lock is established, the temperature will be stable to within ± 0.05°C.

> 🔍 **NOTE:** _____
>
>   The Detector Temperature dialog will not display
>   temperature information during data acquisition.

- Cleans and Skips tab (Setup ► Hardware)

  Click on Load Default Values and click Yes.

- Experiment Setup Main tab (Acquisition ► Experiment Setup...)
  — Exposure Time

    100 ms
  — Accumulations & Number of Images

    1

- Experiment Setup ROI tab (Acquisition ► Experiment Setup...)
  Use this function to define the region of interest (ROI).
  — Spectroscopy Mode
    Selected
  — Clicking on Full loads the full size of the chip into the edit boxes.
- Experiment Setup Timing tab (Acquisition ► Experiment Setup...)
  — Timing Mode
    Free Run
  — Shutter Control
    Normal
  — Safe Mode vs. Fast Mode
    Fast

10. Configure the following spectrograph parameters:
    - Define Spectrograph dialog (Spectrograph ► Define)
      — Click Install/Remove Spectrograph;
      — Highlight the desired spectrograph in the Supported Spectrographs list
        For example:
        - Teledyne Acton Research SP-300i for a Teledyne Acton Research SP2300i;
        - Teledyne Acton Research SCT320 for an IsoPlane.
      — Click Install Selected Spectrograph.
    - Move Spectrograph dialog
      Select the grating to be moved and set it to:
      — 500 nm if using a mercury lamp;
      — 0.0 nm if using a broadband source.

11. Turn on the light source at the spectrograph entrance slit.

12. Begin Data Accumulation by selecting Focus from either:
    - The Acquisition menu; or
    - The Experiment Setup dialog.
    Depending on the display settings, either a spectral band (image) or a graph will be displayed.

    > 🔍 **NOTE:**
    >
    > Background noise will decrease as the camera cools to its default temperature.

13. Turn off the light source.
    If the display changes to a background noise pattern or low intensity graph it has been confirmed that light entering the spectrograph is being seen by the camera. Proceed to Section 6.1.2.1, Focus and Rotational Alignment, on page 50.

14. If little to no visual difference is observed:
    a. Verify the light source has power and is turned on.
    b. Verify that the entrance slit is open a minimum of 10 μm.
    c. Check the Exposure Time on the Experiment Setup Timing tab.
    d. Confirm that Shutter Control is set to Normal on the Experiment Setup Timing tab.
    e. Check the shutter cable connections.

    f. Verify shutter operation. The shutter should be heard opening and closing while running in Focus mode.

- If the shutter can be heard operating and step a through step e have been performed, turn the light source on, wait a minute and then turn the light off while viewing the data display.

  If the problem is resolved, stop acquisition or proceed to Section 6.1.2.1, Focus and Rotational Alignment on page 50.

  Otherwise, stop data acquisition and proceed to step g.

- If you do not hear a shutter operating and step a through step e have been performed, stop data acquisition and continue to step g.

    g. Verify the spectrograph has an entrance slit shutter.

- An externally mounted shutter is easily confirmed.
- Verifying an internally mounted shutter requires access to the inside of the spectrograph. Refer to the spectrograph manual for instructions.

    h. Determine if the PIXIS has a shutter.

Loosen and remove the camera from the spectrograph. If the CCD is visible when looking into the front of the camera, the camera does not have an internal shutter. Re-mount the camera to the spectrograph.

    i. If the camera and spectrograph both have shutters, permanent damage to the shutter driver may occur.

Either disconnect and remove the entrance slit shutter or control it via a Teledyne Princeton Instruments SHC-EXT Control Box.

Perform the following procedure to disconnect and remove an entrance slit shutter:

- External Slit Shutter

  Disconnect the shutter cable and remove the shutter assembly from the spectrograph entrance port.

- Internal Slit Shutter

  Disconnect the shutter cable. Removing an internally mounted shutter requires access to the inside of the spectrograph: refer to the spectrograph manual for removal instructions.

For additional assistance, contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for complete information.

6.1.2.1 Focus and Rotational Alignment

The camera mounting hardware provides two degrees of freedom:

- Focus

  Focus is the process of moving the camera back and forth through the spectrograph's focal plane while watching a live display until the optimal focus has been achieved.

- Rotation

  Rotation is the physical rotation of the camera while watching a live display on the monitor until spectral lines are perpendicular to the rows on the array.

This section provides focus and rotational alignment procedures for the following spectrographs:

- Teledyne Acton Research Series Spectrograph on page 50;
- IsoPlane SCT-320 Spectrograph on page 52.

> ⚠ **CAUTION!** ───────────────
>
> If the PIXIS is equipped with an internal shutter, DO NOT USE the Shutter connector to drive a spectrograph entrance slit shutter.
>
> If both the PIXIS and the spectrograph have shutters, the entrance slit shutter must be removed.
>
> Alternatively, a Teledyne Princeton Instruments SHC-EXT Shutter Control Box may be used to control the opening and closing of the entrance slit shutter. Refer to the spectrograph manual for additional information.

6.1.2.1.1 Teledyne Acton Research Series Spectrograph

Perform the following procedure to focus and rotationally align a Teledyne Acton Research Series Spectrograph:

1. Mount a light source (e.g., mercury pen-ray type,) in front of the entrance slit of the spectrograph.

   Any light source with line output can be used. Standard fluorescent overhead lamps have good calibration lines as well. If there are no line sources available, use a broadband source such as tungsten for the alignment. If this is the case, use a wavelength setting of 0.0 nm for alignment purposes.

2. With the spectrograph properly connected to the PIXIS, turn the power on and allow the spectrograph to initialize.

3. Select Define from the Spectrograph menu.

4. Click Install/Remove Spectrograph and select the desired spectrograph from the Supported Spectrographs list.

   For example, Acton SP300i for a Teledyne Acton Research SP-2300i spectrograph.

5. Click Install Selected Spectrograph.

6. Select Move from the Spectrograph menu.

7. Select the grating to be moved, and set it to
   - 500 nm if using a mercury lamp; or
   - 0.0 nm if using a broadband source.

> **NOTE:**
>
> Overhead fluorescent lights produce a mercury spectrum.
> Use a white card tilted at 45 degrees in front of the entrance
> slit to reflect overhead light into the spectrograph. Select
> 500 nm as the spectral line.

8. Set the slit to a minimum of 10 μm. If necessary, adjust the Exposure Time to maintain optimum (i.e., near full-scale,) signal intensity.
9. Wait until the detector temperature locks at its default temperature.
10. Begin data acquisition by selecting Focus from either:
    - The Acquisition menu; or
    - The Experiment Setup dialog.

    Data will be continuously acquired and displayed but will not be stored until acquisition has been stopped and the Save function on the File menu has been selected.
11. Slowly move the camera in and out of focus.

    The spectral line will go from broad to narrow and back to broad. Leave the camera set for the narrowest achievable line.

    If desired, use the Focus Helper function (Process ► Focus Helper…) to determine the narrowest line width. The Focus Helper can automatically locate peaks and generate a report on peak characteristics during live data acquisition. Refer to the WinSpec/32 online help for additional information.

    Note that the way focusing is accomplished depends on the spectrograph, as follows:
    - Long focal-length spectrographs (e.g., Teledyne Acton Research SP-2300)

      The mounting adapter includes a tube that slides inside another tube to move the camera in or out as required to achieve optimum focus.
    - Short focal-length spectrographs

      There is generally a focusing mechanism on the spectrograph which, when adjusted, will move the optics as required to achieve proper focus.
    - No focusing adjustment

      If there is no focusing adjustment provided by the spectrograph or by the mounting hardware, then the only option is to adjust the spectrograph's focusing mirror.

12. Adjust rotation by rotating the camera while watching a live display of the line.

> 🔍 **NOTE:** ─────────────────────────────
>
> It may be necessary to loosen two set screws that secure the spectrograph adapter.

Choose a peak to monitor during the rotational alignment. This peak will go from broad to narrow and back to broad. Leave the camera rotation set for the narrowest achievable peak.

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

> 🔍 **NOTE:** ─────────────────────────────
>
> When aligning other accessories (e.g., fibers, lenses, optical fiber adapters,) first align the spectrograph to the slit. Then align the accessory without disturbing the camera's position. The procedure is identical to that used to focus the spectrograph (i.e., perform focus and alignment operations while watching a live image).

13. Tighten the spectrograph set screws to secure the spectrograph adapter in place.
14. Halt data acquisition.

6.1.2.1.2   IsoPlane SCT-320 Spectrograph

Because the PIXIS is mounted directly to the mounting plate on the IsoPlane, focusing and alignment is different from the way that focusing and alignment are performed for a Teledyne Acton Research Series spectrograph. The following information assumes that familiarity with the locations of the mounting plate, Micrometer Compartment, and the locking set screw. If not, refer to the IsoPlane manual supplied with the spectrograph.

Perform the following procedure to focus and rotationally align an IsoPlane SCT-320 spectrograph:

1. Mount a Teledyne Acton Research light source (e.g., dual HG/NeAr source,) in front of the entrance slit of the spectrograph.
2. With the IsoPlane properly connected to the host computer, turn the power on, wait for the IsoPlane to initialize.
3. With the PIXIS mounted to the IsoPlane and connected to the host computer, turn on the power and wait for the PIXIS to initialize.
4. Launch WinSpec/32.
5. Select Define from the Spectrograph menu.
6. Click on Install/Remove Spectrograph.
7. Select Acton SCT320 from the Supported Spectrographs list.
8. Click Install Selected Spectrograph.
9. Select Move from the Spectrograph menu.

10. Select the grating to be moved and set it to:
    - 500 nm if using a mercury lamp; or
    - 0.0 nm if using a broadband source.
11. Set the slit to a minimum of 10 μm. If necessary, adjust the Exposure Time to maintain optimum (i.e., near full-scale,) signal intensity.
12. Wait until the detector temperature locks at its default temperature.
13. Remove the cover from the Micrometer Compartment.
14. Using a 3/32" hex wrench, loosen the locking set screw.
15. Turn on Focus mode.
16. While continuously acquiring data, adjust the micrometer until the intensity level of a selected peak or peaks has been maximized.
17. Tighten down the locking set screw.
18. Place the Micrometer Cover on the spectrograph.
19. Replace and tighten all cover screws.
20. Use a 9/64" hex wrench to loosen the four screws at the corners of the detector mounting plate.
21. While watching a live display of the spectrum, select a peak to monitor.
22. Rotate the PIXIS (up to 4 degrees of rotation is possible).

    The peak will go from broad to narrow and back to broad. Leave the PIXIS' rotation set for the narrowest achievable peak.

    Alternatively:

    a. Acquire an image.
    b. Display horizontal and vertical cursor bars.
    c. Compare the vertical bar to the line shape on the screen.
    d. Rotate the detector until the line shape on the screen is parallel with the vertical bar.
23. After completing the rotational alignment, tighten the four mounting plate screws.
24. Halt acquisition.

6.2   LightField First Light Procedure

This section provides information necessary to acquire image and spectroscopic data for the first time using LightField. The purpose of this section is to gain familiarity with the operation of the system and to show that it is functioning properly. Once basic familiarity has been established, additional, more complex configurations can be implemented.

The procedures within this section assume:

- The system has been set up in accordance with the instructions in previous chapters;
- Familiarity with LightField;
  If this is not the case, refer to the online help while performing this procedure.

6.2.1   Imaging Applications

The following procedure assumes:

- The system is being operated in imaging mode;
- The test target is a sharp image, text, or a drawing that can be used to verify that the camera is seeing and can be used to maximize focus.

NOTE:

This procedure uses LightField-specific terminology. Basic familiarity with LightField is assumed. If this is not the case, refer to the LightField Online Help while performing this procedure.

When using different data acquisition software, appropriate changes to this procedure must be made.

Perform the following procedure to set up and configure the system to acquire image data:

1. Mount the test target in front of the PIXIS.
2. Turn on the camera.
3. Turn on the host computer.
4. Launch LightField.
   An icon representing the PIXIS should be visible within the Available Devices area. See Figure 6-2.

Figure 6-2:   Typical LightField Available Devices Area
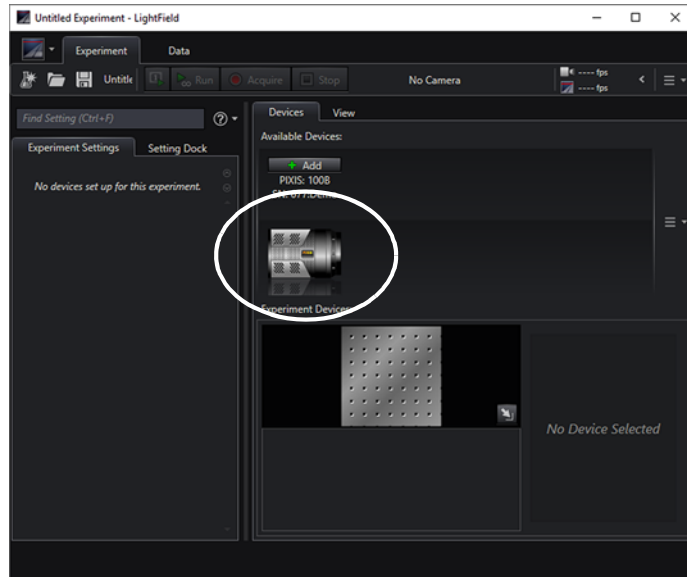
5.   Drag the PIXIS into the Experiment Devices area. See Figure 6-3.

Figure 6-3:   Typical LightField Experiment Devices Area
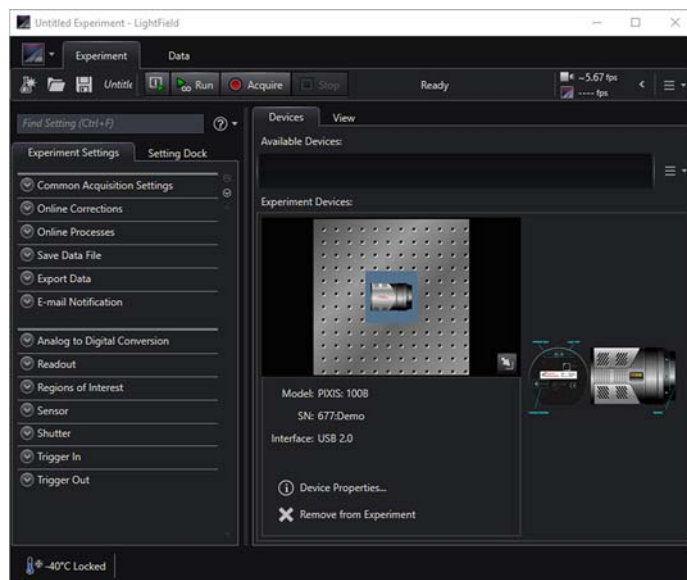
The Experiment Settings stack on the left now displays several expanders with default parameter values configured.

The Status bar along the bottom of the window displays an icon for temperature status.which reports the current temperature and whether the configured temperature has been reached. Clicking on the icon, opens the Sensor expander which is where the set temperature can be configured.

6. Click the View tab above Experiment Devices area to switch to the Data Viewer. See Figure 6-4.

Figure 6-4: **Typical LightField Data Viewer**
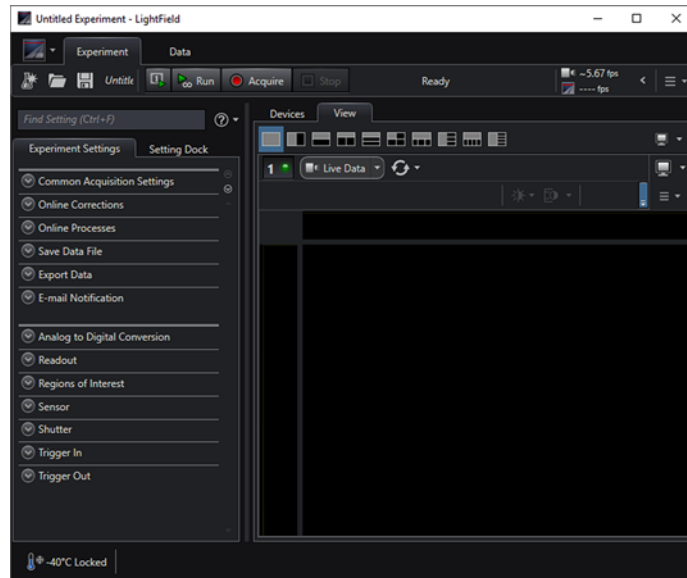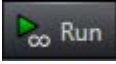
7. Allow the PIXIS to locks at its default temperature.

8. Click ![Run] to start Preview mode. In this mode, images are continuously acquired and displayed. See Figure 6-5.

Figure 6-5: **Typical Data Viewer Displaying an Image**
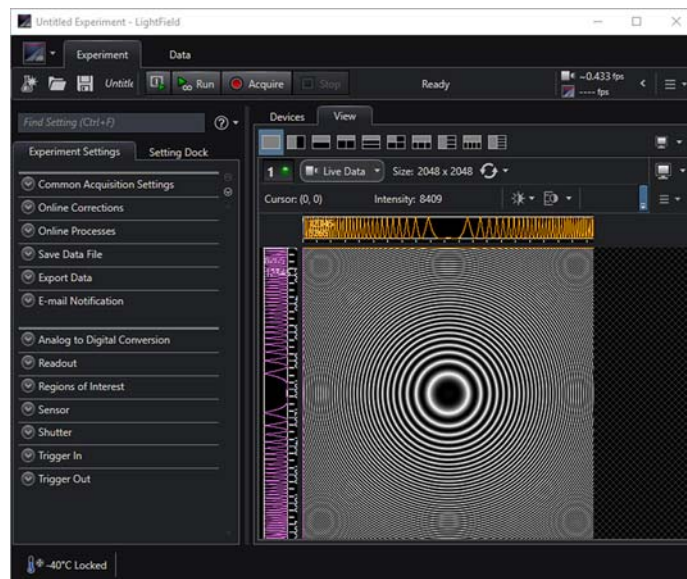
9. Adjust the lens aperture, intensity scaling, and focus for the best image as viewed on the host computer's monitor. Tips include:

- Begin with the lens blocked off and then set the lens at the smallest possible aperture (i.e., the largest f-stop number.)
- Verify there is a suitable target in front of the lens. An object with text or graphics works best.
- Examine the brightest regions of the image to determine if the A/D converter is at full-scale.

  A 16-bit A/D is at full scale when the brightest parts of the image reach an intensity of 65535.

  Adjust the aperture until it is slightly smaller (i.e., a higher f-stop,) than that where maximum brightness on any part of the image occurs.
- Set the focus adjustment of the lens for maximum sharpness in the viewed image.

10. Once the PIXIS has been focused, either:

- Halt Preview mode;
- Continue Preview mode; or
- Begin Acquire mode.

6.2.2   Spectroscopy Applications

The following procedure assumes that:

- The system is being operated in spectroscopy mode.
- The PIXIS does not have an internal shutter.

⚠ **CAUTION!** ————————————————

If the PIXIS is equipped with an internal shutter, DO NOT USE the Shutter connector to drive a spectrograph entrance slit shutter.

If both the PIXIS and the spectrograph have shutters, the entrance slit shutter must be removed.

Alternatively, a Teledyne Princeton Instruments SHC-EXT Shutter Control Box may be used to control the opening and closing of the entrance slit shutter. Refer to the spectrograph manual for additional information.

————————————————————————————

- The PIXIS is being operated with a spectrograph (e.g., a Teledyne Acton Research Series 2300,) on which it has been properly installed.

  Refer to Appendix D, Spectrograph Adapters, on page 127 for complete information.
- The spectrograph has an entrance slit shutter that is being controlled by the PIXIS via the Shutter connector.

- A suitable light source (e.g., mercury pen-ray lamp,) has been mounted in front of the entrance slit of the spectrograph.

  Any light source with line output can be used. Standard fluorescent overhead lamps have good calibration lines as well. If there are no line sources available, it is possible to use a broadband source such as tungsten for the alignment. If this is the case, use a wavelength setting of 0.0 nm for alignment purposes.

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

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

Perform the following procedure to set up and configure the system to acquire a spectrum:

1. Set the spectrograph entrance slit width to a minimum ($10 \mu m$ if possible).
2. Turn on the spectrograph (if applicable.)
3. Mount a light source at the spectrograph entrance slit.
4. Mount the PIXIS to the spectrograph's exit port.
5. Connect the shutter cable between the entrance slit shutter and the PIXIS Shutter connector.
   - External Slit Shutter

     A shutter assembly mounted externally to the spectrograph has shutter cable that plugs into the Shutter connector.
   - Internal Slit Shutter: A shutter mounted internally has an external shutter connector in the sidewall of the spectrograph. Connect a shutter cable from the PIXIS Shutter connector to that connector.
6. Turn on the PIXIS.
7. Turn on the host computer.
8. Launch LightField.

   Icons representing the PIXIS and the spectrograph should be visible within the Available Devices area. See Figure 6-6.

Figure 6-6:   Typical LightField Available Devices Area
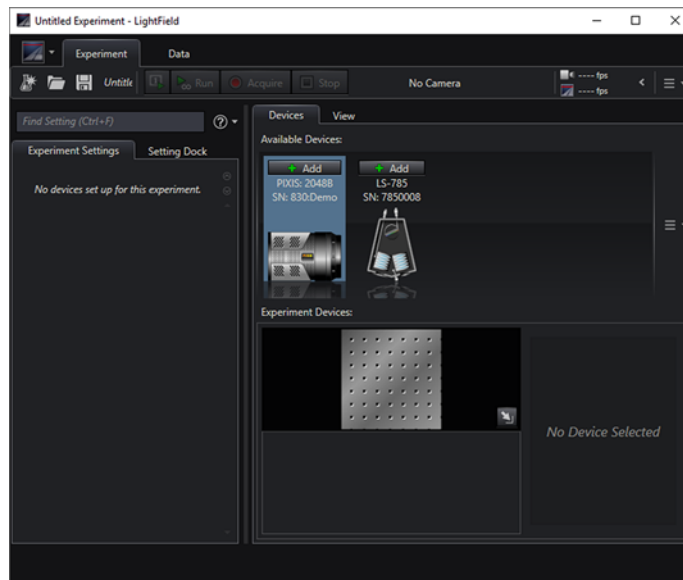
9. Drag each of these icons into the Experiment Devices area.

The Experiment Settings stack on the left now displays several expanders with default parameter values configured.

The Status bar along the bottom of the window displays an icon for temperature status.which reports the current temperature and whether the configured temperature has been reached. Clicking on the icon, opens the Sensor expander which is where the set temperature can be configured.

See Figure 6-7.

Figure 6-7:   Typical LightField Experiment Devices Area
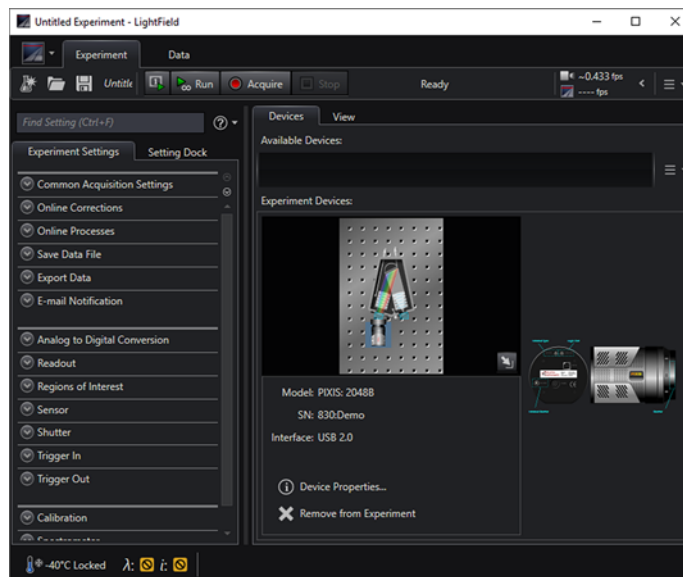
10. Within the Experiment Settings tab, open the Shutter expander and verify the following parameter is configured as indicated:

- Shutter Mode: Normal.

Update this configuration value if necessary.

See Figure 6-8.

Figure 6-8:   Typical LightField Experiment Settings: Shutter Expander Open
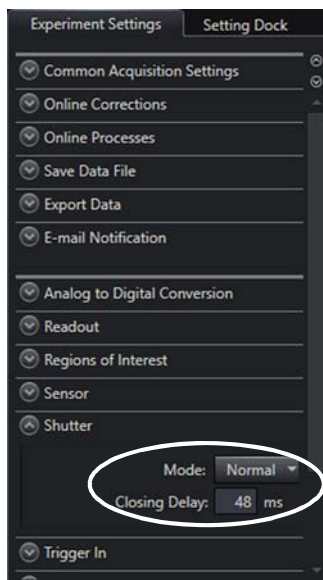
11. Open the Spectrometer expander and select an appropriate grating.

For example, select the 300g/mm (Blaze: 750) grating. Configure the center wavelength to 500 nm for a mercury lamp. Is using a broadband source, configure the center wavelength to 0.0 nm.

> **NOTE:**
>
> Overhead fluorescent lights produce a mercury spectrum. Use a white card tilted at 45 degrees in front of the entrance slit to reflect overhead light into the spectrograph. Select 500 nm as the spectral line.

12. Turn on the light source at the spectrograph's entrance slit.
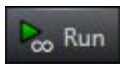
13. Click **▷ Run** to start Preview mode.

Depending on the specific LightField display configuration, either a spectral band (i.e., an image,) or a graph will be displayed.

> **NOTE:**
>
> Background noise will decrease as the camera cools to its default temperature.

14. Turn off the light source.

If the display changes to a background noise pattern or low intensity graph it has been confirmed that light entering the spectrograph is being seen by the camera. Proceed to Section 6.2.2.1, Focus and Rotational Alignment, on page 62.

15. If little to no visual difference is observed:
    a. Verify the light source has power and is turned on.
    b. Verify that the entrance slit is open a minimum of 10 μm.
    c. Check the Exposure Time on the Common Acquisition Settings expander.
    d. Confirm that Shutter Mode is set to Normal on the Shutter expander.
    e. Check the shutter cable connections.
    f. Verify shutter operation. The shutter should be heard opening and closing while operating in Run mode.
       • If the shutter can be heard operating and step a through step e have been performed, turn the light source on, wait a minute and then turn the light off while viewing the data display.

         If the problem is resolved, stop acquisition or proceed to Section 6.2.2.1, Focus and Rotational Alignment on page 62.

         Otherwise, stop data acquisition and proceed to step g.
       • If you do not hear a shutter operating and step a through step e have been performed, stop data acquisition and continue to step g.
    g. Verify the spectrograph has an entrance slit shutter.
       • An externally mounted shutter is easily confirmed.
       • Verifying an internally mounted shutter requires access to the inside of the spectrograph. Refer to the spectrograph manual for instructions.
    h. Determine if the PIXIS has a shutter.

       Loosen and remove the camera from the spectrograph. If the CCD is visible when looking into the front of the camera, the camera does not have an internal shutter. Re-mount the camera to the spectrograph.
    i. If the camera and spectrograph both have shutters, permanent damage to the shutter driver may occur.

       Either disconnect and remove the entrance slit shutter or control it via a Teledyne Princeton Instruments SHC-EXT Control Box.

       Perform the following procedure to disconnect and remove an entrance slit shutter:
       • External Slit Shutter

         Disconnect the shutter cable and remove the shutter assembly from the spectrograph entrance port.
       • Internal Slit Shutter

         Disconnect the shutter cable. Removing an internally mounted shutter requires access to the inside of the spectrograph: refer to the spectrograph manual for removal instructions.

For additional assistance, contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for complete information.

6.2.2.1 **Focus and Rotational Alignment**

The camera mounting hardware provides two degrees of freedom:

- Focus

  Focus is the process of moving the camera back and forth through the spectrograph's focal plane while watching a live display until the optimal focus has been achieved.

- Rotation

  Rotation is the physical rotation of the camera while watching a live display on the monitor until spectral lines are perpendicular to the rows on the array.

This section provides focus and rotational alignment procedures for the following spectrographs:

- Teledyne Acton Research Series Spectrograph on page 62;
- IsoPlane SCT-320 Spectrograph on page 65.

⚠ **CAUTION!** ———————————————

If the PIXIS is equipped with an internal shutter, DO NOT USE the Shutter connector to drive a spectrograph entrance slit shutter.

If both the PIXIS and the spectrograph have shutters, the entrance slit shutter must be removed.

Alternatively, a Teledyne Princeton Instruments SHC-EXT Shutter Control Box may be used to control the opening and closing of the entrance slit shutter. Refer to the spectrograph manual for additional information.

6.2.2.1.1 **Teledyne Acton Research Series Spectrograph**

Perform the following procedure to focus and rotationally align a Teledyne Acton Research Series Spectrograph:

1. Click the View tab above Experiment Devices area to switch to the Data Viewer. See Figure 6-9.

Figure 6-9:   Typical LightField Data Viewer

4411-0106_0028
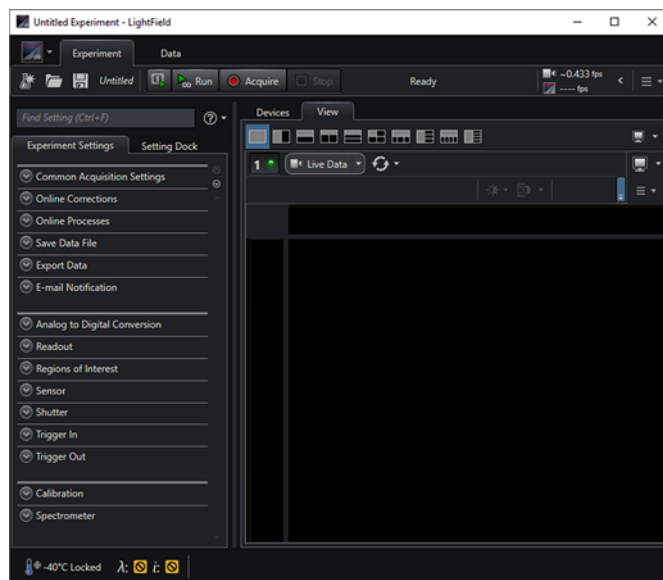
2. Mount a light source (e.g., mercury pen-ray type,) in front of the entrance slit of the spectrograph.

   Any light source with line output can be used. Standard fluorescent overhead lamps have good calibration lines as well. If there are no line sources available, use a broadband source such as tungsten for the alignment. If this is the case, use a wavelength setting of 0.0 nm for alignment purposes.

3. Open the Spectrometer expander, select the grating, and set the center wavelength to:

   - 500 nm when using a mercury lamp; or
   - 0.0 nm when using a broadband source.
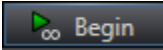
   > **NOTE:**
   >
   > Overhead fluorescent lights produce a mercury spectrum. Use a white card tilted at 45 degrees in front of the entrance slit to reflect overhead light into the spectrograph. Select 500 nm as the spectral line.

4. Set the slit to 10 μm. If necessary, adjust the Exposure Time to maintain optimum (i.e., near full-scale,) signal intensity.

5. Allow the detector temperature to lock at its default temperature.

6. Verify that the spectroscopy-mount adapter moves freely at the spectrograph.

7. From the Experiment Menu, select Align Spectrometer.... See Figure 6-10.

Figure 6-10: LightField Align Spectrometer... Menu Option

4411-0106_0029
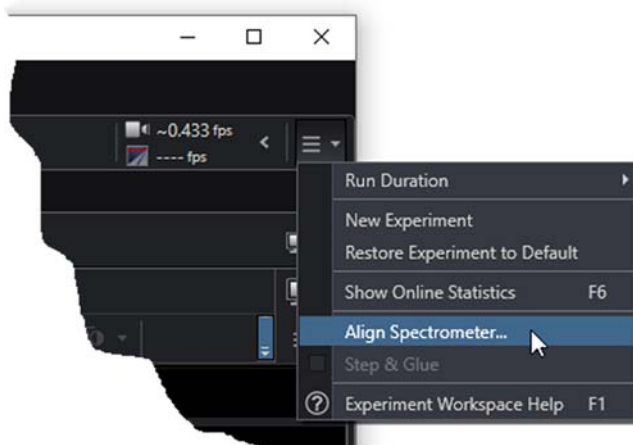
Review the displayed information and then click Begin. Typically, this creates three 1-row high ROIs (i.e., one near the top of the array, one in the middle, and one near the bottom,) and begins data acquisition. Data are continuously acquired and displayed but not stored.

8. Slowly move the camera in and out of focus.

   The spectral line will go from broad to narrow and back to broad. Leave the camera set for the narrowest achievable line.

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

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

   - Long focal-length spectrographs (e.g., Teledyne Acton Research SP-2300)

     The mounting adapter includes a tube that slides inside another tube to move the camera in or out as required to achieve optimum focus.

   - Short focal-length spectrographs

     There is generally a focusing mechanism on the spectrograph which, when adjusted, will move the optics as required to achieve proper focus.

   - No focusing adjustment

     If there is no focusing adjustment provided by the spectrograph or by the mounting hardware, then the only option is to adjust the spectrograph's focusing mirror.

9. Adjust rotation by rotating the camera while watching a live display of the line.

   NOTE: ─────────────────────────

   It may be necessary to loosen two set screws that secure the spectrograph adapter.

   Click on a peak to monitor during the rotational alignment. This positions the large cursor to provide a vertical reference line across all of the ROIs.

10. Rotate the camera while watching the live display of the lines until the selected peak is aligned horizontally in all of the ROIs.

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

    NOTE: ─────────────────────────

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

11. Tighten the spectrograph set screws to secure the spectrograph adapter in place.
12. Halt data acquisition.

6.2.2.1.2   IsoPlane SCT-320 Spectrograph

Because the PIXIS is mounted directly to the mounting plate on the IsoPlane, focusing and alignment is different from the way that focusing and alignment are performed for a Teledyne Acton Research Series spectrograph. The following information assumes that familiarity with the locations of the mounting plate, Micrometer Compartment, and the locking set screw. If not, refer to the IsoPlane manual supplied with the spectrograph.

> ⚠ **CAUTION!**
>
> If the PIXIS is equipped with an internal shutter, DO NOT USE the Shutter connector to drive a spectrograph entrance slit shutter.
>
> If both the PIXIS and the spectrograph have shutters, the entrance slit shutter must be removed.
>
> Alternatively, a Teledyne Princeton Instruments SHC-EXT Shutter Control Box may be used to control the opening and closing of the entrance slit shutter. Refer to the spectrograph manual for additional information.

Perform the following procedure to focus and rotationally align an IsoPlane SCT-320 spectrograph:

1. Mount a Teledyne Acton Research light source (e.g., dual HG/NeAr source,) in front of the entrance slit of the IsoPlane.
2. With the IsoPlane properly connected to the host computer, turn the power on, wait for the IsoPlane to initialize.
3. With the PIXIS mounted to the IsoPlane and connected to the host computer, turn on the power and wait for the PIXIS to initialize.
4. Launch LightField.
5. Once the LightField Workspace is open, drag the icons for the PIXIS and the IsoPlane into the Experiment Devices area.
6. Set the IsoPlane to:
   - 500 nm when using a mercury source; or
   - 0.0 nm if using a broadband source.
7. Remove the cover from the Micrometer Compartment.
8. Using a 3/32" hex wrench, loosen the locking set screw.
9. Allow the PIXIS to achieve temperature lock at its default temperature.
10. Click ▶∞ Run .
11. While continuously acquiring data, adjust the micrometer until the intensity level of a selected peak or peaks has been maximized.
12. Tighten down the locking set screw.
13. Place the Micrometer Cover on the IsoPlane.
14. Replace and tighten all cover screws.
15. Use a 9/64" hex wrench to loosen the four screws at the corners of the detector mounting plate.
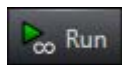
16. While watching a live display of the spectrum, select a peak to monitor.
17. Rotate the PIXIS (up to 4 degrees of rotation is possible).

    The peak will go from broad to narrow and back to broad. Leave the PIXIS' rotation set for the narrowest achievable peak.

> **NOTE:**
>
> LightField's built-in Align Spectrometer function may be used.

Alternatively:

a. Acquire an image.
b. Display horizontal and vertical cursor bars.
c. Compare the vertical bar to the line shape on the screen.
d. Rotate the detector until the line shape on the screen is parallel with the vertical bar.

18. After completing the rotational alignment, tighten the four mounting plate screws.
19. Halt acquisition.

Chapter 7:   Exposure

This chapter discusses factors that may affect the signal acquired on the CCD array, such as:

- Array Architecture;
- Exposure Time;
- CCD Temperature;
- Dark Charge;
- Saturation.

7.1   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 (set in the software), the pixels are read out serially.

CCD arrays perform three essential functions: photons are transduced to electrons, integrated and stored, and finally read out. CCDs are very compact and rugged and can withstand direct exposure to relatively high light levels, magnetic fields, and RF radiation. They are easily cooled and can be precisely thermostatically controlled to within a few tens of millidegrees.

7.1.1   Exposure with a Mechanical Shutter

For some CCD arrays, the PIXIS uses a mechanical shutter to control exposure of the CCD. Figure 7-1 illustrates how the exposure period is measured. The NOT SCAN {Not Reading Out} signal at the LOGIC OUT connector on the back of the PIXIS can be used to monitor the exposure and readout cycle (t_R). This signal is also included in Figure 7-1. The value of t_c is shutter type dependent and is automatically configured for PIXIS cameras shipped with an internal shutter.

Figure 7-1:   Exposure of the CCD with Shutter Compensation
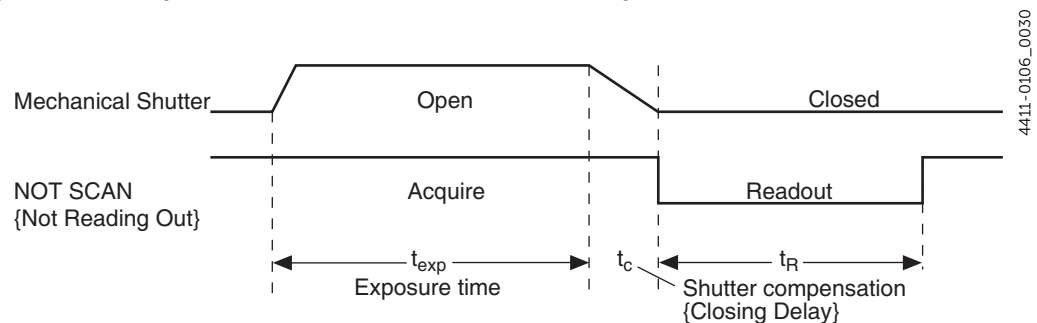
Note that NOT SCAN {Not Reading Out} is low during readout, high during exposure, and high during shutter compensation time.

Since most shutters behave like an iris, the opening and closing of the shutter will cause the center of the CCD to be exposed slightly longer than the edges. It is important to realize this physical limitation, particularly when using short exposures.

⚠️ **CAUTION!**

A shutter can become overheated when short, rapidly repeated exposures are used or if the shutter is held open for an extended period of time. Newer versions of the WinView/WinSpec software and camera hardware monitor the temperature of 45 mm internal shutters to prevent overheating conditions. The temperature of external shutters is NOT monitored!

7.1.2   Continuous Exposure (No Shuttering)

For full-frame imaging CCDs, the standard PIXIS camera for imaging is equipped with an integral shutter. However, inasmuch as it is possible to order the camera without a shutter, the following general discussion of non-shuttered operation is provided.

Slow scan scientific cameras require a shutter to prevent smearing of features during readout. This is because during readout, charge is moved horizontally or vertically across the surface of the CCD. If light is falling on the CCD during readout then charge will continue to accumulate, blurring the image along one direction only.

Because spectroscopy CCDs typically have their parallel shifting aligned vertically (i.e., perpendicular to the spectrum,) smearing does not affect the spectral resolution, only the intensity level of the spectral features. When vertically binned, the readout generally takes a few milliseconds to tens of milliseconds. In experiments where the exposure time is much larger than the readout time, the smearing due to readout is insignificant, and the CCD can be operated without a shutter with very little loss of performance.

If the CCD is set up for imaging mode (i.e., the WinSpec Imaging option has been installed and is selected on the Experiment Setup ► ROI Setup tab,) smearing may be more of a factor. In this case, controlling the light source so that no light falls on the CCD during readout would minimize any smearing. If the light source can be controlled electronically via the output of the LOGIC OUT connector, the CCD can be read out in darkness.

7.2 Exposure Time

Exposure time, which is configured 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 some PIXIS 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, NOT SCAN {Not Reading Out} or SHUTTER {Shutter Open} at the LOGIC OUT connector on the rear panel of the PIXIS can control a customer-supplied external shutter. By using one of the signals to synchronize the shutter operation with exposure, the CCD can be read out in darkness.

7.3 CCD Temperature

Lowering the CCD temperature generally improves the quality of acquired signals.

- In WinX, temperature control is achieved using the Detector Temperature dialog which is accessed from the Setup menu. See Figure 7-2.

Figure 7-2: Typical WinX Detector Temperature Dialog
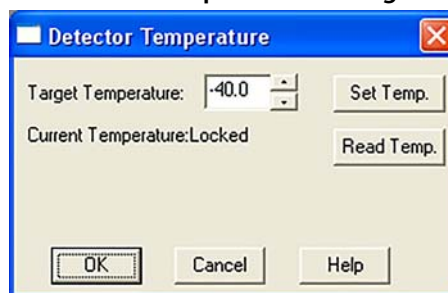
- In LightField, temperature control is configured on the Sensor expander.

Once the target array temperature {Temperature Setpoint} has been configured, the software controls the camera's cooling circuits to reach set array temperature. Upon reaching that temperature, the control loop locks to that temperature for stable and reproducible performance. When temperature lock has been reached (i.e., temperature remains within 0.05°C of the programmed value,) the current temperature is Locked. The on-screen indication allows easy verification of temperature lock.

The time required to achieve lock varies significantly depending on camera type, CCD array type, ambient temperature, etc. Once lock occurs, it is okay to begin focusing. However, waiting an additional twenty minutes before taking quantitative data so that the system has time to achieve optimum thermal stability is recommended.

The deepest operating temperature for a system depends on CCD array size and packaging. Refer to Table A-5, Deepest Operating Temperature by CCD Size, on page 107 for complete information.

NOTE:

In WinX, the Detector Temperature dialog does not display temperature information during data acquisition.

7.4   Dark Charge

Dark charge (or dark current) is the thermally induced buildup of charge in the CCD over time. The statistical noise associated with this charge is known as dark noise. Dark charge values vary widely from one CCD array to another and are exponentially temperature dependent. In the case of cameras with 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. Dark charge effect is more pronounced in cameras having a non-MPP array such as deep-depletion devices.

With the light into the camera completely blocked, the CCD collects a dark charge pattern that is 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, always operate with the lowest CCD temperature possible.

⚠ **WARNING!** ————————————————

If a sudden change in the baseline signal is observed, there may be excessive humidity in the camera vacuum enclosure. Turn off the camera and contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for complete information.

NOTE: ————————————————

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

7.5   Saturation

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

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

Chapter 8:   Analog to Digital Conversion

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;
- 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 8-1.

Figure 8-1:   Array Terms for a CCD with a Dual Output Amplifier
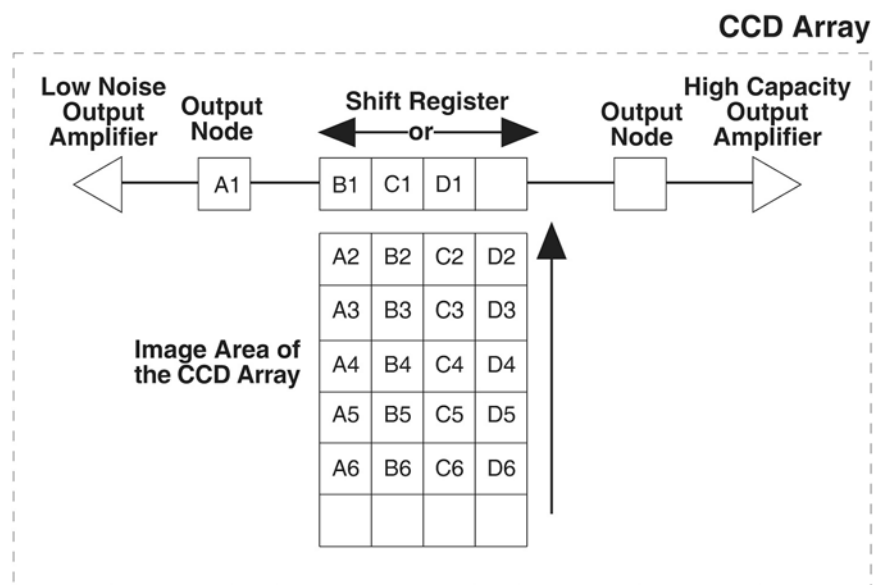
WinX and LightField allow the following parameters to be configured:

- Output Amplifier {Quality};
- Controller Gain;
- Digitization Rate {Speed};
- ADC Offset (Bias).

The following sections describe the impact each of these parameters has on acquired image data.

8.1   Output Amplifier {Quality}

The output amplifier amplifies the collected charge from the output node and outputs it as electrons/count. Although Figure 8-1 shows an array with dual output nodes and amplifiers (i.e., one set at each end of the shift register,) some PIXIS systems are available with a single output node and amplifier.

System with dual output amplifiers allow the output amplifier to be used to be selected 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 for weak signal applications.

> **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 between output amplifier and controller gain selections are provided in Table 8-1.

Table 8-1:   Sample Controller Gain {Analog Gain} vs. Readout Port Values

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

8.2   Controller Gain

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

Selecting the amount of gain is configured on the Acquisition ► Experiment Setup... ► ADC tab {Analog to Digital Conversion expander}.

Valid values are:

- 1 {Low};

  This selection is best suited for applications that measure high-level signals in order to allow the 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.

> **NOTE:**
>
> The Certificate of Performance supplied with each PIXIS provides the measured gain values at all settings.

Example

This example assumes the Low Noise Readout Port has been selected and that the actual incoming light level is identical in all three instances.

> **NOTE:**
>
> The numbers shown 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.

- 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.

8.3   Digitization

After gain has been applied to the signal, the Analog-to-Digital Converter (ADC) converts that analog information (i.e., continuous amplitudes,) into digital data (i.e., 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.

Factors associated with digitization include:

- Digitization Rate {Speed};

  This specifies the speed at which digitization occurs is software-selectable.
- ADC Offset (Bias).

  This is not a user-configurable value: it is set at the factory at the time of manufacture.

These factors are discussed in the following paragraphs.

8.3.1   Digitization Rate {Speed}

PIXIS cameras incorporate dual digitization rates (i.e., 100 kHz and 2 MHz,) which means there is a choice of how quickly the data will be digitized. Dual digitization provides optimum signal-to-noise ratios 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.

- A 2 MHz speed is used for the fastest possible data collection;
- A 100 kHz speed is used where noise performance is the paramount concern.

Switching between the two speeds is completely under software control for total experiment automation.

> **NOTE:**
>
> In WinX, the ADC rate is configured on the Experiment Setup ► ADC tab.
>
> In LightField, the speed is configured on the Analog-Digital Conversion expander.

8.3.2   ADC Offset (Bias)

With 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 this background will appear.

To minimize the amount of this signal that gets digitized, the baseline has been offset by adding a voltage to the signal to bring the A/D output to a non-zero value, typically 500-600 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 500-600 counts lower.

⚠ WARNING!

If a sudden change in the baseline signal is observed, there may be excessive humidity in the camera vacuum enclosure. Turn off the camera and contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for complete information.

NOTE:

It is important to note that the bias level is not noise. It is a fully subtractable readout pattern. Every device has been thoroughly tested to ensure its compliance with Teledyne Princeton Instruments' demanding specifications.

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

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Chapter 9: Full Frame Readout

When operating in Full Frame mode PIXIS reads and processes a complete frame of data at a time via 1 or 2 output ports. Every pixel of information is digitized individually.

NOTE:

With PIXIS cameras there is a choice of amplifier (i.e., low noise or high capacity.) Depending on the selected amplifier, the shift register is read out to the right or the left. For simplicity Figure 9-1 shows the readout to the left.

In Figure 9-1, the top-left section represents a CCD after exposure but prior to the beginning of readout. The capital letters represent different amounts of charge, including both signal and dark charge. This chapter describes the process of readout at full resolution.

Figure 9-1:   Full Frame at Full Resolution
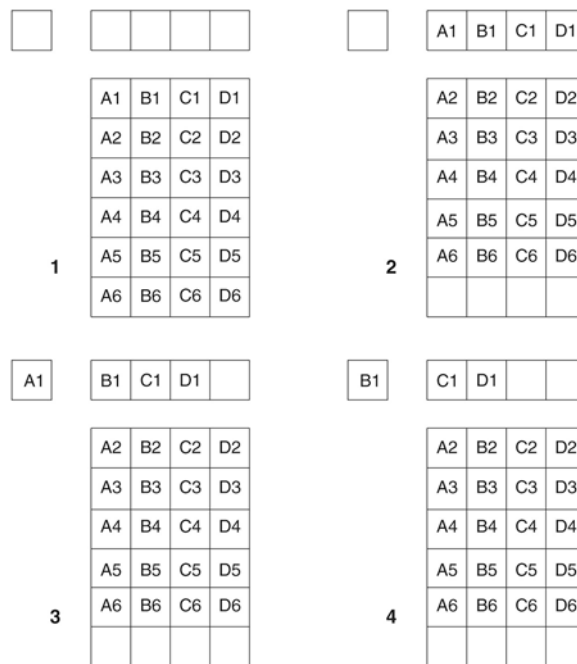
Readout of the CCD begins with the simultaneous shifting of all pixels one row toward the shift register, in this case the row on the top. The shift register is a single line of pixels along the edge of the CCD. The Shift Register is not sensitive to light and is only used to store charge during readout. Typically the shift register pixels hold twice as much charge as the pixels in the imaging area of the CCD.

After the first row has been moved into the shift register, the charge now in the shift register is shifted toward the output node located at one end of the shift register. As each value is emptied into this node it is digitized. Only after all pixels in the first row have been digitized is the second row moved into the shift register. The order of shifting in this 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.

9.1   Calculating Image Acquisition/Readout Time

The total time required to acquire and readout a full frame of data at full resolution is calculated as follows:

(1)
$$t_{FF} = t_R + t_{exp} + t_c$$

where:

- t_R is the CCD readout time;
  Refer to Section 9.1.1, CCD Readout Time, for additional information.
- t_{exp} is the exposure time;
  This is a user-defined value that is configured within WinX or LightField.
- t_c is the shutter compensation time.
  Refer to Section A.6, Internal Shutter Specifications, on page 108 for complete information.

9.1.1   CCD Readout Time

The CCD Readout Time is approximately calculated as follows:

(2)
$$t_R = [N_x \bullet N_y(t_{sr} + t_v)] + (N_x \bullet t_i)$$

where:

- t_R is the readout time;
- N_x is the smaller dimension of the CCD;
- N_y is the larger dimension of the CCD;
- t_{sr} is the time needed to shift one pixel out of the shift register;
- t_v is the time needed to digitize a pixel;
- t_i is the time needed to shift one line into the shift register.

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). To approximate the readout rate of an ROI, in Equation 2 substitute the x and y dimensions of the ROI in place of the dimensions of the full CCD. Some overhead time, however, is required to read out and discard the unwanted pixels.

Chapter 10: 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.

10.1   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 10-1 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 10-1: 2 × 2 Binning
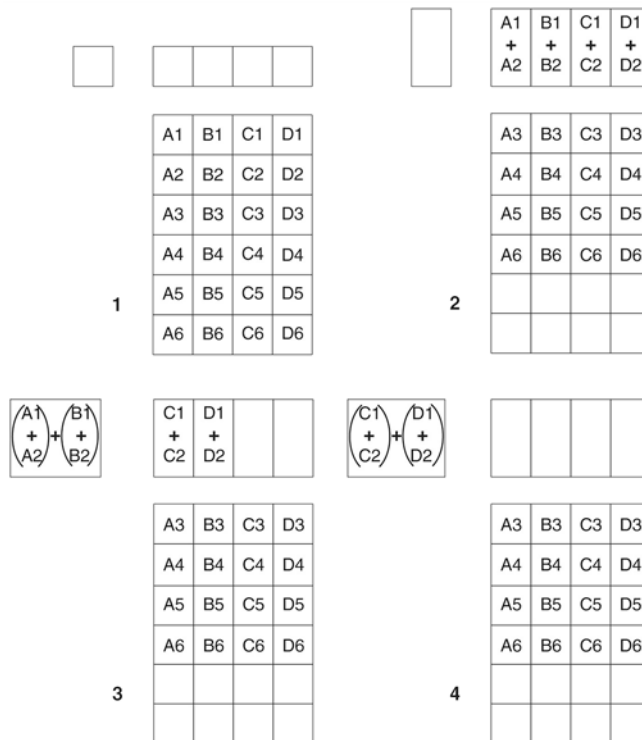
4411-0106_0034

The readout rate for n x n binning is approximated using a more general version of the full resolution equation. The modified equation is:

(1)
$$t_R = \left[N_x \bullet N_y \bullet \left(\frac{t_{sr}}{n} + \frac{t_v}{n^2} \right) \right] + (N_x \bullet t_i)$$

where:

- t_R is the readout time;
- N_x is the smaller dimension of the CCD;
- N_y is the larger dimension of the CCD;
- t_{sr} is the time needed to shift one pixel out of the shift register;
- n is the number of rows/columns being binned;
- t_v is the time needed to digitize a pixel;
- t_i is the time needed to shift one line into the shift register.

10.2　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 corrupted.

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., above 100, camera 1/f noise may reduce the actual S/N ratio to slightly below this theoretical value. Also, if the light source used is photon-flicker 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.

10.3 Array Orientation

For square format CCDs (e.g., 512 x 512B or 1024 x 1024F/B,) the CCD can be oriented in order to achieve binning along either direction of the CCD.

- Binning along columns provides maximum scan rate;
- Binning along the rows minimizes crosstalk and is therefore better for multi-spectral applications.

See Figure 10-2.

Figure 10-2: Binning and Array Orientation
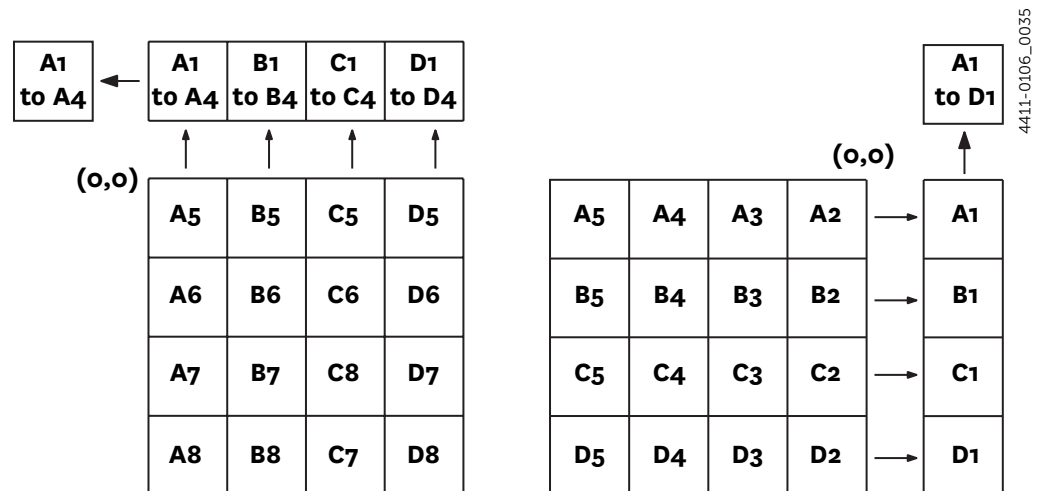
NOTE:

Switching between these orientations is easily achieved by rotating the camera 90° and changing the binning parameters in the application software.

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Chapter 11: Advanced Topics

Prior 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;
- On the Shutter and Trigger expanders in LightField.

With the exception of Edge Trigger, the topics are addressed in order of their appearance on the Timing tab.

- **Timing Modes**
  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.

- **Fast and Safe Modes**
  Discusses the Fast and the Safe modes. Fast is used for real-time data acquisition. Safe is used in WinX when coordinating acquisition with external devices or when the computer speed is not fast enough to keep pace with the acquisition rate.

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

- **Kinetics Mode**
  Describes how to set up and acquire data with the Kinetics Mode (a WinX option, standard with LightField,) which allows full-frame CCDs to take time-resolved images/spectra. Note that full-frame CCDs require mechanical or optical masking of the CCD array.

- **Custom Modes**
  Discusses Custom Chip {Custom Sensor} and Custom Timing modes. These modes allow you to specify an active sub-area of the CCD array and/or a faster vertical shift rate for the purpose of increased frame rate (pixels outside of the area are not read). Custom Chip {Custom Sensor} mode requires mechanical or optical masking of the array to prevent smearing.

11.1 Timing Modes

The basic PIXIS timing modes are Free Run {No Response}, External Sync {Readout Per Trigger}, and External Sync {Readout Per Trigger} with Continuous Cleans {Clean Until Trigger}. These timing modes are combined with the Shutter options to provide the widest variety of timing modes for precision experiment synchronization.

Refer to Table 11-1 for additional information.

Table 11-1: 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}

The shutter options available include Normal, PreOpen {Open Before Trigger}, Disable Opened {Always Open} or Disable Closed {Always Closed}. Disable simply 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 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 illustrated in timing diagrams in the following sections. Except for Free Run, where the modes of shutter operation are identical, both Normal and PreOpen lines are shown in the timing diagrams and flow chart.

The timing diagrams are labeled indicating the exposure time (t_{exp}), shutter compensation time (t_c), and readout time (t_R). These parameters are discussed in greater detail in Chapter 7, Exposure, on page 67. Note that if there is no shutter selected in the software, the shutter compensation time (the time required to close a mechanical shutter) will be approximately 0 ms.

11.1.1   Free Run {No Response}

In the 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. This is illustrated in the flow chart excerpt illustrated in Figure 11-1.

Figure 11-1:   Flowchart: Free Run {No Response}[a]
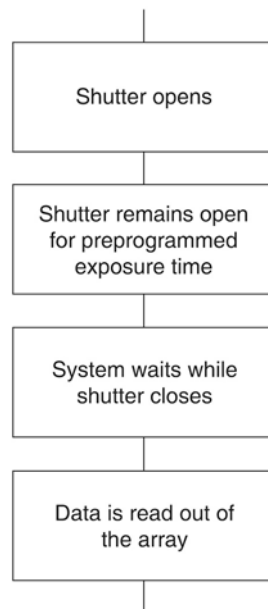
This mode is useful for experiments with a constant light source, such as a CW laser or a DC lamp. Other experiments that can utilize this mode are high repetition studies, where the number of shots that occur during a single shutter cycle is so large that it appears to be continuous illumination.

Other experimental equipment can be synchronized to the camera by using the software-selectable output signal SHUTTER {Shutter Open} or NOT SCAN {Not Reading Out} on the Hardware Setup ► Controller Camera tab {Trigger expander} from the LOGIC OUT connector. Shutter operation and the NOT SCAN {Not Reading Out} output signal are illustrated in Figure 11-2.

Figure 11-2:   Timing Diagram: Free Run {No Response}
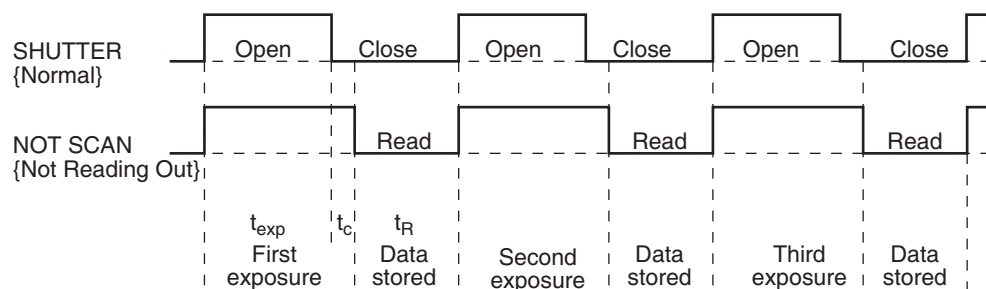
t_{exp} = Exposure Time
t_R = Readout Time
t_c = Shutter Compensation Time* {Closing Delay}

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

---

a. Excerpt from flowchart illustrated in Figure 11-3.

11.1.2   External Sync {Readout Per Trigger}

In this mode all exposures are synchronized to an external source. As shown in Figure 11-3, this mode can be used in combination with Normal or PreOpen {Open Before Trigger} shutter operation. 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.

Figure 11-3: Flowchart: Two External Sync Timing Options
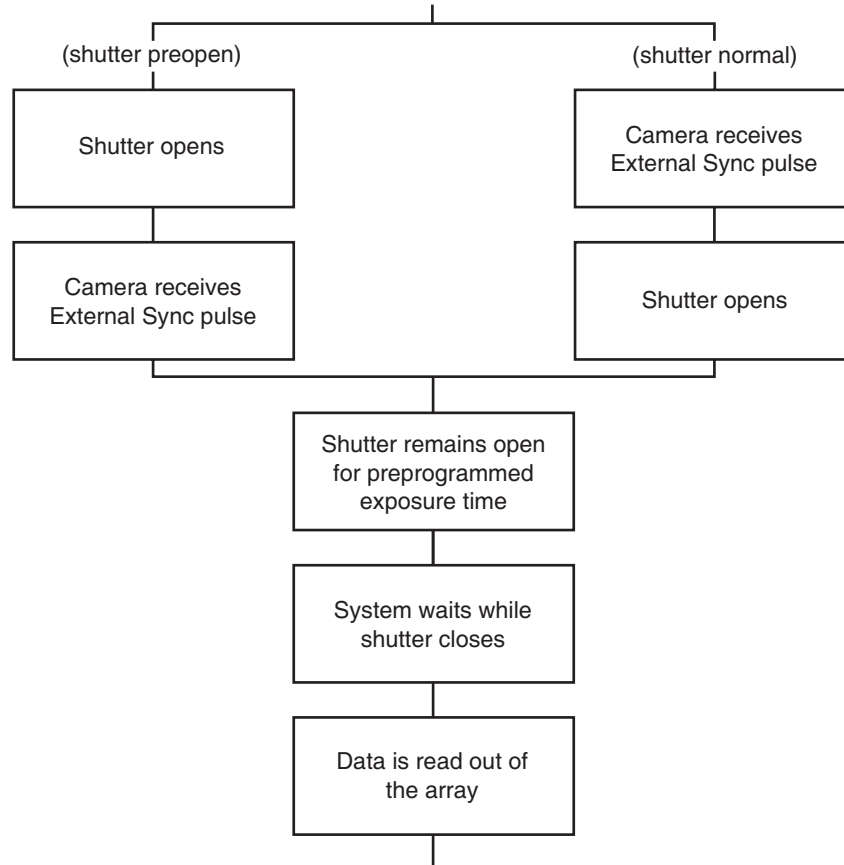
4411-0106_0038

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, this is done on the Experiment Setup ▶ Timing tab, in LightField on the Trigger expander.) Since the shutter requires at least 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 the PreOpen Shutter {Open Before Trigger} mode, on the other hand, 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 cases where an External Sync pulse cannot be provided 8 ms or ~ 20 ms (i.e., the length of time the 25 mm or 45 mm 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 11-4 illustrates the timing diagram for External Sync Mode with a positive edge trigger.

Figure 11-4: Timing Diagram: External Sync Mode (+ Edge Trigger)
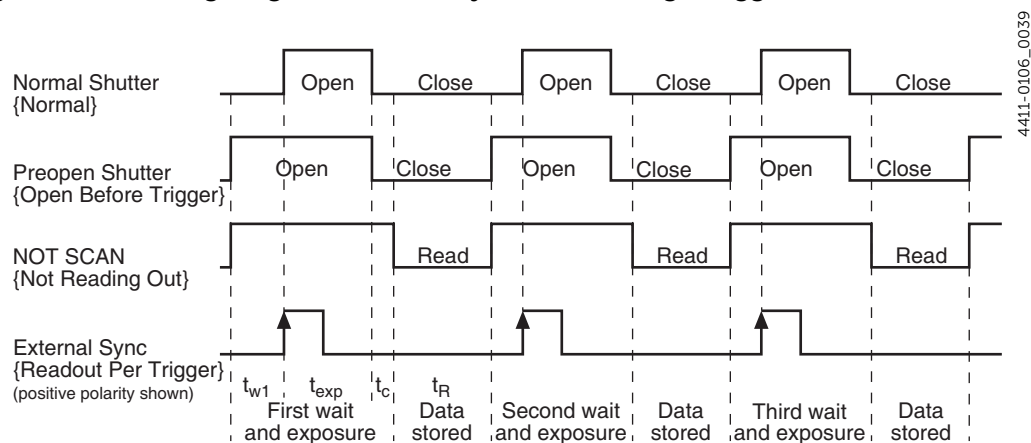
11.1.3   External Sync with Continuous Cleans {Clean Until Trigger} Timing

Another timing mode available with the PIXIS is called Continuous Cleans {Clean Until Trigger}. In addition to the standard cleaning of the array, which occurs after the camera is enabled, this mode will remove any charge from the array until the moment the External Sync pulse is received. Figure 11-5 illustrates a flowchart of this mode.

Figure 11-5: Flowchart: Continuous Cleans {Clean Until Trigger}
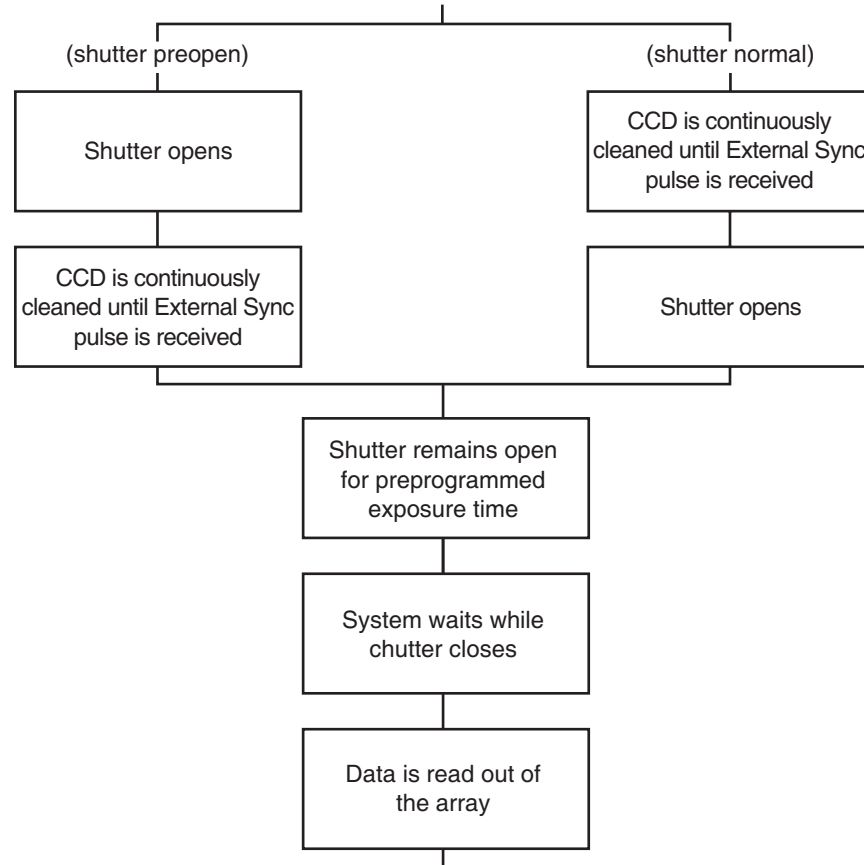
Once the External Sync pulse is received, cleaning of the array stops as soon as the current row is shifted, and frame collection begins. With Normal Shutter {Normal} operation the shutter is opened for the set exposure time. With PreOpen Shutter {Open Before Trigger} operation the shutter is open during the Continuous Cleaning {Clean Until Trigger}, and once the External Sync pulse is received the shutter remains open for the set exposure time, then closes. If the vertical rows are shifted midway when the External Sync pulse arrives, the pulse is saved until the row shifting is completed, to prevent the CCD from getting out of step. As expected, the response latency is on the order of one vertical shift time, from 1-30 μs depending on the array. This latency does not prevent the incoming signal from being detected, since photo generated electrons are still collected over the entire active area. However, if the signal arrival is coincident with the vertical shifting, image smearing of up to one pixel is possible. The amount of smearing is a function of the signal duration compared to the single vertical shift time.

Figure 11-6 and Figure 11-7 illustrate the timing diagrams for WinX Continuous Cleans and LightField Clean Until Trigger, respectively.

NOTE:

If EXT SYNC is still active (in Figure 11-6, this means that if it is still HIGH) at the end of the readout, the hardware may interpret this as a second sync pulse, and so on.

Figure 11-6: Timing Diagram: WinX Continuous Cleans
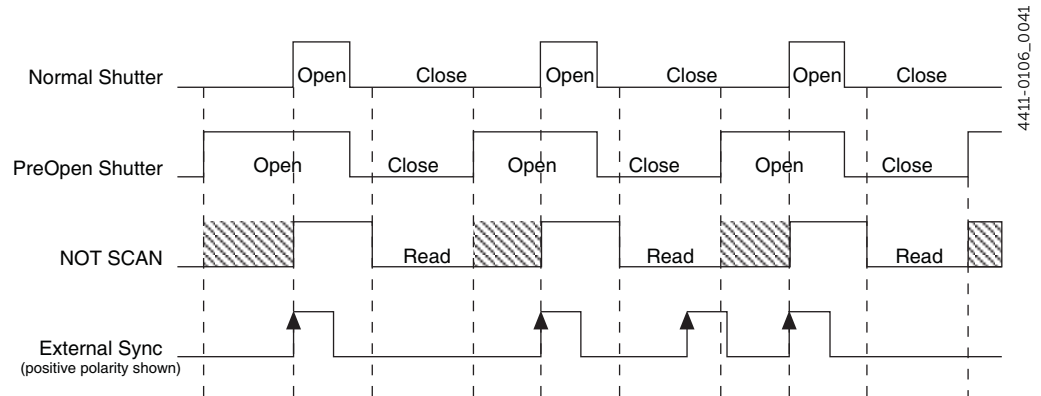
Figure 11-7: Timing Diagram: LightField Clean Until Trigger (CUT)
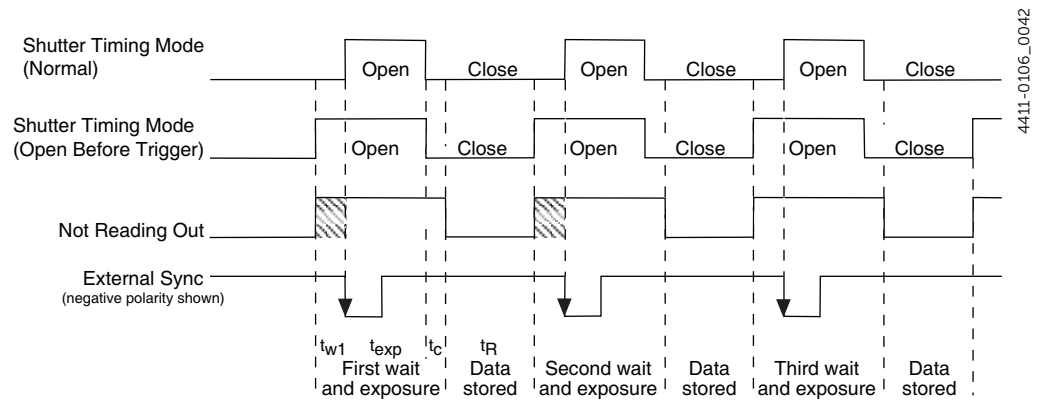
11.1.4   EXT SYNC Trigger Input

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. See Figure 11-8.

Figure 11-8: PIXIS Rear Connector Panel
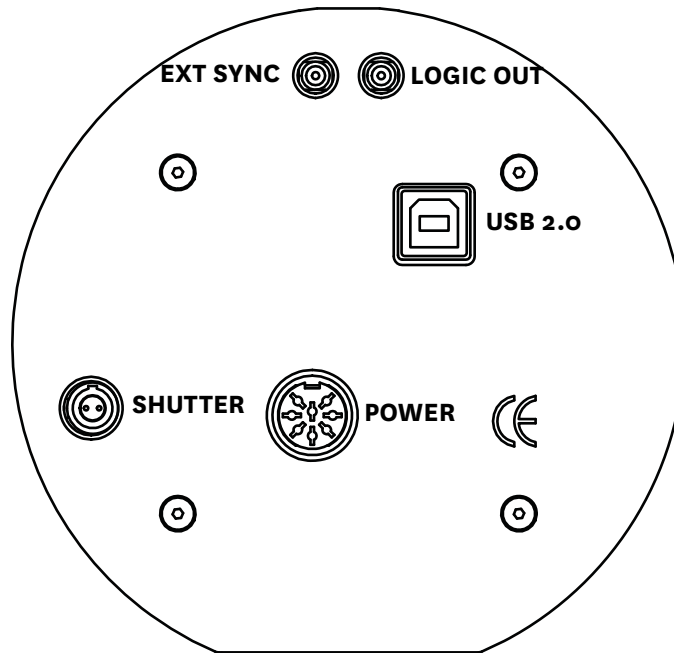
Things to keep in mind when setting up the External Sync pulse input are:

- Pulse Height
  0 to +3.3V_{DC} logic levels (TTL-compatible).
- Pulse Width (trigger edge frequency)
  The time between trigger edges.
- EXT SYNC Connector Impedance
  High impedance.
- Trigger Edge {Polarity}
  Positive or negative polarity must be indicated on the Experiment Setup ► Timing tab {Trigger expander}.

11.2   Fast and Safe Modes

The PIXIS 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 11-9 show the differences between the two modes. In LightField, Fast data collection is always used.

11.2.1   Fast Mode (WinX and LightField)

In Fast Mode, PIXIS 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 has been sent the start command by the computer, all frames are collected without intervention from the computer. The advantage of this mode is that timing is controlled completely through hardware. One drawback is that the computer will only display frames when 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.

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11.2.2   Safe Mode (WinX)

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 Figure 11-9 illustrates, 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 is disabled for a short time after each frame.

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

When running WinX, Safe Mode must be used whenever the system is set up for the optional Kinetics Readout Mode. Refer to Section 11.4, Kinetics Mode, on page 94 for complete information about this mode.

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Figure 11-9: Safe Mode and Fast Mode Operation Flow Charts

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

4411-0106_0043

11.3   LOGIC OUT Control

The TTL-compatible logic level output (i.e., 0 V_{DC} 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 expander}:

- NOT SCAN {Not Reading Out}

  It is at a 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, t_c) 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 11-10 presumes 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 11-10 illustrates the relative timing of each of these LOGIC OUT signals.

Figure 11-10:Timing Diagram: LOGIC OUT Control Signals
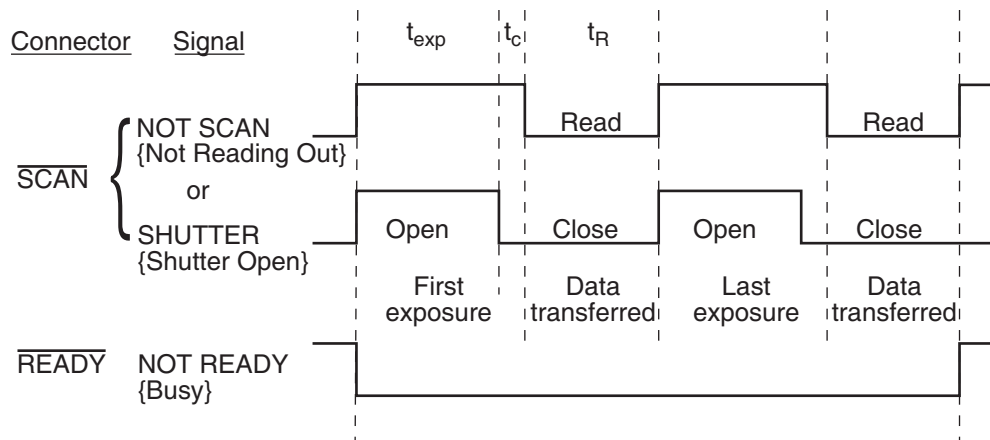
11.4 Kinetics Mode

NOTE:

Previously, Kinetics Mode was a purchased option for WinView/32. Kinetics Mode is now included in the standard LightField and WinX applications.

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 full frame CCDs to take time-resolved images/spectra. Optical or mechanical masking of the array is required.

NOTE:

In WinX, if the Kinetics option has been installed in the PIXIS, this readout mode will be made available when you select the appropriate camera type on the Hardware Setup dialog.

Figure 11-11 is a simplified illustration of kinetics mode. Returning to the 4 x 6 CCD example, 2/3 of the array is now 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 is 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 also illustrated in Figure 11-11.

Figure 11-11: Kinetics Readout
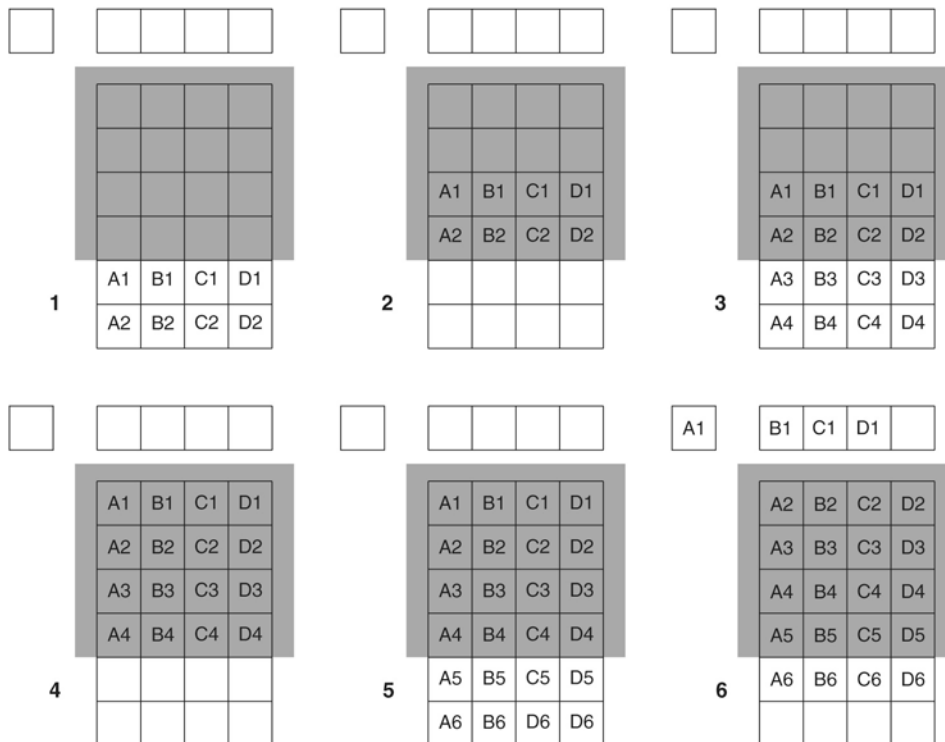
11.4.1   Kinetic Timing Modes and Shutter Control

Kinetics mode operates with three timing modes:

- Free Run {No Response};

  This mode is used for experiments that do not required any experiment synchronization.

- Single Trigger {Readout Per Trigger};

  This mode requires an external TTL pulse be applied to the camera via the EXT SYNC connector on the rear of the PIXIS. See Figure 11-8.

- Multiple Trigger {Shift Per Trigger}.

  This mode requires an external TTL pulse be applied to the camera via the EXT SYNC connector on the rear of the PIXIS. See Figure 11-8.

Figure 11-12 and Figure 11-13 illustrate the configuration dialogs for WinX.

Figure 11-12: Typical WinX Hardware Setup Dialog
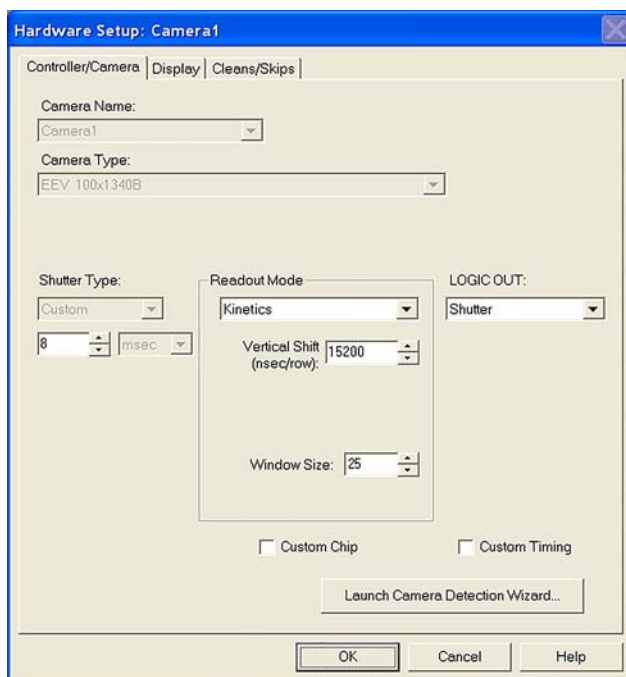
Figure 11-13: Typical WinX Experiment Setup Dialog
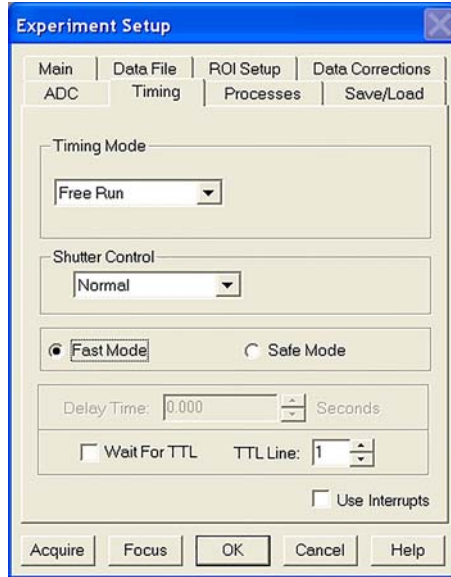
Figure 11-14 and Figure 11-15 illustrate the configuration dialogs for LightField.

Figure 11-14: Typical LightField Sensor Readout Expander: Kinetics Readout Mode
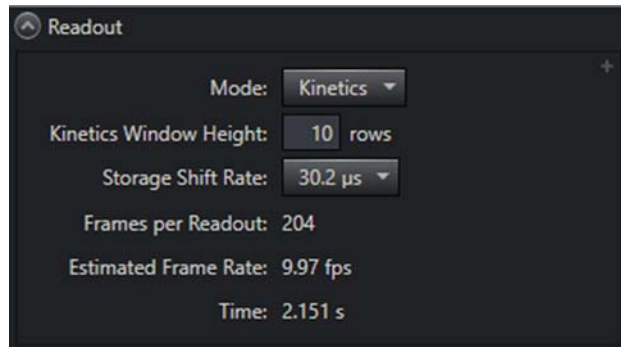
Figure 11-15: Typical Shutter and Trigger expanders: No Response
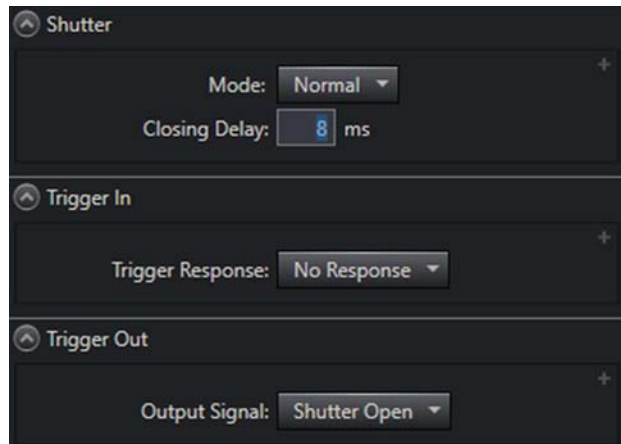
11.4.1.1   Free Run (Non-Triggered Mode)

In the Free Run {No Response} Kinetics mode, the PIXIS takes a series of images, each with the Exposure time set through the software:

- In WinX, the exposure time is configured on the Experiment Setup ► Main tab;
- In LightField, exposure time is configured 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 (i.e., 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 (i.e., SHUTTER {Shutter Open},) or Readout signals (i.e., NOT SCAN {Not Reading Out},) are provided at the LOGIC OUT connector for timing measurements.

Example

Returning to the example illustrated in Figure 11-11 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 11-16 illustrates the timing diagram for this example.

Figure 11-16: Timing Diagram: Free Run {Non-Triggered} Kinetics Mode
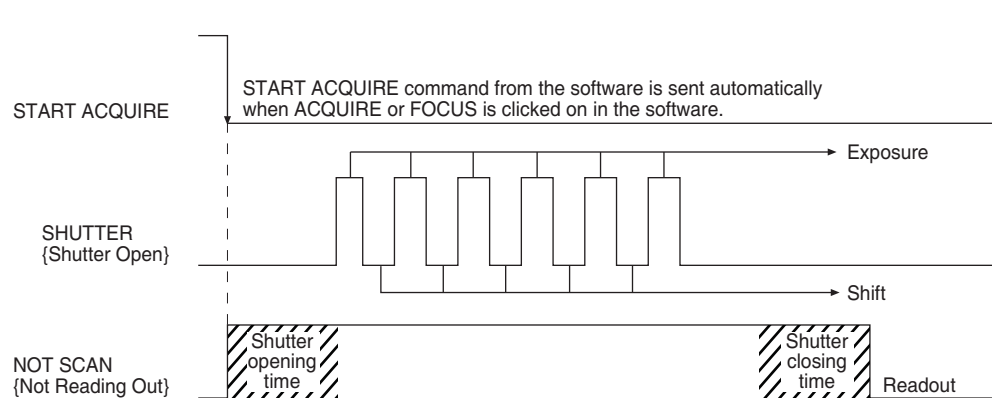
11.4.1.2 Single Trigger Mode

In single trigger mode, the camera requires only one trigger to initiate an entire series of exposure-shift cycles as illustrated in Figure 11-17.

When Acquire or Focus {Run} is clicked, the 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. 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.

Figure 11-17 illustrates the timing diagram where a single External trigger pulse is used to collect a burst of 6 frames.

Figure 11-17: Timing Diagram: Single Trigger, Kinetics Mode
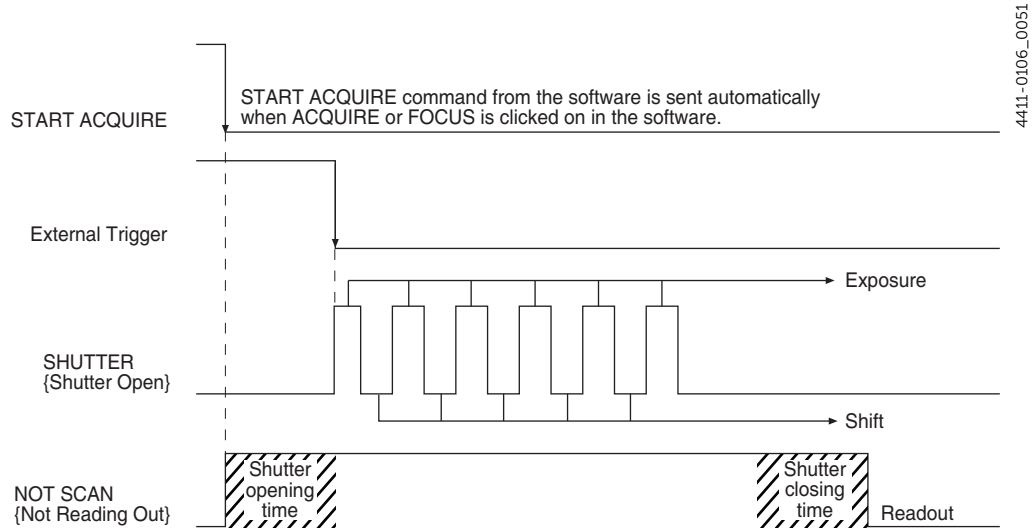
11.4.1.3   Multiple Trigger Mode

In multiple trigger mode, the 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.

Figure 11-18 illustrates the timing diagram where a series of 6 frames is collected with 6 External Sync pulses.

Figure 11-18: Timing Diagram: Multiple Trigger Kinetics Mode
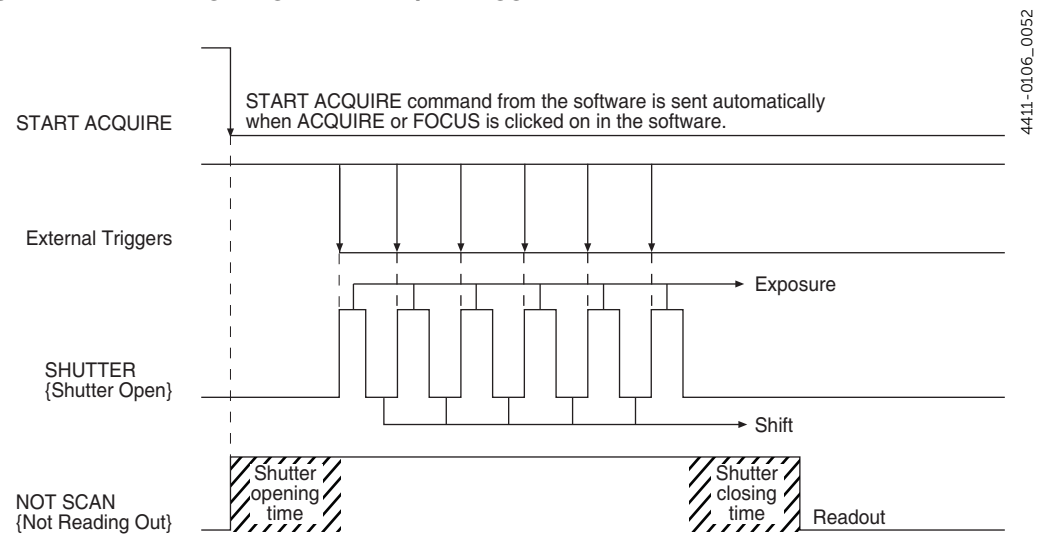
11.5   Custom Modes

Custom Chip and Custom Timing modes are available as an option for the WinX applications; {Custom Sensor} and Custom Timing are standard (sensor and readout mode-dependent) in LightField.

These modes are intended to allow data acquisition at the fastest possible rates for a PIXIS. Custom Chip {Custom Sensor} allows the apparent size of the CCD array to be reduced, while Custom Timing allows a faster vertical shift time to be selected.

11.5.1   Custom Chip

In addition to Binning and ROI there is a third way to reduce Readout Time: Custom Chip {Custom Sensor}. This feature allows the size of the CCD's active area to be redefined 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 sensor's rows. And, unlike both Binning and ROI, Custom Chip {Custom Sensor} also relies on some form of array masking to ensure that no light falls outside the currently set active area.

NOTE:

Custom Chip is a WinX option.

Custom Sensor is standard with LightField. Availability is sensor-dependent.

11.5.1.1   Software Configuration

WARNING!

Teledyne Princeton Instrumentss does not encourage users to change these parameter settings. For most applications, the default settings will give the best results. It is strongly recommended that the factory be contacted for guidance prior to customizing the chip definition.

In WinX, 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 11-19. The default values conform to the physical layout of the CCD array and are optimum for most measurements.

Figure 11-19: Typical WinX Hardware Setup: Custom Chip Dialog
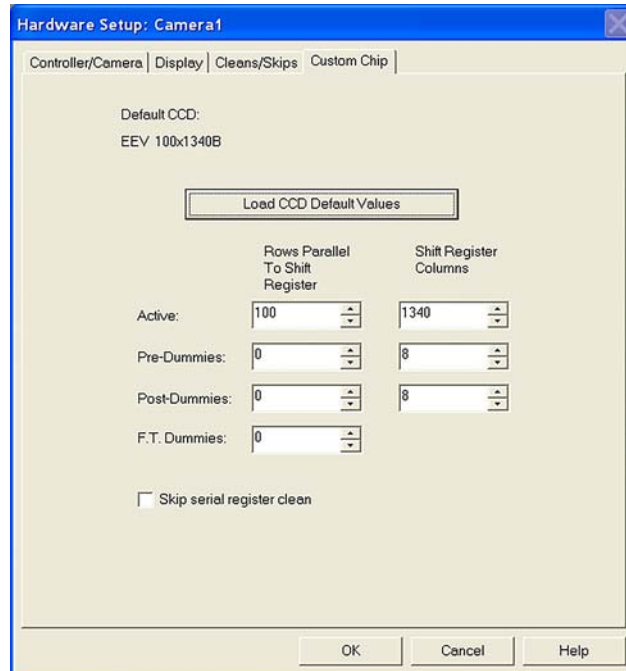
In LightField, the Custom Sensor pane, illustrated in Figure 11-20, is accessed by opening the Sensor expander and clicking on the Custom Sensor button.

Figure 11-20: Typical LightField Custom Sensor Pane
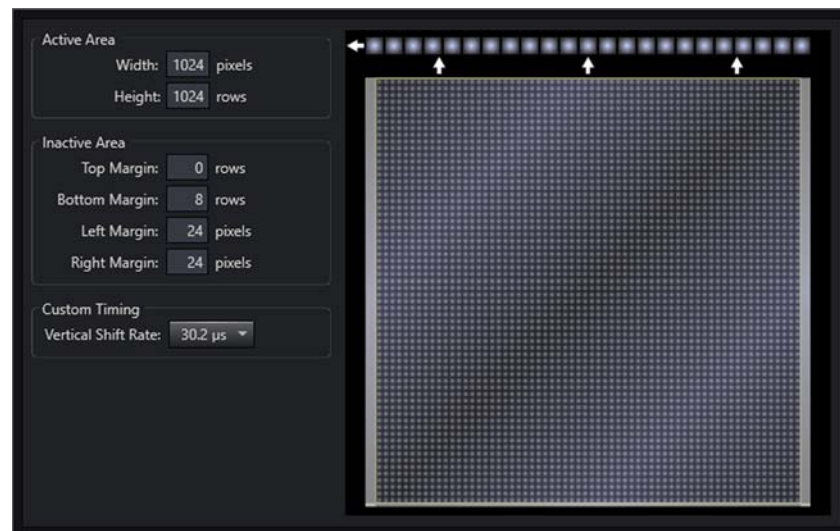
By changing the values in the Active fields, the image acquisition speed can be increased by reducing the size of the active area in the definition. The result will be faster but will yield a lower resolution data acquisition. Operating in this mode would ordinarily require that the chip be masked so 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 in WinX when there are no Pre-Dummy rows, the register clean out is skipped and chip readout is faster.

NOTE: ──────────────────

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

11.5.2   Custom Timing

NOTES: ──────────────────

> 1. Custom Timing is standard with LightField for full frame CCD cameras.
> 2. Custom Timing is fully supported by WinX Version 2.5.18.1 (and later).
> 3. This option is not supported by WinX for 5 MHz systems.

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

In LightField, Custom Timing is accessed via the Custom Sensor button on the Sensor expander. In the Custom Timing panel, select from among the listed Vertical Shift Rate options listed in the pull-down menu. See Figure 11-21.

Figure 11-21: LightField: Custom Timing

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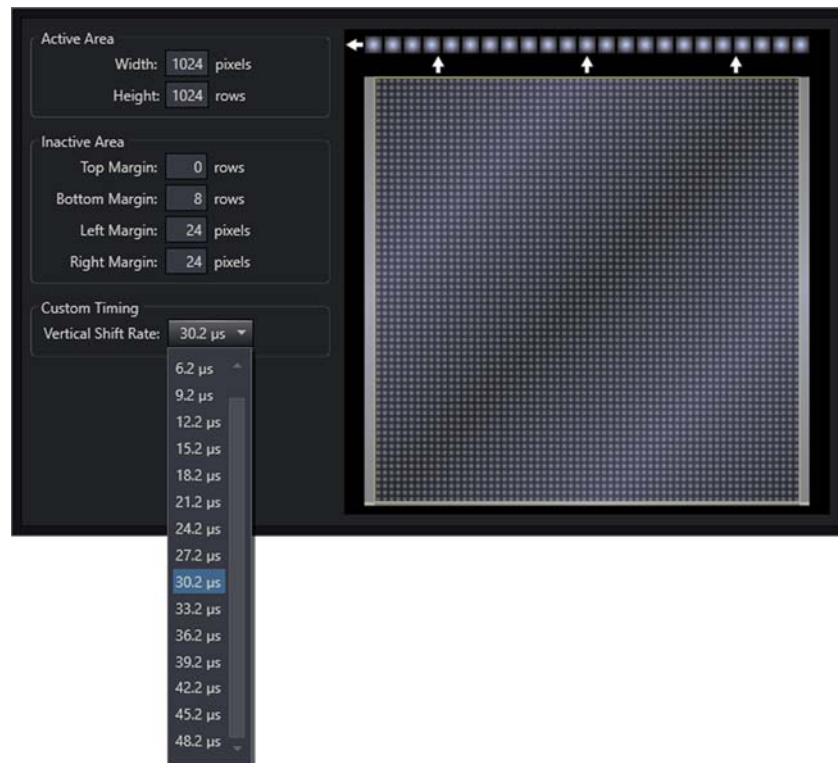
In WinX, if the Custom Timing option is present and selected, the equivalent function is located on the Custom Timing tab on the Hardware Setup dialog. See Figure 11-22.

Figure 11-22:WinX: Vertical Shift
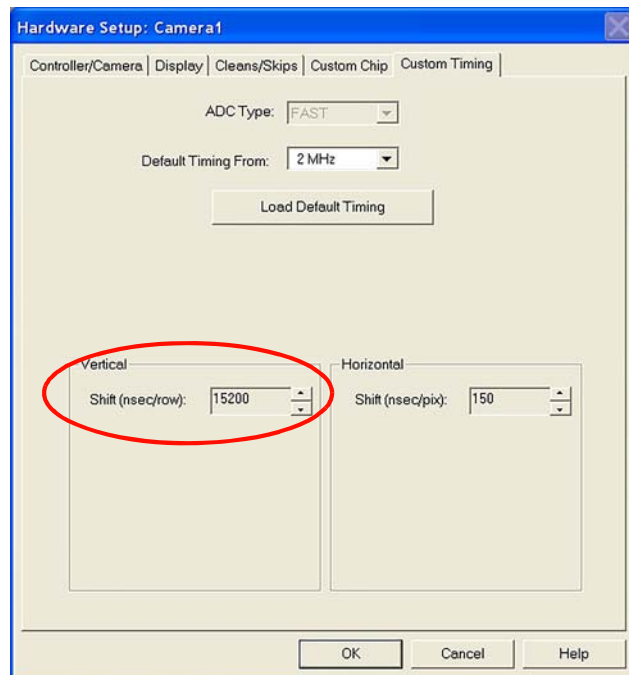
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Appendix A: Technical Specifications

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

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

A.1 System Dimensions and Weight

Precise specifications vary by PIXIS model. Refer to Appendix B, Outline Drawings, on page 111 for complete information.

A.1.1 Vacuum Window

SI-UV fused-silica quartz (0.125"/3.17 mm thick)

A.2 CCD Arrays

Teledyne Princeton Instruments offers a wide-variety of CCDs for scientific imaging and spectroscopy. Contact Teledyne Princeton Instruments for an up-to-date list of arrays supported by the PIXIS. Refer to Contact Information on page 154 for complete information.

A.3 Focal Distance (Optical)

The distance to the focal plane from the front of the mechanical assembly depends on the specific configuration. Refer to Table A-1 for specific information.

Table A-1:   Focal Plane Distances

Application	Adapter	Reference Points[a]	Distance
Imaging	C–Mount	Face of Camera to Focal Plane	0.690" /17.53 mm (optical)
	F–Mount	Face of Camera to Focal Plane	1.83"/46.48 mm (optical)
Spectroscopy	Spec–Mount (3.60" bolt circle, flange)	Mounting Flange to Focal Plane	0.600"/15.24 mm (optical)
	Spec–Mount (3.60"/ 3.88" bolt circle)	Mounting Flange to Focal Plane	0.886"/22.50 mm (optical)

a. Does not include an adapter.

A.4   Power Specifications

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.

The PIXIS camera receives its power from the supplied power supply which in turn plugs into an AC power source. Table A-2 provides power supply specifications for the Large and Small Format PIXIS cameras.

Table A-2:   Power Supply Technical Specifications

Specification	Small Format	Large Format
Input Voltage	100 – 240 V_{AC}	100 – 240 V_{AC}
Input Frequency	47 – 63 Hz	50/60 Hz
Input Current	1.9 A	2.0 A
Output Voltage	12 V_{DC}	12 V_{DC}
Output Current (Maximum)	6.6 A	12.5 A
Power Output (Maximum)	80 W	150 W

A.4.1   Power Connector

Figure A-1 illustrates the pinout of the PIXIS rear panel power connector.

Figure A-1:   PIXIS Rear Panel Power Connector Pinout
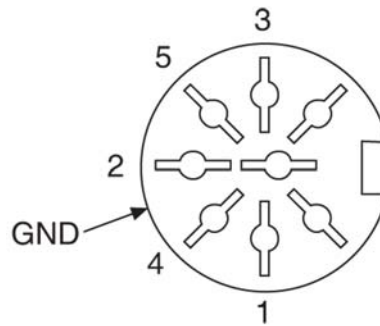
Table A-3 provides power connector pin assignments.

Table A-3:   Power Connector Pinout

Pin Number	Description	Pin Number	Description
1	Return	4	Return
2	Return	5	12 V_{DC}
3	12 V_{DC}	Shell	Ground

A.5 Environmental and Thermal Specifications

Refer to Table A-4 for environmental and thermal specifications.

Table A-4:   PIXIS Environmental and Thermal Specifications

Parameter	Specification		
	Minimum	Nominal	Maximum
Storage Temperature	-20°C		+55°C
Operating Temperature	+5°C		+30°C
Operating Ambient Relative Humidity	<50% (non-condensing)		
Operating Ambient Temperature[a]	18°C		+23°C
Temperature Stability	$\pm$0.05°C closed-loop stabilized-temperature control		
Fan Air Flow (air-cooled systems)	24 CFM at Full Power		

a. Although operation to -25°C is achievable, operation below 0°C is not guaranteed.

NOTE:

Cooling performance may degrade if the room temperature is above +23°C.

Table A-5 lists the deepest operating temperatures by CCD size.

Table A-5:   Deepest Operating Temperature by CCD Size

CCD Size	Typical
512x512	-70°C
1024x1024	-70°C
2048x2048	-65°C
1340x100	-80°C
1340x400	-75°C

A.5.1 Ventilation

A minimum of 1 inch (2.54 cm) clearance is required around all vents on the PIXIS camera.

When PIXIS is operated within an enclosure, >30 cfm air circulation and heat dissipation of 100 W is required.

A.6   Internal Shutter Specifications

PIXIS cameras for imaging applications are typically shipped with an internal shutter.

Refer to Table A-6 for internal shutter specifications.

Table A-6:   Internal Shutter Specifications

	Specification		
	PIXIS 512	PIXIS 1024	PIXIS 2048
Aperture	1 in [25 mm]	1 in [25 mm]	1.8 in [45 mm]
Open Time	8 ms	8 ms	approx. 20 ms
Close Time	8 ms	8 ms	approx. 48 ms

PIXIS cameras for spectroscopy applications are not equipped with an internal shutter. An optional Teledyne Princeton Instruments-supplied 25 mm or 45 mm external shutter may be ordered. Contact Teledyne Princeton Instruments customer support for ordering information. Refer to Contact Information on page 154 for complete information.

A.7   Tripod Mount

¼-20 x 0.25" mounting hole located on the bottom of the PIXIS.

M6 threaded adapter supplied with system.

A.8   CoolCUBE$_{II}$ External Coolant Circulator

Refer to Table A-7 for CoolCUBE$_{II}$ specifications.

Table A-7:   CoolCUBE$_{II}$ External Coolant Circulator Specifications

Parameter	Specification
System Type	Closed Loop
Dimensions	See Figure B-12 on page 122,
Weight (Filled)	6.0 lbs [2.7 kg]
Input Voltage	100 V$_{AC}$/240 V$_{AC}$
Input Current	3 A
Operating Environment	+5°C to +30°C Non-condensing
Coolant	50:50 ethylene glycol and water at 23°C Deionized water recommended
Minimum Flow Rate	2.5 LPM
Maximum Pressure	22 PSI
Coolant Hoses (P/N: 7567-0002)	⅜" ID with no-drip quick disconnects at the circulator ends and ¼" CPC quick disconnects at the camera ends
Coolant Hose Weight (Filled)	3.0 lbs [1.4 kg]

A.9   Minimum Host Computer Specifications

NOTE:

Computers and operating systems experience frequent updates. Therefore, the following sections are intended to provide minimum system requirements for operating a PIXIS camera.

A faster computer with 5 GB or larger memory (RAM) will greatly enhance the software performance during live mode operations.

Contact the factory to determine specific requirements.

A.9.1   Minimum WinX Requirements

The minimum system requirements for WinX are:

- Windows XP (32-bit with SP3 or later,) Vista® (32-bit,) or Windows 7 (32-bit)
- 2 GHz Pentium® 4
- 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)
- 1 GB RAM
- CD-ROM drive
- 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.
- Hard disk with a minimum of 1 GB available.

  A complete installation requires 17-50 MB of space. 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.

A.9.2   Minimum LightField Requirements

The minimum system requirements for LightField are:

- Windows 7/8/10 (64-bit)
- 2 GHz dual core processor
- 4 GB RAM
- CD-ROM drive
- 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.
- 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.

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Appendix B: Outline Drawings

This appendix provides outline drawings for the PIXIS camera system.

📖 **NOTE:** ─────────────────────────────

Dimensions are in inches [mm].

Figure B-1:   Outline Drawing: PIXIS, Adjustable C-Mount, Internal Shutter, Air-Cooled
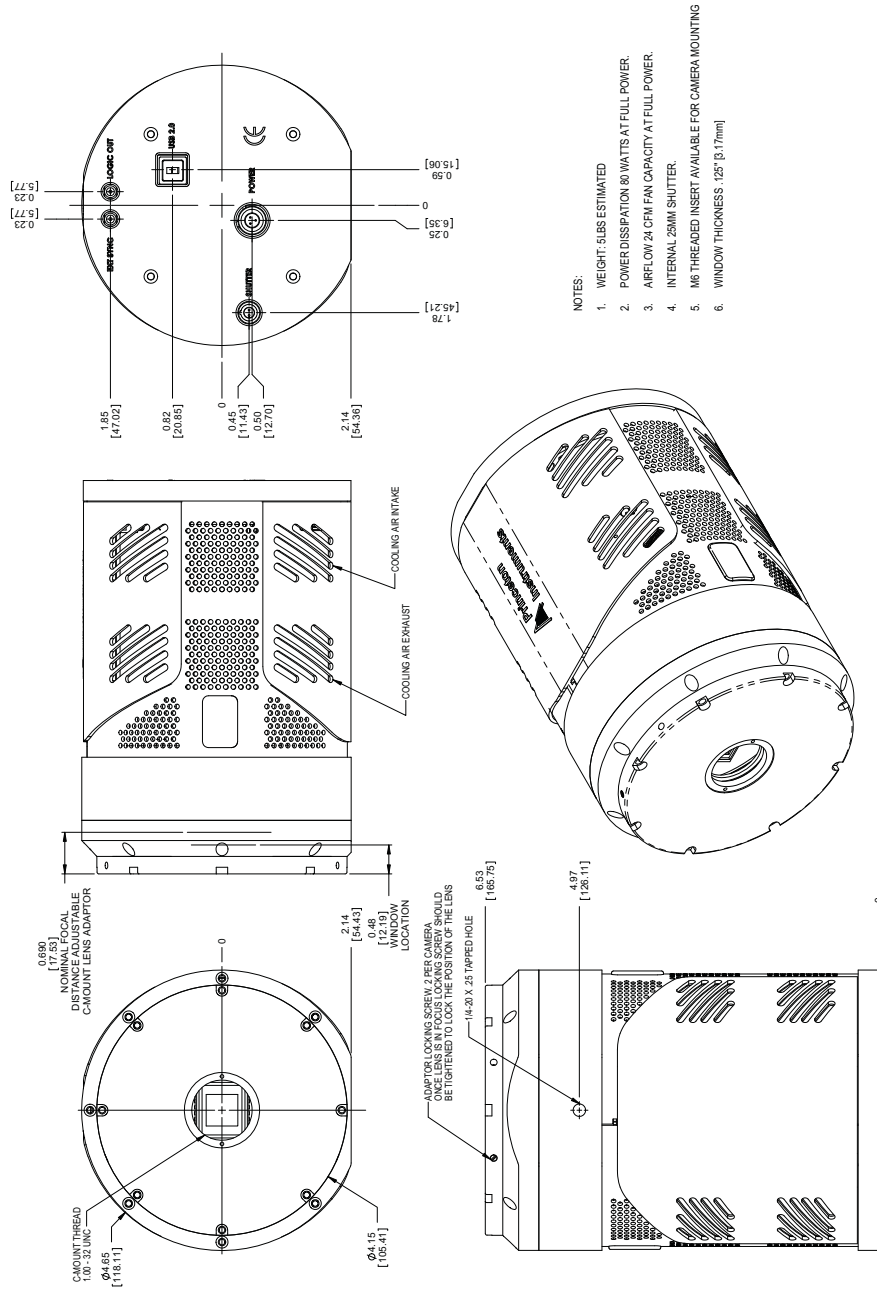
Figure B-2: Outline Drawing: PIXIS, Fixed C-Mount, Internal Shutter, Air-Cooled
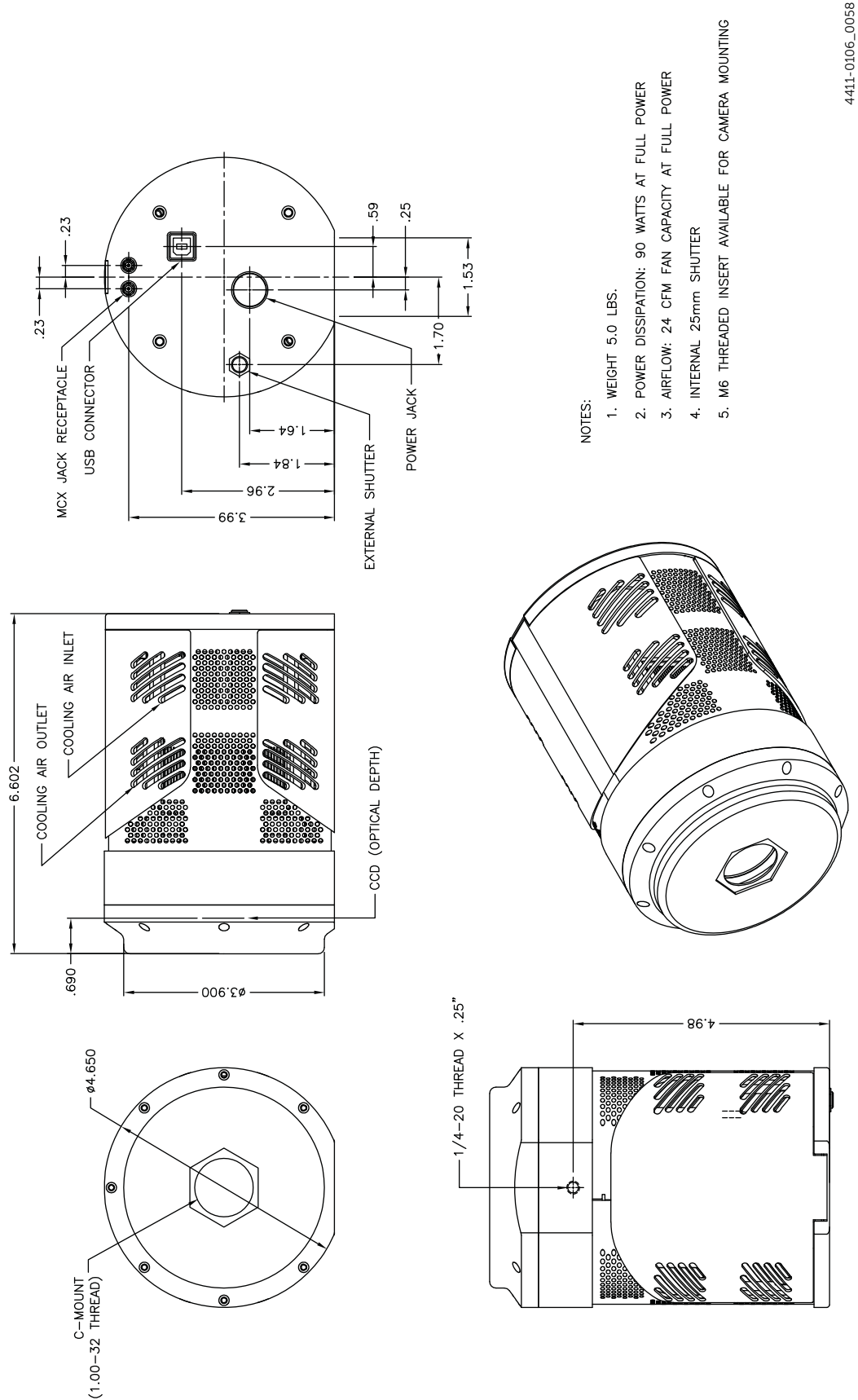
NOTES:
1. WEIGHT 5.0 LBS.
2. POWER DISSIPATION: 90 WATTS AT FULL POWER
3. AIRFLOW: 24 CFM FAN CAPACITY AT FULL POWER
4. INTERNAL 25mm SHUTTER
5. M6 THREADED INSERT AVAILABLE FOR CAMERA MOUNTING

Figure B-3:   Outline Drawing: PIXIS, Adjustable C-Mount, Internal Shutter, Liquid-Cooled
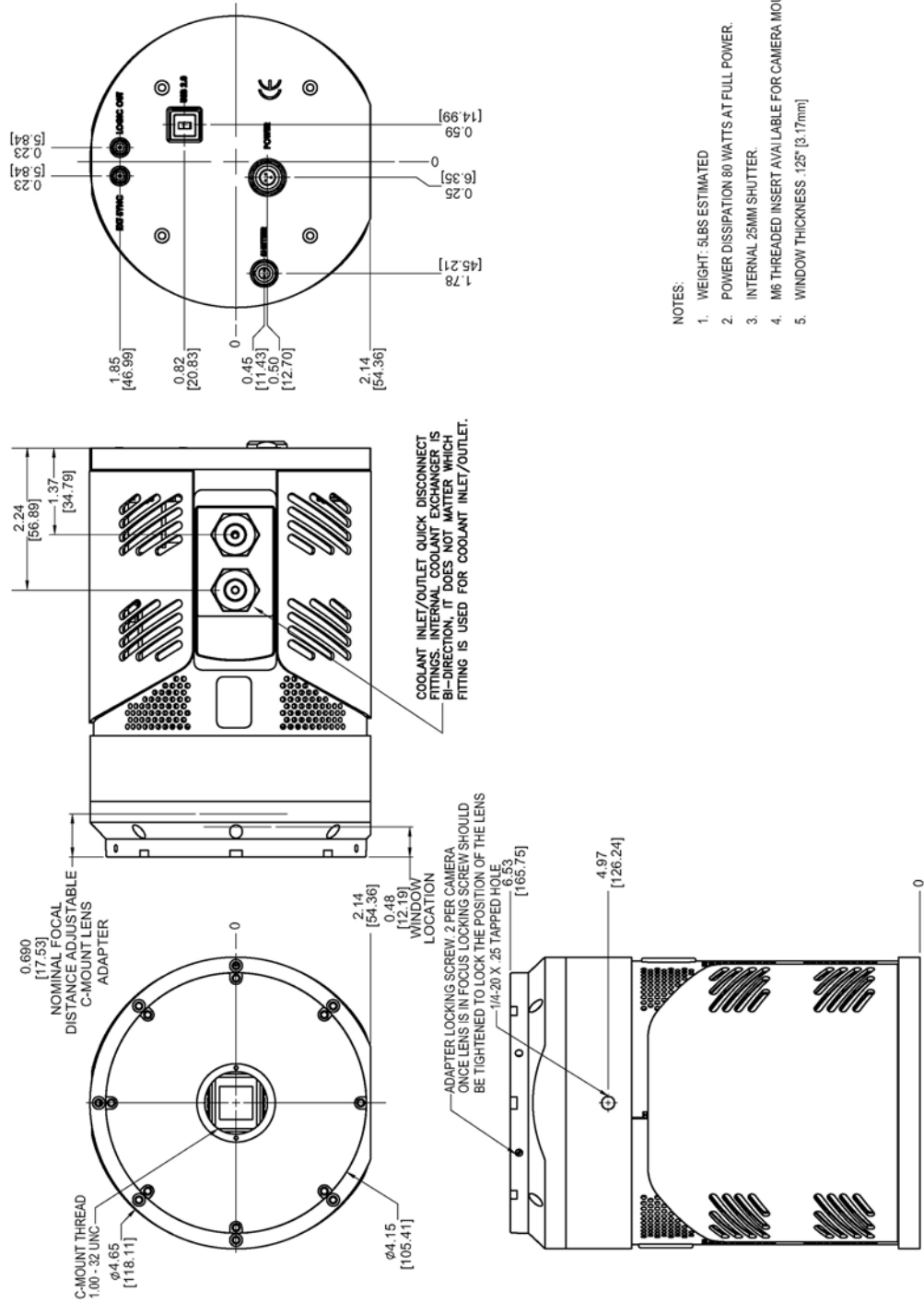
Figure B-4: Outline Drawing: PIXIS, Fixed C-Mount, Internal Shutter, Liquid-Cooled
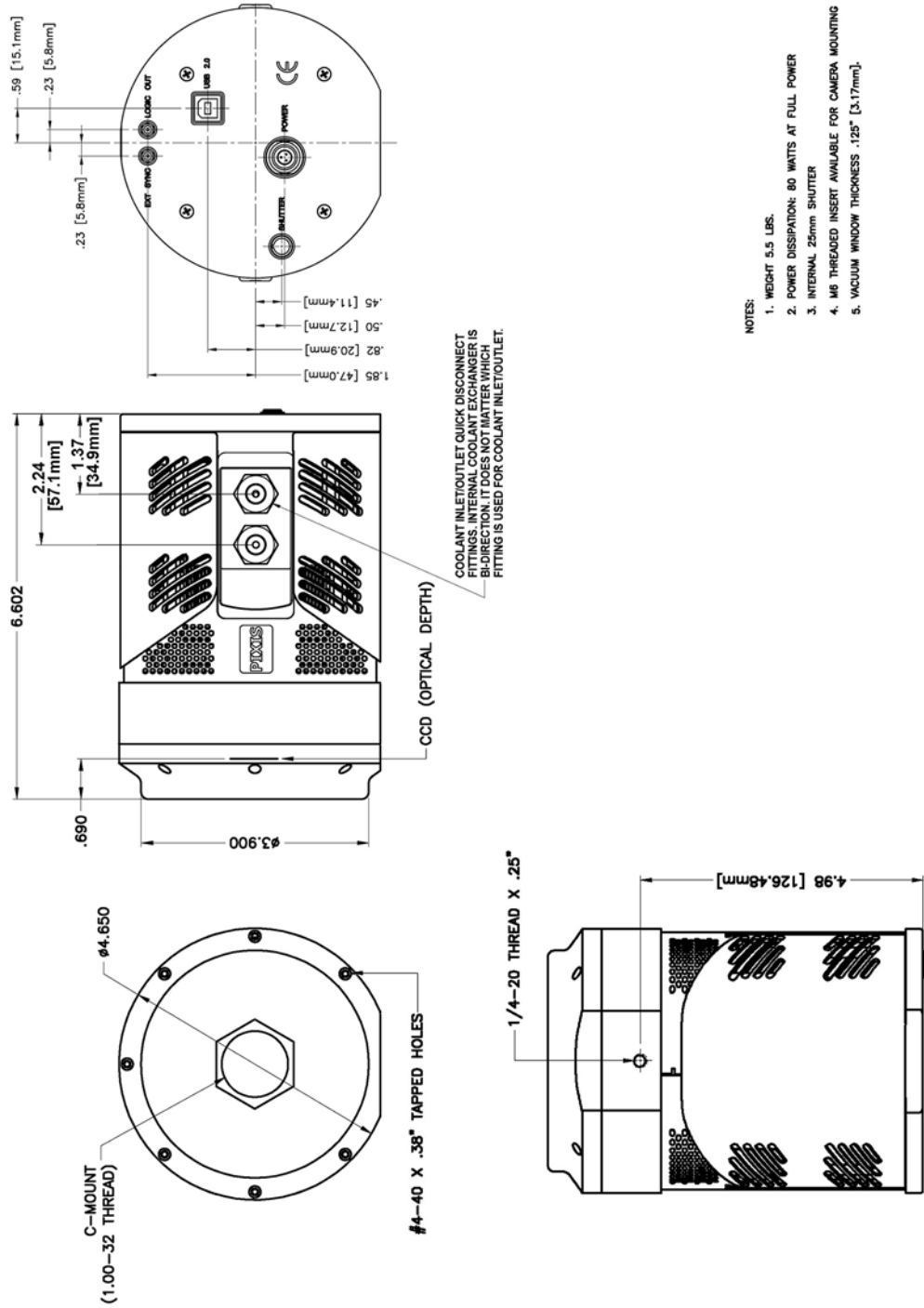
Figure B-5:   Outline Drawing: PIXIS, F-Mount, Internal Shutter, Air-Cooled
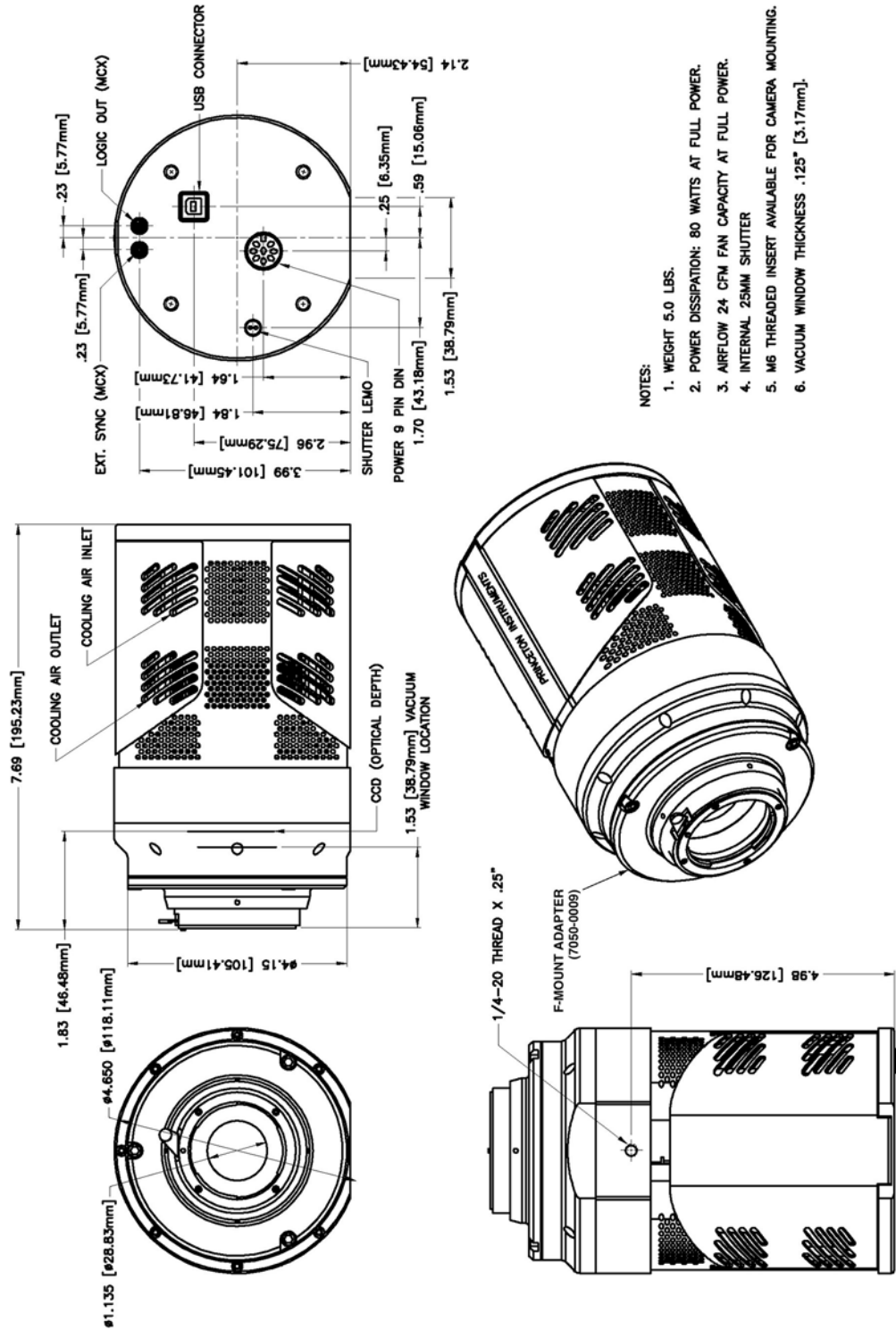
NOTES:

1. WEIGHT 5.0 LBS.
2. POWER DISSIPATION: 80 WATTS AT FULL POWER.
3. AIRFLOW 24 CFM FAN CAPACITY AT FULL POWER.
4. INTERNAL 25MM SHUTTER
5. M6 THREADED INSERT AVAILABLE FOR CAMERA MOUNTING.
6. VACUUM WINDOW THICKNESS .125" [3.17mm].

Figure B-6:   Outline Drawing: PIXIS, F-Mount, Internal Shutter, Liquid-Cooled
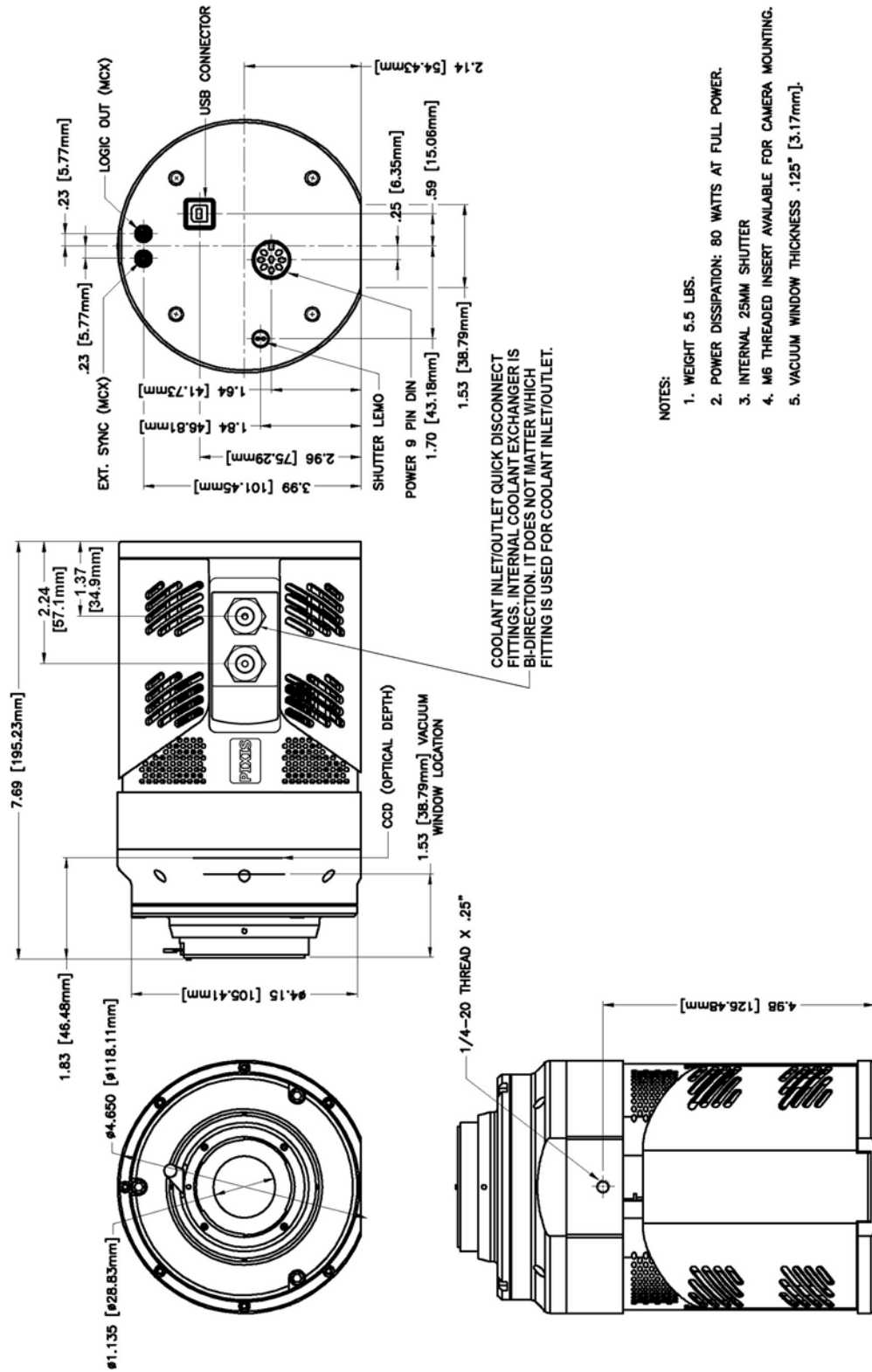
NOTES:

1. WEIGHT 5.5 LBS.

2. POWER DISSIPATION: 80 WATTS AT FULL POWER.

3. INTERNAL 25MM SHUTTER

4. M6 THREADED INSERT AVAILABLE FOR CAMERA MOUNTING.

5. VACUUM WINDOW THICKNESS .125" [3.17mm].

Figure B-7:   Outline Drawing: PIXIS, F-Mount: 2048 x 2048, Internal Shutter, Air-Cooled
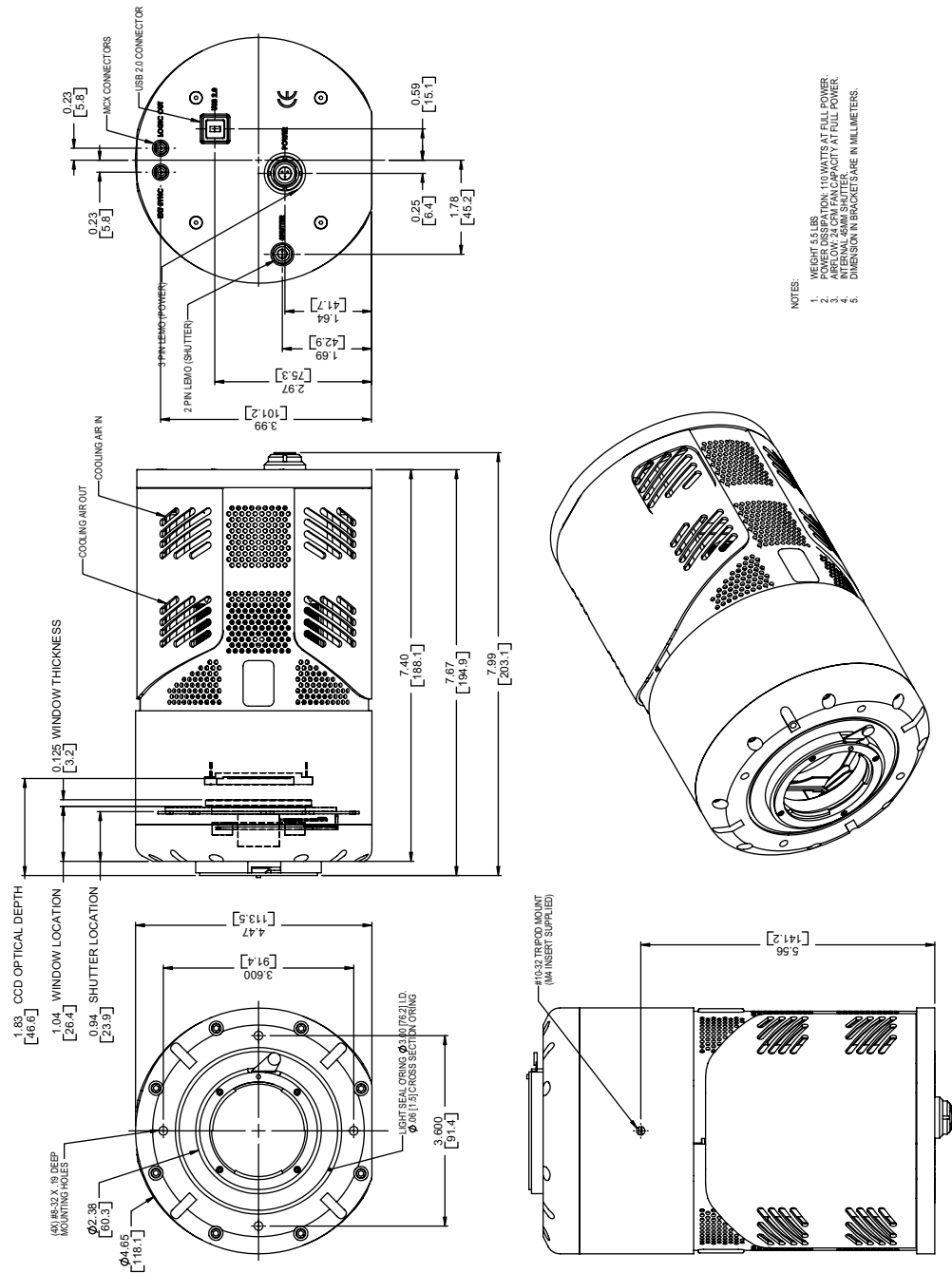
Figure B-8:   Outline Drawing: PIXIS, F-Mount: 2048 x 2048, Internal Shutter; Liquid-Cooled

**Figure B-9:   Outline Drawing: PIXIS, Spectroscopy-Mount, No Internal Shutter, 3.60"
Bolt Circle, Air-Cooled**

NOTES:

1. WEIGHT 5.0 LBS.
2. POWER DISSIPATION: 80 WATTS AT FULL POWER
3. AIRFLOW: 24 CFM FAN CAPACITY AT FULL POWER
4. M6 THREADED INSERT AVAILABLE FOR CAMERA MOUNTING
5. VACUUM WINDOW THICKNESS .125" [3.17mm].
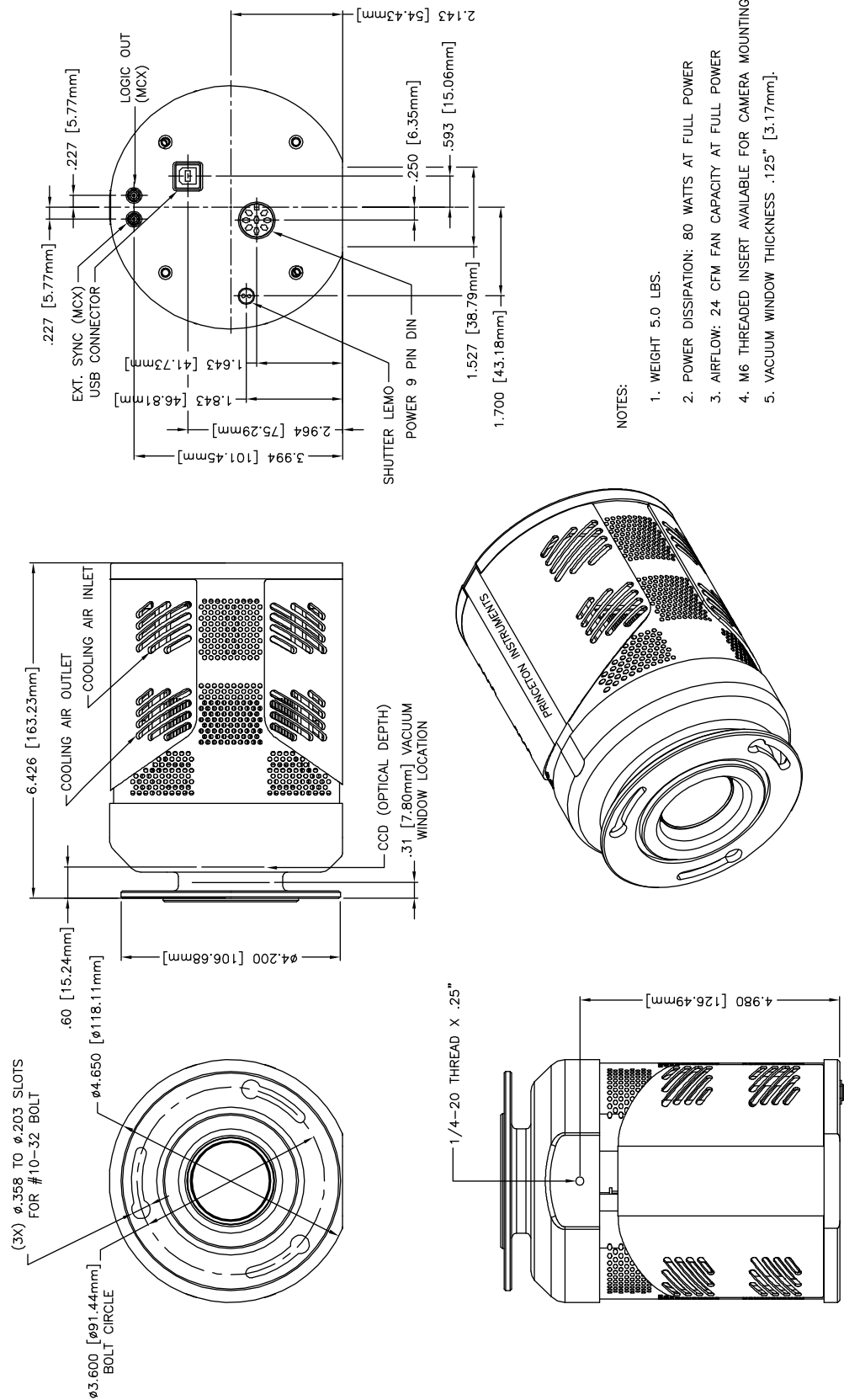
Figure B-10: Outline Drawing: **PIXIS, Spectroscopy-Mount, No Internal Shutter, 3.60"**
Bolt Circle; Liquid-Cooled
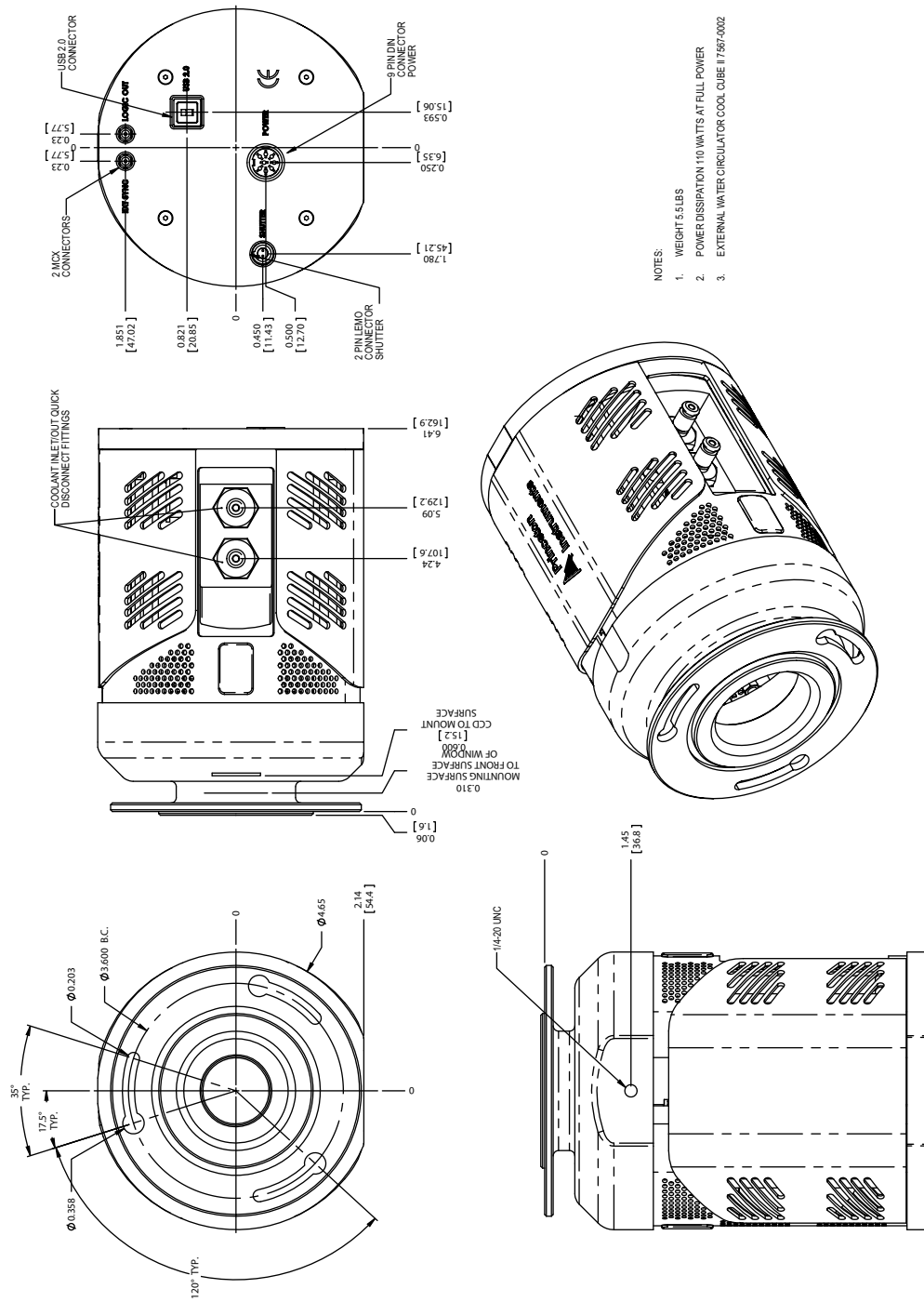
Figure B-11: Outline Drawing: PIXIS, Spectroscopy-Mount: Internal Shutter, 3.60"/ 3.88" Bolt Circles, Air-Cooled

NOTES:

1. WEIGHT 5.0 LBS

2. POWER DISSIPATION: 90 WATTS AT FULL POWER.

3. AIRFLOW 24 CFM FAN CAPACITY AT FULL POWER.

4. INTERNAL 25MM SHUTTER.

5. MS THREAD INSERT AVAILABLE FOR CAMERA MOUNTING.
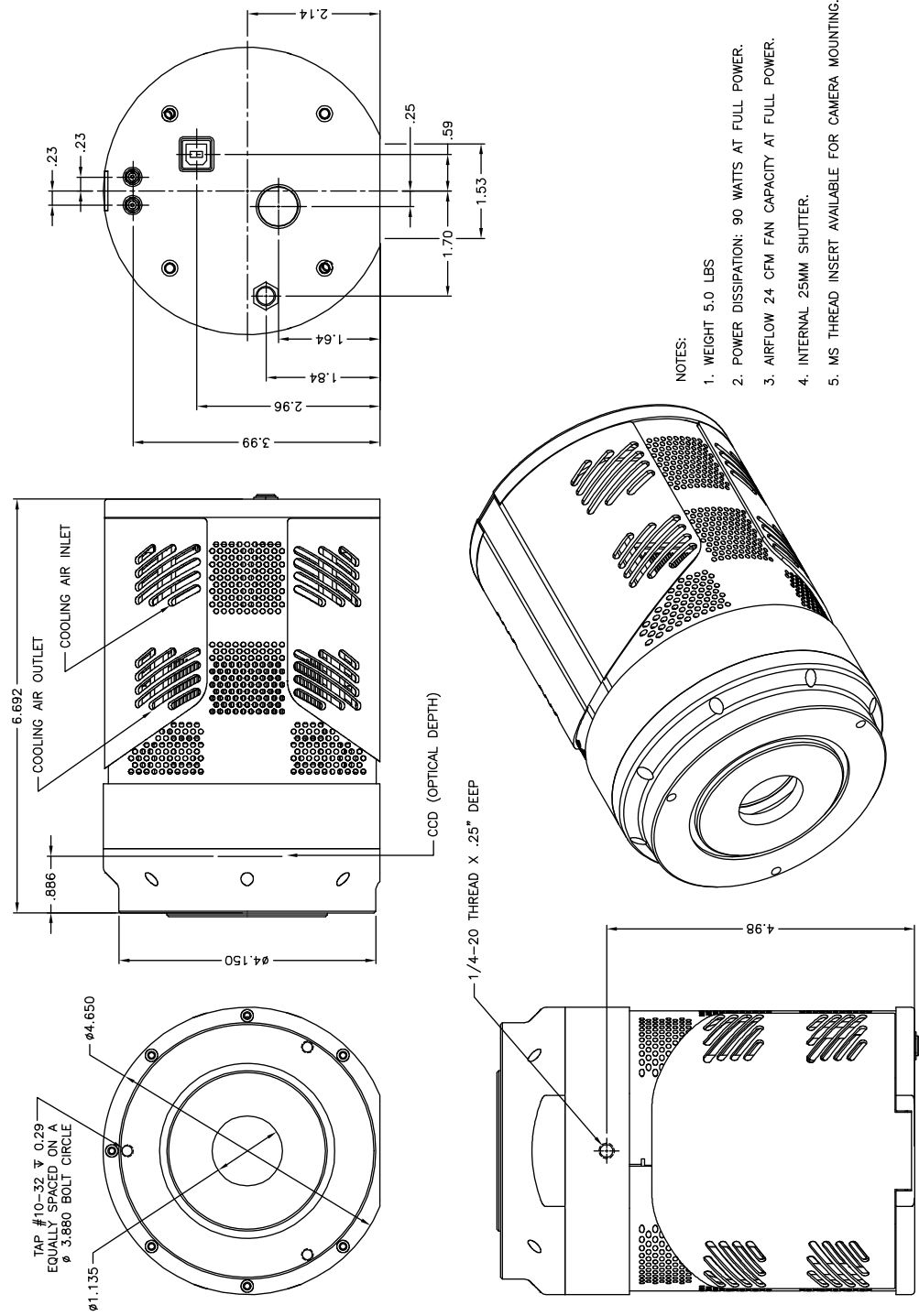
Figure B-12: Outline Drawing: CoolCUBE$_{II}$ Circulator
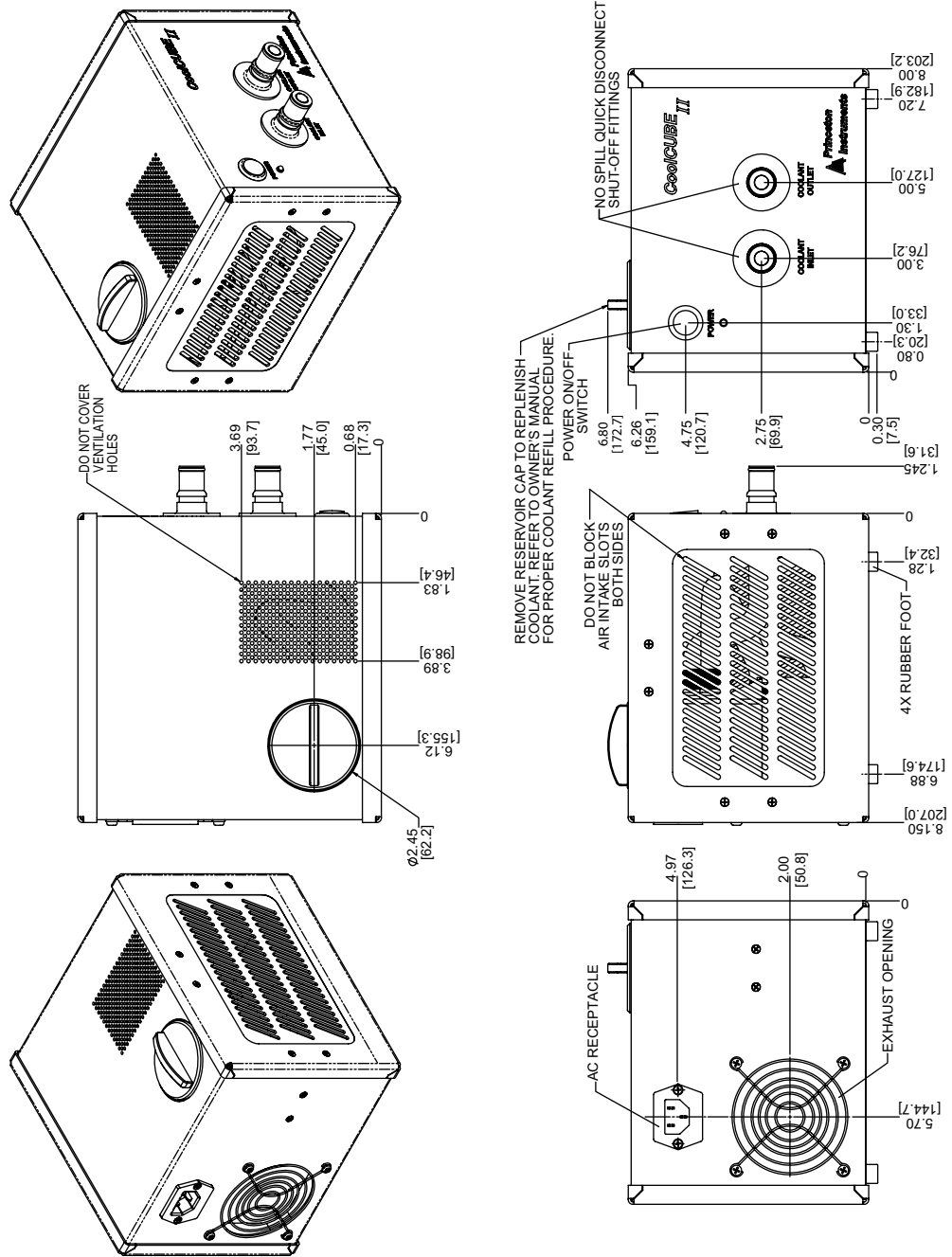
Appendix C: Adapter Adjustment and Focusing Procedures

This appendix provides procedures to adjust and focus Adjustable C-mount and F-mount adapters when using them with a PIXIS camera.

C.1   Adjustable C-Mount Adapter

PIXIS cameras are available with an adjustable C-mount adapter. Each PIXIS is adjusted at the factory for standard C-mount focus distance. However, it may be necessary to adjust the focus distance for certain application

The following tools are required:

- Spanner Tool [supplied].
- Small flat blade screwdriver

4411-0106_0070

Perform the following procedure to adjust the C-Mount focus distance:

1. Use the small flat blade screwdriver to loosen the two lock screws. See Figure C-1

Figure C-1:   Lock Screw Location on a PIXIS

4411-0106_0071

2. Use the Spanner Tool to rotate the C-mount adapter to the desired distance.
3. Tighten the lock screws to lock the C-mount adapter in place.

    To tighten the screws, the face of the adapter should be no more than 0.06" (1.5 mm) from the front surface of the PIXIS' nose.

⚠ CAUTION!

The C-mount lens thread-depth should be 0.21" [5.3 mm] maximum. Otherwise, depending on the adapter's in-out position, the lens may bottom out and damage a shutter if installed. When unsure of the thread depth, remove the adapter from the PIXIS, thread the lens into the adapter until the lens threads are flush with the back surface of the adapter. Note the depth at the front surface, remove the lens, and insert the adapter into the camera nose.

C.2   F-Mount Adapter Focusing Procedure

🔍 NOTE:

This procedure focuses an F-mount adapter, not a lens. Once focused, the adapter should not need to be focused again.

Perform the following procedure to focus an F-mount adapter:

1. Install a lens on the PIXIS as described in Section 5.3, Install a Lens on an Integral F-Mount Adapter, on page 35.
2. The F-mount adapter comprises two sections:
    - The Adapter Body into which a lens is mounted;
    - The Adapter Adjustment Ring secured to the front of the camera.

    Try to rotate the Adapter Body. If it does not rotate, the set screw(s) in the side of the Adapter Adjustment Ring must be loosened.

    Loosen the set screw(s) using a 0.050" hex wrench. See Figure C-2 for the set screw locations.

    Do not remove the screws. Loosen them enough to allow the Adapter Body to be rotated.

Figure C-2:   F-Mount Adapter Adjustment Ring Set Screw Locations
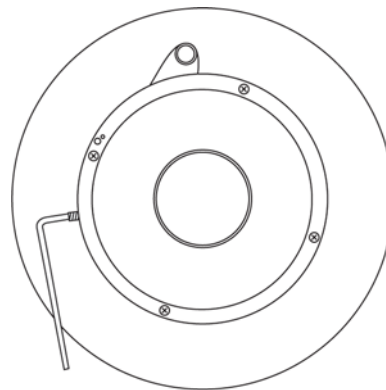
4411-0106_0072

3. Set the lens focus adjustment to the target distance.
4. Block off the lens and set it to the smallest possible aperture (i.e., largest F-stop.)
5. Mount a suitable target at a known distance in front of the lens.

    Typically, a photo resolution chart is used. However, a page of small print will also serve quite well for this purpose.
6. Verify that all cables and connectors are secured.
7. Turn on the system and launch WinView/32.
8. Configure WinView/32 for Free Run and Safe mode. (Refer to the WinView/32 manual if necessary.) Configure a fast exposure time (e.g., 0.1 ms,) and begin data acquisition by selecting Focus.
9. Slowly uncover the lens.
    - If the acquired image is washed out, cover the lens, program a shorter exposure time, and uncover the lens again.
    - If it is too dark, program a longer exposure time.

10. Verify the lens focus is set to the target distance and adjust as necessary.
11. Taking care not to disturb the lens focus, rotate the Adapter Body for maximum sharpness in the acquired image.
12. Once a sharp image has been acquired, use the 0.050" Hex Wrench to tighten the set screws to secure the Adapter Body's position.

This completes the procedure for adjusting the F-mount adapter. It should not be necessary to disturb the adjustment again. In actual measurements with real subjects, the focusing will be done entirely with the lens focus adjustment.

C.3   Lens Focusing Procedure

Except for the lens mount focus procedure that applies to F-mount lenses as described above, there is no difference between focusing considerations for an F-mount lens and a C-mount lens. Simply use the focusing ring on the lens to produce the sharpest image at full aperture. Then stop the lens down to its sharpest aperture (probably at a mid-range aperture setting) and adjust the Exposure Time for the best possible image as observed at the monitor.

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Appendix D: Spectrograph Adapters

Teledyne Princeton Instruments offers a variety of spectrograph adapters for PIXIS systems. The mounting instructions for these adapters are organized by spectrograph model, detector type, and adapter kit number. Refer to Table D-1 for information about installation instructions.

Table D-1:   Spectrograph Adapter Kit Information

Spectrograph	Adapter Plate Number	Information begins on...
Flange Mount to Teledyne Acton Research Series Spectrograph Adapter		page 128
3.60"/3.88" Bolt Circle to Teledyne Acton Research Series Spectrograph Adapter		page 129
C-Mount to Teledyne Acton Research Series Spectrograph Adapter		page 130
Teledyne Acton Research SP-2350/SP-2550 Adjustable C-to Spectroscopy-Mount Adapter	7050-0104	page 132
Teledyne Acton Research SP-2150/SP-2750 Adjustable C-to Spectroscopy-Mount Adapter	7050-0107	page 133
Flange-Mount to IsoPlane SCT-320 Adapter		page 134

D.1 Flange Mount to Teledyne Acton Research Series Spectrograph Adapter

Figure D-1: Flange Mount to Teledyne Acton Research Series Spectrograph Adapter

Sliding Tube and Spacer Plate
(supplied with spectrometer)

4411-0106_0073

Table D-2: Required Hardware: Flange Mount to Teledyne Acton Research Series Spectrograph Adapter

Quantity	Part Number	Description
3	2826-0120	Screw, 10-32 x ½, Hex Head, Stainless Steel

D.1.1 Installation Procedure

Perform the following procedure to install this adapter on the PIXIS camera:

1. Verify the shipping cover has been removed from the spectrograph's detector port.
2. If the spacer plate has been removed, reinstall it on the sliding tube.
3. Leaving ¼" of thread exposed, mount the three (3) hex head screws to the sliding tube.
4. Mount the detector flange on the sliding tube assembly and rotate the detector so the screw heads are over the narrow end of the slots.
5. Tighten the screws.

NOTE:

Adapter parts are machined to provide a tight fit. If removing the sliding tube from the spectrograph is required, first loosen the two set screws that secure it, and then rotate the tube while pulling it out.

If the sliding tube has been removed from the spectrograph, rotate the sliding tube while inserting it. Tighten the set screws afterwards to secure it.

Forcing the tube into the spectrograph could permanently damage the tube and the spectrograph opening.

D.2   3.60"/3.88" Bolt Circle to Teledyne Acton Research Series Spectrograph Adapter

Figure D-2: 3.60"/3.88" Bolt Circle to Teledyne Acton Research Series Spectrograph Adapter
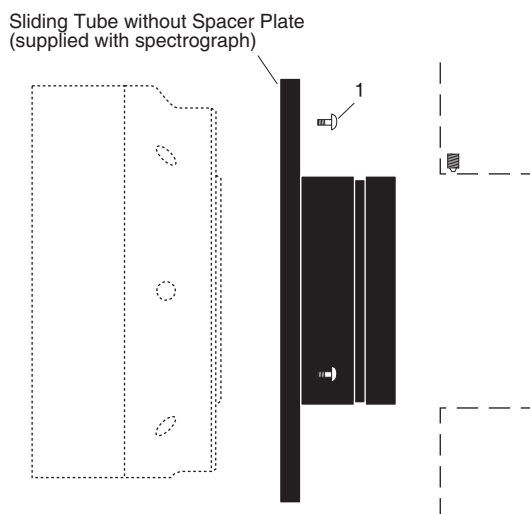
Table D-3: Required Hardware: 3.60"/3.88" Bolt Circle to Teledyne Acton Research Series Spectrograph Adapter

Quantity	Part Number	Description
3	2826-0127	Screw, 10-32 x ¼, Button Head Hex, Stainless Steel

D.2.1   Installation Procedure

Perform the following procedure to install this adapter on the PIXIS camera:

1. Verify the shipping cover has been removed from the spectrograph's detector port.
2. Loosen the set screws securing the sliding tube to the spectrograph.
3. Rotate the sliding tube while carefully removing it from the spectrograph.
4. Remove the three (3) socket head screws to remove the spacer plate from the sliding tube.
5. Mount the sliding tube to the detector's nose using three (3) 10-32 x ¼" screws.
6. Rotate the sliding tube while carefully inserting it into the spectrograph.
7. Secure the sliding tube with the set screws.

NOTE:

Adapter parts are machined to provide a tight fit. If removing the sliding tube from the spectrograph is required, first loosen the two set screws that secure it, and then rotate the tube while pulling it out.

If the sliding tube has been removed from the spectrograph, rotate the sliding tube while inserting it. Tighten the set screws afterwards to secure it.

Forcing the tube into the spectrograph could permanently damage the tube and the spectrograph opening.

D.3 C-Mount to Teledyne Acton Research Series Spectrograph Adapter

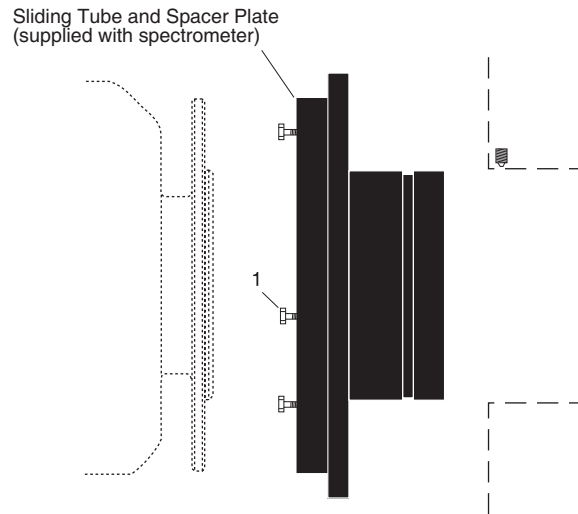**Figure D-3: C-Mount to Teledyne Acton Research Series Spectrograph Adapter**
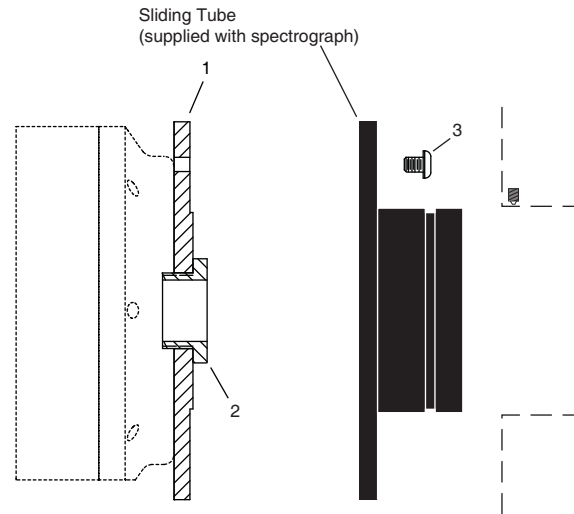
Table D-4: Required Hardware: C-Mount to Teledyne Acton Research Series Spectrograph Adapter

Quantity	Part Number	Description
1	8401-071-01	Adapter Plate
1	8401-071-02	Threaded C-Mount Adapter
3	2826-0127	Screw, 10-32 x ¼, Button Head Hex, Stainless Steel

D.3.1 Installation Procedure

Perform the following procedure to install this adapter on the PIXIS camera:

1. Verify the shipping cover has been removed from the spectrograph's detector port.
2. Loosen the set screws securing the sliding tube to the spectrograph.
3. Carefully rotate the sliding tube while removing it from the spectrograph.
4. If there is a spacer plate installed on the sliding tube, remove it.
5. Place the flat side of the adapter plate against the face of the detector.
6. Insert the threaded C-mount adapter through the center hole in the plate and screw the adapter into the detector's C-mount.

7. Secure the sliding tube to the adapter plate with three (3) 10-32 x ¼ screws.
8. Rotate the sliding tube while carefully inserting it into the spectrograph.
9. Secure the sliding tube with the sets crews.

NOTE:

Adapter parts are machined to provide a tight fit. If removing the sliding tube from the spectrograph is required, first loosen the two set screws that secure it, and then rotate the tube while pulling it out.

If the sliding tube has been removed from the spectrograph, rotate the sliding tube while inserting it. Tighten the set screws afterwards to secure it.

Forcing the tube into the spectrograph could permanently damage the tube and the spectrograph opening.

D.4   Teledyne Acton Research SP-2350/SP-2550 Adjustable C- to Spectroscopy-Mount Adapter

Figure D-4:   Teledyne Acton Research SP-2350/SP-2550 Adjustable C- to Spectroscopy-Mount Adapter
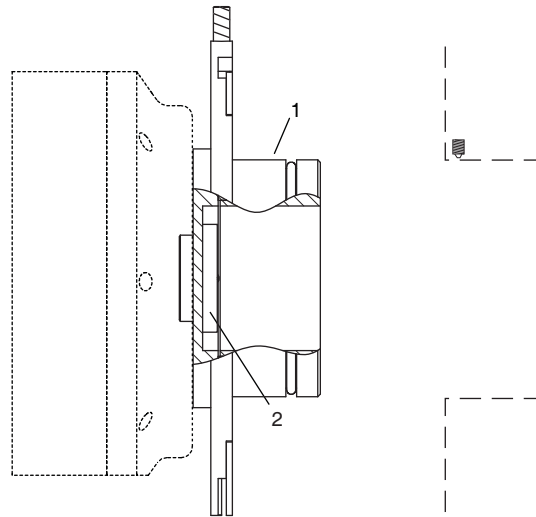
Table D-5:   Required Hardware: Teledyne Acton Research SP-2350/SP-2550 Adjustable C- to Spectroscopy-Mount Adapter

Quantity	Part Number	Description
1	7050-0104	Adapter Plate
1	2518-1284	1.25"-32 Threaded Insert

D.4.1   Installation Procedure

Perform the following procedure to install this adapter on the PIXIS camera:

1. Verify the shipping cover has been removed from the spectrograph's detector port.
2. Place the flat side of the adapter plate against the face of the detector.
3. Insert the threaded insert through the center hole in the plate and screw the adapter into the detector's C-mount.
4. Rotate the sliding tube while carefully inserting it into the spectrograph.
5. Secure the sliding tube with the set screws.

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

D.5   Teledyne Acton Research SP-2150/SP-2750 Adjustable C- to Spectroscopy-Mount Adapter

Figure D-5:   Teledyne Acton Research SP-2150/SP-2750 Adjustable C- to Spectroscopy-Mount Adapter
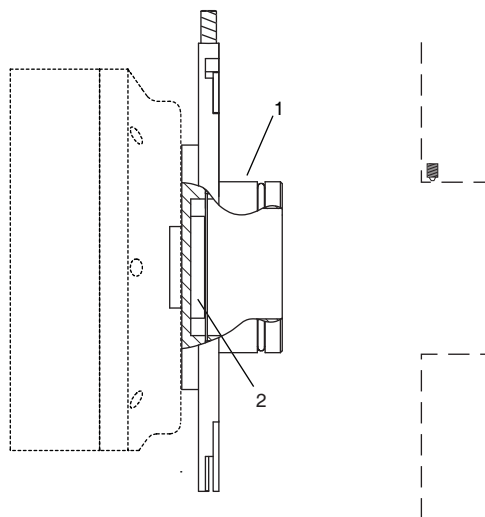
Table D-6:   Required Hardware: Teledyne Acton Research SP-2150/SP-2750 Adjustable C- to Spectroscopy-Mount Adapter

Quantity	Part Number	Description
1	7050-0107	Adapter Plate
1	2518-1284	1.25"-32 Threaded Insert

D.5.1   Installation Procedure

Perform the following procedure to install this adapter on the PIXIS camera:

1. Verify the shipping cover has been removed from the spectrograph's detector port.
2. Place the flat side of the adapter plate against the face of the detector.
3. Insert the threaded insert through the center hole in the plate and screw the adapter into the detector's C-mount.
4. Rotate the sliding tube while carefully inserting it into the spectrograph.
5. Secure the sliding tube with the set screws.

> **NOTE:**
>
> Adapter parts are machined to provide a tight fit. If removing the sliding tube from the spectrograph is required, first loosen the two set screws that secure it, and then rotate the tube while pulling it out.
>
> If the sliding tube has been removed from the spectrograph, rotate the sliding tube while inserting it. Tighten the set screws afterwards to secure it.
>
> Forcing the tube into the spectrograph could permanently damage the tube and the spectrograph opening.

D.6 Flange-Mount to IsoPlane SCT-320 Adapter

Figure D-6: Flange-Mount to IsoPlane SCT-320 Adapter

IsoPlane Mounting Plate

1
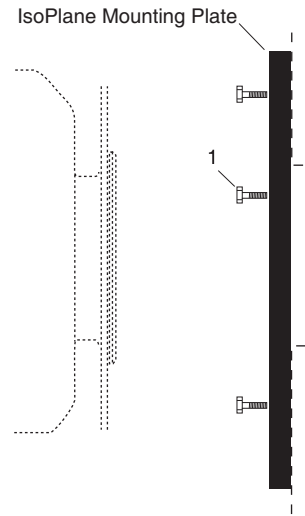
4411-0106_0078

Table D-7: Required Hardware: Flange-Mount to IsoPlane SCT-320 Adapter

Quantity	Part Number	Description
1	2826-0120	Screw, 10-32 x ½, Hex Head, Stainless Steel

D.6.1 Installation Procedure

Perform the following procedure to install this adapter on the PIXIS camera:

1. Verify the shipping cover has been removed from the spectrograph's detector port.
2. Leaving ¼" of thread exposed, screw the three (3) 10-32 x ½ screws into the mounting plate.
3. Mount the detector to the mounting plate. The text on the rear of the detector should be oriented so that it is readable (i.e., not upside down.)
4. Use a 5/16" open end wrench to tighten the three screws.

NOTES:

1. Rotational alignment of the detector with the spectrograph optics is achieved by loosening and subsequently tightening the screws at the mounting plate corners. The holes are slotted to allow about 4° of rotation.
2. If the IsoPlane was ordered with an internal shutter at the entrance slit, the PIXIS, when connected to the Shutter input on the IsoPlane, can control that shutter. If the PIXIS is using its own internal shutter, the IsoPlane shutter will need to be removed. Refer to the IsoPlane SCT-320 manual for shutter removal instructions.

Appendix E: Troubleshooting

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

Recommended troubleshooting guidelines are available for many issues that may occur
while working with a PIXIS system. Refer to Table E-1 for additional information.

Table E-1:   Issues with Recommended Troubleshooting Guidelines

Issue	Information Begins On...
Acquisition Started but Viewer Contents Do Not Update	page 136
Baseline Signal Suddenly Changes	page 136
Camera Stops Working	page 137
Camera1 (or similar name) in Camera Name field	page 137
Controller Is Not Responding	page 138
CoolCUBEII: Low Coolant (Air in the Hoses)	page 139
Temperature Lock Cannot be Achieved or Maintained	page 140
Camera Loses Temperature Lock	page 140
Gradual Deterioration of Cooling Capability	page 141
Data Loss or Serial Violation	page 141
Data Overrun Due to Hardware Conflict Message	page 141
Data Overrun Has Occurred Message	page 142
Devices Missing	page 142
Device is Occupied	page 143
Error Creating Controller Messages	page 144
Overexposed or Smeared Images	page 144
Program Error Message	page 145
Serial Violations Have Occurred Error	page 146
Shutter Failure	page 146

E.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 in either Preview or Acquire mode. If the viewer is not being updated and acquisition is occurring, determine if there is a filename in the top row of the viewer

For example, in Figure E-1, the filename `2010 May 11 13_13_49.raw` is displayed.

If a filename is displayed, click on the camera icon. The existing file data will be cleared from the viewer and live data will then be displayed.

Figure E-1: Typical Acquisition Display
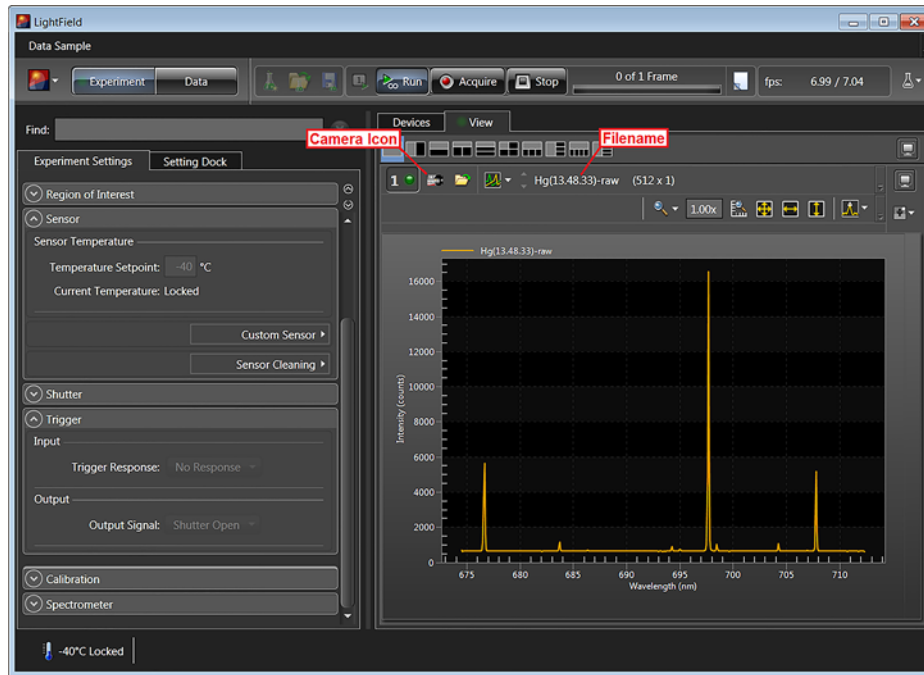
E.2 Baseline Signal Suddenly Changes

A change in the baseline signal is normal if the temperature, gain, or speed setting has been changed.

If this occurs when none of these settings have been changed, there may be excessive humidity in the camera vacuum enclosure.

Turn off the camera and contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for complete information.

E.3   Camera Stops Working

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

- Turn off all AC power.
- Verify that all cables are securely fastened.
- Turn the system on.
- If the camera has an internal shutter and you hear two clicks separated by one second (i.e., the shutter is opening then closing,) the shutter is working. Contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for additional instructions.

If the system still does not respond, contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for complete information.

E.4   Camera1 (or similar name) 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 is displayed within the Hardware Setup title bar and as the active camera on the Hardware Setup ► Controller/Camera tab. See Figure E-2.

Figure E-2:   Camera1 in Camera Name Field

If desired, a more descriptive name may be assigned to the camera by editing the file named PVCAM.INI which is located in the Windows directory. 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 as shown in Figure E-3.

Figure E-3:   Editing Camera Name in Notepad
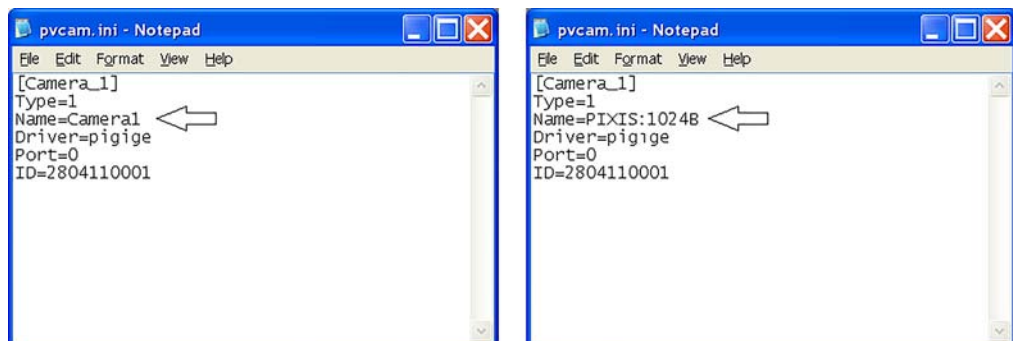
4. Save the edited file.
5. The next time WinX is launched, the new name will be displayed on the Hardware Setup dialog. See Figure E-4.

Figure E-4:   Editing Camera Name in Notepad
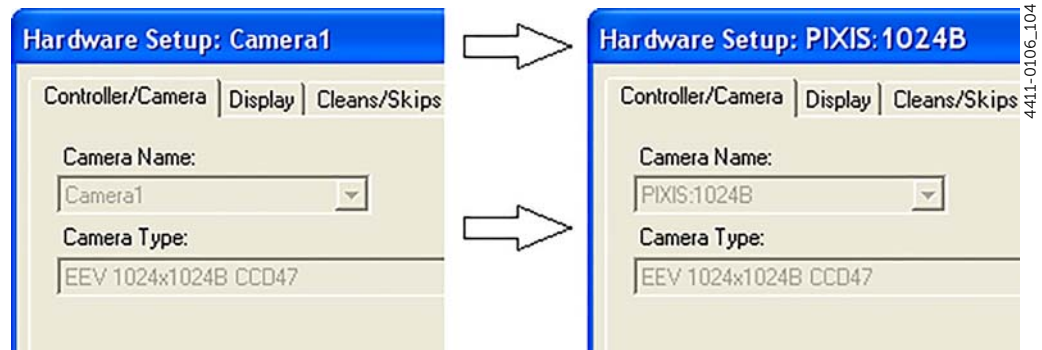
> 🔍 **NOTE:** ─────────────────────────
>
> If the Camera Detection Wizard is launched and run at a later time, the name will be revert back to the default name (i.e., Camera1).)

E.5   Controller Is Not Responding

If this message pops up when you click on OK after selecting the Interface Type during Hardware Setup (i.e., under the WinX Setup menu,) the system has not been able to communicate with the camera.

Check to see if camera has been turned ON and if the 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 the interface card is not installed, close the WinX application and turn the camera OFF. Follow the interface card installation instructions 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 the WinX application with the appropriate interface component selected. Be sure to deselect the interface component that does not apply to your system.

- If the interface card is installed in the computer and is cabled to the USB 2 port on the rear of the camera, close the application and turn the camera OFF. Check the cable connections.

- If the interface card was installed after the application program was installed, close the application program and do a Custom installation of the WinX application with the appropriate interface component selected. Be sure to deselect the interface component that does not apply to your system.

E.6   CoolCUBE$_{II}$: Low Coolant (Air in the Hoses)

⚠ **WARNING!** ————————————————————

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.

————————————————————————————

Perform the following procedure to resolve this issue:

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 VAC, 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, proceed 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, proceed to step 6.

6. Turn the camera on.
7. Launch the application software.

E.7   Cooling Troubleshooting

This section provides recommended troubleshooting guidelines for cooling-related problems.

E.7.1   Temperature Lock Cannot be Achieved or Maintained

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

- Ambient temperature greater than +23°C. This condition affects TE-cooled cameras. If ambient is greater than +23°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 E.6, CoolCUBEII: Low Coolant (Air in the Hoses), on page 139 for complete information.

- There may be air in the hoses. Add coolant. Refer to Section E.6, CoolCUBEII: Low Coolant (Air in the Hoses), on page 139 for complete information.

- Circulator pump is not working. If you do not hear the pump running when the CoolCUBE$_{II}$ is powered on, turn off the circulator and contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for complete information.

- The circulator is higher than the camera. Reposition the circulator so that it is a minimum of 6 inches [150 mm] 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 camera vacuum has deteriorated and needs to be refreshed. Contact Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 154 for complete information.

- 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.

E.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.

E.7.3   Gradual Deterioration of Cooling Capability

While unlikely with the PIXIS 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 to make arrangements for returning the camera to the support facility. Refer to Contact Information on page 154 for complete information.

E.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 application.

E.9   Data Overrun Due to Hardware Conflict Message

Figure E-5 illustrates the Data Overrun Error Dialog that may be displayed when a data overrun error has been detected. This error is typically due to an undersized DMA Buffer having been configured based on the size of the CCD array installed in the camera and is displayed when acquiring a test image, acquiring data, or running in focus mode.

As a general guideline, a large array (e.g., 2048 x 2048,) requires a larger DMA buffer size than is required by a smaller array (e.g., 512 x 512.)

Figure E-5:   Data Overrun Due to Hardware Conflict Dialog

Perform the following procedure to determine the current buffer size and, if necessary, increase the buffer size:

1. To determine the size of the array that is installed in the PIXIS, within WinX, navigate to either the:
   - Setup ► Hardware ► Controller/CCD tab; or
   - Acquisition ► Experiment Setup ► Main tab

   The array size is listed in the Full Chip Dimensions field.
2. Navigate to the Setup ► Environment ► Environment dialog.
3. Adjust/increase the DMA buffer size to a minimum of 32 MB.
   - If the Buffer Size is currently 32 MB, increase it to a minimum of 64 MB.
   - If the Buffer Size is currently 64 MB, increase it to a minimum of 128 MB.

   Click on OK, and close the WinX application.
4. Reboot the Host Computer.
5. Launch WinX and start to acquire data or focus the system.

   If another Data Overrun is detected, increase the DMA buffer size.

E.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:

1. Minimize the number of programs running in the background while you are acquiring data with the WinX application.
2. Run data acquisition in Safe Mode.
3. Add memory.
4. Use binning.
5. Increase the exposure time.
6. Defragment the hard disk.
7. 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 for assistance. Refer to Contact Information on page 154 for complete information.

E.11   Devices Missing

When LightField is started, it looks for devices (i.e., cameras, spectrographs, and/or filters,) that are powered on and connected to the Host Computer via the communications interface. If it cannot detect a device that has been used in a prior experiment, it will continue searching and display the dialog shown in Figure E-6.

Figure E-6:   Devices Missing Dialog

Perform the following system checks to resolve this error:

- Verify the desired device is connected to the Host Computer and powered on.
  - If LightField cannot detect a spectrograph that has been verified as being connected and powered on, cycle the power on the spectrograph. LightField should now detect it.
  - If LightField cannot detect a camera that is powered on and connected via the GigE interface, UDP ports 20200-20202 may need to be opened.

    These ports must be open before LightField can detect a Teledyne Princeton Instruments GigE camera, but they may have been closed as part of Host Computer security (e.g., an anti-virus program or a firewall.) Contact the local Information Technology specialist for assistance.
- Cancel the experiment load.

  Canceling a load means that the last used experiment will not be loaded automatically when LightField opens. However, the experiment can be loaded within LightField after all devices have become available.

  Alternatively, a new experiment design can be started, or a different experiment can be loaded that specifies the available equipment.

E.12   Device is Occupied

It is possible for multiple instances of LightField to be running simultaneously. However, any 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.

Figure E-7 illustrates how LightField indicates that a device is currently in use by another instance of LightField and is not available for use.

Figure E-7:   Typical LightField Device Occupied Indicator

To make a device available for use by 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. The data acquisition may then be started.

E.13　Error Creating Controller Messages

Figure E-8 illustrates the messages that may appear if the PVCAM.INI file has become corrupted or if the camera was not turned on before you started the WinX application and began running the Camera Detection wizard.

Figure E-8:　Error Creating Controller dialog
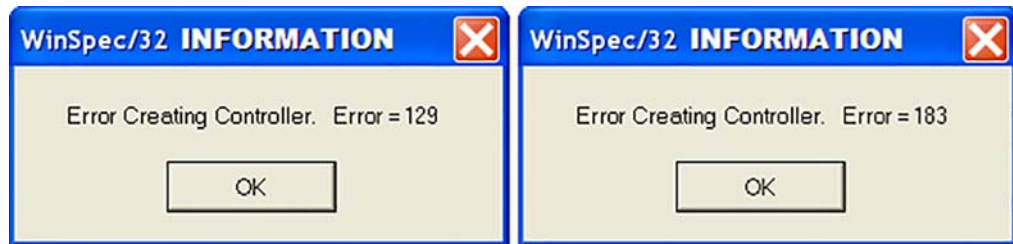
If one of these dialogs pops up:

1. Refer Section E.5, Controller Is Not Responding, on page 138.
2. Run the Camera Detection Wizard.

E.14　Overexposed or Smeared Images

If the camera has an internal shutter, check to see that the shutter is opening and closing correctly. Possible shutter problems include complete failure, in which the shutter no longer operates at all: the shutter may stick or open (causing overexposed or smeared images) or stick closed (resulting in no images). It may even happen that one leaf of the shutter will break and no longer actuate. High repetition rates and short exposure times will rapidly increase the number of shutter cycles and hasten the time when the shutter will have to be replaced.

Shutter replacement is usually done at the factory. If you find that the shutter on your camera is malfunctioning, contact Teledyne Princeton Instruments Customer Support for assistance with a shutter-replacement repair. Refer to Contact Information on page 154 for complete information. Shutters are not covered by the warranty.

E.15   Program Error Message

Figure E-9 illustrates the Program Error Dialog that may be displayed when a data overrun error has been detected. This error is typically due to an undersized DMA Buffer having been configured based on the size of the CCD array installed in the camera and is displayed when acquiring a test image, acquiring data, or running in focus mode.

As a general guideline, a large array (e.g., 2048 x 2048,) requires a larger DMA buffer size than is required by a smaller array (e.g., 512 x 512.)

Figure E-9:   Typical Program Error Dialog
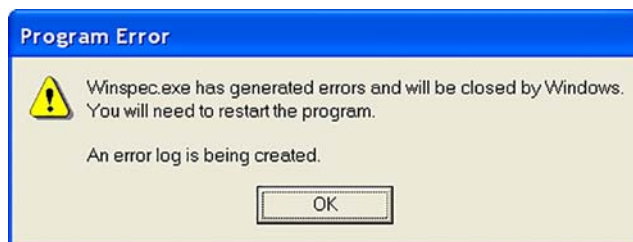
Perform the following procedure to determine the current buffer size and, if necessary, increase the buffer size:

1. To determine the size of the array that is installed in the PIXIS[model], within WinX, navigate to either the:

    - Setup ► Hardware ► Controller/CCD tab; or

    - Acquisition ► Experiment Setup ► Main tab

    The array size is listed in the Full Chip Dimensions field.

2. Navigate to the Setup ► Environment ► Environment dialog.

3. Adjust/increase the DMA buffer size to a minimum of 32 MB.

    - If the Buffer Size is currently 32 MB, increase it to a minimum of 64 MB.

    - If the Buffer Size is currently 64 MB, increase it to a minimum of 128 MB.

    Click on OK, and close the WinX application.

4. Reboot the Host Computer.

5. Launch WinX and start to acquire data or focus the system.

    If another Data Overrun is detected, increase the DMA buffer size.

E.16 Serial Violations Have Occurred Error

Figure E-10 illustrates the error dialog that is displayed when acquiring an image or focusing the PIXIS[model] when one or more of the following conditions exists:

- The PIXIS system is not turned ON.
- There is no communication between the PIXIS[model] and the Host Computer.
- The PIXIS[model] is turned off while being focused.
- A cable becomes disconnected while the PIXIS[model] is being focused.

Figure E-10: Typical Serial Violations Have Occurred Error Dialog
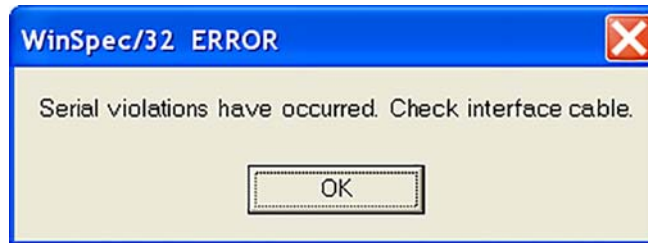
Perform the following procedure to resolve this error:

1. If necessary turn OFF the camera system.
2. Verify the computer interface cable is secured at both ends.
3. After making sure that the cable is connected, turn the PIXIS[model] system power ON.
4. Click OK on the error message dialog and retry acquiring an image or running in focus mode.

E.17 Shutter Failure

Refer to Section E.14, Overexposed or Smeared Images, on page 144.

Appendix F: WinSpec/32/LightField Cross Reference

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

F.1 WinSpec/32-to-LightField Terminology

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

Table F-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 F-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

F.2   LightField to WinSpec/32

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

Table F-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 F-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
Fax: 1-609-587-1970

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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