Part of the Teledyne Imaging Group

PI-MAX®3 System Manual

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www.princetoninstruments.com

Revision History

Issue	Date	List of Changes
Issue 2	August 20, 2019	Issue 2 of this document incorporates the following changes: • Rebranded as Teledyne Princeton Instruments.
Issue 1.D	September 21, 2015	Issue 1.D of this document incorporates the following changes: • Added clarification information about Time Stamping; • Updated TRIGGER IN connector description for input levels $\pm$5.5 V_{DC}.
Issue 1.C	September 5, 2012	Issue 1.C of this document incorporates the following changes: • Added information about 1024 x 256 orientation needing to be flipped; • Global update Sub-Nanosecond to Picosecond; • Added IsoPlane Mounting information to Spectrograph Adapter appendix; • Added Controller Gain/Analog Gain topic.
Issue 1.B	September 26, 2011	Issue 1.B of this document incorporates the following changes: • Added LightField support; • Added Sub-Nanosecond chapter; • Added MCP Gating chapter; • Inserted Flange-to-Spectrograph Quick Start; • Removed Kinetics references; • Updated Response Linearity specification.
Issue 1.A	February 8, 2010	This is the initial release of this document.

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Attention!

WARNING!

Intensified CCD detectors, such as the PI-MAX®3, when biased on, can be irreparably damaged if continuously exposed to light levels higher than twice the A/D saturation level. Thus it is critical that you not establish conditions that could result in damage to the intensifier.

Although intensified detectors are less prone to damage from background light when operated gated, they are at significant risk to damage from high-intensity light sources like a laser.

High intensity sources can damage the intensifier before the protection circuits have time to respond or even cause spot damage without the protection circuits acting at all.

If a sustained alarm indication occurs when the controller is turned on, either completely cover the intensifier to reduce light to halt the overload condition, or reduce the laboratory illumination further until safe operating conditions are established.

Alarm

To reduce the risk of detector damage, the PI-MAX3 detector is equipped with an audible alarm in the detector head that is activated when the intensity of light falling on the image intensifier exceeds a preset threshold.

NOTE:

It is normal for this alarm to sound briefly when the system is turned on.

While the alarm is sounding, the photocathode is disabled. Immediately switch the I.I.T. switch on the back of the PI-MAX3 to the off position. Cover the detector window and switch the I.I.T. switch to on only after the illumination level has been lowered.

If the alarm sounds continuously even after the illumination level is adequately low, shut the system down and contact Teledyne Princeton Instruments Customer Service for guidance. Refer to Contact Information on page 248 for more information.

CAUTION!

Discontinue operation and contact Teledyne Princeton Instruments Customer Service at once if sporadic or continuous unwarranted alarms occur. They may indicate intensifier damage or another situation that requires immediate attention.

Unigen™ II Coating

For greater sensitivity, the PI-MAX3 camera with Unigen II coating comes without a protective window over the intensifier. Do not scratch the image intensifier's coated surface.

To remove any lint or dust, use very clean dry nitrogen with < 5 PSI pressure.

If you have any questions please contact your sales contact or Teledyne Princeton Instruments Customer Service. Refer to Contact Information on page 248 for more information.

Chapter 1: About this Manual

Thank you for purchasing a PI-MAX3 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 248 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 PI-MAX3 system.

This document provides all information necessary to safely install, configure, and operate the PI-MAX3, 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 PI-MAX3 camera system. To guarantee up-to-date information, always refer to the current release of each document listed.

Table 1-1: Related Documentation

Document Number	Document Title
4411-0046	WinView/32 Imaging Software User Manual
4411-0048	WinSpec/32 Spectroscopy Software User Manual
4411-0103	WinXTest Software User Manual
–	LightField 6 Online Help
–	PI-MAX3 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, PI-MAX3 Camera System
  This chapter provides an introduction to, and overview information about, Teledyne Princeton Instruments' PI-MAX3 camera system.
- Chapter 3, PI-MAX3 Image Acquisition
  This chapter provides a high-level overview of how PI-MAX3 acquires, transfers, and processes image data.
- Chapter 4, Installation Overview
  This chapter cross-references system setup actions with the relevant manuals and/or manual pages. It also contains system block diagrams.
- Chapter 5, System Setup
  This chapter provides detailed information about installing and setting up the PI-MAX3 for both spectroscopy and imaging.
- Chapter 6, First Light
  This chapter provides abbreviated directions for getting your PI-MAX3 into operation as soon as possible.
- Chapter 7, Operation
  This chapter provides information about experiment setup, temperature control, background subtraction, array readout, binning, and digitization.
- Chapter 8, WinX/32 and Gated Operation
  This chapter discusses issues specific using WinX/32 and operating the PI-MAX3 system in gate mode.
- Chapter 9, LightField and Gated Operation
  This chapter discusses issues specific using LightField and operating the PI-MAX3 system in gate mode.
- Chapter 10, Timing Generator Pulses and Sequences
  This chapter discusses and illustrates the trigger modes available when operating the system in gate mode.
- Chapter 11, WinX/32 and Dual Image Feature (DIF)
  This chapter discusses using WinX/32 with the mode specifically designed for capturing a pair of gated images in rapid succession.
- Chapter 12, LightField and Dual Image Feature (DIF)
  This chapter discusses using LightField with the mode specifically designed for capturing a pair of gated images in rapid succession.
- Chapter 13, MCP Gating
  This chapter discusses how to configure a PI-MAX3 that has an installed MCP Gating board.
- Chapter 14, Picosecond Option
  This chapter discusses how to configure a PI-MAX3 that has an installed picosecond board.
- Chapter 15, Tips and Tricks
  This chapter discusses a number of issues that can have a bearing on getting good experimental results.

- Chapter 16, Troubleshooting
  This chapter provides recommended troubleshooting procedures.
- Appendix A, Technical Specifications
  This appendix provides system-level technical specifications.
- Appendix B, Outline Drawings
  This appendix provides outline drawings for the PI-MAX3 camera, the PI-MAX3 power supply, and the CoolCUBE$_{II}$ coolant circulator.
- Appendix C, WinSpec/32 and LightField Cross References
  This appendix provides two alphabetically sorted tables that cross-reference terms used by WinX/32 and LightField.
- Appendix D, Extender Bracket Kit
  This appendix explains how to use this kit to mount the PI-MAX3 to any laboratory table with either 25 mm or 1 inch hole spacing.
- Appendix E, Mounting and Focusing C- and F-Mount Lenses
  This appendix discusses the focusing of an F-mount adapter, as well as the focusing of F-mount and C-mount lenses.
- Appendix F, C-, F-, and Spectroscopy- Mount Adapters
  This appendix describes how to change the adapter on the front of the PI-MAX3 to another type if you have multiple adapters.
- Appendix G, Spectrograph Adapters
  This appendix provides mounting instructions for the spectroscopy-mount adapter and for the spectrograph adapters available for PI-MAX3 cameras with spectroscopy-mounts.
- Appendix H, Glossary
  This appendix provides definitions of commonly used words and terms related to intensified camera characteristics and usage.
- Warranty and Service
  This section provides warranty information for the PI-MAX3. Contact information is also provided.

1.3.1 Conventions Used In this Document

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

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

Table 1-2: Terminology Conventions Used

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

1.4 Safety Related Symbols Used in this Manual

CAUTION!

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

WARNING!

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

WARNING! RISK OF ELECTRIC SHOCK!

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

1.5 PI-MAX3 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 PI-MAX3 camera system is used in a manner not specified by Teledyne Princeton Instruments, the protection provided by the equipment may be impaired.
2. The PI-MAX3 has internal power supplies that generate hazardous (and potentially lethal) voltages. It contains no user-serviceable parts. Do not attempt to operate it with the covers removed.
3. 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.

1.5.1 Intensifier Modes and Safety

- WinX/32 Applications

  The Experiment Setup **Main** screen in WinX/32 applications allows you to select one of two intensifier modes:

  — Gate Mode;

    In Gate Mode, the photocathode is biased on only for the time that each gate pulse is applied. As a result, the tolerance to room light is higher in gated operation, but the risk of damaging overload from intense light sources such as lasers remains. In fact, intense light sources in gated experiments can cause spot damage that would be undetected by the alarm circuit.

  — Safe Mode

    In Safe Mode, the photocathode is continuously biased OFF and the intensifier is as safe as it can be.

- LightField

  In LightField, you can enable or disable the intensifier on the **Common Acquisition Settings** expander. When the intensifier is enabled, the camera can be gated; when disabled, the photocathode is continuously biased OFF and the intensifier is as safe as it can be.

NOTE:

In order for gating to occur, the I.I.T. switch on the back of the PI-MAX3 must also be in the ON position.

1.5.2 Audible Alarm

NOTE:

It is normal for the alarm to sound briefly when the system is turned on.

To reduce the risk of camera damage, the PI-MAX3 camera is equipped with an audible alarm in the camera, activated when the intensity of light falling on the image intensifier exceeds a preset threshold. While the alarm is sounding, the photocathode is disabled. Immediately switch the **I.I.T.** switch on the back of the PI-MAX3 to the OFF position. Cover the detector window and only switch the **I.I.T.** switch to ON after the illumination level has been lowered. If the alarm sounds continuously even when the illumination level is adequately low, shut the system down and contact the factory for guidance.

CAUTION!

Discontinue operation and contact the factory at once if sporadic or continuous unwarranted alarms occur. They may indicate intensifier damage or another situation that requires immediate attention.

1.5.3 High Intensity Light Damage

WARNING!

Intensified CCD cameras such as the PI-MAX3, when biased on, can be irreparably damaged if continuously exposed to light levels higher than twice the A/D saturation level. Thus it is critical that you not establish conditions that could result in damage to the intensifier. Although intensified cameras are less prone to damage from background light when operated gated, they are at significant risk to damage from high-intensity light sources like a laser. High intensity sources can damage the intensifier before the protection circuits have time to respond, or even cause spot damage without the protection circuits acting at all. If a sustained alarm indication occurs when the camera is turned on, immediately switch the **I.I.T.** switch on the back of the PI-MAX3 to the off position. Cover the detector window and only switch the **I.I.T.** switch to on after the illumination level has been lowered.

If the alarm sounds continuously even when the illumination level is adequately low, shut the system down and contact the factory for guidance.

1.6 Precautions

To prevent permanently damaging the PI-MAX3 system, observe the following precautions at all times.

CAUTION!

1. Always switch off and unplug the PI-MAX3 power supply before changing your system configuration in any way.
2. Whenever you turn the PI-MAX3 power supply, be sure to leave it OFF for at least 30 seconds before switching it back ON. If you switch it ON too soon, a fault logic state is established that causes the overload alarm to sound continuously.
3. 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.
4. Never operate the camera cooled without proper evacuation or backfill. This could damage the CCD! Do not open the purge valve.
5. Never connect or disconnect any cable while the PI-MAX3 system is powered on. Reconnecting a charged cable may damage the CCD.
6. Never prevent the free flow of air through the equipment by blocking the air vents.

Chapter 2: PI-MAX3 Camera System

Teledyne Princeton Instruments' PI-MAX3 is an advanced Intensified CCD (ICCD) camera system designed for general macro-imaging and microscopy imaging applications. It is ideal for applications involving ultra low light measurements, or measurements of transient effects. PI-MAX3 uses a proximity-focused microchannel plate (MCP) image intensifier (Gen II and Filmless Gen III intensifiers available) fiber-optically coupled to a CCD array. The fastest intensifiers can be gated in as little as 3 ns or less with an exceptionally high on/off light-transmission ratio. The CCD array provides a low noise, high dynamic range readout device that can be scanned at a variety of pixel rates. A number of different arrays are available to match the PI-MAX3 to the widest possible range of experimental requirements.

The operation of the camera system is under complete control of WinView/32 (Imaging,) WinSpec/32 (Imaging and Spectroscopy,) or LightField® software packages. In pulsed/gated experiments where the camera needs to be synchronized to a light source such as a laser, the internal timing generator is used.

All PI-MAX3 systems consist of standard hardware and software as well as the appropriate interface hardware for your host computer system. Figure 2-1 shows those items that are typically included as part of a standard PI-MAX3 Camera system.

Figure 2-1: Typical PI-MAX3 System Components

This chapter provides an introduction to, and overview information about, Teledyne Princeton Instruments' PI-MAX3 camera system.

2.1 PI-MAX3 Camera

The PI-MAX3 camera, illustrated in Figure 2-2, houses the CCD and intensifier and supplies all of the high voltages needed to operate the intensifier.

Figure 2-2: Typical PI-MAX3 **Camera**

The camera can be operated in one of the following two modes:

- Safe mode;
  In Safe mode, the photocathode is gated off.
- Gate mode.
  In Gate mode, the photocathode is biased on only during the time each gate pulse is applied.

The PI-MAX3 contains the analog and digital electronics, scan control and exposure timing hardware, and controller I/O connectors. Readout modes supported include full resolution, simultaneous multiple sub-images, and nonuniform binning. Single or multiple software-defined regions of interest can also be tested without having to digitize all the pixels of the array. Flexible exposure, set through software, is also fully supported.

The PI-MAX3 contains two High Speed analog-to-digital converters. The effective digitization rate is software-selectable. After the data is converted, it is transferred directly from the camera to the host computer memory via the high speed interface cable.

2.1.1 Mount Adapters

The front of the PI-MAX3 camera is designed to accept three types of adapters:

- C-mount;
- F-mount;
- Spectroscopy-mount.

The mount adapter specified when the system was ordered has been installed on PI-MAX3 at the factory. The other two mounts are supplied in the PI-MAX3 accessory kit.

For additional information about these mount adapters, refer to:

- Appendix E, Mounting and Focusing C- and F-Mount Lenses, on page 221;
- Appendix G, Spectrograph Adapters, on page 227.

2.1.2 Cooling

Cooling within the PI-MAX3 is performed by a cooling fan and a multi-stage Peltier cooler that is thermally coupled to the CCD.

A ventilation fan runs continuously to remove heat generated by the thermoelectric cooler and the electronics. Air is drawn into the camera through the rear grill, picks up the heat from the electronics and the cooler, and is then exhausted through the side ventilation slots.

With air-cooling alone, at an ambient temperature of 25°C, temperature lock at –25°C will generally occur within ten to fifteen minutes. Note that the exact cooling performance is a function of the CCD array installed. Also, if the lab is particularly warm, achieving temperature lock might take longer or not occur at all.

NOTE:

Liquid coolant circulation can also be used with the PI-MAX3 camera.

Photocathode cooling to reduce equivalent background illumination (EBI) can be achieved via a dry nitrogen source.

NOTE:

Clear PVC tubing (3 feet, 5/32" OD, 1/32" wall, McMaster-Carr 5006K42) is supplied with the PI-MAX3 to connect to a dry nitrogen source for cooling the photocathode.

2.1.3 GigE Ethernet Card

4411-0129_0003

This card must be installed in the host computer to control the PI-MAX3 camera and to receive data from the camera.

2.1.4 Extender Bracket Kit

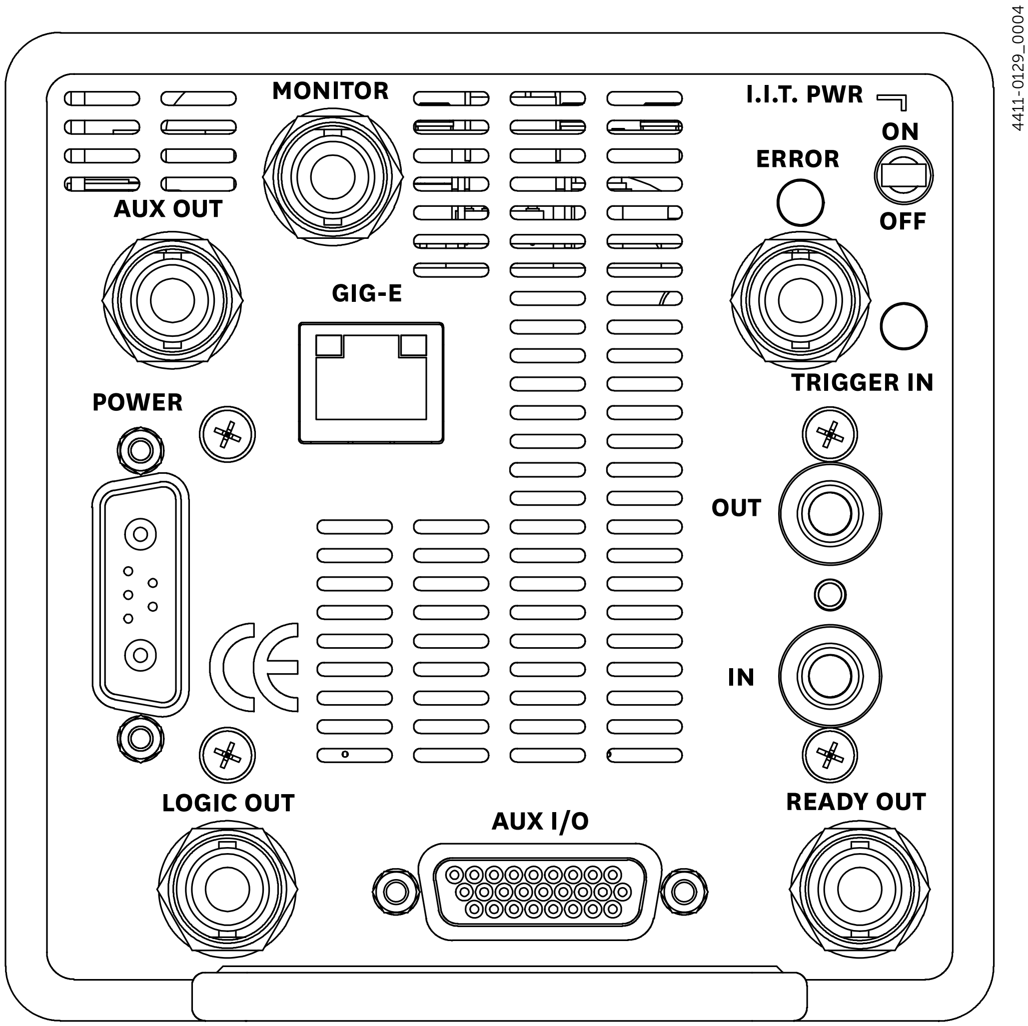
Each PI-MAX3 camera is shipped with an Extender Bracket kit that, when mounted to the rear of the camera, allows the PI-MAX3 to be secured to a laboratory table with tapped mounting hole arrays with ¼-20 on 1" spacing, or M6 on 25 mm spacing.

2.1.5 PI-MAX3 Rear-Panel Connectors and Indicators

Figure 2-3 illustrates the rear-panel connectors and indicators on a PI-MAX3 camera.

CAUTION!
Always turn the power off at the power supply before connecting or disconnecting any cable that interconnects the camera and the computer or serious damage to the CCD may result. This damage is NOT covered by the manufacturer's warranty.

Figure 2-3: PI-MAX3 **Rear-Panel Connectors**



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

Table 2-1: PI-MAX3 Rear-Panel Connectors and Indicators (Sheet 1 of 2)

Label	Description
MONITOR	BNC port for TTL logic 1 pulse delayed ± 3 ns with respect to photocathode gating. Cable delay, ~1.5 ns/ft, will be in addition to the delay at the connector.
I.I.T PWR ON/OFF	This switch biases the image intensifier photocathode ON or OFF. • When the I.I.T. switch is set to ON, the photocathode can be gated ON. *Exception: Selecting SAFE on the Experiment Setup Main screen overrides control and will prevent the photocathode from being biased on regardless of the I.I.T. switch setting.* • When the I.I.T. switch is set to OFF, then the photocathode cannot be turned on from software. **CAUTION:** It is advisable to set the I.I.T. switch to OFF as a fail-safe measure if the PI-MAX3 is left ON but unused for a period of time.
ERROR	This RED LED lights to warn of excessive repetition rate. Must be off for proper operation. **NOTE:** Excess Rep Rate LED is also activated by MCP bracket pulsing. The MCP bracket repetition rate limit is 6.25 kHz.
TRIGGER IN	When external triggering is selected within the software, the internal timing generator will be triggered by an externally derived trigger pulse (range of ± 5.5 V) applied to this input. The threshold, slope, coupling mode (i.e., AC or DC,) and input impedance (i.e., High or 50Ω,) are selectable in software. The corresponding Green LED flashes each time PI-MAX3 is triggered. At high repetition rates, the LED glows steadily. **NOTE:** In gated operation, the Green LED indicator flashes each time the PI-MAX3 is triggered. The actual triggering can also be readily determined by observing the signal at the PI-MAX3 Monitor output with a fast oscilloscope.
COOLANT PORTS: • OUT • IN	Two standard ¼" barbed brass fittings for circulating coolant are located on the back panel. Either port may be used as the inlet. The coolant cannot be chilled. Use the Teledyne Princeton Instruments CoolCUBE$_{II}$ coolant circulator. For additional information, refer to: • Section 5.5, Connect PI-MAX3 to CoolCUBE$_{II}$, on page 45 • Section 7.5, Temperature Control, on page 68. **NOTE:** Although circulating water will extend the PI-MAX3's cooling capabilities, it is not necessary. Most of the PI-MAX3 cooling is provided by the fan.
READY OUT	Level at this BNC is initially LOW. It changes state on completion of cleaning cycles before the first exposure.

Table 2-1: PI-MAX3 Rear-Panel Connectors and Indicators (Sheet 2 of 2)

Label	Description
AUX I/O	26-pin male DB connector. Provides access to the following five I/O signals that can be used to input a trigger to initiate data acquisition, to monitor frame readout status, and to control an external shutter: • T_0 Out; • Pre-Trigger In; • SyncMASTER1; • General Purpose Input 0; • SyncMASTER2. Refer to Section A.1.1, AUX I/O Connector Pinout, on page 201 for additional information.
LOGIC OUT	0 to +3.3V logic level output (TTL-compatible). WinView/WinSpec32 (Version 2.5.25 or higher) software-selectable Acquiring, Image Shift, Logic 1, Read Out, Shutter, and Wait for Trigger signal. When the Invert LOGIC check box is checked, the output is at a logic low when the action is occurring.
POWER	7-pin D specialty connector; connects to the PI-MAX3 external power supply.
GIG-E	Ethernet port.
AUX OUT	DC-coupled variable delay trigger output for synchronizing other system components with the PI-MAX3 internal timing generator. The host software sets the Delay Time of this output with respect to the internal timing generator trigger time. The source impedance is approximately 100Ω and it will provide >1 V into 50Ω.

2.1.6 Power

All voltages required by PI-MAX3 camera systems are generated and delivered by an external power supply included with each PI-MAX3 camera using the supplied cables.

CAUTION!

Use of a power supply other than that provided with the PI-MAX3 camera may severely and permanently damage the camera and will void the camera warranty. For specific power supply requirements, contact Teledyne Princeton Instruments. Refer to Contact Information on page 248 for complete information.

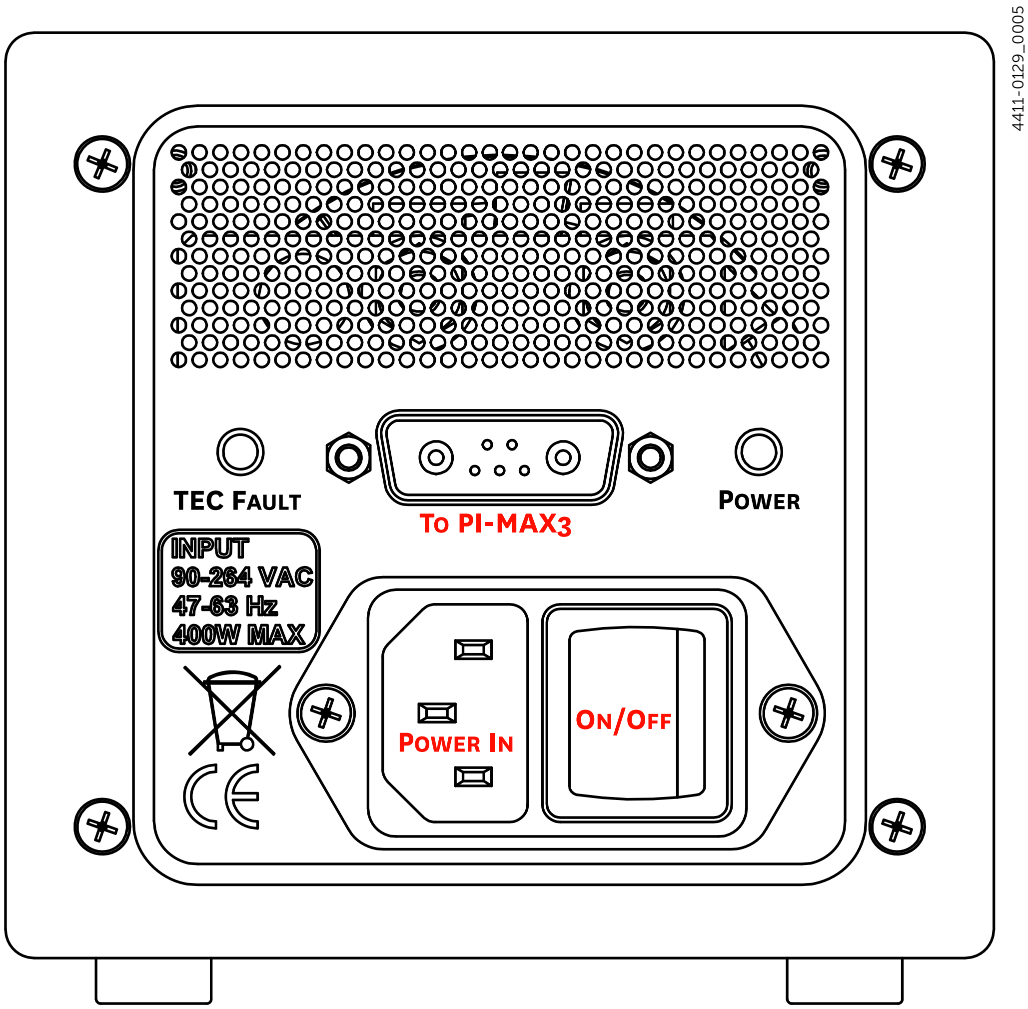
The receptacle on the power supply should be compatible with the line-voltage line cords in common use in the region to which the system is shipped. If the power supply receptacle is incompatible, a compatible adapter should be installed on the line cord, taking care to maintain the proper polarity to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

Figure 2-4 shows the connectors and indicators found on the rear of the PI-MAX3 power supply.

REFERENCES:

Refer to Section A.1.2, Power Requirements, on page 204 for complete voltage specifications.

Figure 2-4: PI-MAX3 **Power Supply Connectors and Indicators**



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

Table 2-2: PI-MAX3 **Power Supply Connectors and Indicators (Sheet 1 of 2)**

Label	Description
Power In	Line Input for the power supply,
TEC Fault	This Red LED is normally extinguished. When illuminated or flashing, this LED indicates a fault within the system has been detected.

Table 2-2: PI-MAX3 Power Supply Connectors and Indicators (Sheet 2 of 2)

Label	Description
Power LED	When illuminated, this Green LED indicates that the power supply is turned on. When extinguished, the power supply is turned off.
On/Off	Turns the power supply ON (**1**) and OFF (**0**).
To PI-MAX3	7-pin D specialty connector; connects to the PI-MAX3.

2.2 Application Software

Teledyne Princeton Instruments offers a number of data acquisition software packages for use with PI-MAX3 camera systems, including:

- LightField®

  The PI-MAX3 camera can be operated using LightField, Teledyne Princeton Instruments' 64-bit Windows® compatible software package.

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

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

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

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

NOTE:

PI-MAX3 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.

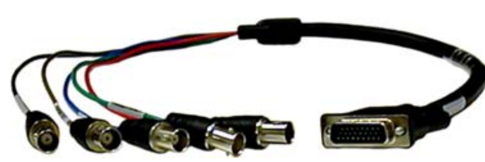
2.3 Optional Accessories

This section provides information about optional accessories that are available for the PI-MAX3 system.

2.3.1 Cables

Table 2-3 describes the cables that may be included with a PI-MAX3 Camera System.

Table 2-3: Standard PI-MAX3 **Camera System Cables**

Cable	Part Number	Description/Purpose	Length
Ethernet	6050-0621	CAT 5e/6 Ethernet cable for connecting the PI-MAX3 to the host computer. The distance between the camera and the computer can be over 50 meters. Contact the factory for longer cables.  4411-0129_0006	5 m [16.4 ft]
AUX I/O	6050-0660	Female DB26, high-density connector that connects to the AUX I/O connector. Provides access to five I/O signals via BNC connectors that can be used to input a trigger to initiate data acquisition, to monitor frame readout status, and to control an external shutter: • T_0 Out; • Pre-Trigger In; • SyncMASTER1; • General Purpose Input 0; • SyncMASTER2. Refer to Section A.1.1, AUX I/O Connector Pinout, on page 201 for additional information.  4411-0129_0007	Varies

NOTE:

Additional cables may be required depending upon system requirements.

2.3.2 CoolCUBE$_{II}$ Coolant Circulator

Liquid-cooled PI-MAX3 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 CoolCUBE$_{II}$ circulator unit continuously pumps the 50:50 mixture of room temperature (23°C) water and ethylene glycol.

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

2.3.3 Spectrograph

The PI-MAX3 camera system may also include a spectrograph. If so, the camera must be properly mounted to it as described in the manual supplied with the spectrograph.

If the spectrograph will be computer-controlled, a suitable interface cable will additionally be required.

Refer to Appendix G, Spectrograph Adapters, on page 227, for complete mounting information.

2.4 PI-MAX3 Camera and System Maintenance

WARNING!

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

2.4.1 Camera

Although there is no periodic maintenance that needs to be performed on a PI-MAX3 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.

2.4.2 Cleaning Optical Surfaces: Unigen™II Coating

For greater sensitivity, the PI-MAX3 camera with Unigen II coating comes without a protective window over the intensifier. Do not scratch the image intensifier's coated surface. To remove any lint or dust, use very clean dry nitrogen with < 5 PSI pressure. If you have any questions please contact your sales contact or the factory.

2.4.3 Cleaning Optical Surfaces: Protective Window

Optical surfaces may need to be cleaned 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.

2.4.4 Flushing and Refilling the CCD Chamber

CAUTION!
Under normal conditions the CCD chamber is sealed and backfilled so there is no danger of damage due to condensation.

CAUTION!
Operating a PI-MAX3 that is no longer backfilled with dry air or dry nitrogen may result in condensation on the array that could cause irreversible damage. Such damage would not be covered by the Warranty.

Before a PI-MAX3 camera leaves the factory, its CCD chamber is backfilled with clean dry air or dry nitrogen. For proper operation it is essential that the integrity of the front enclosure be maintained.

In normal operation, the CCD chamber should remain sealed for the life of the detector and should require no maintenance to assure integrity. If it should ever happen that the CCD chamber becomes unsealed, contact the factory and arrange to return the detector to the factory where it can be properly flushed, backfilled and resealed again. Refer to Contact Information on page 248 for complete information.

2.4.5 Repairs

Because the PI-MAX3 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 248 for complete information.

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

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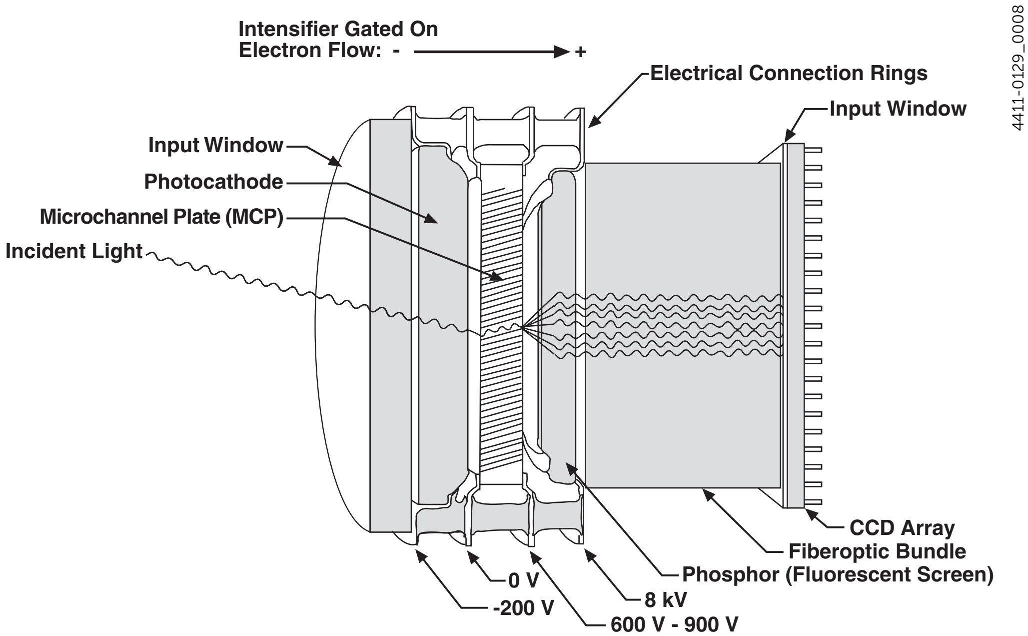
Chapter 3: PI-MAX3 Image Acquisition

This chapter provides a high-level overview of how PI-MAX3 acquires, transfers, and processes image data.

Figure 3-1 illustrates the primary components of an intensifier-CCD such as that incorporated into the PI-MAX3.

Figure 3-1: Primary Components of an Intensifier-CCD



In the PI-MAX3 camera, the input image is focused onto the photocathode of an image intensifier tube. The tube electronically amplifies the image and outputs it, much brighter, as gray-scaled green light. That light is then coupled to the CCD using a fused fiber-optic bundle from the output of the image intensifier to the front side of the CCD. The image at the output of the image intensifier is translated to the input of the CCD at the same size.[1] After being detected by the CCD, the image is read out to the internal controller, where it is digitized, and then transferred to the computer for processing via a high-speed data link.

1. Units having a tapered fiber optic bundle may also be available. Contact the factory for information.

3.1 Image Acquisition Process

This section describes the process by which photons are converted to data that can be displayed on a computer monitor.

NOTE:

For simplicity, triggers and gate pulses are not mentioned. It is assumed that a high speed (GigE) serial interface card is installed in the host computer.

When reading through the following steps, remember that electrons are attracted to more positively charged surfaces and are repelled by more negatively charged surfaces. This principal is used to control electron flow through the intensifier tube. Changing the photocathode voltage with respect to the voltage at the MCP input is used to switch (gate) the intensifier on and off.

1. Incident photons pass through the intensifier input window, strike the photocathode, and release electrons. (See Figure 3-1.)
2. Assuming that the intensifier is gated ON (the photocathode is more negative than the MCP input), these electrons will be attracted to the MCP input. Gating acts like a shutter in that gating the intensifier on allows the CCD to "see" light and gating the intensifier off prevents the CCD from seeing light.
3. Since the voltage at the MCP output is much more positive, most of the electrons accelerate into the MCP channels and, if they hit the channel walls, will generate additional electrons, resulting in electron gain. The amount of gain is adjusted by increasing or decreasing the voltage at the MCP output.
4. When the electrons exit the channels they are further accelerated by a constant high voltage (5-6 kV) and strike the phosphor coating on the fluorescent screen causing it to release photons. Because of the MCP gain, there are now many photons for each photon that struck the photocathode surface.
5. The photons released by the coating are transferred to the surface of the CCD (via fiberoptic or lens) and produce charge at the pixels they strike. Note that fiberoptic coupling is not only the most efficient coupling possible, but lens-coupling effects such as vignetting are eliminated.
6. Charge accumulates in the pixel wells until the intensifier is gated off (the photocathode is more positive than the MCP input).
7. At that point, the accumulated charge is shifted to the serial register where it is read out to an on-chip amplifier that converts the charge to an analog voltage.
8. This voltage is input to the selected analog-to-digital (A/D) converter(s) where it is digitally encoded. The conversion speed and the quality of the data are dependent on the effective ADC rate.
9. The digitized information is transmitted from the camera through the Ethernet cable to the interface card in the host computer where it is stored in RAM.
10. The application software retrieves the information from RAM, processes it, displays it, and/or stores it to a file according to user-defined settings.

Chapter 4: Installation Overview

Table 4-1 lists the sequence of actions required to install a PI-MAX3 system and prepare to gather data. Refer to the indicated references for additional information.

Refer to Section 4.1, System Block Diagrams, on page 37 for high-level block diagrams of typical system configurations.

Table 4-1: PI-MAX3 Installation Actions (Sheet 1 of 2)

Action	Refer to...
1. If the system components have not already been unpacked, unpack them and inspect their carton(s) and the system components for in transit damage.	Section 5.1, Unpack the System, on page 39.
2. Verify that all system components have been received.	Section 5.2, Examine Equipment and Verify Parts Inventory, on page 40.
3. If the camera will be used on a spectrograph, mount it to the equipment using the required adapter(s).	Section G, Spectrograph Adapters, on page 227.
4. If the appropriate interface card is not already installed in the host computer, install it and its drivers.	Host Computer Manual
5. If the application software is not already installed in the host computer, install it.	Section 5.4, Install Application Software, on page 42.
6. With the PI-MAX3 power supply and computer power turned OFF, connect the Ethernet cable (GigE) to the PI-MAX3 and the interface card in the host computer.	
7. Air-Cooled System: Plug the power supply into the rear of the camera and plug the power supply into the power source. Liquid-Cooled System: Make the hose and power connections to the camera and plug the circulator into the power source. Add coolant if necessary. Turn on the circulator.	Section 5.5, Connect PI-MAX3 to CoolCUBE$_{II}$, on page 45.
8. If the photocathode will be cooled, connect the supplied PVC tubing to the hose barb on the front of the camera and to a dry nitrogen source.	Section 5.6, Connect PI-MAX3 to Dry Nitrogen Source, on page 46.
9. Turn the PI-MAX3 power supply ON.	

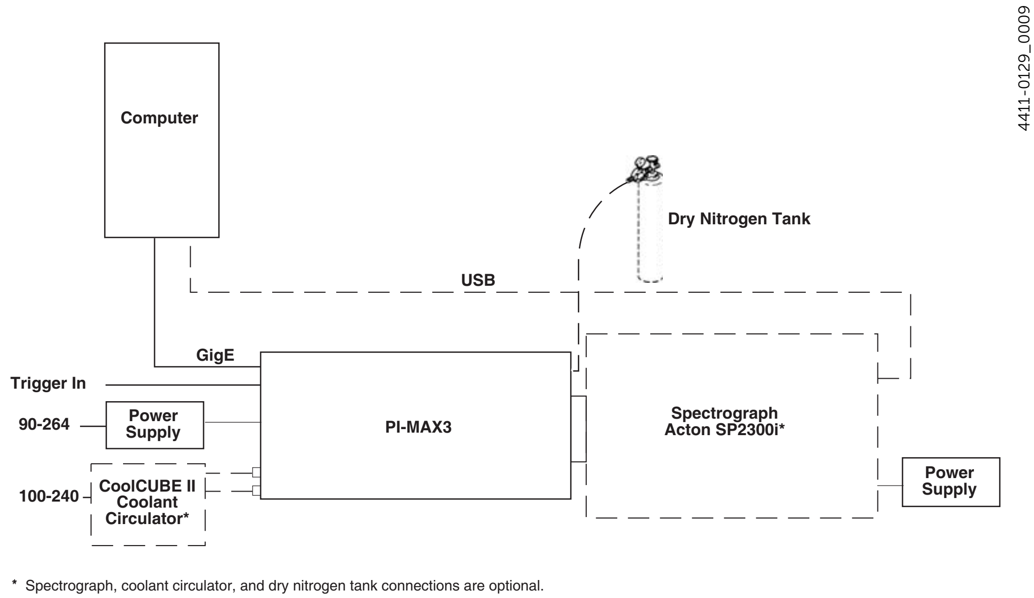
Table 4-1: PI-MAX3 Installation Actions (Sheet 2 of 2)

Action	Refer to...
10. Turn on the host computer and launch WinX/32 or LightField. When the host computer boots, you may be asked for the location of the interface drivers. WinX/32: If this is the first time you have used a WinX/32 application, the Camera Detection wizard will automatically run. This wizard retrieves information from the camera and enters this information as the default parameters for your system. LightField: When LightField boots, it will detect the camera and automatically place its icon in the Available Devices area. When you move that icon to the Experiment Devices area, the default parameters will automatically be loaded into the expanders.	 WinView/32 or WinSpec/32 manual LightField Online Help
11. Verify the hardware setup information or change the parameters, as appropriate. Enter the pulser information. Enter the experiment setup parameters. If using a spectrograph, enter or edit that setup information.	WinView/32 or WinSpec/32 manual LightField Online Help
12. Set the target array temperature. The typical target temperature is −25°C.	Section 7.5.2, Setting the Temperature, on page 70.
13. When the system reaches temperature lock, begin acquiring data in focus mode. • WinX/32 applications • LightField applications	 Section 6.1, WinX/32 First Light, on page 49 Section 6.2, LightField First Light, on page 58
14. Adjust the focus for the best image or spectral lines. • When using WinSpec/32, you may want to use the Focus Helper function for this purpose. • When using LightField, you may want to use the Align Spectrometer function.	Appendix E, Mounting and Focusing C- and F-Mount Lenses, on page 221. Appendix G, Spectrograph Adapters, on page 227

4.1 System Block Diagrams

This section provides typical system-level block diagrams.

Figure 4-1: Block Diagram: PI-MAX3



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Chapter 5: System Setup

This chapter provides information and procedures necessary to setup a PI-MAX3 system for both imaging and spectroscopic applications.

WARNING!

Voltages inside the PI-MAX3 may exceed 6,000 volts. To avoid possible hazard to personnel, use the instrument only according to the directions in this manual and only for the purposes for which it is designed. Never attempt to operate the PI-MAX3 with its covers removed.

CAUTION!

Image intensified detectors can be destroyed if exposed to excessive light levels. Teledyne Princeton Instruments cannot take responsibility for PI-MAX3 detector damage due to misuse.

Intensified cameras are particularly susceptible to overload damage when operated in conjunction with high-intensity light sources such as lasers. Spot damage can occur without the overload condition being detected.

NOTE:

Refer to Appendix A, Technical Specifications, on page 197 for information about system requirements, including environmental, storage, power, and minimum host computer requirements.

The PI-MAX3 has an audible alarm and shutdown circuit to bias the photocathode off if excessive photocathode current is detected. The circuit automatically resets and biases the photocathode back on after approximately 0.5 seconds. The short-term protection provided will not prevent intensifier damage if excessive light is allowed to continuously fall on the intensifier.

It is also possible for excessively bright spots to damage the intensifier tube without triggering the alarm.

5.1 Unpack the System

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

Save the original packing materials so you can safely ship the camera system to another location or return it to Teledyne Princeton Instruments for repairs if necessary.

5.2 Examine Equipment and Verify Parts Inventory

Verify that all equipment and parts necessary to set up the PI-MAX3 have been received. A typical system consists of:

- PI-MAX3 camera (Gen II or Filmless Gen III);
- PI-MAX3 power supply;
- Timing Generator;
  Integrated into the PI-MAX3
- Accessory Kit
  Includes:
  - Light Table Mount Extender;
  - AUX I/O Cable;
  - PVC tubing;
  - Double-ended Screwdriver with Magnetic top;
  - Two Adapter Mounts;
    C mount, F-mount, and spectroscopy mounts are supplied, one of which has been factory installed).
- GigE Computer Interface
- Host Computer (customer supplied);
- WinView/32, WinSpec/32, or LightField CD-ROM;
- User Manuals;
- Interface Dependent Components:
  - Computer Interface GigE cable
    Standard Ethernet Cable, 5 m (P/N: 6050-0621).
    Additional lengths up to 100 m are available.
  - Interface Card
    User-provided GigE interface card. (Intel Pro1000 recommended).
- System Dependent Components:
  - CoolCUBE$_{II}$ Coolant Circulator;
  - Coolant Tubing.

If there are any problems, contact the Teledyne Princeton Instruments Customer Support. Refer to Contact Information on page 248 for complete information.

5.3 Mount the PI-MAX3

This section provides information about mounting the PI-MAX3 for both Imaging and Spectroscopy Applications.

5.3.1 Imaging Applications

The PI-MAX3 is supplied with the lens mount specified when the system was ordered. This is typically either a screw-type C-mount lens or a bayonet type F-mount lens which allows a lens of the corresponding type to be mounted quickly and easily.

The installed mount is secured by four (4) Phillips head screws which must be removed to change mounts.

REFERENCES:

For information about changing mounts and focusing the system, refer to:

- Appendix E, Mounting and Focusing C- and F-Mount Lenses, on page 221;
- Appendix F, C-, F-, and Spectroscopy- Mount Adapters, on page 223;
- Appendix G, Spectrograph Adapters, on page 227.

The PI-MAX3 can be mounted at any attitude or angle but additional camera support may be required.

The camera can rest on any secure surface. However, take care not to block the ventilation openings.

CAUTION!

Cameras equipped with F-mount must never be mounted with the camera nose-up where the lens mount would be required to support the camera's weight. The F-mount is not designed to sustain the weight of the camera in this orientation and the camera could pull free.

Always provide additional support for the camera.

When the camera must be mounted in a nose-up position beneath a table, take care to protect the mounting components from lateral stresses, such as might occur should someone accidentally bump the camera with a knee while working at the table. One solution to this problem would be to install a barrier between the camera and operator to prevent any accidental contact.

There are no special constraints on nose-down operation. Again, however, good operating practice might make it advisable to take steps to prevent accidental contact from unduly stressing the mounting components. Be sure liquid connections do not leak in this orientation.

CAUTION!

Always begin with the lens stopped all the way down (i.e., the largest f/stop number,) to minimize the risk of overloading the intensifier.

5.3.2 Spectroscopy Applications

The PI-MAX3 detector must be properly mounted to the spectrograph to achieve the highest resolution. When oriented properly the text on the back of the detector should be right side up

Take care not to block the ventilation openings.

For additional information, refer to Section G.2, PI-MAX3 (3.60" 3-Hole Slotted Flange) to Teledyne Acton Research Series Spectrograph, on page 231.

5.4 Install Application Software

This section provides the procedures to install the application software.

5.4.1 Install WinX/32

NOTES:

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

Perform the following procedure to install WinView/32 or WinSpec/32 application software:

1. Insert the installation CD into the CD drive on the host computer.

   The Installation Wizard will automatically launch.
2. When the **Select Installation Type** dialog is displayed, select the desired type of installation.
   - Typical

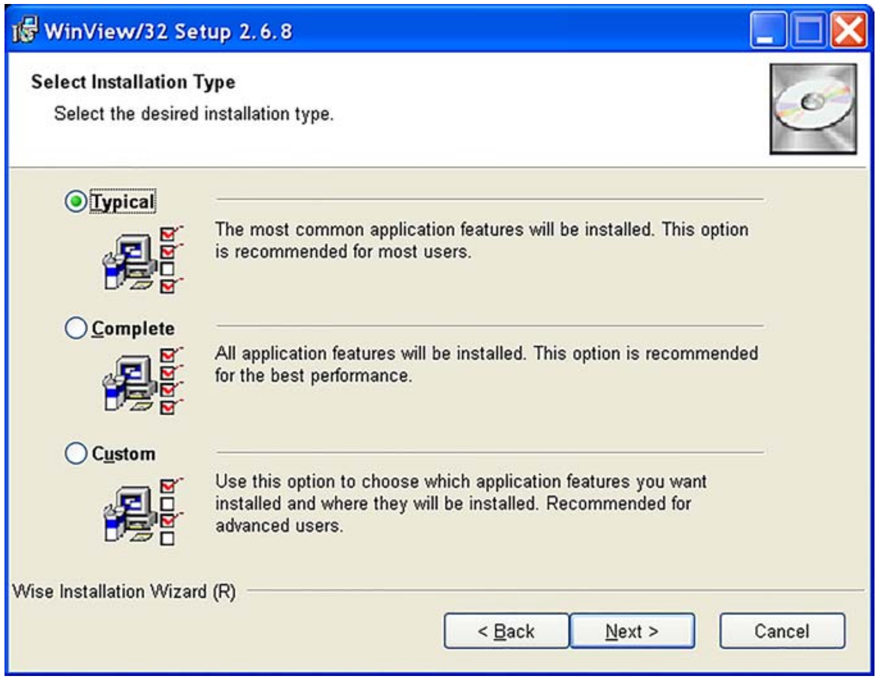
     Installs the required drivers and the most commonly installed program files.
   - Complete

     Installs all application features.
   - Custom

     Allows the customer to select which program files, options, and drivers to install.

   Figure 5-1 illustrates a typical WinView/32 Setup dialog.

Figure 5-1: Typical WinView/32 Setup Dialog: Select Installation Type



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3. Click **Next >** to proceed with the installation. Follow all on-screen prompts.
4. Once the installation has been completed, 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 GigE card.

REFERENCES:

For additional information, refer to Section 6.1, WinX/32 First Light, on page 49.

5.4.2 Install LightField

NOTES:

1. Install the GigE Adapter card before installing the LightField application software.
2. Verify the operating system for the host computer is 64-bit Windows Vista or 64-bit Windows 7.
3. Verify the host computer is connected to the Internet. Internet connectivity is required for product activation.

Perform the following procedure to install LightField application software:

1. Insert the installation CD into the CD drive on the host computer. The **Installation Wizard** will automatically launch. See Figure 5-2.

Figure 5-2: Typical LightField Installation Wizard Dialog

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2. After the installation finishes, reboot the host computer.
3. Connect the PI-MAX3 system components to the host computer and turn them on.
4. Launch LightField, activate it, and begin experiment configuration.

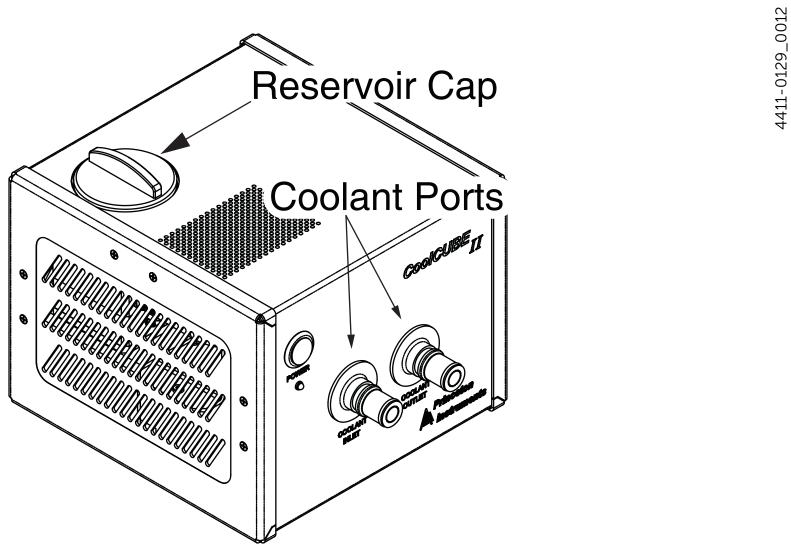
REFERENCES:

For additional information, refer to Section 6.2, LightField First Light, on page 58.

5.5 Connect PI-MAX3 to CoolCUBE$_{II}$

For liquid-cooled PI-MAX3 cameras, the CoolCUBE$_{II}$ circulator provides a vibration-free method of heat removal. Figure 5-3 illustrates a typical CoolCUBE$_{II}$ circulator.

Figure 5-3: Typical CoolCUBE$_{II}$ Coolant Circulator



Perform the following procedure to connect the PI-MAX3 to the CoolCUBE$_{II}$:

1. Verify the camera and circulator power switches are turned off.
2. Verify the circulator is a minimum of 6 inches [150 mm] below the PI-MAX3.
   The vertical distance should not exceed 10 feet [3 m.]
   Typically, the camera is at table height and the circulator is on the floor.
3. Make the coolant connections between the circulator and the camera.
   It does not matter which hose from the circulator is plugged into which coolant port on the camera.
   It is recommended that hoses be secured to the camera hose barbs with the clamp supplied.

NOTES:

1. Verify there are no kinks in the hoses that impede the coolant flow. Lack of sufficient flow can seriously harm the detector and any resulting damage is not covered under warranty.
2. Damage caused by water leaking into the PI-MAX3 voids the warranty.

4. Unscrew the reservoir cap on top of the CoolCUBE$_{II}$ and 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 on the CoolCUBE$_{II}$.
6. Plug the CoolCUBE$_{II}$ into a 100-240 V_{AC}, 47-63 Hz power source.

7. Turn the CoolCUBE$_{II}$ on.

   Verify 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$_{II}$ particularly at start up and do not prevent proper operation

   - If there are no problems, proceed to step 8.
   - If there are leaks or air bubbles:
     a. Turn the CoolCUBE$_{II}$ off.
     b. Correct any problem(s) by securing the hoses or adding more coolant to the reservoir.
     c. Turn the CoolCUBE$_{II}$ back on.
     d. Recheck for leaks and/or air bubbles.
     e. If there are no problems, proceed to step 8.
8. Turn on the PI-MAX3.
9. Launch the application software.

5.6 Connect PI-MAX3 to Dry Nitrogen Source

Equivalent Background Illumination (EBI) can impose limitations on ultra-low-light or photon-counting applications. Reduction of EBI can be achieved by directly cooling the photocathode via a dry nitrogen source.

Perform the following procedure to connect the PI-MAX3 to a dry nitrogen source:

1. Remove the 3 foot [0.9 m] clear PVC tubing from the Accessory Kit.
2. Slip one end of the tubing on the plastic hose barb on the front of the PI-MAX3.
3. Connect the other end to a source of dry nitrogen.

5.7 Configure Default System Parameters

This section provides information about configuring default system parameters in both WinX/32 and LightField.

5.7.1 WinX/32 Applications (Version 2.5.25.X and Higher)

Perform the following procedure to configure default PI-MAX3 system parameters when using WinX/32:

1. Verify the PI-MAX3 is connected to the host computer and that its power supply is turned on.
2. Launch the WinX/32 application.

   The **Camera Detection Wizard** will automatically run if this is the first time a Teledyne Princeton Instruments application has been installed (i.e., WinView/32, WinSpec/32, ore WinXTest/32,) and a supported camera is attached.

   Otherwise, when installing a new camera type, click on the **Launch Camera Detection Wizard...** on the Controller/CCD tab to start the wizard.

3. On the **Camera Detection Wizard — Welcome** dialog, the checkbox should remain unchecked. See Figure 5-4.

   Click **Next >**.

Figure 5-4: Typical Camera Detection Wizard — Welcome Dialog

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4. Follow on-screen prompts to complete the initial hardware setup.

   The **Camera Detection Wizard** automatically enters default parameter values on the Hardware Setup dialog tabs.

   It then provides the opportunity to acquire a test image to confirm the system is working properly.

   REFERENCES:

   For a step-by-step procedure about basic system setup and operation, refer to Section 6.1, WinX/32 First Light, on page 49.

5.7.2 LightField Applications

Perform the following procedure to configure default PI-MAX3 system parameters when using LightField:

1. Verify the PI-MAX3 and spectrograph (when using a spectroscopy system,) are connected to the host computer, and the PI-MAX3's and spectrograph's power supplies are turned on.
2. Launch LightField.

   As LightField starts, it detects available device(s) and places appropriate icons in the **Available Devices** area on the **Experiment** workspace.
3. Once LightField has finished booting, drag a desired icon into the **Experiment Devices** area.

   The appropriate expanders will be loaded into the **Experiment Settings** stack on the left-hand side of the window.

   Default system parameters will automatically be configured.

REFERENCES:

For a step-by-step procedure about basic system setup and operation, refer to Section 6.2, LightField First Light, on page 58.

Chapter 6: First Light

This chapter provides step-by-step procedures for placing a PI-MAX3 system in operation for the first time using WinX/32 and LightField.

To minimize setup complexity, the following procedures are configured using:

- Imaging Mode;
- SuperSYNCHRO Internal Trigger Mode.

Setup can be performed under normal lighting.

Since these First Light procedures do not require a spectrograph, information pertaining to the cabling and mounting of a spectrograph is omitted,.

REFERENCES:

Information that may be of importance with some applications is omitted in this chapter for the sake of brevity.

- Refer to Chapter 7, Operation, on page 63 for information about the general operation and configuration of the PI-MAX3;
- Refer to Chapter 8, WinX/32 and Gated Operation, on page 97 for information about configuring Gating with WinX/32;
- Refer to Chapter 9, LightField and Gated Operation, on page 125 for information about configuring Gating with LightField.

6.1 WinX/32 First Light

This section provides the step-by-step procedure for acquiring an imaging measurement in WinX/32 for the first time. 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.

6.1.1 Required Equipment

The following items are required to operate the PI-MAX3 camera system in accordance with the procedure in this section:

- Teledyne Princeton Instruments PI-MAX3 camera with C-mount adapter;
- PI-MAX3 power supply;
- User-supplied C-mount lens with smallest aperture of f/16 or f/22;
- Host Computer equipped with a GigE Ethernet interface card;
- Standard Ethernet cable;
- WinX/32 Application Software.

6.1.2 Procedure

This procedure assumes:

- The PI-MAX3 system has been set up according to prior chapters;
- Prior sections of this chapter have been read;
- Familiarity with the WinX/32 software;
- The PI-MAX3 camera is being operated in imaging mode;
- The target that is being used is a sharp image, text, or a drawing that can be used to verify that the PI-MAX3 is seeing and can be used to maximize focus.

NOTE:

This procedure is based on WinX/32 software. Basic familiarity with the software is assumed. If this is not the case, you may want to review the software manual or have it available while performing this procedure.

Perform the following procedure to configure the PI-MAX3 system to acquire an image with WinX/32 in Gating Mode for the first time:

WARNING!

All system components must be turned off before connecting or disconnecting cables.

1. Connect the PI-MAX3 power supply to:
   - The rear of the PI-MAX3;
   - An AC power source.
2. Connect one end of the GigE cable (P/N: 6050-0621) to the PI-MAX3 GigE connector and the other end to the host computer's GigE Interface card connector.
3. Set the PI-MAX3 I.I.T. On/Off switch to off
4. Confirm that only room light will be present.
5. If a C-mount adapter is not on the camera, refer to Appendix F, C-, F-, and Spectroscopy- Mount Adapters, on page 223 for complete information about installing it.
6. When the C-mount adapter is in place, screw in the lens and set it to the smallest aperture (i.e., f/16 or f/22.)
7. Place a suitable target (i.e., a non-light source,) approximately 9 inches in front of the camera.

CAUTION!

Verify the lens has been stopped all the way down (i.e., the largest f/ stop number,) to minimize the risk of overloading the intensifier.

8. Turn on the PI-MAX3 power supply.

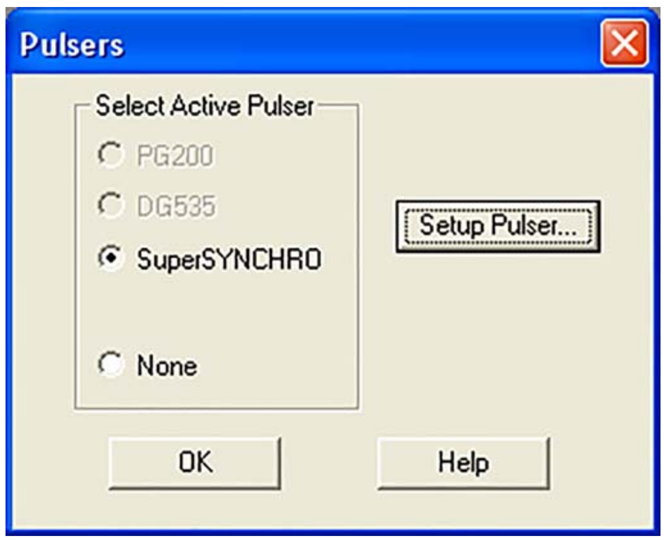
NOTE:

The PI-MAX3 overload alarm may sound briefly and then stop. This is normal and is not a cause for concern.

However, if the alarm sounds continuously, even when there is no light entering the camera/spectrograph, there is something wrong. Turn off all power and contact Teledyne Princeton Instruments Customer Service for assistance. Refer to Contact Information on page 248 for complete information.

9. Turn on the host computer.
10. Launch WinX/32.
11. From the **Setup** menu, select **Pulsers** to display the Pulsers dialog. See Figure 6-1.

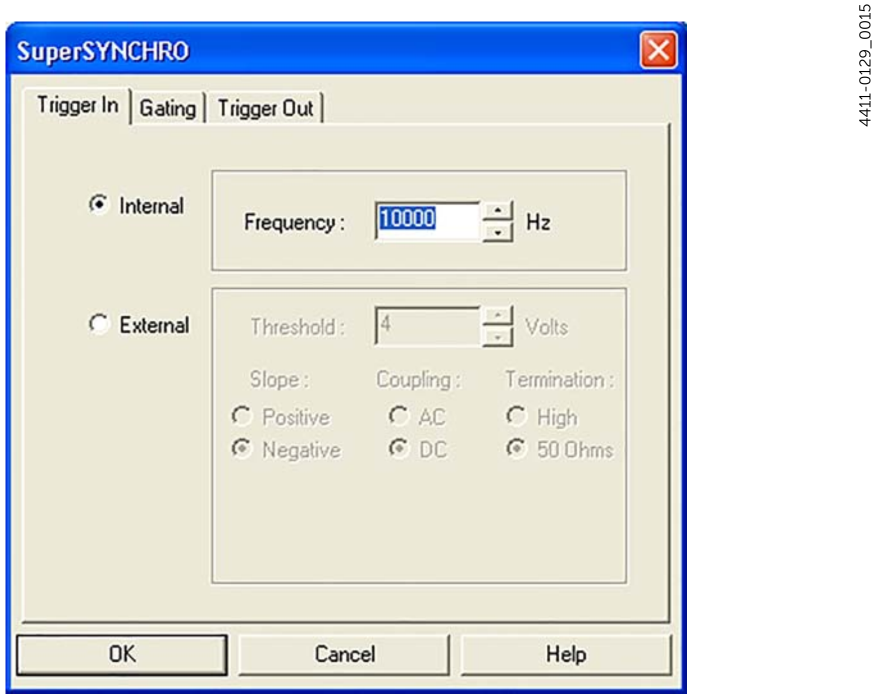
Figure 6-1: Typical WinX/32 Setup ► Pulsers Dialog



12. On the **Pulsers** dialog, select **SuperSYNCHRO** and then click on the **Setup Pulser...** button to display the SuperSYNCHRO dialog.

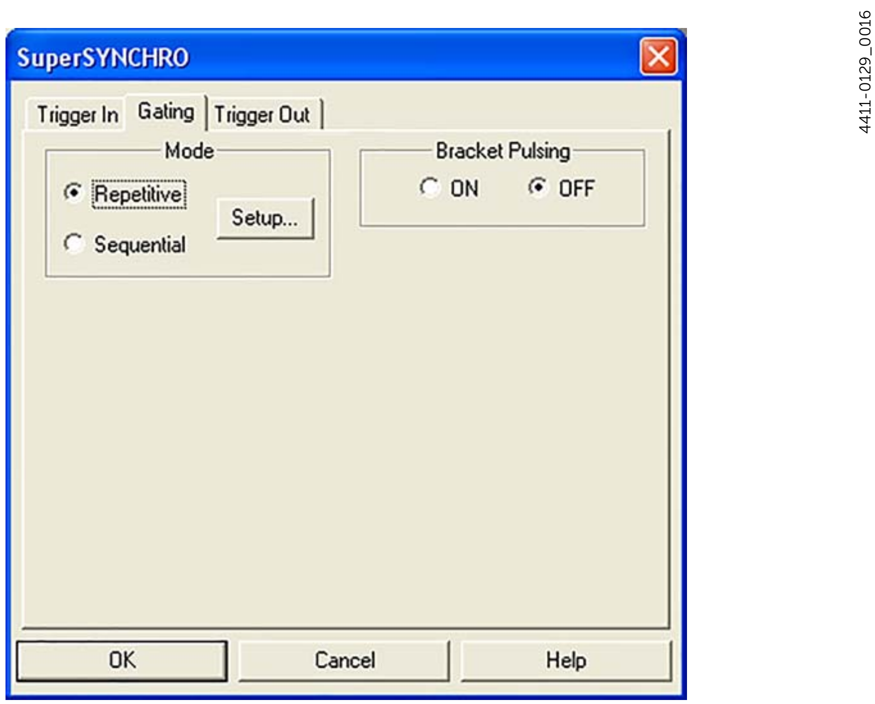
13. On the **SuperSYNCHRO ► Trigger In** tab, confirm that **Internal** is selected and that the Frequency is 10000 Hz. See Figure 6-2.

Figure 6-2: Typical WinX/32 SuperSYNCHRO ► Trigger In Tab Dialog



14. Click on the **Gating** tab, select **Repetitive** and click **Setup...**. See Figure 6-3.

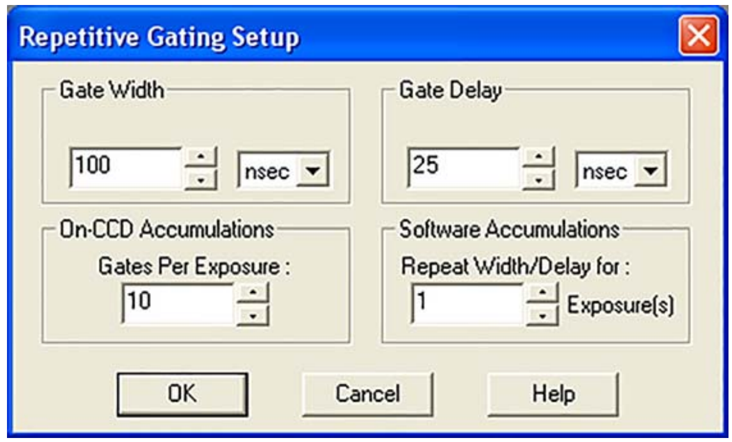
Figure 6-3: Typical WinX/32 SuperSYNCHRO ► Gating Tab Dialog



15. On the **Repetitive Gating** Setup dialog, configure the following parameters as indicated:
    - **Gate Width**: 50 ms;
    - **Gate Delay**: 10 ns;
    - **Gates Per Exposure**: 1;
    - **Repeat Width/Delay** for: 1.

    See Figure 6-4.

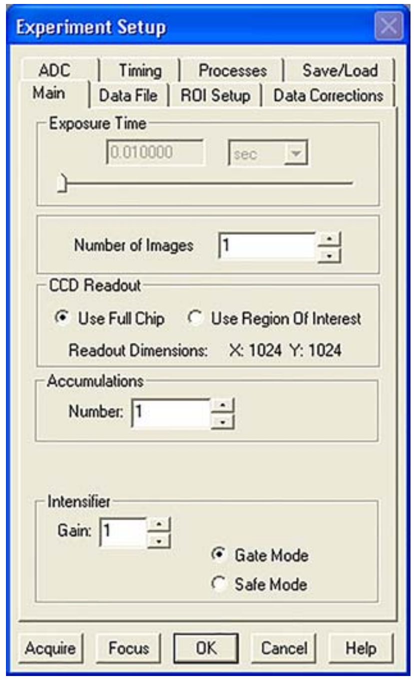
Figure 6-4: Typical WinX/32 Repetitive Gating Setup Dialog



16. Click **OK**.
17. From the **Acquisition** ► **Experiment Setup** ► **Main** tab, configure the following parameters as indicated:
    - **CCD Readout**: Use Full Chip;
    - **Intensifier** Section:
      - **Gain**: 1;
      - **Gate Mode**: selected.

    See Figure 6-5.

Figure 6-5: Typical WinX/32 Experiment Setup ► Main Tab Dialog



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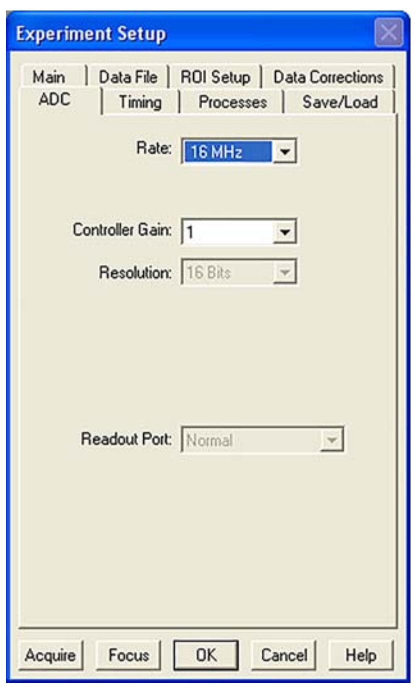
18. Click on the **ADC** tab to configure the **Rate** as indicated based on CCD type:
    - **Kodak 1024 x 1024**: 16 MHz;
    - **CCD30-11**: 1 MHz.

    See Figure 6-6.

Figure 6-6: Typical WinX/32 Experiment Setup ► ADC Tab Dialog



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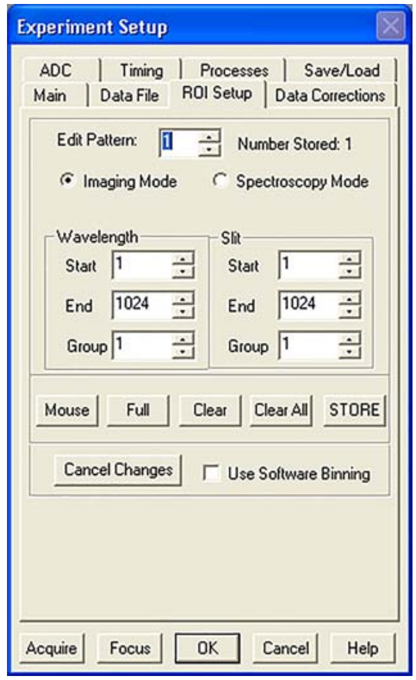
19. When using WinSpec/32, go to the **Experiment Setup** ► **ROI Setup** tab and select **Imaging Mode**. See Figure 6-7.

Figure 6-7: Typical WinX/32 Experiment Setup ► ROI Setup Tab Dialog



4411-0129_0020

20. Click **OK** to save all parameter settings and dismiss the dialog.
21. Verify that room or ambient lighting is subdued.
22. Set the PI-MAX3 I.I.T switch to on.

NOTE:

The PI-MAX3 overload alarm may sound briefly and then stop. This is normal and is not a cause for concern.

However, if the alarm sounds continuously, even when there is no light entering the camera/spectrograph, there is something wrong. Turn off all power and contact Teledyne Princeton Instruments Customer Service for assistance. Refer to Contact Information on page 248 for complete information.

23. From the host computer, click on the **ACQ** button  or select **Acquisition** ► **Acquire** from the WinX/32 menu bar.

    Data acquisition will begin and an acquired image will be displayed on the computer monitor.

    See Figure 6-8.

Figure 6-8: Typical WinX/32 First Light Acquired Image

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If no image is displayed, check the software settings.

24. If an image is displayed, you have confirmed that the PI-MAX3 can acquire an image.

    If the image is out of focus, reposition the target and/or rotate the lens. Click on **Acquire** to confirm that the degree of focus has changed.

REFERENCES:

For additional information about focusing the PI-MAX3 system, refer to:

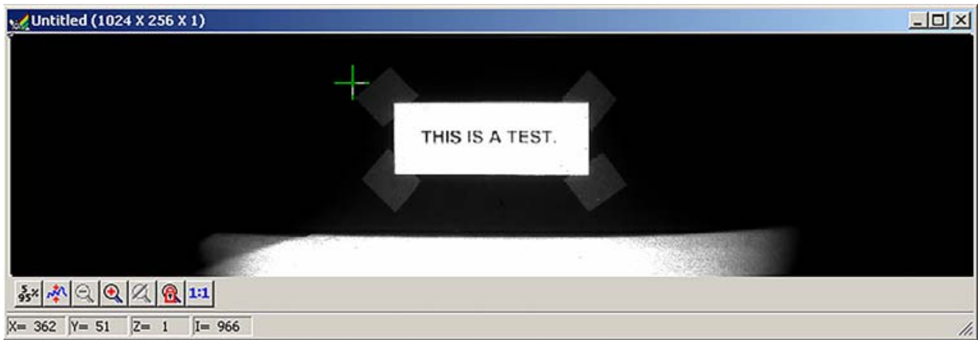
- Appendix E, Mounting and Focusing C- and F-Mount Lenses, on page 221;
- Appendix G, Spectrograph Adapters, on page 227.

Images acquired with an older PI-MAX3: 1024 x 256 camera may be upside down, similar to the image shown in Figure 6-8. When this occurs, there are two solutions:

- Physically invert the camera;
- Change the image orientation via Reverse and Flip configuration parameters found on the **Setup** ► **Hardware** ► **Hardware Setup** ► **Display** tab.

  See Figure 6-9 for the resulting updated image.

Figure 6-9: Typical WinX/32 First Light Acquired Image, Reversed/Flipped



4411-0129_0022

25. Once it has been confirmed that PI-MAX3 is acquiring images properly, turn the PI-MAX3 I.I.T. switch to off.
26. Close the WinX/32 application.
27. If the PI-MAX3 will not be used with the lens, replace the C-mount lens with the screw-in dust cover provided with the C-mount adapter.

    If a different adapter will be used, install the desired adapter. Refer to Appendix F, C-, F-, and Spectroscopy- Mount Adapters, on page 223 for complete information.

NOTE:

Always use the adapter's dust cover whenever the PI-MAX3 is not being used.

6.2 LightField First Light

This section provides the step-by-step procedure for acquiring an imaging measurement in LightField for the first time. 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.

6.2.1 Required Equipment

The following items are required to operate the PI-MAX3 camera system in accordance with the procedure in this section:

- Teledyne Princeton Instruments PI-MAX3 camera with C-mount adapter;
- PI-MAX3 power supply;
- User-supplied C-mount lens with smallest aperture of f/16 or f/22;
- Host Computer equipped with a GigE Ethernet interface card;
- Standard Ethernet cable;
- LightField Application Software.

6.2.2 Procedure

This procedure assumes:

- The PI-MAX3 system has been set up according to prior chapters;
- Prior sections of this chapter have been read;
- Familiarity with the LightField software;
- The PI-MAX3 camera is being operated in imaging mode;
- The target that is being used is a sharp image, text, or a drawing that can be used to verify that the PI-MAX3 is seeing and can be used to maximize focus.

NOTE:

This procedure is based on LightField. Basic familiarity with the LightField software is assumed. If this is not the case, you may want to refer to the online help system while performing this procedure.

Perform the following procedure to configure the PI-MAX3 system to acquire an image with LightField for the first time:

WARNING!

All system components must be turned off before connecting or disconnecting cables.

1. Connect the PI-MAX3 power supply to:
   - The rear of the PI-MAX3;
   - An AC power source.
2. Connect one end of the GigE cable (P/N: 6050-0621) to the PI-MAX3 GigE connector and the other end to the host computer's GigE Interface card connector.
3. Set the PI-MAX3 I.I.T. On/Off switch to off
4. Confirm that only room light will be present.
5. If a C-mount adapter is not on the camera, refer to Appendix F, C-, F-, and Spectroscopy- Mount Adapters, on page 223 for complete information about installing it.

6. When the C-mount adapter is in place, screw in the lens and set it to the smallest aperture (i.e., f/16 or f/22.)
7. Place a suitable target (i.e., a non-light source,) approximately 9 inches in front of the camera.

CAUTION!

Verify the lens has been stopped all the way down (i.e., the largest f/ stop number,) to minimize the risk of overloading the intensifier.

8. Turn on the PI-MAX3 power supply.

NOTE:

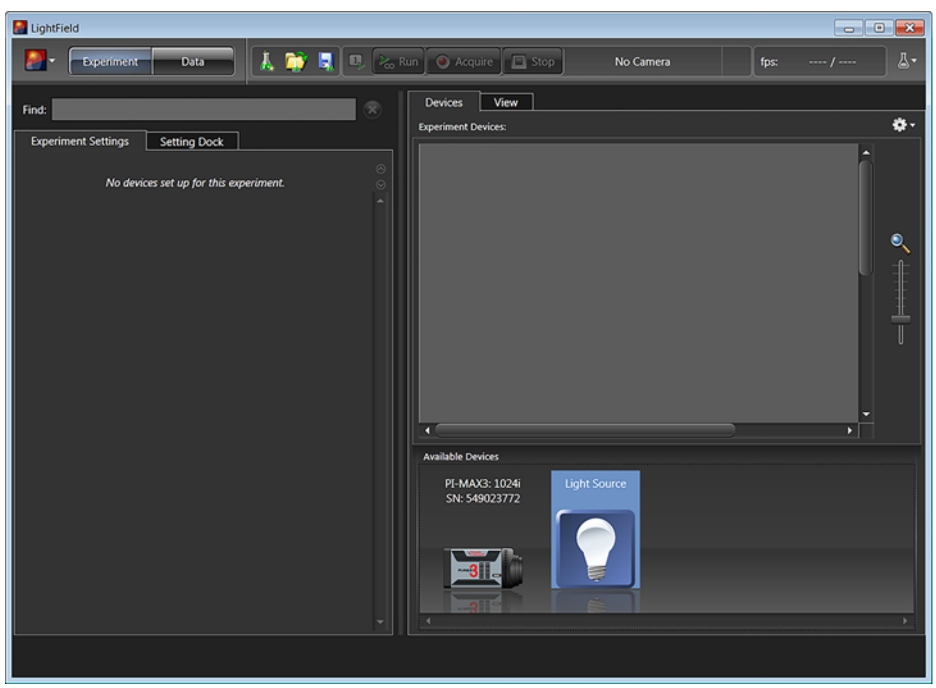
The PI-MAX3 overload alarm may sound briefly and then stop. This is normal and is not a cause for concern.

However, if the alarm sounds continuously, even when there is no light entering the camera/spectrograph, there is something wrong. Turn off all power and contact Teledyne Princeton Instruments Customer Service for assistance. Refer to Contact Information on page 248 for complete information.

9. Turn on the host computer.
10. Launch LightField.

    The **Experiment Workspace** will be displayed with an icon representing the PI-MAX3 included in the **Available Devices** area. See Figure 6-10.

Figure 6-10: Typical LightField Available Devices Area



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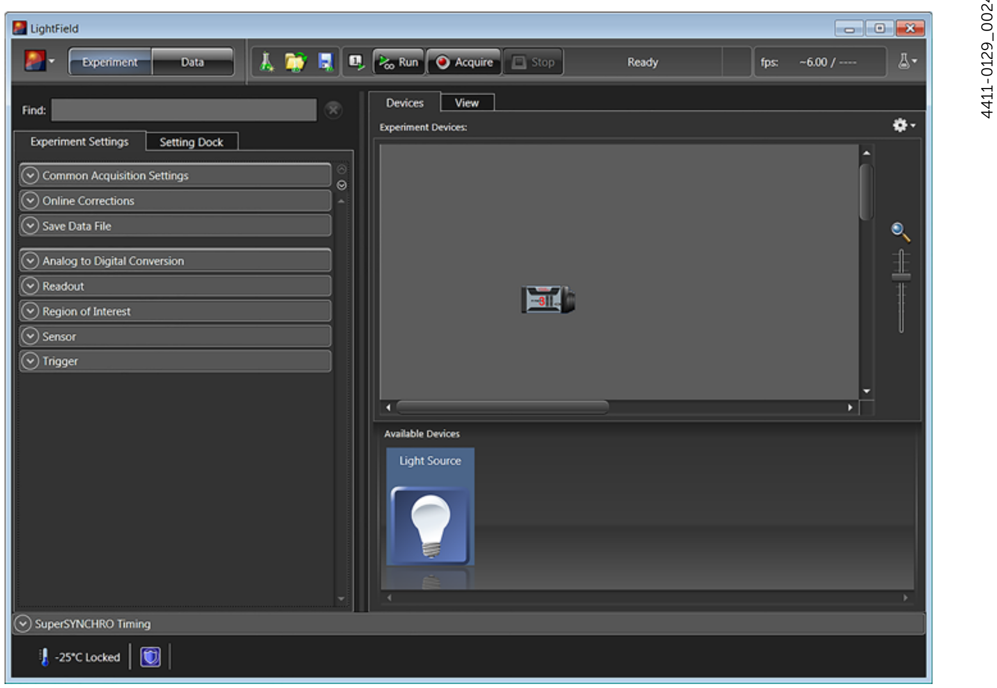
11. Drag the icon representing the PI-MAX3 into the **Experiment Devices** area. See Figure 6-11.

Figure 6-11: Typical LightField Experiment Devices Area with PI-MAX3



The **Experiment Settings** stack on the left now displays several expanders, including the **SuperSYNCHRO Timing** expander, just above the **Status** bar at the bottom of the workspace. Because this is a new experiment, the default parameter values for the PI-MAX3 will be configured.

The **Status** bar displays icons for **Temperature Status** and **Intensifier Status**:

- Temperature Status reports the current temperature and whether the set temperature has been reached.
- Intensifier Status reports whether or not the **I.I.T. Power** switch on the rear of the PI-MAX3 is turned on and whether the **Enable Intensifier** check box is checked.

Clicking on either of these icons opens a panel where you can view more information about the status and/or click on a hyperlink to access the expander where status affecting changes can be made.

12. If the camera in use is a PI-MAX3: 1024 x 256 that was manufactured prior to January, 2012, perform these additional steps:
    a. Open the **Online Corrections** expander.
    b. Click on the bottom button on the **Orientation** image.
       The icon will rotate 180°. See Figure 6-12.

Figure 6-12: Typical LightField Online Corrections ► Orientation Indicator

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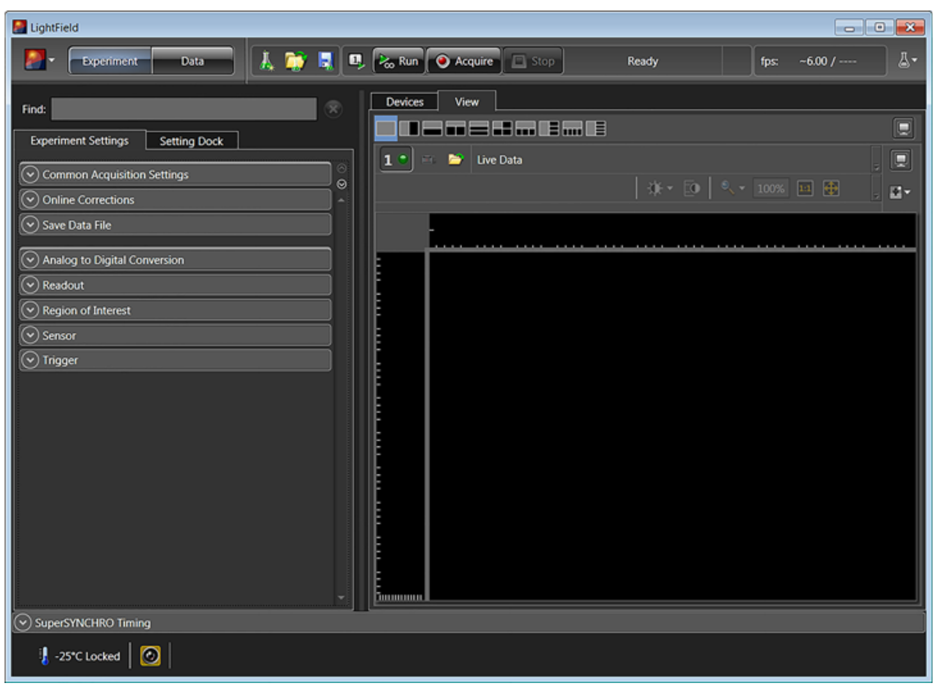
Unless changes are made to the orientation or a new experiment is created, data will be displayed correctly.

NOTE:

A new experiment resets all camera parameters to their default settings. Therefore, the orientation for a PI-MAX3: 1024 x 256 camera must be corrected whenever a new experiment is created.

13. Verify the **I.I.T. Power** switch on the rear of the PI-MAX3 is in the on position.
14. Verify **Enable Intensifier** is selected on the **Common Acquisition Settings** expander.
15. Click on the **View** tab located above **Experiment Devices**. See Figure 6-13.

Figure 6-13: Typical LightField Experiment Workspace ► View Tab



4411-0129_0026

16. Click on the **Acquire** button  to start Acquire mode. See Figure 6-14.
    - If an image is displayed, you have confirmed that the PI-MAX3 can acquire an image;
    - If the image is out of focus, reposition the target and/or rotate the lens and click on **Acquire** to confirm that the focus has changed;

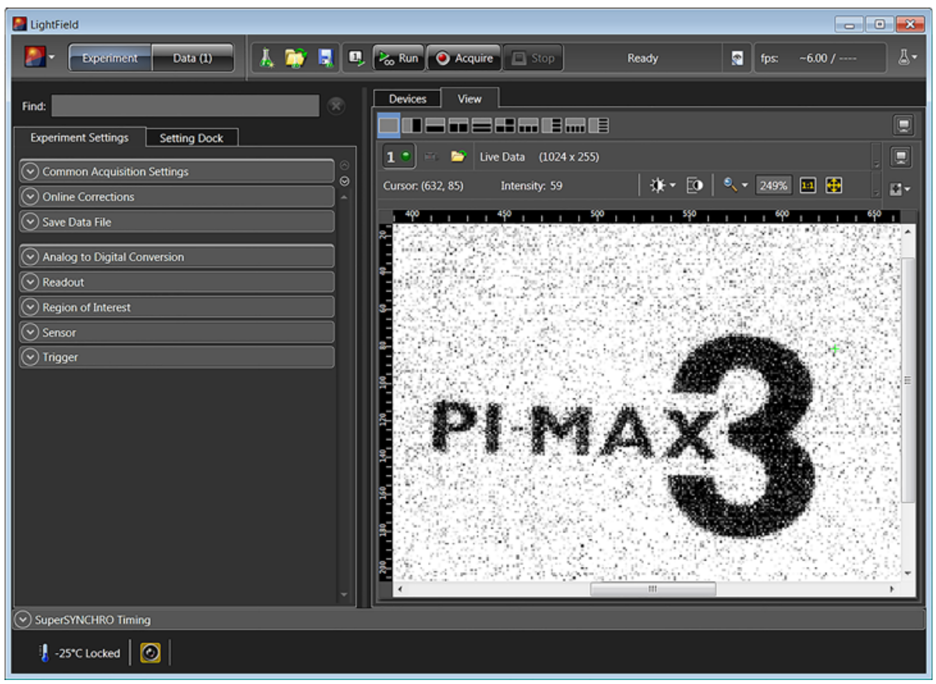
REFERENCES:

For additional information about focusing the PI-MAX3 system, refer to:

- Appendix E, Mounting and Focusing C- and F-Mount Lenses, on page 221;
- Appendix G, Spectrograph Adapters, on page 227.

    - If the image is upside down, you need to change the orientation via the **Online Corrections** expander.

Figure 6-14: Typical LightField View Tab with Image



4411-0129_0027

17. Once it has been confirmed that PI-MAX3 is acquiring images properly, turn the PI-MAX3 I.I.T. switch to off.
18. Close the WinX/32 application.
19. If the PI-MAX3 will not be used with the lens, replace the C-mount lens with the screw-in dust cover provided with the C-mount adapter.

    If a different adapter will be used, install the desired adapter. Refer to Appendix F, C-, F-, and Spectroscopy- Mount Adapters, on page 223 for complete information.

NOTE:

Always use the adapter's dust cover whenever the PI-MAX3 is not being used.

Chapter 7: Operation

This chapter provides general operation factors that apply to Gate Mode operation of the PI-MAX3 system. The following factors play a part before, during, and after the exposure and readout of the CCD array:

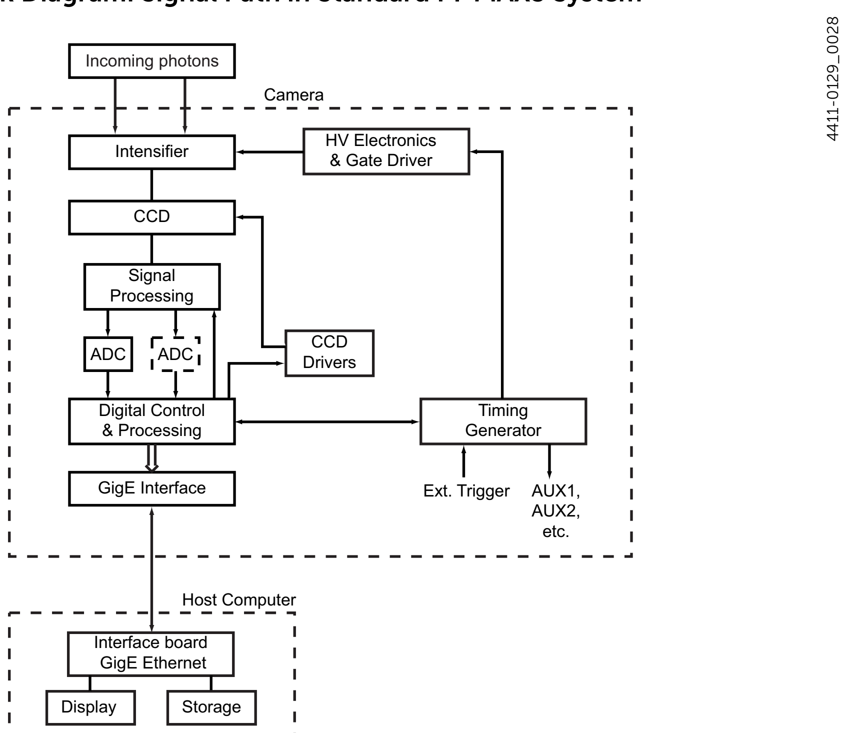
- Dark Charge;
- Clean Cycles,
- Continuous Cleans;
- Exposure Modes;
- Readout;
- Digitization;
- Software binning;
- Background Subtraction.

Factors specific to an intensifier mode and pulser are discussed in the appropriate chapter.

7.1 Data Acquisition Sequence

When data are acquired, the CCD array is exposed to an incoming signal which integrates on the array. At the end of the exposure which may include multiple gates the charge from the array pixels must be read out, digitized, and transferred to the host computer before the image from the array appears on the computer screen. This is illustrated in Figure 7-1.

Figure 7-1: Block Diagram: Signal Path in Standard PI-MAX3 System



7.2 WinX/32 System On/Off Sequences

The following on/off sequences are specific to WinX/32 and the Ethernet interface:

- Power On Sequence

  The PI-MAX3 power supply must be turned on before the WinX/32 application software (WinView/32 or WinSpec/32) is opened to ensure communication between the controller and the computer. If the WinX/32 application is opened and the PI-MAX3 power supply is off, many of the functions will be disabled and you will only be able to retrieve and examine previously acquired and stored data. You must close the WinX/32 application software, turn on the power supply, and reopen the WinX/32 application software before you can set up experiments and acquire new data.
- Power Down Sequence

  The WinX/32 application software must be closed before turning off the power supply. If you turn off the power supply before closing the WinX/32 application software, the communication link with the PI-MAX3 will be broken. You can operate the program in a playback mode (i.e., examine previously acquired data) but will be unable to acquire new data until you have closed the WinX/32 application software, turned on the power supply, and then re opened the WinX/32 application software.

7.3 Pre-Exposure Removal of Accumulated Charge

The purpose of the CCD array is to acquire a signal of interest that can then be digitized and transmitted to the host computer for storage, display, and post-processing. It will acquire signal whenever the camera has power, whether or not the intensifier is being gated to take an exposure. If the intensifier is off, dark charge will be the main source of signal accumulation on the array. To counteract this, clean cycles and continuous clean cycles are used to remove the dark charge while the camera is waiting to acquire the signal of interest. Dark charge, clean cycles, and continuous clean cycles are described in the paragraphs that follow.

7.3.1 Dark Charge

As soon as the PI-MAX3 camera is powered on, thermally-induced charge will begin integrating on the CCD array even if the photocathode is biased off. Because dark charge is thermally-induced, reducing the array temperature significantly reduces the rate at which this charge accumulates in the pixel wells. Even so, enough dark charge could accumulate in the pixels between data acquisitions to affect dynamic range at the beginning of an exposure. To prevent this from happening, clean cycles repeatedly shift and discard any signal that has integrated on the array PI-MAX3 is waiting for a Start Acquisition command from the host computer.

After the Start Acquisition command is received, a final clean cycle occurs and exposure begins. During the exposure, both the signal of interest and dark charge integrate on the array. The longer the exposure and the warmer the camera, the larger and less uniform the dark charge will appear. To minimize the dark charge contribution to the acquired signal, you should operate with the lowest temperature possible for your camera. Reducing the gate width may also be helpful.

To further reduce the dark charge contribution to an acquired signal, you may be able to perform background subtraction, which subtracts a dark charge background from raw data acquired using the same experiment conditions. Refer to Section 7.7, Background Subtraction, on page 71.

CAUTION!

If you observe a sudden change in the baseline signal you may have excessive humidity in the camera's CCD enclosure. Immediately turn off the controller. Contact Teledyne Princeton Instruments Customer Support for assistance. Refer to Contact Information on page 248 for complete information.

NOTE:

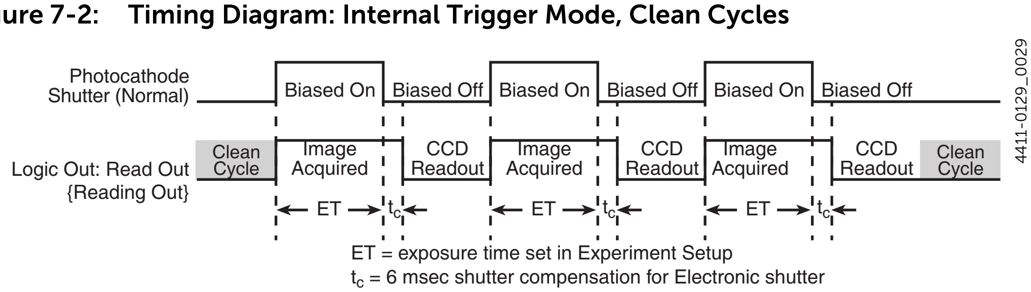
Do not be concerned about either the DC level of this background noise or its shape unless it is very high, i.e., > 1000 counts with 16-bit A/D. What you see is not noise. It is a fully subtractable readout pattern. Refer to Section 7.7, Background Subtraction, on page 71 for complete information.

7.3.2 Cleaning

The basic cleaning function is implemented by clean cycles. These cycles start when you turn the camera on and a clean pattern is programmed into the camera. Their purpose is to remove charge that accumulates on the array while the camera not acquiring data (i.e., exposing and reading out the array.)

Figure 7-2 illustrates the timing diagram for an experiment configured to acquire three (3) images using Internal trigger mode configured on **SuperSYNCHRO Trigger In** tab {**Trigger** expander} and **Gate Mode** selected on **Experiment Setup Main** tab {In LightField, the equivalent of Gate Mode is active when **Enable Intensifier** is checked on the **Common Acquisition Settings** expander}. In this diagram, clean cycles occur before the first exposure and after the last readout period. They do not need to occur between exposures since each readout cleans the array before the next exposure starts.

Figure 7-2: Timing Diagram: Internal Trigger Mode, Clean Cycles



The configuration of clean cycles is performed on the **Hardware Setup ► Cleans/Skips** tab {via the **Sensor Cleaning** pane accessed on the **Sensor** expander}. When you set up the camera for the first time, default values are automatically programmed into the following parameters. These will give the best results for most applications. Even so it is a good idea to know what these entries mean with regard to cleaning.

- **Number of Cleans** {**Number of Clean Cycles**}

  Typically set to one (1).

  These are additional clean cycles that can be required after a start exposure signal is received and the current clean cycle has finished.

  The maximum value for this entry depends on the camera.
- **Number of Strips per Clean** {**Clean Cycle Height**}

  Configures the number of rows that will be shifted and discarded per clean cycle.

  Although a large number such as the number of rows in the array may result in the best cleaning of the array, the trade off is that there may be a significant delay between the receipt of a start exposure signal and the beginning of the actual exposure. This delay occurs because the current clean cycle must be completed before a start exposure signal received during the cycle will be implemented.

  Typically, the default setting is much smaller and in time-critical experiments, the setting should be 1 or 2.
- **Clean Before Exposure** {**Clean Before Exposure**}

  Available only for cameras that have a Frame Transfer CCD and is only available for selection when in Full Frame mode is active.

  Normally, cleaning occurs until the acquisition starts. When **Clean Before Exposure** is active, cleaning occurs up until acquisition starts and the entire CCD will be cleaned once right after the readout occurs. It is a clean operation for the next exposure and it matters only when multiple images are taken with a short exposure time.

  NOTE:

  Clean Before Exposure is not relevant when you are in a triggered mode.

- **Continuous Cleans** {**Clean Until Trigger**}

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

- **Skip Serial Register Clean** (deselected) {**Clean Serial Register**}

  The Top margin inactive parallel strips on a CCD are made up of the dark pixels that come before the active strips on a sensor as they exit to the serial register. When these are available (i.e., Pre Dummies {Top Margin} > 0,) they serve the purpose of cleaning the serial register before readout of the active strips.

  In LightField, if there are no inactive parallel strips (i.e., {Top Margin} = 0,) selecting **Clean Serial Register** forces a clean of the serial register before readout of the active strips.

NOTE:

The start of the exposure is signaled by the **Read Out** {**Reading Out**} output of the LOGIC OUT connector going low but will not occur until the current clean cycle and the additional user-defined number of cleans (typically 0) have finished.

Number of Cleans is configured on the **Setup** ► **Hardware** ► **Cleans/Skips** tab {**Sensor Cleaning** panel on **Sensor** expander}.

If you enter a value other than 0 you will further delay the start of the exposure by that number of clean cycles.

7.4 Phosphor Decay Delay

WinX/32 and LightField allow you to enter a delay between the end of the exposure time and the beginning of the array readout. This time is inserted to allow the phosphor to decay to 1% before readout occurs and will vary depending on the phosphor type. This delay has no effect on the actual time it takes for the phosphor to decay.

NOTE:

In the case of an experiment using a PI-MAX3: 1024i and a very short exposure time, artifacts will appear in the first frame unless the phosphor decay delay is set to 3 ms. This amount of delay will ensure that the vertical registers (under the mask) are cleared before the acquired signal is shifted under the mask.

Figure 7-3 illustrates a typical **WinX/32 Hardware Setup** ► **Phosphor Decay Delay** dialog and Figure 7-4 shows the LightField Co**mmon Acquisition Setting** ► **Advanced** ► **Phosphor Decay Delay** dialog.

Figure 7-3: Typical WinX/32 Hardware Setup Dialog: Phosphor Decay Delay

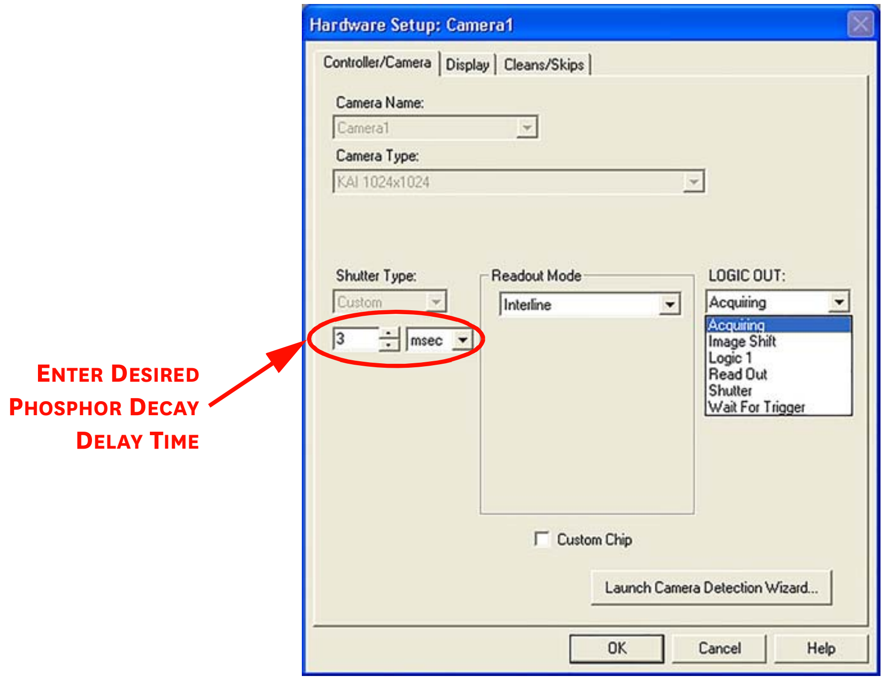


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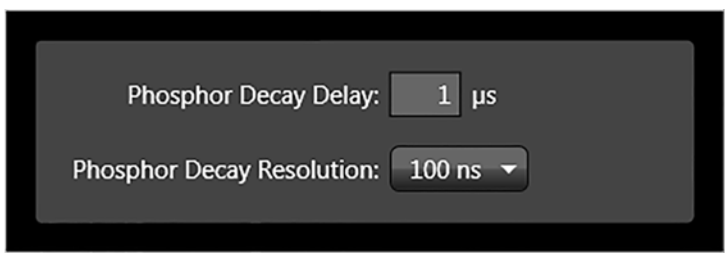
Figure 7-4: Typical LightField Common Acquisition Settings ► Advanced ► Phosphor Decay Delay Dialog



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7.5 Temperature Control

CAUTION!

Under normal conditions, the front end of the camera is sealed and backfilled so there is no danger of damage due to condensation.

7.5.1 Cooling Method

Cooling the CCD array reduces the amount of dark charge thereby acting to improve the signal-to-noise ratio. An internal Peltier device directly cools the cold finger on which the CCD is mounted. The heat produced by the Peltier device is then removed by the air drawn into the camera by the internal fans and exhausted through the side-panel grill. The fans are always running and cooling the CCD and the internal electronics.

Additional heat removal can be performed by circulating coolant through an internal heat block.

7.5.1.1 Air-cooling

With air-cooling alone, at an ambient temperature of 25°C, temperature lock at -25°C should typically take ten to twenty minutes. Cooling performance is affected by the CCD array being used (i.e., larger arrays may take longer to cool than smaller arrays.)

Also, if the lab is particularly warm, achieving temperature lock might take longer or not be obtainable at all.

7.5.1.2 Supplemental Circulating Coolant

Allows temperature lock to be achieved more rapidly than would be required to lock at the same temperature with air-cooling alone.

In addition, it will be possible to achieve temperature lock at lower temperatures, typically three or four degrees lower than would be possible with air-cooling alone.

Use the Teledyne Princeton Instruments CoolCUBE$_{II}$ coolant circulator. It is a closed circulation system that depends on ambient air-cooling of the circulating coolant.

Unless the laboratory has high humidity, the ambient temperature coolant should prevent condensation inside the PI-MAX3.

Refer to Section 5.5, Connect PI-MAX3 to CoolCUBE$_{II}$, on page 45 for information about setting up the CoolCUBE$_{II}$ circulator.

CAUTION!

Cooling performance can be enhanced by circulating water with a temperature below laboratory ambient but this approach will increase the risk of condensation inside the PI-MAX3. This condensation can cause catastrophic failure of the camera electronics. Any resulting damage would be considered to have resulted from improper operation and will **not** be covered by the Warranty. Even ordinary tap water is too cold to be used without risk! For safety, the water should be no colder than the laboratory ambient temperature. Closed circulation systems that depend on ambient air-cooling of the circulating water will generally give good results. If you feel that you must use water colder than the laboratory ambient temperature, it is absolutely essential that the PI-MAX3 be operated where the humidity is low enough to prevent internal condensation. If the coolant is below the freezing temperature of water, we advise using a mixture of 50% water and 50% ethylene glycol as the coolant.

The easiest and most practical way to achieve the required low humidity is to put the PI-MAX3 inside a closed container and to then purge the container with a continuous flow of dry nitrogen. On completion of the experiment, be sure to continue the purge until the PI-MAX3's internal cold surfaces have had time to warm to the ambient laboratory temperature. Contact Teledyne Princeton Instruments Customer Support for assistance. Refer to Contact Information on page 248 for complete information.

7.5.2 Setting the Temperature

Regardless of the type of cooling, the CCD array temperature is set via the application software. When WinX/32 is the controlling software, temperature control is done via the **Setup** ► **Detector Temperature** menu choice. When LightField is being used, temperature control is done on the **Sensor** expander.

Once the target (desired) array temperature {Temperature Setpoint} has been set, the software controls the camera's cooling circuits to reach set array temperature. On reaching that temperature, the control loop locks to that temperature for stable and reproducible performance. When the Target Temperature {Temperature Setpoint} has been reached, the current temperature is **Locked**. The on-screen indication allows easy verification of temperature lock.

Temperature lock to a set temperature in the operating range will typically occur within ten minutes. Another five minutes will be required for maximum temperature stability to be achieved.

NOTE:

The WinX/32 **Detector Temperature** dialog will not display temperature information while you are acquiring data.

7.6 Exposure

Data acquisition has two parts:

- Exposure;

  Exposure refers to the integration of a signal of interest on the CCD array.
- Readout.

  Readout is the transfer of the integrated signal from the array pixels to a shift register and from there to a preamplifier.

During exposure, each pixel in the two-dimensional grid of individual pixels 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 exposure time via gating sequences defined in the application software, the pixels are read out serially.

Because CCD arrays are always sensitive to light, light must not be allowed to fall on the array during readout (with a few exceptions). Intensified cameras such as the PI-MAX3 rely on gating the intensifier off, to prevent light from reaching the array. During each data acquisition, the intensifier is gated on and off (this may happen a number of times if there are multiple gates per exposure) to allow the pixels to register light during the on period. It is gated off for the readout period.

7.6.1 Exposure with an Image Intensifier

PI-MAX3 cameras use an image intensifier both to gate light on and off and to greatly increase the brightness of the image. In these cameras the image intensifier detects and amplifies the light, and the CCD is used for readout. The exposure programmed by software in this case refers to duration of gating of the intensifier.

The MCP (microchannel plate) of the intensifier is composed of more than 10^6 individual miniature electron multipliers with an excellent input to output spatial geometric accuracy. Intensifier gain is varied by adjusting the voltage across the MCP or the voltage across the MCP output and the phosphor. This second parameter is a factory adjustment, as it affects both the gain and the resolution of the intensifier.

Detection of extremely weak Continuous Wave (CW) signals (e.g., luminescence and Raman scattering from solid state samples,) is typically limited by the dark current of the intensifier's photocathode, usually referred to as the equivalent background illumination (EBI).

7.6.2 Saturation

When signal levels in some part of the image are very high, charge generated in one pixel may exceed the well capacity of the pixel, spilling over into adjacent pixels in a process called "blooming." If this is the case, you could reduce the intensifier gain or read out more frequently, with signal averaging to enhance S/N (Signal-to-Noise ratio) accomplished through the software.

CAUTION!
Signals large enough to bloom may damage the intensifier.

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

7.7 Background Subtraction

Each CCD has its own dark charge pattern or background that can be subtracted from the total acquired signal. By subtracting this background, you can eliminate the dark charge, which might otherwise hide low-intensity signal.

When setting up for background subtraction, set up the experiment conditions for acquiring the actual image (i.e., camera temperature, gating sequences, region of interest, timing mode, etc.,) and then, while blocking the incoming signal from the array, acquire a dark charge background image under those conditions. Once the background image has been acquired, save it to disk.

After storing the background data to disk, you have two choices for background subtraction:

- Automatic

  In WinX, this approach requires that you activate **Background** and specify the background filename on the **Acquisition** ► **Experiment Setup...** ► **Data Corrections** tab before acquiring an image.

  In LightField, you must check the **Apply Background Subtraction** box on the **Online Corrections** expander and select the appropriate background file or acquire a new background. When you acquire an image, the specified background will be subtracted automatically from the raw image data before the corrected data is displayed and is available for storage to disk.

- Post-Processing

  If you prefer to acquire and preserve the raw image data, make sure that **Background** is not active on the **Acquisition** ► **Experiment Setup...** ► **Data Corrections** tab {**Apply Background Subtraction** box is not checked}. Then, acquire the image and save the raw image data to disk.

  — In WinX/32 you would then use the **Image** (or **Spectra**) **Math** function (accessed from the **Process** menu) to subtract a background data file from the raw image data. The resulting data can then be saved to disk in a separate file.

  — In LightField you would open the data in the **Data Workspace**, select **Background...** from the **Processes** pull-down list, choose the appropriate background file, click on **Preview**, and then click on **OK**. You can now click on the **Save** button, edit the filename if desired, and save the data to disk.

7.8 Readout of the Array

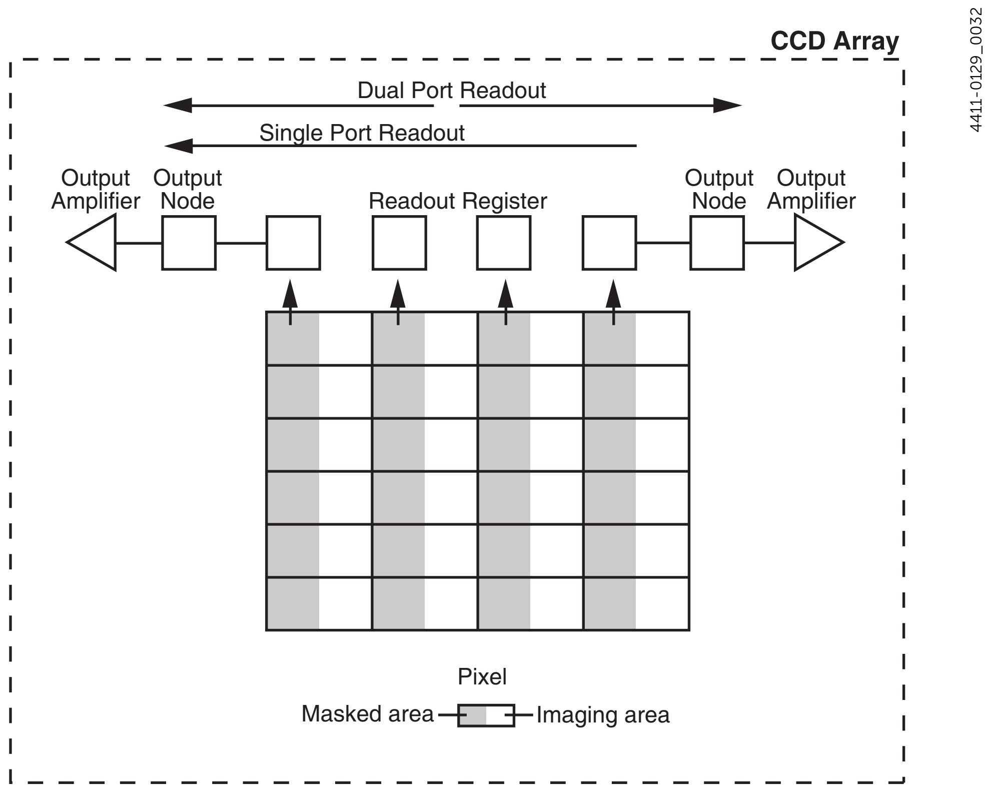
At the end of the exposure, the charge from the pixels is shifted to the shift register, amplified, and digitized. Depending on the experiment design, binning may also occur as part of the readout operation.

- For the PI-MAX3:1024i camera and WinX, dual port readout mode is selected whenever full image readout is selected or when the region of interest (ROI) is defined to be horizontally symmetrical and centered. Single port readout is activated when the ROI is not horizontally symmetrical and centered. The same rules apply whether or not binning is utilized. Readout in single port mode may be slower than dual port mode readout. The port used for single port mode is dictated by the CCD design.
- For the PI-MAX3:1024i camera and LightField, when 2 port readout is selected, you can acquire either a full image or a region of interest (ROI) defined to be horizontally symmetrical and centered. If the ROI is not horizontally symmetrical and centered, single port readout must be selected. The same rules apply whether or not binning is utilized. Readout in single port mode may be slower than dual port mode readout. The port used for single port mode is dictated by the CCD design.
- For the PI-MAX:1024x256, signal is read out of a single port.

7.8.1 Interline CCD Readout

In this section, a simple 6 x 4 pixel interline CCD is used to demonstrate how charge is shifted and digitized using a single port. See Figure 7-5.

Figure 7-5: Typical Interline CCD Readout



Two modes of readout can occur:

- Overlapped;

  In Overlapped Readout mode, each exposure begins while the readout of the prior exposure is in progress.
- Non-Overlapped.

  In Non-Overlapped Readout mode, which is automatically selected when the exposure time is shorter than readout time, each readout is completed before the next exposure begins.

7.8.1.1 Non-Overlapped Mode Exposure and Readout

Figure 7-6 illustrates exposure and readout when operating in the Non-Overlapped mode. Non-overlapped operation occurs automatically any time the exposure time is shorter than the readout time.

Figure 7-6: Non-Overlapped Mode Exposure and Readout

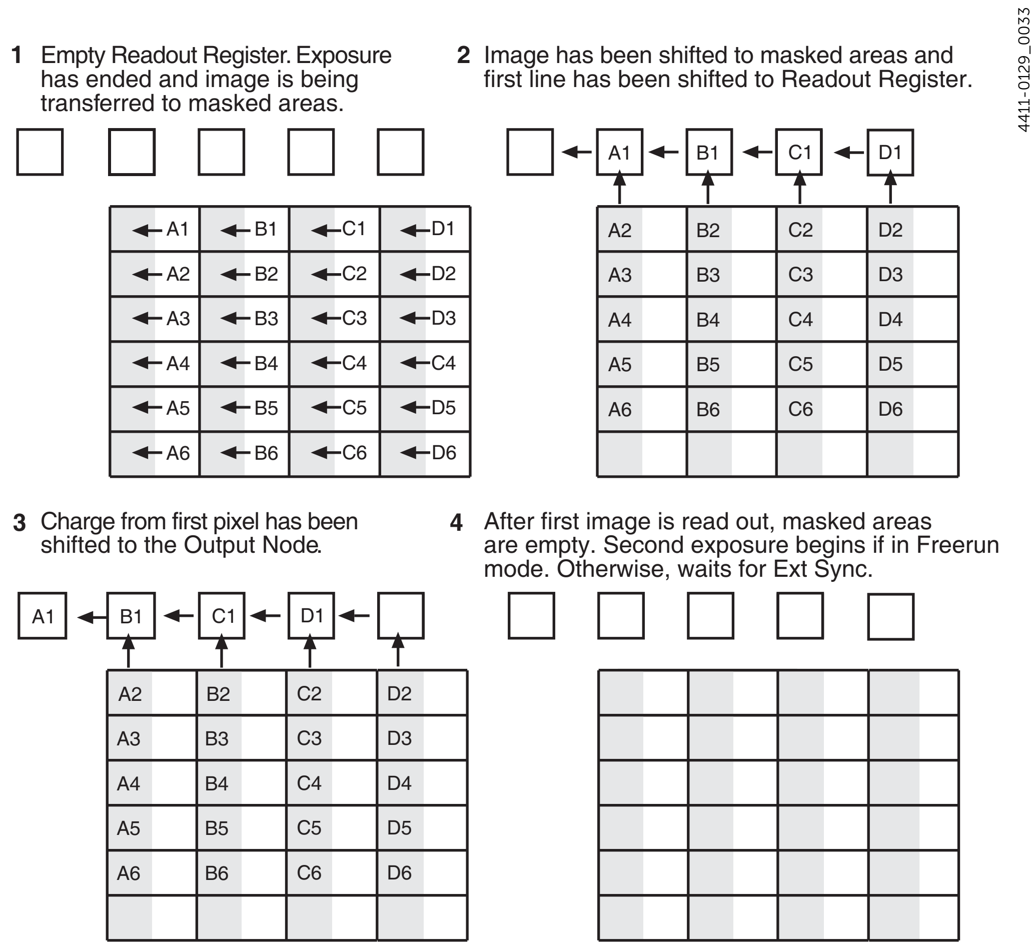


Figure 7-6 is comprised of four different sections, each depicting subsequent stages in the exposure-readout cycle.

- Section 1

  This section represents the array early in its exposure.

  The imaging areas contain charge proportional to the amount of light integrated on each of them. The masked (i.e., storage,) areas are empty because no charge has been transferred to them.

  The arrows between adjacent imaging and masked areas indicate the direction charge will be shifted when the transfer occurs.
- Section 2

  This section represents shows the status early in the readout cycle.

  Charge in the imaging areas has been transferred to the adjacent masked areas and up-shifting to the readout register has started.

  Note that a second exposure does not begin while the readout is in progress because the intensifier is not gated on at this time.

- Section 3

  This section represents transfer to the output node.

  The lowermost pixel in each column is shown empty. Each row of charges is moved in turn into the readout register, and from there to the output node and off the array for further processing.

  The process continues until all charge has been completely transferred out of the array.

  The image intensifier is off during this time so no signal charge is accumulated, but dark current does accumulate.

  Because this scheme is less time efficient than that used in Overlapped Mode, the frame rate may be lower during Non-Overlapped Mode than in Overlapped Mode using the some gating configuration.
- Section 4

  This section represents the end of Readout.

  Both the imaging and storage areas are empty.

  When the intensifier is gated on again, signal charge will again be accumulated.

NOTE:

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

7.8.1.2 Interline Readout Rate

Equations that define the rate at which the CCD is read out are provided in this section.

Assuming the shutter selection is **None**, the time required to take an entire frame at full resolution in non-overlapped timing mode is:

(1) $$t_R + t_{exp}$$

where:

- t_R is the CCD readout time;
- t_{exp} is the exposure time;

The readout time is approximately given by:

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

where:

- 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.

Refer to Table 7-1 for typical readout rates, in frames per second (fps,) for a PI-MAX3: 1003 Kodak 1024 x 1024 interline array running at 16 MHz.

Table 7-1: Readout Rates: Kodak 1024 x 1024 Array, 16 MHz Dual Port Mode

Binning	Region of Interest Size		
	1024 x 1024	400 x 400	200 x 200
1 x 1	25.8 fps	36.2 fps	42.5 fps
2 x 2	56.3 fps	49.5 fps	50.0 fps
4 x 4	94.5 fps	58.7 fps	54.6 fps[a]

a. ROI increased to 202 x 200 to accommodate GigE rules.

NOTE:

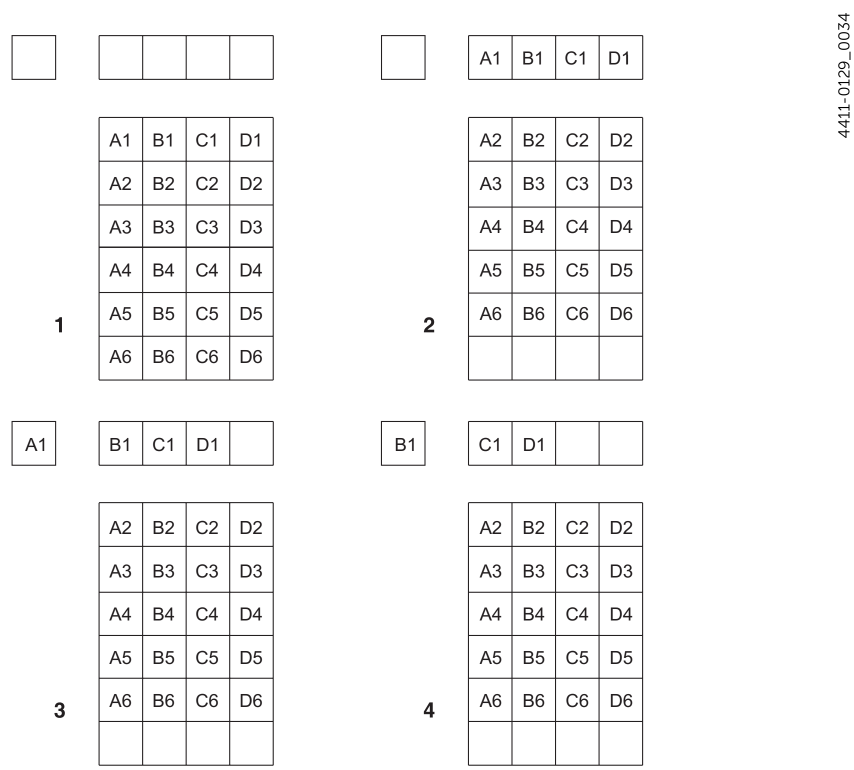
A subsection of the CCD can be read out at full resolution, sometimes increasing the readout rate while retaining the highest resolution in the Region Of Interest (ROI).

7.8.2 Full Frame CCD Readout

The PI-MAX3: 1024 x 256 camera uses a full frame CCD for data acquisition. This section describes readout at full resolution where every pixel is digitized individually.

In Figure 7-7, the upper-left section represents a CCD after exposure but before the beginning of readout. The capital letters represent different amounts of charge, including both signal and dark charge.

Figure 7-7: Full Frame Readout



Readout of the CCD begins with the simultaneous shifting of all pixels one row toward the shift register which, in Figure 7-7, is the row on top. The shift register is a single line of pixels along the edge of the CCD, not sensitive to light and used for readout only. Typically the shift register pixels hold twice as much charge as pixels in the imaging area of the CCD.

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

The order of shifting in 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.

The equations used to calculate the rate at which the CCD is read out are shown below.

The time needed to take a full frame at full resolution is:

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

where:

- t_R is the CCD readout time;
- t_{exp} is the exposure time;
- t_c is the phosphor decay time.

The readout time is approximately given by:

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

where

- 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.

Provided the number of horizontal pixels is divisible by four, 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, within 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.

Refer to Table 7-2 for typical readout rates, in frames per second (fps,) for a PI-MAX3: e2v CCD30-11 1024 × 256 full frame array running at 2 MHz.

Table 7-2: Readout Rates: e2v CCD30-11 1024 × 256 Array at 2 MHz

Binning	Region of Interest Size		
	1024 x 256	1024 x 10[a]	1024 x 1[a]
1 x 1	6.67 fps	–	–
1 x 256	270 fps	–	–
1 x 10	–	1567 fps	–
1 x 1	–	–	1831 fps

a. CCD format using Custom Chip Mode

7.8.3 Binned Readout (Hardware Binning)

Binning is the process of adding the charge 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.

Hardware binning reduces readout time and the burden on computer memory by summing charge before the preamplifier reads out the signal. 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.

- In WinX, hardware binning is configured on the **Acquisition** ► **Experiment Setup...** ► **ROI Setup** tab by entering a value in the Group fields. For example, a **2** in each of the Group fields will configure 2 x 2 hardware binning.
- In LightField, hardware binning is configured on the **Region of Interest** expander. First by verifying that hardware binning is selected on the **Advanced** fly-out pane, then selecting **Full Sensor Binned**, and entering a **2** in fields or by clicking on the **Edit ROIs...** button and creating a custom ROI with **Bin W** and the **Bin H** values set to **2**.

Limitations of hardware binning include:

- Lowered resolution because charge from adjacent pixels is summed into a super pixel.
- Increased possibility to blooming. Because shift register pixels typically hold only twice as much charge as image pixels, the binning of large sections may result in saturation and spilling of charge back into the image area.
- Possible data loss if the total charge binned together exceeds the capacity of the shift register or output node.
- For dual port operation, there are symmetry requirements that limit the choice of patterns. Regions of interest (ROIs) must be symmetrical about the center line (horizontal).
- The number of pixels in the serial (horizontal) direction must be evenly divisible by 4, even after binning.

The possibility of blooming or data loss 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 post-processing binning is accomplished in software, producing a result that represents many more photons than was possible using hardware binning.

7.8.3.1 CCD Type and Readout Port(s)

The PI-MAX3 will either have a full frame or an interline CCD. Full frame CCDs such as the 1024x256 device have a single port for readout. The 1024x1024 interline CCD is designed for either dual or single port readout. When single port readout is active, the port used has been set at the factory.

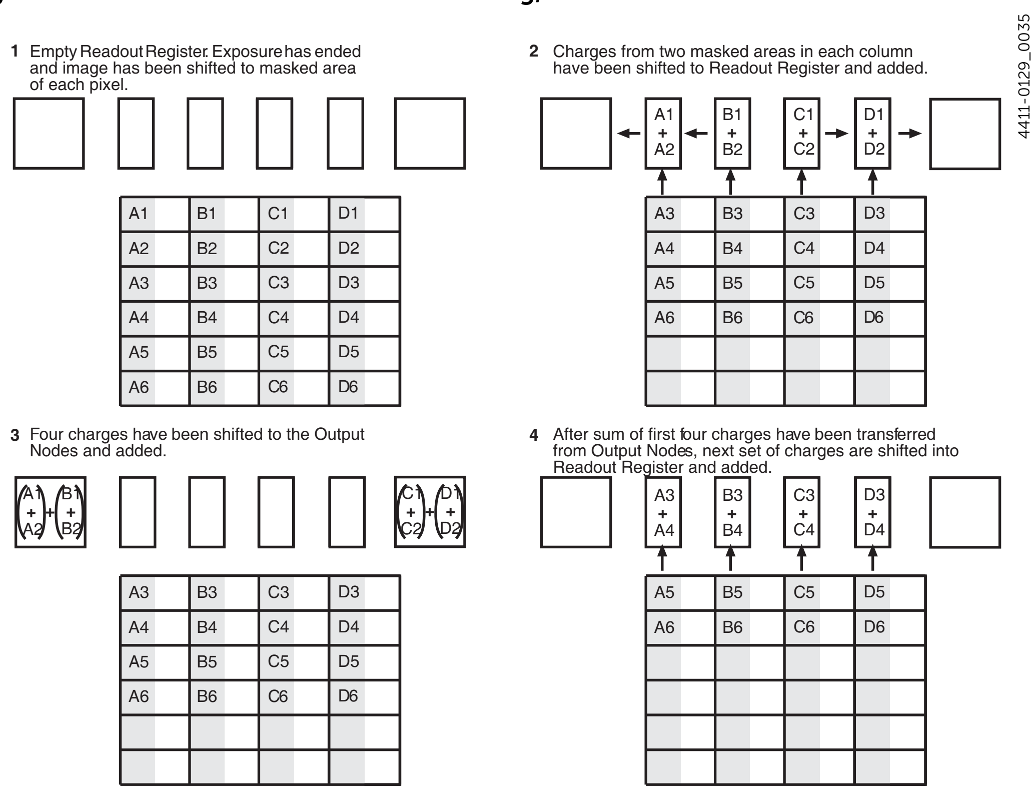
Dual port readout is about two times faster than single port readout and occurs whenever the full frame is being read out or when an ROI is symmetrical about the horizontal center of the CCD.

- In WinX, a single port readout will automatically occur when an ROI is not symmetrical about the horizontal center of the CCD.
- In LightField, you can either change the ROI location/size or select single port readout (via the **Advanced** panel on the Region of Interest expander).

7.8.3.1.1 Full Frame Binning

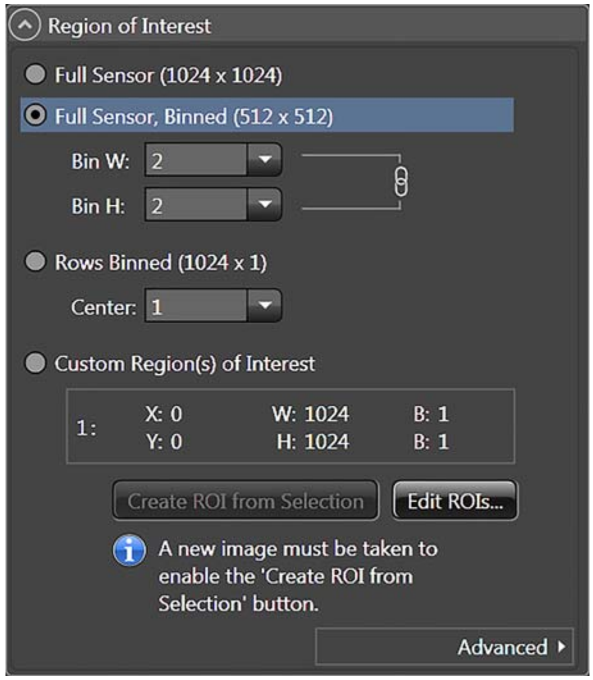
Figure 7-8 illustrates 2 x 2 binning with dual port operation for an interline array. Each pixel of the image displayed by the software represents 4 pixels of the array.

Figure 7-8: Dual Port Readout: 2 x 2 Binning, Interline CCD



[Figure 7-9](#) illustrates the LightField **Region Of Interest** (ROI) expander with parameter values for Full Sensor 2 x 2 binning.

Figure 7-9: Typical LightField ROI Expander: Dual Port Readout, 2 x 2 Binning, Interline CCD



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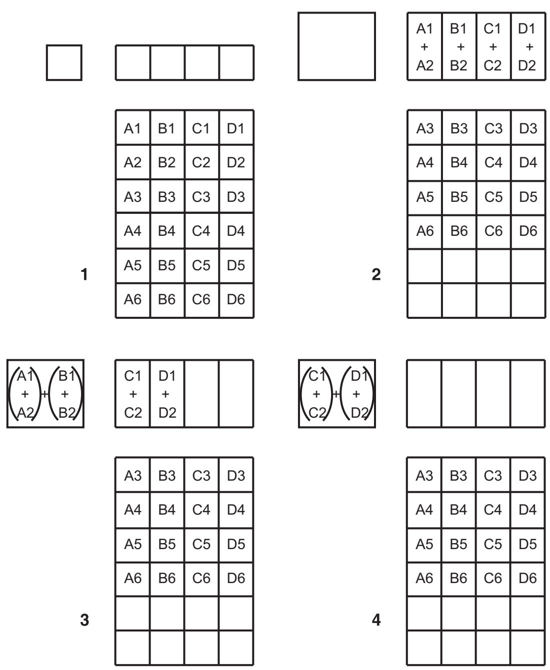
[Figure 7-10](#) illustrates single port operation for a full frame array.

Figure 7-10: Single Port Readout: 2 x 2 Binning, Full Frame CCD



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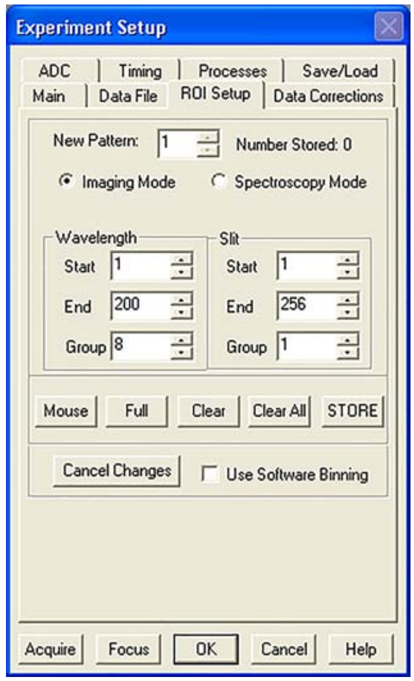
7.8.3.1.2 WinX/32: Partial Frame ROI Binning

When configuring a partial frame ROI, regardless of the array type (i.e., full frame or interline,) keep in mind that for the PI-MAX3 the following constraint applies: the number of pixels in the serial (horizontal) direction must be evenly divisible by 4, even after binning.

Figure 7-11 shows the WinX/32 **Experiment Setup ► ROI Setup** tab dialog on which ROI Binning is configured.

Figure 7-11: Typical WinX/32 Experiment Setup ► ROI Setup Tab Dialog



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Examples

The following configuration examples include partial frame ROIs with and without binning. See Figure 7-11 for corresponding configuration parameters.

NOTE:

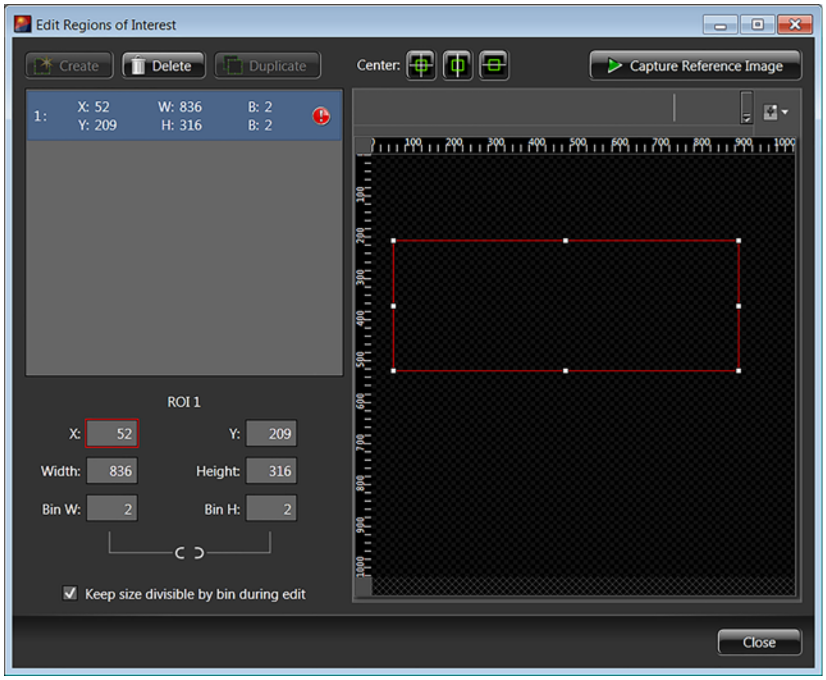
WinX/32 may refer to the horizontal axis as either X or Wavelength depending on the specific application.

- X Start to End = 200 pixels, no grouping (binning).
  Since 200/4=50, this is a valid ROI setup.
- X Start to End = 200 pixels and grouping (binning) is by 8.
  The resulting number of super pixels is 25. Since 25/4=6.25, this is not a valid ROI setting for the horizontal direction.
- X Start to End = 240 pixels, no grouping (binning).
  Since 240/4=60 this is a valid ROI setup.
- X Start to End = 240 pixels and grouping (binning) is by 3.
  The resulting number of super pixels is 80. Since 80/4=20, this is a valid ROI setup.
- X Start to End = 240 pixels and grouping (binning) is by 16.
  The resulting number of super pixels is 15. Since 15/4=3.75, this is not a valid ROI setting for the horizontal direction.

7.8.3.1.3 LightField: Partial Frame ROI Binning

Partial Frame ROI binning can be defined via the Region of Interest expander's **Custom Region(s) of Interest** function and the **Edit Regions of Interest** window. See Figure 7-12.

Figure 7-12: LightField: Edit Regions of Interest Dialog



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The ROI illustrated in Figure 7-12 has been created for a PI-MAX3:1024i using dual port readout. Because the ROI is not centered horizontally, an **Experiment Conflict** is shown.

If you click on the **Experiment Conflict** icon  a pop up window will report the nature of the conflict. In this case, the ROI needs to be centered horizontally. Click on the middle Center button  to reposition the ROI correctly.

NOTE:

Only one ROI can be created when dual port readout is selected. When single port readout is active (the CCD is a 1024x256 or single port is selected for the 1024x1024 interline), multiple ROIs can be created and the horizontal centering is not required.

Figure 7-13 illustrates single port operation for a partial frame with an interline CCD.

Figure 7-13: Single Port Readout: 2 x 2 Binning, Partial Frame, Interline CCD

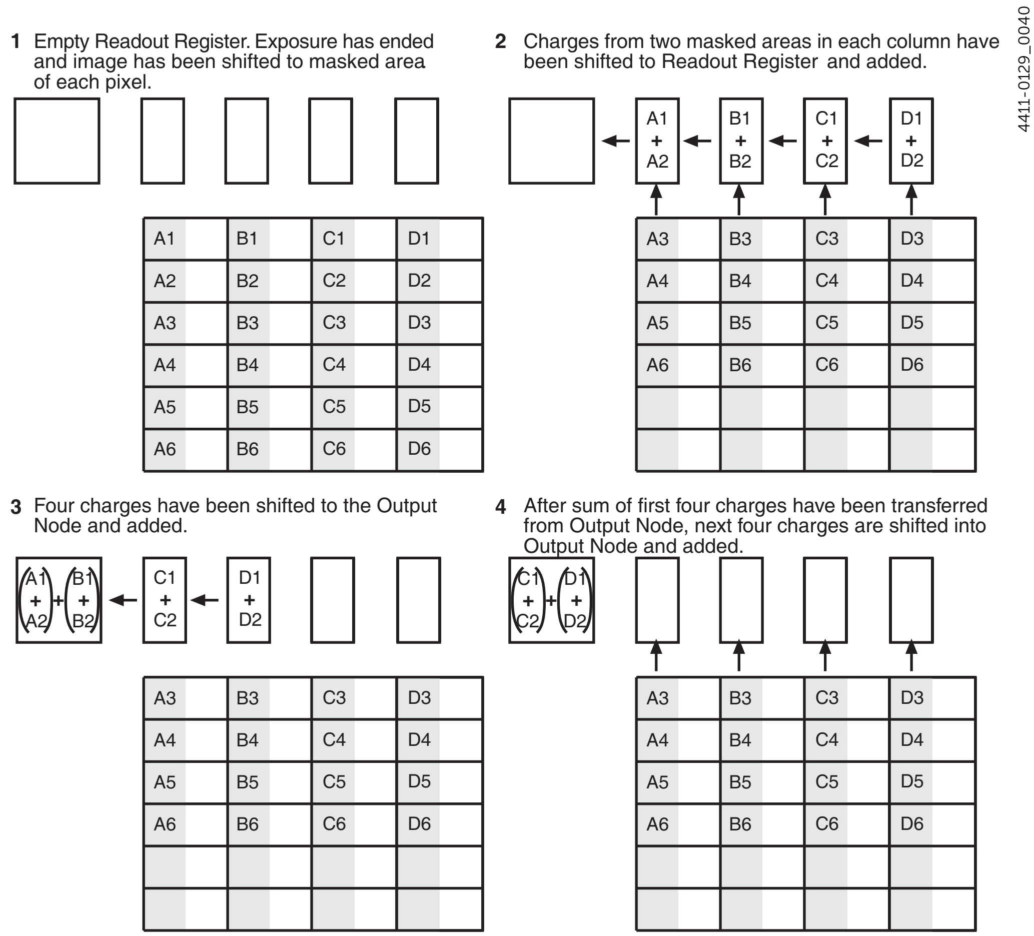
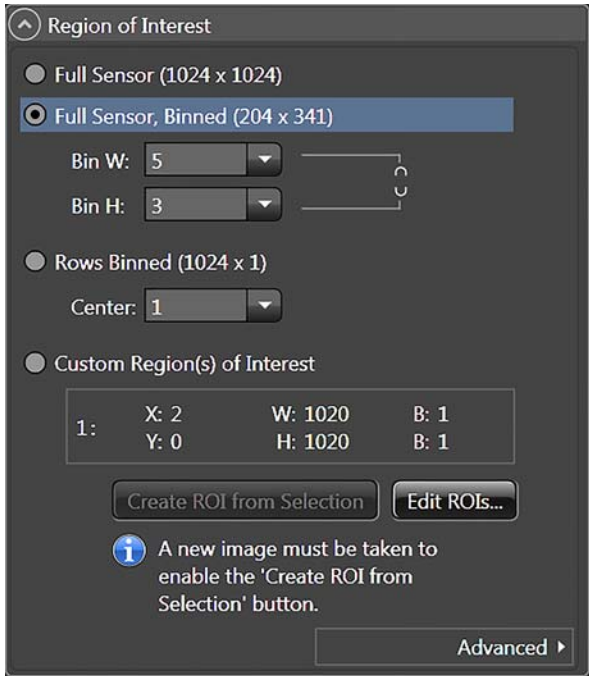


Figure 7-14 illustrates LightField's **Region of Interest** expander for the following configuration:

- Interline CCD with Dual Port Readout;
- 5 x 3 Binning.

Both the **Full Sensor Binned** and the **Custom Region(s) of Interest** results of using the 5 and 3 bin values are reported.

Figure 7-14: LightField Region Of Interest Expander: Dual Port Readout, 5 x 3 Binning, Interline CCD



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NOTE:

On LightField's **Region of Interest** expander, you can select **Full Sensor, Binned** and enter Bin W and Bin H values that would not be allowed if you selected **Custom Region(s) of Interest** and entered them in the **Edit ROIs...** dialog.

For example, a Bin W=5 and a Bin H=3 would not be allowed via the **Edit ROIs...** dialog until you created a horizontally centered ROI whose dimensions would permit even division by those values.

If you use the **Full Sensor, Binned** function, LightField creates the appropriately sized ROI and reports the resulting image size.

The **Custom Region(s) of Interest** area shows the non-binned ROI size and the bin values that will be applied.

7.9 Software Binning

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

Software binning 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.

In WinX/32 and LightField, software binning can either be set up to occur automatically or as a manual post-processing operation.

- WinX/321

  Automatic software binning is set up by entering **Group** parameters on the **Acquisition** ► **Experiment Setup...** ► **ROI Setup** tab card and then selecting the **Use Software Binning** checkbox. The drawback to automatic binning is that the raw data is lost.

  Alternatively, you can acquire raw data and then use the post-processing binning function (located on the **Process** ► **Binning and Skipping...** dialog) to select the input data, enter the binning parameters, and save the result to an appropriately named file.

- LightField

  Automatic software binning is set up by entering the **Bin W** and **Bin H** parameters directly on the **Region of Interest** expander or when creating a Custom ROI via the **Edit Regions of Interest** window.

  Alternatively you can acquire raw data, load the file in the Data Workspace, select **Software Binning** from the **Processes** menu, enter the binning parameters, preview the resulting data, **OK** the process, and then use the Data Workspace **Save** function to save the result to an appropriately named file.

7.10 Controller Gain {Analog Gain}

Controller gain, which is 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.

Three factors should be considered when configuring Controller Gain:

- The intensity of the incoming signal;
- Binning;
- CCD saturation.

Selecting the amount of gain is done on the **Acquisition** ► **Experiment Setup...** ► **ADC** tab {**Analog to Digital Conversion** expander}. The choices are:

- 1 {Low};

  Users who measure high-level signals may wish to select 1{Low} for digitization of larger signals: more electrons are required per ADU.

  Since binning combines the signal from two or more pixels, the user may also want to select 1 {Low} if binning is being applied.

  In both instances, the goal is to prevent CCD saturation and maximize signal acquisition.
- 2 {High}.

  Users who consistently measure low-level signals may wish to select 2 {High}, which requires fewer electrons to generate an ADU and reduces some sources of noise. If saturation occurs at this setting, 1 {Low} should be selected.

7.11 Digitization

During readout, an analog signal representing the charge of each pixel (or binned group of pixels) is digitized. The number of bits per pixel is 16.

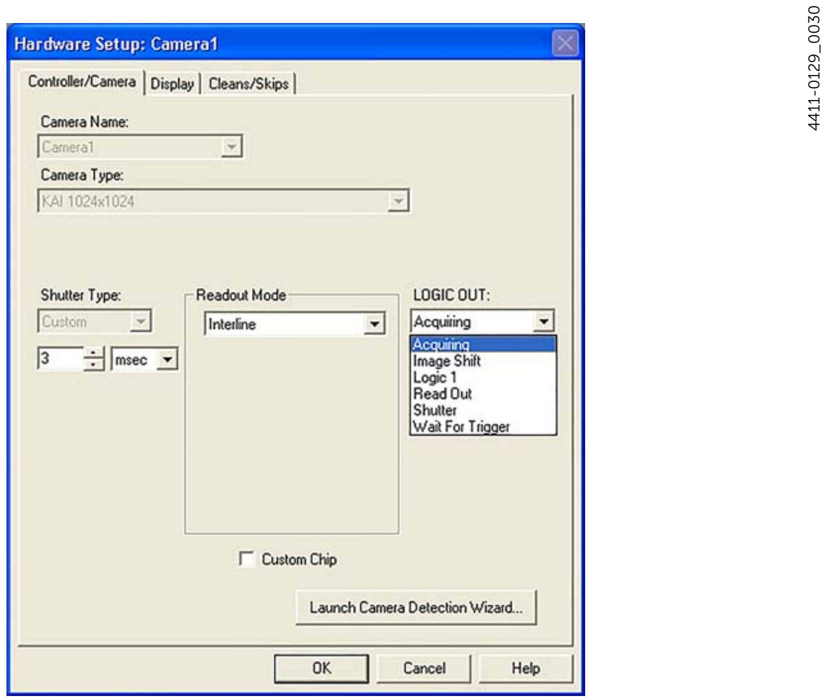
Some PI-MAX3 cameras have two complete analog channels including separate A/D converters. Because the readout noise of CCD arrays increases with the readout rate, it is sometimes necessary to trade off readout speed for high dynamic range. The two analog converters, both high speed, are optimized for slower read rates by digitally processing the signal in the camera before transferring it to the host

7.12 Logic Out Control

The TTL-compatible logic level output (0 to +3.3 V_{DC}) from the **LOGIC OUT** connector on the rear panel can be used to monitor camera status and control external devices. By default, the logic output level is high while the action is occurring.

Figure 7-15 illustrates the WinX/32 dialog on which Logic Out is configured.

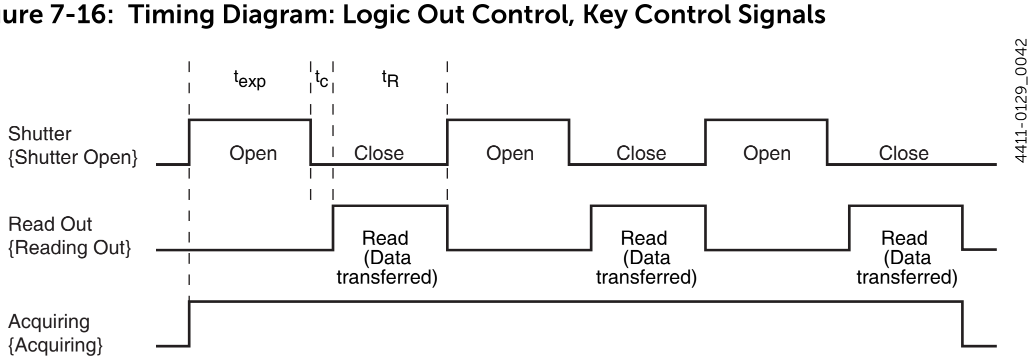
Figure 7-15: Typical WinX/32 Hardware Setup ► Hardware ► Controller/Camera Tab Dialog



The timing of the level changes depends on the output type selected on the **Setup** ► **Hardware** ► **Controller/Camera** tab {**Trigger** expander}:

- Acquiring {Acquiring}
  After a start acquisition command, this output changes state on completion of the array cleaning cycles that precede the first exposure. Initially low, it goes high to mark the beginning of the first exposure. In Focus mode operation it remains high until the system is halted. If a specific number of frames have been programmed, it remains high until all have been taken and then returns low.
  Figure 7-16 illustrates the timing diagram for key control signals when three frames have been programed.

Figure 7-16: Timing Diagram: Logic Out Control, Key Control Signals



- Image Shift {Shifting Under Mask}
  This level is at a logic high while the image is being shifted under the mask.
- Logic 1 {Always High}
  The level at the connector is high.
- Read Out {Reading Out}
  It is at a logic high when CCD is being read; otherwise low.
- Shutter {Shutter Open}
  This level is at a logic high when the photocathode is gated on (signal is accumulating on the CCD) and can be used to drive an external electro-mechanical shutter. Contact the factory for more information.
- Wait for Trigger {Waiting For Trigger}
  This level is at a logic high when the camera is ready to acquire and is waiting for an external trigger (through the EXT SYNC connector) before exposing the CCD. The level goes low when a trigger is detected: exposure begins. The Wait for Trigger (WFT) signal goes high immediately after readout or after preopen (if it is active). If continuous cleans is enabled, the camera will check for a trigger at the EXT SYNC connector before entering a continuous clean cycle. If none has occurred, a cleaning cycle is initiated and completed. Before the next cycle begins, the EXT SYNC connector is checked again, and exposure will start if a trigger has occurred.

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

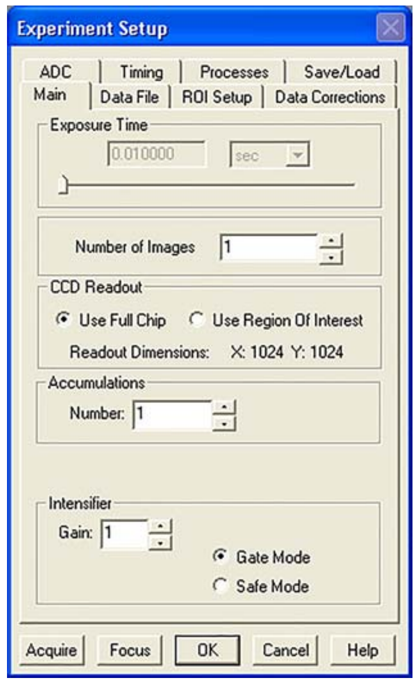
7.13 WinX/32 Experiment Setup

This section provides information about configuring each system parameter within WinX/32.

7.13.1 Experiment Setup ► Main Tab

In WinX, the first experiment setup parameters are typically configured on the **Experiment Setup ► Main** tab. See Figure 7-17.

Figure 7-17: Typical WinX/32 Experiment Setup ► Main Tab Dialog



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These parameters determine such things as the number of separate frames (denoted as images or spectra) that will be acquired, how much of the CCD will be used to acquired data, the intensifier gain, and the intensifier mode. The Main parameters are described briefly below.

- Number of Images/Spectra and Accumulations

  This is the number of sequential frames the software will collect and store in a single file. Each frame will be digitized and stored, but all of the frames will be in a single file. A frame may contain data from more than one region of interest as defined via the **ROI Setup** tab.

  If the **Accumulations** > 1, each stored frame will contain summed data sets from two or more exposures. The number of separate frames stored will the same as it would be for Accumulations =1, but the total number of exposures required would be the product of the **Number of Images/Spectra** parameter times the **Accumulations** value.

- CCD Readout

  This parameter selection determines whether the entire CCD array will be used to acquire a frame or if only a rectangular portion (or portions) of the array will be used. When **Use Region of Interest** is selected, data will be collected from the region(s) defined on **ROI Setup** tab. The full chip size or the sum of the active region(s) as defined on the ROI tab is displayed.

- Intensifier Gain

  The Intensifier gain setting provides continuous adjustment over a range of 1 to 100. Gain is approximately proportional to the number entered. 100 is maximum gain or 100%; 1 is approximately 1% of maximum gain. The default setting will give good results in many applications. Gain can only be changed when acquisition is NOT occurring: you must stop acquisition, change the gain, and then restart acquisition. We suggest beginning with a low setting and then increasing it until optimum results are obtained.

  NOTE:

  The intensifier gain also affects the Equivalent Background Illumination (EBI) of the intensifier. One result of this is that, to properly perform background subtraction, a new background must be taken whenever the intensifier gain is changed.

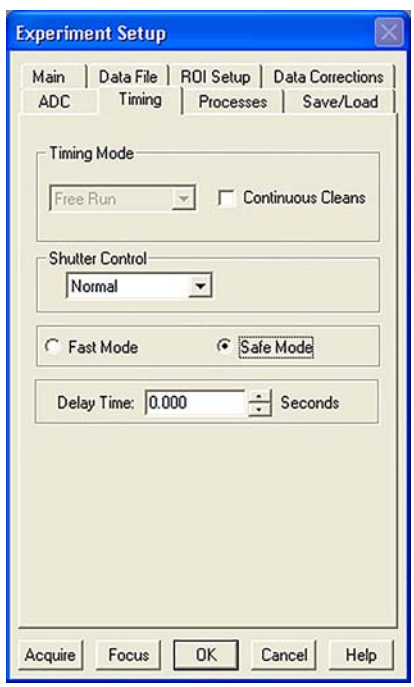
- Intensifier Mode

  The Intensifier Mode selection determines whether the intensifier will be biased on or off by the defined pulser gate timing (Gate Mode) or it will be continuously biased off until Gate mode is selected (Safe Mode).

7.13.2 Experiment Setup ► Timing Tab

Experiment setup requires the selection of a variety of experiment timing parameters. The parameters described in this section are those that appear on the **Experiment Setup ► Timing** tab. See Figure 7-18.

Figure 7-18: Typical WinX/32 Experiment Setup ► Timing Tab Dialog



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With the exception of Fast Mode/Safe Mode, which is described in full, the following paragraphs briefly describe these timing parameters. The settings appropriate to the intensifier mode and selected pulser are discussed in Chapter 8, WinX/32 and Gated Operation, on page 97.

- Timing Mode

  The timing mode parameter refers to the PI-MAX3's synchronization of data acquisition with an external TTL signal applied to the **TRIGGER IN** connector on the back of the camera or an internal trigger generated by the internal timing generator. The modes available depend on the selected intensifier mode (**Safe** or **Gate**) and the selected pulser (**SuperSYNCHRO**).

- Fast Mode or Safe Mode

  In WinX, the Fast Mode or Safe Mode selection determines whether the PI-MAX3 will run the experiment according to the experiment timing, with no interruptions from the computer, or the computer will interrupt the acquisition flow to process each frame as it is received. Figure 7-19 compares the two modes.

  NOTE:

  The Safe Mode on the **Timing** tab is not the same as the **Intensifier** Safe Mode on the **Main** tab.

  Fast Mode operation is primarily for collecting "real-time" sequences of experimental data, where timing is critical and events cannot be missed. Once the PI-MAX3 is sent the Start Acquisition command by the computer, all frames are collected without further intervention from the computer. The advantage of this timing mode is that timing is controlled completely through hardware. A drawback to this mode is that the computer will only display frames when it is not performing other tasks. Image display has a lower priority, so the image on the screen may lag several images behind. A second drawback is that a data overrun may occur if the number of images collected exceeds the amount of allocated RAM or if the computer cannot keep up with the data rate.

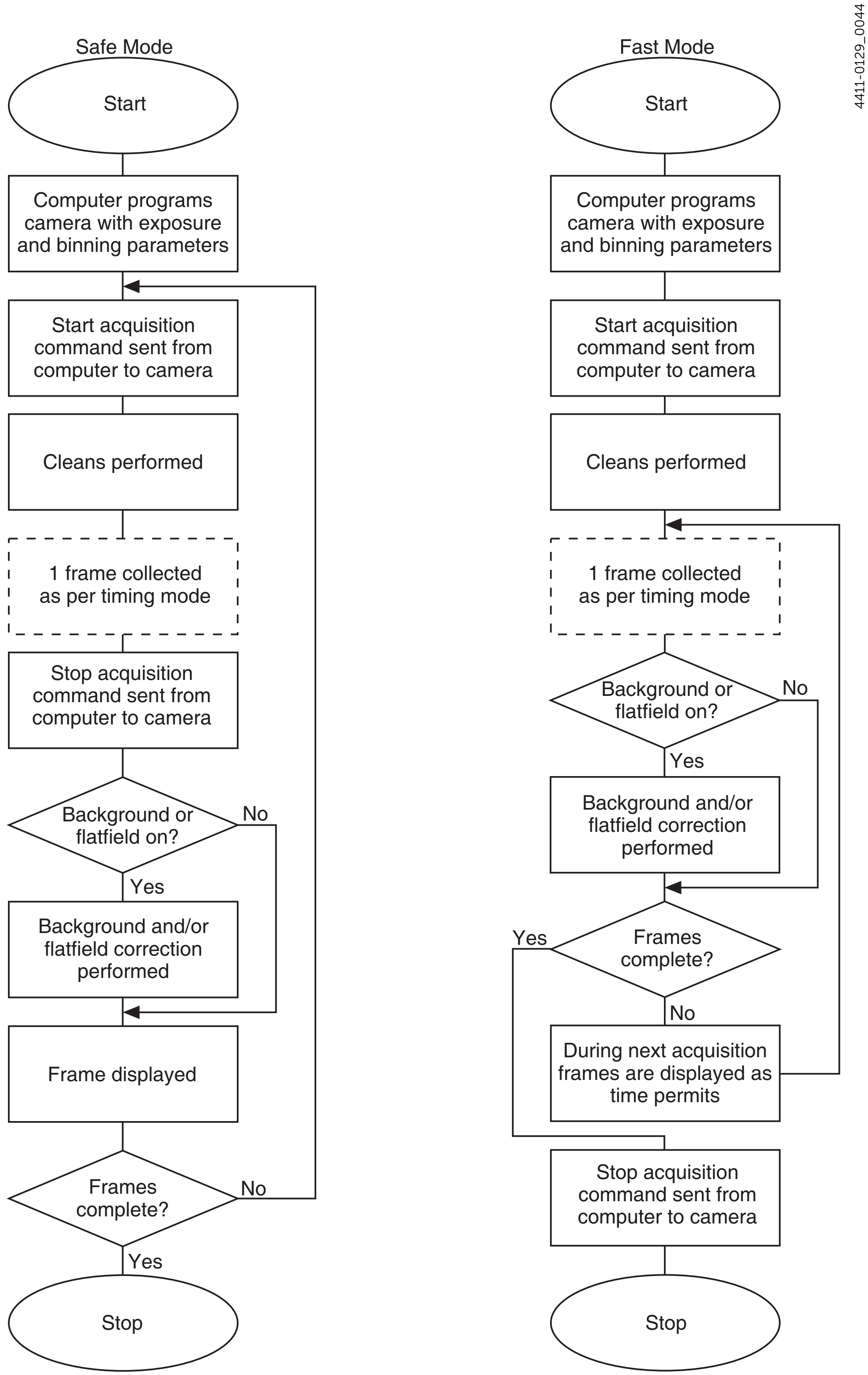
  Safe Mode operation is primarily useful for experiment setup, including alignment and focusing, when it is necessary to have the most current image displayed on the screen. It is also useful when data collection must be coordinated with external devices such as external shutters and filter wheels. As seen in Figure 7-19, in Safe Mode operation, the computer controls when each frame is taken. After each frame is received, the detector sends the Stop Acquisition command to the detector, instructing it to stop acquisition. Once that frame is completely processed and displayed, another Start Acquisition command is sent from the computer to the detector, 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 PI-MAX3 is disabled for a short time after each frame.

- Delay Time

  Allows a delay to be inserted between successive frame acquisitions. This parameter is only active in Safe Mode operation, in which each frame must be completely processed before the next one can be taken. The Delay Time inserts an additional delay after the computer has finished processing the previous frame before the next one can be acquired.

Figure 7-19: Flowcharts: Fast Mode versus Safe Mode



7.14 LightField Experiment Setup

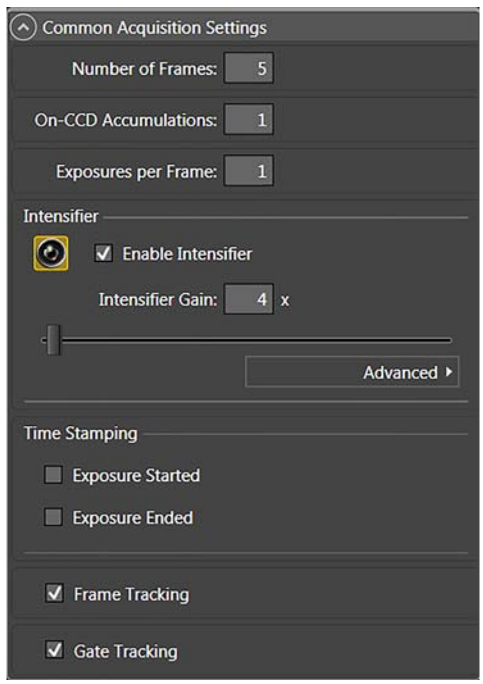
This section provides information about configuring each system parameter within LightField.

Initial experiment setup for LightField is an easy process. If your PI-MAX3 is powered on when you start LightField, the camera will be detected and its icon will be placed in the **Available Devices** area. When you drag the icon into the **Experiment Devices** area, the appropriate expanders will be loaded in the **Experiment Settings** stack. If this is the first time you have started LightField with this camera, the default settings for the camera will have been loaded into the expanders. The following paragraphs provide brief descriptions of several of the **Experiment Settings** expanders. For detailed descriptions of all of the expanders, refer to the LightField User's Manual and LightField's Online Help.

7.14.1 Common Acquisition Settings Expander

Figure 7-20 illustrates a typical LightField Common Acquisitions Setting expander.

Figure 7-20: Typical LightField Common Acquisitions Settings Expander



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The **Common Acquisitions Setting** expander includes the **Number of Frames**, **On-CCD Accumulations**, and **Exposures per Frame** settings that determine how many images will be acquired, whether multiple frames will be used to create a single frame, and whether multiple exposures will occur while a frame is being acquired.

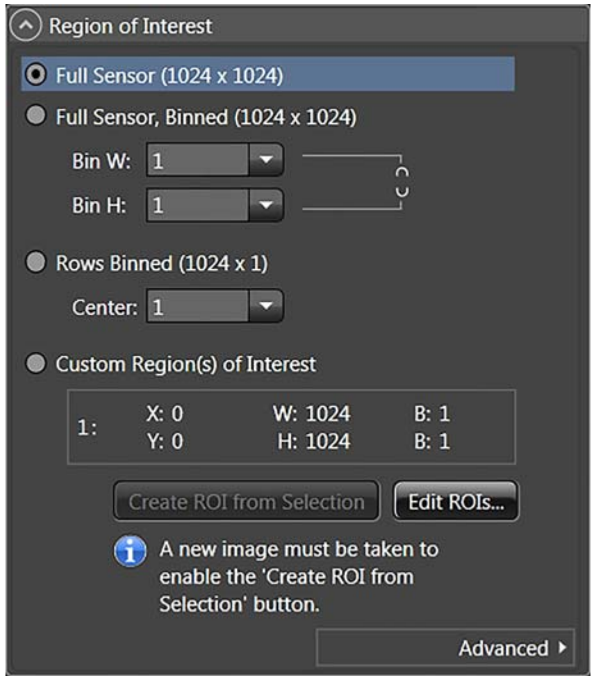
In addition, this expander is where the intensifier is enabled and the amount of intensifier gain can be set. The **Advanced** fly-out allows you to enter a **Phosphor Decay Delay Time** and choose its resolution.

Finally, you can specify time stamping information to be stored and displayed with the data.

7.14.2 Region of Interest Expander

Figure 7-21 illustrates a typical LightField Region of Interest expander.

Figure 7-21: Typical LightField Region of Interest Expander



4411-0129_0046

The **Region of Interest** expander allows you to specify how much of the total sensor image area will be used to acquire the data (i.e., full sensor, or one or more regions of interest.) This is also where you can set up and select either hardware or software binning.

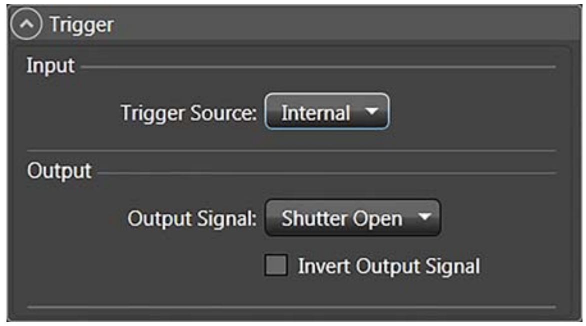
The **Advanced** button opens a fly-out pane where you the type of binning (i.e., hardware or software,) to be used if you have entered bin values other than 1.

The **Edit ROIs** button opens the **Edit Regions of Interest** window where you can capture a reference image to help you define which area or areas on the sensor are to be included when data acquisition is started. You can draw a selection box to define an area or you can key values into the ROI fields.

7.14.3 Trigger Expander

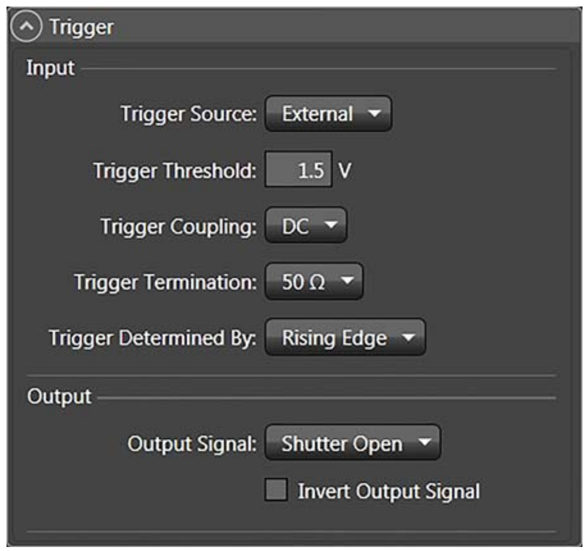
Figure 7-22 illustrates a typical LightField Internal Trigger expander, while Figure 7-23 illustrates a typical LightField External Trigger expander.

Figure 7-22: Typical LightField Trigger Expander: Internal Trigger Source



4411-0129_0047

Figure 7-23: Typical LightField Trigger Expander: External Trigger Source



4411-0129_0048

The **Trigger** expander is where you specify the trigger source (i.e., Internal or External,) to be used to trigger gating.

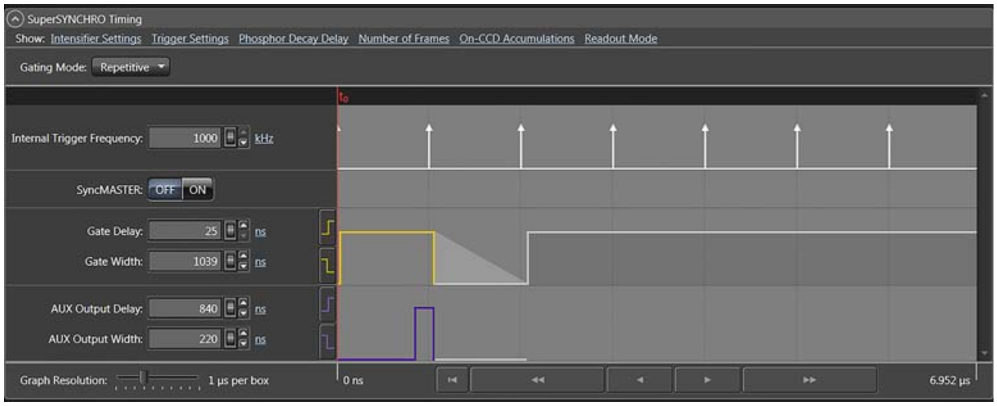
- Internal trigger uses the user-selected **Internal Trigger Frequency** configured on the **SuperSYNCHRO Timing** expander.
- External requires that you define the external trigger so LightField will be able to recognize it when it occurs at the **TRIGGER IN** BNC on the rear of the PI-MAX3.

This is also where you can choose the logic level output of the **LOGIC OUT** BNC.

7.14.4 SuperSYNCHRO Expander

Figure 7-24 illustrates a typical LightField SuperSYNCHRO Timing expander.

Figure 7-24: Typical LightField SuperSYNCHRO Timing Expander



4411-0129_0049

The **Super SYNCHRO Timing** expander is located at the bottom of the LightField desktop. This is where you select the type of gating (i.e., Repetitive, Sequential, or DIF,) and enter the gate delay and width information.

This is also where you can enter gate width and delay information for the **AUX OUT** BNC.

When **Internal Trigger** is the selected Trigger Source, or **SyncMASTER** is turned on, you can also enter the **Internal Trigger Frequency**. The hyperlinks open the appropriate expanders so you can check or make changes to the current settings for the intensifier, trigger, phosphor decay delay, number of frames, on-CCD accumulations, and readout mode.

Note that you can grab and drag the top of the **SuperSYNCHRO Timing** expander up to show more of the panel or drag the top down so you can see more of the **Experiment Settings** stack or the **Device/View** panel.

Chapter 8: WinX/32 and Gated Operation

This chapter discusses gated operation with the SuperSYNCHRO™ timing generator and aspects of operation of the PI-MAX3 not covered in Chapter 6, First Light, on page 49. We additionally suggest that you review Chapter 15, Tips and Tricks, on page 183, which contains information that should prove helpful in getting good results in more complex measurements.

Gating provides electronic shutter action by controlling the photocathode bias, allowing the detection of low light level signals in the presence of interfering light sources of much greater energy. For instance, in combustion research, a pulsed laser probe is used to investigate the chemistry within a flame. Since the flame itself emits broadband light continuously, the integrated flame emission is much greater than the integrated signal resulting shortly after the laser probe (such as laser-induced fluorescence or Raman). Fortunately, since the laser pulse is very short and the time at which it occurs is known, it is possible to gate for a few nanoseconds during the laser pulse, thus reducing the flame emission interference by approximately the measurement duty factor ratio.

Exposure time is the time space from which charge integrating on the CCD will get summed into the reported data. Gate width is the time during which light will be detected by the intensifier, intensified, and applied to the CCD. Basically, the intensifier controls what the chip sees during the exposure time.

For signal to be detected, it must fall in a valid gate width during a valid exposure. Many gate pulses can be placed into one exposure at repetitive or sequential intervals because there is no temporal measure inside a given exposure. All incident signals get summed (integrated) into one value per pixel/superpixel inside a given exposure.

Using presently available image intensifiers and gate pulse generators, optical gate times ≤4 ns Full Width at Half Maximum (FWHM) are possible. Since the control is electronic, the gate width can be made virtually as long as desired, allowing a wide range of experiment requirements to be satisfied in one instrument setup. Further, in UV measurements, where the On:Off ratio is only 10^4:1, the PI-MAX3's MCP bracketing feature can be used to extend the On:Off ratio to 10^6:1.

8.1 Precautionary Measures

WARNING!

Intensified CCD detectors, such as the PI-MAX3, when biased ON, can be irreparably damaged if continuously exposed to light levels higher than twice the A/D saturation level. Thus it is critical that you not establish conditions that could result in damage to the intensifier

Although intensified detectors are less prone to damage from *background light* when operated gated, they are at **significant risk** of damage from high-intensity light sources such as lasers. High intensity sources can damage the intensifier before the protection circuits have time to respond, or even cause spot damage without the protection circuits acting at all.

If a sustained alarm indication occurs when the controller is turned on, immediately switch the **I.I.T.** switch on the back of the PI-MAX3 to the **OFF** position. Cover the detector window and only switch the **I.I.T.** switch to **ON** after the illumination level has been lowered to safe operating conditions.

8.1.1 Intensifier Modes and Safety

The Experiment Setup **Main** screen in WinX/32 applications allows you to select one of two intensifier modes:

- Gate Mode

  In Gate Mode, the photocathode is biased on only for the time that each gate pulse is applied. As a result, the tolerance to room light is higher in gated operation, but the risk of damaging overload from intense light sources such as lasers remains. In fact, intense light sources in gated experiments can cause spot damage that would be undetected by the alarm circuit.
- Safe Mode

  In Safe Mode, the photocathode is continuously biased OFF and the intensifier is as safe as it can be.

NOTE:

In order for gating to occur, the I.I.T. switch on the back of the PI-MAX3 must also be in the **ON** position.

8.1.2 Alarm

NOTE:

It is normal for the alarm to sound briefly when the system is turned on.

To reduce the risk of detector damage, the PI-MAX3 detector is equipped with an audible alarm in the detector head, activated when the intensity of light falling on the image intensifier exceeds a preset threshold. While the alarm is sounding, the photocathode is disabled. Immediately toggle the I.I.T. switch (on the back of the PI-MAX) to the OFF position. Cover the detector window and only switch the I.I.T. switch to ON after the illumination level has been lowered. If the alarm sounds continuously even when the illumination level is adequately low, shut the system down and contact the factory for guidance.

CAUTION!

Discontinue operation and contact the factory at once if sporadic or continuous unwarranted alarms occur. They may indicate intensifier damage or another situation that requires immediate attention.

8.2 Timing Mode

When in **Gate Mode**, the internal timing generator only operates using **Internal Sync** timing. This timing mode initiates a readout cycle after each internal timing generated pulse ensemble.[1] The handshakes that prevent a readout from occurring while the timing generator is busy and that prevent the timing generator from pulsing the photocathode ON while a readout cycle is in progress are performed within the camera.

NOTES:

1. Automatically configured parameters may not be visible in some versions of the software.
2. The Accumulations and Images (or Spectra) parameters (WinView/32 or WinSpec/32 Acquisition Setup Main tab) govern how the data will be processed. Integrating multiple events on the CCD really brings the power of the PI-MAX3 to bear on low-light gate-mode experiments. If the experiment allows, many pulses can be summed on the CCD with no pulse artifacts in the readout. The signal increases nearly linearly with the number of pulses (within limits imposed by the CCD).

1. An internal timing generator pulse ensemble consists of a Gate Start pulse, a Gate Stop pulse, and one or more Auxiliary pulses.

For this mode, the following parameters are automatically configured by the application software and cannot be changed:

- Exposure Time is set to 0;
- Continuous Cleans is disabled;
- Shutter Control is set to Disabled Opened.

Table 8-1: Timing Mode, Shutter Control, and Ext. Trigger Input when Using the Internal Timing Generator

Timing Mode	Shutter Control	External Trigger Input
Controlled by Internal Timing Generator	Controlled by Internal Timing Generator	Trigger In BNC

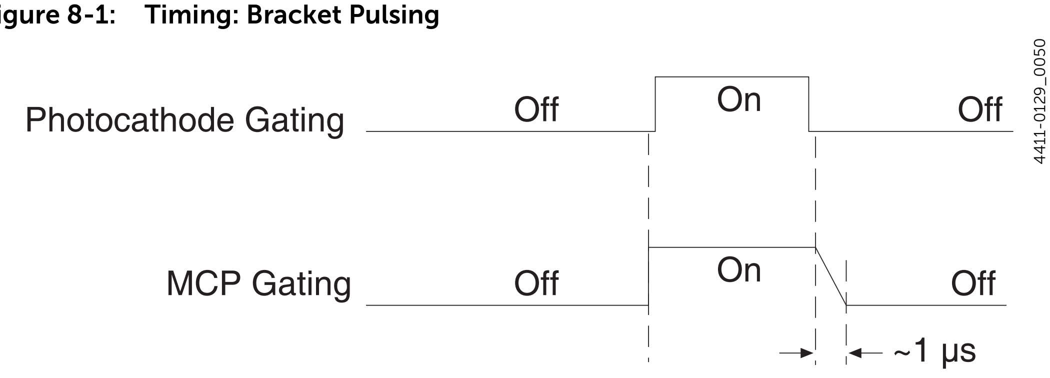
8.3 MCP Bracket Pulsing

The principal utility of gating is that it allows temporal discrimination against background light. By allowing the photocathode to see only during the event of interest, very high background illumination levels can be tolerated without materially degrading experiment results. The limit on this technique is set by the light leakage of the intensifier, which, although it is very good, is not without limit. In the visible, the on/off ratio of a typical Gen II Intensifier with just the photocathode gated is excellent, typically between 10^6 and 10^7. In most measurements, this ratio is sufficient to assure that the signal reaching the CCD during the intensifier Off times will be too small to affect the data.

Below 350 nm, however, a second leakage mechanism occurs, optical leakage through the photocathode to the UV-sensitive MCP, which reduces the On:Off ratio to about 2×10^4 at 200 nm. This is the dominant response of a Gen II image intensifier to UV photons when the photocathode is electrically off. At an On:Off ratio of 20,000, the ability of a camera with conventional photocathode (only) gating to perform certain kinds of measurements in the UV is adversely affected.

MCP bracket pulsing[1] keeps the MCP biased OFF except for an interval that brackets the timing of the photocathode gate as shown in Figure 8-1. For emitted photoelectrons to be accelerated in the MCP, the MCP must be biased ON. In conventional intensified cameras, the MCP is biased ON continuously. In the PI-MAX3, however, when bracket pulsing is ON, the MCP is biased OFF until just before the photocathode is gated ON and is biased OFF shortly after the photocathode is biased OFF.

Figure 8-1: Timing: Bracket Pulsing



1. Bracket pulsing is not available for cameras having a filmless Gen III Intensifier. Gen III Intensifiers do not respond in the UV.

By bracket pulsing the MCP off (in addition to photocathode gating), the on/off ratio of the Gen II PI-MAX3 in UV is improved by 2-3 orders of magnitude. The resulting UV ratio exceeds even the high levels normally achieved in the visible. Applications that benefit from this new approach include LIF and nanosecond pump-probe experiments.

NOTE:

Bracket pulsing does not help in the visible region. Under extremely low duty-factor conditions, the only remedy is to install an external shutter ahead of the camera.

8.3.1 Bracket Pulsing in LIF Measurements

Most experiments using laser-induced fluorescence to probe combustion flows are performed with UV probe/lasers. Atomic emission from flames also has significant UV content. If the flame is continuous, the UV background will also be continuous. Even where a flame is transient (e.g., an internal combustion engine,) its lifetime can be many milliseconds, compared to the nanosecond time scale of the laser used. This background can be a million times as long. If the background is bright, then a UV on/off ratio of 20,000:1 will be overwhelmed by the duty cycle and will not be adequate for extracting a signal of 10^{-5}. In high dynamic range quantitative measurements, backgrounds must be kept to an absolute minimum. MCP bracket pulse gating dramatically improves the rejection of CW and even millisecond time-scale background.

An alternative to suppressing background for imaging has been the use of very narrow spectral bandpass filters. In the UV, these filters are expensive and they can have low transmission at their central wavelength. An additional filter is required for each wavelength to be imaged. The use of electronic temporal rejection of CW or quasi-CW background may make it unnecessary to use these filters, thus increasing the optical throughput, sensitivity, and quantitative precision of the measurement.

8.3.2 Bracket Pulsing in Nanosecond Pump Probe Experiments

Some nanosecond pump-probe experiments combine a nanosecond or faster pump with a flash lamp probe. The duration of the probe flash can be 10-50 μs and a gate is used to select the specific nanosecond-scale time slice to be observed within the much longer probe flash. In these absorbance experiments, accurate measurement of absorbance values depends critically on the lack of stray light contamination, particularly at moderate to high optical density levels. Selecting a 5 ns time window out of a 10 μs pulse is already one part in 2,000. If UV leakage gives an on/off ratio of only 20,000:1, contamination could be 10% or higher. This would limit the optical density to 1.0, and it could make linear quantitation difficult beyond 0.1 OD.

MCP bracket pulse gating can substantially improve the on/off ratio in such an experiment. Even with a 1 μs MCP pulse, the rejection of flash-lamp leakage can add more than an order of magnitude of range, to 2.0 OD.

8.3.3 Limitations of Bracket Pulse Gating

MCP bracket pulse gating is most useful in rejecting background that lasts microseconds up to CW. Fast transient backgrounds can be in the form of stray laser light scattering (e.g., Raleigh, MIE, or Raman,) or unwanted fast fluorescence. Because these usually fall below the MCP bracket pulsing 35 ns delay restriction, these measurements cannot be improved much by MCP bracket pulsing in the PI-MAX3.

Electrically, gating the MCP will only reduce leakage at wavelengths where the MCP has photoelectric response (primarily in the UV.) Thus, for visible and NIR wavelengths where leakage is primarily optical, the improvement will be minimal (although the on/off ratio is already very good in these regions.) Note that in some spectroscopic applications, visible leakage may appear to be reduced by MCP pulsing. This is because the second order UV spectrum overlays the first order visible spectrum in a grating spectrograph. MCP pulsing can eliminate unwanted sensitivity to CW or quasi-CW second order UV, causing the apparent improvement.

Also, keep in mind that MCP bracket pulsing adds 10 ns delay to the photocathode gating. Even though the bracket timing is controlled automatically by the software, in an experiment where it is necessary to delay the arrival of the laser pulse at the sample, this will mean inserting an additional delay of 10 ns (min gate delay = 25 ns, with bracket = 35 ns) to accomplish coincidence at the detector. MCP bracketing should only be used in experiments where it is going to make a difference.

Also, MCP bracket gating limits the repetition rate to 6.25 kHz. Without it the gate repetition rate can be up to 1 MHz (more with option boards.) This is not a significant limitation in most cases. Note that with a 10 ns gate at 6.25 kHz, the on/off ratio = 16,000, close to the non-bracket value.

Note that background light need not be the limiting factor in measurements where MCP bracket pulsing is unable to provide the required degree of rejection. In such measurements, the option remains of installing an external shutter ahead of the PI-MAX3.

8.3.4 Impact of Bracket Pulsing on Delay

If operating in the UV when bracket pulsing is activated (Gen II Intensifier only,) the MCP gate automatically brackets the photocathode gate pulse to further enhance the on/off ratio. There is, however, a limitation of bracket pulsing that can complicate the coincidence of the signal and gate at the camera. Because MCP bracket gating is slower than photocathode gating (35 ns is required to gate the MCP on, and another 1 μs to gate the MCP off at the end of the photocathode gate.) As a result, MCP bracket pulsing should not be used in experiments where the delay between the trigger and the photocathode gate is less than 35 ns.

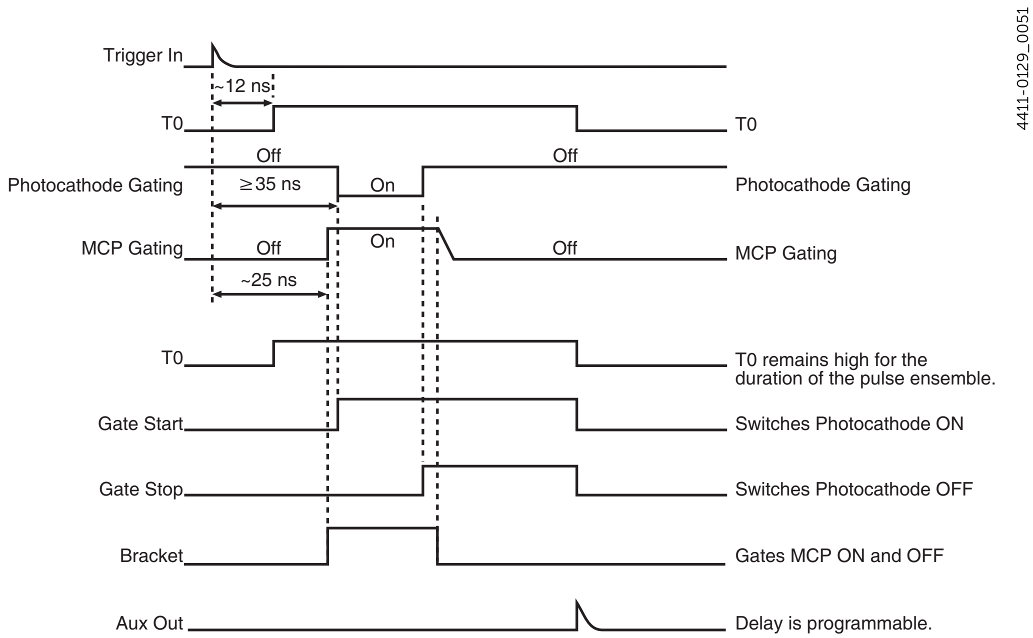
8.3.5 Setup

MCP Bracket pulse implementation is accomplished by selecting Bracket Pulsing ON from the host software. Figure 35, is a timing diagram for bracket pulsing. Insertion delay between trigger and T0 is ~ 12 ns. Insertion delay to photocathode gate is 35 ns (i.e., the minimum delay in bracket mode is 35 ns): this delay allows the MCP to be up to full gain before the photocathode is gated on.

NOTE:

Because Gen III Intensifiers do not respond in the UV, bracket pulsing is not available for these intensifiers.

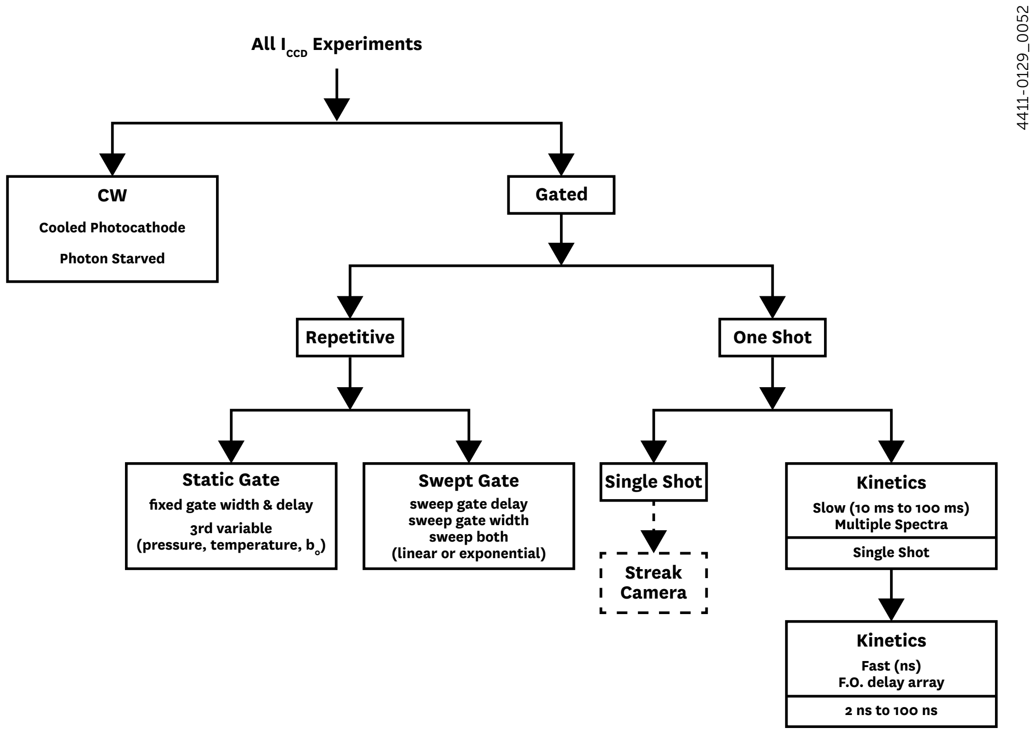
Figure 8-2: Timing Diagram: PI-MAX3 MCP Bracket Pulsing



8.4 Additional Experiments

Figure 8-3 illustrates the kinds of experiments that can be performed with a PI-MAX3 detector.

Figure 8-3: Typical PI-MAX3 Experiments



Of the many gated measurements that can be performed with a PI-MAX3, most will fall in one of the following categories:

- Static Gate

  This type of experiment may also be referred to as **Repetitive-Continuous**.

  There is a repetitive trigger, and the Gate Width and Gate Delay are fixed.

  A variable in the experiment (e.g., pressure, concentration, wavelength, or temperature,) is varied.

- Swept Gate

  In this type of experiment, Gate Width, Gate Delay, or both may be varied.

  — Repetitive-Sequential 1

  The Trigger is repetitive, Gate Width is fixed, and Delay is varied over the course of the measurement.

  The result of the experiment is a plot of intensity vs. time, such as might be obtained with a sampling oscilloscope. This technique is used to measure lifetime decays.

  — Repetitive-Sequential 2

  The Trigger is repetitive and Gate Width and Delay are varied over the course of the measurement.

  Gate Width and Delay can be incremented in a linear fashion or in an exponential fashion. Increasing the Gate Width is useful for trying to find fine detail in a weak decaying signal. If you choose linear, you have to take a lot more points. Exponential lets you take data points closer together where the signal is changing rapidly and further apart where the signal is changing slowly.

- Single Shot
  A single shot experiment is one where you have only one chance to catch the data. Any experiment that can't be repeated more often than once a minute, such as high power lasers and explosives, is considered a single shot. You have to catch the trigger when it comes. Prior to the event, the CCD runs in continuous cleans mode. You don't have the luxury of having the CCD just sitting there doing nothing because the CCD will be accumulating dark current. When the trigger arrives, the intensifier gates, the continuous cleans stop, and the array is read out with a minimum of dark current. Pre-Trigger can be helpful if available.

8.4.1 Swept Gate Experiment [Fixed Width; Variable Delay]

This section provides information about configuring a Swept Gate experiment with fixed Gate Width and variable Gate Delay (i.e., Repetitive-Sequential 1).

8.4.1.1 Experiment is Master Clock

NOTE:
In this configuration, the experiment itself serves as the Master Clock.

This experiment attempts to time-resolve a Xenon light flash from a commercially available strobe light. Since the strobe does not have a pre-trigger out, an electrical trigger is generated by using a photodiode. Output from the photodiode is connected to the **Trigger In** BNC of the PI-MAX3. See Figure 8-4.

Figure 8-4: Block Diagram: Swept Gate Experiment [Fixed Width, Variable Delay]

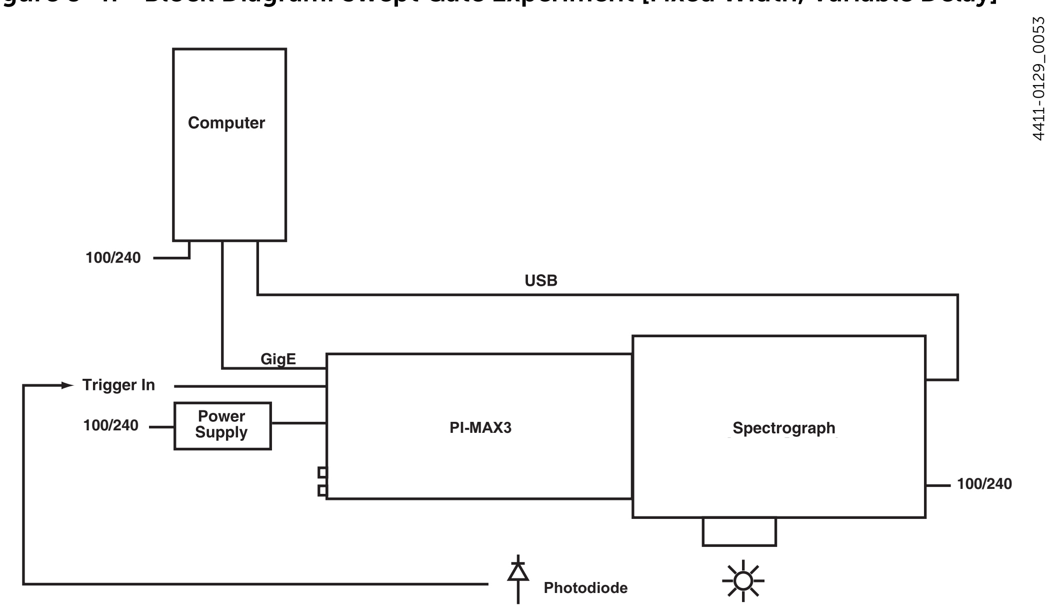
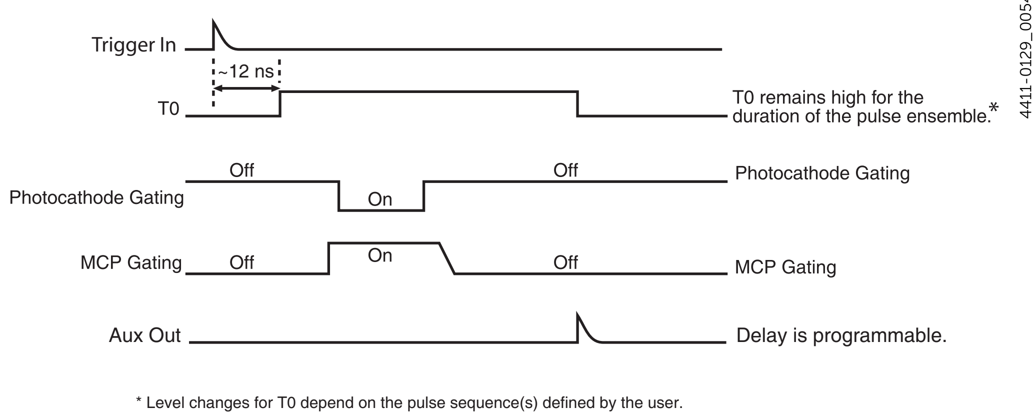


Figure 8-5 illustrates the timing diagram for this experiment.

Figure 8-5: Timing Diagram: Swept Gate Experiment [Fixed Width, Variable Delay]



Perform the following procedure to configure this experiment:

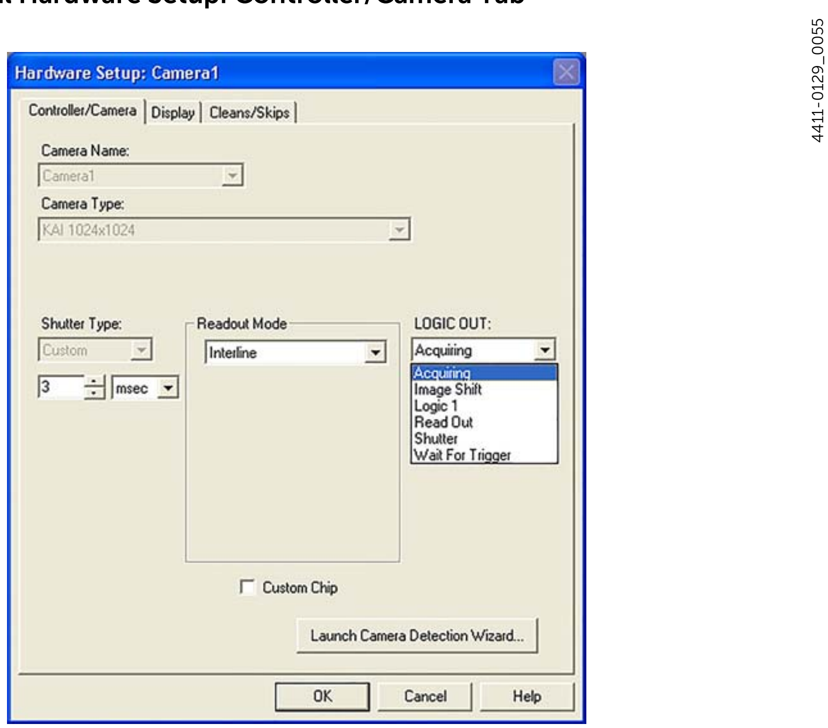
NOTE:

Because this procedure uses the experiment as its Master Clock, refer to Figure 8-4 and Figure 8-5 for connection information.

1. Turn on the equipment and start the WinX/32 application software (Version 2.5.25 or higher).
2. Open the **Setup** ► **Hardware** ► **Hardware Setup** dialog.

   The **Hardware Setup** dialog is displayed similar to that illustrated in Figure 8-6 which shows information for a KAI 1024 x 1024 interline camera.

Figure 8-6: Typical Hardware Setup: Controller/Camera Tab



a. Click **Load Default Values** on the **Cleans/Skips** tab.

b. Configure the detector temperature by selecting **Detector Temperature** on the **Setup** menu. Entering the desired Target Temperature and click **Set Temp**. Finally, click **OK**. Refer to the WinView/32 or WinSpec/32 manual as necessary.

3. If you have a spectrograph, configure the spectrograph properties using the menu items on the **Spectrograph** menu (WinSpec/32 only).

   If the spectrograph being used has not been installed, first click on **Install/Remove Spectrograph** and do so before setting the properties. Figure 8-7 through Figure 8-9 illustrate the WinSpec/32 sequence for an Action 300I spectrograph.

Figure 8-7: Typical Define Spectrograph Dialog

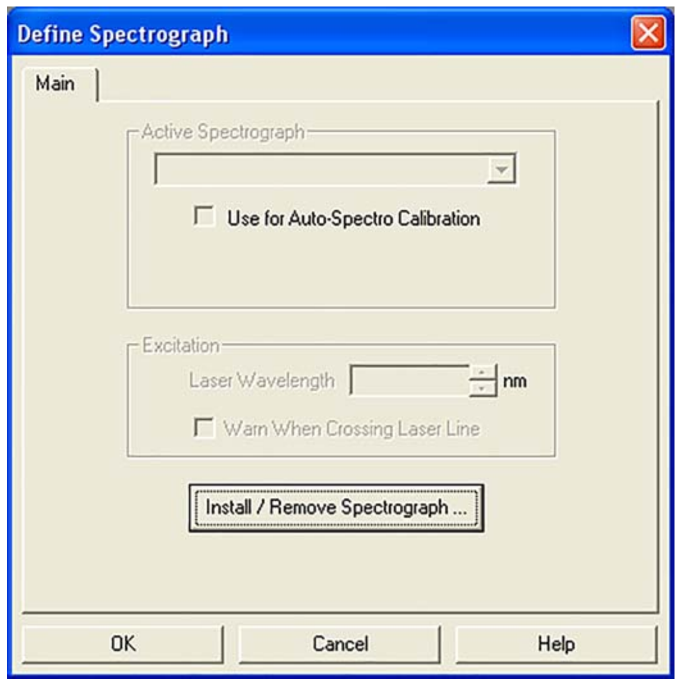


Figure 8-8: Typical Install/Remove Spectrographs Dialog

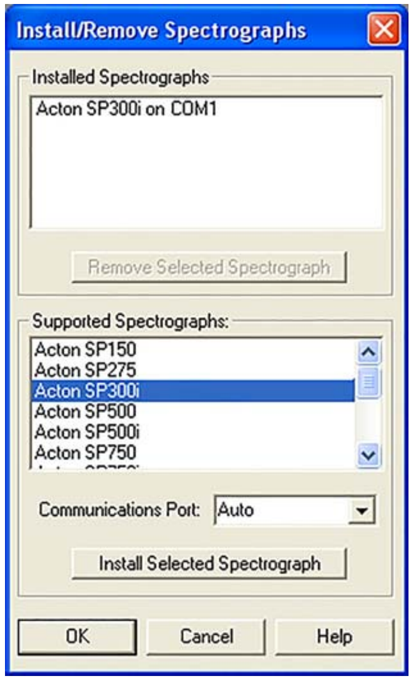


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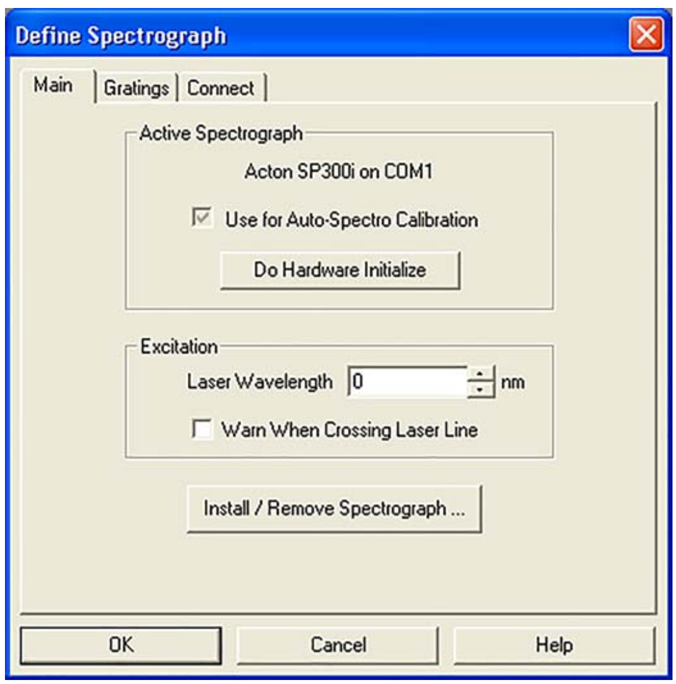
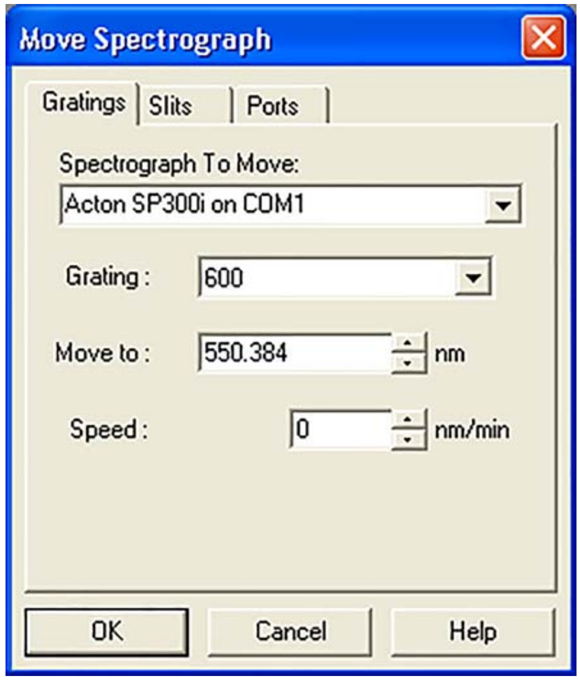
Figure 8-9: Typical Define Spectrograph Dialog: Main Tab [Acton SP300i]



4411-0129_0058

4. After you have installed and defined the spectrograph, move the grating to the desired wavelength. See Figure 8-10.

Figure 8-10: Typical Move Spectrograph Dialog

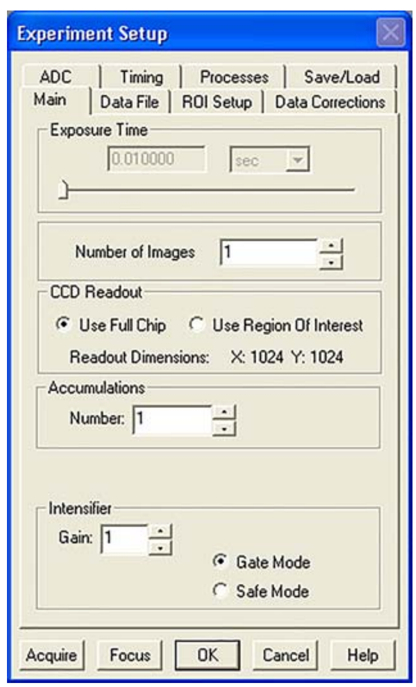


4411-0129_0059

5. At this point, verify that the camera is focused by running it in **Internal Trigger** mode. Perform the following procedure to configure Internal Trigger mode:

   a. On the **Experiment Setup** ► **Main** tab, choose **Gate Mode**, and configure a value between 0 and 100 for **MCP gain**. See Figure 8-11.

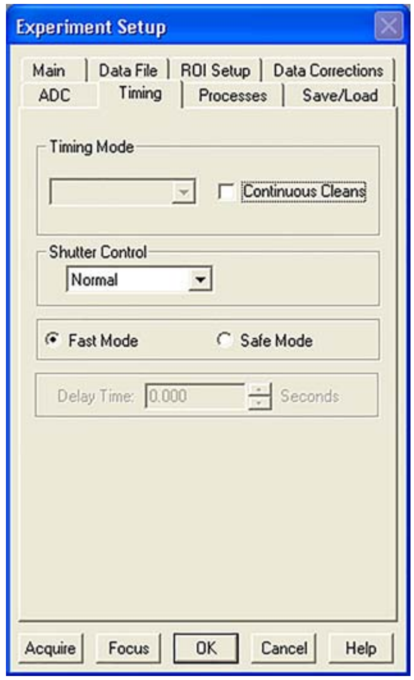
Figure 8-11: Typical Experiment Setup Dialog: Main Tab



4411-0129_0060

b. On the **Timing** tab, select **Fast Mode**. See Figure 8-12.

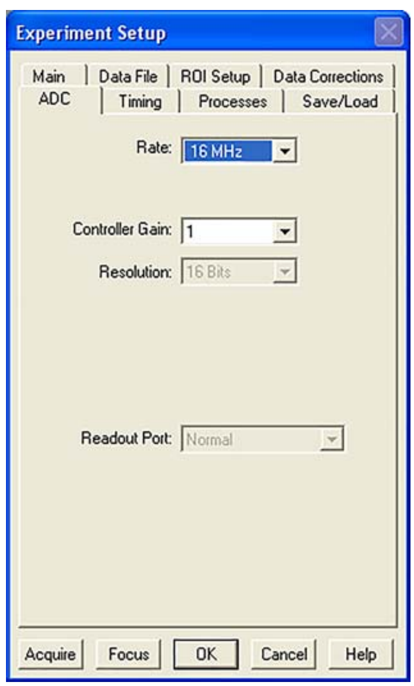
Figure 8-12: Typical Experiment Setup Dialog: Timing Tab



4411-0129_0061

c. On the **ADC** tab, select the appropriate rate. See Figure 8-13.

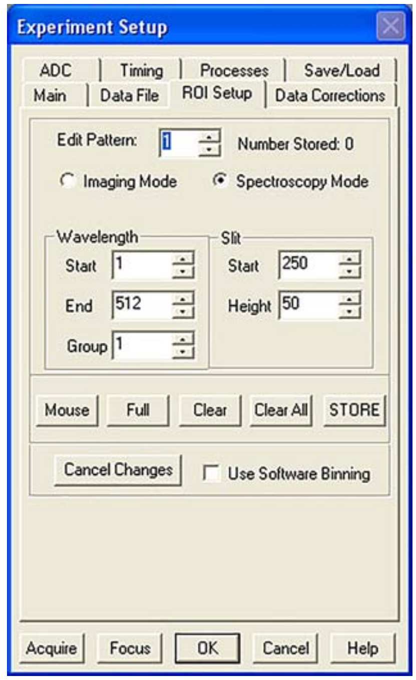
Figure 8-13: Typical Experiment Setup Dialog: ADC Tab



4411-0129_0062

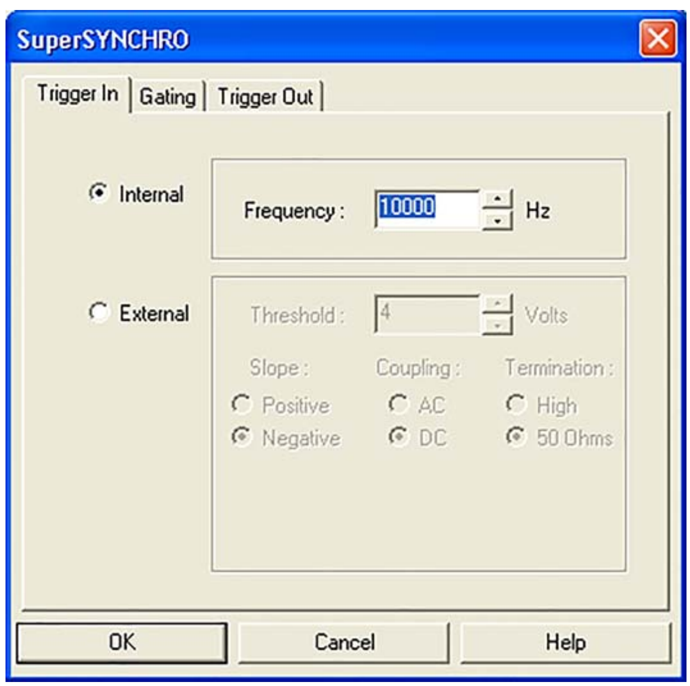
d. On the **ROI Setup** tab, select the appropriate ROI. See Figure 8-14.

Figure 8-14: Typical Experiment Setup Dialog: ROI Setup Tab



e. On the **SuperSYNCHRO Trigger In** tab, select **Internal**. See Figure 8-15.

Figure 8-15: Typical SuperSYNCHRO Dialog: Trigger In Tab

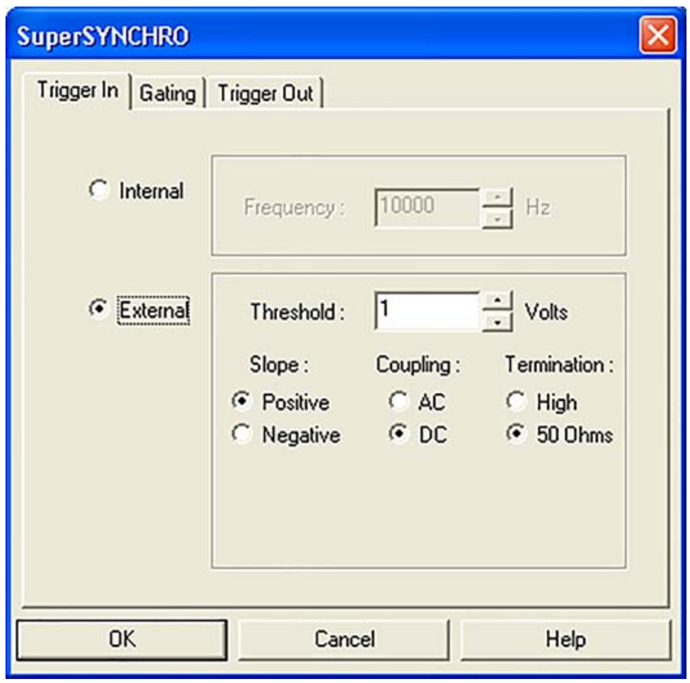


6. After setting the parameters and making sure the ambient light level is low, click **Focus**.
   - If the readout mode is currently set to **Use Region of Interest** on the **Main** tab, the camera will start acquiring data immediately.
   - If the readout mode is currently set to **Use Full Chip** you will be asked if you want to change the setting to **Use Region of Interest** before focus mode is activated.

     Click **Yes** and the camera will begin acquiring data.
7. After you make sure that the camera is seeing, stop data acquisition.
8. Perform the following procedure to configure the pulser/SuperSYNCHRO:
   a. After selecting SuperSYNCHRO as the active pulser, click **Setup Pulser...**.

   Define the external trigger on the **Trigger In** tab. See Figure 8-16.

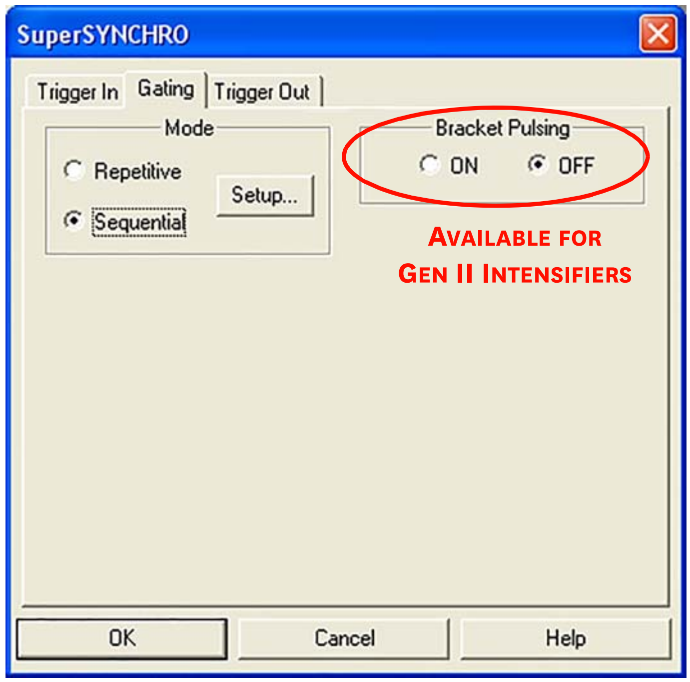
Figure 8-16: Typical SuperSYNCHRO Dialog: Trigger In Tab



4411-0129_0065

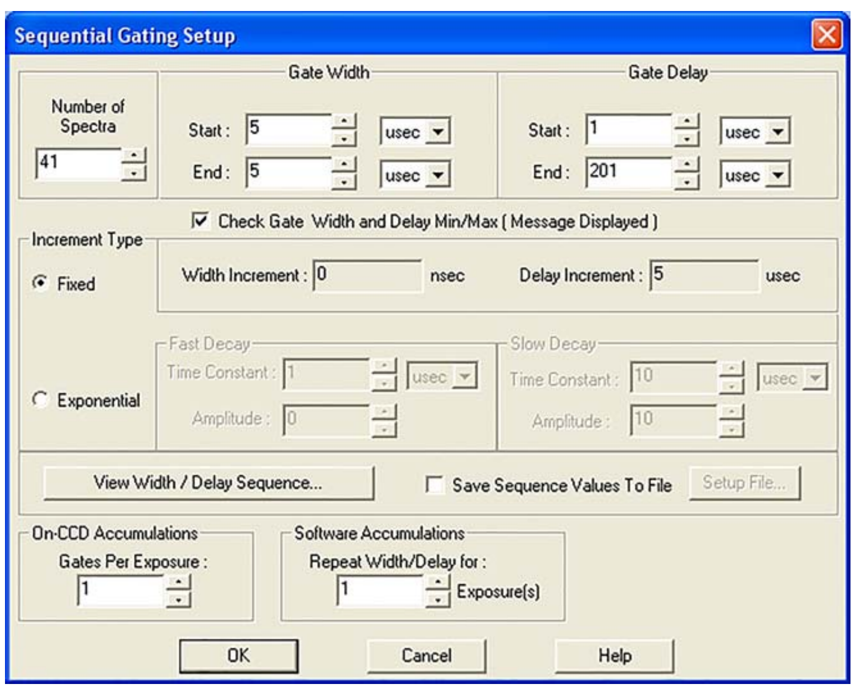
b. On the **Gating** tab, select **Sequential** as the **Active Mode** and then click **Setup...**. If you have a Gen II intensifier, set **Bracket Pulsing** to **OFF** for this experiment. See Figure 8-17.

Figure 8-17: Typical SuperSYNCHRO Dialog: Gating Tab



c. Click **Setup...** to display the **Sequential Gating Setup** dialog. See Figure 8-18.

Figure 8-18: Typical Sequential Gating Setup Dialog

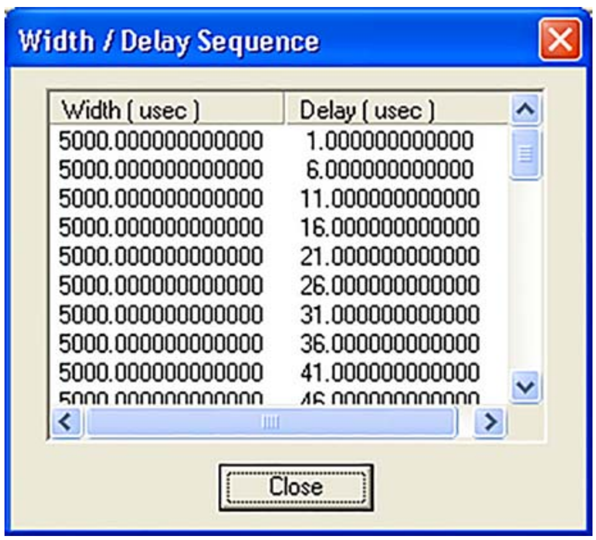


d. Configure the Pulse Sequence parameters as indicated:
- Configure the **Number of Spectra** to be acquired.
  In this case, 41.
- Under **Increment Type**, select **Fixed Increment**.
- Under **Gate Width**, configure the desired **Start** and **End** times.

> **NOTE:**
> Since this experiment requires a fixed gate width these values will be the same.

- Under **Gate Delay from T0 Out**, configure the desired **Start** and **End** durations.
  For this experiment:
  - **Start** delay is 1 μs;
  - **End** delay is 201 μs.
- Under **On-CCD Accumulations**, configure the number of **Gates per Exposure**.
  In this case, 1.
- To verify the Gate Delay for each of the 41 spectra, click **View Width/Delay Sequence...**.
  See Figure 8-19.

Figure 8-19: Typical Width/Delay Sequence Dialog



4411-0129_0068

e. The functions on the **Trigger Out** tab allow you to enable the **SyncMASTER™** trigger output from the **SyncMASTER1** and **SyncMASTER2** connectors on the **AUX I/O** cable and configure the **Aux. Out** signal at the **AUX OUT** connector on the rear of the PI-MAX3.

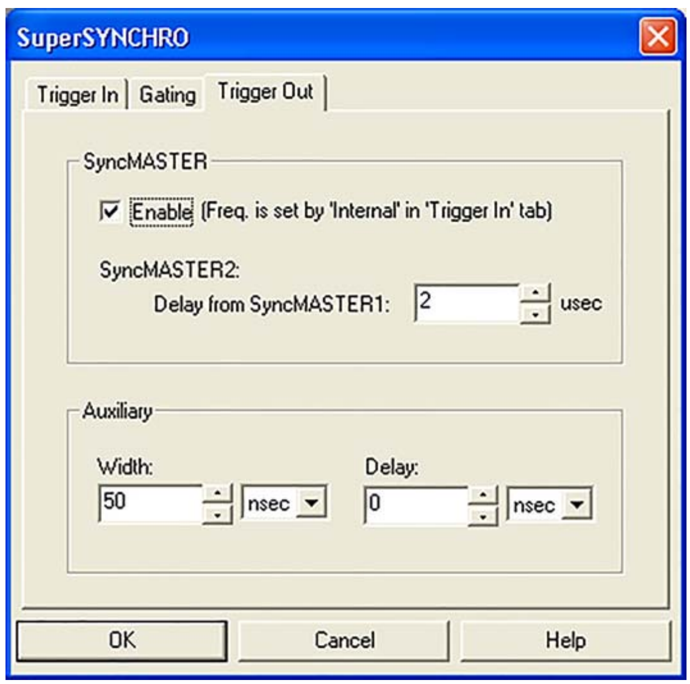
- When you enable **SyncMASTER 1**, the output of the **SyncMASTER1** connector will be at the frequency entered on the **Trigger In** tab.
- The output of the **SyncMASTER2** connector will be at the same frequency as that of **SyncMASTER1**. However, you can enter a delay so the edges of that signal will occur after the edges of **SyncMASTER1**.

  When using the **Aux. Out** signal from the **SuperSYNCHRO** to trigger a piece of equipment, enter the **Auxiliary** pulse **Delay** time on the **Trigger Out** tab. The delay is based on T0. This is, in effect, a delay from **SyncMASTER1** which also starts at T00.

  Configure the pulse width needed to trigger the equipment.

  See Figure 8-20.

Figure 8-20: Typical SuperSYNCHRO Dialog: Trigger Out Tab

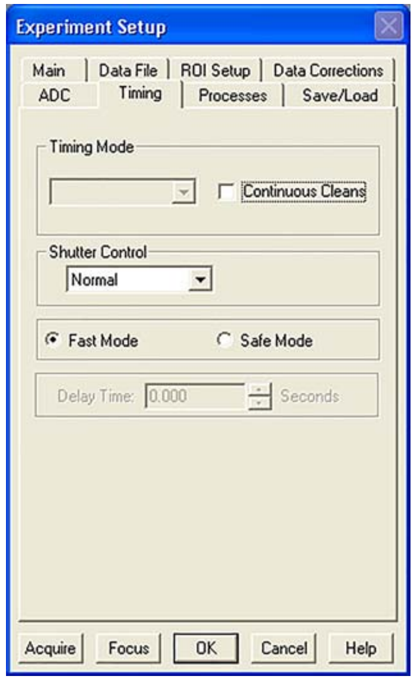


4411-0129_0069

f. Click **OK** to program the **SuperSYNCHRO**.

9. Perform the following procedure to configure the experiment parameters on the **Experiment Setup** dialog.
   a. On the **Timing** tab, configure timing as shown in Figure 8-21.

Figure 8-21: Typical Experiment Setup Dialog: Timing Tab



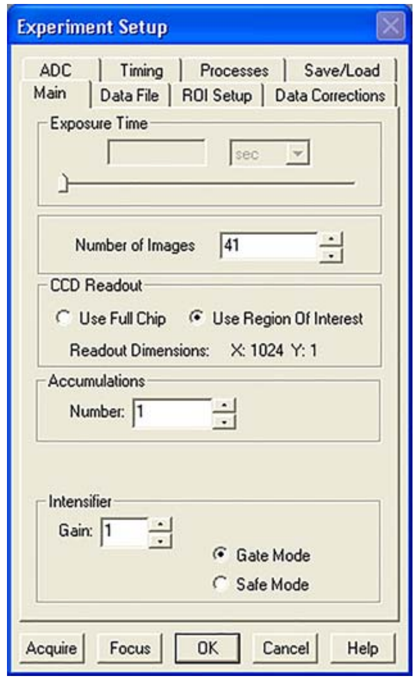
4411-0129_0712

10. On the **Main** tab, configure the **Intensifier: Gain** value and select **Gate Mode**.

> **NOTE:**
>
> In **Gate Mode**, the photocathode is only biased on for the time that each gate pulse is applied. This limits the risk of damage resulting from room light.
>
> However, there is a risk of damaging overload from intense light sources such as lasers.

See Figure 8-22.

Figure 8-22: Typical Experiment Setup Dialog: Main Tab



4411-0129_0070

NOTE:

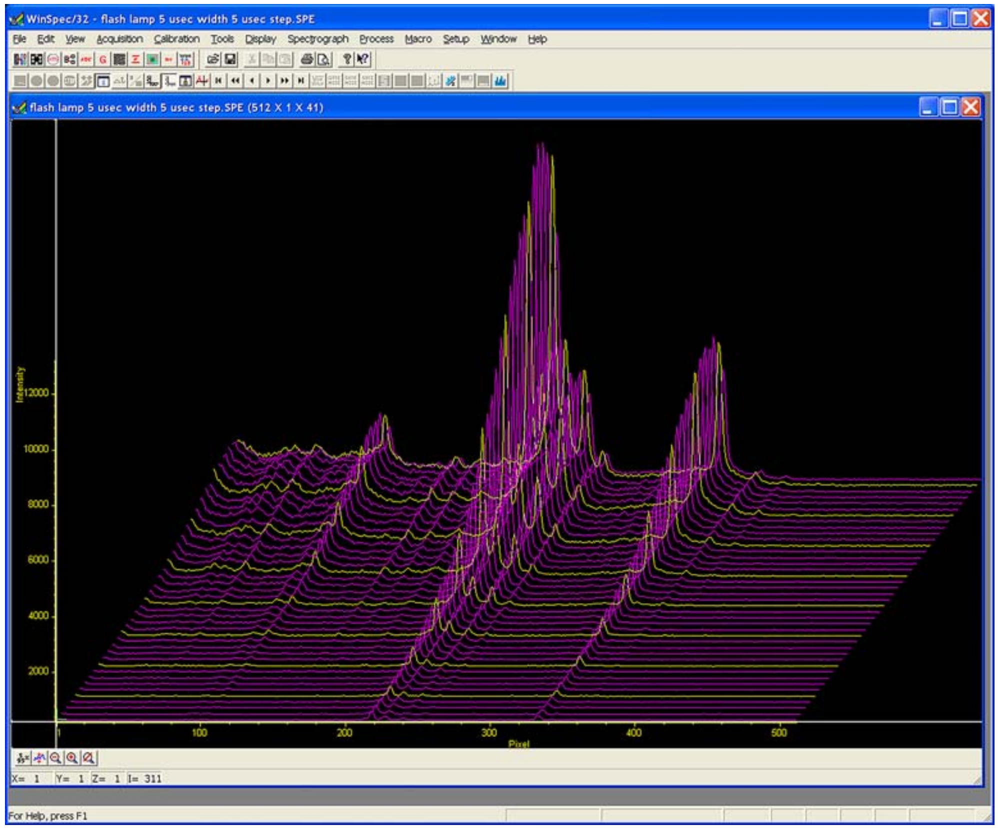
The number of spectra is automatically updated/ programmed depending on the number configured on the **Sequential Gating Setup** dialog. See Figure 8-18.

11. After verifying all connections and equipment readiness, click **Acquire** to begin acquiring the spectra/images.

    Figure 8-23 illustrates a typical 3-D graph for a **Sequential-Repetitive** experiment with Fixed Width and Variable Delay as configured in step 8 of this procedure.

Figure 8-23: Typical 3D Experiment Results

4411-0129_0071



8.4.1.2 SyncMASTER1 as Master Clock

When using a light source that is equipped with **Trigger In**, the PI-MAX3 SyncMASTER function can be used as the Master clock. Figure 8-24 illustrates the block diagram for this configuration, and Figure 8-25 is the timing diagram.

Figure 8-24: Block Diagram: PI-MAX3 SyncMASTER1 as Master Clock

4411-0129_0072

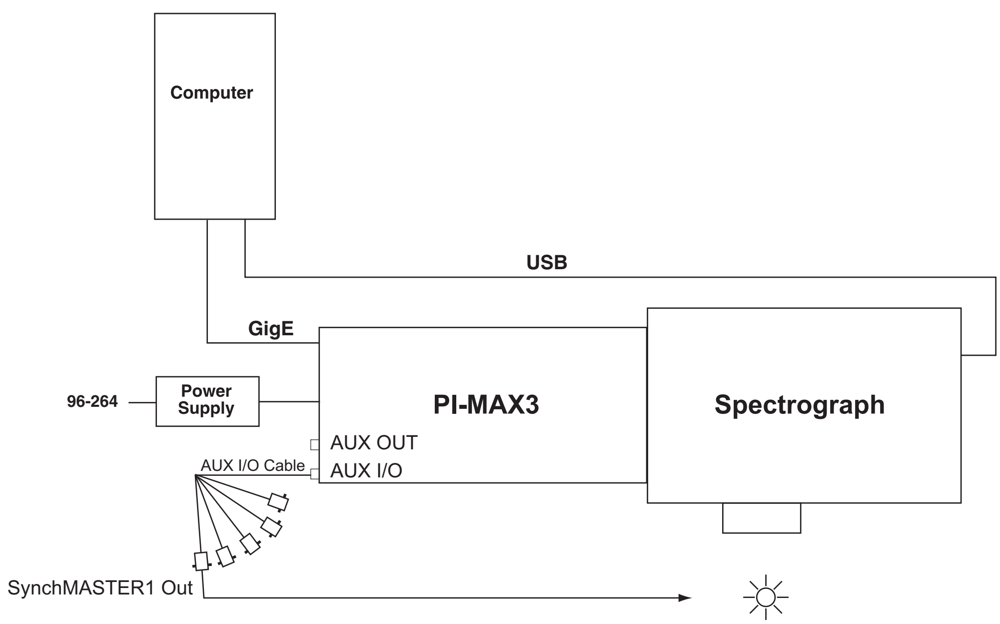
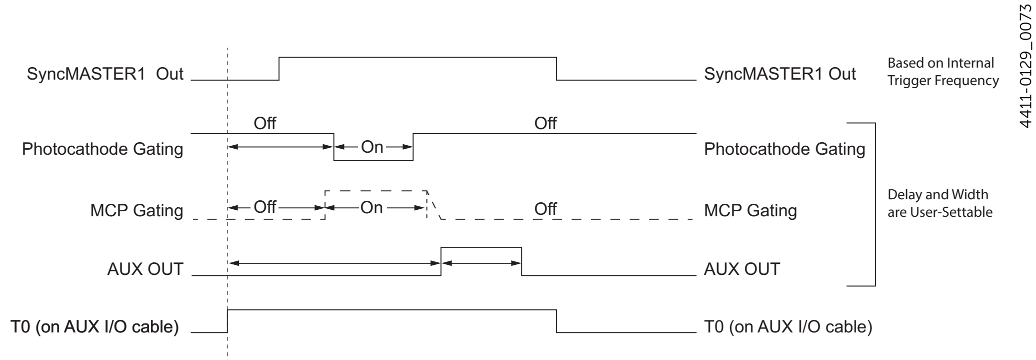


Figure 8-25: Timing Diagram: PI-MAX3 SyncMASTER1 as Master Clock



The setup procedure is much the same as that described in Section 8.4.1.1, Experiment is Master Clock, on page 105.

The differences are:

- Internal Trigger is selected;
- SyncMASTER is enabled;
- A cable is connected between the PI-MAX3's AUX I/O cable's SyncMASTER1 BNC and the light source (experiment) for triggering the event.

8.4.2 Swept Gate Experiment [Variable Width, Variable Delay]

The procedure to configure a Swept Gate experiment with variable width and delay is similar to that for a Swept Gate experiment with fixed width and variable delay with the following configuration changes:

- In addition to configuring differing start and end values for the Gate Delay, differing start and end values for the Gate Width must be configured.

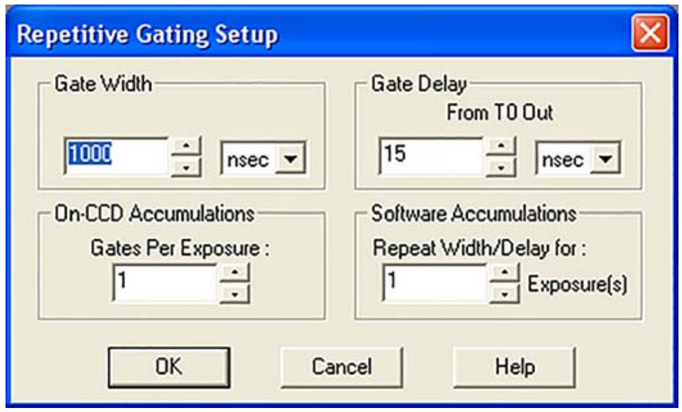
Refer to Section 8.4.1, Swept Gate Experiment [Fixed Width; Variable Delay], on page 105 for complete configuration information.

8.4.3 Static Gate Experiment [Fixed Width, Fixed Delay]

The procedure to configure a Static Gate experiment with fixed width and delay is similar to that for a Swept Gate experiment with the following configuration changes:

- **Gate Mode** is configured as **Repetitive**;
- Gate Width and Gate Delay are configured on the Repetitive Gating Setup dialog. See Figure 8-26.

Figure 8-26: Typical Repetitive Gating Setup Dialog



Refer to Section 8.4.1, Swept Gate Experiment [Fixed Width; Variable Delay], on page 105 for additional configuration information.

8.4.4 Single Shot Experiment

A single shot experiment offers one chance to capture an event. As in any gated experiment, the time budget of the experiment is crucial. If there is no pre-trigger from the experiment, a photodiode can be used to generate an electrical trigger from the laser light. In this situation, light has to be delayed by optical means (fiber-optic cable or mirror reflections) to allow sufficient time for the electronics to be activated after receiving the trigger. Another important thing to note in single shot experiments is that the CCD is set in "Continuous Cleans" mode so that there is no dark charge accumulation while it is waiting for the trigger.

The following experiment is an attempt to capture a 60 ns fluorescence generated by a single shot laser. The time budget for this experiment is provided in Table 8-2.

NOTE:

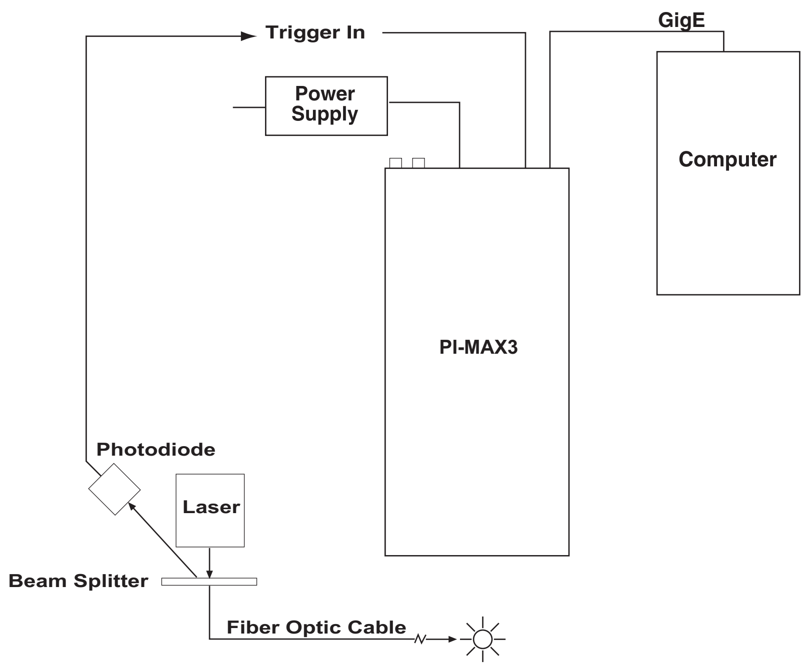
This information is important in order to choose the correct length fiber-optic cable.

Table 8-2: Sample Single Shot Experiment Time Budget

Delay Source	Delay (ns)	Total Delay (ns)	Fiber-Optic Cable Length
Photodiode (light ► TTL pulse)	2	30	A minimum of 21 feet of fiber-optic cable is required.
Photodiode ► PI-MAX3 (2 feet BNC cable)	3		
PI-MAX3	25		

In this experiment, the cables are kept as short as possible to minimize the length of the fiber-optic cable required. Figure 8-27 illustrates the hardware block diagram for this experiment.

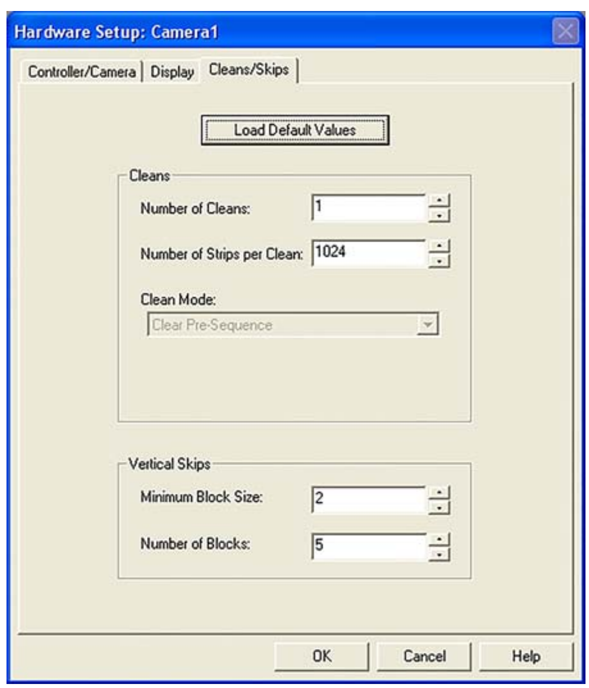
Figure 8-27: Block Diagram: Single Shot



4411-0129_0075

After setting up the appropriate hardware, default values for **Cleans and Skips** are loaded. See Figure 8-28.

Figure 8-28: Typical Cleans and Skips Default Values

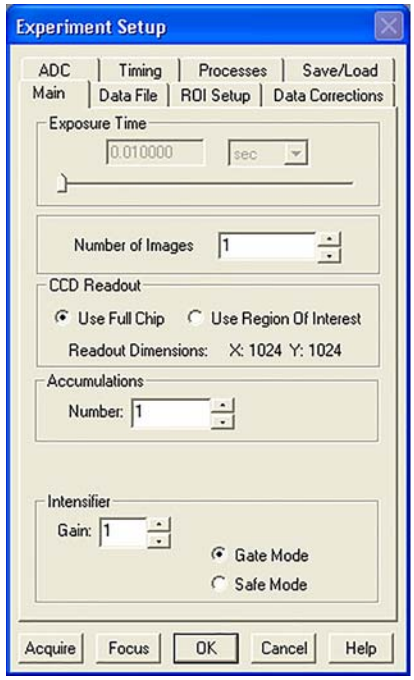


4411-0129_0076

If the CCD has to wait more than a few seconds for the external trigger, it is advisable to increase the number of cleans.

The sequence of operations is similar to the Sequential experiments. After focusing the camera on the fluorescing sample, the camera is set in Gate mode and the appropriate Gain is selected. See Figure 8-29.

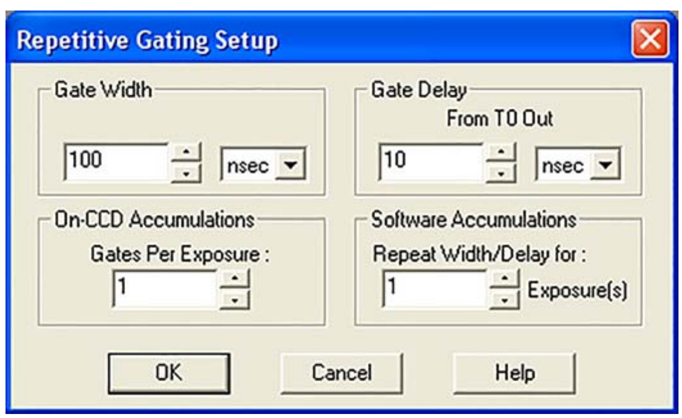
Figure 8-29: Typical Experiment Setup Dialog: Main Tab, Gain Configuration



4411-0129_0060

Gate width and gate delay are set in such a way that the intensifier is gated ON during the entire event (in this case the event is a 60 ns fluorescence). See Figure 8-30.

Figure 8-30: Repetitive Gating Setup: 100 ns Width, 10 ns Delay



4411-0129_0077

Figure 8-31 shows the result of the experiment.

Figure 8-31: Single Shot Result: Fluorescence Spot, 100 ns Width, 10 ns Delay

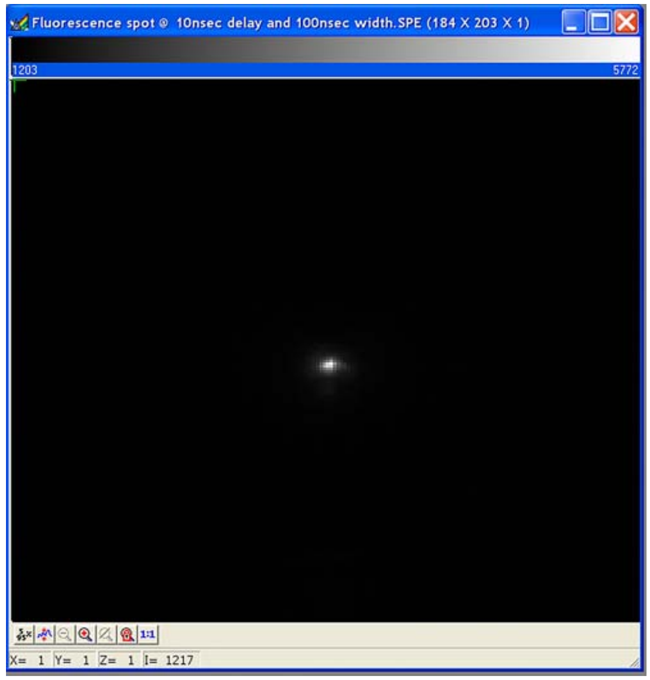
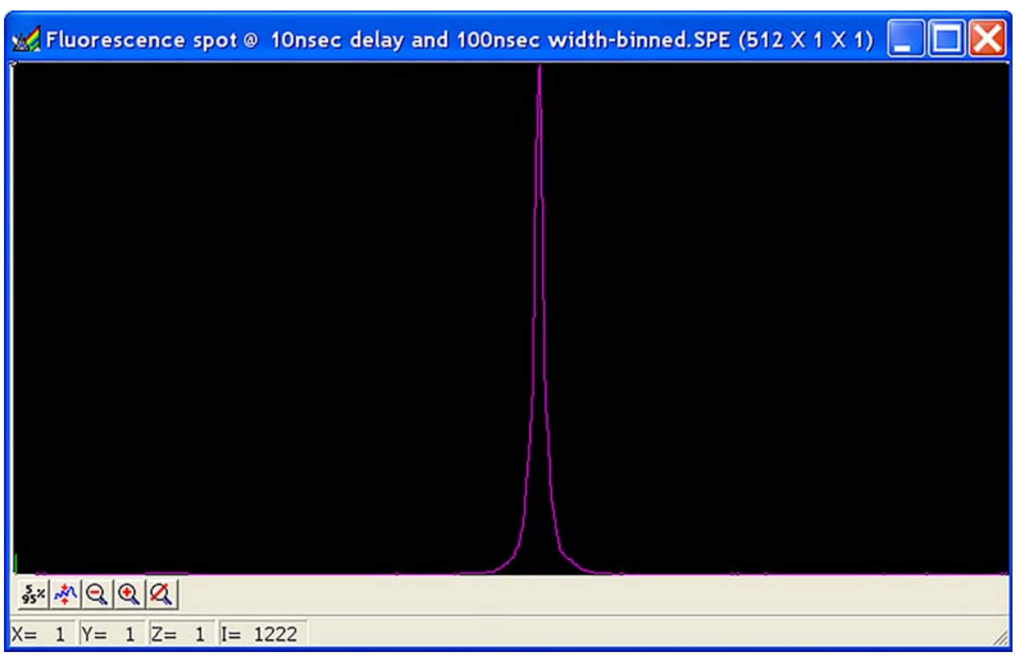


Figure 8-32 shows the peak obtained by binning, in the vertical direction, the entire region around the fluorescence spot.

Figure 8-32: Single Shot Result: Fluorescence Spot, 100 ns Width, 10 ns Delay, Binned Vertically



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Chapter 9: LightField and Gated Operation

This chapter discusses gated operation with the SuperSYNCHRO™ timing generator and aspects of operation of the PI-MAX3 not covered in Chapter 6, First Light, on page 49. We additionally suggest that you review Chapter 15, Tips and Tricks, on page 183, which contains information that should prove helpful in getting good results in more complex measurements.

Gating provides electronic shutter action by controlling the photocathode bias, allowing the detection of low light level signals in the presence of interfering light sources of much greater energy. For instance, in combustion research, a pulsed laser probe is used to investigate the chemistry within a flame. Since the flame itself emits broadband light continuously, the integrated flame emission is much greater than the integrated signal resulting shortly after the laser probe (such as laser-induced fluorescence or Raman). Fortunately, since the laser pulse is very short and the time at which it occurs is known, it is possible to gate for a few nanoseconds during the laser pulse, thus reducing the flame emission interference by approximately the measurement duty factor ratio.

Exposure time is the time space from which charge integrating on the CCD will get summed into the reported data. Gate width is the time during which light will be detected by the intensifier, intensified, and applied to the CCD. Basically, the intensifier controls what the chip sees during the exposure time.

For signal to be detected, it must fall in a valid gate width during a valid exposure. Many gate pulses can be placed into one exposure at repetitive or sequential intervals because there is no temporal measure inside a given exposure. All incident signals get summed (integrated) into one value per pixel/superpixel inside a given exposure.

Using presently available image intensifiers and gate pulse generators, optical gate times ≤4 ns Full Width at Half Maximum (FWHM) are possible. Since the control is electronic, the gate width can be made virtually as long as desired, allowing a wide range of experiment requirements to be satisfied in one instrument setup. Further, in UV measurements, where the On:Off ratio is only 10^4:1, the PI-MAX3's MCP bracketing feature can be used to extend the On:Off ratio to 10^6:1.

9.1 Precautionary Measures

WARNING!

Intensified CCD detectors, such as the PI-MAX3, when biased ON, can be irreparably damaged if continuously exposed to light levels higher than twice the A/D saturation level. Thus it is critical that you not establish conditions that could result in damage to the intensifier

Although intensified detectors are less prone to damage from *background light* when operated gated, they are at **significant risk** of damage from high-intensity light sources such as lasers. High intensity sources can damage the intensifier before the protection circuits have time to respond, or even cause spot damage without the protection circuits acting at all.

If a sustained alarm indication occurs when the controller is turned on, immediately switch the **I.I.T.** switch on the back of the PI-MAX3 to the **OFF** position. Cover the detector window and only switch the **I.I.T.** switch to **ON** after the illumination level has been lowered to safe operating conditions.

9.1.1 Intensifier Modes and Safety

The Experiment Setup **Main** screen in WinX/32 applications allows you to select one of two intensifier modes:

- Gate Mode

  In Gate Mode, the photocathode is biased on only for the time that each gate pulse is applied. As a result, the tolerance to room light is higher in gated operation, but the risk of damaging overload from intense light sources such as lasers remains. In fact, intense light sources in gated experiments can cause spot damage that would be undetected by the alarm circuit.

- Safe Mode

  In Safe Mode, the photocathode is continuously biased OFF and the intensifier is as safe as it can be.

NOTE:

In order for gating to occur, the I.I.T. switch on the back of the PI-MAX3 must also be in the **ON** position.

9.1.2 Alarm

NOTE:

It is normal for the alarm to sound briefly when the system is turned on.

To reduce the risk of detector damage, the PI-MAX3 detector is equipped with an audible alarm in the detector head, activated when the intensity of light falling on the image intensifier exceeds a preset threshold. While the alarm is sounding, the photocathode is disabled. Immediately toggle the I.I.T. switch (on the back of the PI-MAX) to the OFF position. Cover the detector window and only switch the I.I.T. switch to ON after the illumination level has been lowered. If the alarm sounds continuously even when the illumination level is adequately low, shut the system down and contact the factory for guidance.

CAUTION!

Discontinue operation and contact the factory at once if sporadic or continuous unwarranted alarms occur. They may indicate intensifier damage or another situation that requires immediate attention.

9.2 Timing Mode

When you are in **Gate Mode**, the internal timing generator will only operate using **Internal Sync** timing. This timing mode initiates a readout cycle after each internal timing generated pulse ensemble.[1] The handshakes that prevent a readout from occurring while the timing generator is busy and that prevent the timing generator from pulsing the photocathode ON while a readout cycle is in progress are performed within the camera.

NOTES:

1. Automatically configured parameters may not be visible in some versions of the software.
2. The Accumulations and Images (or Spectra) parameters (WinView/32 or WinSpec/32 Acquisition Setup Main tab) govern how the data will be processed. Integrating multiple events on the CCD really brings the power of the PI-MAX3 to bear on low-light gate-mode experiments. If the experiment allows, many pulses can be summed on the CCD with no pulse artifacts in the readout. The signal increases nearly linearly with the number of pulses (within limits imposed by the CCD).

1. An internal timing generator pulse ensemble consists of a Gate Start pulse, a Gate Stop pulse, and one or more Auxiliary pulses.

For this mode, the following parameters are automatically configured by the application software and cannot be changed:

- Exposure Time is set to 0;
- Continuous Cleans is disabled;
- Shutter Control is set to Disabled Opened.

Table 9-1: Timing Mode, Shutter Control, and Ext. Trigger Input when Using the Internal Timing Generator

Timing Mode	Shutter Control	External Trigger Input
Controlled by Internal Timing Generator	Controlled by Internal Timing Generator	Trigger In BNC

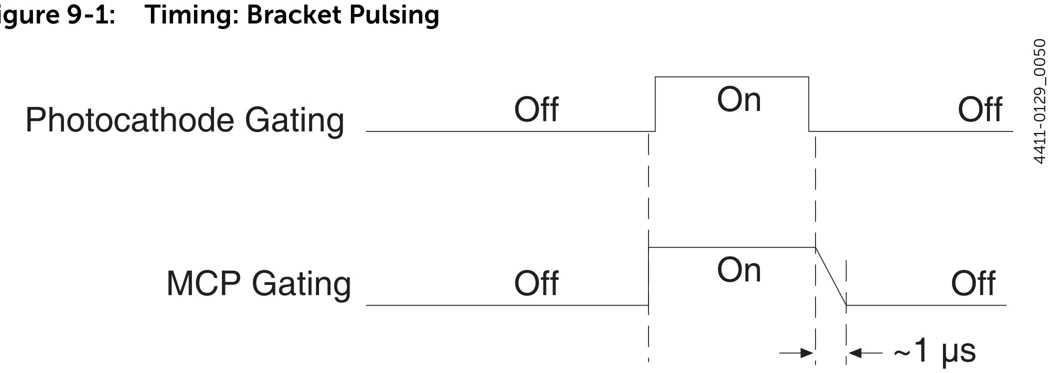
9.3 MCP Bracket Pulsing

The principal utility of gating is that it allows temporal discrimination against background light. By allowing the photocathode to see only during the event of interest, very high background illumination levels can be tolerated without materially degrading experiment results. The limit on this technique is set by the light leakage of the intensifier, which, although it is very good, is not without limit. In the visible, the on/off ratio of a typical Gen II Intensifier with just the photocathode gated is excellent, typically between 10^6 and 10^7. In most measurements, this ratio is sufficient to assure that the signal reaching the CCD during the intensifier Off times will be too small to affect the data.

Below 350 nm, however, a second leakage mechanism occurs, optical leakage through the photocathode to the UV-sensitive MCP, which reduces the On:Off ratio to about 2×10^4 at 200 nm. This is the dominant response of a Gen II image intensifier to UV photons when the photocathode is electrically off. At an On:Off ratio of 20,000, the ability of a camera with conventional photocathode (only) gating to perform certain kinds of measurements in the UV is adversely affected.

MCP bracket pulsing[1] keeps the MCP biased OFF except for an interval that brackets the timing of the photocathode gate as shown in Figure 9-1. For emitted photoelectrons to be accelerated in the MCP, the MCP must be biased ON. In conventional intensified cameras, the MCP is biased ON continuously. In the PI-MAX3, however, when bracket pulsing is ON, the MCP is biased OFF until just before the photocathode is gated ON and is biased OFF shortly after the photocathode is biased OFF.

Figure 9-1: Timing: Bracket Pulsing



1. Bracket pulsing is not available for cameras having a filmless Gen III Intensifier. Gen III Intensifiers do not respond in the UV.

By bracket pulsing the MCP off (in addition to photocathode gating), the on/off ratio of the Gen II PI-MAX3 in UV is improved by 2-3 orders of magnitude. The resulting UV ratio exceeds even the high levels normally achieved in the visible. Applications that benefit from this new approach include LIF and nanosecond pump-probe experiments.

NOTE:

Bracket pulsing does not help in the visible region. Under extremely low duty-factor conditions, the only remedy is to install an external shutter ahead of the camera.

9.3.1 Bracket Pulsing in LIF Measurements

Most experiments using laser-induced fluorescence to probe combustion flows are performed with UV probe/lasers. Atomic emission from flames also has significant UV content. If the flame is continuous, the UV background will also be continuous. Even where a flame is transient (e.g., an internal combustion engine,) its lifetime can be many milliseconds, compared to the nanosecond time scale of the laser used. This background can be a million times as long. If the background is bright, then a UV on/off ratio of 20,000:1 will be overwhelmed by the duty cycle and will not be adequate for extracting a signal of 10^{-5}. In high dynamic range quantitative measurements, backgrounds must be kept to an absolute minimum. MCP bracket pulse gating dramatically improves the rejection of CW and even millisecond time-scale background.

An alternative to suppressing background for imaging has been the use of very narrow spectral bandpass filters. In the UV, these filters are expensive and they can have low transmission at their central wavelength. An additional filter is required for each wavelength to be imaged. The use of electronic temporal rejection of CW or quasi-CW background may make it unnecessary to use these filters, thus increasing the optical throughput, sensitivity, and quantitative precision of the measurement.

9.3.2 Bracket Pulsing in Nanosecond Pump Probe Experiments

Some nanosecond pump-probe experiments combine a nanosecond or faster pump with a flash lamp probe. The duration of the probe flash can be 10-50 μs and a gate is used to select the specific nanosecond-scale time slice to be observed within the much longer probe flash. In these absorbance experiments, accurate measurement of absorbance values depends critically on the lack of stray light contamination, particularly at moderate to high optical density levels. Selecting a 5 ns time window out of a 10 μs pulse is already one part in 2,000. If UV leakage gives an on/off ratio of only 20,000:1, contamination could be 10% or higher. This would limit the optical density to 1.0, and it could make linear quantitation difficult beyond 0.1 OD.

MCP bracket pulse gating can substantially improve the on/off ratio in such an experiment. Even with a 1 μs MCP pulse, the rejection of flash-lamp leakage can add more than an order of magnitude of range, to 2.0 OD.

9.3.3 Limitations of Bracket Pulse Gating

MCP bracket pulse gating is most useful in rejecting background that lasts microseconds up to CW. Fast transient backgrounds can be in the form of stray laser light scattering (e.g., Raleigh, MIE, or Raman,) or unwanted fast fluorescence. Because these usually fall below the MCP bracket pulsing 35 ns delay restriction, these measurements cannot be improved much by MCP bracket pulsing in the PI-MAX3.

Electrically, gating the MCP will only reduce leakage at wavelengths where the MCP has photoelectric response (primarily in the UV.) Thus, for visible and NIR wavelengths where leakage is primarily optical, the improvement will be minimal (although the on/off ratio is already very good in these regions.) Note that in some spectroscopic applications, visible leakage may appear to be reduced by MCP pulsing. This is because the second order UV spectrum overlays the first order visible spectrum in a grating spectrograph. MCP pulsing can eliminate unwanted sensitivity to CW or quasi-CW second order UV, causing the apparent improvement.

Also, keep in mind that MCP bracket pulsing adds 10 ns delay to the photocathode gating. Even though the bracket timing is controlled automatically by the software, in an experiment where it is necessary to delay the arrival of the laser pulse at the sample, this will mean inserting an additional delay of 10 ns (min gate delay = 25 ns, with bracket = 35 ns) to accomplish coincidence at the detector. MCP bracketing should only be used in experiments where it is going to make a difference.

Also, MCP bracket gating limits the repetition rate to 6.25 kHz. Without it the gate repetition rate can be up to 1 MHz (more with option boards.) This is not a significant limitation in most cases. Note that with a 10 ns gate at 6.25 kHz, the on/off ratio = 16,000, close to the non-bracket value.

Note that background light need not be the limiting factor in measurements where MCP bracket pulsing is unable to provide the required degree of rejection. In such measurements, the option remains of installing an external shutter ahead of the PI-MAX3.

9.3.4 Impact of Bracket Pulsing on Delay

If operating in the UV when bracket pulsing is activated (Gen II Intensifier only,) the MCP gate automatically brackets the photocathode gate pulse to further enhance the on/off ratio. There is, however, a limitation of bracket pulsing that can complicate the coincidence of the signal and gate at the camera. Because MCP bracket gating is slower than photocathode gating (35 ns is required to gate the MCP on, and another 1 μs to gate the MCP off at the end of the photocathode gate.) As a result, MCP bracket pulsing should not be used in experiments where the delay between the trigger and the photocathode gate is less than 35 ns.

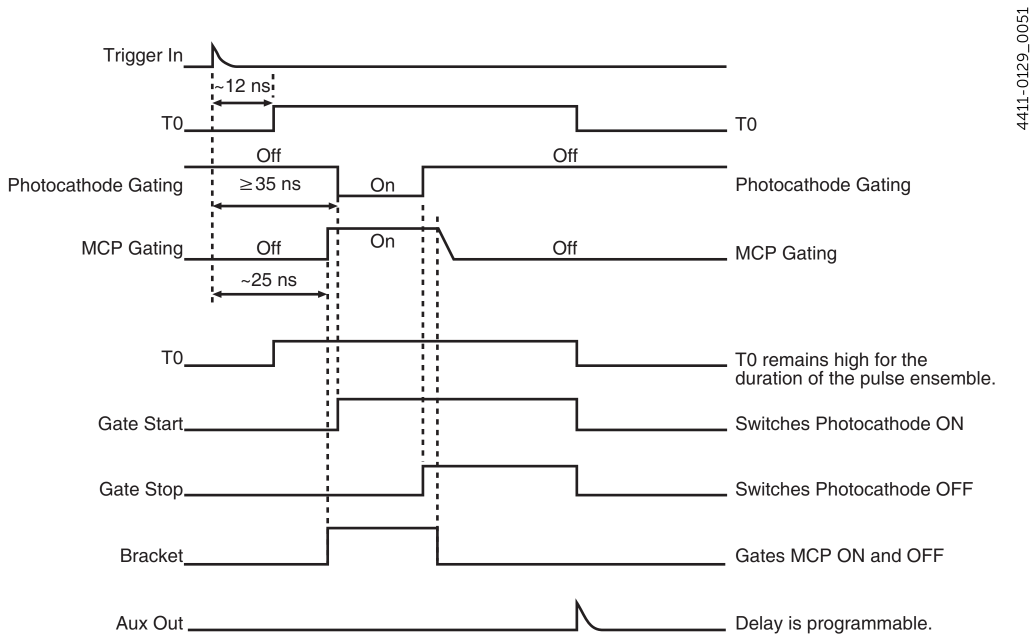
9.3.5 Setup

MCP Bracket pulse implementation is accomplished by selecting Bracket Pulsing ON from the host software. Figure 35, is a timing diagram for bracket pulsing. Insertion delay between trigger and T0 is ~ 12 ns. Insertion delay to photocathode gate is 35 ns (i.e., the minimum delay in bracket mode is 35 ns): this delay allows the MCP to be up to full gain before the photocathode is gated on.

NOTE:

Because Gen III Intensifiers do not respond in the UV, bracket pulsing is not available for these intensifiers.

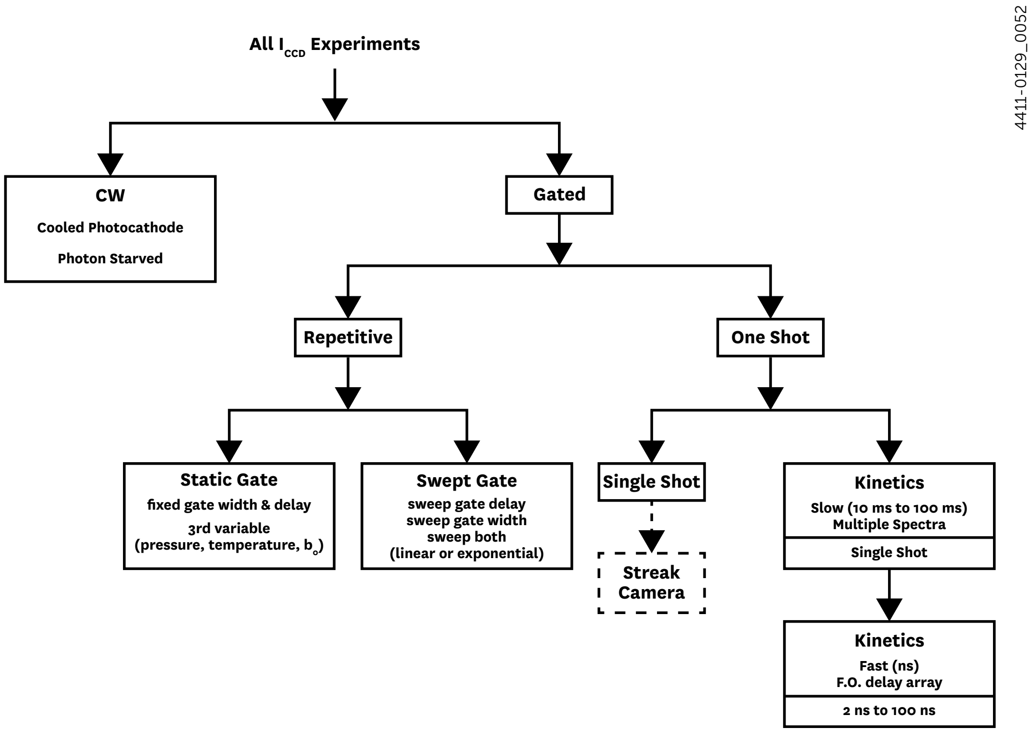
Figure 9-2: Timing Diagram: PI-MAX3 MCP Bracket Pulsing



9.4 Additional Experiments

Figure 9-3 illustrates the kinds of experiments that can be performed with a PI-MAX3 detector.

Figure 9-3: Typical PI-MAX3 Experiments



Of the many gated measurements that can be performed with a PI-MAX3, most will fall in one of the following categories:

- Static Gate

  This type of experiment may also be referred to as **Repetitive-Continuous**.

  There is a repetitive trigger, and the Gate Width and Gate Delay are fixed.

  A variable in the experiment (e.g., pressure, concentration, wavelength, or temperature,) is varied.
- Swept Gate

  In this type of experiment, Gate Width, Gate Delay, or both may be varied.

  — Repetitive-Sequential 1

  The Trigger is repetitive, Gate Width is fixed, and Delay is varied over the course of the measurement.

  The result of the experiment is a plot of intensity vs. time, such as might be obtained with a sampling oscilloscope. This technique is used to measure lifetime decays.

  — Repetitive-Sequential 2

  The Trigger is repetitive and Gate Width and Delay are varied over the course of the measurement.

  Gate Width and Delay can be incremented in a linear fashion or in an exponential fashion. Increasing the Gate Width is useful for trying to find fine detail in a weak decaying signal. If you choose linear, you have to take a lot more points. Exponential lets you take data points closer together where the signal is changing rapidly and further apart where the signal is changing slowly.

- Single Shot
  A single shot experiment is one where you have only one chance to catch the data. Any experiment that can't be repeated more often than once a minute, such as high power lasers and explosives, is considered a single shot. You have to catch the trigger when it comes. Prior to the event, the CCD runs in continuous cleans mode. You don't have the luxury of having the CCD just sitting there doing nothing because the CCD will be accumulating dark current. When the trigger arrives, the intensifier gates, the continuous cleans stop, and the array is read out with a minimum of dark current. Pre-Trigger can be helpful if available.

9.4.1 Swept Gate Experiment [Fixed Width; Variable Delay]

This section provides information about configuring a Swept Gate experiment with fixed Gate Width and variable Gate Delay (i.e., Repetitive-Sequential 1).

9.4.1.1 Experiment is Master Clock

NOTE:
In this configuration, the experiment itself serves as the Master Clock.

This experiment attempts to time-resolve a Xenon light flash from a commercially available strobe light. Since the strobe does not have a pre-trigger out, an electrical trigger is generated by using a photodiode. Output from the photodiode is connected to the **Trigger In** BNC of the PI-MAX3. See Figure 9-4.

Figure 9-4: Block Diagram: Swept Gate Experiment [Fixed Width, Variable Delay]

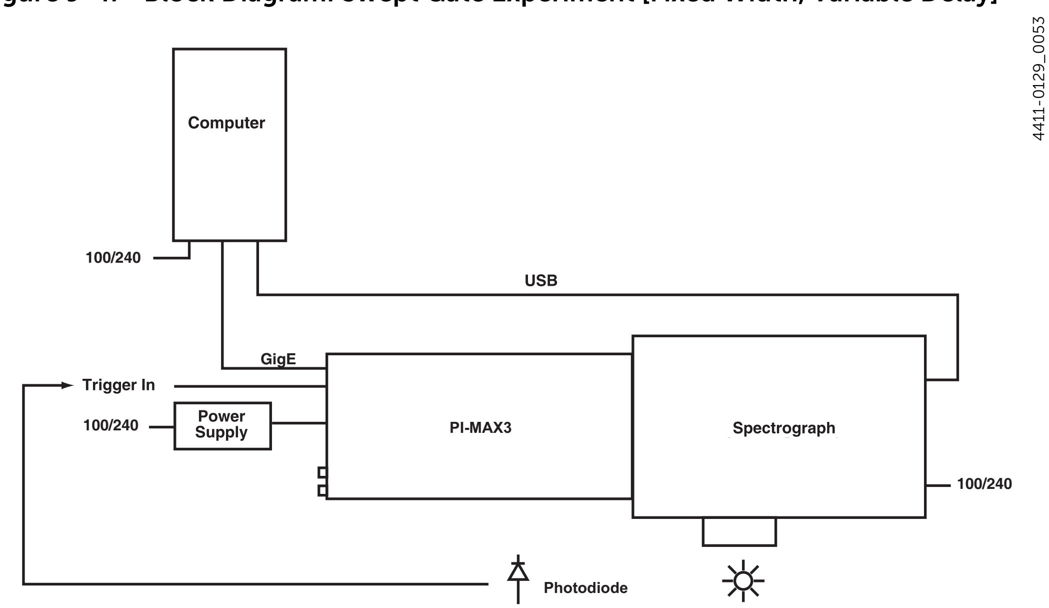
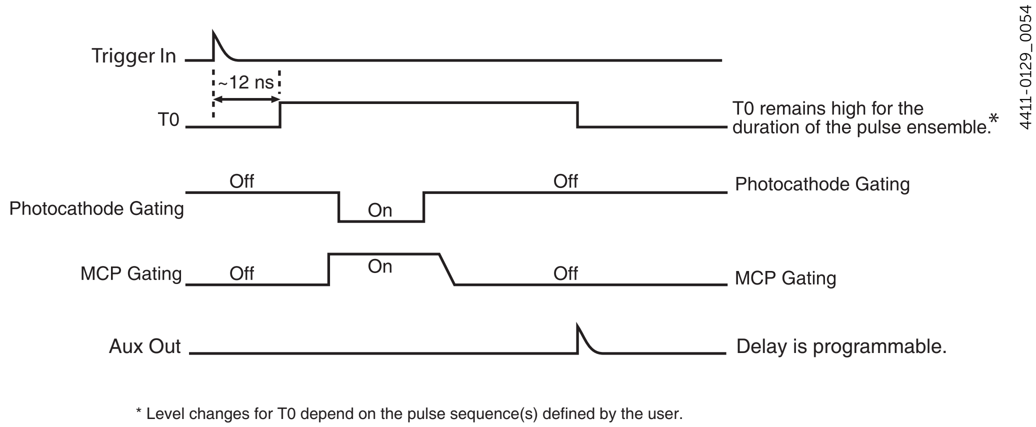


Figure 9-5 illustrates the timing diagram for this experiment.

Figure 9-5: Timing Diagram: Swept Gate Experiment [Fixed Width, Variable Delay]



Perform the following procedure to configure this experiment:

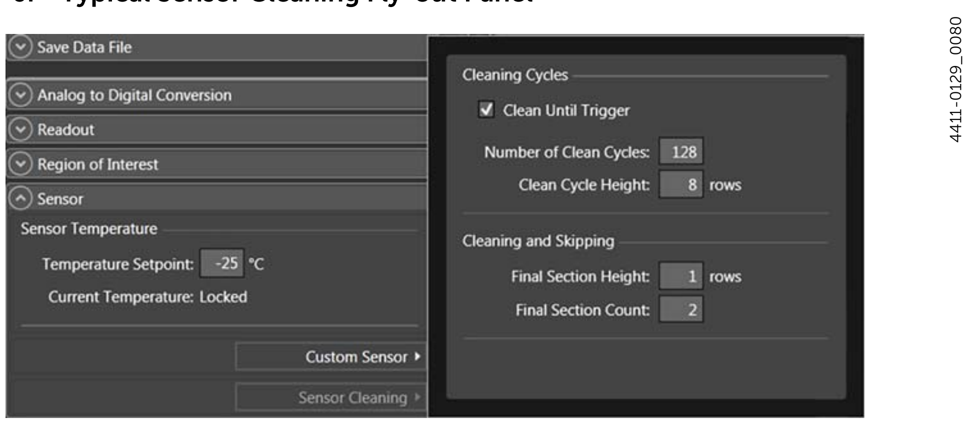
NOTE:

Because this procedure uses the experiment as its Master Clock, refer to Figure 9-4 and Figure 9-5 for connection information.

1. Turn on the equipment and launch LightField.
2. Open the **Sensor** expander and click on **Sensor Cleaning**.

   The **Sensor Cleaning** fly-out panel is displayed similar to that illustrated in Figure 9-6 which shows the setup for a PI-MAX3: 1024i camera.

Figure 9-6: Typical Sensor Cleaning Fly-out Panel



   a. If one or more orange reset buttons are shown on the fly-out pane, click on them to reset to the default values.
   b. Configure the Sensor Temperature by entering the desired Temperature Setpoint.

3. If using a Teledyne Acton Research spectrograph, verify it was turned on when LightField was launched.

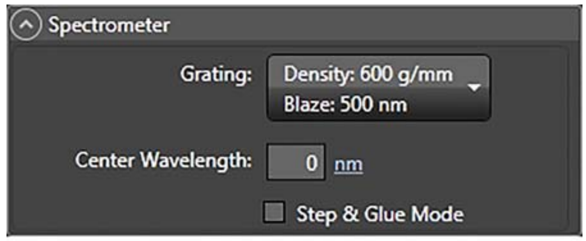
   If using an LS-785, its icon should be in the Available Devices area.

   When the respective spectrograph icon is dragged into the **Experiment Devices** area, the **Spectrometer** expander is added to the **Experiment Settings** stack.

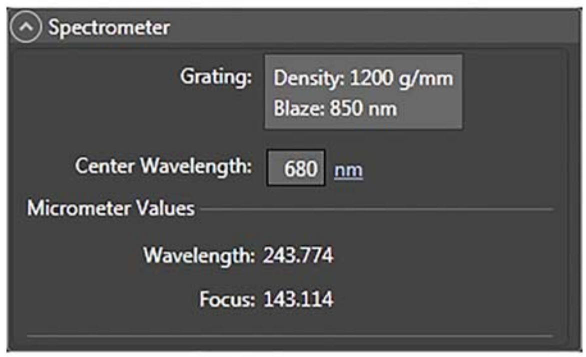
   Configure the spectrograph parameters using the fields on the **Spectrometer** expander. See Figure 9-7.

Figure 9-7: Typical Spectrometer Expanders

4411-0129_0081



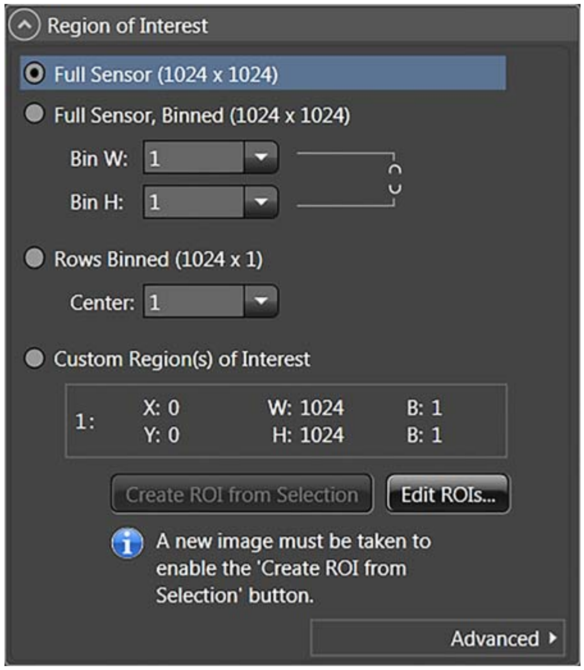
TELEDYNE ACTON RESEARCH SERIES SPECTROMETER



LS-785 SPECTROMETER

4. Move the grating to the desired wavelength.
5. On the **Region of Interest** expander, select **Full Sensor**. See Figure 9-8.

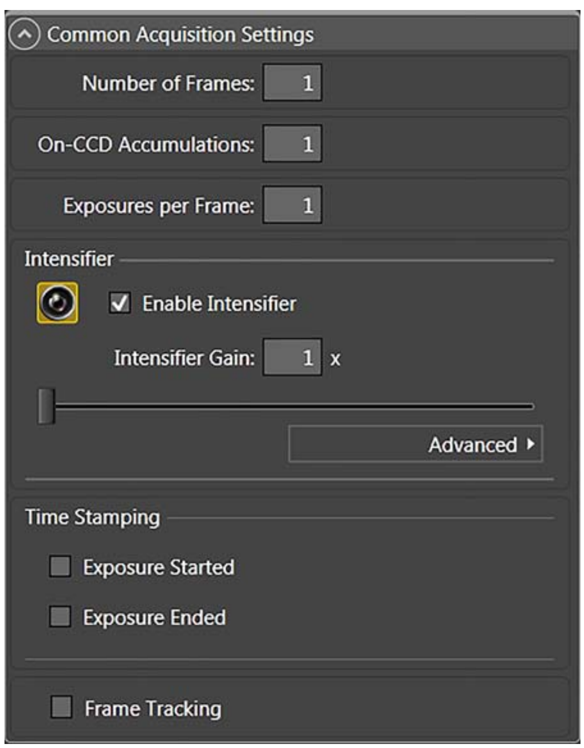
Figure 9-8: **Typical Region of Interest Expander: Full Sensor Selected**



4411-0129_0082

6. At this point, verify that the camera is focused by running it in **Internal Trigger** mode. Perform the following procedure to configure Internal Trigger mode:
   a. On the **Common Acquisition Settings** expander, check **Enable Intensifier** and configure a value between 1 and 1000 for **Intensifier Gain**.
      See Figure 9-9.

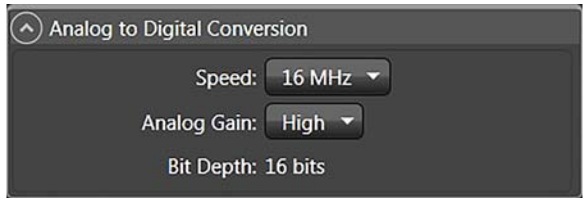
Figure 9-9: **Typical Common Acquisition Settings Expander**



4411-0129_0083

b. On the **Analog to Digital Conversion** expander, select the desired **Speed** and **Analog Gain**. See Figure 9-10.

Figure 9-10: Typical Analog to Digital Conversion Expander



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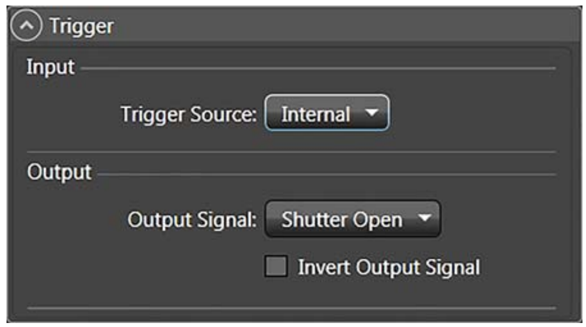
c. On the **Trigger** expander, select **Internal**. See Figure 9-11.

Figure 9-11: Typical Trigger Expander: Internal Trigger Source Selected



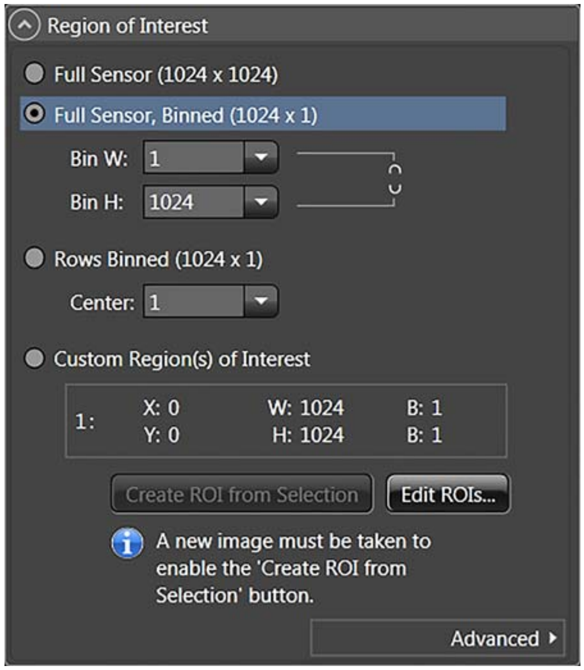
4411-0129_0085

7. After setting the parameters and making sure the ambient light level is low, click on the **View** tab, followed by **Run** to begin acquiring data.

> **NOTE:**
> This data will not be saved.

8. After you verify that the camera is seeing, stop data acquisition.
9. On the **Region of Interest** expander, select **Full Sensor, Binned** and enter 1024 in the **Bin H** field. See Figure 9-12.

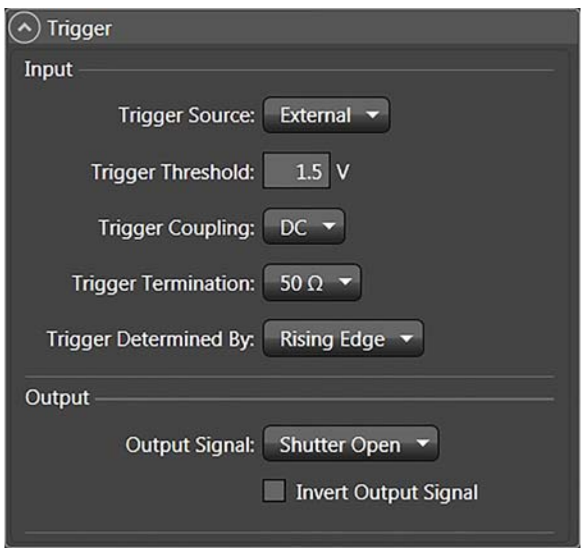
Figure 9-12: Typical Region of Interest Expander: Full Sensor Binned



4411-0129_0086

10. On the **Trigger** expander, change **Trigger Source** to **External**, and define the external trigger parameters. See Figure 9-13.

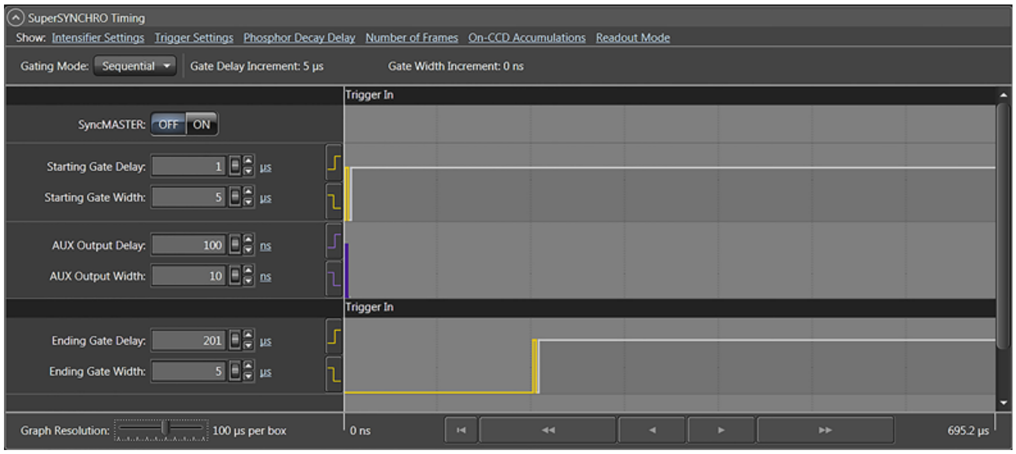
Figure 9-13: Typical Trigger Expander: External Trigger Source



4411-0129_0087

11. Perform the following procedure to configure Gate Timing:
    a. Open the SuperSYNCHRO Timing expander located just above the Status bar. See Figure 9-14.

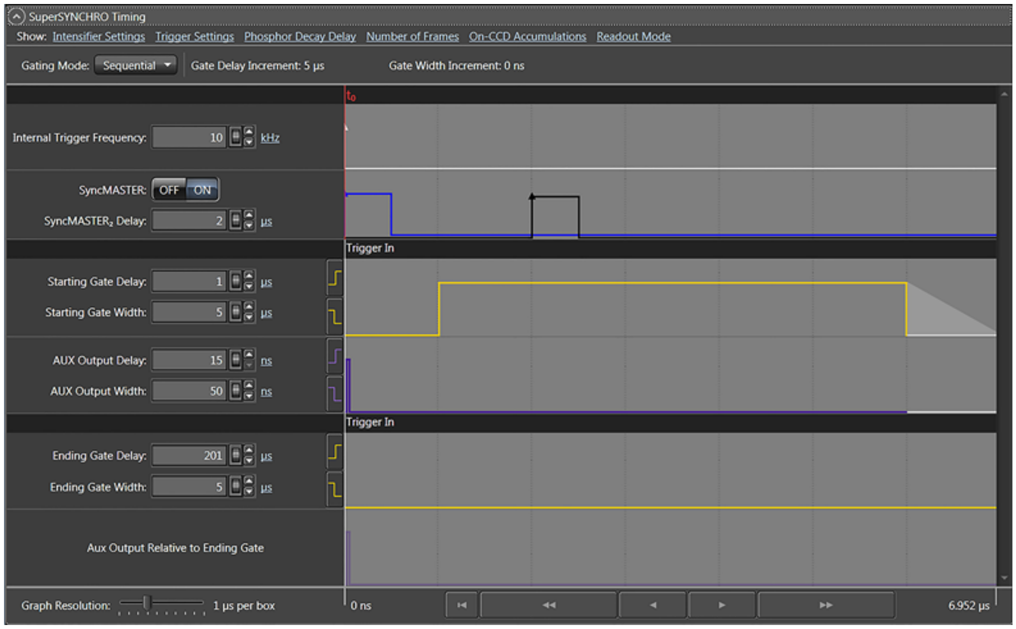
Figure 9-14: Typical SuperSYNCHRO Timing Expander



b. Select **Sequential** as the Active Mode.
   If you have a Gen II intensifier, set **Bracket Pulsing** to **OFF** for this experiment.
c. Define the pulse sequence as follows:
   - Click on the **Number of Frames** hyperlink. Enter the number of frames to be acquired. For this experiment, enter 41.
   - Configure the Start Time and End Time for the **Gate Width**.
     Since this experiment requires a fixed gate width, these values will be the same.
   - Configure the Start and End Durations for the **Gate Delay**.
     For this experiment, the Start Delay is 1 μs and the End Delay is 201 μs.
   - Click the **On-CCD Accumulations** hyperlink and enter the number of **On CCD Accumulations** per frame. For this experiment, enter 1.
d. The **SyncMASTER ON** button allows you to enable the **SyncMASTER™** trigger output from the **SyncMASTER1** and **SyncMASTER2** connectors on the **AUX I/O** cable and select the frequency for the SyncMASTER outputs. You can also set up the **AUX Output** signal at the **AUX OUT** connector on the rear of the PI-MAX3.
   - When you enable **SyncMASTER**, the output of the **SyncMASTER1** connector will be at the frequency configured in the **Internal Trigger Frequency** field.
   - The output of the **SyncMASTER2** connector will be at the same frequency as that of **SyncMASTER1**. However, you can enter a delay so the edges of that signal will occur after the edges of **SyncMASTER1**.
   - If you are using the **AUX Output** signal from the **SuperSYNCHRO** to trigger a piece of equipment, configure the **Auxiliary** pulse delay time. Configure the pulse width needed to trigger the equipment.

Figure 9-15 illustrates a typical SuperSYNCHRO Timing configuration with SyncMASTER on.

Figure 9-15: Typical SuperSYNCHRO Timing with SyncMASTER On



4411-0129_0089

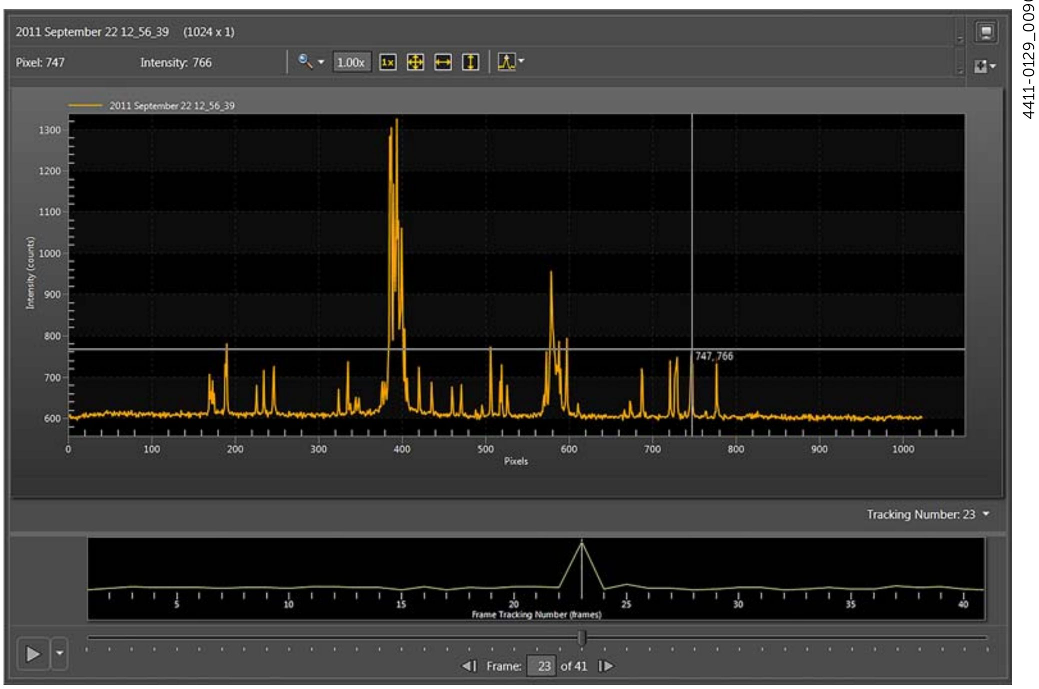
12. After verifying all connections and equipment readiness, collapse the **SuperSYNCHRO Timing** expander.
13. If necessary, click on the **View** tab to view it, and click **Acquire** to begin acquiring the spectra (or images).

NOTE:

The photocathode is biased on only for the time that each gate pulse is applied. This limits the risk of damage resulting from room light. However, there is a risk of damaging overload from intense light sources such as lasers.

Figure 9-16 displays the graph for a **Sequential-Repetitive** experiment with fixed width and variable delay. **Show Frame Cross Section** has been selected. The intensity of the selected point was at its maximum in Frame 23.

Figure 9-16: Typical Experiment Results with Frame Cross-Section Active



9.4.1.2 SyncMASTER1 as Master Clock

When using a light source that is equipped with **Trigger In**, the PI-MAX3 SyncMASTER function can be used as the Master clock. Figure 9-17 illustrates the block diagram for this configuration, and Figure 9-18 is the timing diagram.

Figure 9-17: Block Diagram: PI-MAX3 SyncMASTER1 as Master Clock

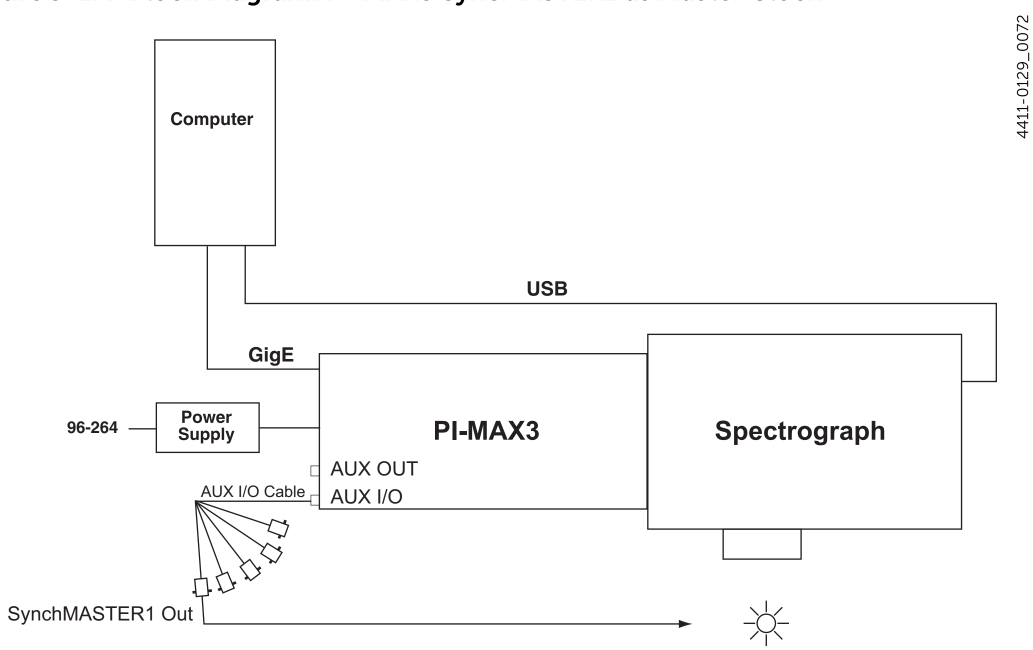
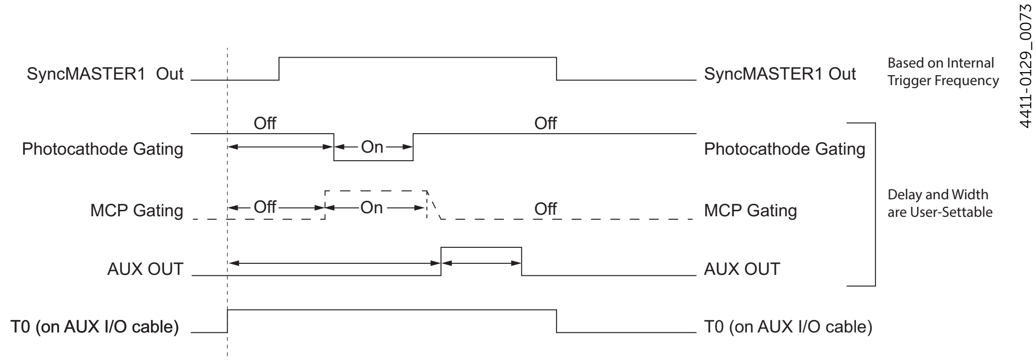


Figure 9-18: Timing Diagram: PI-MAX3 SyncMASTER1 as Master Clock



The setup procedure is much the same as that described in Section 9.4.1.1, Experiment is Master Clock, on page 133.

The differences are:

- Internal Trigger is selected;
- SyncMASTER is enabled;
- A cable is connected between the PI-MAX3's AUX I/O cable's SyncMASTER1 BNC and the light source (experiment) for triggering the event.

9.4.2 Swept Gate Experiment [Variable Width, Variable Delay]

The procedure to configure a Swept Gate experiment with variable width and delay is similar to that for a Swept Gate experiment with fixed width and variable delay with the following configuration changes:

- In addition to configuring differing start and end values for the Gate Delay, differing start and end values for the Gate Width must be configured.

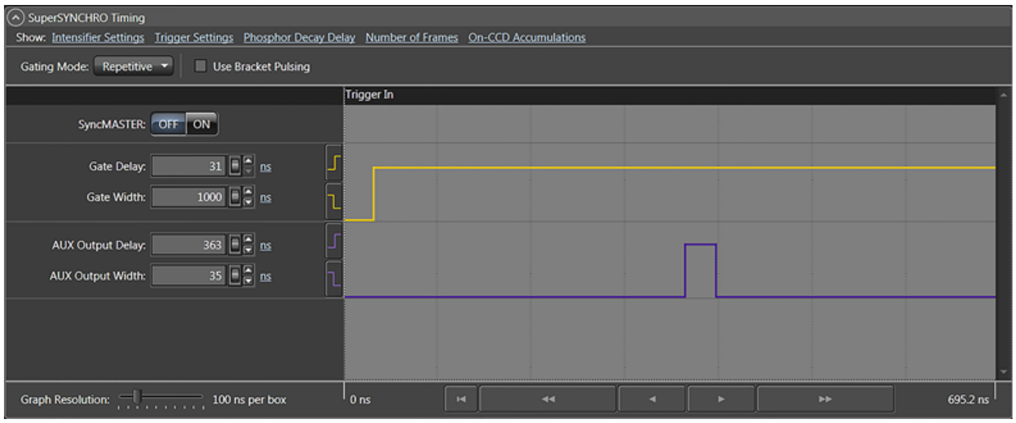
Refer to Section 9.4.1, Swept Gate Experiment [Fixed Width; Variable Delay], on page 133 for complete configuration information.

9.4.3 Static Gate Experiment [Fixed Width, Fixed Delay]

The procedure to configure a Static Gate experiment with fixed width and delay is similar to that for a Swept Gate experiment with the following configuration changes:

- **Gate Mode** is configured as **Repetitive**;
- Gate Width and Gate Delay are configured on the **SuperSYNCHRO Timing** expander. See Figure 9-19.

Figure 9-19: Typical SuperSYNCHRO Timing Expander: Repetitive Gating



4411-0129_0091

Refer to Section 9.4.1, Swept Gate Experiment [Fixed Width; Variable Delay], on page 133 for additional configuration information.

9.4.4 Single Shot Experiment

A single shot experiment offers one chance to capture an event. As in any gated experiment, the time budget of the experiment is crucial. If there is no pre-trigger from the experiment, a photodiode can be used to generate an electrical trigger from the laser light. In this situation, light has to be delayed by optical means (fiber-optic cable or mirror reflections) to allow sufficient time for the electronics to be activated after receiving the trigger. Another important thing to note in single shot experiments is that **Sensor Cleaning** is configured to **Clean Until Trigger** so that there is no dark charge accumulation while it is waiting for the trigger.

The following experiment is an attempt to capture a 60 ns fluorescence generated by a single shot laser. The time budget for this experiment is provided in Table 9-2.

NOTE:

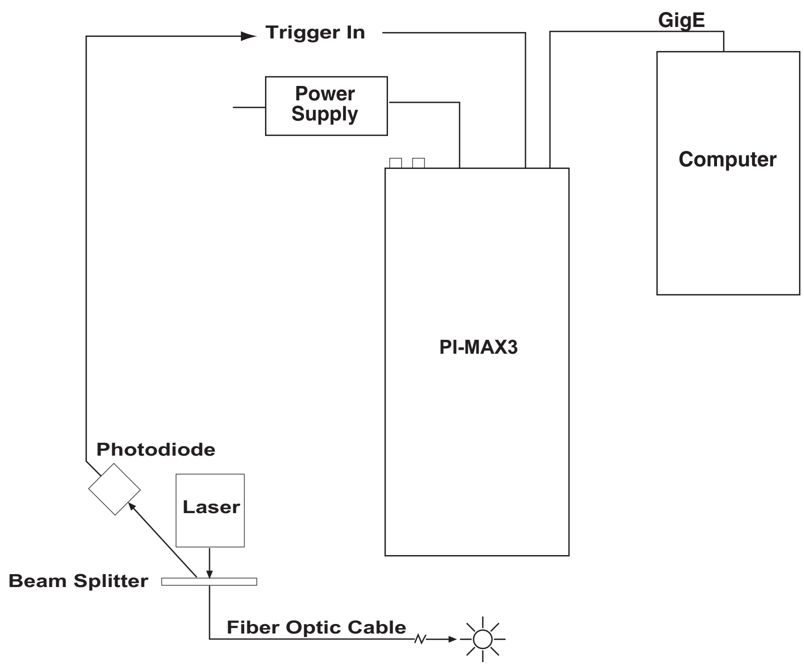
This information is important in order to choose the correct length fiber-optic cable.

Table 9-2: Sample Single Shot Experiment Time Budget

Delay Source	Delay (ns)	Total Delay (ns)	Fiber-Optic Cable Length
Photodiode (light ► TTL pulse)	2	30	A minimum of 21 feet of fiber-optic cable is required.
Photodiode ► PI-MAX3 (2 feet BNC cable)	3		
PI-MAX3	25		

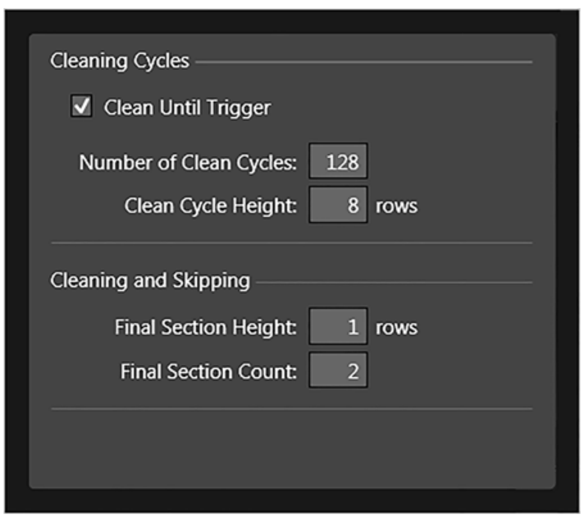
In this experiment, the cables are kept as short as possible to minimize the length of the fiber-optic cable required. Figure 9-20 illustrates the hardware block diagram for this experiment.

Figure 9-20: Block Diagram: Single Shot



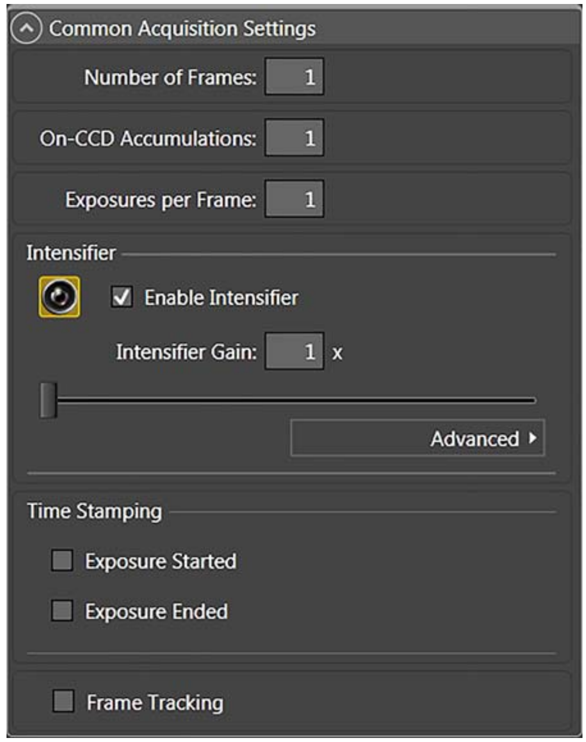
After setting up the appropriate hardware, default values for **Cleaning and Skipping** are loaded. See Figure 9-21.

Figure 9-21: Typical Cleans and Skips Default Values



The sequence of operations is similar to the Sequential experiments. After focusing the camera on the fluorescing sample, the appropriate Gain is selected. See Figure 9-22.

Figure 9-22: Typical Common Acquisition Settings Expander: Configure Gain



Gate width and gate delay are set in such a way that the intensifier is gated ON during the entire event (in this case the event is a 60 ns fluorescence). See Figure 9-23.

Figure 9-23: Repetitive Gating Setup: 100 ns Width, 25 ns Delay

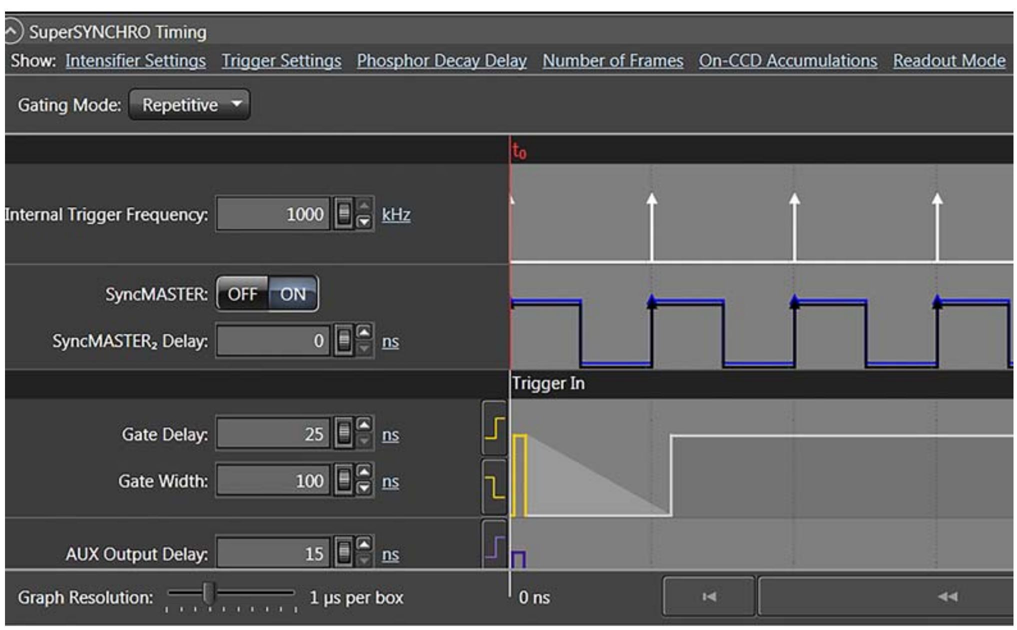


Figure 9-24 shows the result of the experiment.

Figure 9-24: Single Shot Result: Fluorescence Spot, 100 ns Width, 25 ns Delay

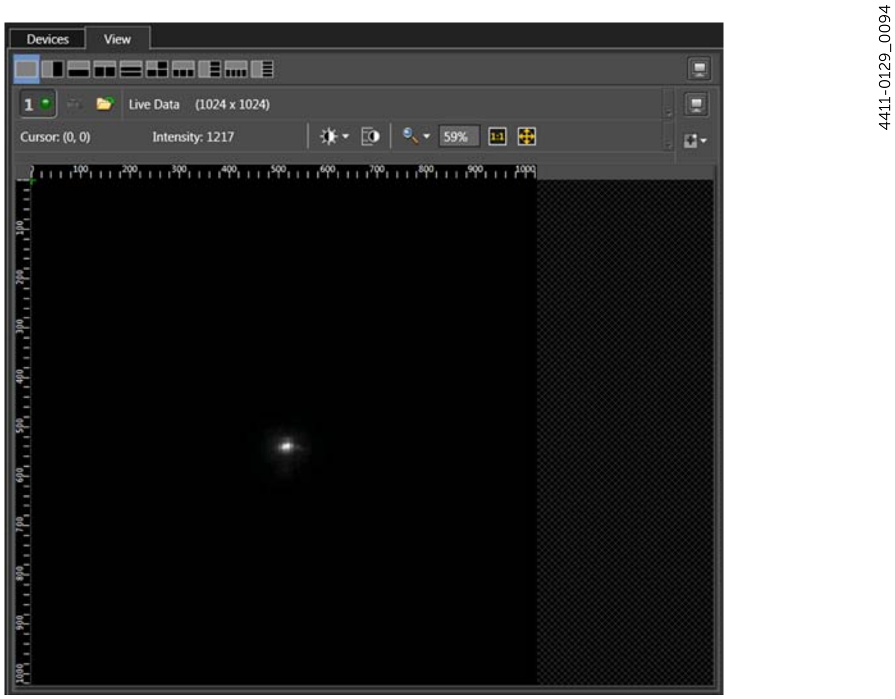
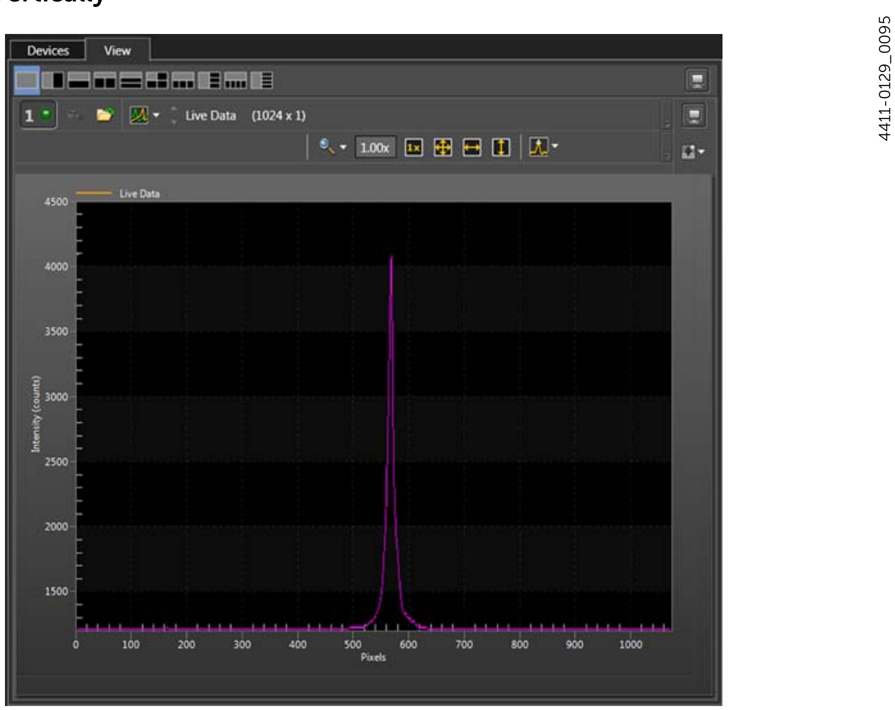


Figure 9-25 shows the peak obtained by binning, in the vertical direction, the entire region around the fluorescence spot.

Figure 9-25: Single Shot Result: Fluorescence Spot, 100 ns Width, 25 ns Delay, Binned Vertically



Chapter 10: Timing Generator Pulses and Sequences

This chapter discusses Timing Generator pulses and sequences.

10.1 Pulse Set

A pulse set includes the following signals:

- MCP_GATE;
- START;
- STOP;
- AUX1;
- SyncMASTER.

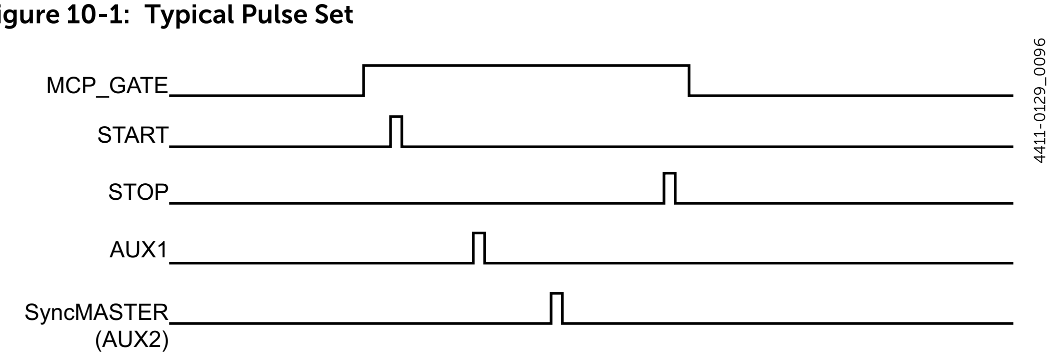
START and STOP define the photocathode gate pulse.

NOTE:

MCP GATE, START, and STOP are not visible to the user and are included for information purposes only.

See Figure 10-1.

Figure 10-1: Typical Pulse Set



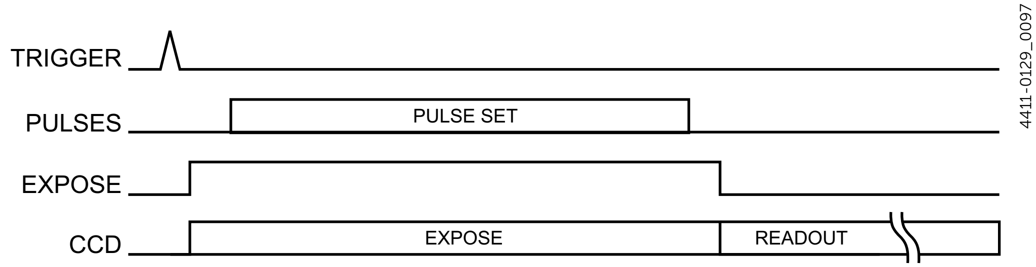
The EXPOSE signal remains high for the duration of the pulse set and goes low upon approximately 15 ns after pulse completion.

10.1.1 Supported Timing Generator Trigger Modes

PI-MAX3 supports the following Trigger Modes:

- Trigger per Pulse
  The pulse set is initiated by its own internal or external trigger. See Figure 10-2.

Figure 10-2: Timing Diagram: Trigger per Pulse



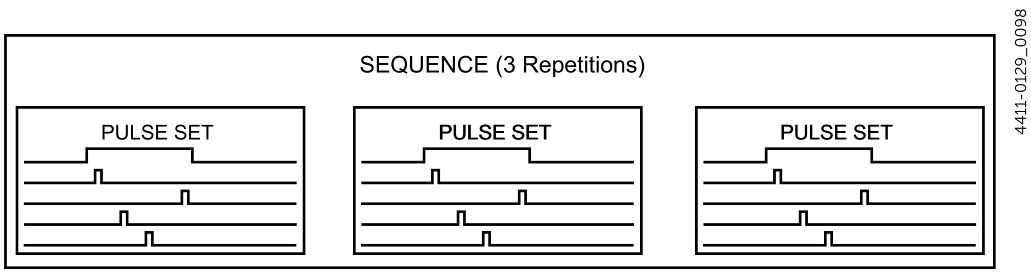
Supported Trigger Sources are:

- Source 1
  This is the Timing Generator's internal trigger. A pulse set is initiated by the timing generator's internal trigger.
- Source 2
  External Trigger input on the **TRIGGER IN** BNC. A pulse set is initiated by an external trigger.

10.2 Single Sequence

A sequence is the repetition of one pulse set X number of times. Figure 10-3 shows a sequence with the pulse set repeated three (3) times.

Figure 10-3: Single Sequence with Three Repetitions



The EXPOSE signal remains high for the duration of the sequence and goes low approximately 15 ns after the sequence has been completed.

10.2.1 Supported Timing Generator Trigger Modes

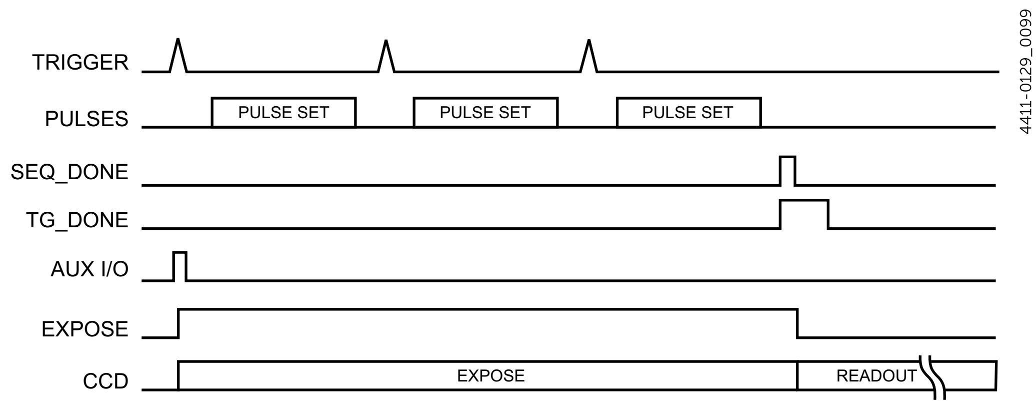
PI-MAX3 supports the following Trigger Modes:

- Trigger per Pulse
  Each pulse of the single sequence is initiated by its own trigger.

  NOTE:
  All triggers must originate from the same source and all must be either internal or external.

  See Figure 10-4.

Figure 10-4: Timing Diagram: Sequence with 3 Repetitions and Trigger per Pulse



Supported Trigger Sources are:

- Source 1
  This is the Timing Generator's internal trigger. Each pulse set of the sequence is initiated by the timing generator's internal trigger.
- Source 2
  External Trigger input on the **TRIGGER IN** BNC. Each pulse set is initiated by an external trigger.

10.3 Time Stamping

Time Stamping provides the ability to include the following timing data with each frame of acquired data:

- Exposure Started;
  This time stamp indicates the time control is passed from the camera FPGA to the timing generator, not the actual image intensifier gate time.
  Once control is passed to the timing generator, the timing generator waits for a trigger or triggers (internal or external, as configured by the user.) The timing generator then executes the timing the user has selected.
  When the timing generator completes its task(s), control is then returned to the camera FPGA.
- Exposure Ended.
  This time stamp indicates the time when the timing generator returns control to the camera FPGA.

The resolution for PI-MAX3 time stamps is 1 µs.

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Chapter 11: WinX/32 and Dual Image Feature (DIF)

The purpose of PI-MAX3 DIF is to acquire a pair of gated images in rapid succession. The time between frames can be as short as 2 μs (limit imposed by P46 phosphor decay time) with exposure times as short as 5 ns. The DIF capability is ideally suited to capturing rapidly evolving events. These experiments fall into two broadly applicable categories:

- Single Trigger;

  Single trigger experiments involve a single impulse event that evolves over time such as a laser-induced plasma or luminescence decay.
- Dual Trigger.

  Dual trigger experiments involve two impulses separated in time such as double laser pulse velocimetry measurements.

11.1 Requirements

The PI-MAX3 must use an interline CCD. In addition, it is recommended that the intensifier have a fast decay phosphor (P46). Since DIF operation involves acquiring images in rapid succession, phosphor persistence can become the limiting factor in the rate of image acquisition.

WinView/32 or WinSpec/32 software (version 2.5.26 or higher) can control the DIF functionality of the PI-MAX3 and provide full access to the two DIF timing modes:

- Single Trigger;
- Dual Trigger.

11.2 Interline CCD Operation

An interline CCD consists of alternating columns of light sensitive pixels and storage pixels. The light sensitive columns are referred to as the active area and acquire the image. The storage pixels are called the masked area and store the image in the dark while it is read out. With this architecture, the CCD can acquire a second image while the first image is being read out, unlike a standard CCD, which must read out the first image before the second acquisition can begin. The ability of the interline CCD to quickly transfer an image under the masked columns and hold it there makes DIF possible. As soon as the first image is acquired, it is shifted under the masked area and held. The second exposure begins and is held in the active area until the first image has been read out.

11.3 Timing Modes

The following two DIF timing/readout modes are available in WinX:

- Single Trigger Mode
  Two shot, one trigger for both shots.
- Dual Trigger Mode
  Two shot, each shot requires a trigger.

The trigger(s) can be generated by an external source connected to the PI-MAX3 or the PI-MAX3 can generate the trigger(s) internally. In WinX, DIF readout is selected on the **Hardware Setup** ► **Controller/Camera** tab. The timing mode (i.e., single or dual trigger,) is configured on the **Acquisition** ► **Experiment Setup...** ► **Timing** tab.

11.4 Configure a Single Trigger DIF Experiment

Figure 11-1 illustrates the system block diagram for a single-trigger DIF experiment.

Figure 11-1: Typical System Block Diagram: DIF Operation

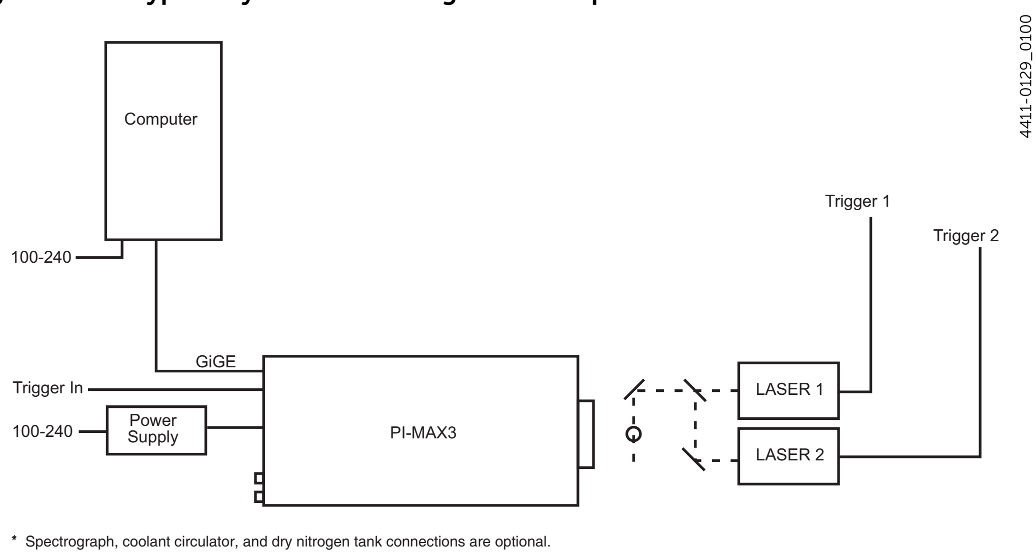
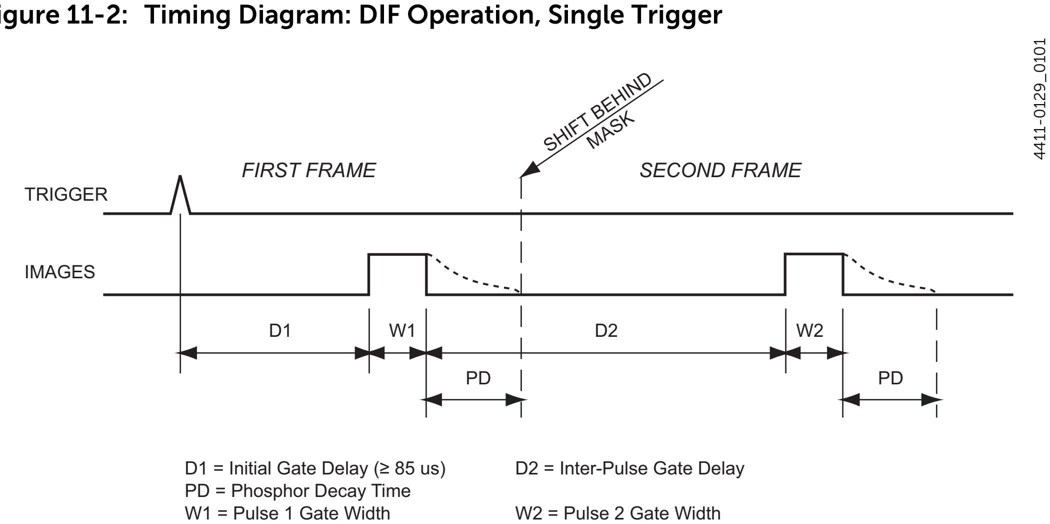


Figure 11-2 shows the timing diagram for single-trigger DIF operation.

Figure 11-2: Timing Diagram: DIF Operation, Single Trigger



NOTE:

For the purposes of this procedure, it is assumed that either WinView/32 or WinSpec/32 is being used to control the system.

Operating PI-MAX3 in DIF mode is similar to standard operation of a PI-MAX3 with SuperSYNCHRO. Perform the following procedure to configure a single-trigger DIF experiment:

1. Align and focus the PI-MAX3 on the area of interest for the experiment.

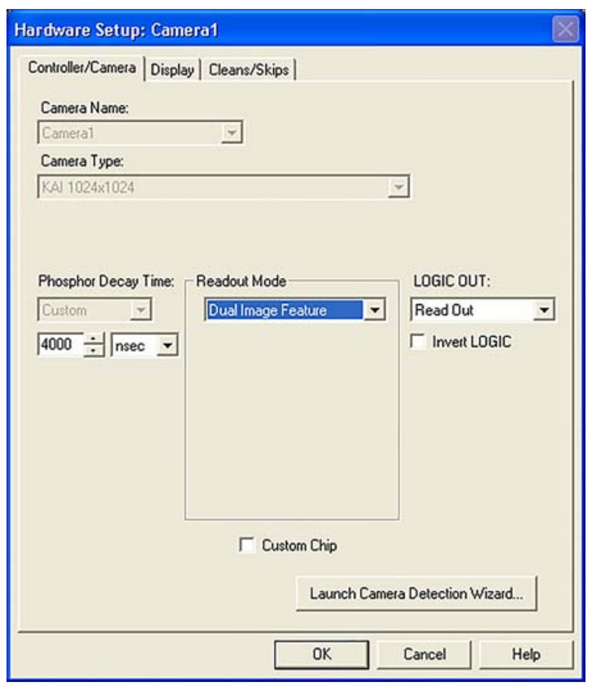
   This is best performed while the PI-MAX3 is operating in Interline mode (i.e., before switching to DIF mode.)

   Verify that the **Phosphor Decay Time** is appropriate for the phosphor used by the camera. This information is found on the **Setup ► Hardware Setup ► Controller/ Camera** tab. Refer to Chapter 6, First Light, on page 49 for information about initial focus.

2. After the alignment and focus, the PI-MAX3 system needs to be put into DIF mode. On the **Setup ► Hardware Setup ► Controller/ Camera** tab, select **Dual Image Feature** as the **Readout Mode**, and then click **OK**.

   See Figure 11-3.

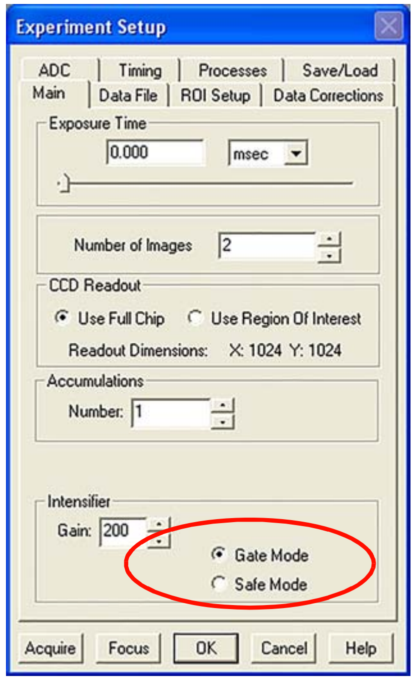
Figure 11-3: Typical Hardware Setup ► Controller/Camera Tab



4411-0129_0102

3. Configure the PI-MAX3 to Gate Mode for the intensifier to operate properly. This can be done by clicking the **Gate Mode** button on the Custom Toolbar, or by selecting **Gate Mode** on the **Acquisition** ► **Experiment Setup...** ► **Main** tab. See Figure 11-4.

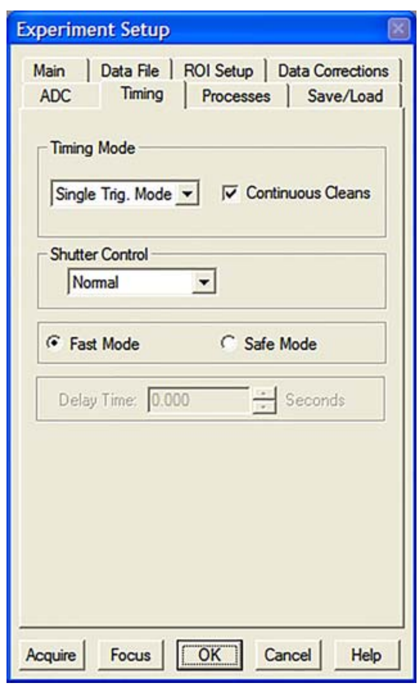
Figure 11-4: Typical Experiment Setup... ► Main Tab



4411-0129_0103

4. On the **Acquisition** ► **Experiment Setup...** ► **Timing** tab, verify **Timing Mode** is configured for **Single Trig. Mode. Continuous Cleans** is also recommended for DIF. See Figure 11-5.

Figure 11-5: Typical Experiment Setup... ► Timing Tab



4411-0129_0104

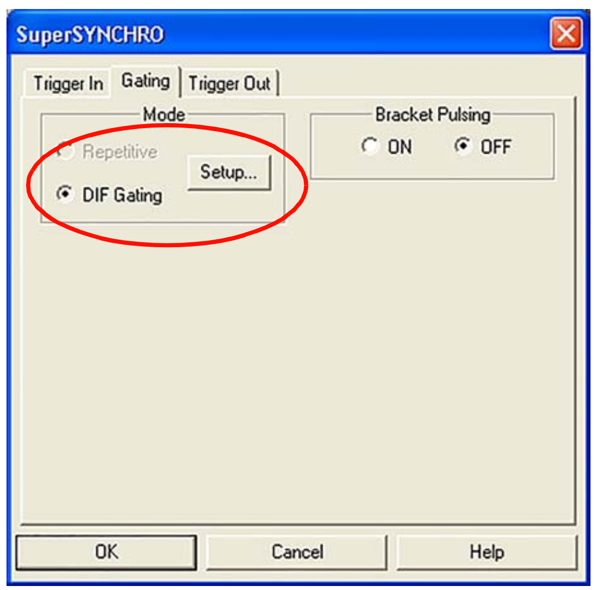
5. Select **Pulsers** from the **Setup** menu, select **SuperSYNCHRO**, and click on the **Setup Pulser** button. See Figure 11-6.

Figure 11-6: Typical Pulsers Dialog

Perform the following procedure to configure SuperSYNCHRO:

a. On the **Gating** tab of the **SuperSYNCHRO** dialog, select **DIF Gating** and click the **Setup** button.

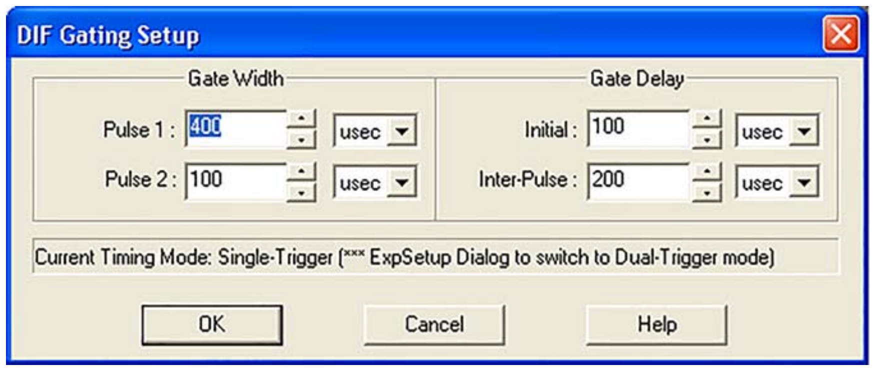
Figure 11-7: Typical SuperSYNCHRO Dialog



b. On the **DIF Gating Setup** dialog, configure the **Gate Width** and **Gate Delay** times:
   - When configuring the **Initial Gate Delay** time, verify that it is ≥75 µs;
   - When configuring the **Inter-Pulse Gate Delay** time, verify that the delay is greater than the **Phosphor Decay Time** configured on the **Setup** ► **Hardware Setup** ► **Controller/Camera** tab.

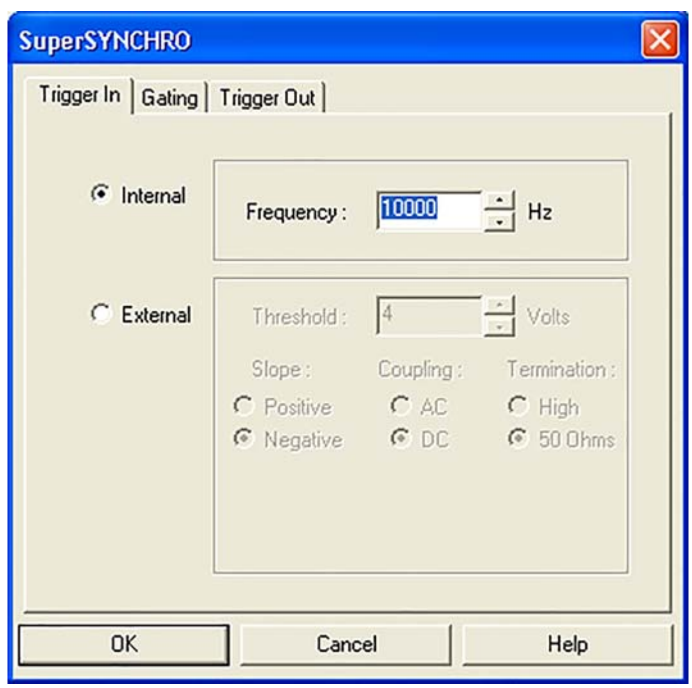
   See Figure 11-8.

Figure 11-8: Typical DIF Gating Setup Dialog



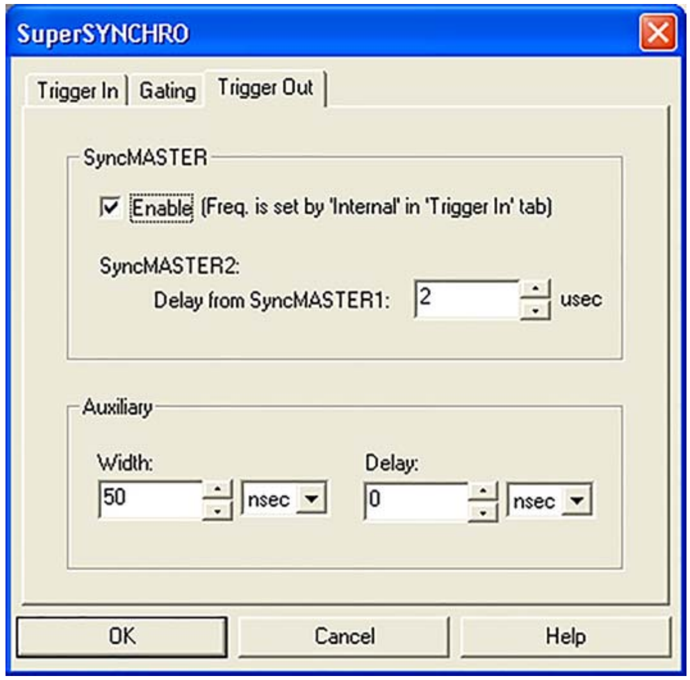
c. On the **Trigger In** tab, select **Internal** or **External** triggering.
   When using External triggering, verify the trigger characteristics match the active trigger edge, etc. of the trigger pulse that will be used.

Figure 11-9: Typical SuperSYNCHRO Dialog: Trigger In Tab



d. If required, on the **Trigger Out** tab, configure output triggers.

Figure 11-10:Typical SuperSYNCHRO Dialog: Trigger Out Tab



4411-0129_0069

e. At the bottom of the **SuperSYNCHRO** dialog, click **OK** to download the gating sequence to the SuperSYNCHRO.

6. When the experiment is ready, click on the **ACQ** button or select **Acquire** on the Acquisition menu to start the image acquisition.

11.5 Configure a Dual Trigger DIF Experiment

Figure 11-1 illustrates the system block diagram for a dual-trigger DIF experiment.

Figure 11-11: Typical System Block Diagram: DIF Operation

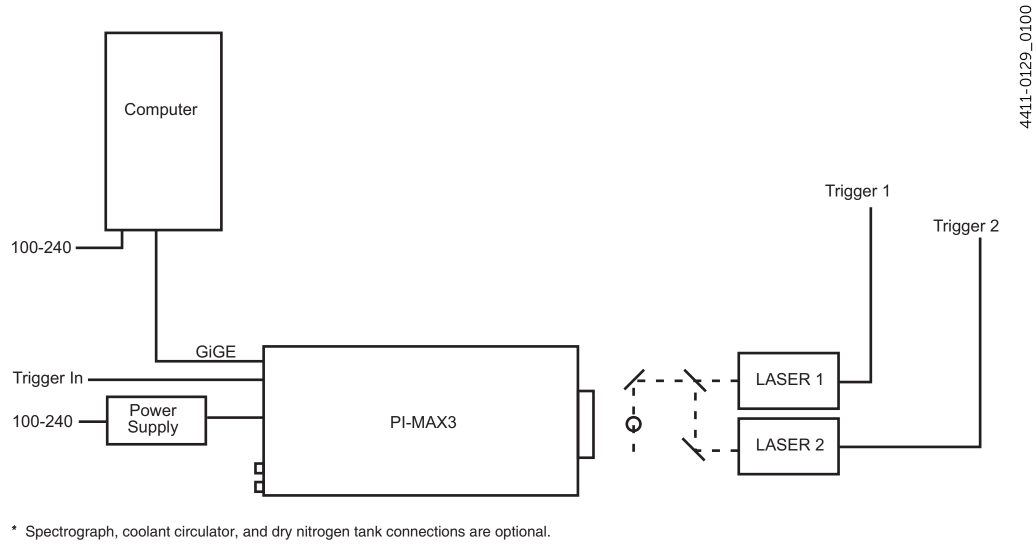
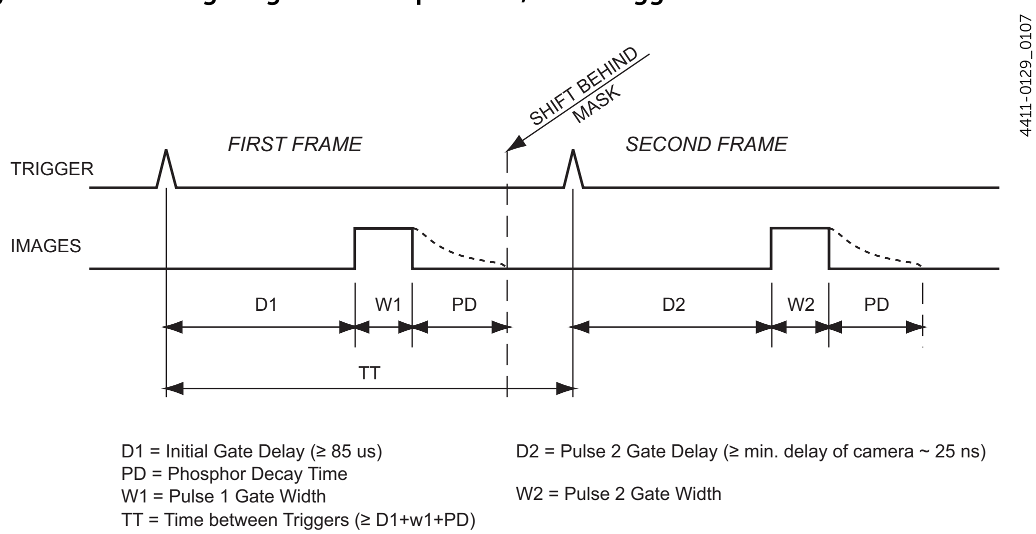


Figure 11-2 shows the timing diagram for dual-trigger DIF operation.

Figure 11-12: Timing Diagram: DIF Operation, Dual Trigger



NOTE:

For the purposes of this procedure, it is assumed that either WinView/32 or WinSpec/32 is being used to control the system.

Operating PI-MAX3 in DIF mode is similar to standard operation of a PI-MAX3 with SuperSYNCHRO. Perform the following procedure to configure a dual-trigger DIF experiment:

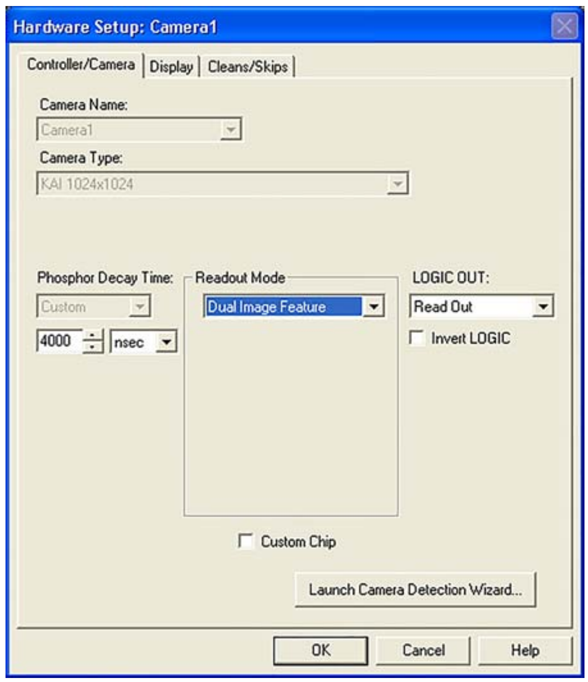
1. Align and focus the PI-MAX3 on the area of interest for the experiment.

   This is best performed while the PI-MAX3 is operating in Interline mode (i.e., before switching to DIF mode.)

   Verify that the **Phosphor Decay Time** is appropriate for the phosphor used by the camera. This information is found on the **Setup** ► **Hardware Setup** ► **Controller/ Camera** tab. Refer to Chapter 6, First Light, on page 49 for information about initial focus.
2. After the alignment and focus, the PI-MAX3 system needs to be put into DIF mode. On the **Setup** ► **Hardware Setup** ► **Controller/ Camera** tab, select **Dual Image Feature** as the **Readout Mode**, and then click **OK**.

   See Figure 11-3.

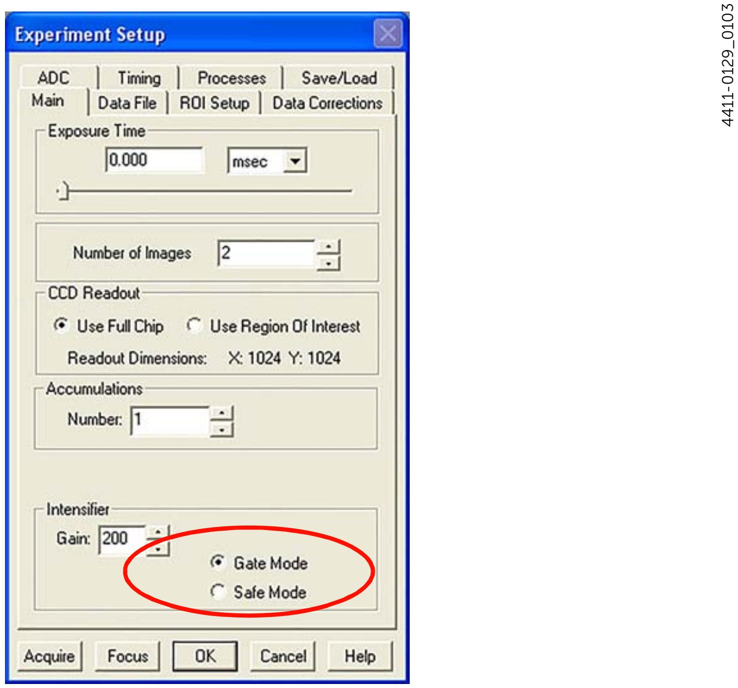
Figure 11-13: Typical Hardware Setup ► Controller/Camera Tab



4411-0129_0102

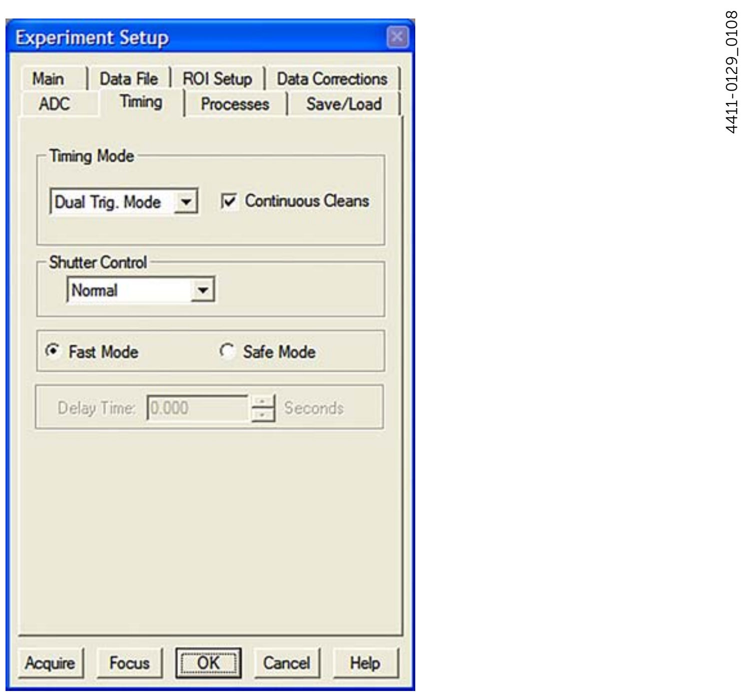
3. Configure the PI-MAX3 to Gate Mode for the intensifier to operate properly. This can be done by clicking the **Gate Mode** button on the Custom Toolbar, or by selecting **Gate Mode** on the **Acquisition ► Experiment Setup... ► Main** tab. See Figure 11-4.

Figure 11-14: Typical Experiment Setup... ► Main Tab



4. On the **Acquisition ► Experiment Setup... ► Timing** tab, verify **Timing Mode** is configured for **Dual Trig. Mode**. **Continuous Cleans** is also recommended for DIF. See Figure 11-5.

Figure 11-15: Typical Experiment Setup... ► Timing Tab



5. Select **Pulsers** from the **Setup** menu, select **SuperSYNCHRO**, and click on the **Setup Pulser** button. See Figure 11-6.

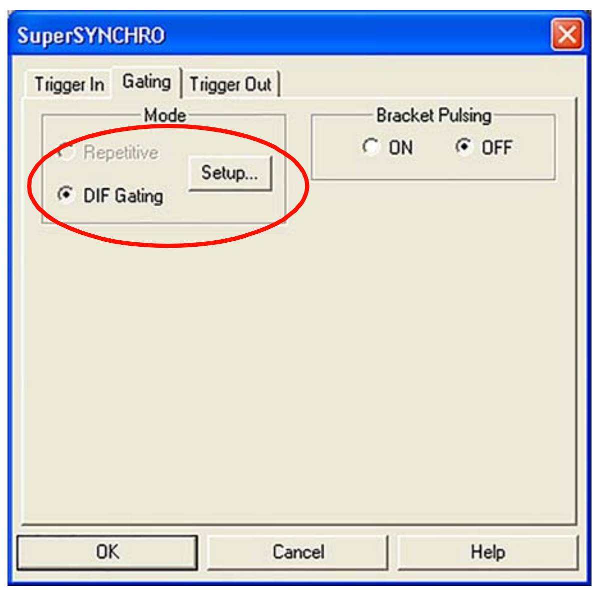
Figure 11-16:Typical Pulsers Dialog

4411-0129_0014

Perform the following procedure to configure SuperSYNCHRO:

a. On the **Gating** tab of the **SuperSYNCHRO** dialog, select **DIF Gating** and click the **Setup** button.

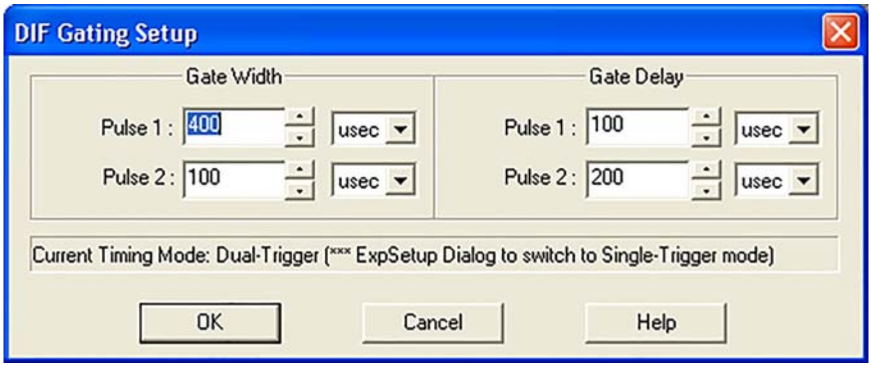
Figure 11-17:Typical SuperSYNCHRO Dialog



4411-0129_0105

b. On the **DIF Gating Setup** dialog, configure the **Gate Width** and **Gate Delay** times:
When configuring the **Pulse 1 Gate Delay** time, verify that it is ≥75 µs;
See Figure 11-8.

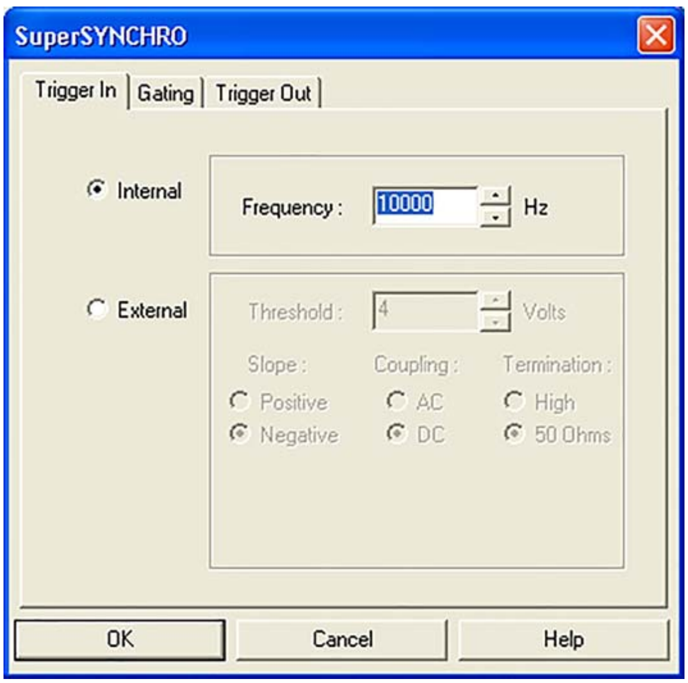
Figure 11-18:Typical DIF Gating Setup Dialog: Dual Trigger



4411-0129_0109

c. On the **Trigger In** tab, select **Internal** or **External** triggering.
When using External triggering, verify the trigger characteristics match the active trigger edge, etc. of the trigger pulse that will be used.

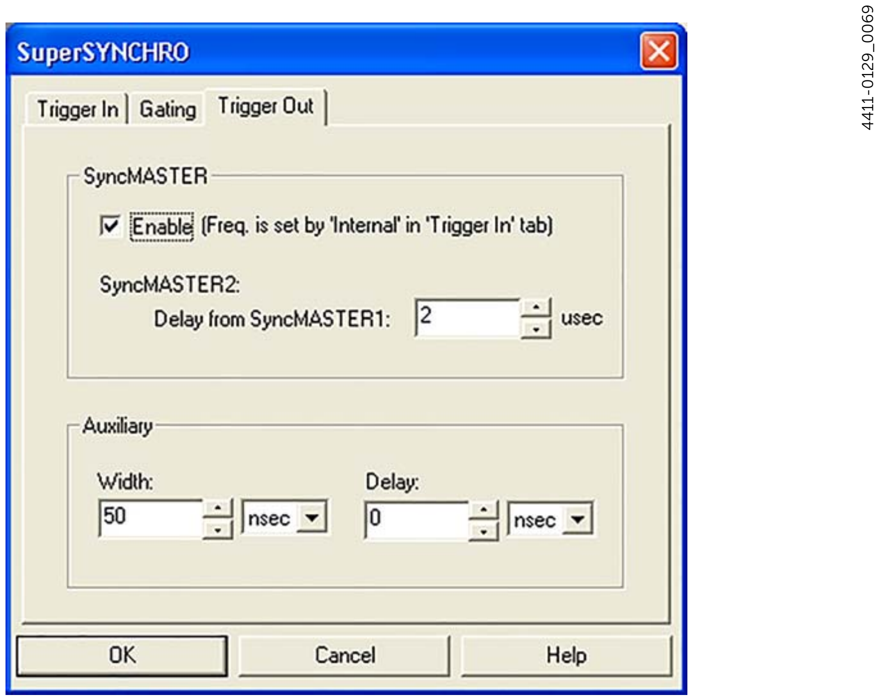
Figure 11-19:Typical SuperSYNCHRO Dialog: Trigger In Tab



4411-0129_0064

d. If required, on the **Trigger Out** tab, configure output triggers.

Figure 11-20:Typical SuperSYNCHRO Dialog: Trigger Out Tab



e. At the bottom of the **SuperSYNCHRO** dialog, click **OK** to download the gating sequence to the SuperSYNCHRO.

6. When the experiment is ready, click on the **ACQ** button or select **Acquire** on the Acquisition menu to start the image acquisition.

11.6 Tips and Tricks

Experiments using the DIF feature of the PI-MAX3 can be complex, and timing of the events is usually rather exacting. Here are several points to consider that may make the experiment setup or troubleshooting much smoother and easier.

- The most important piece of equipment in a DIF experiment is an oscilloscope. The PI-MAX3 has a MONITOR BNC on the back of the camera which is very useful for seeing when the two image exposures occur during the course of the experiment. The use of the **MONITOR** BNC and an oscilloscope is discussed in more detail in Chapter 15, Tips and Tricks, on page 183.
- The short time between the two images in DIF requires an intensifier with a fast phosphor. P46 phosphor has a decay time of ~ 2 μs which means it takes 2 μs for the phosphor emission to drop to 10% of its peak value. The decay is not a simple single exponential. Even after 100 μs there may be 1% or more of the first image on the phosphor screen. It is usually possible to subtract a percentage of the first image from the second image to remove the residual image. If this is not possible, there are intensifiers with P47 phosphor, which is an order of magnitude faster than P46.
- The software uses the **Phosphor Decay Time** to determine how long to wait after the gate pulse to shift the image. This value can be adjusted in the Hardware Setup dialog. If there is some residual image from the first frame in the second frame, simply increase the Phosphor Decay Time to allow the phosphor more time to decay before shifting the image. If residual image is not an issue, then Phosphor Decay Time can be shortened to decrease the time between the two DIF images.

Chapter 12: LightField and Dual Image Feature (DIF)

The purpose of PI-MAX3 DIF is to acquire a pair of gated images in rapid succession. The time between frames can be as short as 450 ns. The second image will have some remnants from the first image due to the longer persistence of the P46 phosphor. Exposure times can be as short as 2.5 ns.The DIF capability is ideally suited to capturing rapidly evolving events. These experiments fall into two broadly applicable categories:

- Single Trigger;

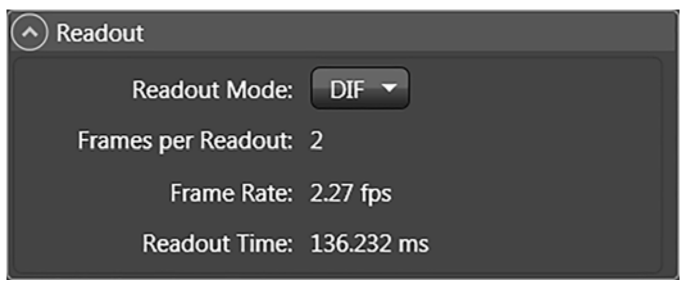
  Single trigger experiments involve a single impulse event that evolves over time such as a laser-induced plasma or luminescence decay.
- Dual Trigger.

  Dual trigger experiments involve two impulses separated in time such as double laser pulse velocimetry measurements.

12.1 Requirements

For DIF operation, the PI-MAX3 must use an interline CCD. On the **Readout** expander, **Readout Mode** must be configured to **DIF**. See Figure 12-1.

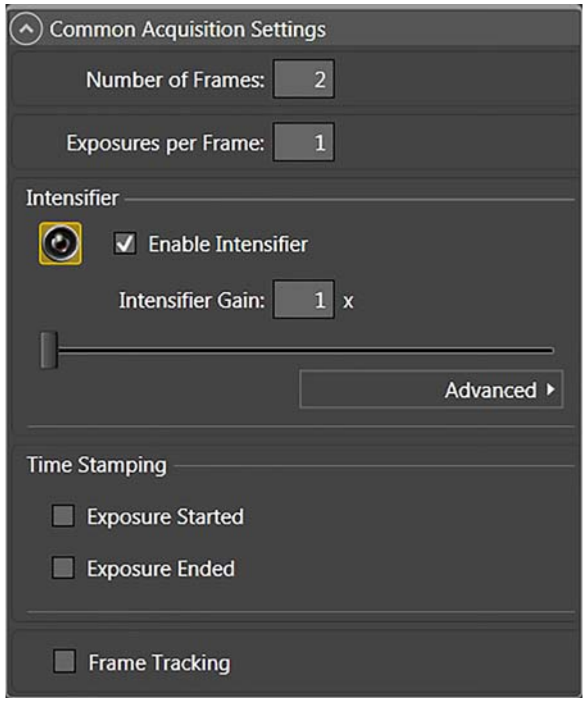
Figure 12-1: Typical Readout Expander



4411-0129_0110

Additionally, the number of frames, which is configured on the **Common Acquisitions Setting** expander, must be a multiple of 2. See Figure 12-2.

Figure 12-2: Typical Common Acquisition Settings Expander



Finally, it is recommended that the intensifier have a fast decay phosphor (P46). Since DIF operation involves acquiring images in rapid succession, phosphor persistence can become the limiting factor in the rate of image acquisition.

NOTE:

As of this writing, PI-MAX3: 1024i is the only PI-MAX3 that supports DIF mode.

12.2 Interline CCD Operation

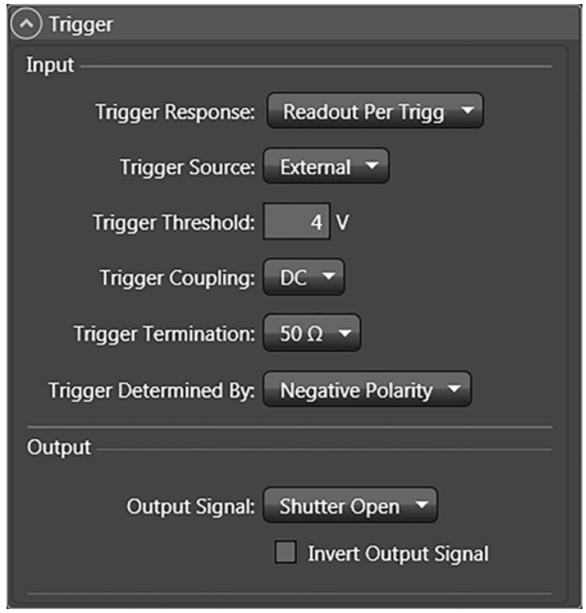
An interline CCD consists of alternating columns of light sensitive pixels and storage pixels. The light sensitive columns are referred to as the active area and acquire the image. The storage pixels are called the masked area and store the image in the dark while it is read out. With this architecture, the CCD can acquire a second image while the first image is being read out, unlike a standard CCD, which must read out the first image before the second acquisition can begin. The ability of the interline CCD to quickly transfer an image under the masked columns and hold it there makes DIF possible. As soon as the first image is acquired, it is shifted under the masked area and held. The second exposure begins and is held in the active area until the first image has been read out.

12.3 Trigger Configuration

Triggering for DIF operation is configured on the **Trigger** and the **SuperSYNCHRO** expanders.

Trigger configuration consists of selecting the **Trigger Response** and the **Trigger Source**. See Figure 12-3.

Figure 12-3: Typical Trigger Expander

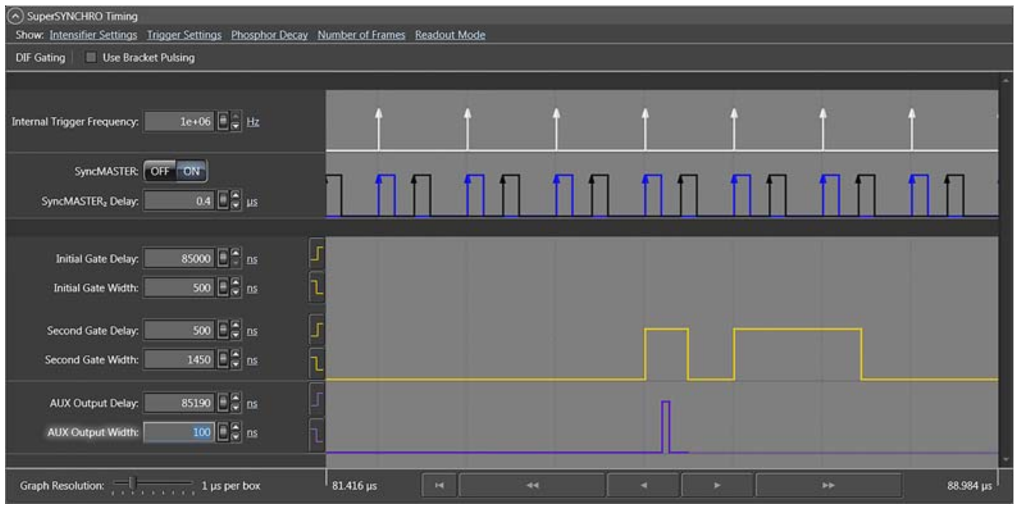


- Trigger Response
  Trigger Response determines whether one or two triggers will be required for an acquisition.
  The trigger(s) can either be internally generated by the PI-MAX3 or can be generated by an external source connected to the **TRIGGER IN** connector on the rear of the camera.
  Supported Trigger Responses are:
  - Readout Per Trigger
    Two shot, one trigger for both shots.
  - Shift Per Trigger
    Two shot, each shot requires a trigger.
- Trigger Source
  Trigger Source is configured via the **Trigger Source** pull-down.
  Supported Trigger Source are:
  - External
    In order for the PI-MAX3 to recognize triggers from an external source, additional trigger characteristics must be configured on the **Trigger Expander**, including:
    - Trigger Threshold;
    - Trigger Coupling;
    - Trigger Termination:
    - Trigger Determined By (i.e., polarity.)

— Internal

Trigger pulses will be generated by the PI-MAX3 using the Internal Trigger Frequency setting that has been configured on the SuperSYNCHRO Timing expander. See Figure 12-4.

Figure 12-4: Typical SuperSYNCHRO Timing Expander: DIF



The range of valid frequencies is 2 Hz to 1 MHz, in 1 Hz increments.

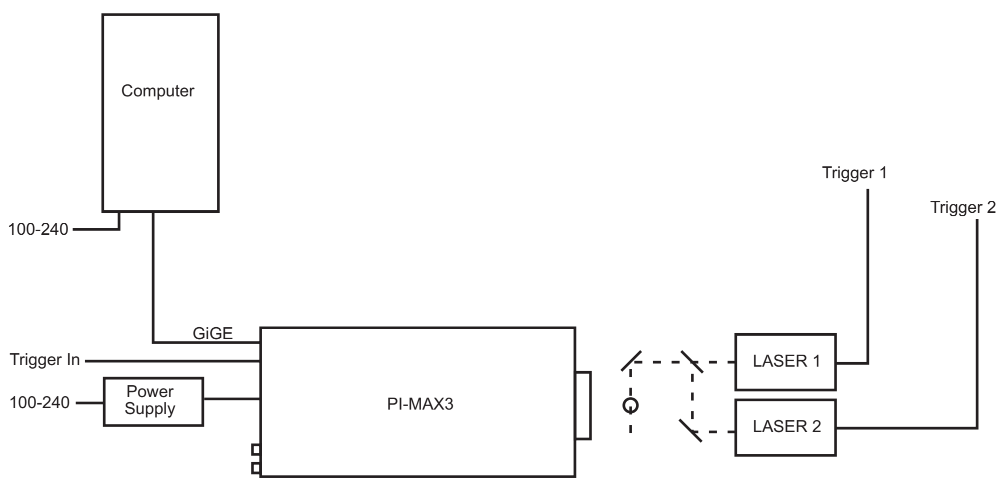
NOTE:

The Internal Trigger Frequency setting also determines the frequencies of SynchMASTER1 and SyncMASTER2 outputs.

12.3.1 Configure a Single Trigger DIF Experiment

Figure 12-5 illustrates the system block diagram for a single-trigger DIF experiment.

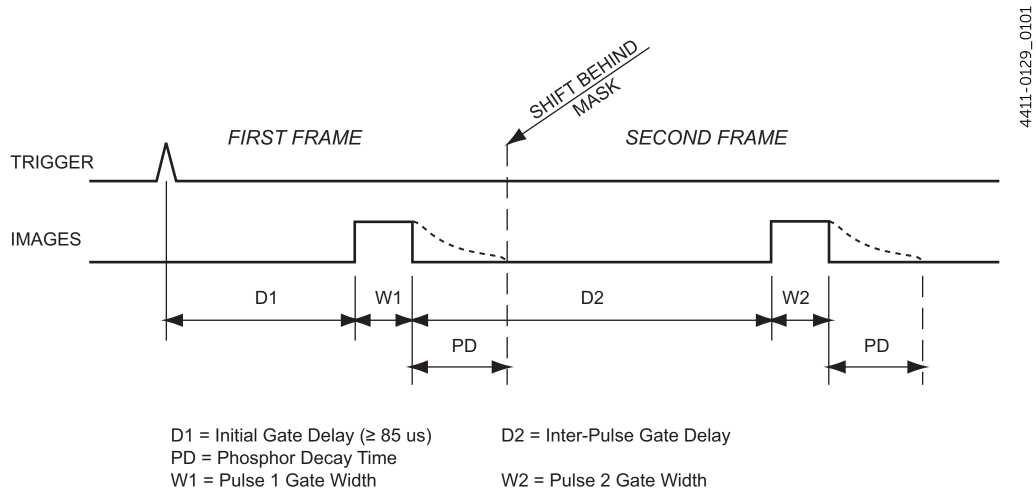
Figure 12-5: Typical System Block Diagram: DIF Operation



* Spectrograph, coolant circulator, and dry nitrogen tank connections are optional.

Figure 12-6 shows the timing diagram for single-trigger DIF operation.

Figure 12-6: Timing Diagram: DIF Operation, Single Trigger



Operating PI-MAX3 in DIF mode is similar to standard operation of a PI-MAX3 with SuperSYNCHRO. Perform the following procedure to configure a single-trigger DIF experiment:

1. Align and focus the PI-MAX3 on the area of interest for the experiment.

   This is best performed while the PI-MAX3 is operating in Full Frame readout mode (i.e., before switching to DIF mode.)

   Verify that the **Phosphor Decay Time** is appropriate for the phosphor used by the camera. This information is accessed by clicking **Advanced** on the **Common Acquisition Settings** expander.

   NOTE:

   The **Phosphor Decay Delay** setting tells LightField how long to wait after the gate pulse to shift the image.

   If there is some residual image from the first frame in the second frame, simply increase the Phosphor Decay Delay setting to allow more time for the phosphor emission to decay before shifting the image.

   If residual image is not an issue, then the **Phosphor Decay Delay** setting can be decreased to reduce the time between the two DIF images.

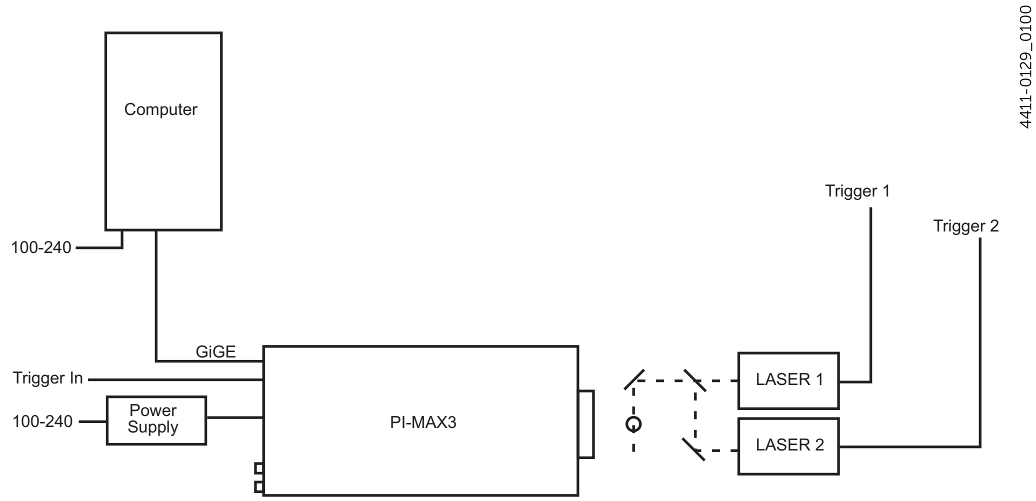
2. After alignment and focus, the PI-MAX3 system needs to be configure for DIF mode.
   - On the **Readout** expander, select configure **Readout Mode** to **DIF**;
   - On the **Common Acquisition Settings** expander, configure **Number of Frames** to a multiple of 2 (e.g., 2, 4, 6, etc.)

3. On the **Trigger** expander:
   - Verify **Trigger Response** is configured to **Readout Per Trigger**.
     If necessary, configure this as required.
   - Select the desired **Trigger Source**:
     — External
       Verify the trigger characteristics configured on the **Trigger** expander match the active trigger edge, etc. of the trigger pulse that will be used.
     — Internal
       Configure the desired **Internal Trigger Frequency** on the **SuperSYNCHRO Timing** expander.
4. Open the **SuperSYNCHRO Timing** expander at the bottom of the LightField workspace and perform the following procedure:
   a. Configure the following parameters as required:
      - Internal Trigger Frequency;
      - Gate Width;
      - Gate Delay;
      - Aux Output Delay;
      - Aux Output Width;
      - SyncMASTER state (i.e., On or Off.)
   b. Use the hyperlinks at the top of the expanded panel to make any necessary changes to the following parameter configurations:
      - Intensifier Settings;
      - Trigger Settings;
      - Phosphor Decay Delay Time;
      - Number of Frames (i.e., a multiple of 2);
      - Readout Mode (i.e., DIF or Full Frame).
   c. When using PI-MAX3 generated internal triggers for DIF acquisition, configure the desired **Internal Trigger Frequency**.
   d. Configure the desired Gate Width and Delay Times for the first and second images:
      - The **Initial Gate Delay** time will be ≥85 μs;
      - The **Second Gate Delay** time will be ≥0.441 μs.
   e. If required, configure the **AUX Output** trigger.
   f. To have trigger outputs from the **SyncMASTER1** and **SyncMASTER2** connectors on the AUX I/O cable, click **SyncMASTER ON**.
      By enabling SyncMASTER:
      - The output of the **SyncMASTER1** connector will be the Internal Trigger Frequency.
      - The **SyncMASTER2** output will be at the same frequency but can be delayed by between 0 ns and 999700 ns, in 100 ns increments.
5. Verify:
   - The I.I.T. Power switch on the rear of the PI-MAX3 is turned ON;
   - **Enable Intensifier** is checked on the **Common Acquisition Settings** expander.
6. When the experiment is ready, click **Acquire**.

12.4 Configure a Dual Trigger DIF Experiment

Figure 12-7 illustrates the system block diagram for a dual-trigger DIF experiment.

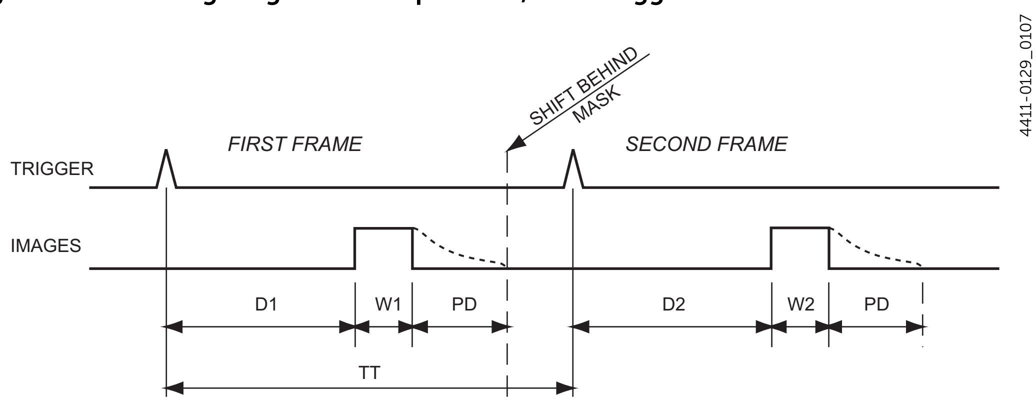
Figure 12-7: Typical System Block Diagram: DIF Operation



* Spectrograph, coolant circulator, and dry nitrogen tank connections are optional.

Figure 12-8 shows the timing diagram for dual-trigger DIF operation.

Figure 12-8: Timing Diagram: DIF Operation, Dual Trigger



D1 = Initial Gate Delay (≥ 85 us)
PD = Phosphor Decay Time
W1 = Pulse 1 Gate Width
TT = Time between Triggers (≥ D1+w1+PD)

D2 = Pulse 2 Gate Delay (≥ min. delay of camera ~ 25 ns)
W2 = Pulse 2 Gate Width

Operating PI-MAX3 in DIF mode is similar to standard operation of a PI-MAX3 with SuperSYNCHRO. Perform the following procedure to configure a single-trigger DIF experiment:

1. Align and focus the PI-MAX3 on the area of interest for the experiment.

   This is best performed while the PI-MAX3 is operating in Full Frame readout mode (i.e., before switching to DIF mode.)

   Verify that the **Phosphor Decay Time** is appropriate for the phosphor used by the camera. This information is accessed by clicking **Advanced** on the **Common Acquisition Settings** expander.

   NOTE:

   The **Phosphor Decay Delay** setting tells LightField how long to wait after the gate pulse to shift the image.

   If there is some residual image from the first frame in the second frame, simply increase the Phosphor Decay Delay setting to allow more time for the phosphor emission to decay before shifting the image.

   If residual image is not an issue, then the **Phosphor Decay Delay** setting can be decreased to reduce the time between the two DIF images.

2. After alignment and focus, the PI-MAX3 system needs to be configure for DIF mode.
   - On the **Readout** expander, select configure **Readout Mode** to **DIF**;
   - On the **Common Acquisition Settings** expander, configure **Number of Frames** to a multiple of 2 (e.g., 2, 4, 6, etc.)
3. On the **Trigger** expander:
   - Verify **Trigger Response** is configured to **Shift Per Trigger**.

     If necessary, configure this as required.
   - Select the desired **Trigger Source**:
     - External

       Verify the trigger characteristics configured on the **Trigger** expander match the active trigger edge, etc. of the trigger pulse that will be used.
     - Internal

       Configure the desired **Internal Trigger Frequency** on the **SuperSYNCHRO Timing** expander.
4. Open the **SuperSYNCHRO Timing** expander at the bottom of the LightField workspace and perform the following procedure:

   a. Configure the following parameters as required:
      - Internal Trigger Frequency;
      - Gate Width;
      - Gate Delay;
      - Aux Output Delay;
      - Aux Output Width;
      - SyncMASTER state (i.e., On or Off.)

b. Use the hyperlinks at the top of the expanded panel to make any necessary changes to the following parameter configurations:
   - Intensifier Settings;
   - Trigger Settings;
   - Phosphor Decay Delay Time;
   - Number of Frames (i.e., a multiple of 2);
   - Readout Mode (i.e., DIF or Full Frame).

c. When using PI-MAX3 generated internal triggers for DIF acquisition, configure the desired **Internal Trigger Frequency**.

d. Configure the desired Gate Width and Delay Times for the first and second images:
   - The **Initial Gate Delay** time will be ≥85 μs;
   - The **Second Gate Delay** time will be ≥0.441 μs.

e. If required, configure the **AUX Output** trigger.

f. To have trigger outputs from the **SyncMASTER1** and **SyncMASTER2** connectors on the AUX I/O cable, click **SyncMASTER ON**.
   By enabling SyncMASTER:
   - The output of the **SyncMASTER1** connector will be the Internal Trigger Frequency.
   - The **SyncMASTER2** output will be at the same frequency but can be delayed by between 0 ns and 999700 ns, in 100 ns increments.

5. Verify:
   - The I.I.T. Power switch on the rear of the PI-MAX3 is turned ON;
   - **Enable Intensifier** is checked on the **Common Acquisition Settings** expander.
6. When the experiment is ready, click **Acquire**.

12.5 Tips and Tricks

Experiments using the DIF feature of the PI-MAX3 can be complex, and timing of the events is usually rather exacting. Here are several points to consider that may make the experiment setup or troubleshooting much smoother and easier.

- The most important piece of equipment in a DIF experiment is an oscilloscope. The PI-MAX3 has a MONITOR BNC on the back of the camera which is very useful for seeing when the two image exposures occur during the course of the experiment. The use of the **MONITOR** BNC and an oscilloscope is discussed in more detail in Chapter 15, Tips and Tricks, on page 183.
- The short time between the two images in DIF requires an intensifier with a fast phosphor. P46 phosphor has a decay time of ~ 2 μs which means it takes 2 μs for the phosphor emission to drop to 10% of its peak value. The decay is not a simple single exponential. Even after 100 μs there may be 1% or more of the first image on the phosphor screen. It is usually possible to subtract a percentage of the first image from the second image to remove the residual image. If this is not possible, there are intensifiers with P47 phosphor, which is an order of magnitude faster than P46.
- The software uses the **Phosphor Decay Time** to determine how long to wait after the gate pulse to shift the image. This value can be adjusted on the **Advanced** fly-out panel of the **Common Acquisition Settings** expander. If there is some residual image from the first frame in the second frame, simply increase the Phosphor Decay Time to allow the phosphor more time to decay before shifting the image. If residual image is not an issue, then Phosphor Decay Time can be shortened to decrease the time between the two DIF images.

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Chapter 13: MCP Gating

MCP gating (not to be confused with MCP bracket pulsing) provides a unique combination of nanosecond-scale gating speed and high ultraviolet QE. Normally, such high UV QE is only available in so-called slow gate intensifiers (i.e., those without a nickel underlay.) The PI-MAX3 applies the primary gating pulse to the MCP portion of the tube and applies the bracket pulse to the photocathode. Consequently, it provides the full benefit of bracket pulsing along with enhanced QE.

The main limitations with this option are that there is a somewhat larger propagation delay and larger optical FWHM than a standard fast gate PI-MAX3. Insertion delay between trigger and T_0 is ~12 ns. Insertion delay to the photocathode gate is ≥30 ns. Insertion delay to MCP gate is 75-225 ns (dependent on the individual intensifier): this delay allows the photocathode to be fully on before the MCP is gated. Pulse repetition rate is limited to 10 kHz.

13.1 Setup and Operation

The PI-MAX3 must have an installed MCP Gating board.

1. Make all of the required cable connections for your experiment.
2. Switch on the equipment and start the application software.
3. Set up the gating parameters. You may want to start with a relatively long gate to acquire the phenomenon of interest.
4. Begin running the experiment.
5. Finally, narrow down the gate to the desired operation.

NOTE:

Pulse repetition rate is limited to 10 kHz.

13.2 Gain Variation

MCP gain approximately doubles for each 50 V increase in voltage. Therefore, small ripples in the MCP voltage as a result of the gating waveform will cause gain changes that vary with time after the rising edge of the gate pulse. A gain overshoot of 20% to 30% during the first 20 ns of a gate pulse is typical, with smaller variations later in time if a wider gate pulse is used. For a given gain setting and pulse width, these variations are reasonably repeatable, and may be calibrated.

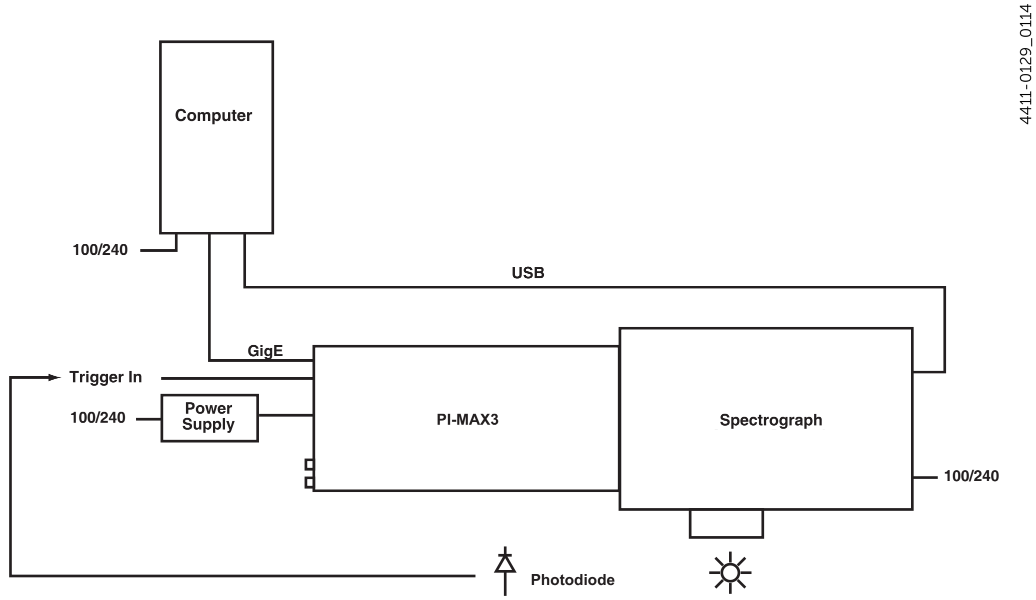
13.3 Fluorescence Experiment

A typical laser-induced fluorescence experiment might incorporate a pulsed laser that excites a sample with the laser beam and that additionally provides a trigger to the PI-MAX3. When the laser pulse hits the sample, some atoms are raised to a higher energy state and then spontaneously relax to the ground state, emitting photons as they do to generate the fluorescence signal. This signal can be applied to a spectrograph that spreads the fluorescence spectrum across the photocathode of the PI-MAX3. The spectrum would then be intensified and applied to the PI-MAX3's CCD array.

13.4 Hardware Configuration for MCP Gated Operation

Figure 13-1 illustrates the hardware block diagram for an MCP gated experiment using SuperSYNCHRO™.

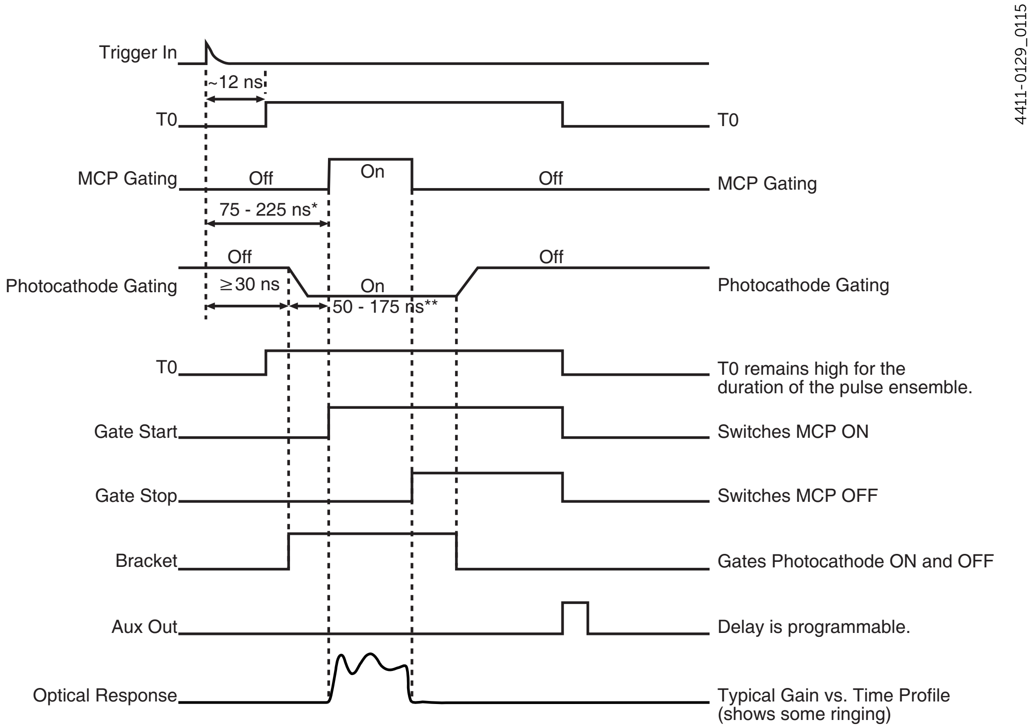
Figure 13-1: Hardware Block Diagram: MCP Gated Operation



The laser trigger output is applied to the PI-MAX3's **TRIGGER IN** connector to initiate the timing sequence. SuperSYNCHRO outputs gate the MCP on and off. To prevent artifacts from the laser from degrading the data, it is essential that SuperSYNCHRO be inhibited during each readout.

Figure 13-2 is the timing diagram for MCP gating of the photocathode.

Figure 13-2: Timing Diagram: MCP Gated Operation



* T_d+T_{pk} typical. Depends on individual image intensifier

** Depends on individual image intensifier

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Chapter 14: Picosecond Option

The picosecond gating option for the PI-MAX3 allows optical gates down to less than 500 ps or to the lowest gate width the intensifier will support, whichever is greater. It consists of a Picosecond Gating Board installed in the PI-MAX3 and additional modifications to support the board.

The picosecond option can operate up to a 100 kHz repetition rate (the primary gate generator goes to 1 MHz) and has a few nanoseconds' larger insertion delay than the primary gate generator.

REFERENCES:

Refer to Section 14.4, Repetition Rate Issues, on page 180, for detailed information about achievable repetition rates.

The MONITOR BNC output operates differently in picosecond operation.

14.1 Activating Picosecond Operation

The activation of Picosecond depends on the data acquisition software being used:

- WinX/32
  Automatically selects the picosecond gating board whenever the gate width is set below 3 ns.
- LightField

  The **Picosecond Widths** button Picosecond Widths ▾ will be added to the **SuperSYNCHRO Timing** expander when a PI-MAX3 equipped with the picosecond gating board is detected and loaded as an experiment device.

14.2 Gain and Gate Width

The apparent gain of the intensifier falls off as the gate width is reduced. Typically, at the lower limit, the gain is less than 10% of the value observed at 50 ns.

- WinX/32
  The software automatically selects the appropriate gate pulse generator to use when the user selects a gate width.
  The standard switch-over width is 3 ns.
- LightField
  The user selects one of the available gate widths from the **Picosecond Widths** drop down list and that width will be automatically entered in the **Gate Width** field(s).

NOTE:

When Sequential Gating is active, the starting and ending gate widths are the same: there are NO gate width sequences. However, differing starting and ending gate delays (swept delay) can be used with a constant gate width.

14.3 MONITOR Operation

The **MONITOR** output at the BNC on the rear panel is calibrated to provide a rising edge at the time the optical gate is opening (±500 ps.) The MONITOR width is NOT indicative of the optical gate width. It does NOT change width when the gate width is changed in the picosecond mode. This is because at these speeds, the electrical pulse width is not directly translated into optical gate width. In addition, many users do not have oscilloscopes available that will reliably capture picosecond pulse widths. Therefore, it was decided to use a pulse width of ~6 ns, regardless of the selected gate width. The true optical gate width is shown in the application software and this is calibrated at the factory using a fast pulsed laser.

14.4 Repetition Rate Issues

The picosecond gate generator operates at high peak power levels and therefore has a lower repetition rate capability than the primary gate generator. The normal peak repetition rate for the picosecond gate generator is 100 kHz. However, it will allow 2 gates to be generated at up to 1 MHz to allow for DIF operation. In addition, the 100 kHz repetition rate cannot be sustained continuously. Practically, it must be interrupted periodically to read the CCD so this is not as great a problem as it may seem.

The picosecond gate generator includes a digital average duty factor limiting circuit that will lock out gating and illuminate the red LED on the rear panel to limit the average heat buildup in the gating circuit. This allows continuous operation at 10 kHz, and varying numbers of gates per frame at higher rates, depending on the read out time. Acquisitions of a few frames can usually be done with more gates per frame without hitting the limit and red light.

Typical data for sustained operation with a PI-MAX3: 1024i are presented in Table 14-1.

Table 14-1: Typical PI-MAX3: 1024i Picosecond Operation Data: Sustained Operation

Repetition Rate (kHz)	ADC Rate (MHz)	Binning & ROI	Readout Time (ms)	Gates/Frame
90	16	Full frame	~40	450
75	16	Full frame	~40	461
50	16	Full frame	~40	500
50	16	1H x 100V ROI	~3.4	145
25	16	Full frame	~40	666
10	any	any	–	No limit

14.5 Timing

When using optical gate widths from a few nanoseconds to a fraction of a nanosecond, timing is obviously critical. The PI-MAX3 is calibrated with respect to the optical input plane (front mounting plane) and the rear panel. All other propagation paths must be accounted for by the user. These are significant, considering a 1 meter coaxial cable represents typically 4.5 ns delay, or 9 times the gate width, assuming the gate width is set to 500 ps. To get the best representation of the **MONITOR** output, the user should use a high bandwidth oscilloscope set at 50Ω input impedance. The rise time of the **MONITOR** pulse is typically less than 500 ps when terminated into 50Ω.

14.6 Methods for Finding a Short Optical Pulse

Method 1

The textbook method is to calculate all the delays in the optical and trigger paths and set the PI-MAX3 delay accordingly. If one does all the arithmetic correctly and has accurate numbers for all of the delays involved, this method will work.

In practice it seldom works because either some of the delays are not accurately known or something gets overlooked. The sum of the optical delays must be greater than the trigger delay (including the PI-MAX3 minimum delay.) Calculating the sums after the fact is still a valuable check on the system, even if the timing is achieved using Method 2.

Method 2

A more direct and usually more convenient method is to start with a gate pulse much wider than the optical pulse and configure the PI-MAX3 so the optical gate is wide enough to be sure it encompasses the optical pulse. This method works well if the pulse is conveniently repetitive, such as one derived from a repetitive laser.

Once the pulse is found, it is an easy matter to reduce the pulse width and adjust the delay until the precise timing needed is achieved. The PI-MAX3 repetitive and sequential gating can be used to good advantage in this method.

14.6.1 Example

This example is simplified in that it does not address all of the possible settings for Gate mode setup. It is intended to a sense of how to locate the signal of interest by successively decreasing gate pulse parameters.

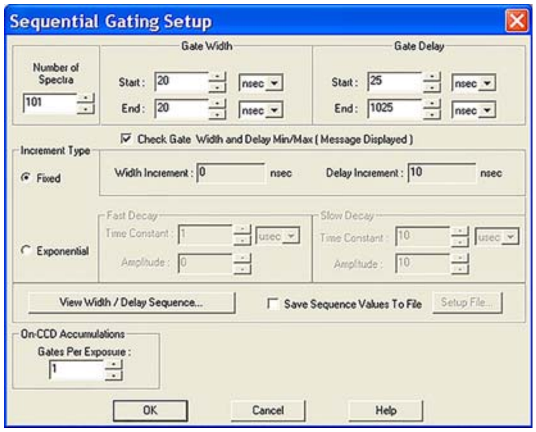
Perform the following procedure:

1. Suppose we start with a 1 μs gate and delay set to the minimum value for the PI-MAX3 (approximately 25 ns,) and we see the pulse. We then know the pulse is arriving between 25 ns and 1.025 μs.

WinX/32	LightField
 4411-0129_0116 Number of Images/Spectra: 1	Gate Mode: Repetitive Number of Frames: 1 Gate Delay: 25 ns Gate Width: 1 μs

2. We now set the sequential gating parameters for 20 ns gate width and 101 images/spectra {frames} at 10 ns per image/spectra {frames}. This spans the 1 µs.

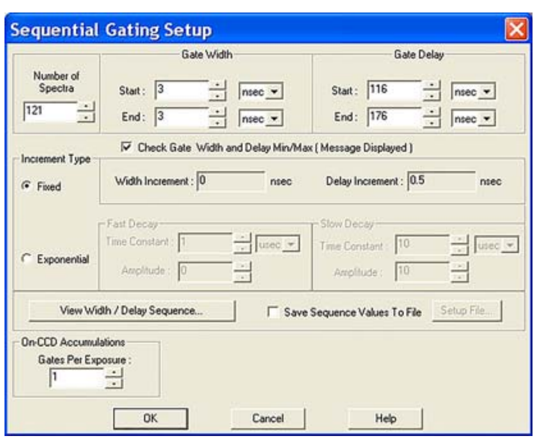
   We set the starting gate delay of 25 ns, ending gate delay of 1025, and take the sequence. We can then quickly look through the images or spectra (in WinX/32 or LightField) and see to the nearest 10 ns when the optical pulse arrived.

<table>
<tr><th>WinX/32</th><th>LightField</th></tr>
<tr><td>


4411-0129_0117
Number of Images/Spectra: 101
</td><td>Gate Mode: Sequential
Number of Frames: 101
Starting Gate Delay: 25 ns
Starting Gate Width: 20 ns
Ending Gate Delay: 1025 ns
Ending Gate Width: 20 ns
Reported Date Delay Increment: 10 ns</td></tr>
</table>

3. Assuming we found the signal in the 12th frame, we now set a narrower gate (e.g., 3 ns) and sweep about this value in 500 ps steps with a span of 60 ns to find the time within 500 ps.

   Adjust the experiment for best signal strength and/or signal to noise ratio, then jump down to the final gate width (if width < 500 ps is desired) and again do a sweep to find the exact timing that maximizes the result. This method has the advantage of assuring that the camera is seeing the pulse with the most favorable set-up before narrowing the gate width down.

<table>
<tr><th>WinX/32</th><th>LightField</th></tr>
<tr><td>


4411-0129_0118
Number of Images/Spectra: 121
</td><td>Gate Mode: Sequential
Number of Frames: 121
Starting Gate Delay: 116 ns
Starting Gate Width: 3 ns
Ending Gate Delay: 176 ns
Ending Gate Width: 3 ns
Reported Date Delay Increment: 0.5 ns</td></tr>
</table>

Chapter 15: Tips and Tricks

In Chapter 6, First Light, Chapter 8, WinX/32 and Gated Operation, and Chapter 9, LightField and Gated Operation, the objective was to show how to take an image or spectrum with a minimal operating configuration and following a simple procedure. In this chapter, we consider factors that affect more complex measurements.

15.1 Overexposure Protection

WARNING!

Image intensified detectors such as the PI-MAX3 can be destroyed if exposed to excessive light levels. Teledyne Princeton Instruments cannot take responsibility for damage due to misuse.

Intensified detectors must not be continuously exposed to high-level radiation ($\geq 10^{-4}$ foot candles). When the illumination level is not quantitatively known, toggle the I.I.T. switch (on the back of the PI-MAX3) to the OFF position while you are adjusting the incoming light level. After making adjustments, toggle the switch to the ON position. If the alarm sounds repetitively, toggle the switch back to OFF and readjust the lighting conditions.

If the experimental conditions dictate that only a small portion of the photocathode is illuminated over relatively long periods of time, change the illuminated region of the photocathode periodically to avoid long term localized photocathode or MCP damage.

If you can do so, it is a good idea to avoid intense light on the intensifier even when it is off. High light levels increase EBI, often for hours, even when the intensifier is off. Image burn-in can occur with some photocathode types.

NOTE:

The audible alarm and protection circuits are not fail-safe protection, particularly when working with high intensity sources such as lasers. For additional information, refer to Section 8.1.2, Alarm, on page 99.

15.2 Signal Delay

For the detector to see a transient signal, it is essential that it be gated on when the signal arrives at the detector. If this requirement isn't given careful consideration, it is possible to set up an experiment in which the signal will come and go before the detector is gated on. If this happens, no proper data can be taken. Depending on the nature of the experiment and the specific equipment involved, a number of different factors may need to be considered to be assured that the detector gates at the right time.

15.2.1 Time Budgets

A time budget is a listing of all the delays in the system that affect coincidence of the signal and gate at the camera. Given a system that, in addition to the PI-MAX3 and an internal timing generator, contained a low-jitter pulsed laser triggered from an external timer and an external trigger source that is also triggering the pulse generator, a time budget for this system might appear as follows.

PI-MAX3 **Internal Timing Generator**

- Signal Delay
  - Cable Delay from External Timer to Laser: 10 ns (6 ft cable is assumed)
  - Delay (at laser); Trigger to Laser Pulse: 10 ns
  - Delay; Laser Pulse to Sample: 10 ns
  - Delay; Fluorescence Signal to Detector: 5 ns

  Total Signal Delay: 35 ns
- Gate On Delay
  - Cable Delay from External Timer to PI-MAX3: 15 ns (10 ft cable is assumed)
  - PI-MAX3 Insertion Delay; Trigger to Start of Gate Open Pulse: 25 ns

  Total Gate On Delay: 40 ns

In this example, although the Signal Delay and the Gate On Delay are close, if the signal is a pulse lasting only a few nanoseconds, it will have come and gone before the Gate opens, and no valid experimental data could be taken. Obviously, this sample time budget is unlikely to match any actual system and the values for both the Signal Delay and the Gate On Delay could be very different from those indicated here. Nevertheless, it illustrates the importance of making a record of the delays that will be encountered in any system to determine their possible impact on experimental results.

15.2.2 Measuring Coincidence

In addition to preparing a Time Budget, it is advantageous if you can directly measure the timing of the critical signals. A fast oscilloscope can be used for this purpose. Without an oscilloscope to monitor the signals, it will be difficult to determine the timing with sufficient accuracy.

NOTE:

If you have a set of matching probes, use them. Major brand oscilloscope probes of the same model are usually matched to better than 1 ns. If you choose to use coaxial cables, measure the delay of each and use that information in the calculations.

The PI-MAX3 **Monitor** BNC connector provides a pulse coincident with respect to the actual intensifier photocathode gating by $\pm$5 ns. Note that this output is not designed for good fidelity but rather for accurate timing. The amplitude is typically more than a volt and we suggest that you monitor the pulse with a high impedance probe (you can also use 50Ω coaxial cable to a 50Ω oscilloscope and you will get a lower amplitude pulse).

The signal timing will probably be more difficult to measure. Typically, you might divert a small portion of the laser beam using a pellicle mirror located near the sample position. By directing the beam to a PIN diode module, you could obtain an electrical signal that could be monitored with the oscilloscope to accurately indicate the arrival of the laser beam at the sample position. Note that the indicated time would have to be corrected for the insertion delay of the path from the pellicle mirror to the oscilloscope, including the insertion time of the PIN diode, which might be on the order of the 10 ns. This correction would have to be compared with the delays that would normally exist between the sample position and the detector to determine the actual time the signal would arrive at the detector. Also, the oscilloscope will have its own insertion delay, perhaps 20 ns, and an uncertainty of nominally 1% of the time base.

Another consideration is how to trigger the oscilloscope. If there is a common trigger source for the sample position signal and for the gating, that trigger could also be used to trigger the oscilloscope, allowing both signals to be observed simultaneously. Another possibility is to trigger the oscilloscope from the PIN diode signal to observe the Monitor signal, or to trigger the oscilloscope from the Monitor signal to observe the PIN diode signal. The signal that occurs first would have to be used as the oscilloscope trigger.

NOTE:

This is not necessarily always the case. Digital oscilloscopes can display signals that occur before the trigger.

15.2.3 Adjusting the Signal Delay

The PI-MAX3 internal timing generator gives the user wide latitude with respect to adjusting the delay between the time the timing generator is triggered and the time the Gate On and Off edges are generated. This being the case, as long as the light signal applied to the detector occurs after the minimum delay time of the timing generator (25 ns), there will be no problem establishing the necessary coincidence.

On the other hand, if the light signal applied to the detector occurs before the minimum delay time of the timing generator, then no amount of adjusting the delay at the timing generator can rectify the problem. The light signal itself will have to be delayed.

If a common source is triggering both the timing generator and the laser, a very convenient solution is to insert electrical delay (long cable) between the trigger source and the laser. This is generally preferable to establishing the necessary delay optically via mirrors or fiber optic cable.

Alternatively, pass the laser output through a length of optical fiber cable. By using different lengths of fiber, almost any desired signal delay can be achieved. Yet another solution would be to set up two separated parallel mirrors with a small angle between them. Typically, it will be easily possible to bounce the laser beam back and forth between the mirrors half a dozen times to obtain the necessary delay. In any case, once the light signal is arriving at the detector after the minimum gate time, the timing generator delay adjustments can be used to bring them into coincidence. Keep in mind that using optical cable or mirrors to delay the signal will carry some intensity penalty, which might have an adverse affect on measurement results in some experiments.

15.2.4 Optimizing the Gate Width and Delay

When the basic delay questions have been answered, the next consideration is optimization of the Gate Width and Delay. The goal is to have the gate just bracket the signal event. One effective approach is to:

1. Begin with minimum delay and a gate width far wider than the optical signal pulse to be measured.
2. While observing the data signal at the computer monitor, gradually increase the delay until the event vanishes. This will mark the point at which the gate is opening just after the signal, causing the signal to be lost.
3. Reduce the delay until the signal reappears.
4. Then begin reducing the gate width (not the delay.) As the gate is narrowed, the amount of EBI generated will decrease so the signal-to-noise ratio should improve. When the point is reached where the gate becomes narrower than the signal being measured, the observed signal data will degrade. You may have to adjust the delay to keep the signal in view.
5. From there increase the width slightly for maximum signal and optimum signal-to-noise.

15.3 Lasers

Pulsed lasers are used in many experiments where a gated intensified detector might be used to recover the signal. For example, in combustion measurements, a laser pulse might be applied to a flame and the resulting fluorescence studied as the signal to be analyzed. Because this short-term signal is much weaker than the integrated light emitted by the flame, an intensified gated detector should be used to do the measurement.

Because available lasers differ so widely with respect to their characteristics and features, there is no way to discuss specifically how to incorporate your particular laser into a measurement system. It is necessary that users be familiar with the features, operation, and limitations of their equipment. Nevertheless, the following observations might prove helpful.

15.3.1 Free Running Lasers

These lasers behave essentially as oscillators. They typically exhibit little jitter from pulse to pulse and are very easy to synchronize with the experiment.

- If the laser has a Pre-trigger Output, it can be used to trigger the timing generator.
  - If the interval between the pre-trigger and the laser output is long enough, the timing generator delay can then be adjusted to catch the laser pulse following each pre-trigger.
  - If the interval between the pre-trigger and the laser output is not long enough to accommodate all insertion delays, the timing generator delay can be adjusted to catch the next laser pulse.

    As long as the laser's jitter relative to the period is small, this is a perfectly valid way to operate.
- If the laser does not have a Pre-trigger Output, one option is to use a pellicle mirror and a PIN diode to obtain the timing generator trigger.

  Again, the timing generator delay could be adjusted to catch the next laser pulse to achieve the necessary synchronization between the optical signal and the photocathode gate at the detector, although this would cause at least every other laser pulse to be lost.

15.3.2 Triggered Lasers

- Timing Generator as Trigger Source

  Using the PI-MAX3's **SyncMASTER1** signal to trigger the laser allows you to get rid of the propagation delay for the External Trigger (25 ns) and to set up all timing relative to T_0.

  You will still need to consider the delays from:

  — The cable to the laser (1.5 ns/ft);

  — Internal delay from trigger to firing (laser dependent, 50 ns for example);

  — The PI-MAX3's internal minimum allowable gate delay (25 ns).

- External Source Triggers Both Timing Generator and Laser

  This is the more complex case because it contains many sources of delay that would have to be considered.

  A carefully prepared Time Budget could prove invaluable in determining what steps need to be taken to bring the gate and signal into coincidence at the detector. In addition, actually measuring delays with a fast oscilloscope as previously described could be very helpful.

  If the laser provides a Pre-Trigger Output that can be used to trigger the Timing Generator, it may not be necessary to use mirrors or fiber-optic cable to delay the laser pulse.

  If there is no Pre-Trigger, then taking steps to delay the arrival of the laser pulse at the sample would likely be necessary. The easiest solution would be to insert electrical delay between the external trigger source and the laser.

15.3.3 Jitter

Jitter, the uncertainty in the timing of the laser output, is a critical laser performance parameter in gated experiments. If the jitter is significant relative to the duration of the signal pulse, the gate width will have to be wide enough to accommodate it, and the temporal discrimination against unwanted signal will be reduced.

Some types of high power laser pulse have considerable jitter, even using a pre-trigger. Where this is the case, there is no choice but to trigger from the actual laser pulse. One way of doing that is to use a pellicle mirror and PIN diode as previously described and then to delay the light (usually by multiple reflections between mirrors or in an optical fiber) until the gate opens.

15.4 Inhibiting the Pulser During Readout

In Gate mode operation, if gating pulses are applied to the detector during a readout, it will cause undesirable artifacts in the data. In experiments where the time between cycles is longer than the readout time, there is no possibility of this happening and it is not a matter of concern. If the experiment is such that it is possible for a new gate to be applied before the readout of the previously gathered data set is complete, preventive action will be required. With a PI-MAX3, the timing generator is inhibited internally.

15.5 Lens Performance

Imaging applications require that a lens be mounted to the detector. Because the lens characteristics affect system performance, it may be helpful to review some basic lens concepts.

Basically, light from an object enters the front of the lens and is focused to a sharp image on the photocathode of the intensifier. The ability of the lens to do this well depends on a number of factors which are discussed in the following sections.

15.5.1 Throughput

The throughput of a lens is determined by its aperture which can ordinarily be set to a number of different values, or f/ stops. The higher the number after the slash, the smaller the aperture and the lower the throughput.

Depth of field considerations make the focus adjustment most sensitive at maximum aperture (smallest f/).

15.5.2 Depth of Field

Depth of field is a measure of how the sharpness of a lens varies with respect to the distance of an object from the lens. For any given aperture, there is a depth of field, usually marked on the barrel of the lens. Objects within the zone will be sharply imaged. Objects closer or further than the depth of field will not be as sharp. The further an object is from the point of sharpest focus, the less sharp its image on the CCD will be. The point of maximum sharpness is located 1/3 of the way into the depth of field zone. For example, if the indicated depth of field for the selected aperture extended from 3 ft to 6 ft, the point of maximum sharpness will be at 4 ft.

For good focusing sensitivity, the depth of field should be small (i.e., large aperture.) If the aperture is small, the depth of field will be deep, making it difficult to establish the point of sharpest focus. For example, with a 50 mm lens, at f/4 the depth of field will extend from 8 ft to infinity. By focusing at full aperture, the depth of field will be as shallow as possible. As a result, the effects of even very small focusing adjustments will be readily observed, allowing the focus to be set with precision. Once the optimum focus setting has been achieved, the aperture can be reduced to the point of maximum sharpness. In some experiments, you may wish to adjust the aperture for optimum signal level. However, the experiment setup parameters established with the applications software can also be used to adjust the signal level, allowing the lens aperture and focus to be optimized.

15.6 Baseline Signal

With the detector completely blocked, the CCD will collect a dark charge pattern, dependent on the exposure time, detector temperature, and intensifier gain setting. The longer the exposure time and the warmer the detector the larger and less uniform this background will appear.

After temperature lock has been established, wait about 5 minutes for the detector temperature to completely stabilize. Then try taking a few dark charge readings with the detector operated with the I.I.T. switch set to OFF.

NOTE:

Do not be concerned about either the baseline level of this background or its shape, unless it is very high, i.e., > 1000 counts (or > 3000 counts at Gain=2 for some cameras). What you see is not noise. It is a fully subtractable readout pattern. Each CCD has its own dark charge pattern, unique to that particular device. In addition, a small offset is built in to prevent noise or pattern from going below zero. Every device has been thoroughly tested to ensure its compliance with Teledyne Princeton Instruments' demanding specifications.

15.7 Temperature Lock

If the PI-MAX3 Detector loses temperature lock, the internal temperature of the camera has gotten too high, such as might occur if the operating environment is particularly warm or if you are attempting to operate at a too cold temperature. If this happens, an internal thermo-protection switch will disable the cooler circuits to protect them. Although the thermo-protection switch will protect the camera, users are advised to power down and correct the operating conditions that caused the thermal-overload to occur. Note that the cooling performance of the detector can be enhanced by circulating water coolant. Refer to Section 7.5, Temperature Control, on page 68.

Turn the controller off for fifteen or twenty minutes. Then turn it back on and set a warmer temperature from the software **Detector Temperature** dialog. Temperature lock should be re-established within a few minutes.

15.8 Intensifier Alarm

CAUTION!

Contact Teledyne Princeton Instruments immediately if sporadic or continuous unwarranted alarms occur. They may indicate intensifier damage or another situation that requires immediate attention.

To reduce the risk of detector damage, PI-MAX3 detectors are equipped with an audible alarm in the detector head which is activated when the intensity of light falling on the image intensifier exceeds a preset threshold. While the alarm is sounding, the photocathode is temporarily disabled. Toggle the I.I.T. switch on the back of the PI-MAX3 to the OFF position. Cover the detector window and only switch the I.I.T. switch to ON after the illumination level has been lowered. If the alarm sounds repetitively even when the illumination level is adequately low, select **Safe Mode** in the WinX/32 application or shut the system down and contact the factory for guidance.

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Chapter 16: Troubleshooting

WARNING!

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

CAUTION!

If a sudden change in the baseline signal is observed, there may be excessive humidity in the CCD enclosure of the camera. Contact the factory for information about how to have the camera diagnosed or repaired. Refer to Contact Information on page 248 for complete information.

Refer to Table 16-1 for issues which have recommended troubleshooting procedures in this chapter.

Table 16-1: List of Recommended Troubleshooting Procedures

Issue	Information begins on...
Alarm Sounds Repetitively	page 192
Alarm Sounds Sporadically	page 192
Baseline Signal Suddenly Changes by > 1000 ADU	page 192
Camera Is Not Responding	page 192
Camera Stops Working	page 193
Temperature Lock Cannot be Achieved or Maintained	page 193
Gradual Deterioration of Cooling Capability	page 194
Data Loss or Serial Violation	page 194
Error Occurs at Computer Power Up	page 194
Ethernet Network is Not Accessible	page 194
Excessive Readout Noise	page 196

16.1 Alarm Sounds Repetitively

Immediately reduce the light entering the camera. This can be done by switching the **I.I.T.** switch on the back of the PI-MAX3 to OFF until you lower the source illumination by either decreasing the lens aperture or by completely blocking the light into the camera window with a lens cap (or equivalent) until the light level has been lowered.

If the alarm sounds repetitively even when the illumination level is adequately low, switch the **I.I.T.** to OFF and turn off the PI-MAX3 power supply. Then contact the factory. This may indicate intensifier damage or another situation that requires immediate attention.

16.2 Alarm Sounds Sporadically

It is normal for the alarm to sound briefly when the high-voltage supply is first turned on. However, if the alarm sounds sporadically, contact the factory at once. This may indicate intensifier damage or another situation that requires immediate attention. Refer to Contact Information on page 248 for complete information.

16.3 Baseline Signal Suddenly Changes by > 1000 ADU

There are two possible reasons for this change:

- The temperature setting has been changed.

  In this case, a change in baseline signal is normal.
- There may be excessive humidity in the CCD enclosure of the camera.

  If the temperature setting has not been changed and you observe a baseline signal change, turn off the system immediately. An excess humidity condition should be corrected promptly or permanent damage not covered by the Warranty could occur. Have the unit serviced by Teledyne Princeton Instruments or an authorized Teledyne Princeton Instruments service facility.

16.4 Camera Is Not Responding

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

- If the Camera is ON, the problem may be with the interface card, its driver, interrupt or address conflicts, or the cable connections.
- If the interface card is not installed, close the application software and turn the PI-MAX3 power supply OFF.

  Follow the interface card manufacturer's installation instructions and cable the interface card to the **GIG-E** port on the rear of the camera. Then perform a Custom installation of WinSpec/32 or WinView/32 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 GIG-E port on the rear of the camera, close the application program and turn the camera OFF. Check the cable connections and secure the cables if connections are loose.
- If the interface card was installed after the WinX/32 application software has been installed, close the application program and do a Custom installation of WinSpec/32 or WinView/32 with the GigE interface component selected. Be sure to deselect the interface component that does not apply to your system.

16.5 Camera Stops Working

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

1. Turn off all AC power.
2. Verify that all cables are securely fastened and that all locking screws are in place and all slide latches are in the latched position.
3. Correct any apparent problems and turn the system on.
4. If the system still does not respond, contact Customer Support. Refer to Contact Information on page 248 for complete information.

16.6 Cooling Troubleshooting

This section provides information about troubleshooting cooling-related problems.

16.6.1 Temperature Lock Cannot be Achieved or Maintained

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

- Ambient temperature greater than +20°C.

  This condition affects TE cooled cameras. If ambient is greater than +20°C, you will need to cool the camera environment or raise the set temperature.
- Airflow through the camera and/or circulator is obstructed.

  The camera needs to have approximately two (2) inches (50 mm) clearance around the vented covers. If there is an enclosure involved, the enclosure needs to have unrestricted flow to an open environment. The camera vents its heat out the side vents near the nose. The air intake is at the rear of the camera.
- A hose is kinked. Unkink the hose.
- Coolant level is low.

  Add 50:50 mix of ethylene glycol and water. Refer to manufacturer's instructions for adding coolant.
- There may be air in the hoses.

  Remove air and add 50:50 mix of ethylene glycol and water. Refer to manufacturer's instructions for removing excess air and adding coolant.
- Circulator pump is not working.

  If you do not hear the pump running when the circulator is powered on, turn off the circulator and contact the manufacturer's Customer Support.
- CoolCUBE$_{II}$:

  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 target array temperature is not appropriate for your camera and CCD array.
- The PI-MAX3's internal temperature may be too high, such as might occur if the operating environment is particularly warm, if you are attempting to operate at a temperature colder than the specified limit, or if you have turned off the fan and are not circulating coolant through the camera. TE cameras are equipped with a thermal-protection switch that shuts the cooler circuits down if the internal temperature exceeds a preset limit. Typically, camera operation is restored automatically in about ten minutes. Although the thermal-protection switch will protect the camera, it is nevertheless advised to power down and correct the operating conditions that caused the thermal-overload to occur.

16.6.2 Gradual Deterioration of Cooling Capability

While unlikely with the PI-MAX3 camera's guaranteed permanent vacuum for the life of the camera, if you see a gradual deterioration of the cooling capability, it might be due to a damaged camera vacuum. This can affect temperature performance such that it may be impossible to achieve temperature lock at the lowest temperatures. In the kind of applications for which cooled CCD cameras are so well suited, it is highly desirable to maintain the system's lowest temperature performance because lower temperatures result in lower thermal noise and better the signal-to-noise ratio.

Contact the factory to make arrangements for returning the camera to the support facility. Refer to Contact Information on page 248 for complete information.

16.7 Data Loss or Serial Violation

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

16.8 Error Occurs at Computer Power Up

If an error occurs at boot up, either the Interface is not installed properly or there is an address or interrupt conflict. Turn off the computer, try a new address or interrupt and reinstall the card. Be sure the Interface is firmly mounted in the slot.

NOTE:

Since interrupts and DMA channels cannot be shared, verify no other boards in the host computer use this interrupt or these DMA channels.

16.9 Ethernet Network is Not Accessible

When Teledyne Princeton Instruments software is installed, all Intel Pro/1000 interface card drivers found on the host computer are updated with the Intel Pro/1000 Grabber Adapter (Vision High-Performance IP Device) driver provided by Pleora Technologies, Inc. If this computer is connected to an Ethernet network via an Intel Pro/1000 card that does not use the Pleora driver, the network connection will be broken. The tool used to restore the network connection depends on whether you are using WinX/32 (32-bit) or LightField (64-bit).

16.9.1 WinX/32 Applications

1. Locate the `EbDriverTool32.exe` file by either:
   - Downloading the file to the host computer from the following location:

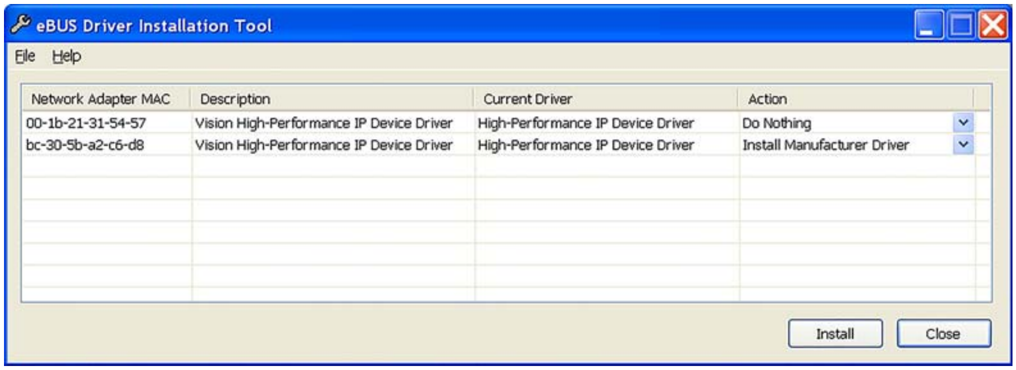
     `ftp://ftp.princetoninstruments.com/public/Software/Official/WinX32/GigE/`
   - Navigating to the default Pleora directory on the host computer which is typically:

     `C:\Program Files\Common Files\Pleora`

   The `EbDriverTool32.exe` (or possibly `EbDriverTool.exe`,) file may be in a subdirectory.
2. Run the file.

3. When the program executes, select the appropriate Ethernet card. See Figure 16-1.
   Under the Action column, select **Install Manufacturer Driver** from the pull-down menu.

Figure 16-1: Typical WinX/32 eBUS Driver Installation Tool Dialog



4. After making the selection, click **Install**.
5. After the installation you may be prompted to reboot the host computer.
   If prompted:
   - Click **Yes** to initiate the reboot;
   - Click **No** to wait before rebooting.
     If you select **No**, you may be required to close the **eBUS Driver Installation Tool** dialog.
     Reboot the computer at your convenience.
6. Verify that the network connection has been re-established. If a reboot was required, wait until the reboot has occurred before verifying the connection.

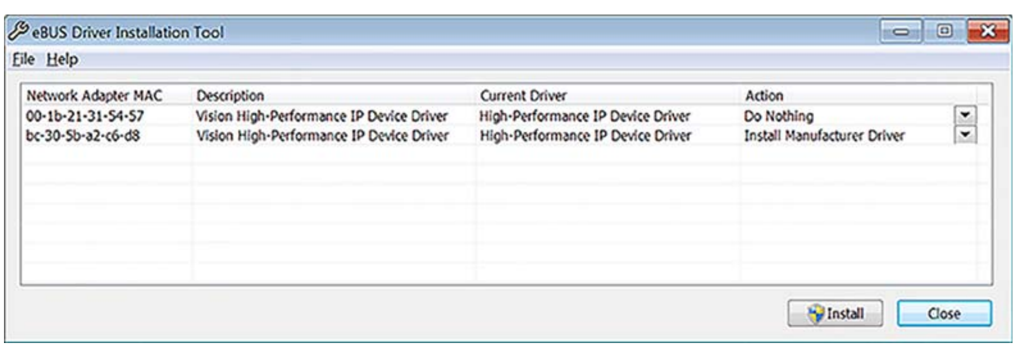
16.9.2 LightField Applications

1. Locate the `EbDriverTool64.exe` file. Typically it is located in the following directory:

   `C:\Program Files\Common Files\Pleora`

   The `EbDriverTool64.exe` file may be in a subdirectory.
2. Run the file.
3. When the program executes, select the appropriate Ethernet card. See Figure 16-2.
   Under the Action column, select **Install Manufacturer Driver** from the pull-down menu.

Figure 16-2: Typical LightField eBUS Driver Installation Tool Dialog



4. After making the selection, click on Install.
5. After the installation you may be prompted to reboot the host computer.
   If prompted:
   - Click **Yes** to initiate the reboot;
   - Click **No** to wait before rebooting.
     If you select **No**, you may be required to close the **eBUS Driver Installation Tool** dialog.
     Reboot the computer at your convenience.
6. Verify that the network connection has been re-established. If a reboot was required, wait until the reboot has occurred before verifying the connection.

16.10 Excessive Readout Noise

Excessive readout noise with the intensifier off indicates possible moisture accumulation in the CCD. This should be corrected promptly or permanent damage not covered by the Warranty could occur.

Normal camera noise is a function of the gain setting and temperature as well as CCD type, but is typically in the range of 1-50 ADU_{rms} (6 -300 ADU_{pk-pk}). This is on top of offset that typically is about 600 counts. Moisture accumulation produces a coarser noise with many spikes ≥300 ADU. If these types of spikes occur, especially after the camera has been in use for an extended period, turn off the system immediately. Have the unit serviced by Teledyne Princeton Instruments or an authorized service facility of Teledyne Princeton Instruments.

Appendix A: Technical Specifications

CAUTION!
All specifications are subject to change.

This appendix provides some technical information and specifications for PI-MAX3 cameras and optional accessories. Additional information may be found on data sheets available on the Teledyne Princeton Instruments website (www.princetoninstruments.com).

A.1 Camera Specifications

Refer to Table A-1 for CCD array specifications for PI-MAX3 detectors.

Table A-1: CCD Specifications

Specification	PI-MAX3 1024i	PI-MAX3 1024 x 256
CCD Type	Kodak KAI:1003 (interline)	e2v CCD30-11 (full frame)
CCD Format	1024 x 1024	1024 x 256
CCD Pixel Size	12.8 µm x 12.8 µm	26 µm x 26 µm
Imaging Area	13.1 mm x 13.1 mm (18 mm diameter)	18 mm x 6.7 mm or 25 mm x 6.7 mm
Intensifier Size	18 mm	18 mm or 25 mm
Intensifier Type	Gen II, Gen III filmless, or UNIGEN II	
Phosphor Type	P43, P46[a] (optional)	P43, P46 (optional)
Pixel Full Well (minimum)	130 ke^-	450 ke^-
Read Noise (typical)	16 e^-_{rms} @ 4 MHz digitization 30 e^-_{rms} @ 16 MHz digitization 35 e^-_{rms} @ 32 MHz digitization	14 e^-_{rms} @ 500 kHz digitization 15 e^-_{rms} @ 1 MHz digitization 22 e^-_{rms} @ 2 MHz digitization

a. Contact Teledyne Princeton Instruments for P46 and P47 Phosphor availability.

Dimensions

Refer to Appendix B, Outline Drawings, on page 209.

Gating

Jitter: ~35 ps RMS
Minimum delay from trigger: ~25 ns (without bracket pulse), ~35ns with bracket pulse
Delay, width granularity: 10 ps.
Repetition Rate: 1 MHz ("full voltage" pulse), not burst length limit

Maximum Repetition Rate (photocathode)

Sustained: 1 MHz in variable mode; 6.25 kHz with bracket

Digital Conversion: 16 bits

TTL Requirements

Rise time: ≤40 ns

Duration: ≥100 ns.

Image Intensifier: 18 mm or 25 mm

Method of Coupling: fiber optic

Mounts

Three different interchangeable mounts/adapters are available so that C-mount lenses, F-mount lenses, and spectrograph can all be readily accommodated. Changeover from one mounting system to another can be accomplished in moments with no adjustments required. Any one of the three mount types is simply secured by four screws, which require a small Phillips screwdriver.

Available mounts include:

- Spectroscopy Adapter
  Three 120° slots in concentric configuration with 3.6" bolt circles.
- F-Mount Adapter[1]
  Accepts standard F-mount latching mechanism.
- C-Mount Adapter
  Accepts standard C-mount threaded lenses.

Focal Depth

Distance from adapter flat to photocathode surface

- Spectroscopy:
  Mounting face to image plane is factory preset to an optical distance of 0.894″ ±0.010″ [22.71 mm ±0.25 mm].
- F-Mount
  Mounting face to image plane is factory preset to an optical distance of 1.831″ ±0.010″ [46.50 mm ±0.25 mm].
- C-Mount
  Mounting face to image plane is factory preset to an optical distance of 0.690″ ±0.010″ [17.53 mm ±0.25 mm].

Vignetting

With fiber optic coupling there is no vignetting. With a 1024 × 256 array, which has a width of 26 mm, pixels that fall beyond the 18 mm or 25 mm width (depending on intensifier width) of the intensifier will not be illuminated.

Gen II Spatial Resolution

1:1 coupling: typically 70 μm spot size FWHM

Gen II High Res Spatial Resolution

1:1 coupling: typically 45 μm spot size FWHM

Filmless Gen III Spatial Resolution

1:1 coupling: typically 42 μm spot size FWHM

Geometric Distortion: typically < 1 pixel

1. Similar mount for Canon lenses may also be available. Contact the factory for information.

Sensitivity

Variable intensifier gain adjustment (via software) allows sensitivities from 1-80 counts/photoelectron for Gen II and 1-200 counts/photoelectron for Gen III. Some phosphor choices may result in lower values. Gain adjustment range is 1-100.

Gating ON/OFF Ratio

Visible (550 nm):

- 5×10^6:1 typical.

UV (250 nm):

- 10^4:1 with photocathode gating only;
- 10^6:1 with supplemental MCP bracket pulsing typical.

Response Linearity

Linearity is difficult to predict in ICCD systems, especially at high frame rates. Most intensifiers cannot generate sufficient light in a single gate to achieve full scale illumination, or even approach it. Generally, it takes a few milliseconds for an intensifier to recover from a single gate event (if the charge output is significant). Good linearity is observed when the light intensity is low and the signal is built up over a large number of exposures or over a long exposure. Poor linearity is observed when one attempts to get large signal amplitude from a single short exposure. This is a general property of MCP image intensifiers, not just of Teledyne Princeton Instruments ICCDs.

Photocathode Dark Charge (EBI)

Red-blue enhanced, < 5 counts/pixel-second;

Red-enhanced, < 15 counts/pixel-second.

Phosphor Decay

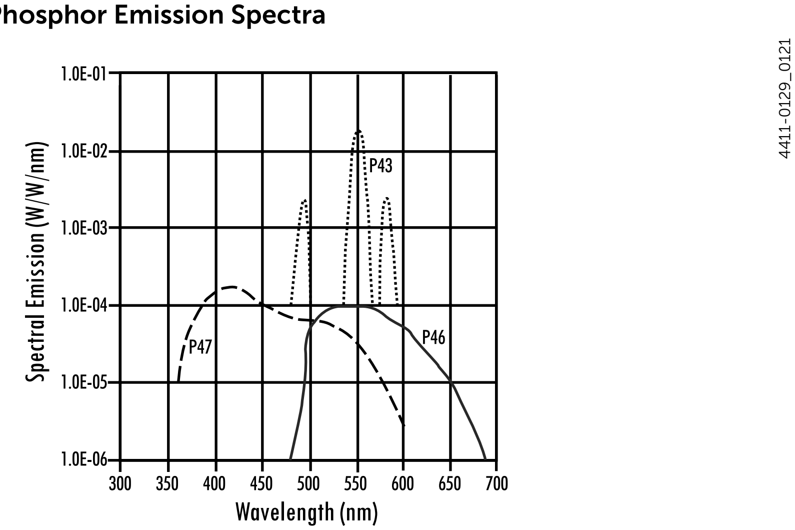
- 3 ms P43 standard
- 2 μs P46 phosphor is optional

Phosphor Emission Spectra

See Figure A-1

- P43 = Gd2O2S:Tb
- P46 = Y3Al5O12:Ce

Figure A-1: Typical Phosphor Emission Spectra



Spectral Range

Gen II:

- Red-blue enhanced, 180-900 nm;
- Red enhanced, 360-920 nm

Filmless Gen III:

- HQ, 450-900 nm;
- HQ (Blue), 375-900 nm

Non-uniformity

Typically:

- 12%$_{pk-pk}$ for Gen II 18 mm intensifiers
- 16%$_{pk-pk}$ for Gen II 25 mm intensifiers

CCD Cooling

Down to -25°C air cooled; supplementary cooling with circulating room-temperature water will enhance cooling performance. Temperatures to 35°C are achievable with supplemental circulating coolant via a CoolCUBE$_{II}$ circulator. Chilled coolant can achieve even lower temperatures but must be used with extreme caution.

REFERENCES:

Before initiating supplemental water cooling, refer to warning in Section 7.5, Temperature Control, on page 68.

Readout Noise

1-1.5 counts RMS in gated operation (100 kHz).

A/D Converters

- Standard: 16-bit, 80 MHz readout rate.
  One or two converters depending on the CCD.
- Linearity: better than 1%.
- Readout noise: Dependent on the pixel rate and CCD type.

Input: TRIGGER IN

Rear Panel BNC.

This is the main trigger input to timing generator. Used for triggering by an external source.

When external triggering is selected in the software, the internal timing generator will be triggered by an externally derived trigger pulse (range of ±5.5 V) applied to this input. The threshold, slope, coupling mode (AC or DC), and input impedance (High or 50Ω) are selectable in software.

The associated Green LED flashes each time PI-MAX3 is triggered (glows steadily at high repetition rates).

The actual triggering can also be readily determined by observing the signal at the Monitor output with a fast oscilloscope.

Outputs:

- READY:
  TTL signal. Represents camera status. It changes state when ready just before the exposure.
- Gig-E:
  Gigabit Ethernet connector.
- LOGIC OUT:
  0 to +3.3V programmable logic level output (TTL-compatible).
  The output can be programmed via software as:
  - ACQUIRING;
  - IMAGE SHIFT;
  - LOGIC 1;
  - READ OUT;
  - SHUTTER;
  - WAIT FOR TRIGGER.

  The output can also be inverted through software.

REFERENCES:

Refer to Section 7.12, Logic Out Control, on page 87 for complete information about these signals.

- AUX Out:
  DC-coupled programmable delay trigger output to synchronize external devices with PI-MAX3.
  The delay is from T0: 0.01 ns - 1.0 s.
- Monitor: TTL signal to monitor actual gate timing

A.1.1 AUX I/O Connector Pinout

Figure A-2 illustrates a typical AUX I/O cable. Refer to Table A-2 for BNC connector usage and identification.

Figure A-2: Typical AUX I/O Cable

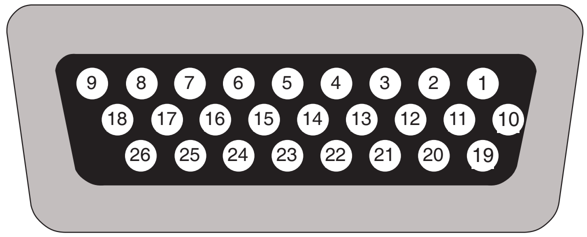
4411-0129_0007

Table A-2: AUX I/O Cable Leads

Name	Color	Pin Center	Pin Return
T0 OUT	Red	Pin 1	Pin 3
PRE-TRIG IN	Green	Pin 2	Pin 6
SyncMASTER1	Blue	Pin 7	Pin 18
GP INPUT 0	Gray	Pin 8	Pin 20
SyncMASTER2	Black	Pin 23	Pin 25

Figure A-3 illustrates the pinout of the 26-pin AUX I/O connector.

Figure A-3: AUX I/O Connector Pinout



The AUX I/O (Input/Output Status) connector provides information about trigger function, DAC, and TTL signals. Inputs must be at least 2.4 V_{DC} for a TTL high and less than 0.9 V_{DC} for a low.

The numbers on the I/O connector diagram correspond to the numbers assigned to the definition of each of the pins. The I/O connector is a female, DB26, high-density connector. The I/O cable is included with the PI-MAX3 camera. Refer to Table 2-3, Standard PI-MAX3 Camera System Cables, on page 29 for additional information about the AUX I/O cable.

Refer to Table A-3 for pin names and descriptions.

Table A-3: AUX I/O Connector Pinout and Signal Description (Sheet 1 of 3)

PIN #	Signal Name and Description
1	T_0 Output LVCMOS FPGA output with limited ESD protection, goes high at T0. Indicates a trigger has been received.
2	Pre-Trigger Input LVCMOS ESD-protected input. Pre-Trigger is an optional signal that may be used to terminate the continuous cleans instruction operation. In ordinary operation there is a one clean cycle jitter between the trigger and the finish of cleaning (i.e., the clean cycle in process must be completed.) A rising edge will cause a pre-trigger. ***NOTE:*** The camera must already be in Acquire mode before the pre-trigger is sent to the input.
3	GND System chassis ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.
4	Lockout Output LOW indicates I.I.T. is locked off.
5	NOT USED
6	GND System chassis ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.
7	SyncMASTER1 Output LVCMOS Active high. User-configurable output. SyncMASTER1 can be user-configured to provide a user-specified continuous frequency output (not just when the camera is taking data) until halted by the user. In this configuration, the output could be used to synchronize a laser, shutter, AOTF, etc., with the camera.

Table A-3: AUX I/O Connector Pinout and Signal Description (Sheet 2 of 3)

PIN #	Signal Name and Description
8	General Purpose Input 0 Reserved for future use as general LVCMOS input limited ESD protection.
9	L_Shutter Via 1 kΩ Do Not Use.
10	Source Comp Future Use. Analog Input.
11	Logic GND Do Not Use.
12	+5.9 V Thru 100 Ω
13	NOT USED
14	General Purpose Output 3 Via 1 kΩ Reserved
15	General Purpose Output 2 Via 1 kΩ Reserved
16	General Purpose Output 1 Via 1 kΩ Reserved
17	SyncMASTER2 Output Via 1 kΩ)
18	GND System chassis ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.
19	NOT USED
20	GND System chassis ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.
21	General Purpose Input 2 Via 1 kΩ Reserved
22	General Purpose Input 1 Via 1 kΩ Reserved
23	SyncMASTER2 Via 10 Ω Programmable continuous frequency output (100 ns - 6.55 ms delay from SyncMASTER1) synchronize external devices with PI-MAX3, e.g. Q-switch.

Table A-3: AUX I/O Connector Pinout and Signal Description (Sheet 3 of 3)

PIN #	Signal Name and Description
24	NOT USED
25	GND System chassis ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.
26	General Purpose Input 3 Via 1 kΩ Reserved

A.1.2 Power Requirements

Nominally 100, 120, 220 or 240 V_{AC}. Refer to the Fuse/Voltage label on the rear of the power supply for details.

All DC voltages required by PI-MAX3 cameras are generated and delivered by an external power supply included with each PI-MAX3 camera using the supplied cables.

CAUTION!

Whenever the PI-MAX3 power supply is turned off, be sure to leave it off for a minimum of 30 seconds before switching it back on.

If it is turned on too soon, a fault logic state is established that causes the overload alarm to sound continuously.

A.1.3 Environmental Requirements

Storage temperature: <55°C

Operating temperature: 30°C > T > +25°C

Supplemental Cooling Water Flow Rate: 1-3 liters per minute

NOTE:

Circulating water will enhance cooling performance but is not required.

Relative humidity: <80% non-condensing

A.1.4 Ventilation

Camera

Allow a minimum of one-inch clearance for side and rear air vents. There are internal fans located behind an intake opening in the rear panel. Their purpose is simply to cool the camera and TE-cooler. The fans run continuously whenever the camera is powered. Air enters the through the openings in the rear panel and is exhausted through ventilation openings on the side panels. It is important that there be an adequate airflow for proper functioning. As long as both the camera's intake ventilation openings and the fan exhaust opening aren't obstructed, the camera will remain quite cool.

Power Supply

There is an internal fan located at the rear panel behind an exhaust opening. Its purpose is simply to cool the power supply electronics. This fan runs continuously whenever the power supply is powered. Air enters the through ventilation openings in the side panels, flows past the warm electronics, and is drawn out the rear by the fan. It is important that there be an adequate airflow for proper functioning. As long as both the intake ventilation openings and the fan exhaust opening are not obstructed, the power supply will remain quite cool.

A.2 Internal Pulser

The PI-MAX3 incorporates an internal gate pulse generator and high voltage power supply controlled by the internal timing generator

Gating Speed

- Fast Gate Intensifier
  - Gen II 18 mm: <5 ns FWHM;
  - Gen II 25 mm: <7 ns FWHM;
  - Filmless Gen III 18 mm: < 5 ns FWHM;
- Slow Gate Intensifier
  - 18 mm: ~50 ns FWHM;
    Contact the factory or Teledyne Princeton Instruments representative.
  - 25 mm: ~100 ns FWHM;
    Contact the factory or Teledyne Princeton Instruments representative.

Propagation Delay: ≤25 ns (35 ns with bracket).

Maximum Repetition Rate (MCP bracket pulsing): 6.25 kHz

MCP Bracket Pulsing: MCP requires 35 ns to gate On and ~1 μs to gate Off.

NOTE:

Bracket pulsing only applies to units having a Gen II Image Intensifier.

In the case of units having a Filmless Gen III Image Intensifier, bracket pulsing does not apply.

A.3 Intensifier Quantum Efficiency

Figure A-4 shows the Quantum Efficiency curve for selected Gen II Intensifiers.

Figure A-5 shows the Quantum Efficiency curve for selected Gen III Filmless Intensifiers.

Figure A-4: QE Curve: Gen II Intensifier

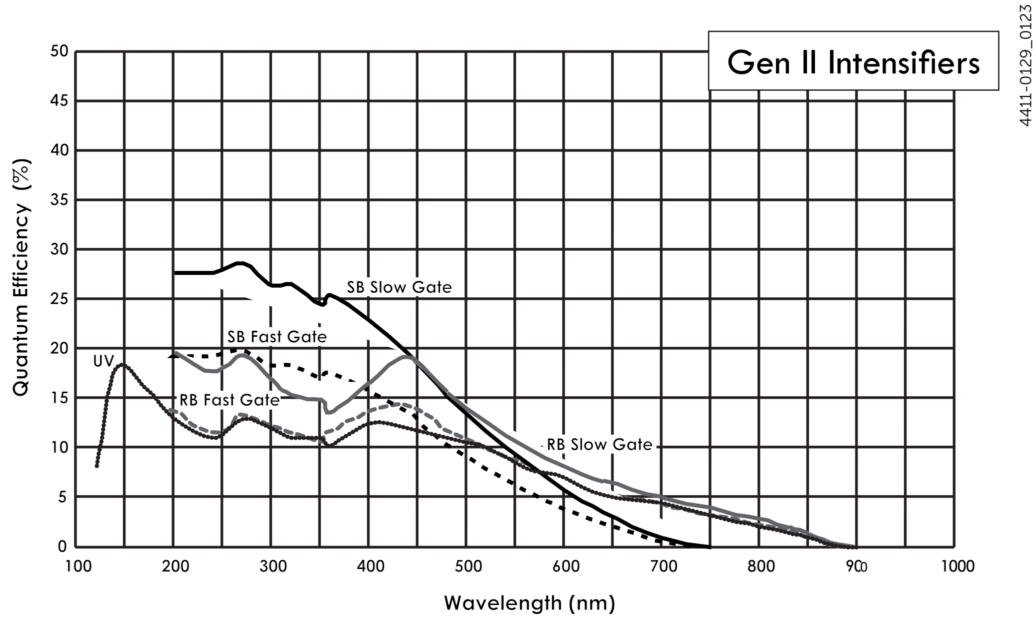
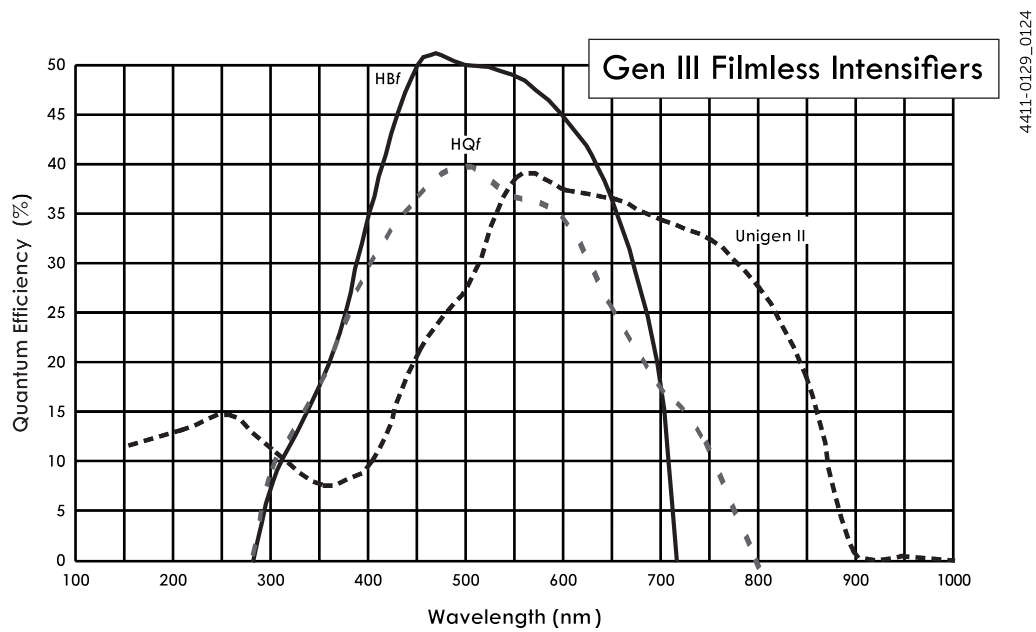


Figure A-5: QE Curve: Gen III Filmless Intensifier



A.4 CoolCUBE$_{II}$ Circulator

Closed loop system

Hoses

Two 3 m (10 foot) hoses may be supplied with the PI-MAX3 camera. These hoses are made up of a 3 meter (2 foot) piece of ¼" ID hose joined by a reducer to a 2.4 meter (8') piece of 3/8" ID 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 CoolCUBE$_{II}$ connectors.

NOTE:

Part numbers for the hose, reducer fitting, and CoolCUBE$_{II}$ fitting are McMaster MCM # 5624K11 (1/4 ID) and #5624K12 (3/8 ID); McMaster # MCM 91355K32 (3/8-1/4 Reducer); and CPC # NS6D17006 (3/8" Quick Disconnect), respectively.

Coolant

50:50 ethylene glycol and water at 23°C

Dimensions

Refer to Appendix B, Outline Drawings, on page 209.

Circulator Weight (Filled)

6.0 lbs (2.7 kg)

Hose Weight (Filled)

3.0 lbs (1.4 kg) per hose

A.5 Minimum Host Computer Requirements

NOTE:

Computers and operating systems experience frequent updates. Therefore, the following sections are intended to provide minimum system requirements for operating a PI-MAX3 camera.

A faster computer with 2 GB or larger memory (RAM) will greatly enhance the software performance during live mode operations.

Contact the factory to determine specific requirements.

The minimum system requirements are:

- Operating System:
  - WinView/32 and WinSpec/32:

    Windows® XP (32-bit with SP3 or later,) Windows Vista® (32-bit,) or Windows 7® (32-bit)
  - LightField:

    Windows Vista (64-bit) or Windows 7 (64-bit)
- 2 GHz Pentium® 4;
- 1 GB RAM;
- CD-ROM Drive;
- One unused PCI card slot (32-bit)

  PCI 2.3 compliant, 32-bit, 33/66 MHz bus
- Super VGA monitor and graphics card supporting at least 65535 colors with at least 128 MB of memory.

  Memory requirement is dependent on desired display resolution.
- Hard disk with a minimum of 1 GB available. A complete installation requires approximately 50 MB of space, with the remainder 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.

Appendix B: Outline Drawings

NOTE:
Dimensions are in inches and [mm] unless otherwise noted.

B.1 PI-MAX3

Figure B-1: Outline Drawing: PI-MAX3 with C-Mount Adapter

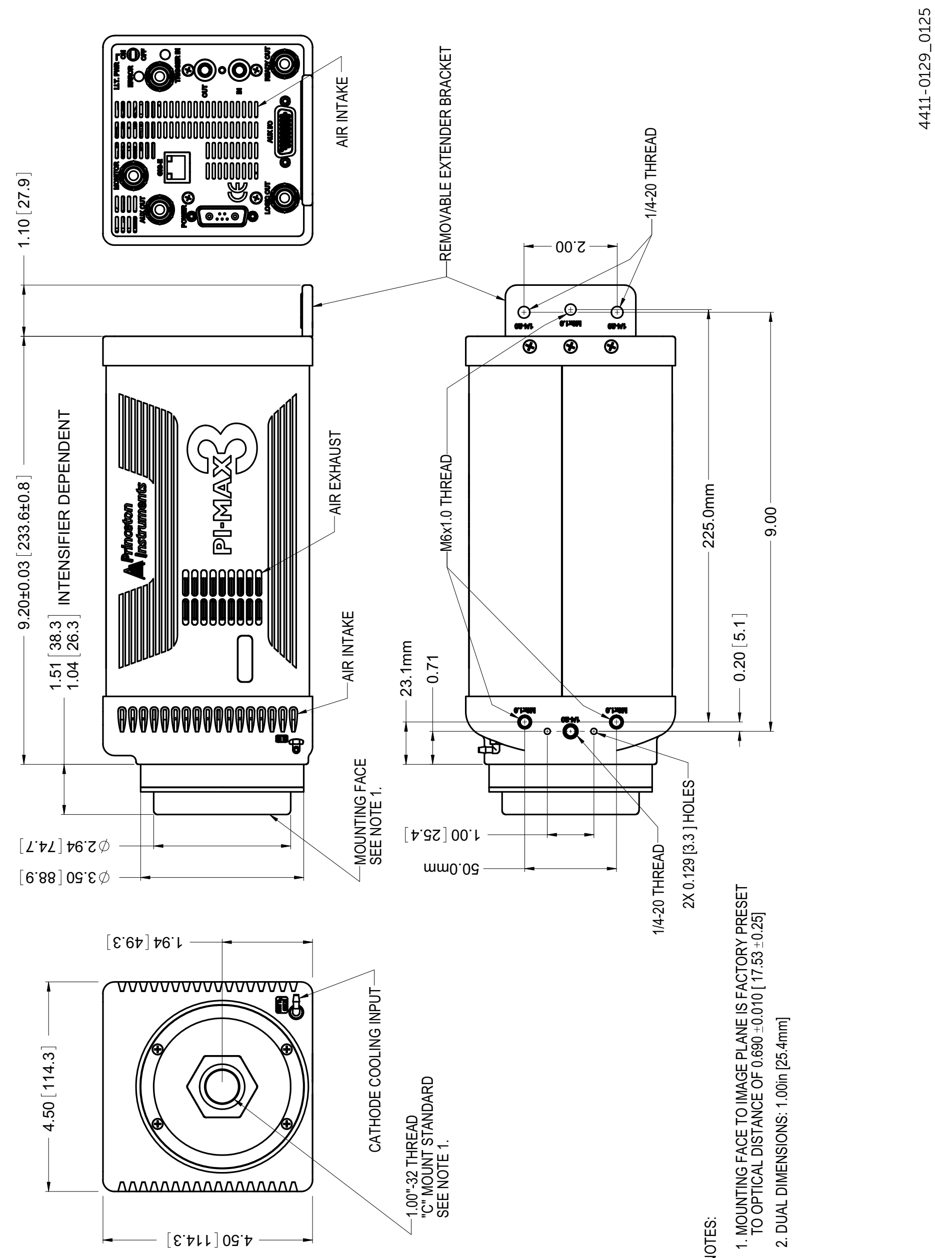


Figure B-2: Outline Drawing: PI-MAX3 with F-Mount Adapter

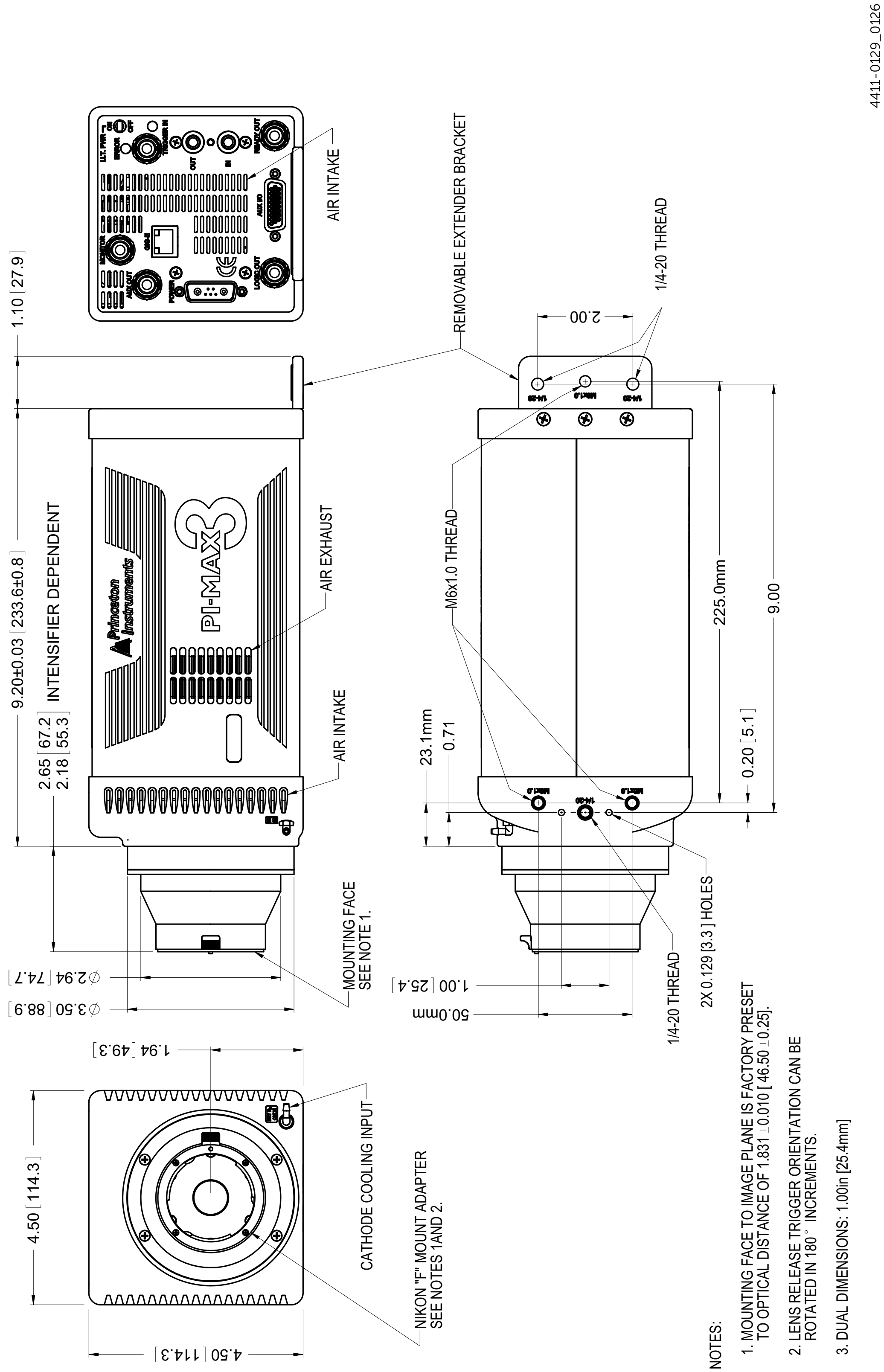
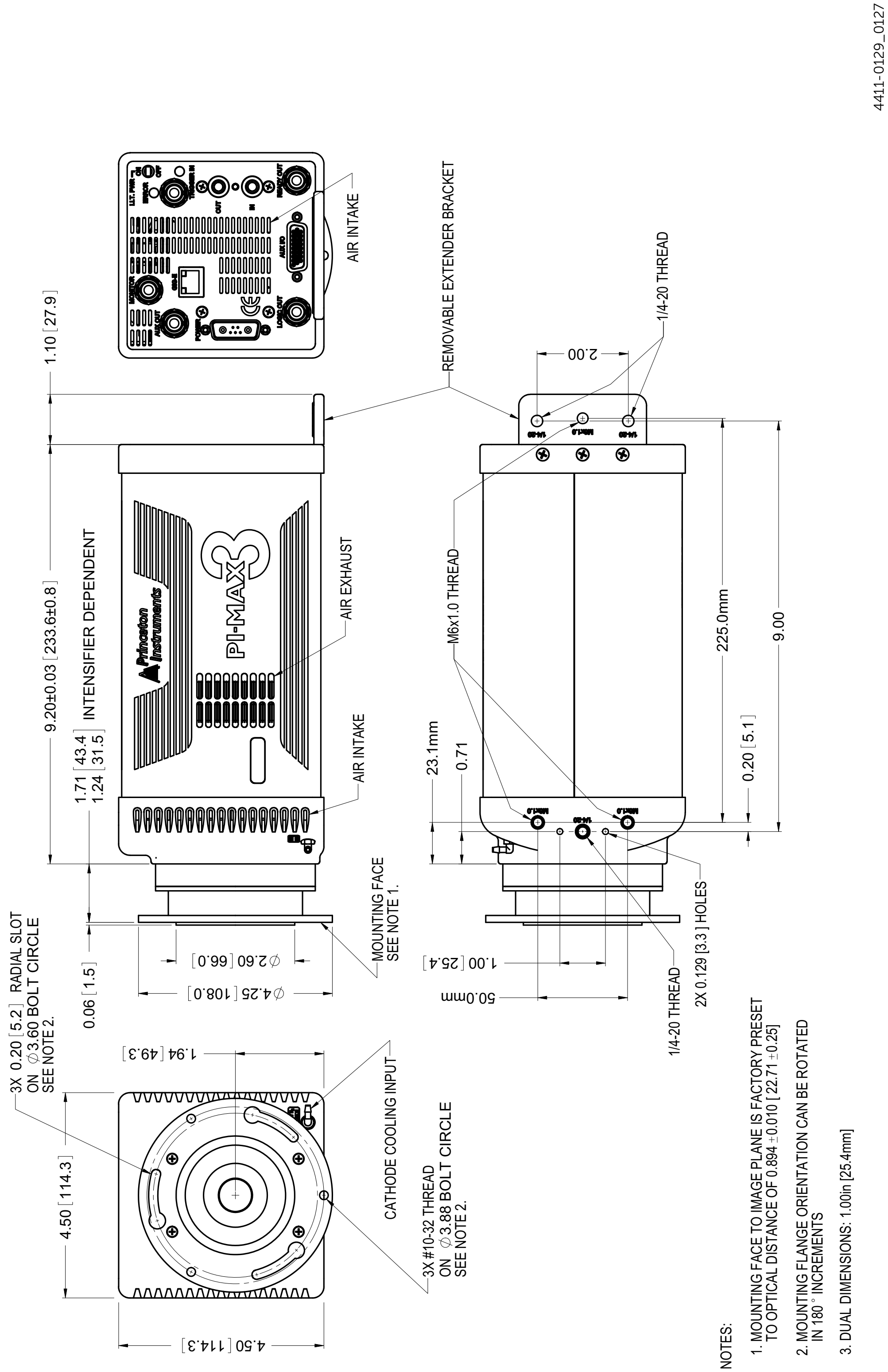
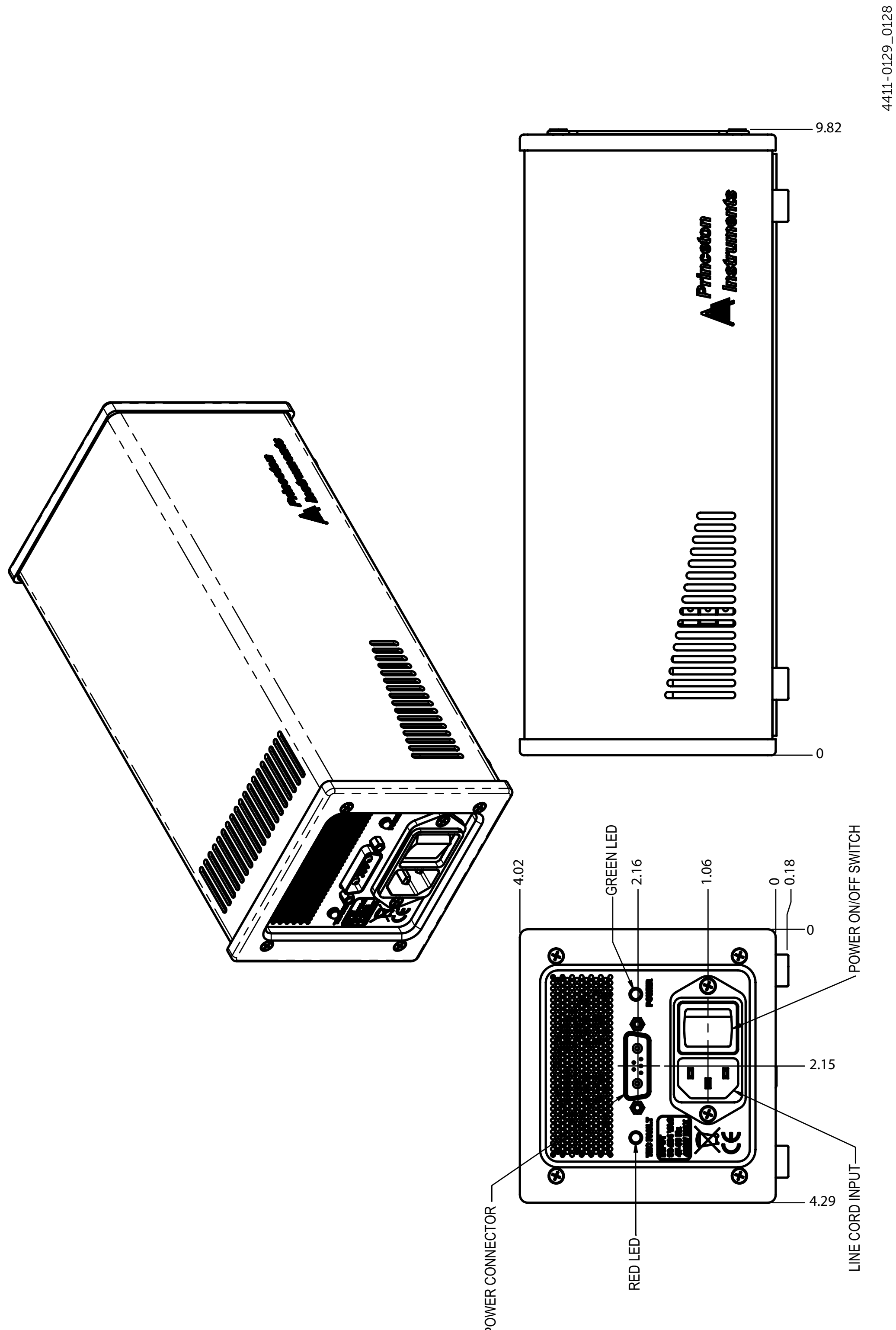


Figure B-3: Outline Drawing: PI-MAX3 with Spectroscopy-Mount Adapter



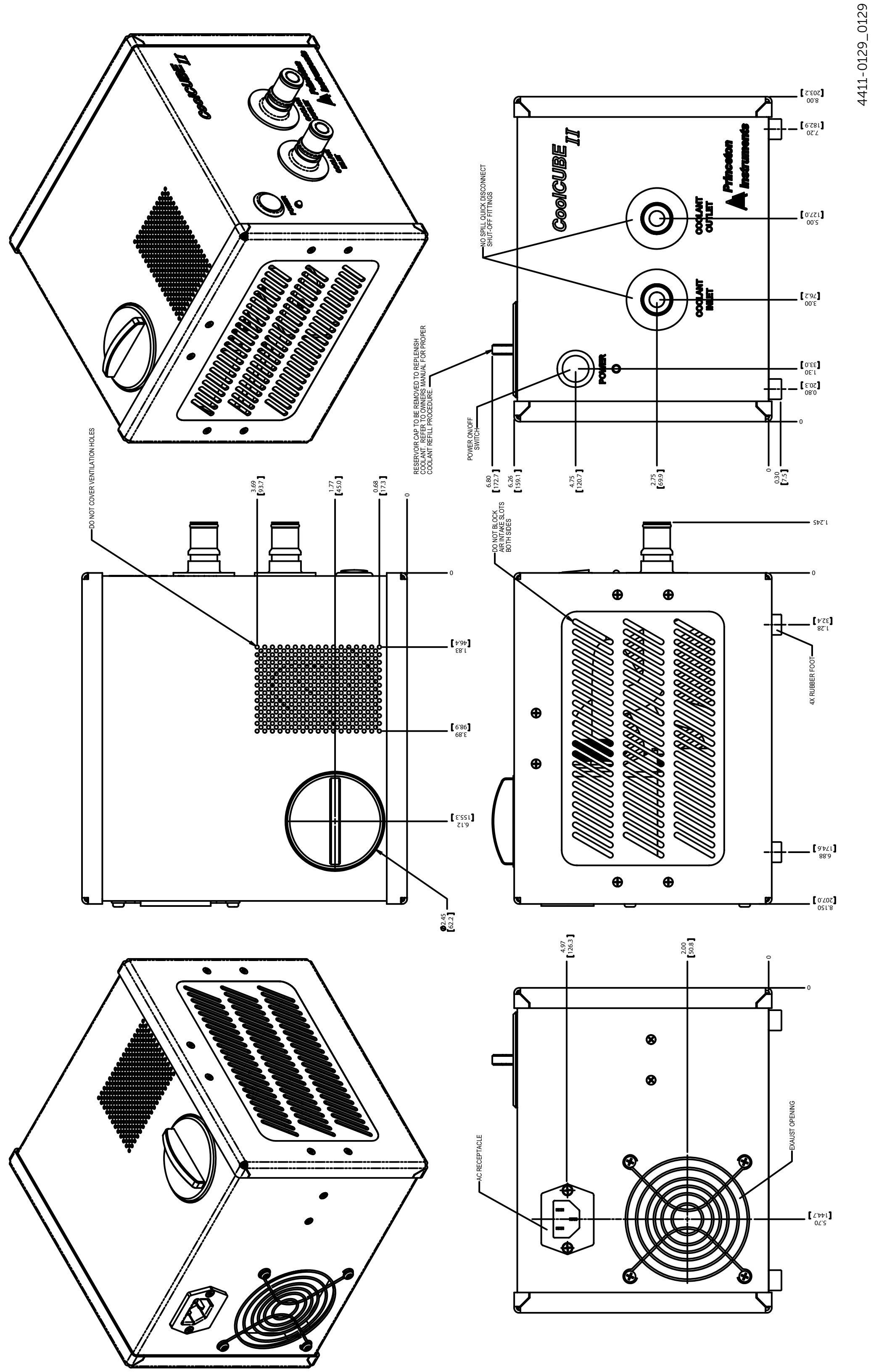
B.2 PI-MAX3 Power Supply

Figure B-4: Outline Drawing: PI-MAX3 Power Supply



B.3 CoolCUBE$_{II}$ Circulator

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



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Appendix C: WinSpec/32 and LightField Cross References

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

C.1 WinSpec/32-to-LightField Terminology

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

Table C-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 C-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

C.2 LightField to WinSpec/32

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

Table C-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

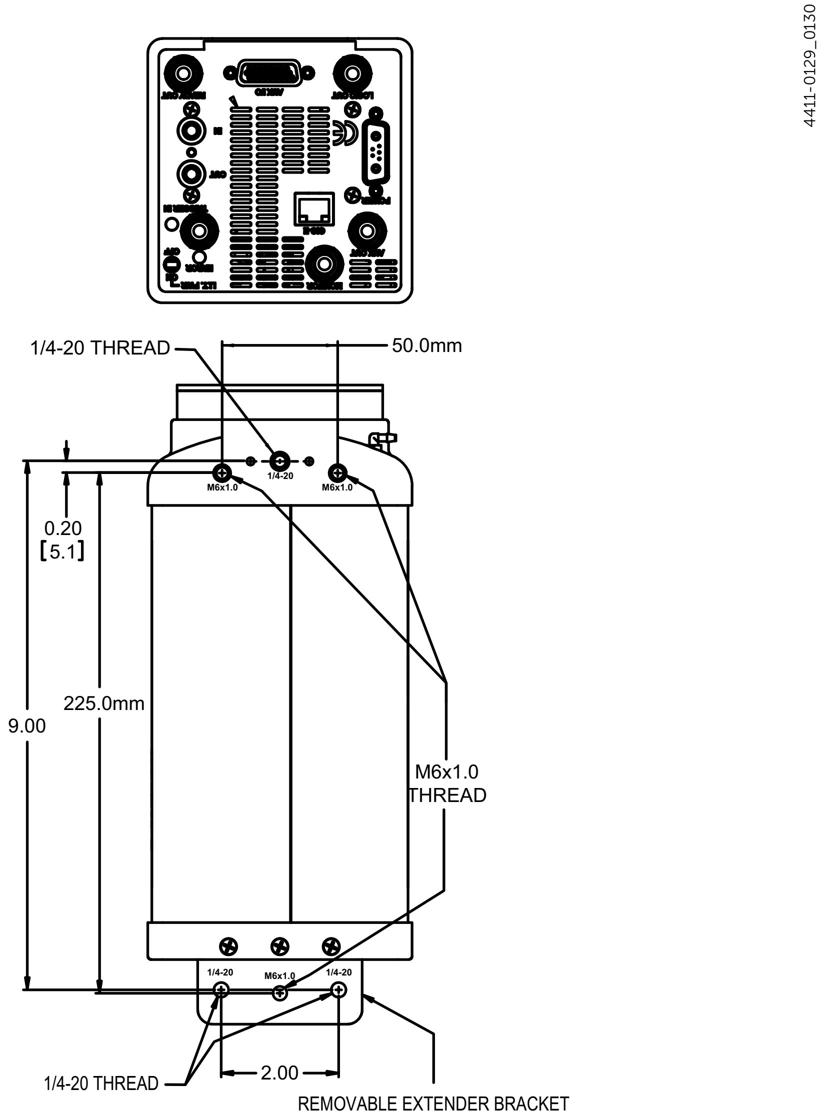
Table C-2: LightField-to-WinSpec/32 Cross Reference (Sheet 2 of 2)

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

Appendix D: Extender Bracket Kit

An Extender Bracket kit is shipped with each PI-MAX3.After securing the bracket at the rear of the PI-MAX3, you can mount the PI-MAX3 to any laboratory table with either 25 mm or 1 inch hole spacing. Figure D-1 illustrates a typical extender bracket mounted to the PI-MAX3.

Figure D-1: Extender Bracket Kit Mounted to PI-MAX3



Perform the following procedure to secure the plate to the camera:

1. Remove the extender bracket and three (3) 6-32x¼" flat head screws from the bag.
2. Turn the camera upside down.
3. With the rear of the camera facing you, place the tongue of the bracket into the cutout under the now topmost edge. The text on the bracket should be visible.

4. Secure the plate with the three screws.
5. Turn the camera right side up and secure it to the laboratory table.

   If using one or more mounting holes at the bottom front of the camera, tighten the fastener(s) there before tightening down the fastener(s) at the extender bracket.

> **NOTE:**
>
> The table mounting holes in the plate are elongated to allow for tolerance variations.

Appendix E: Mounting and Focusing C- and F-Mount Lenses

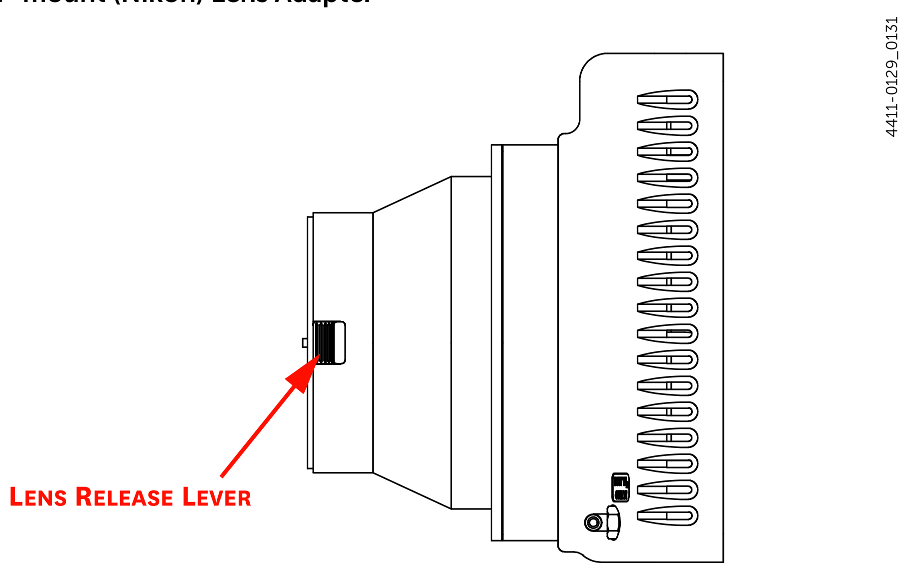
This appendix provides information about the mounting and focus of C- and F-mount lenses.

E.1 Lens Mounting

C-mount lenses simply screw clockwise into the threaded lens mount at the front of the camera. In mounting a C-mount lens, tighten it securely by hand (no tools).

To mount an F-mount lens on the camera, locate the large indicator dot on the side of the lens. See Figure E-1.

Figure E-1: F-mount (Nikon) Lens Adapter



There is a corresponding dot on the front side of the camera lens mount. Line up the dots and slide the lens into the mount. Then turn the lens counterclockwise until a click is heard. The click means that the lens is now locked in place.

Removing either type lens is equally simple. In the case of a C-mount lens, rotate the lens counterclockwise until it is free of the mount. In the case of an F-mount lens, press the locking lever on the mount while rotating the lens clockwise until it comes free and can be pulled straight out.

Both types of lenses typically have provisions for focusing and aperture adjustment, with the details varying according the make and model of the lens.

CAUTION!
Always begin with the lens stopped all the way down (largest f/ stop number) to minimize the risk of overloading the intensifier.

E.1.1 Mounting Orientation

The PI-MAX3 can be mounted at any attitude or angle. The camera can rest on any secure surface. Take care not to block the ventilation openings.

> **CAUTION!**
> In the case of cameras equipped with F-mount, do not mount the camera in the nose-up operation where the lens mount would be required to hold the camera's weight. The F-mount is not designed to sustain the weight of the camera in this orientation and the camera could pull free. You must provide additional support for the camera.

Should the camera be mounted in the nose-up position beneath a table, take care to protect the mounting components from lateral stresses, such as might occur should someone accidentally bump the camera with a knee while working at the table. One solution to this problem would be to install a barrier between the camera and operator to prevent any accidental contact.

There are no special constraints on nose-down operation. Again, however, good operating practice might make it advisable to take steps to prevent accidental contact from unduly stressing the mounting components.

> **CAUTION!**
> Always begin with the lens stopped all the way down (largest f/ stop number) to minimize the risk of overloading the intensifier.

E.2 Len Focusing

There is no difference between focusing considerations for an F-mount lens and a C-mount lens. Simply rotate the lens-focusing ring for the sharpest observed image. The lens will show maximum focus sensitivity at full aperture (lowest f-stop setting). Once the point of optimum focus is obtained, you may wish to adjust the lens aperture to f/8 or f/11, that is, somewhere near mid-range aperture, where the lens will probably be sharper than it is with the lens aperture completely open. Some readjustment of the Exposure Time may be required to achieve the most pleasing image.

Appendix F: C-, F-, and Spectroscopy-Mount Adapters

F.1 Accessory Kits

This section provides information about available accessory kits for the PI-MAX3.

F.1.1 PI-MAX3 18 mm Tube

Among the items in the accessory kit shipped with an 18 mm PI-MAX3 are:

- Three adapter kits:
  - C-mount;
  - F-mount;
  - Spectroscopy-mount.

  One of these adapters will have been factory-installed on the camera.
- A reversible screwdriver with magnetic top;
  See Figure F-1.

Figure F-1: Screwdriver with Reversible Flat and Phillips Tips

- A PI-MAX3 (with spectroscopy-mount adapter) to Teledyne Acton Research spectrograph quick start sheet.

F.1.2 PI-MAX3 25 mm Tube

Among the items in the accessory kit shipped with a 25 mm PI-MAX3 are:

- Two adapter kits:
  - F-mount;
  - Spectroscopy-mount.

  One of these adapters will have been factory-installed on the camera.
- A reversible screwdriver with magnetic top;
  See Figure F-1.
- A PI-MAX3 (with spectroscopy-mount adapter) to Teledyne Acton Research spectrograph quick start sheet.

F.2 Adapter Kits

Table F-1 provides information about individual adapter kits that may be shipped in the accessory kit.

Table F-1: Adapter Kit Information

Kit	Part Number	Contents
C-Mount Adapter	7389-0031	Adapter, 4-40x 7/16 flat head Phillips screws, dust cover
F-Mount Adapter	7389-0033	Adapter, 4-40x 7/16 flat head Phillips screws, dust cover
Spectroscopy-Mount Adapter	7389-0032	Adapter, 4-40x7/16 flat head Phillips screws, dust cover
NVUV Spectroscopy-Mount Adapter	7389-0039	Adapter, 4-40x7/16 flat head Phillips screws, o-ring (2.739" I.D.), o-ring (2.614" I.D.), dust cover

F.3 PI-MAX3 to Teledyne Acton Research Spectrograph Quick Start Guides

Because each PI-MAX3 system is shipped with a spectroscopy-mount adapter kit, a quick start guide for mounting a PI-MAX3 with spectroscopy-mount adapter to a Teledyne Acton Research spectrograph is included. Typically, the guide assumes that there is a spectroscopy-mount adapter mounted to the face of the PI-MAX3 camera.

F.4 Standard C-, F-, and Spectroscopy-Mount Adapters

Perform the following procedure to change from one adapter to another:

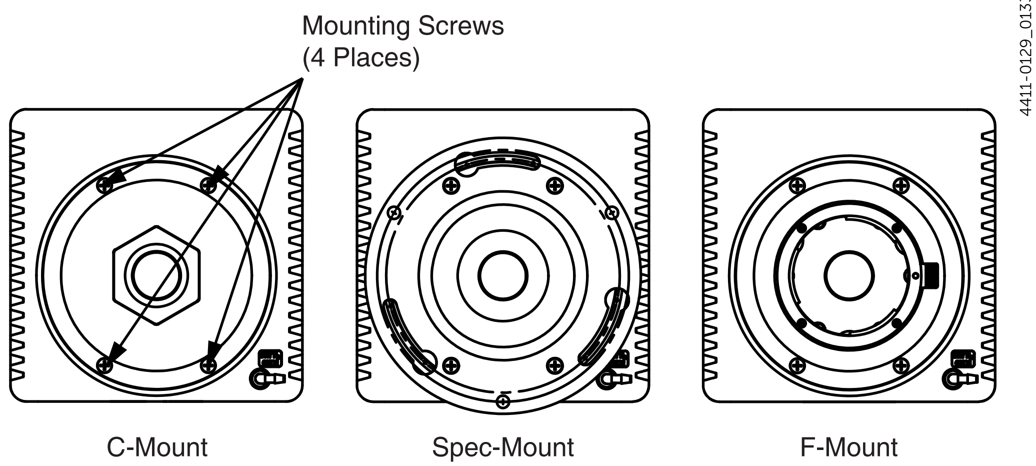
1. Using the supplied screwdriver, remove the four (4) Phillips head screws that secure the adapter to the front of the PI-MAX3.

   NOTE:

   If the Phillips end of the screwdriver is not available, pull the driver shaft out of the handle, flip the shaft, and insert the flat end into the handle.

   See Figure F-2.

Figure F-2: PI-MAX3 Mount Adapters

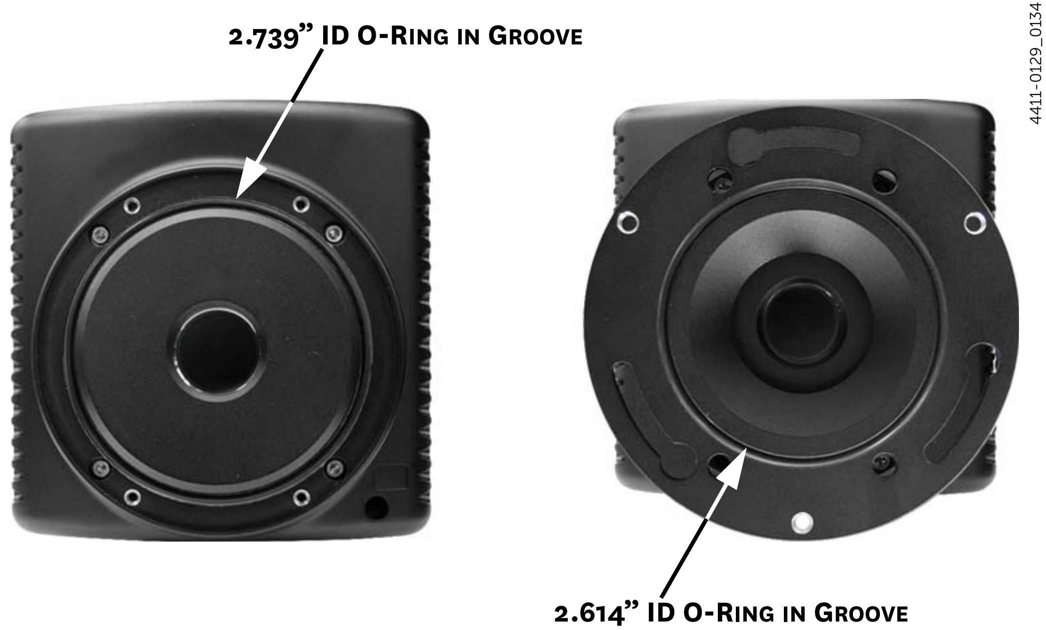


2. Remove the existing adapter and store it in a safe place.
3. Using the same screws, mount the new adapter to the front of the PI-MAX3.

F.5 Spectroscopy-Mount for NVUV Cameras

In addition to the spectroscopy adapter, NVUV cameras require two o-rings, each with a different inner diameters (I.D). Typically, the camera would be shipped with the adapter mounted to the face of the camera and the 2.739" ID o-ring (lightly coated with vacuum grease) would already be in the groove between the face of the camera and the spectrograph adapter. The 2.614" ID o-ring (lightly coated with vacuum grease) is installed in the groove on the face of the spectrograph adapter. Figure F-3 illustrates where the two different o-rings are installed.

Figure F-3: O-ring Positions for PI-MAX3 NVUV Cameras



Perform the following procedure to mount an NVUV spectroscopy-mount adapter:

1. Using the supplied screwdriver, remove the four (4) Phillips head screws that secure the current adapter to the front of the PI-MAX3.

   NOTE:

   If the Phillips end of the screwdriver is not available, pull the driver shaft out of the handle, flip the shaft, and insert the flat end into the handle.

2. Remove the existing adapter and store it in a safe place.
3. After lightly applying vacuum grease to the o-rings, position the larger diameter ring in the groove on the face of the camera.
4. Using the same screws, mount the spectroscopy-mount adapter to the front of the PI-MAX3.
5. Position the small diameter ring in the groove on the face of the adapter.

A spare set of o-rings may be supplied. If you need to use one of these spares, be sure to lightly coat it with vacuum grease before putting it in place. Lightly coating the o-rings with vacuum grease helps to insure air-tight seals between the camera and adapter and between the adapter and the spectrograph’s sliding tube.

F.6 Optical Distance from Mounting Face to Image Plane

Each adapter has a preset optical distance from the mounting face to the image plane. The distance varies from one adapter type to another and is explained on the PI-MAX3 outline drawings. For quick reference, the distances are given below.

- C-Mount

  Mounting face to image plane is factory preset to an optical distance of 0.690” ±0.010” [17.53 mm ±0.25 mm].
- Spectroscopy

  Mounting face to image plane is factory preset to an optical distance of 0.894” 0.010” [22.71 mm ±0.25 mm].
- F-Mount

  Mounting face to image plane is factory preset to an optical distance of 1.831” ±0.010” [46.50 mm ±0.25 mm].

Appendix G: Spectrograph Adapters

A PI-MAX3 with the spectroscopy-mount adapter can be readily mounted to a Teledyne Acton Research Series spectrograph or to an IsoPlane SCT-320 spectrograph. Mounting the camera to a Teledyne Acton Research Series spectrograph requires a male sliding tube that slides into the spectrograph for setting the focus. Mounting a PI-MAX3 to an IsoPlane is a matter of bolting it directly to the mounting plant on the IsoPlane.

NOTES:

1. When mounted to a spectrograph, the text on the back of the PI-MAX3 should be right side up.
2. A C-mount adapter plate and nut are available for mounting a camera with a C-mount adapter to a Teledyne Acton Research Series spectrograph. Refer to Section G.3, PI-MAX3 to Teledyne Acton Research (C-Mount Adapter), on page 233 for mounting instructions.

G.1 Spectrograph-Detector Focus

The detector mounting hardware provides two degrees of freedom: focus and rotation. In this context, focus means to physically move the detector back and forth through the focal plane of the spectrograph. The approach taken is to slowly move the detector in and out of focus and adjusting for optimum while watching a live display on the monitor, followed by rotating the detector and again adjusting for optimum. The following procedure, which describes the focusing operation with a Teledyne Acton Research SP-2300i spectrograph, can be easily adapted to other spectrographs. For IsoPlane SCT-320 related focusing information, refer to Section G.1.2, IsoPlane SCT-320 Spectrograph, on page 229.

NOTES:

1. Use a USB-powered or a DC-powered light source. The 60 Hz of an AC-powered light source may make it more difficult to achieve focus.
2. If you must use an AC light source, set the SuperSYNCHRO Internal frequency to around 10 Hz.

G.1.1 Teledyne Acton Research Series Spectrograph

Perform the following procedure to focus a PI-MAX3 when mounted on a Teledyne Acton Research series spectrograph:

1. Mount a light source such as a mercury pen-ray type in front of the entrance slit of the spectrograph. Any light source with line output can be used. Standard fluorescent overhead lamps have good calibration lines as well. If there are no line sources available, it is possible to use a broad band source such as tungsten for the alignment. If this case, use a wavelength setting of 0.0 nm for alignment purposes.

2. With the spectrograph properly connected to the computer, turn the power on, wait for the spectrograph to initialize.
3. With the PI-MAX3 mounted to the spectrograph and connected to the computer, turn on the power and wait for the detector to initialize.
4. Boot the application software. If you are using WinSpec/32 you will need to define the spectrograph. If you are using LightField, you will need to drag the icons for the PI-MAX3 and the spectrograph into the Experiment Devices area.
5. Set the spectrograph to 435.8 nm if using a mercury source or to 0.0 nm if using a broadband source.

NOTE:

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

6. Set the slit to 25 μm. If necessary, readjust the SuperSYNCHRO frequency to maintain optimum (near full-scale) signal intensity.
7. Begin running in Focus or Preview mode.
8. Slowly move the detector in and out of focus. You should see the spectral line go from broad to narrow and back to broad. Leave the detector set for the narrowest achievable line.

   The method of focusing depends on the spectrograph, as follows.

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

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

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

     If there is no focusing adjustment, either provided by the spectrograph or by the mounting hardware, then the only recourse will be to adjust the spectrograph's focusing mirror or to shim the detector.
9. Next adjust the rotation.

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

NOTE:

In LightField, you can use the Align Spectrometer function.

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

NOTE:

When aligning accessories (e.g., fibers, lenses, optical fiber adapters,) first align the spectrograph to the slit. Then align the accessory without disturbing the detector position. The procedure is identical to that used to focus the spectrograph (i.e., focus/align while watching a live image.)

G.1.2 IsoPlane SCT-320 Spectrograph

Because the PI-MAX3 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 you are familiar 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.

NOTES:

1. When adjusting focus for IsoPlane for the first time with a PI-MAX3, it is likely that the IsoPlane focus mirror will need to be adjusted. If the IsoPlane was previously used with a PIXIS or other Teledyne Princeton Instruments camera with a back focus distance of approximately 0.6 inches, the focus setting will need to be changed to a much lower micrometer reading when focusing using a PI-MAX3 since the PI-MAX3 has a back focus distance of approximately 0.9 inches.
2. If the PI-MAX3 has a 25 mm intensifier, some vignetting of the sides of the focal plane is normal. Vignetting is much less likely to occur if the PI-MAX3 has an 18 mm diameter intensifier.
3. If the IsoPlane was ordered with a shutter at the entrance slit and a PI-MAX3 is to be used with this IsoPlane, the shutter must either be removed from the IsoPlane or controlled by a Teledyne Acton Research SHC-EXT external shutter control box if one is available. Refer to the IsoPlane manual for shutter removal instructions.

Perform the following procedure to focus a PI-MAX3 when mounted on an IsoPlane SCT-320 spectrograph:

1. Mount a Teledyne Acton Research light source such as the dual HG/NeAr source in front of the entrance slit of the spectrograph.
2. With the spectrograph properly connected to the computer, turn the power on, wait for the spectrograph to initialize.
3. With the PI-MAX3 mounted to the spectrograph and connected to the computer, turn on the power and wait for the detector to initialize.
4. Boot the application software. If you are using WinSpec/32 you will need to define the spectrograph. If you are using LightField, you will need to drag the icons for the PI-MAX3 and the spectrograph into the Experiment Devices area.
5. Set the spectrograph to 435.8 nm if using a mercury source or to 0.0 nm if using a broadband source.
6. Remove the cover from the Micrometer Compartment.
7. Using a 3/32" hex wrench, loosen the locking set screw.
8. While continuously acquiring data, adjust the micrometer until you maximize the intensity level of a selected peak or peaks.
9. Tighten down the locking set screw.
10. Place the Micrometer Cover on the spectrograph. Replace and tighten all of the cover screws.

11. Next adjust the rotation. First, use a 9/64” hex wrench to loosen the four screws at the corners of the detector mounting plate. While watching a live display of the line, rotate the detector (up to 4 degrees of rotation are possible). The line will go from broad to narrow and back to broad. Leave the detector rotation set for the narrowest achievable line.

   NOTE:
   With LightField, you can use the Align Spectrometer function.

12. Alternatively, take an image, display the horizontal and vertical cursor bars, and compare the vertical bar to the line shape on the screen. Rotate the detector until the line shape on the screen is parallel with the vertical bar.
13. After completing the rotational alignment, tighten the four screws.

G.2 PI-MAX3 (3.60" 3-Hole Slotted Flange) to Teledyne Acton Research Series Spectrograph

This section provides the installation procedure used to mount a PI-MAX3 to a Teledyne Acton Research series spectrograph.

G.2.1 Required Tools

Figure G-1 shows the tools required for this procedure.

Figure G-1: Required Tools

4411-0129_0135

G.2.2 Procedure

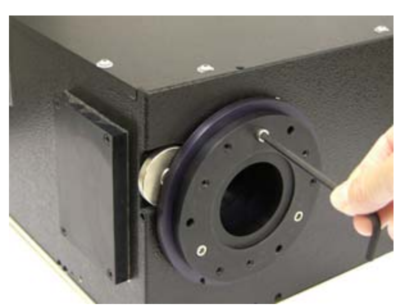
Perform the following procedure to mount a PI-MAX3 to a Teledyne Acton Research series spectrograph:

> ⚠ **CAUTION!**
> Adapter parts are machined to provide a tight fit. It may be necessary to rotate the detector back and forth when inserting the sliding tube into the spectrograph. Forcing the tube into the spectrometer could permanently damage the tube and the spectrometer opening.

1. Remove shipping plate and store.

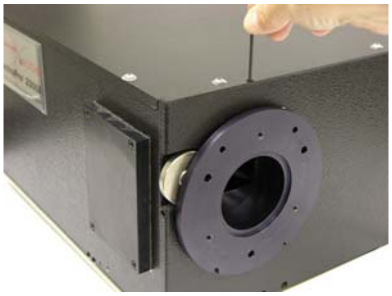
4411-0129_0136

2. Remove spacer and store.



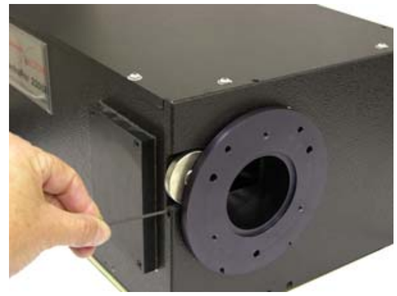
4411-0129_0137

3. Loosen setscrew with 3/32" hex wrench.



4411-0129_0138

4. Loosen setscrew.

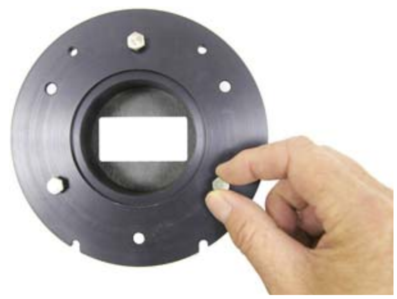


4411-0129_0139

5. Gently rotate and pull.

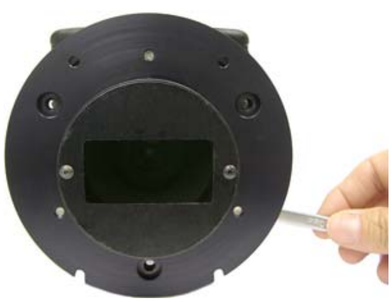
4411-0129_0140

6. Finger tighten hex head screws. Leave about ¼" thread exposed.



4411-0129_0141

7. Mount tube to camera, align baffle with bottom/top of camera, and tighten mounting screws.



4411-0129_0142

8. Gently rotate while inserting.

4411-0129_0143

9. Tighten setscrew.

4411-0129_0144

10. Tighten setscrew.

4411-0129_0145

G.3 PI-MAX3 to Teledyne Acton Research (C-Mount Adapter)

Figure G-2 illustrates how to mount a PI-MAX3 to a Teledyne Acton Research spectrograph with a C-Mount Adapter.

Figure G-2: PI-MAX3 to Teledyne Acton Research with C-Mount Adapter

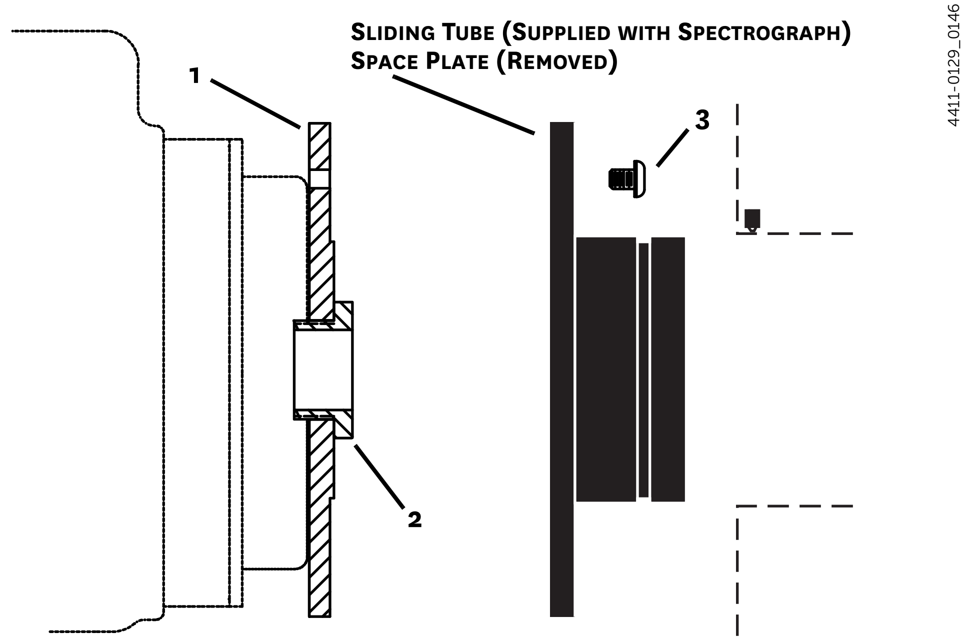


Table G-1 lists the required hardware to mount a PI-MAX3 to a Teledyne Acton Research spectrograph with a C-Mount Adapter.

Table G-1: Required Hardware: PI-MAX3 to Teledyne Acton Research with C-Mount Adapter

Item	Qty	P/N	Description
1	1	8401-071-01	Adapter Plate
2	1	8401-071-02	Threaded C-Mount Adapter
3	3	2826-0127	Screw, 10-32 × ¼, Button Head Allen Hex, Stainless Steel

NOTE:

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

Perform the following procedure to mount a PI-MAX3 to a Teledyne Acton Research spectrograph with a C-Mount Adapter:

1. Verify the shipping cover has been removed from the detector port on the spectrograph.
2. Loosen the set screws holding the sliding tube in the spectrograph and remove the tube.

   If there is a spacer plate installed on the sliding tube, remove it.
3. Place the flat side of the adapter plate against the face of the detector.
4. Insert the threaded C-mount adapter through the center hole in the plate and screw the adapter into the detector's C-mount.
5. Using three (3) ¼" long button head screws, secure the sliding tube to the adapter plate.
6. Gently insert the sliding tube into the spectrograph and secure it with the setscrews.

G.4 PI-MAX3 to IsoPlane SCT-320

Figure G-3 illustrates how to mount a PI-MAX3 to an IsoPlane SCT-320.

Figure G-3: PI-MAX3 to IsoPlane SCT-320

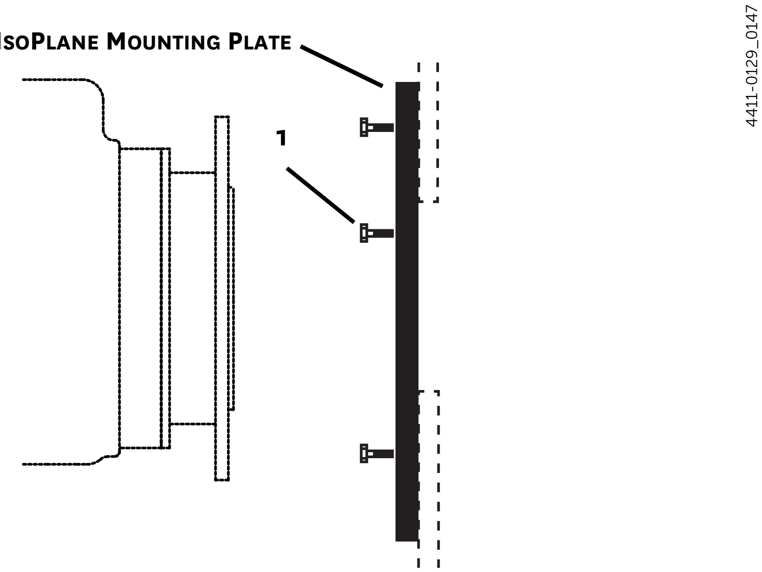


Table G-1 lists the required hardware to mount a PI-MAX3 to an IsoPlane SCT-320.

Table G-2: Required Hardware: PI-MAX3 to IsoPlane SCT-320.

Item	Qty	P/N	Description
1	3	2826-0120	Screw, 10-32 x ½, Hex Head, Stainless Steel

Perform the following procedure to mount a PI-MAX3 to an IsoPlane SCT-320:

1. Verify the shipping cover has been removed from the detector mounting plate on the IsoPlane.
2. Leaving ¼" of thread exposed, screw the three (3) hex head screws into the mounting plate.
3. Mount the detector to the mounting plate. The text should be right-side-up/ readable on the back of the detector.
4. Tighten the three screws using a 5/16" open end wrench.

NOTES:

1. Rotational alignment of the detector with the spectrograph optics is done 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, an external shutter control box will be required to control the shutter or the shutter will need to be removed. Refer to the IsoPlane SCT-320 manual for shutter removal instructions.

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Appendix H: Glossary

Binning: A process that may occur in the readout register and the output node (on-chip or hardware binning) or is performed as a post-process (software binning). Binning combines charge from rectangular groups of adjacent pixels into super pixels. When done on-chip, this process reduces readout time and the burden on computer memory; the drawbacks are lowered resolution and the possibility of saturation and blooming. Software binning avoids the problem of saturation and blooming.

Blooming: The spillover of excess charge into adjacent pixels.

Bracket Pulsing: Refer to MCP Bracket Pulsing.

Burst Mode: PTG term. Used when a short burst of very rapid gate pulses is needed to synchronize data acquisition with a high frequency signal of interest. Occurring during the CCD array exposure time, a burst has a maximum repetition rate of 500 kHz, generating a high voltage pulse every 2 μs. The burst can be driven from an external trigger or from the internal oscillator.

CCD Array Dimensions and Pixel Size: Arrays that are square or nearly square are typically used for imaging applications, while rectangular arrays are typically used in spectroscopy applications. The smaller the pixel size, the better the resolution, but the pixel full-well capacity smaller. Conversely, the larger the pixel size, the poorer the resolution, and the greater the pixel full-well capacity.

CCD Spectral Sensitivity: Coatings applied to the CCD input window can enhance sensitivity in the UV regions. Deep-depletion enhances sensitivity in the NIR.

CCD Array Dynamic Range: The dynamic range of a CCD is the maximum achievable signal divided by the camera noise, where the signal strength is determined by the full-well capacity and noise is the sum of dark and read noises. The greater the dynamic range, the better the CCD is able to detect differences between the dimmest and brightest intensities in an image. The readout speed affects the dynamic range of a pixel: the faster the speed, the higher the noise, and the smaller the dynamic range.

Dark Charge or Dark Current: The thermally induced buildup of charge in the CCD over time. Dark charge values vary widely from one CCD array to another and are exponentially temperature dependent. In the case of cameras that have MPP type arrays, the average dark charge is extremely small. However, the dark-charge distribution is such that a significant number of pixels may exhibit a much higher dark charge, limiting the maximum practical exposure. To minimize the collection of dark charge, operate the camera at the lowest CCD temperature possible.

Since each CCD has its own dark charge pattern, unique to that particular device, acquiring and saving a dark charge "background image" under conditions identical to those used to acquire the "actual" image and then subtracting that image from the actual image will significantly reduce dark-charge effects.

EBI: Equivalent Background Illumination. EBI comes from thermally-generated electrons that cannot be distinguished from those generated by light photons. EBI can be reduced by cooling the intensifier (or environment) and is usually negligible in gated applications.

Exposure Time: The period during which the camera allows incoming signal to integrate on the CCD array. For signal to be detected and integrated on the CCD array, it must both fall in a valid gate width and in a valid exposure time. In Gate Mode, the exposure time is determined by an internal pulse ensemble defined by the internal timing generator gating setup.

External Sync: Readout synchronization mode where the CCD array is synchronized to an external source (i.e., the array is scanned upon arrival of an external trigger pulse.)

External Trigger Mode: Trigger mode where gate pulses are delayed from external input trigger pulses. Also a detector readout synchronization mode where the detector is scanned continuously but data storage does not begin until the arrival of an external trigger pulse.

Frame: The area of the CCD array that is readout after an exposure time ends.

For a 1024 x 1024 array, a full frame would consist of the entire 1024 x 1024 pixel area. In the WinX/32 software, the number of frames to be acquired during a data acquisition is determined by the Number of Images (or Number of Spectra) parameter on the Experiment Setup ► Main tab. If the parameter value is greater than 1, multiple frames of data will be acquired and stored in a single data file.

Frame Rate (fps): The number of frames that can be readout per second. The effective frame rate can be increased by defining a Region of Interest (ROI) that is smaller than the full-frame size. This means that a selected portion of the image can be displayed and the remainder of the accumulated charge discarded. The frame rate generally increases with reduction in the size of the detected area. For example, a CCD with a sensor size of 1000 x 1000 and an output rate of ten frames/second can produce 100 frames/second if the read-out region is reduced to 100 x 100 pixels.

Full-Well Capacity: The number of electrons that can be stored in a pixel. The smaller the pixel, the fewer electrons can be stored; therefore, either the exposure times need to be shorter or the signal intensity must be lower. Note that binning relies on the full-well capacity of the pixels in the serial shift register and of the output node. Typically, a serial shift register pixel has a full-well capacity that is 2 times greater than that of an image pixel and the output node has a full-well capacity that is about 1.5-2 times greater than that of a serial register pixel.

Filmless Gen III Intensifier: Filmless Gen III intensifier devices use GaAsP photocathodes which have no ion barrier film (MCP).

Gen III filmless intensifiers offer ultra-fast gating as well as >50% QE for the best combination of sensitivity in the visible region (<780 nm) and gate speed.

FWHM: Full Width Half-Maximum. Time period from the mid-point of the leading edge to the mid-point of the trailing edge of the gate pulse. Used to describe pulse width.

Gate Delay: The time between the beginning of the trigger pulse (either internal or external) and the beginning of the photocathode gate pulse.

Gate Mode: PI-MAX3 intensifier mode in which the photocathode is biased on only for the time that each gate pulse is applied. In this way, the array can be exposed to multiple images during a single exposure time. As a result, the tolerance to room light is higher in gated operation, but the risk of damaging overload from intense light sources such as lasers remains. In fact, intense light sources in gated experiments can cause spot damage that would be undetected by the alarm circuit.

Gate Width: The time during which light will be detected by the intensifier, intensified, and applied to the CCD. Basically, the intensifier controls what the chip sees during the exposure time. For signal to be detected, it must both fall in a valid gate width and in a valid exposure time.

Gen I Intensifier: Obsolete. Developed in the early 1960's. Used electrostatic focusing and electron acceleration to achieve signal gains up to 150. These intensifiers could detect images under ambient light intensity as low as 0.01 lux. Problems included image distortion, short-lived components, and large size.

Gen II Intensifier: Introduced in the late 1960's and early 1970's. Incorporated MCPs with resulting signal gain improvement (up to 20,000.) Not as efficient as a Gen I Intensifier. However has high resolution, no image distortion, and is small. Can detect images under ambient light intensity as low as 0.001 lux.

Gen III Intensifier: Gen II Intensifier technology with GaAs added as the photocathode coating. Highly sensitive in the NIR region above 800 nm but relatively insensitive in the blue/green region.

Utilizes high-resolution MCPs (6 μm diameter channels) and ion-barrier films. 2-3 orders of magnitude more sensitive to light than Gen II Intensifier devices. Can detect images under ambient light intensify as low as 0.0001 lux.

Gen IV Intensifier: Introduced in 1999. No ion barrier film and exhibit enhanced QE, SNR, dynamic range, and high-light-level resolution.

Input Windows: The intensifier and the CCD array both have input windows.

- MgF2:
  High vacuum UV transmission between 100 nm and 200 nm.
- Quartz:
  Excellent transmission over 190 nm - 1100 nm.
- Clear glass (BK7):
  - Visible
    400 nm -700 nm
  - NIR
    700 nm - 2500 nm)

Anti-Reflection (A/R) coatings may be added to input windows to reduce signal loss and glare caused by reflection.

Intensifier-CCD Coupling: Transmission of the emitted photons is either through a fiberoptic bundle or with a lens. The drawback to lens coupling is lower throughput (5% – 10%) and increased stray light in the camera system. The advantages are that the intensifier can be removed and the camera can be used as a standard CCD imager conversely an intensifier can be added to an existing camera.

Fiberoptic coupling results in a throughput of >60%, are capable of sensitivities approaching single-photoelectron detection, and have a much better signal-to-noise ratio (SNR) than lens-coupled devices. Disadvantages are that the fiberoptic bundle is permanently attached to the CCD array and that the camera must be operated in a dry, non-vacuum inert environment.

Intensifier Gating Speed: Temporal resolution in a PI-MAX3 is made possible by switching the intensifier on and off (gating) very rapidly. Typical fast-gate intensifiers have minimum gate widths (FWHM) of approximately 2 ns. For slow-gated devices the FWHM is about 50 ns. Refer to FWHM.

Fast-gating is achieved by adding a nickel (Ni) underlayer to photocathode. However, this layer may produce an effective QE reduction of as much as 40%. Slow-gate intensifiers have neither the Ni layer nor its effects on QE.

Intensifier On/Off Ratio: The ratio of light output when the intensifier is gated on and off: The higher the ratio, the better the gating. A high on/off ratio is necessary to eliminate the background and to faithfully reproduce transient events. In the visible region on/off ratios exceeding 10^6:1 is typically achieved. In the UV region, the on/off ratio is typically much poorer (10^4:1) though with MCP Bracket Pulsing ratios in the UV region can be improved dramatically (10^7:1). Refer to Section 8.3, MCP Bracket Pulsing, on page 100.

Intensifier Size: 18 mm diameter and 25 mm diameter. Generally speaking, the larger diameter gives a larger field of view at the surface of the CCD array. The coupling of the intensifier to the CCD array is also a factor in determining the field view. A fiberoptic reducing taper of 1.27:1 will increase the field of view, while a taper of 1:1 will have no effect.

Intensifier Types: Refer to:

- Gen I Intensifier;
- Gen II Intensifier;
- Super Gen II Intensifier;
- Gen III Intensifier;
- Filmless Gen III Intensifier;
- Gen IV Intensifier.

lp/mm: line pairs per millimeter. A measure of resolution based on the ability of the imaging system to differentiate between two parallel lines. The higher the value, the finer the resolution.

lux: The SI unit of illuminance, equal to one lumen per square meter.

MCP: MicroChannel Plate.

Composed of cylindrical channels through which electrons from the photocathode travel and generate additional electrons, resulting in electron gain. At the output of the MCP is a phosphor-coated fluorescent screen that converts the electrons to photons that subsequently strike the CCD array and generate charge in the array pixels.

MCP Bracket Pulsing: Available for PI-MAX3 cameras with a Gen II Intensifier. This technique enhances the intensifier's on/off ratio in UV measurements by automatically adjusting the on/off switching of the MCP to bracket the photocathode gate pulse. By switching off the MCP, unwanted UV signal that strikes the photocathode (even though gated off) is prevented from passing through the MCP to integrate on the CCD array.

MCP Gating: Available for PI-MAX$_{MG}$ cameras. Applies the primary gating pulse to the MCP portion of the tube and, if chosen by the user, applies the bracket pulse to the photocathode.

MCP Resolution: The MCP is a slightly conductive glass substrate with millions of parallel traversing channels containing a secondary electron emitter on their inner walls. The smaller the diameter and more tightly grouped the channels, the higher the resolution.

Phosphor Decay Time: A delay between the end of the exposure time and the beginning of the array readout. This time is inserted to allow the phosphor to decay to 1% before readout occurs and will vary depending on the phosphor type.

Phosphor Type: A phosphor is a chemical substance that fluoresces when excited by x-rays, an electron beam, or ultraviolet radiation. Phosphors usually emit green light with decay times ranging from hundreds of nanoseconds to a few milliseconds.

- P43 offers high resolution (~ 3 ms decay);
- P46 offers fast decay for high-repetition rate spectroscopy (~ 2 μs decay);
- P47 offers even faster decay (0.4 μs).

The Phosphor Decay Time, inserted between the end of the exposure time and the beginning of the array readout, allows for the decay time.

Photocathode Coatings: Coatings on the photocathode convert a portion of the incident photons into electrons. Any photons that are not captured by the photocathode are lost from the final signal produced by the intensifier. Therefore, the kind of coating and the resulting QE of the photocathode is very important. The choice of coating determines the most effective spectral range for the intensifier. For example GaAs (gallium arsenide) has high QE in the VIS and NIR regions. Multi-alkali coatings have fair photoconversion in the visible (VIS) and ultraviolet (UV) but have relatively limited response in the near IR (NIR).

Pulse Ensemble: PTG term. Consists of a Gate Start pulse, a Gate Stop pulse, and an Auxiliary pulse. At the end of the ensemble, the photocathode is gated off, phosphor decay time elapses to allow for phosphor decay, and then the CCD array is readout.

QE: Refer to Quantum Efficiency

Quantum Efficiency: The percentage of incident photons converted to electronic charge. The throughput of the input windows, the spectral sensitivity of the photocathode and the CCD array, the illuminated surface (front or back) of the CCD array, the intensifier on/off ratio, the MCP resolution, the MCP gain, and the intensifier-CCD coupling all contribute to the total system QE.

RAM: Random Access Memory used to store data such as experiment parameters.

Region of Interest: A square or rectangular set of contiguous pixels on the CCD array that is usually smaller than the full frame. Using an ROI to acquire data results in a faster readout of the array since data from pixels outside of that ROI is discarded.

ROI: Refer to Region of Interest.

Safe Mode: PI-MAX3 intensifier mode in which the photocathode is continuously biased off.

Saturation: Caused when a pixel well is completely filled with charge. Once a pixel is saturated, additional charge will spillover (bloom) into adjacent pixels. Ways to deal with saturation include lowering the array temperature (to reduce the dark charge component), shortening the exposure time (to reduce the signal component), and decreasing the gain (also to reduce the signal component).

Scan / Scanning: The process of reading out the contents of a CCD array.

Super Gen II Intensifier: Gen II Intensifier devices that employ novel photocathodes with extended spectral range or high QE in a particular wavelength.

Vertical Shift Time: Reports the speed (in μs) at which a single row will be shifted vertically.

This information is based on the value in the Vertical Shift box. The higher the value in that box, the longer the vertical shift time. This information appears for the Frame Transfer.

Vertical Shift: Determines the speed of the image transfer from the exposed area of an array to the masked area. Setting a lower value increases the shift speed. A higher value gives a slower shift. If the shift is too fast, not all of the charge will be transferred. If too slow, image smearing will be increased due to the exposure that takes place while the transfer is in progress. The default value gives good results in most measurements.

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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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