PI-MAX®/PI-MAX2™ System

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Princeton Instruments

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Attention!

WARNING

Intensified CCD detectors, such as the PI-MAX, 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. In **Shutter Mode** operation, it will be necessary to keep the lab lighting be subdued when working with an intensified detector. If a sustained alarm indication occurs when the controller is turned on, either completely cover the intensifier to reduce the light to halt the overload condition, or reduce the laboratory illumination still further until safe operating conditions are established.

Alarm

To reduce the risk of detector damage, the PI-MAX 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 switch the **MCP On/Off** switch (on the back of the PI-MAX) to the **OFF** position. Cover the detector window and only switch the **MCP On/Off** 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.

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

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.

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Chapter 1
Introduction

The Princeton Instruments PI-MAX® Intensified CCD camera is 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-MAX uses a proximity-focused microchannel plate (MCP) image intensifier (Gen II and Gen III intensifiers available) fiber-optically coupled to a CCD array. The fastest intensifiers can be gated in as little as 2 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-MAX to the widest possible range of experimental requirements. In operation, data acquired by the camera is routed to the computer for processing and display. The computer controls both the system configuration and data acquisition via software, of which Princeton Instruments WinView/32 is an example.

Unless otherwise indicated, PI-MAX will be used to refer to both the standard PI-MAX and the 5 MHz PI-MAX2™ cameras.

PI-MAX System Components

All PI-MAX systems consist of standard hardware and software as well as the appropriate interface hardware for your computer system. Some PI-MAX systems also include an optional PTG or DG535 pulser.

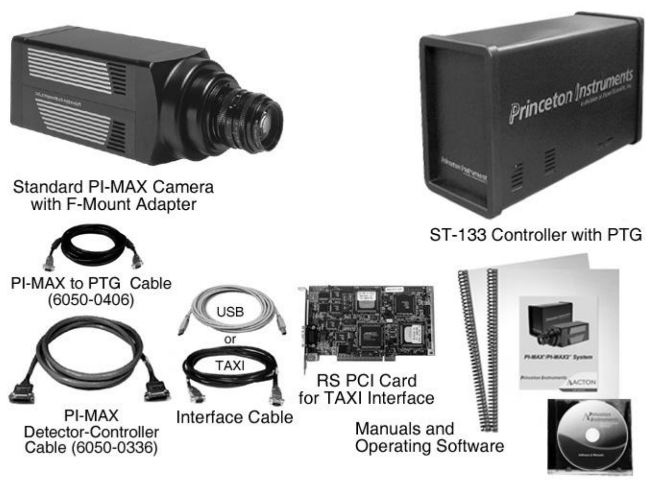


Figure 1. Typical Standard PI-MAX System Components

Camera Head

The PI-MAX camera head houses the CCD and intensifier and it supplies all of the high voltages needed to operate the intensifier (see Chapter 3 for more info). Cooling within the camera head is performed by a cooling fan and a multi-stage Peltier cooler that is thermally coupled to the CCD (liquid coolant circulation can also be used for the standard PI-MAX camera). C-, F-, and spectroscopy mount adapters are available.

The camera can be operated in one the following three modes: Safe mode, Shutter mode, and Gate mode. In safe mode, all the high voltages in the camera head are disabled so high intensity light will not damage the intensifier. In **Shutter Mode**, the intensifier's photocathode is biased ON for the set Exposure Time and OFF during each readout of the array. In Gate mode, the photocathode is biased on only during the time each gate pulse is applied.

ST-133 Controller

In addition to containing the power supply, the ST-133 Controller contains the analog and digital electronics, scan control and exposure timing hardware, and controller I/O connectors, all mounted on user-accessible plug-in modules.

Readout modes supported include full resolution, simultaneous multiple subimages, 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. Completely flexible exposure, set through software, is also fully supported.

The ST-133 contains two analog-to-digital converters (High Speed and Low Noise) and the choice of A/D converter is software-selectable. After the data is converted, it is transferred directly from the ST-133 to the host computer memory via a high-speed serial link. (A frame buffer with standard composite video, either RS-170 (EIA) or CCIR, whichever was ordered, is also provided.) A proprietary Interface card places the data from the controller directly into the host computer RAM using Direct Memory Access (DMA). The DMA transfer process ensures that the data arrives at sufficiently high speed to prevent data loss from the controller. Since the data transfer rate is much higher than the output rate from the A/D, the latter becomes the limiting factor for the data acquisition rate. Once the digital data is in RAM, the image acquisition program can transfer the image into its own working RAM for viewing and further processing.

Cables

- Detector-Controller cable:

  PI-MAX: 6050-0336, 15 foot/4.6 meter, 25-pin D

  PI-MAX2: 6050-0499 cable set (6050-0492 Signal cable and 6050-0493 Power cable), 15 foot

- Computer Interface Cable:

  TAXI: 6050-0148-CE, 25 foot/7.6 meter or

  USB 2: 6050-0494, 16.4 foot/5 meter. Not supported by PI-MAX2.

Computer Interface Card: Princeton Instruments High Speed PCI card or user-provided USB 2.0 interface card.

Manuals: PI-MAX System manual and optional application software manual.

Optional Application Software: Princeton Instruments' WinView/32 or WinSpec/32 application program.

Optional Pulser: Programmable Timing Generator (PTG) plug-in module (with **PI-MAX to PTG** cable) for the ST-133 that eliminates the need for an external timing generator or a Stanford Research DG535 timing generator with cables.

Summary of PI-MAX Data Acquisition

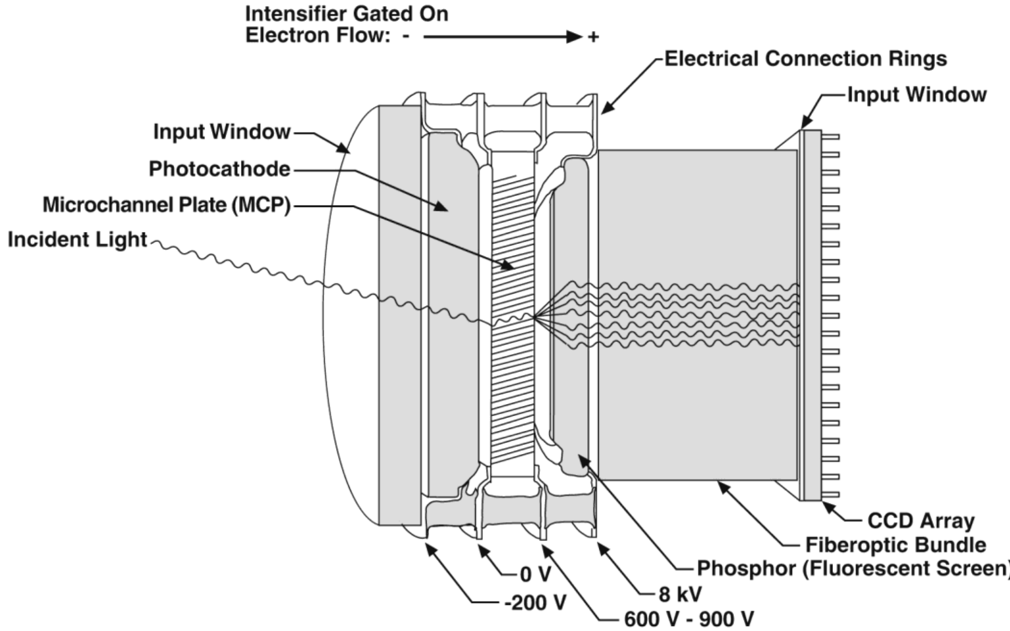


Figure 2. Major Components of the Intensifier-CCD

In the PI-MAX 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 window. The image at the output of the image intensifier is translated to the input of the CCD at the same size.* After being detected by the CCD, the image is read out to the Controller, where it is digitized and transferred to the computer for processing via a high-speed data link.

The sequence below steps through the process by which photons are converted to data that can be displayed on a computer monitor. For the sake of simplicity, triggers and gate pulses are not mentioned and it is assumed that a PCI interface card is installed in the host computer. When reading through the sequence, keep in mind 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 2 above.)
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

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

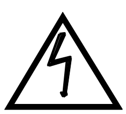
additional electrons, resulting in electron gain. *The amount of gain is adjusted by increasing or decreasing the voltage at the MCP output.*

4. When the electrons exit the channels they are further accelerated by a constant high voltage (5-8 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), pass through the input window, 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 where it is digitally encoded. The conversion speed and the quality of the data are dependent on the A/D selected (High Speed or Low Noise).
9. The digitized information is transmitted from the camera head through the TAXI 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.

Safety Information

Safety Related Symbols Used in This Manual

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



Caution! 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.

Grounding and Safety

The ST-133 is of Class I category as defined in IEC Publication 348 (Safety Requirements for Electronic Measuring Apparatus). It is designed for indoor operation only. Before turning on the controller, 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.

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

Inspect the supplied 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 as that of the original ones to avoid hazard due to electrical shock.

Intensifier Modes and Safety

The Experiment Setup **Main** screen in WinX applications (WinView/32 and WinSpec/32) allows you to select one of three intensifier modes: **Shutter Mode**, **Gate Mode** or **Safe Mode**. In **Shutter Mode** operation, the photocathode is biased on continuously during the exposure time and the room illumination must be subdued to prevent an overload alarm from occurring. 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. In **Safe Mode**, the photocathode is continuously biased OFF and the intensifier is as safe as it can be.

Audible Alarm

To reduce the risk of camera damage, the PI-MAX camera is equipped with an audible alarm in the camera 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 switch the **MCP On/Off** switch on the back of the PI-MAX to the **OFF** position. Cover the detector window and only switch the **MCP On/Off** 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.

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

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.

High Intensity Light Damage

WARNING! Intensified CCD cameras such as the PI-MAX, 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. In **Shutter Mode** operation, it will be necessary to keep the lab lighting be subdued when working with an intensified camera. If a sustained alarm indication occurs when the controller is turned on, immediately switch the **MCP On/Off** switch on the back of the PI-MAX to the **OFF** position. Cover the detector window and only switch the **MCP On/Off** 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.

Precautions

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

- Always switch off and unplug the ST-133 Controller before changing your system configuration in any way.
- Whenever you turn the ST-133 power OFF, 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.
- Never remove the camera's front window, as it is necessary to maintain vacuum (or to maintain a dry nitrogen environment).
- 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.
- Never operate the camera cooled without proper evacuation or backfill. This could damage the CCD!
- Never connect or disconnect any cable while the PI-MAX system is powered on. Reconnecting a charged cable may damage the CCD.
- Never prevent the free flow of air through the equipment by blocking the air vents.

Cleaning and Maintenance

Cleaning the Controller and Camera

Although there is no periodic maintenance that *must* be performed on the PI-MAX Camera, users are advised to wipe it down with a clean damp cloth from time to time.

Note: The cloth should be just damp enough to pick up dust – not wet.

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.

Cleaning Optical Surfaces

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.

Flushing and Refilling the Intensifier Chamber

WARNING!

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

WARNING!

Operating an Intensified PI-MAX 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-MAX camera leaves the factory, its front enclosure is backfilled with clean dry air or, in the case of the sealed-nose IVUV detector, only dry nitrogen. For proper operation it is essential that the integrity of the front enclosure be maintained. ***NEVER remove the window from in front of the intensifier or loosen the backfill port screw (see page 199).*** If this enclosure should be opened to the air, the array and intensifier will be exposed to atmospheric moisture, which could condense on the array as it cools and possibly cause irreversible damage.

In normal operation, the front enclosure should remain sealed for the life of the detector and should require no maintenance to assure integrity. If it should ever happen that the front enclosure becomes unsealed, contact the factory and arrange to return the detector to the factory where it can be properly flushed, backfilled and resealed again. See page 232 for contact information.

Repairs

Save the original packing materials. Because the PI-MAX system contains no user-serviceable parts, repairs must be done by Princeton Instruments. Should your system need repair, contact Princeton Instruments customer support for instructions (telephone, e-mail, and address information are provided on page 232 of this manual).

Use the original packing materials whenever shipping the system or system components.

Manual Organization

This manual provides the user with all the information needed to install a PI-MAX Intensified CCD camera and place it in operation. Topics covered include a detailed description of the camera, installation and setup, first time data acquisition, tips and tricks, microscopy applications, temperature control and more. A brief description of each of the chapters follows.

Notes:

1. The general identifier "ST-133" is used for both the ST-133A Controller and the ST-133B Controller. Where there is a difference, the specific identifier is used.
2. "WinX" is a generic term for WinView/32, WinSpec/32, and WinXTest application software.

Chapter 1**,** ***Introduction*** provides an overview of the PI-MAX camera. Topics include a description, theory of operation, and specifications.

Chapter 2, Installation Overview cross-references system setup actions with the relevant manuals and/or manual pages. It also contains system layout diagrams.

Chapter 3, System Setup provides detailed directions for installing and setting up the PI-MAX for both spectroscopy and imaging.

Chapter 4, First Light provides abbreviated directions for getting your PI-MAX into operation as soon as possible.

Chapter 5, General Operation Factors provides information about experiment setup, temperature control, background subtraction, array readout, binning, and digitization. These are factors that should be considered whether you are setting an experiment in shutter or gate mode.

Chapter 6, Shutter Mode Operation discusses issues specific to operating the PI-MAX system in shutter mode.

Chapter 7, Gated Operation with a PTG discusses issues specific to operating the PI-MAX system in gate mode with an installed PTG.

Chapter 8, Gated Operation with a DG535 discusses issues specific to operating the PI-MAX system in gate mode with a Stanford Research DG535.

Chapter 9**,** ***Kinetics Operation*** describes the Kinetics option and includes example experiments.

Chapter 10, PI-MAX2 DIF Camera describes the operation of the PI-MAX2 DIF system.

Chapter 11, Tips and Tricks discusses a number of issues that can have a bearing on getting good experimental results.

Chapter 12**,** ***Microscopy Applications*** discusses how to mount the PI-MAX camera to a microscope. Includes discussion of various adapters, focusing considerations and sensitivity to damage from EMF spikes generated by Xenon or Hg arc lamps.

Chapter 13, TTL Control discusses the purpose and operation of the TTL In/Out Function.

Chapter 14, System Component Descriptions describes the PI-MAX Camera, the ST-133, and other system components. Includes descriptions of connectors and other front and rear panel features.

Chapter 15, Troubleshooting provides information regarding possible system problems.

Appendix A, Specifications provides general specifications as well as operating environment and internal pulser specifications.

Appendix B, Outline Drawings includes outline drawings for the ST-133A Controller, the ST-133B Controller, and the PI-MAX camera.

Appendix C*, *Software explains how the PI-MAX camera is controlled using the WinX application software.

Appendix D*, *C-Mount and F-Mount Adapters provides information on the C-Mount and F-Mount adapters available for the PI-MAX Camera. Also includes a discussion of lens focusing.

Appendix E, Spectroscopy-Mount and Spectrograph Adapters provides mounting instructions for the spectroscopy-mount adapter and for the spectrograph adapters available for PI-MAX cameras with spectroscopy-mounts.

Appendix F*, *IVUV Detector discusses the purge requirements of the IVUV variant of the PI-MAX.

Appendix G*, *USB 2.0 Limitations covers the currently known limitations associated with operating under the USB 2.0 interface.

Appendix H*, *Glossary provides definitions of commonly used words and terms related to intensified camera characteristics and usage.

Declarations of Conformity contains the Declarations of Conformity for PI-MAX systems.

Warranty & Service details the warranties for Princeton Instruments equipment and software.

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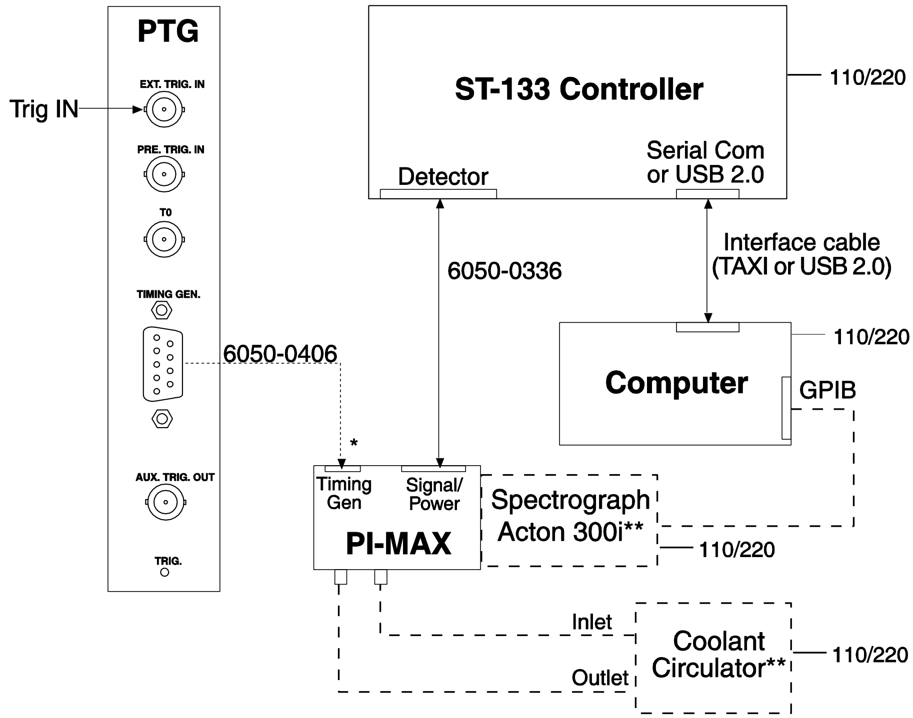
Chapter 2
Installation Overview

The list and diagrams below briefly describe the sequence of actions required to install your system and prepare to gather data. Refer to the indicated references for detailed information.

Action	Reference
1. If the system components have not already been unpacked, unpack them and inspect their carton(s) and the system components for in-transit damage.	Chapter 3 System Setup, page 33
2. Verify that all system components have been received.	Chapter 3 System Setup, page 33
3. If the components show no signs of damage, verify that the appropriate voltage settings have been selected for the Controller.	Chapter 3 System Setup, page 36
4. If the Camera will be used on a spectrograph or microscope, mount it to the equipment using the required adapter(s).	Spectroscopy: Appendix E, page 203 Microscopy: Chapter 12, page 143
5. If the application software is not already installed in the host computer, install it.	Application manual.
6. If the appropriate interface card is not already installed in the host computer, install it.	Chapter 3 System Setup, page 38
7. With the Controller and computer power turned OFF, connect the interface cable (TAXI or USB) to the Controller and the interface card in the host computer. Then tighten down the locking hardware.	Chapter 3 System Setup, page 42 (TAXI) or page 42 (USB 2.0)
8. With the Controller power turned OFF, connect the Detector-Controller cable(s) to the appropriate connector(s) on the rear of the **Controller**. Adjust the slide latches so the cable connection is locked or tighten down the locking hardware, as appropriate.	Chapter 3 System Setup, page 42 Chapter 15 Troubleshooting, page 181
9. With the Controller power turned OFF, connect the Detector-Controller cable(s) to the appropriate connector(s) on the rear of the **Camera**. Then tighten down the locking hardware.	Chapter 3 System Setup, page 42
10. With the Controller power turned OFF, connect the Controller power cord to the rear of the controller and to the power source.	
11. With the Controller power turned OFF, make the cable connections to the PTG or the DG535 Timing Generator.	Chapter 3 System Setup, page 43
12. If the system is cooled by coolant circulation, make the tubing connections between the coolant circulator and the Camera.	Chapter 3 System Setup, page 44

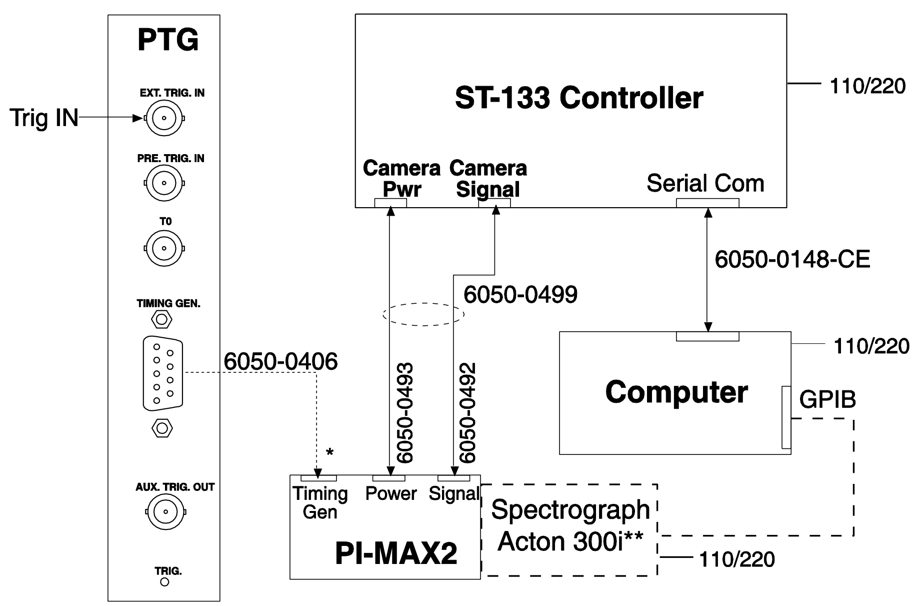
Action	Reference
13. Turn the Controller ON.	
14. Turn on the computer and begin running the WinX application. When the computer boots, you may be asked for the location of the interface drivers. If this is the first time you have used a WinX application, the Camera Detection wizard will automatically run. This wizard retrieves information from the camera and/or ST-133 and enters this information as the default parameters for your system.	Chapter 3 System Setup, page 38 (PCI drivers), page 40 (USB drivers), page 44 (Camera Detection Wizard) WinView/32 or WinSpec/32 manual
15. 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 that setup information	WinView/32 or WinSpec/32 manual Configuring the Software for Shutter Mode Operation, page 49
16. Set the target array temperature.	Setting the Temperature, page 58
17. When the system reaches temperature lock, wait an additional 20 minutes and then begin acquiring data in focus mode.	Initial Data Acquisition, page 51
18. Adjust the focus for the best image or spectral lines. If you are using WinSpec/32, you may want to use the Focus Helper function for this purpose.	Appendix D C-Mount and F-Mount Adapters, page 201 Appendix E Spectroscopy-Mount and Spectrograph Adapters, page 204



* In current systems, the Timing Gen. cable can remain connected during Shutter Mode operation. Older systems may require that it be disconnected.

** Spectrograph and coolant circulator connections are optional.

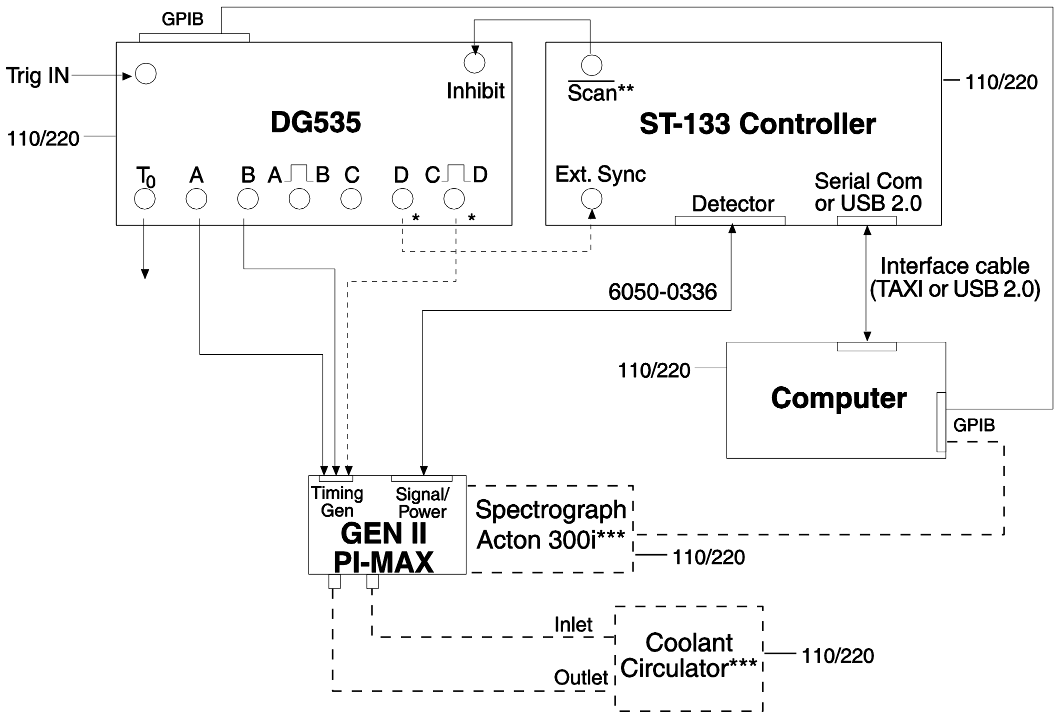
Figure 3. PI-MAX with PTG System Diagram



* In current systems, the Timing Gen. cable can remain connected during Shutter Mode operation. Older systems may require that it be disconnected.

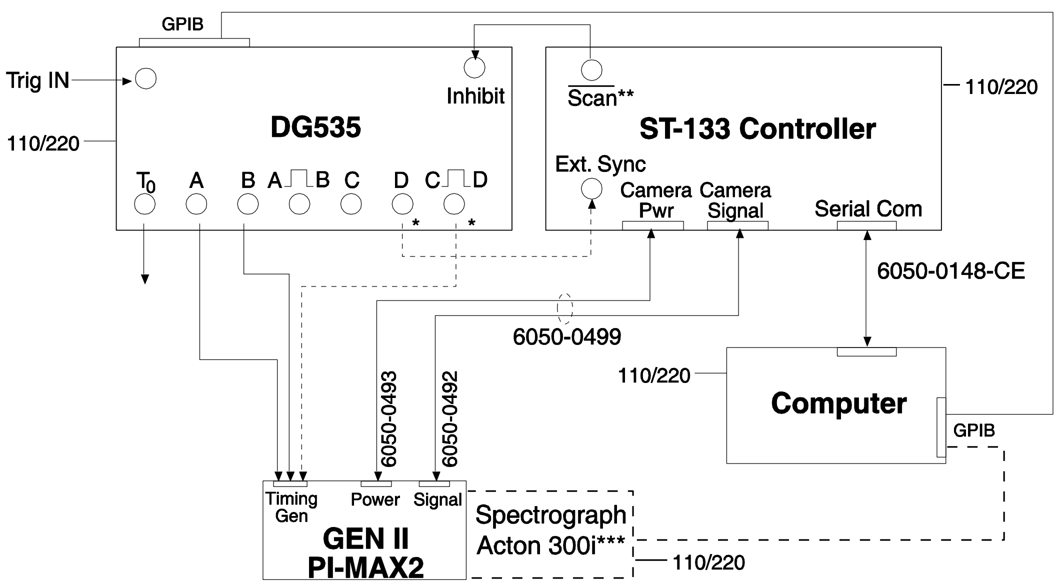
** Spectrograph connection is optional.

Figure 4. PI-MAX2 with PTG System Diagram



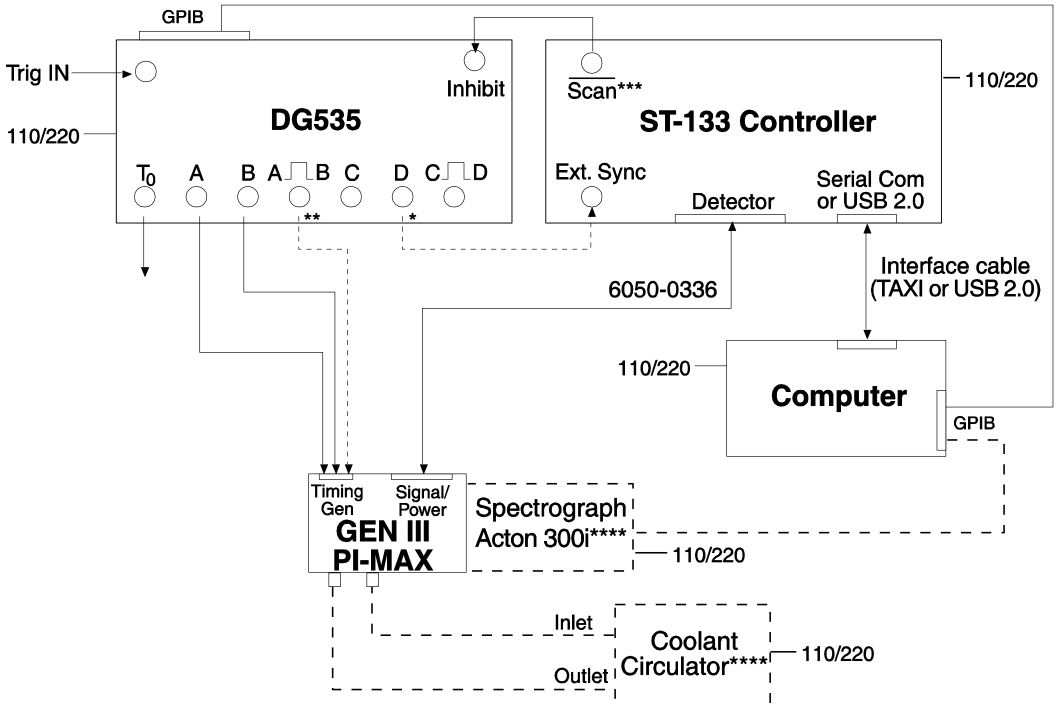
* Disconnect these cables for Shutter Mode operation.
** Signal at Scan Output must be Shutter.
*** Spectrograph and coolant circulator connections are optional.

Figure 5. Gen II PI-MAX with DG535 System Diagram



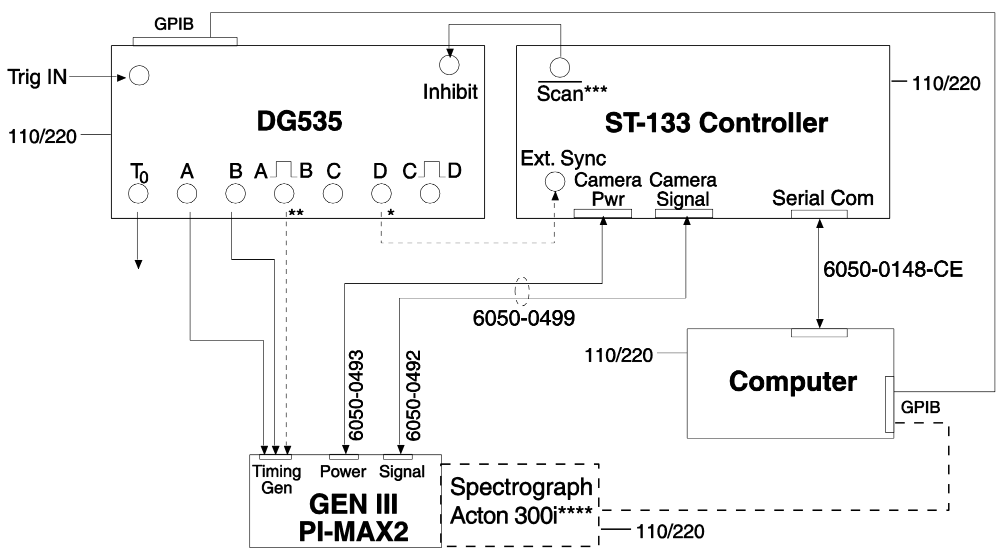
* Disconnect these cables for Shutter Mode operation.
** Signal at Scan Output must be Shutter.
*** Spectrograph connection is optional.

Figure 6. Gen II PI-MAX2 with DG535 System Diagram



*	Disconnect this cable for Shutter Mode operation.
**	Not required for current systems but may be required by some older systems.
***	Signal at $\overline{\text{Scan}}$ Output must be Shutter.
****	Spectrograph and coolant circulator connections are optional.

Figure 7. Gen III PI-MAX with DG535 System Diagram



*	Disconnect this cable for Shutter Mode operation.
**	Not required for current systems but may be required by some older systems.
***	Signal at $\overline{\text{Scan}}$ Output must be Shutter.
****	Spectrograph connection is optional.

Figure 8. Gen III PI-MAX2 with DG535 System Diagram

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Chapter 3

System Setup

Introduction

This chapter includes general instructions for setting up a PI-MAX system for operation in both imaging and spectroscopic applications. For microscopy applications, also see Chapter 12, *Microscopy Applications.*

Dangers and Warnings

DANGER

> Voltages inside the PI-MAX 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-MAX with its covers removed.

WARNING

> Image intensified detectors can be *destroyed* if exposed to excessive light levels. Princeton Instruments cannot take responsibility for PI-MAX 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.

The PI-MAX 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 about 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.

Unpacking the System

During unpacking, check the system components for possible signs of shipping damage. If there are any, notify Princeton Instruments and file a claim with the carrier. 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. Please save the original packing materials so you can safely ship the camera system to another location or return it to Princeton Instruments for repairs if necessary.

Checking the Equipment and Parts Inventory

Confirm that you have all of the equipment and parts required to set up the PI-MAX system. A typical system consists of:

- PI-MAX camera (Gen II or Gen III).
- ST-133 Controller.

- Timing Generator: a PTG (installed in the ST-133) or a Stanford Research Systems DG535 Digital Delay/Pulse Generator with Inhibit Option and GPIB cables.*
- Detector-Controller cable:
  - PI-MAX: DB25 to DB25 cable. Standard length is 15 ft (6050-0336).
  - PI-MAX2: Cable set, 15 ft (6050-0499)
- Computer Interface: TAXI or USB 2.0.
- Computer: Can be purchased from Princeton Instruments or provided by user.
- WinView/WinSpec CD-ROM
- User Manuals
- Interface Dependent Components:
  - Controller-Computer Interface cable:
    - TAXI cable: DB9 to DB9 cable (6050-0148-CE is standard) or
    - USB cable: Five (5) meter cable (6050-0494) is standard
  - Interface Card: High Speed PCI Interface board for TAXI interface. USB 2.0 board for USB 2.0 interface is user-provided: native USB 2.0 support on the motherboard or USB 2.0 Interface Card (Orange Micro 70USB90011 USB 2.0 PCI is recommended for desktop; SIIG, Inc. USB 2.0 PC Card, Model US2246 for laptop).
- System Dependent Components
  - PI-MAX to DG535 cable (6050-0385) and Filter (2550-0347)
  - PI-MAX to PTG cable: Custom DB9 to DB9 cable (6050-0406, 15 ft/5 m is standard)
  - GPIB cables if a DG535 has been ordered
  - Coolant Circulator and Coolant Tubing

If there are any problems, contact the Princeton Instruments Customer Support department (see page 232 for contact information).

System Requirements

Environmental

Storage temperature ≤55°C

Operating environment temperature: 30°C > T > -25°C

Relative humidity <50% noncondensing...

Ventilation

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

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* Contact factory for information on how to install/enable the DG535 Inhibit function.

ST-133: There is an internal fan located at the right side of the rear panel behind an exhaust opening. Its purpose is simply to cool the controller electronics. This fan runs continuously whenever the controller is powered. Air enters the unit through ventilation openings on the side panels, flows past the warm electronic components as it rises, and is drawn out the rear of the controller by the fan. It is important that there be an adequate airflow for proper functioning. As long as both the controller's intake ventilation openings and the fan exhaust opening aren't obstructed, the controller will remain quite cool.

Power

Camera: The PI-MAX camera receives its power from the ST-133, which in turn plugs into a source of AC power.

ST-133: The ST-133 Controller can operate from any one of four different nominal line voltages: 100, 120, 220, or 240 V AC. Refer to the Fuse/Voltage label on the back of the ST-133 for fuse, voltage, and power consumption information.

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

Caution

Whenever you turn the ST-133 power OFF, 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.

Host Computer

Note: Computers and operating systems all undergo frequent revision. The following information is only intended to give an approximate indication of the computer requirements. Please contact the factory to determine your specific needs.

Requirements for the host computer depend on the type of interface, TAXI or USB 2.0, that will be used for communication between the ST-133 and the host computer. Those requirements are a listed below according to protocol.

TAXI Protocol:

- AT-compatible computer with 200 MHz Pentium® II (or better).
- Windows® XP (32-bit, SP3 or later) or Vista (32-bit) operating system.
- High speed PCI serial card (or an unused PCI card slot). Computers purchased from Princeton Instruments are shipped with the PCI card installed if High speed PCI was ordered.
- Minimum of 32 Mbytes of RAM for CCDs up to 1.4 million pixels. Collecting multiple spectra at full frame or high speed may require 128 Mbytes or more of RAM.
- CD-ROM drive.
- Hard disk with a minimum of 80 Mbytes available. A complete installation of the program files takes about 17 Mbytes and the remainder is required for data storage, depending on the number and size of spectra collected. Disk level compression programs are not recommended.

- Super VGA monitor and graphics card supporting at least 256 colors with at least 1 Mbyte of memory. Memory requirement is dependent on desired display resolution.
- IEEE-488 GPIB port (required by DG535 Timing Generator, if present). May also be required by Spectrograph.
- Two-button Microsoft® compatible serial mouse or Logitech three-button serial/bus mouse.

USB 2.0 Protocol:

- AT-compatible computer with Pentium 3 or better processor and runs at 1 GHz or better.
- Windows® XP (32-bit, SP3 or later) or Vista® (32-bit).
- Native USB 2.0 support on the mother board or USB Interface Card (Orange Micro 70USB90011 USB 2.0 PCI is recommended for desktop; SIIG, Inc. USB 2.0 PC Card, Model US2246 for laptop)
- Minimum of 256 Mb of RAM.
- CD-ROM drive.
- Hard disk with a minimum of 80 Mbytes available. A complete installation of the program files takes about 17 Mbytes and the remainder is required for data storage, depending on the number and size of spectra collected. Disk level compression programs are not recommended.
- Super VGA monitor and graphics card supporting at least 256 colors with at least 1 Mbyte of memory. Memory requirement is dependent on desired display resolution.
- IEEE-488 GPIB port (required by DG535 Timing Generator, if present). May also be required by Spectrograph.
- Two-button Microsoft compatible serial mouse or Logitech three-button serial/bus mouse.

Verifying Controller Voltage Setting

The ST-133's power requirements are discussed in Appendix A. Note that the PI-MAX power requirements are entirely provided by the ST-133 via the Detector-Controller cable.

The Power Module on the rear of the Controller contains the voltage selector drum, fuses and the power cord connector. The appropriate voltage setting is set at the factory and can be seen on the back of the power module. *Each setting actually defines a range and the setting that is closest to the actual line voltage should have been selected.* The correct fuses for the country where the ST-133 is to be shipped are installed at the factory.

Figure 9. Power Module

Note: On ST-133s, the voltage ranges and fuse ratings may be printed above or below the power module.

To Check the Controller's Voltage Setting:

1. Look at the lower righthand corner on the rear of the Controller. The current voltage setting (100, 120, 220, or 240 VAC) is displayed on the Power Module.
2. If the setting is correct, continue with the installation. If it is not correct, follow the instructions on page 168 for changing the voltage setting and fuses.

Mounting the PI-MAX

Imaging Applications

The PI-MAX is supplied with the lens mount specified when the system was ordered, normally either a screw-type C-mount lens or a bayonet type F-mount lens, allowing a lens of the corresponding type to be mounted quickly and easily. The installed mount is secured by three setscrews, which must be loosened to remove it. Appendix D illustrates the mounts and also discusses focusing.

The PI-MAX can be mounted at any attitude or angle. The camera can rest on any secure surface. Take care not to block the ventilation openings.

WARNING

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.

WARNING

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

Spectroscopy Applications

The PI-MAX detector must be properly mounted to the spectrograph to achieve the highest resolution. In the correct orientation, the text on the back of the detector should be right side up. Take care not to block the ventilation openings. Refer to Appendix E for spectrograph adapter mounting instructions.

Microscopy Applications

If the camera is going to be mounted to a microscope, refer to Chapter 12 for mounting instructions and other information relating to microscopy applications. Many standard microscope adapters are available through Princeton Instruments.

Installing the Application Software

Installation is performed via the WinX installation process. If you are installing WinView/32 or WinSpec/32 for the first time and have a TAXI interface, you should run the installation before the PCI interface card is installed in the host computer. On the **Select Components** dialog (see Figure 10), click on the **AUTO PCI** button to install the interface card drivers (PCI and the Princeton Instruments USB drivers) and the most commonly installed program files. Select the **Custom** button if you would like to choose among the available program files or do not want to install the PCI driver.

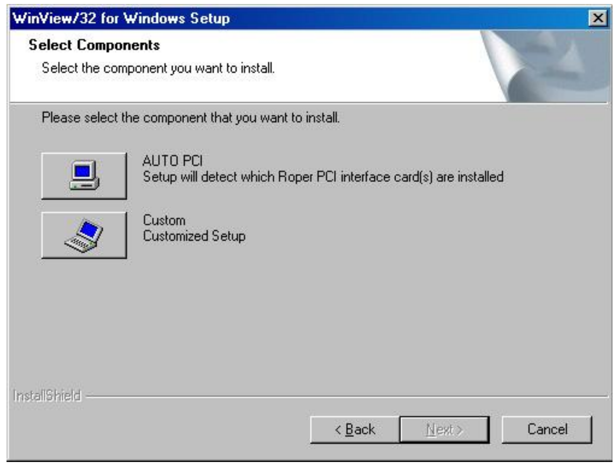


Figure 10. WinView/32 Installation: Interface Card Driver Selection

Note: WinView/32 and WinSpec/32 (versions 2.6.0 and higher) do not support the ISA interface.

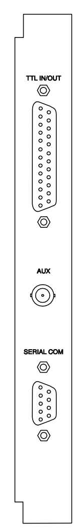
Setting up the Communication Interface

PI-MAX and PI-MAX2 camera systems require either an installed Princeton Instruments (RSPI) PCI card or an installed USB2.0 interface card in the host computer. The type of interface card is dictated by the Interface Control Module installed in the ST-133 controller.

Setting up a PCI Interface

Administrator privileges are required under Windows® XP, and Window Vista® to install software and hardware.

A PCI card must be installed in the host computer if the communication between computer and controller uses the TAXI protocol (i.e., the **Interface Control Module** installed in the ST-133 has a 9-pin **SERIAL COM** connector as shown in the figure at right). With TAXI protocol, the standard cable provided with an ST-133 is 7.6 meters (25 feet) (cable lengths up to 50 meters are available) and the digitization rate may be as high as 5 MHz.



A computer purchased from Princeton Instruments will be shipped with the PCI card already installed. Otherwise, a PCI card will be shipped with the system and you will have to install it in the host computer at your location.

Note: The PCI card can be installed and operated in any Macintosh® having a PCI bus, allowing the ST-133 to be controlled from the Macintosh via IPLab™ software and the PI Extension.

Caution If you are using the WinX application software, either **High Speed PCI** or **PCI(Timer)** can be the selected Interface type. This selection is accessed on the **Hardware Setup| Interface** tab. **High Speed PCI** allows data transfer to be interrupt-driven and gives the highest performance in some situations. **PCI(Timer)** allows data transfer to be controlled by a polling timer. This selection is recommended when there are multiple devices sharing the same interrupt.

To Install a PCI Serial Buffer Card in the Host Computer:

1. Review the documentation for your computer and PCI card before continuing with this installation.
2. To avoid risk of dangerous electrical shock and damage to the computer, verify that the computer power is OFF.
3. Remove the computer cover and verify that there is an available PCI slot.
4. Install the PCI card in the slot.
5. Make sure that the card is firmly seated and secure it.
6. Replace and secure the computer cover and turn on the computer only. If an error occurs at bootup, either the PCI card was not installed properly or there is an address or interrupt conflict. Refer to Chapter 15 "Troubleshooting", page 165 for instructions.

Note: The PCI card has no user-changeable jumpers or switches.

To Install the PCI Card Driver

The following information assumes that you have already installed the WinX application software (WinView/32, WinSpec/32, or WinXTest).

1. After you have secured the PCI card in the computer and replaced the cover, turn the computer on.
2. At bootup, Windows will try to install the new hardware. If it cannot locate the driver, you will be prompted to enter the directory path, either by keyboard entry or by using the browse function.

   If you selected **AUTO PCI** during the application software installation, the required INF file is automatically copied into the Windows\Inf directory and the PCI card driver file is copied into the Windows\System32\ Drivers directory. Refer to Table 1 for the appropriate file names and locations.

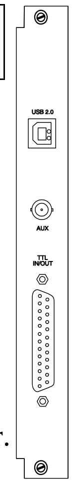
Windows Version	**PCI Inf Filename Located in "Windows"\Inf directory***	**PCI Device Driver Name Located in "Windows"\System32\Drivers directory**
Windows® XP and Windows Vista® (32-bit)	rspi.inf (in Windows\inf, for example)	rspipci.sys (in Windows\System32\drivers, for example)

* The Inf directory may be hidden.

Table 1. PCI Driver Files and Locations

Setting up a USB 2.0 Interface

Administrator privileges are required under Windows® XP and Windows Vista® (32-bit) to install software and hardware.



Your system has been configured to use the USB communication protocol if the **Interface Control Module** installed in the ST-133 has a **USB 2.0** connector as shown in the figure at right). The advantages to the USB 2.0 interface are that it uses a much higher data transfer rate than many common serial data formats (such as the TAXI protocol) and it simplifies the connection to external devices. USB supports "plug and play" -- you do not need to be heavily involved in the setup process.

USB 2.0 Limitations

- Maximum cable length is 5 meters (16.4 feet)
- 1 MHz is currently the upper digitization rate limit for the ST-133 Controller. Large data sets and/or long acquisition times may be subject to data overrun because of host computer interrupts during data acquisition.
- USB 2.0 is not supported by the Princeton Instruments PC Interface Library (EZ-DLLS).
- Some WinX (WinView/32 and WinSpec/32) 2.5.X features are not fully supported with USB 2.0. Refer to Appendix G, page 217, for more information.

Note: If you are installing the USB 2.0 interface on a laptop, you will need to perform all of the operations described in this section. In addition, if you are using the recommended USB Interface Card (SIIG, Inc. USB 2.0 PC Card, Model US2246), you must replace the OrangeUSB USB 2.0 Host Controller driver installed for that card with the appropriate Microsoft driver. Instructions for making the replacement are included in ***"To Update the OrangeUSB USB 2.0 Driver"***.

To Update the OrangeUSB USB 2.0 Driver:

This procedure is highly recommended when a laptop computer will be used to communicate with the ST-133. As stated before, we recommend the SIIG, Inc. USB 2.0 PC Card, Model US2246 if USB 2.0 is not native to the laptop's motherboard. To reduce the instances of data overruns and serial violations, the OrangeUSB USB 2.0 Host Controller installed for the SIIG card, should be replaced by the appropriate Microsoft driver (Windows XP or Vista (32-bit), depending on the laptop's operating system.)

Note: This procedure may also be performed for desktop computers that use the Orange Micro 70USB90011 USB 2.0 PCI.

1. Download and install Microsoft Service Pack Pack 3 (for Windows XP) if the service pack has not been installed.
2. From the Windows **Start** menu, select **Settings|Control Panel**.
3. Select **System** and then **System Properties**.
4. Select the **Hardware** tab and click on **Device Manager** button.
5. Expand **Universal Serial Bus Controllers**.
6. Right-mouse click on **OrangeUSB USB 2.0 Host Controller** and select **Properties**.

7. On the **Driver** tab, click on the **Update Driver…** button. You may have to wait a minute or so before you will be allowed to click on the button.
8. When the **Upgrade Device Driver Wizard** appears, click on **Next**. Select the **Search for a suitable driver …** radio button.
9. On the next screen select the **Specify a location** checkbox.
10. Browse and select the location. Click on **OK**.
11. In the **Driver Files Search Results** window, check the **Install one of the other drivers** check box.
12. Select the **NEC PCI to USB Enhanced Host Controller B1** driver. Click on **Next** and the installation will take place. When the **Completing the Upgrade Device Driver Wizard** window appears, click on **Finish**. You will then be given the choice of restarting the computer now or later. According to the window text, the hardware associated with the driver will not work until you restart the computer.

To Install the Princeton Instruments USB 2 Interface:

The following information assumes that:

- You have verified that the host computer meets the required specifications for USB 2.0 communication with the PI-MAX or PI-MAX2 system (see page 35).
- A USB 2.0 board and its driver are installed in the host computer.
- The ST-133 has an installed USB 2.0 Interface Control module.
- You have already installed the WinX application software (versions 2.5.15 and higher). Versions 2.5.15 and higher automatically install the driver and INF files required to support the USB 2.0 Interface Control module.

1. Before installing the Princeton Instruments USB2 Interface, we recommend that you defragment the host computer's hard disk. This operation reduces the time the computer spends locating files. Typically, the "defrag" utility "Disk Defragmenter" can be accessed from the Windows® Start menu and can usually accessed from the Programs/Accessories/System Tools subdirectory.
2. After defragmenting the hard disk, turn off the computer and make the USB cable connections between the host computer and the ST-133. Then, turn the ST-133 on before turning on the host computer.
3. At bootup, Windows will detect the Princeton Instruments USB 2 Interface hardware (i.e., the USB 2.0 Interface Control module). You may be prompted to enter the directory path(s) for the apausbprop.dll and/or the apausb.sys file(s), either by keyboard entry or by using the browse function. If you selected **AUTO PCI** during the application software installation, the required INF file is automatically copied into the Windows\Inf directory and the USB driver file is copied into the "Windows"\System32\ Drivers directory. Refer to Table 2 for the appropriate file names and locations.

Windows Version	USB Inf Filename Located in "Windows"\Inf directory*	USB Device Driver Name Located in "Windows"\System32\Drivers directory
Windows® XP and Windows Vista® (32-bit)	rspi.inf (in Windows\inf, for example)	rspipci.sys (in Windows\System32\drivers, for example)

* The Inf directory may be hidden.

Table 2. USB Driver Files and Locations

Connecting the Interface (Controller-Computer) Cable

TAXI® Cable (6050-0148-CE)

Caution Turn the Controller power OFF (OFF = 0, ON = |) before connecting or disconnecting the Detector-Controller cable.

To Connect the TAXI Cable:

1. Verify that the Controller power is OFF.
2. Verify that the Computer power is OFF.
3. Connect one end of the TAXI cable to the 9-pin port on the Interface card in the host computer.
4. Tighten down the screws to lock the connector in place.
5. Connect the other end to the "Serial Com" port on the rear of the Controller.
6. Tighten down the screws to lock the connector in place.

USB 2.0 Cable (6050-0494)

Caution Turn the Controller power OFF (OFF = 0, ON = |) before connecting or disconnecting the Detector-Controller cable.

To Connect the USB 2.0 Cable:

1. Verify that the Controller is OFF.
2. Verify that the Computer power is OFF.
3. Connect one end of the USB cable to the USB port on the host computer.
4. Connect the other end to the USB 2.0 port on the rear of the Controller.

Connecting the Detector-Controller Cable

Caution Turn the Controller power OFF (OFF = 0, ON = |) before connecting or disconnecting the Detector-Controller cable.

To Connect the Detector-Controller Cable:

1. Verify that the Controller is OFF.
2. Connect the Detector-Controller cable to the Controller.

   PI-MAX: Connect the male end of the cable to the "Detector" port on the Controller. Refer to "***Securing the Detector-Controller Cable Slide Latch***", page 181.

   PI-MAX2: Connect the male ends of the cable set the "Camera Signal" and "Camera Pwr" ports on the Controller.

3. Lock the connector(s) in place.
4. Connect the Detector-Controller cable to the camera.

   PI-MAX: Connect the female end of the cable to the "Power/Signal" port on the camera.

   PI-MAX2: Connect the female ends of the cable set to the "Signal" and "Power" ports on the camera.
5. Lock the connectors in place.

Connecting to the Timing Generator

PTG

1. Verify that the Controller power is OFF.
2. If you are planning to operate in **Gate Mode** (see Chapter 7 for more information), connect the **PI-MAX to PTG** cable (6050-0406) to the **Timing Gen** connector on the PTG board and to the **Timing Gen** connector on the back of the PI-MAX. Secure the cable with the locking hardware provided.
3. If you are using an external signal to trigger the gate timing sequence, use a BNC cable to connect the signal source to the **Ext. Trig. In** connector on the PTG.

DG535

1. Verify that the Controller power is OFF.
2. Connect the Filter (2550-0347) to the **Timing Gen** connector on the back of the PI-MAX and secure the locking hardware.
3. Connect the **PI-MAX to DG535** cable (6050-0385) to the Filter on the back of the PI-MAX and secure the locking hardware. The cable branches into three BNC cables, which connect as follows.
   - The **A Start** cable connects to the DG535 **A** BNC output.
   - The **B Stop** cable connects to the DG535 **B** BNC output.
   - **Gen II Intensifier:** Connect the **C+D-Gen II/A+B-Gen III** cable to the DG535 **C⎍D** output if the PI-MAX has a Gen II intensifier and you plan to do bracket pulsing. Leave the cable disconnected if you plan to operate in **Shutter Mode** or will not be bracket pulsing.
   - **Gen III Intensifier:** Connect the **C+D-Gen II/A+B-Gen III** cable to the DG535 **A⎍B** output if the PI-MAX has a Gen III Intensifier.
4. Connect the DG535-to-Computer GPIB cable (6050-0170) from the **IEEE-488 GPIB Std Port** connector on the back of the DG535 to the interface connector of the computer's IEEE-488 Interface card.
5. Connect a BNC cable from the ST-133's **Ext. Sync** input to the DG535's BNC **D** output.
6. Connect a BNC cable from the Controller's **SCAN** connector to the **Inhibit** input of the DG535 *(The DG535 must be equipped with the Inhibit option)*. This connection serves to prevent the DG535 from sending triggers while the array is being read out.

Making the Coolant Circulator-Camera Connections

PI-MAX2 cameras do not use supplemental water cooling. However, PI-MAX cameras have two coolant ports on the back panel for connection to a coolant circulator. The two ports are identical; it does not matter which is used for inflow and which for outflow.

Caution

1. Do not use any coolant fittings other than those supplied by Princeton Instruments. Although standard pipefittings are similar, in most cases they are not the same. Forcing these fittings into the cooling block will permanently damage the threads.
2. Coolant should be no colder than +15°C to prevent condensation at 50% relative humidity. Operating a PI-MAX camera with coolant at a colder temperature could cause induced condensation in the electronics enclosure and possible catastrophic damage to the camera. ***Damage resulting from this type of operation will void the warranty.***
3. Coolant can be water or it can be a 50:50 mixture of ethylene glycol and water, if the coolant temperature is below the freezing point for water.
4. Take care that the coolant used is pH neutral. Acidic or alkaline coolant can damage the camera fittings and internal cooling block through corrosion. Such damage could be very expensive to repair.

1. Set up the coolant circulator according to the directions in the user manual for that equipment. Do not apply power to the circulator until directed to do so.
2. Using 1/4", thin-wall plastic tubing, make the hose connections between the water ports on the rear of the camera to the ports on the coolant circulator. The two water ports are identical so either can be used for inflow. For best cooling performance, the tubing should be no longer than necessary.
3. Using suitable clamps, secure the tubing at both ends. Barb-sleeve clamps (PI part number 2518-0301) are provided. Make the hose connections between the circulator and the camera.

Recommended Flow Rate and Fluid Pressure

Flow Rate: > 1 liter/minute. Users are advised to install a flow meter to monitor the rate.

Fluid Pressure: 25 psig (maximum).

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

Software changes implemented in WinX version 2.15.9.6 affected the way in which default parameters were entered for camera systems. Therefore, two sets of instructions are included. Follow the instructions appropriate to the software version that you installed. Note that these instructions assume that you have performed the computer interface installation.

WinX Versions 2.5.19.6 and later

1. Make sure the ST-133 is connected to the host computer and that it is turned ON.

2. Run the WinX application. The **Camera Detection wizard** will automatically run if this is the first time you have installed a Princeton Instruments WinX application (WinView/32, WinSpec/32, or WinXTest/32) and a supported camera. Otherwise, if you installing a new camera type, click on the **Launch Camera Detection Wizard…** button on the **Controller/CCD** tab to start the wizard.

3. On the **Welcome** dialog (Figure 11), leave the checkbox unselected and click on **Next**.

Figure 11. Camera Detection Wizard - Welcome dialog

4. Follow the instructions on the dialogs to perform the initial hardware setup: this wizard enters default parameters on the Hardware Setup dialog tabs and gives you an opportunity to acquire a test image to confirm the system is working.

WinX Versions before 2.5.19.6

1. Make sure the ST-133 is connected to the camera and the host computer and that it is turned on.

2. For ST-133s containing a TAXI Interface module, go to Step 5.

3. For ST-133s containing a USB 2.0 Interface module, run RSConfig from the **Windows|Start|Programs|PI Acton** menu or from the directory where you installed the WinX application (WinView/32, WinSpec/32, or WinXTest).

4. When the RSConfig dialog (Figure 12) appears, you can change the camera name to one that is more specific or you can keep the default name "Camera1". When you have finished, click on the **Done** button.

Note: If the first camera in the list is not the "Princeton Style (USB2)", you will need to edit the PVCAM.INI file created by RSConfig. See the instructions in ***"Demo, High Speed PCI, and PCI(Timer) are Choices on Hardware Wizard:Interface dialog (Versions 2.5.19.0 and earlier)"***, page 172.

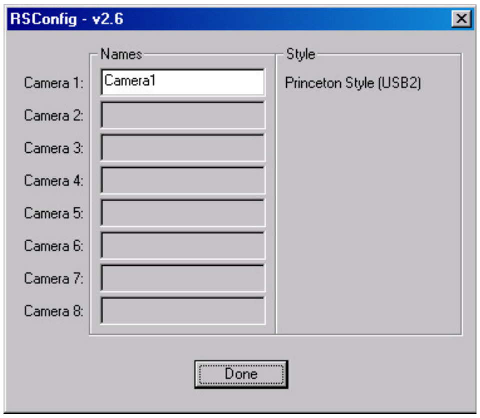


Figure 12. RSConfig dialog

5. Open the WinX application and, from **Setup|Hardware…,** run the Hardware Setup wizard and make the appropriate selections for your system. After the wizard is finished, the **Controller/Camera** tab card will be displayed.

   Note: If your system is using the USB 2.0 interface, click the **Yes** radio button if the PVCAM dialog (Figure 13) is displayed. Otherwise, click **No** and continue through the wizard.

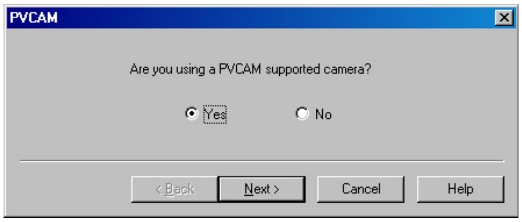


Figure 13. Hardware Setup wizard: PVCAM dialog

6. You should now be able to set up experiments and acquire data. Run the software in focus mode to verify communication between the ST-133 and the host computer.

Chapter 4

First Light

Introduction

This chapter contains procedures (imaging and spectroscopy) that you can use to verify PI-MAX system operation. To reduce the complexity of the setup (hardware and software), these procedures are run in **Shutter Mode**. Much of the setup can be performed under normal lighting. However, the risk of overloading the camera in this mode demands that you subdue room or ambient illumination to where it is hard to see with the eye before data acquisition is started.

Procedures for operating in Gate mode are included in the Gate Mode Operation chapters for the PTG and the DG535.

Note: Issues that could be of importance in some applications are omitted in this chapter for the sake of brevity. General application issues are addressed in Chapter 6 and those that are specific to Shutter Mode and to Gate Mode are addressed in the appropriate chapters.

Required Equipment and Cables

The equipment and cables listed below are required to set up and run the PI-MAX camera system in accordance with the procedures in this chapter. ***Additional equipment and cables required for Gate mode operation and for timing modes other than Free Run are not included in this list.***

- Princeton Instruments PI-MAX Camera
- Princeton Instruments ST-133 Controller.
- PC equipped with a Princeton Instruments (RSPI) PCI Interface card.
- Cables:
  - **PI-MAX to Controlle**r: 6050-0336 for standard PI-MAX or 6050-0499 cable set for PI-MAX2
  - **TAXI high-speed serial data:** 6050-0148 CE
- The system may also include a spectrograph. If so, the camera must be properly mounted to it as described in the spectrograph manual. If the spectrograph will be computer-controlled, a suitable interface cable will additionally be required. See Appendix E ***"Spectroscopy-Mount and Spectrograph Adapters"***, starting on page 203.

Cable Connections

WARNING! ***All of the system components must be turned off before connecting or disconnecting cables.***

The following cabling configuration is used when operating in Shutter Mode. *If the system includes a spectrograph, see your spectrograph manual for information on the spectrograph's cabling requirements.*

1. Connect the PI-MAX to Controller cable.
    - **PI-MAX:** Connect cable 6050-0336 from the **Power/Signal** connector on the back of the PI-MAX to the **Detector** connector on the back of the Controller.
    - **PI-MAX2:** Connect cable set 6050-0449 as follows. Connect cable 6050-0492 from the **Signa**l connector on the back of the PI-MAX2 to the **Camera Signal** connector on the back of the Controller. Connect cable 6050-0493 from the **Power** connector on the back of the PI-MAX2 to the **Camera Pwr** connector on the back of the Controller.
2. Connect the Controller-to-Computer Interface cable.
    - **PI-MAX:** For standard PI-MAX systems, the Controller-to-Computer interface type is determined by the Interface card (TAXI or USB 2) installed in the Controller.
        - **TAXI Interface:** Connect serial data cable (6050-0148 CE) from the ST-133 **SERIAL COM** connector to the computer's Princeton Instrument (RSPI) PCI Serial Interface card connector.
        - **USB 2 Interface:** Connect the USB cable (6050-0494) from the ST-133 **USB 2.0** connector to the computer's **USB 2.0** Interface card connector.
    - **PI-MAX2:** PI-MAX2 systems use the TAXI communication protocol. Connect the TAXI serial data cable (6050-0148 CE) from the ST-133 **SERIAL COM** connector to the computer's Princeton Instruments (RSPI) **PCI** card connector.
3. If the system includes a PTG, no other cable connections are required for operating in Shutter Mode. Procedures for operating with a PTG or a DG535 in Gate Mode are included in the appropriate Gated Operation chapter.

Before Turning on the System

1. Set the PI-MAX MCP On/Off switch to OFF.
2. **Imaging application:** Have the lens stopped down to its smallest aperture (typically f/16). For all experiments, it may be advisable to initially have the intensifier covered with a black cloth and/or a lens cap over the lens, as well.
3. **Spectroscopy application:** Set the spectrograph entrance slit width to minimum (10 µm if possible).

Turning on the System and Setting Up the Software

1. Turn on the ST-133.

   Note: The PI-MAX 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 with no light entering the spectrograph, something is wrong. Turn off the power and contact the factory for guidance.

2. Turn on the computer power.
3. Start the WinX application software (WinView/32 or WinSpec/32 as appropriate).

Configuring the Software for Shutter Mode Operation

Setup menu

1. Select **Hardware**.
2. On the **Controller/Camera** tab, make the following settings.*

   Use PVCAM: (WinX Versions 2.5.19.0 and earlier) If you are using the USB 2.0 interface, verify that the box is checked.
   Controller Type: ST133 for standard PI-MAX or ST-133-5 MHz for PI-MAX2
   Version: 3 or higher
   Camera Type: TH 512 × 512 7895, Marconi (EEV) 256 × 1024 (6 ph) CCD 30-11, Kodak 1024 x 1024, Marconi 1024 x 1024 CCD 47-10, or RS 1340 × 1300 CCD 36-40 whichever array is installed in the camera.
   Shutter Type: Electronic
   Readout Mode: Full Frame (or Interline for Kodak 1024 x 1024)
   LOGIC OUT Output: Shutter
   User Defined Chip: not checked
   User Defined Timing: not checked
   RS170 Type: NTSC or PAL, according to your video monitor type.
   Note: RS170 is not currently supported under USB 2.0 or by PI-MAX2 cameras.

3. On the **Cleans/Skips** tab, make the following settings.

   Number of Cleans: 1
   Number of Strips per Clean: 4
   Minimum Block Size: 16
   Number of Blocks: 32
   Note: Incorporating Cleans minimizes the dark current. However, if an External Sync occurs while a Clean is in progress, the Clean will go to completion before the experiment begins, introducing jitter that can be as large as one complete Clean cycle. If the experiment can tolerate this level of jitter, then operation with Cleans = 1 is recommended. On the other hand, if the experiment requires that jitter be reduced to an absolute minimum, then Cleans should be set to "0." Note that the effect of changing the Cleans setting will only be visible if operating in the **Fast** mode as selected on the Experiment Setup **Timing** tab.

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* Instead of selecting parameters individually, another option is to open the **Setup** menu, select **Load Factory Defaults** and then **From Controller** to load the values stored in the Controller.

4. Select **Detector Temperature** from the **Setup** menu. Set the temperature to -10°C. Temperature lock should occur within ten minutes. Perhaps another twenty minutes will be required for maximum temperature stability to be achieved. To see when the array temperature reaches and stabilizes at the target temperature, leave the Detector Temperature dialog open. When the target temperature is reached, the dialog will report that the Current Temperature has **Locked**.

   Note: If you are using the USB 2.0 interface, the Detector Temperature dialog will not display temperature information while you are acquiring data.

Acquisition menu

1. Select Experiment Setup
2. On the **Main** tab, make the following settings.

   Exposure Time: 10 ms
   CCD Readout: Use Full Chip
   Intensifier
      Gain: 8
      Shutter Mode: selected

3. On the **ADC** tab, select the SLOW ADC Type if this selection is available.
4. On the **Timing** tab, make the following settings:

   Timing Mode: Free Run.
   Continuous Cleans: Checked.
   Shutter Control: Normal checked.
   Mode: Safe Mode

5. Click on **OK** to execute the selections and close the dialog.

Pulser

Because this procedure is being set up for Shutter Mode operation, no Pulser parameters need to be entered. The ST-133 will gate the intensifier on and off based on the Exposure time.

Pre-Acquisition Check

Room Illumination

Shutter Mode operation has been selected for this *First Light* procedure to reduce the setup complexity. However, there is a risk of overloading the camera. For operation in the **Shutter Mode**, the room lighting should be subdued to where it is hard to see with the eye. *The camera is about 100 times more sensitive than the eye.*

If Imaging with a Lens

1. Begin with an aperture of nominally f/16 (lens stopped down as far as possible).
2. Provide a suitable target at the focal distance.
3. Cover the lens.

If Taking Spectra

1. If using a spectrograph, set up to either take an image, or to bin on chip and use a region of interest, reading out the data as a spectrum. This will require selecting **Use Region of Interest** (ROI) on the Experiment Setup **Main** page followed by specifying the ROI via the Experiment Setup **ROI Setup** page.
2. Block light from entering the spectrograph.
3. Mount a suitable light source, such as a mercury pen-ray lamp, 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, as do the neon bulbs commonly used as power-on indicators on power strips.* If there are no "line" sources available, it is possible to use a broadband source such as tungsten for the alignment. If this is the case, use a wavelength setting of 0.0nm for alignment purposes.

Note: If you purchased an optical-fiber adapter and cable, install them only after the regular alignment procedure has been successfully completed. Consult the Optical Fiber Adapter manual for specific instructions.

Initial Data Acquisition

1. Verify that room or ambient lighting is subdued.
2. Set the PI-MAX MCP On/Off switch to ON.

   Note: The PI-MAX 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 with no light entering the lens or spectrograph, something is wrong. Turn off the power and contact the factory for guidance.

3. If you are using a spectrograph, set the software to display a spectrum. With WinSpec/32, this is done by selecting **Layout** on the **Display** menu and then selecting **Graph** on the **General** tab. When viewing the spectrum, select a strip at about mid-range on the CCD by setting the ROI in software.
4. At the computer, select **Focus** mode (WinX **Acquisition** menu). Data acquisition will begin and each frame acquired will be displayed on the computer monitor. Since the intensifier is covered, the PI-MAX lens is capped, or the entrance to the spectrograph is covered, only noise will be displayed.

4. Carefully uncover the intensifier, unblock the spectrograph entrance slit, and/or remove the lens cap. The displayed images should now contain real data over a noise background. If the target is illuminated by overhead fluorescence, some images will be bright and some dark. This occurs because the fluorescent lights flash at 120 Hz (2× 60 Hz line frequency). Because the data acquisition is not synchronized with the line, some images will be acquired at the instant when the lights are on, and others will be acquired at the instant when they are off.

   Note: If the overload warning sounds continuously, immediately cover the intensifier with a black opaque cloth, cap the lens, or reduce the room illumination further.

5. Make adjustments for a good image or spectrum.

   - If the image or spectrum is washed out because the CCD is saturated, reduce the exposure time or the light falling on the intensifier. If it is too dark, increase the exposure time.

   - If using a lens, adjust the lens aperture to maximum (smallest f/ number) possible without the alarm sounding. If necessary, decrease the set Exposure Time to obtain the best viewable (but not yet focused) image as the aperture opens.

6. To stop Focus operation without storing the current frame, click on the **Stop** icon (or select **Stop Acquisition** on the **Acquisition** menu). To store the current frame and stop focus operation, click on the **Start Storage** icon (or select Start Storage on the Acquisition menu).

Focusing

Instructions for focusing C-mount and F-mount lenses are provided in Appendix D. Instructions for focusing the detector on a spectrograph are provided in Appendix E.

Final Comments

This completes the *First Light* directions. If you have followed the instructions, you should have verified the basic operation of your system and performed initial focusing. Subsequent chapters provide more information about operating a PI-MAX system, including a chapter about operating factors that should be considered for both Shutter and Gate modes of operation and separate chapters to discuss specific setup and operating considerations for these modes.

Chapter 5
General Operation Factors

Introduction

The purpose of the First Light chapter was to help you get your system up and running so you could verify that it worked. The step-by-step procedures provided the appropriate settings but did not explain why those settings were selected. The information in this chapter covers general operation factors that apply to both **Shutter Mode** and **Gate Mode** operation of the PI-MAX system. These 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, and background subtraction. Factors that are specific to a particular intensifier mode and pulser are included in the appropriate chapter.

Data Acquisition Sequence

When data is acquired, the CCD array is exposed to an incoming signal, which integrates on the array. At the end of the exposure time, the charge from the array pixels must be read out, digitized, and transferred to the computer before the image from the array appears on the computer screen. This sequence is shown in the block diagram below (Figure 14).

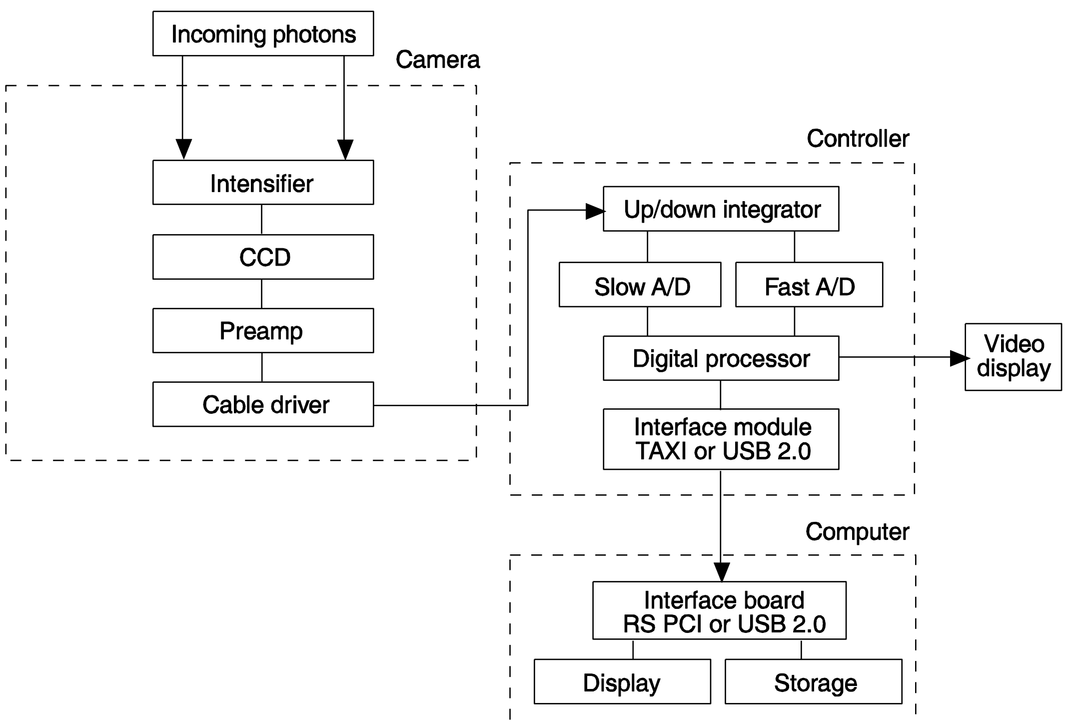

Figure 14. Block Diagram of Signal Path in Standard PI-MAX System

USB 2.0 and System On/Off Sequences

The following on/off sequences are specific to the USB 2.0 interface:

1. The ST-133 must be turned on before the WinX application software (WinView/32 or WinSpec/32) is opened to ensure communication between the controller and the computer. If the WinX application is opened and the ST-133 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 application software, turn on the ST-133, and reopen the WinX application software before you can set up experiments and acquire new data.
2. The WinX application software must be closed before turning off the ST-133. If you turn off the ST-133 before closing the WinX application software, the communication link with the controller 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 application software, turned on the ST-133, and then re-opened the WinX application software.

Pre-Exposure Removal of Accumulated Charge

Introduction

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 is connected to an ST-133 that is turned on, 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.

Dark Charge

As soon as the ST-133 is powered on with a connected PI-MAX camera, 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 while the ST-133 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 time, both the signal of interest and dark charge integrate on the array. The longer the exposure time 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 exposure time 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 (see ***"Background Subtraction"***, page 59).

Notes:

1. 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 ***"Background Subtraction"***, page 59, for more information.
2. Offset and excess noise problems are more likely to occur if the controller and camera weren't calibrated and tested as a system at the factory.

Caution

If you observe a sudden change in the baseline signal you may have excessive humidity in the camera's vacuum enclosure. ***Immediately*** turn off the controller. *Then, contact Princeton Instruments Customer Support for further instructions. See page 232 for contact information*.

Clean Cycles

As stated before, dark charge integrates on the array whenever the camera is on, whether or not data acquisition is occurring. To minimize the dark charge and other noise in the pixel wells when data acquisition is idle, the Clean Cycles function shifts accumulated charge in a predefined number of rows to the shift register and then discards it.

Clean cycles start when you turn the controller on and a clean pattern is programmed into the ST-133. At the end of a cycle, the ST-133 checks to see if a Start Acquisition command has been received. If it has been received, the user-defined number of cleans (typically 0) will be then performed before the exposure time starts. If a Start Acquisition has not been received, the next clean cycle begins.

The number of rows that are shifted and discarded during a clean cycle are defined in the application software (for example, on the WinView/WinSpec **Hardware Setup|Cleans/ Skips** tab). The most effective cleaning occurs when the number of rows equals the number of rows on the CCD. However, you need to keep in mind that a clean cycle must be completed before a Start Acquisition command will be implemented. The more rows in a cycle, the greater the delay between the command receipt and the beginning of an exposure. Because of this timing issue, the number of rows per clean cycle is usually much smaller than the number of rows on the array.

The timing diagram below is for an experiment set up to acquire three (3) images in Free Run timing mode with normal shutter operation selected. 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.

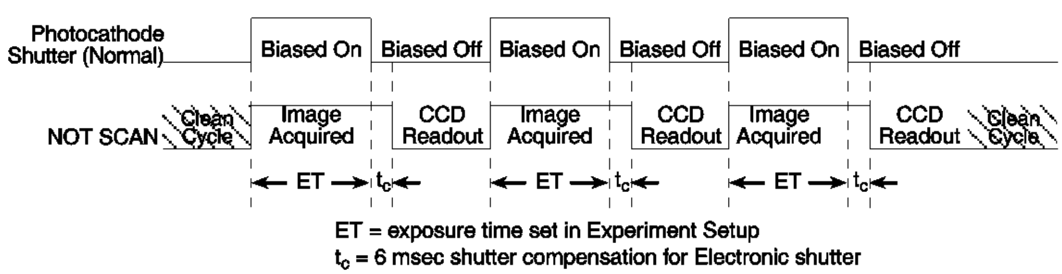

Figure 15. Clean Cycles in Free Run Operation

Note: The start of the exposure is signaled by the **NOT SCAN** output of the SCAN connector going high 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 defined on the **Setup|Hardware Setup|Cleans/Skips** tab. If you enter a value other than "0", you will further delay the start of the exposure by that number of clean cycles.

Continuous Cleans Cycles

The Continuous Cleans function is provided when the start of an exposure is tied to an external trigger (i.e., the experiment is being run in **External Sync** timing mode) to ensure that the array will continue to be cleaned until the External Sync pulse is received. The continuous clean cycles are defined by the same parameter values as the standard clean cycles. The difference is that continuous clean cycles occur between **NOT SCAN** going high and External Sync pulse arrival. Continuous cleans cycles ensure that ambient light and dark current signal integrating on the array is continuously removed while the ST-133 is waiting for an External Sync pulse after the receipt of the Start Acquisition signal.

Note: When the **External Sync** arrives during a continuous clean cycle, that cycle must be completed before the exposure will begin. In time critical experiments, the number of rows per clean (set on the **Hardware Setup| Cleans/Skips** tab) should be 1 or 2 to minimize the delay.

Figure 16 shows the timing diagram for an experiment with External Sync trigger active on the negative edge. Note that the timing diagram shows two possible setups for the photocathode. In the first setup (Normal), the photocathode is biased on when External Sync goes low. Because it takes time to bias the photocathode on, part of the incoming signal may be missed while the photocathode is turning on. In the second setup (PreOpen), the photocathode is biased on when the following conditions are met: the command is received, clean cycles finish, and the **NOT SCAN** signal goes high. The advantage is that the photocathode is fully on when the exposure (triggered by External Sync) begins. The disadvantage is that ambient light is no longer being blocked from the array. Continuous cleans provide a way to get rid of the signal that accumulates on the array during that period.

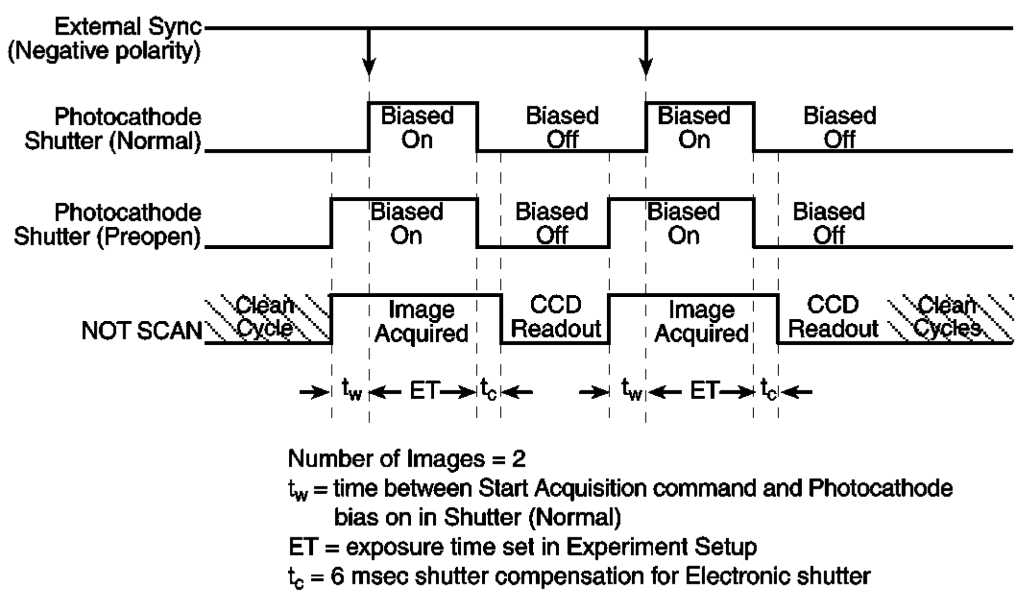

Figure 16. Timing Diagram: External Sync without Continuous Cleans

Figure 17 shows a timing diagram that is basically the same as the one shown in Figure 16. The difference is the continuous cleans (indicated by the shaded areas labeled CC) that now occur during t_w (the waiting period during which External Sync will be accepted).

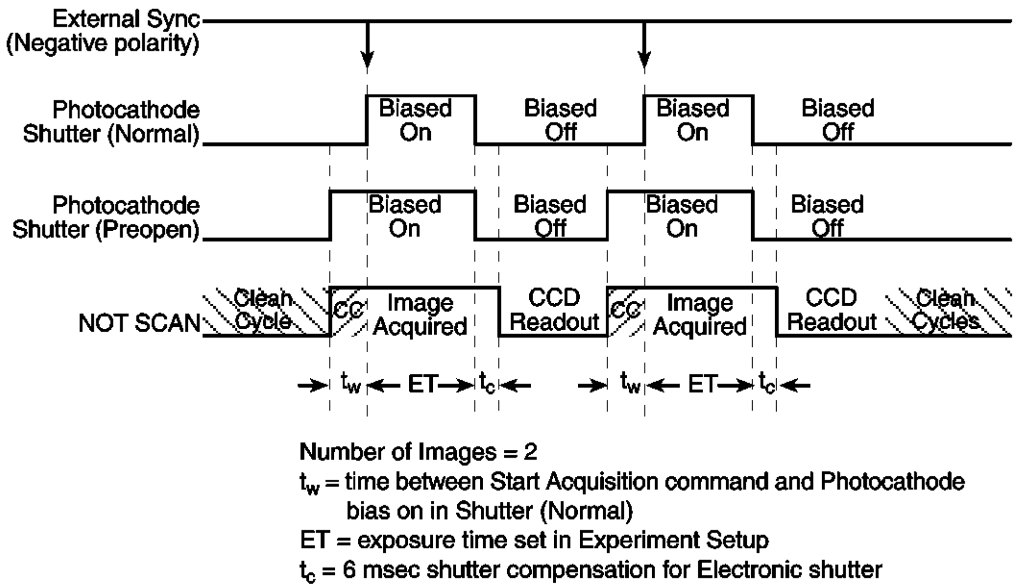

Figure 17. Timing Diagram: External Sync with Continuous Cleans

Shutter Compensation Time

Shutter Compensation Time is the amount time inserted between the end of the exposure time and the beginning of the array readout. This amount of time is determined by the **Shutter Type** choice on the **Hardware Setup|Controller/Camera** tab card). For a PI-MAX, the appropriate choices are "Electronic" and "None". When "Electronic" is selected, 6 ms is inserted to allow time for the phosphor to decay: this choice is appropriate for a P43 phosphor. No time is inserted when "None" is selected: this choice is appropriate for a P46 phosphor.

Temperature Control

WARNING

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

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 fan and exhausted through the back-panel grill. The fan is always running and cooling the CCD and the internal electronics. Additional heat removal can be performed by circulating water through an internal heatblock.

Air-cooling: With air-cooling alone, at an ambient temperature of 25°C, temperature lock at -20° 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.

Supplemental Water-cooling: 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.

WARNING

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-MAX***. This condensation can cause ***catastrophic failure*** of the detector 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-MAX 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-MAX inside a plastic bag and to then purge the bag with a continuous flow of dry nitrogen. On completion of the experiment, be sure to continue the purge until the PI-MAX's internal cold surfaces have had time to warm to the ambient laboratory temperature. Contact the factory if you require additional information.

See ***"Making the Coolant Circulator-Camera Connections"***, page 44 for additional information regarding the use of water with a temperature below laboratory ambient.

Setting the Temperature

Regardless of the type of cooling, the CCD array temperature is set via the software **Detector Temperature** dialog, accessed by selecting **Detector Temperature** on the **Setup** menu (WinView/32 or WinSpec/32). Temperature lock to a set temperature in the operating range will typically occur within ten minutes. Perhaps another twenty minutes will be required for maximum temperature stability to be achieved. To see when the array temperature reaches and stabilizes at the target temperature, leave the **Detector Temperature** dialog open. When the target temperature is reached, the dialog will report that the Current Temperature has **Locked**.

Note: If you are using the USB 2.0 interface, the **Detector Temperature** dialog will not display temperature information while you are acquiring data.

Exposure

Data acquisition has two parts: exposure and readout. Exposure refers to the integration of a signal of interest on the CCD array and 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 (set 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-MAX rely on gating the intensifier off, to prevent light from reaching the array. During each data acquisition, the intensifier is gated on for the duration of the exposure time, allowing the pixels to register light, and is then gated off for the readout period.

Exposure with an Image Intensifier

PI-MAX 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. For shorter exposures, a PTG or a DG535 timing generator is required.

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 brightness intensity (EBI). All standard intensified cameras made by Princeton Instruments have the lowest EBI values possible.

Saturation

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

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

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 (camera temperature, exposure time, 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 is acquired, save it to disk.

After storing the background data to disk, you have two choices for background subtraction: automatic or post-processing.

- **Automatic:** This approach requires that you activate "Background" and specify the background filename on the **Acquisition|Experiment Setup…|Data Corrections** tab before acquiring an image. When you acquire an image, the specified background file data will automatically be subtracted 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. Then, acquire the image, save the raw image data to disk, and, via the Image (or Spectra) Math function (accessed from the **Process** menu), subtract the background file data from the raw image data. The subsequent data can then be saved to a separate file.

Readout of the Array

At the end of the exposure time, the charge from the pixels is shifted to the shift register, amplified, and digitized. In this section, a simple 6 × 4 pixel CCD is used to demonstrate how charge is shifted and digitized. As described below, three different types of readout are available: full frame, interline, and binned. Full frame readout, for full frame CCDs, reads out the entire CCD surface at the same time. Interline readout, for interline CCDs, can readout the array using either overlapped or non-overlapped mode. Binned readout (also known as Hardware Binning) adds the charge from adjacent pixels together to form a single pixel (sometimes called a super-pixel) *before* the preamplifier reads out the signal.

Full Frame Readout

The upper left drawing in Figure 18 represents a CCD after exposure but before the beginning of readout. The capital letters represent different amounts of charge, including both signal and dark charge. This section explains readout at full resolution, where every pixel is digitized separately.

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

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

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

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

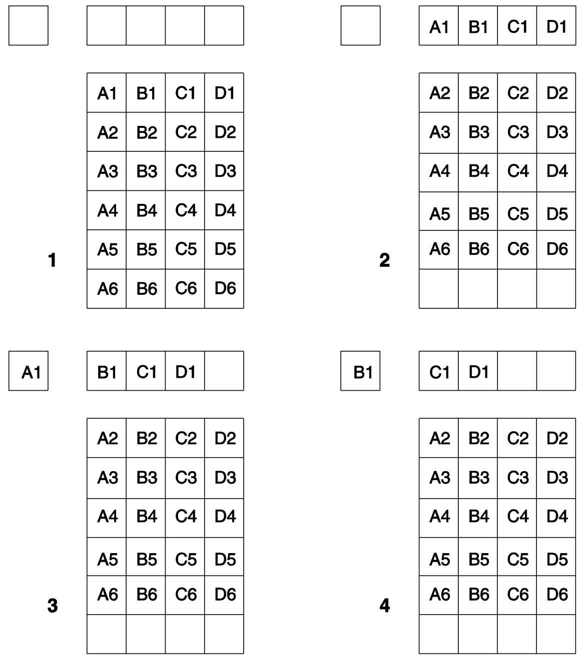

Figure 18. Full Frame at Full Resolution

Interline Readout

In this section, a simple 6 × 3 pixel interline CCD is used to demonstrate how charge is shifted and digitized. As described below, two different types of readout, overlapped and non-overlapped can occur. In overlapped operation, each exposure begins while the readout of the previous one is still in progress. In non-overlapped operation (selected automatically if the exposure time is shorter than the readout time) each readout goes to completion before the next exposure begins.

Overlapped Operation Exposure and Readout

Figure 19 illustrates exposure and readout when operating in the overlapped mode. Figure 19 contains four parts, each depicting a later stage in the exposure-readout cycle. Eight columns of cells are shown. Columns 1, 3, and 5 contain imaging cells while columns 2, 4, and 6 contain storage cells. The readout register is shown above the array.

Part 1 of the figure shows the array early in the exposure. The imaging cells contain charge proportional to the amount of light integrated on each of them. The storage cells are empty because no charge has been transferred to them. The arrows between adjacent imaging and storage cells indicate the direction the charge will be shifted when the transfer occurs.

Part 2 of Figure 19 shows the situation early in the readout. The charge in the imaging cells has been transferred to the adjacent storage cells and up-shifting to the readout register has started. Note that a new exposure begins immediately.

Part 3 of Figure 19 shows the transfer to the output node. The lowermost cell 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 of the array for further processing. The process continues until all charges have been completely transferred out of the array. The imaging cells continue accumulating charge throughout the readout process. Integrating in this way while the readout takes place achieves the maximum possible time efficiency.

Part 4 of Figure 19 illustrates the situation at the end of the readout. The storage cells and readout register are empty, but the ongoing accumulation of charge in the imaging cells continues until the end of the programmed exposure.

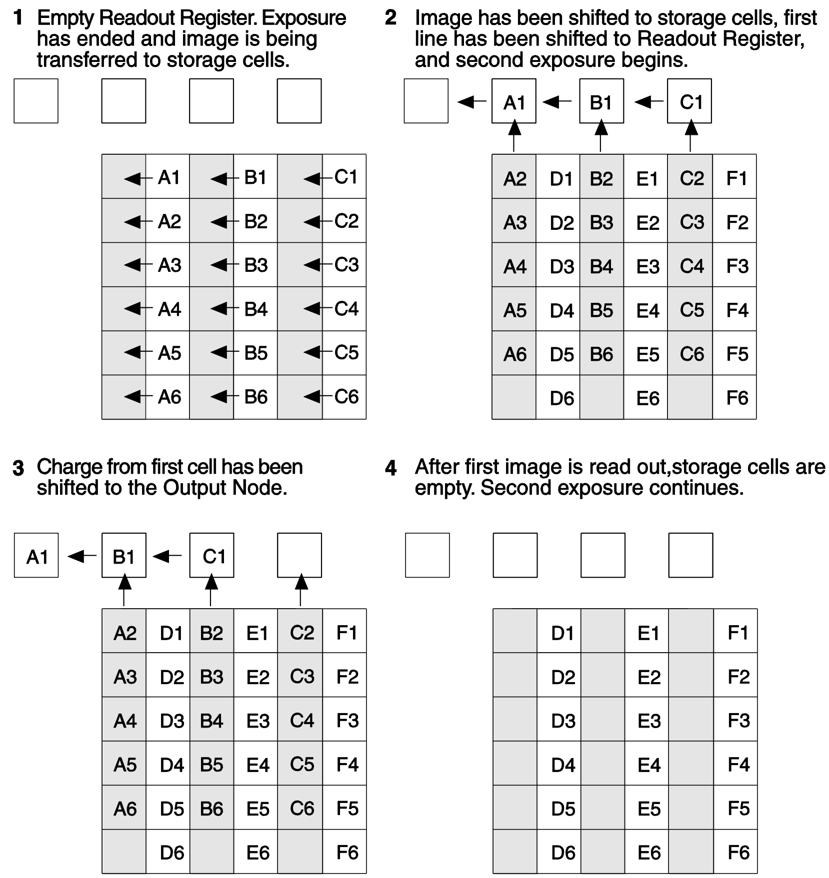

Figure 19. Overlapped Mode Exposure and Readout

Non-Overlapped Operation Exposure and Readout

Figure 20 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 20 contains four parts, each depicting a later stage in the exposure-readout cycle.

Part 1 of the figure shows the array early in the exposure. The imaging cells contain charge proportional to the amount of light integrated on each of them. The storage cells are empty because no charge has been transferred to them. The arrows between adjacent imaging and storage cells indicate the direction the charge will be shifted when the transfer occurs.

Part 2 of Figure 20 shows the situation early in the readout cycle. The charge in the imaging cells has been transferred to the adjacent storage cells and up-shifting to the readout register has started. Note that a second exposure doesn't begin while the readout is in progress.

Part 3 of Figure 20 shows the transfer to the output node. The lowermost cell 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 of the array for further processing. The process continues until all charges have been completely transferred out of the array. The imaging cells are electronically switched off and do not accumulate any charge as the readout takes place. Because this scheme is less time efficient than that used in the overlapped mode, the frame rate may be lower in non-overlapped operation than it is in overlapped operation with the some exposure time settings.

Part 4 of Figure 20 illustrates the situation at the end of the readout. Both the imaging and storage cells are empty. In Free Run operation, the imaging cells will be switched back on immediately, allowing charge accumulation to begin. In Ext Sync operation with no PreOpen, they are not switched back on until after the External Sync pulse is detected.

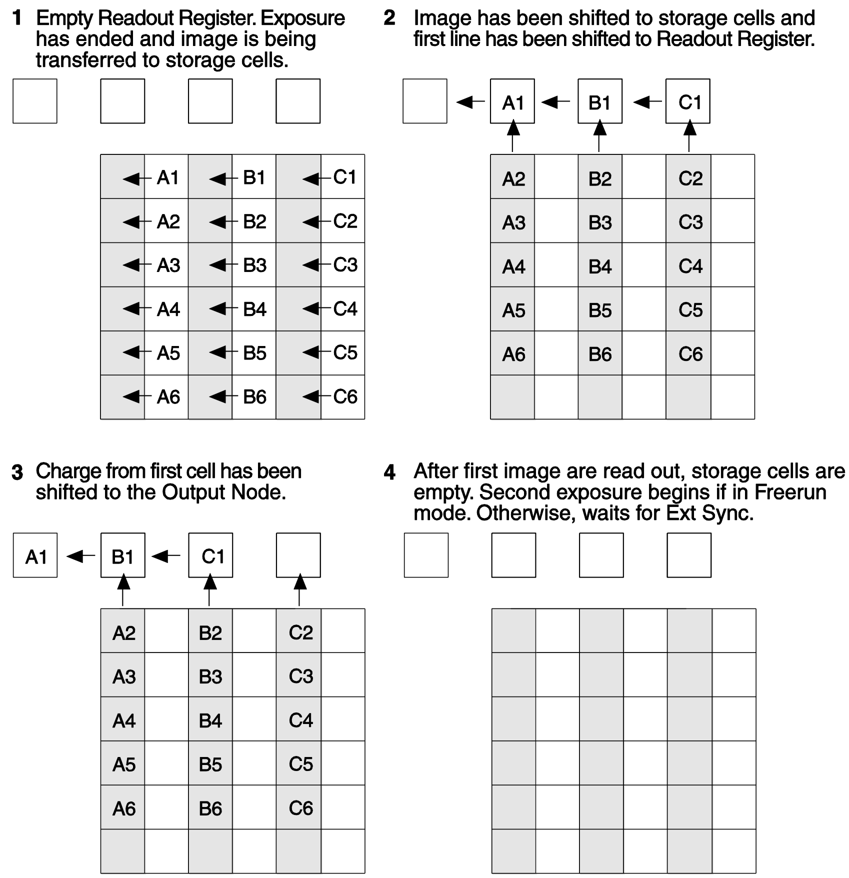

Figure 20. Non-Overlapped Mode Exposure and Readout

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).

Readout Rate for Interline

Below are the equations that determine the rate at which the CCD is read out. Tables of values for CCDs supported at the time of the printing of this manual also appear below.

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

$$t_R + t_{exp} \tag{1}$$

where

t_R is the CCD readout time,
t_{exp} is the exposure time.

The readout time is approximately given by:

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

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

The readout rate in frames per second for the PI-MAX2:1003 Kodak 1024 × 1024 interline array running at 5 MHz is shown in Table 3.

	Region of Interest Size		
Binning	**1024 × 1024**	**400 × 400**	**200 × 200**
1 × 1	4	10	17
2 x 2	8	17	27
4 × 4	15	27	37

Table 3. Readout Rates for Kodak 1024 × 1024 Array at 5 MHz

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).

Binned Readout (Hardware Binning)

Introduction

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 the WinX application, hardware binning is set up on the **Acquisition|Experiment Setup…|ROI Setup** tab card by entering a value in the **Group** fields: for example, a "2" in each of the Group fields will set up 2 x 2 hardware binning.

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.

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.

Full Frame CCD

Figure 21 shows an example of 2 × 2 binning for a full frame CCD. Each pixel of the image displayed by the software represents 4 pixels of the CCD array. Note that in WinSpec, Y-axis (slit) binning occurs automatically: the **Image** option must be installed and selected for any other binning format to be available.

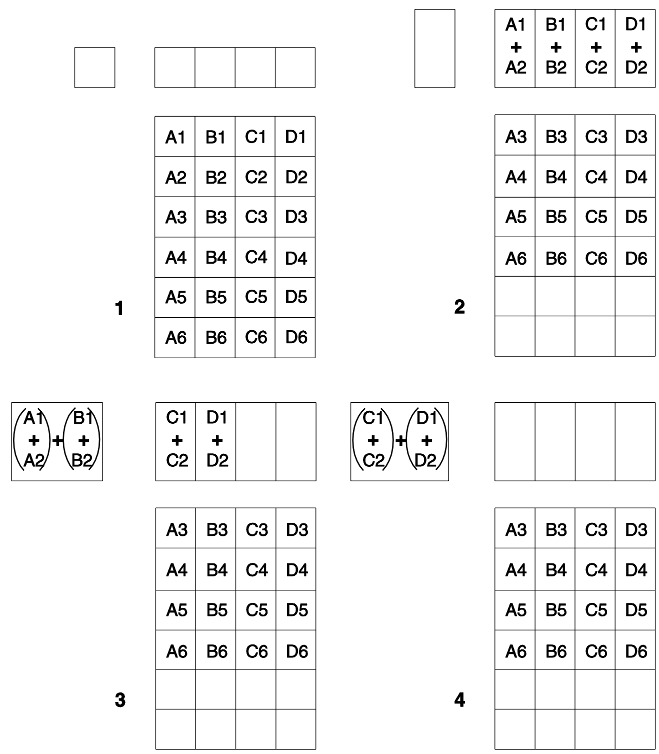

Figure 21. 2 × 2 Binning for Full Frame CCD

Interline CCD

Figure 22 shows an example of 2 × 2 binning. Each pixel of the image displayed by the software represents 4 pixels of the CCD array. Rectangular bins of any size are possible.

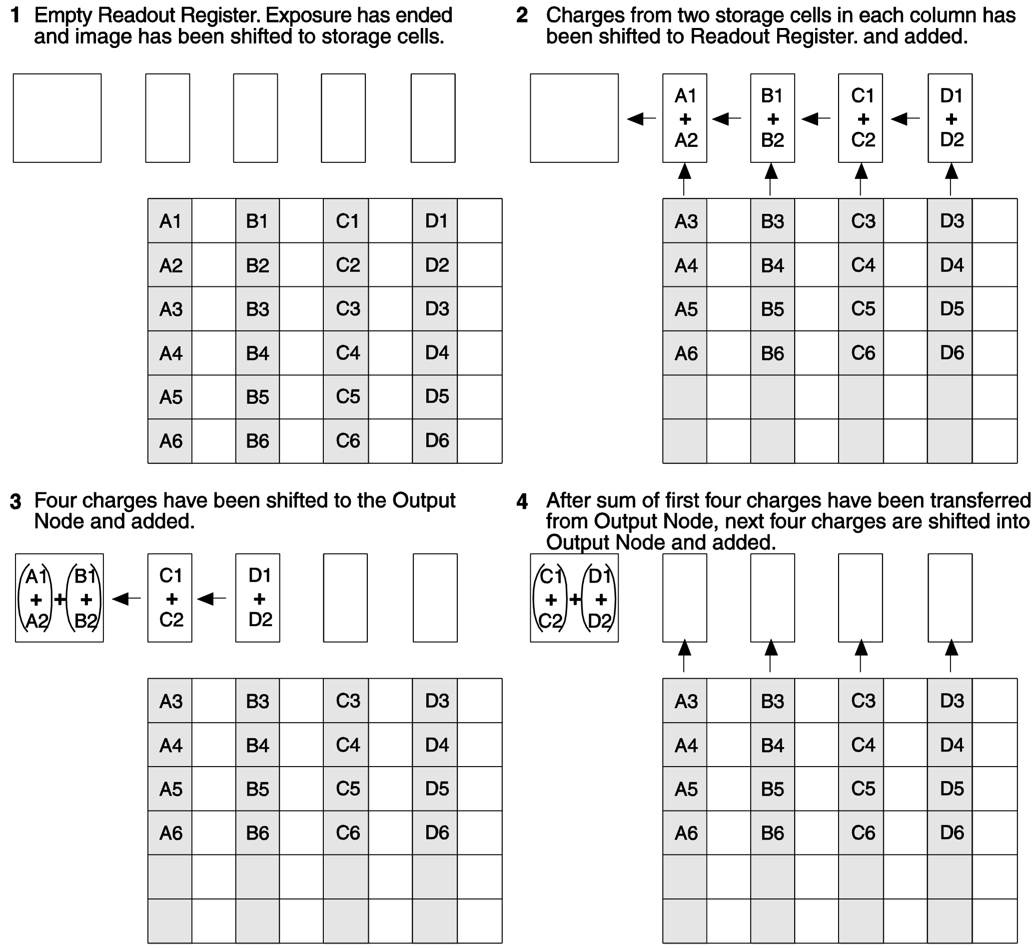

Figure 22. 2 × 2 Binning for Interline CCD

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

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 the WinX application software, software binning can either be set up to occur automatically or as a manual post-processing operation. 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.

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 based on both the hardware and the settings programmed into the camera through the software.

For PI-MAX systems, the ST-133 has 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, one optimized for high speed, the other for high precision, provide a solution to this problem. Switching between the channels is completely under software control for total experiment automation.

Experiment Setup|Main

Typically, the first experiment setup parameters are selected/entered on the **Experiment Setup|Main** tab. These parameters determine such things as how long the signal of interest will be allowed to integrate on the CCD, 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.

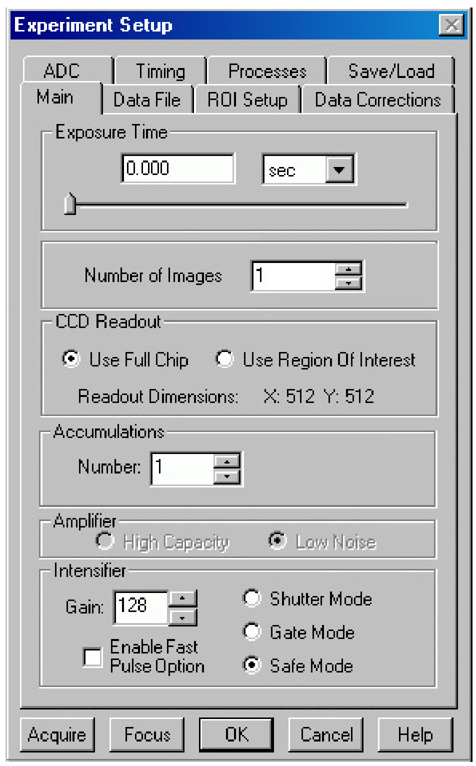

Figure 23. Experiment Setup|Main tab

Exposure Time

Exposure time is the "time space" from which charge accumulating on the CCD will be summed into the reported data. When the system is being run in Shutter Mode and Free Run or External Sync mode, the exposure time is determined by the user-set value in the experiment setup. When Shutter Mode and Internal Sync are active, the exposure time is set to zero (0). When Gate Mode is active, the intensifier controls what the CCD sees during the exposure time.

An exposure can be zero and still have valid data, provided the CCD is not clearing off charge acquired before the integration time: this is the condition of **External Sync with no cleans**, and the integration time is 'unofficially' started at either the Start Acquisition command or from the last readout. This is contrary to **External Sync Continuous Cleans** in which accumulated charge is removed prior to the integration time.

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.

Amplifier

If the CCD is a Thomson 512 × 512 CCD array, either the high-capacity (fast) or the low-noise array output node can be selected. The actual selection is made by selecting **FAST** (high capacity) or **SLOW** (low noise) on the **Experiment Setup|A/D** tab. The parameter indications **High Capacity** and **Low Noise** on the **Experiment Setup|Main** tab are reported values only. The default setting is read from non-volatile RAM (NVRAM) in the PI-MAX. If the selection is changed, the new setting is written to the NVRAM and becomes the new starting default.

- **High Capacity:** Allows the camera to collect 16-bit images at a readout rate of up to 1 million pixels per second.
- **Low Noise:** When operating at a lower speed, the camera provides superior noise performance.

Intensifier Gain

The Intensifier gain provides continuous adjustment over an arbitrary range of 0-to-255. The default setting of 128 will give good results in many applications. Once the ST-133 is turned on, the gain can be adjusted any time during image acquisition. We suggest beginning with a low setting and then increasing it until optimum results are obtained.

Note: The intensifier gain also affects the dark charge of the intensifier (EBI). 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 act as a mechanical shutter that is biased on or off based on the set exposure time (Shutter Mode), it will be biased on or off by the defined pulser gate timing (Gate Mode), or it will be continuously biased off until either Shutter mode or Gate mode is selected (Safe Mode).

Experiment Setup|Timing

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 (Figure 24). 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 6 "Shutter Mode Operation", Chapter 7 "Gated Operation with a PTG", and Chapter 8 "Gated Operation with a DG535".

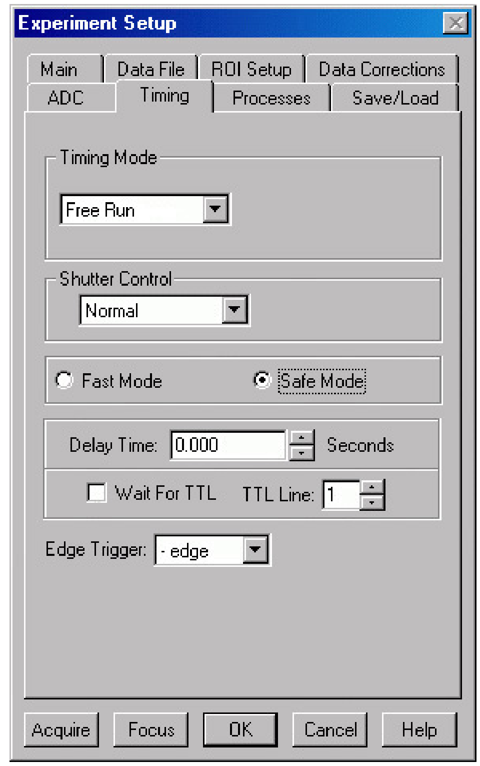

Figure 24. Experiment Setup|Timing dialog

Timing Mode

The timing mode parameter refers to the ST-133's synchronization of data acquisition with an external TTL signal applied to the Ext Sync connector on the back of the ST-133 or an internal trigger generated by a PTG. The modes available depend on the selected intensifier mode (**Shutter**, or **Gate**) and the selected pulser (**None**, **PTG**, or **DG535**).

Shutter Control

Since the ST-133 is gating the photocathode on and off as if it were a mechanical shutter, you may have the choice of **Normal**, **Disabled Closed**, or **Disabled Open** "shutter" settings. **Normal** is available for the Free Run and External Sync timing modes. **Disabled Closed** simply means that the photocathode will not be gated during the experiment and is useful for acquiring background frames. **Disabled Open** is required for the PTG Internal Sync control. Additionally, the **PreOpen** checkbox is only available for the External Sync modes and for Internal Sync for PTG: PreOpen biases the photocathode on before data acquisition is started.

Fast Mode or Safe Mode

The Fast Mode or Safe Mode selection determines whether the ST-133 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 25 compares the two modes.

Fast Mode operation is primarily for collecting “real-time” sequences of experimental data, where timing is critical and events cannot be missed. Once the ST-133 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 video monitor connected to the VIDEO output will always display the current image.* 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 25, 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 ST-133 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.

Wait for TTL and TTL Line

When checked, acquisition will not begin until a TTL high (Level 1) is detected on the specified line of the ST-133's TTL In/Out connector. For example, suppose **Wait for TTL** and **TTL Line 2** were selected, and you then clicked on **Focus** or **Acquire**. Data collection would not begin until additionally, a TTL high was detected on TTL Line 2 of the controller’s TTL In/Out connector. Note that data acquisition, once initiated, cannot be halted by reversing the TTL state on the selected line.

With **Wait for TTL** selected in **Ext. Sync.** mode operation, after detecting a TTL 1 on the specified line, the system still waits for the External Sync edge before data acquisition is initiated.

Notes:

1. TTL In/Out control is not currently supported under USB 2.0.
2. TTL control is further described in Chapter 13, starting on page 149.

Edge Trigger

When running in **Ext. Sync.** mode, this parameter setting determines whether synchronization will take place on the positive-going or negative-going edge of the External Sync signal.

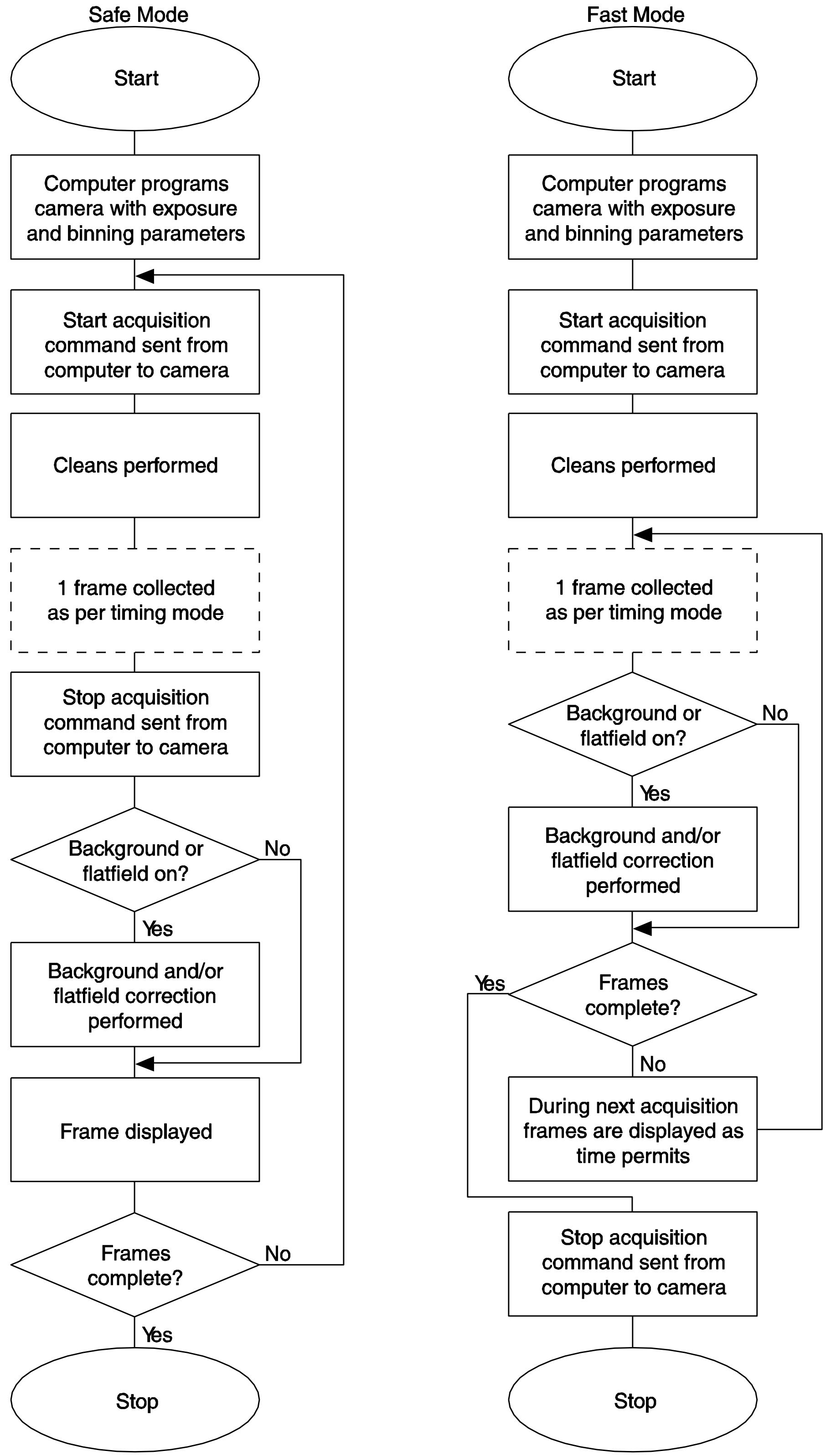

Figure 25. Safe Mode and Fast Mode Operation

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Chapter 6
Shutter Mode Operation

Introduction

Shutter Mode is the simplest PI-MAX intensifier operating mode and, as in Chapter 4, can be used to verify initial operation and to focus the camera and/or spectrograph. In Shutter Mode operation, intensifier gating is under the control of signals from the ST-133. These signals are applied to the PI-MAX via the cable connected to the Power/Signal connector. Their generation and timing are under software control and the ST-133 treats the photocathode as if it were a mechanical shutter. With the exception of the Internal Sync (PTG) timing mode, the photocathode is held biased ON during the selected exposure time, allowing the PI-MAX to see light continuously during that time, and is biased OFF for the readout period.

Note: No timing generator is needed for **Shutter Mode** operation.

Cabling

With the exception of the Internal Sync (PTG) timing mode, a timing generator is not used in **Shutter Mode** operation.

- If a PTG is installed in the ST-133, older systems require that cable to the PI-MAX's **Timing Gen.** connector be disconnected; newer systems ignore the connector when **Shutter Mode** is being used.
- If a DG535 is cabled to the PI-MAX and the ST-133, the DG535 should be powered down or the cables to the ST-133 **Ext. Sync** connector and to the PI-MAX's **Timing Gen.** connector should be disconnected.

Shutter Control

Since the ST-133 is gating the photocathode on and off as if it were a mechanical shutter, you have the choice of **Normal** and **PreOpen** "shutter" settings. **Normal** is available for the Free Run and External Sync timing modes. **PreOpen** is only available for the External Sync modes and Internal Sync for PTG.

- **Normal:** The photocathode is biased on and off in synchronism with system timing. With External Sync and External Sync with Continuous Cleans modes, photocathode gating is controlled by the External Sync pulse. The ST-133 waits for the pulse and then gates the photocathode on for the set exposure time. As soon as the exposure is complete, the photocathode is biased off, the shutter compensation time elapses, and the array is read out.
- **PreOpen:** Available in the External Sync and External Sync with Continuous Cleans modes, photocathode gating is only partially synchronized to the experiment. The photocathode is gated on as soon as the ST-133 is ready to receive an External Sync pulse. When the External Sync pulse arrives at the Ext Sync input, the photocathode remains on until the end of the set exposure time, the photocathode is biased off, the

shutter compensation time elapses, and the array is read out. If additional frames are to be acquired, the photocathode will be gated on again and the ST-133 will wait for an External Sync pulse.

PreOpen would be selected for experiments in which the event occurs before the photocathode would have time to gate on (i.e., the time between the External Sync pulse and the event is shorter than the propagation delay between the External Sync pulse and the time it takes to bias the photocathode on).

Note: The main drawback to this shutter setting is that the CCD is exposed to any ambient light while the photocathode is gated on between frames. To counteract signal integration during this period, you could choose **Continuous Cleans**.

Timing Modes

Timing Mode	"Shutter" Control	Pulser	Ext Trigger Input
Free Run	Normal	None	None
External Sync	Normal	None	Ext Sync BNC
External Sync	PreOpen	None	Ext Sync BNC
External Sync w/Continuous Cleans	Normal	None	Ext Sync BNC
External Sync w/Continuous Cleans	PreOpen	None	Ext Sync BNC
Internal Sync	PreOpen, Disabled Open	PTG	Ext. Trig. In. BNC

Table 4. Timing Mode, Shutter Control, Ext. Trigger Input for Shutter Mode

The timing mode selection determines when signal integration will begin and end on the CCD array and when the acquired signal will be read out. The following three timing modes are available in **Shutter Mode**:

- **Free Run:** One cycle follows another automatically at the fastest frame rate possible. The intensifier is gated on for the set Exposure Time during each cycle, gated off at the end of the exposure time, and then read out. Any External Sync signals are ignored.
- **External Sync:** A suitable signal from an external source must be applied to the ST-133's **Ext. Sync** input. When the External Sync pulse is detected, the intensifier will be gated on and pass light to the CCD for the set Exposure Time, will be gated off at the end of the exposure time, and CCD array readout will occur. The Accumulations and Images parameters remain active; the proper number of pulses need to be applied to finish the experiment. Note that when Continuous Cleans is selected, there will be a delay between the time that the intensifier is gated on and the start of the desired signal integration on the CCD array.
- **Internal Sync: (PTG only)** This timing mode is only available if there is a PTG installed in the ST-133. If Internal Sync is selected, the PTG will control the timing of the camera as if the camera were in External Sync mode and the PTG was the external trigger source. The PTG also has its own External Trigger In BNC that accepts a wide variety of inputs, as opposed to the External Sync of the ST-133, which only accepts TTL levels.

  In order for the ST-133 to see signals from the PTG when Internal Sync is selected, the following parameters should be set as indicated:

Continuous Cleans: Disabled

Shutter Type: Electronic Shutter

Trigger Polarity: Negative edge

Timing Modes and Cleans/Continuous Cleans

This section provides timing diagrams, grouped by timing mode, to further describe the purpose and timing of clean cycles and continuous clean cycles. See Chapter 5, for general information about Clean cycles and Continuous Cleans cycles.

Free Run

The timing diagram below is for an experiment set up to acquire three (3) images in Free Run timing mode with normal shutter operation selected. 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.

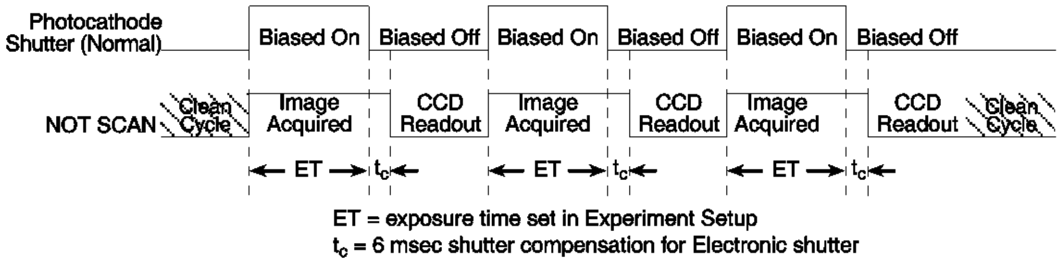

Figure 26. Clean Cycles in Free Run Operation

Note: The start of the exposure is signaled by the **NOT SCAN** output signal of the **SCAN** connector going high but will not occur until the current clean cycle and the additional user-defined number of cleans have finished. "Number of Cleans" is defined on the **Setup|Hardware Setup|Cleans/Skips** tab. If you enter a value other than "0", you will further delay the start of the exposure by that number of clean cycles.

External Sync

Figure 27 is a flowchart that shows the sequence of actions depending on the type of Shutter Control. Figure 28 is a timing diagram of the same sequences with an External Sync trigger active on the negative edge. In the first setup (Normal), the photocathode is biased on when External Sync goes low. Because it takes some time to bias the photocathode on, part of the incoming signal may be missed while this is happening. In the second setup (PreOpen), the photocathode is biased on when the following conditions are met: the Start Acquisition command is received, clean cycles finish, and the **NOT SCAN** signal goes high. The advantage is that the photocathode is already biased on when the exposure (triggered by External Sync) begins. The disadvantage is that ambient light is no longer being blocked from the array. Continuous cleans provide a way to get rid of the signal that accumulates on the array during that period.

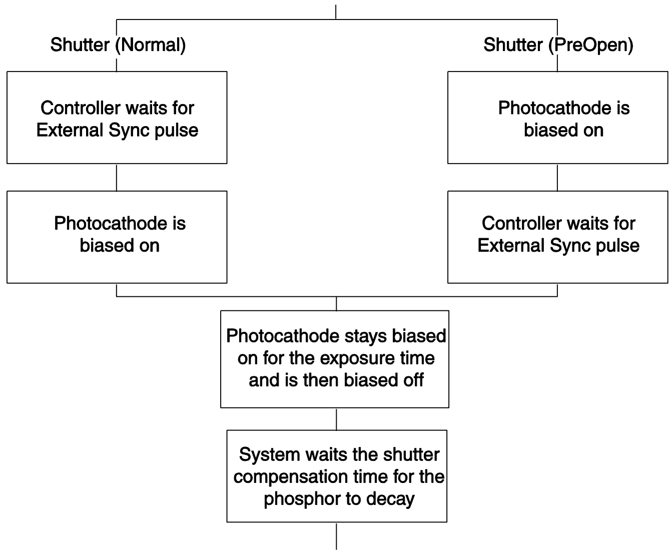

Figure 27. Flowchart of Two External Sync Timing Options in Shutter Mode

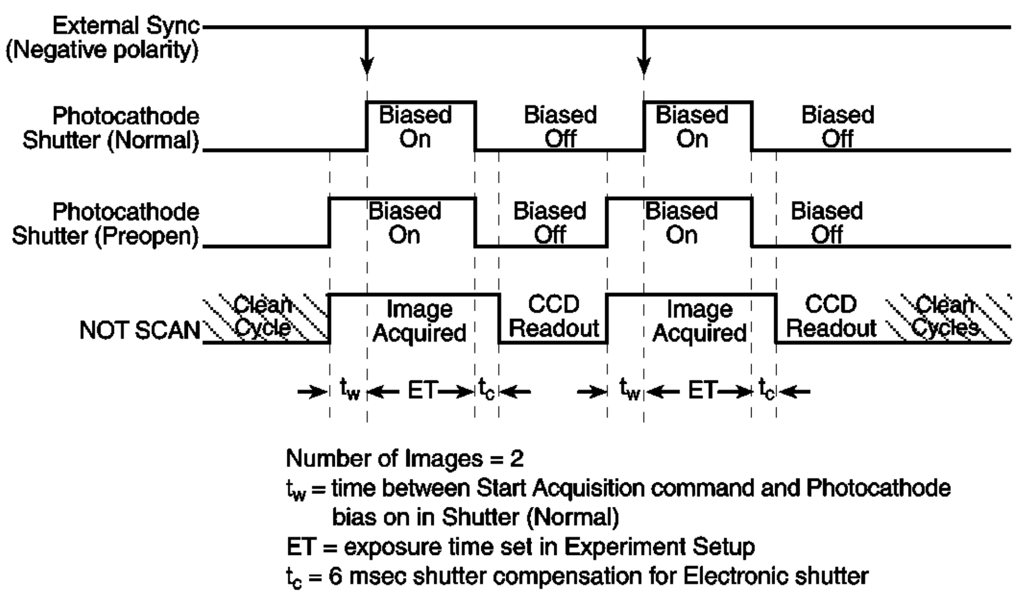

Figure 28. Timing Diagram: External Sync

Figure 29 shows a timing diagram that is basically the same as the one shown in Figure 28. The difference is the continuous cleans (indicated by the shaded areas labeled CC) that now occur during t_w (the waiting period during which External Sync will be accepted).

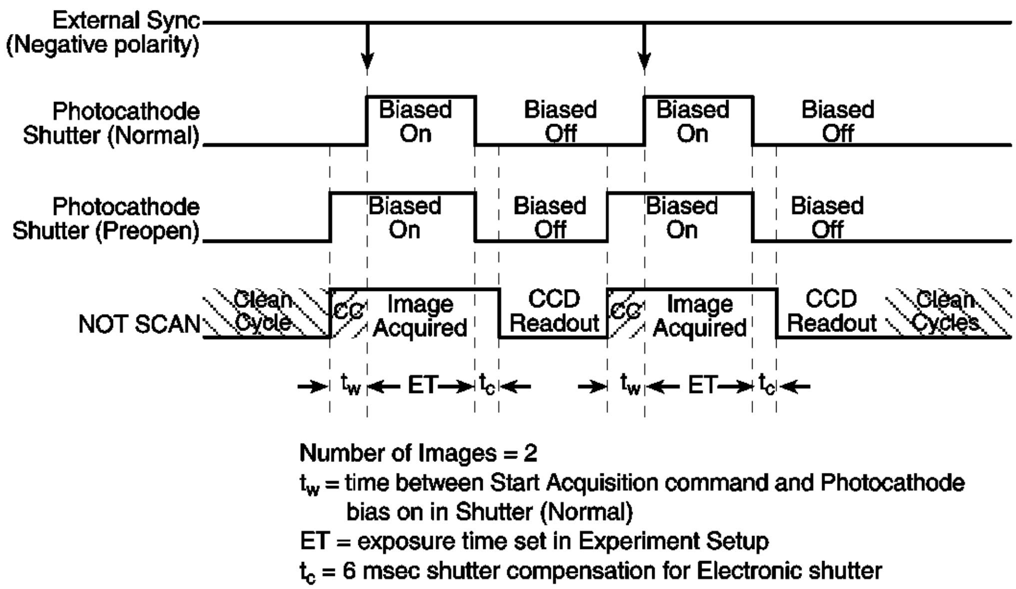

Figure 29. Timing Diagram: External Sync with Continuous Cleans

Further information about the sequence of events for External Synchronization is detailed below based on Shutter Control setting, Clean Cycles, and Continuous Cleans

- **Ext Sync & Shutter Control = Normal**
  Normal clean cycles occur while waiting for the Start Acquisition command. When it is received, a final clean cycle occurs and then the controller waits for the Ext Sync to appear at its Ext Sync BNC. When it occurs, the photocathode is biased on and signal of interest integration begins on the array. Dark charge accumulates on the array in the time between the end of the last clean cycle and the arrival of the Ext Sync.

- **Ext Sync & Shutter Control = PreOpen**
  Normal clean cycles occur while waiting for the Start Acquisition command. When it is received, a final clean cycle occurs and the photocathode is biased on. The controller waits for the Ext Sync to appear at its Ext Sync BNC. When it occurs, the signal of interest integration begins on the array. Dark charge accumulates on the array in the time between the end of the last clean cycle and the arrival of the Ext Sync.

- **Ext Sync w/ Continuous Cleans & Shutter Control = Normal**
  Normal clean cycles occur while waiting for the Start Acquisition command. When it is received, clean cycles continue to occur while the controller waits for the Ext Sync to appear at its Ext Sync BNC. When it occurs, the current clean cycle goes to completion, the photocathode is biased on, and signal of interest integration begins on the array. Dark charge accumulation on the array is minimized during the time between the receipt of the Start Acquisition command and the arrival of the Ext Sync.

- **Ext Sync w/ Continuous Cleans & Shutter Control = PreOpen**
  Normal clean cycles occur while waiting for the Start Acquisition command. When it is received, the photocathode is biased on and clean cycles continue to occur while the controller waits for the Ext Sync to appear at its Ext Sync BNC.

When it occurs, the current clean cycle goes to completion, signal of interest integration begins on the array. Ambient light and dark charge accumulation on the array is minimized during the time between the receipt of the Start Acquisition command and the arrival of the Ext Sync.

Internal Sync (PTG)

Clean cycles function as previously described. However, the Continuous Cleans function is disabled.

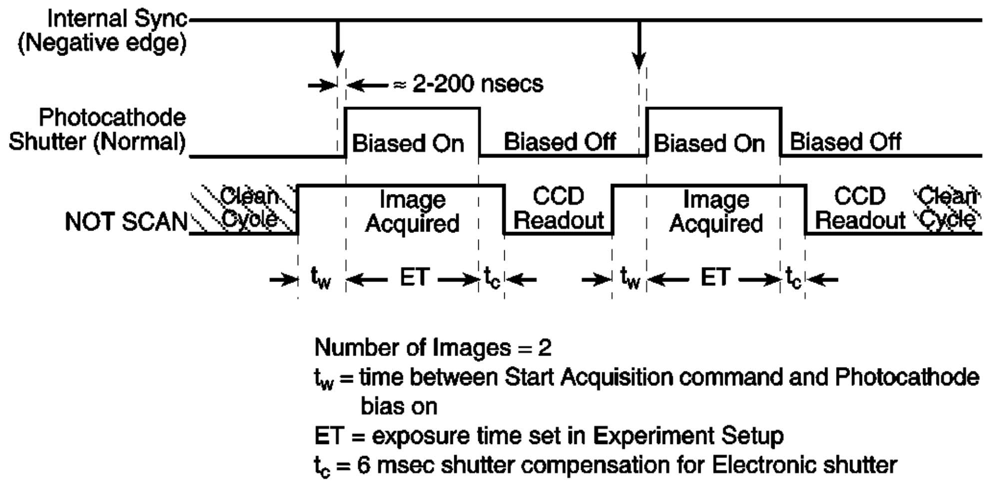

Figure 30. Timing Diagram: Internal Sync (PTG)

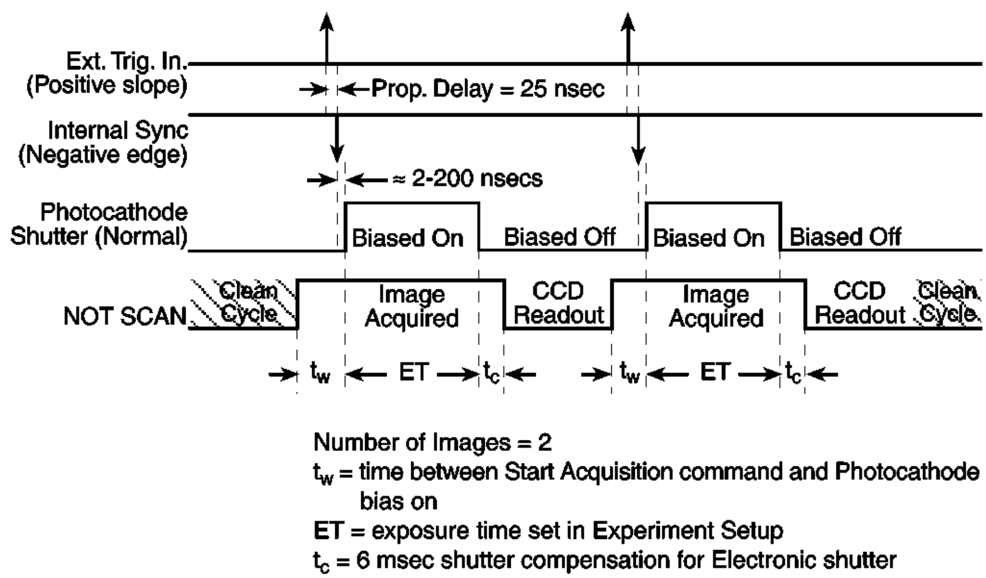

Figure 31. Timing Diagram: Internal Sync with an External Trigger

External Triggering

When an **External Sync** timing mode is selected, the ST-133 waits for the Start Acquisition command from the computer and a TTL level change (negative- or positive-edge as set on the **Experiment Setup|Timing** tab) to occur at the **Ext Sync** BNC before starting the exposure time. The camera will begin the data acquisition cycle as soon as the current clean cycle ends. The data acquisition cycle includes the exposure time, shutter compensation time (unless Shutter Type is **None**), and the readout time.

If a PTG is installed in the ST-133 and **Internal Sync** is selected, the PTG will act as if it were an external trigger source. In turn, the PTG can be triggered to start by an external trigger inserted at its **Ext. Trig. In.** BNC. If you want to use an external trigger to trigger the PTG, you must go to the **PTG|Triggers** tab and enter the characteristics of an external trigger that, when input at the **Ext. Trig. In** BNC, will trigger the PTG's internal pulse.

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Chapter 7
Gated Operation with a PTG

Introduction

This chapter discusses gated operation with a PTG and aspects of operation of the PI-MAX not covered in Chapter 4, *First Light*. We additionally suggest that you review Chapter 11, *Tips and Tricks*, which contains information that should prove helpful in getting good results in more complex measurements.

Gate Mode operation is more complex than **Shutter Mode** operation because of the additional cabling and timing considerations that apply. However, it is in gated operation that the PI-MAX achieves its maximum power and utility, able to recover extremely faint fast signals in the presence of large ambient light levels.

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 both fall in a valid gate width and in a valid exposure time. Many gate pulses can be placed into one exposure time at random 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 ≤ 2 ns FWHM (full width at half maximum) 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-MAX's MCP bracketing feature can be used to extend the On:Off ratio to 10^6:1.

Precautionary Measures

WARNING

Intensified CCD detectors, such as the PI-MAX, 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. In **Shutter Mode** operation, it will be necessary to keep the lab lighting be subdued when working with an intensified detector. If a sustained alarm indication occurs when the controller is turned on, immediately switch the **MCP On/Off** switch on the back of the PI-MAX to the **OFF** position. Cover the detector window and only switch the **MCP On/Off** switch to **ON** after the illumination level has been lowered to safe operating conditions.

Intensifier Modes and Safety

The Experiment Setup **Main** screen allows selection of three modes, **Shutter Mode**, **Gate Mode** and **Safe Mode**. In **Shutter Mode** operation, the photocathode is biased on continuously during the exposure time and the room illumination must be subdued to prevent an overload alarm from occurring. In **Gate Mode**, the photocathode is biased on only during the time 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. Intense light sources in gated experiments can cause spot damage that would be undetected by the alarm circuit. In **Safe Mode**, the photocathode is continuously biased OFF and the intensifier is as safe as it can be.

Alarm

To reduce the risk of detector damage, the PI-MAX 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 **MCP On/Off** switch (on the back of the PI-MAX) to the **OFF** position. Cover the detector window and only switch the **MCP On/Off** 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.

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

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.

* The Gate pulse is produced inside the PI-MAX from the Start and Stop signals supplied by the Timing Generator.

Timing Mode

When you are in **Gate Mode**, the PTG will only operate using **Internal Sync** timing. This timing mode initiates a readout cycle after each PTG pulse ensemble.* The handshakes that prevent a readout from occurring while the PTG is busy and that prevent the PTG from pulsing the photocathode ON while a readout cycle is in progress are performed through the ST-133 backplane. For this mode, the following parameters are automatically set by the application software and cannot be changed: **Exposure Time** is set to 0, **Continuous Cleans** is disabled, and **Disabled Opened** and **PreOpen** are selected for Shutter Control.

Timing Mode	"Shutter" Control	Ext Trigger Input
Controlled by PTG	Controlled by PTG	Ext Trig In. BNC

Table 5. Timing Mode, Shutter Control, and Ext. Trigger Input when a PTG is the Timing Generator

Note: 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-MAX 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).

Fast Gating

A particularly noteworthy feature of the PI-MAX is its ability to gate in as little as 2 ns or less when the PI-MAX has been configured with a fast gate intensifier. The camera's exceptional gating performance can be easily demonstrated with a straightforward experimental setup.

The following fast-gated experiment was performed using the PI-MAX camera with the fast-gate option and operated in conjunction with Princeton Instruments' WinSpec/32 software, a Hamamatsu PL0-01 Picosecond Light Source, and a PTG. Other equipment included a computer and an ST-133 Controller. To do the experiment, 60 ps pulses from the Hamamatsu Light Source triggered from the timing generator were applied to the PI-MAX and a gated measurement was performed.

Sequential Gating Setup

Number of Spectra: 61
Start Gate Width: 2 ns
End Gate Width: 2 ns
Start Gate Delay: 102 ns
End Gate Delay: 105 ns
Increment Type: Fixed
Delay Increment: 0.05 ns

* A PTG pulse ensemble consists of a Gate Start pulse, a Gate Stop pulse, and an Auxiliary pulse.

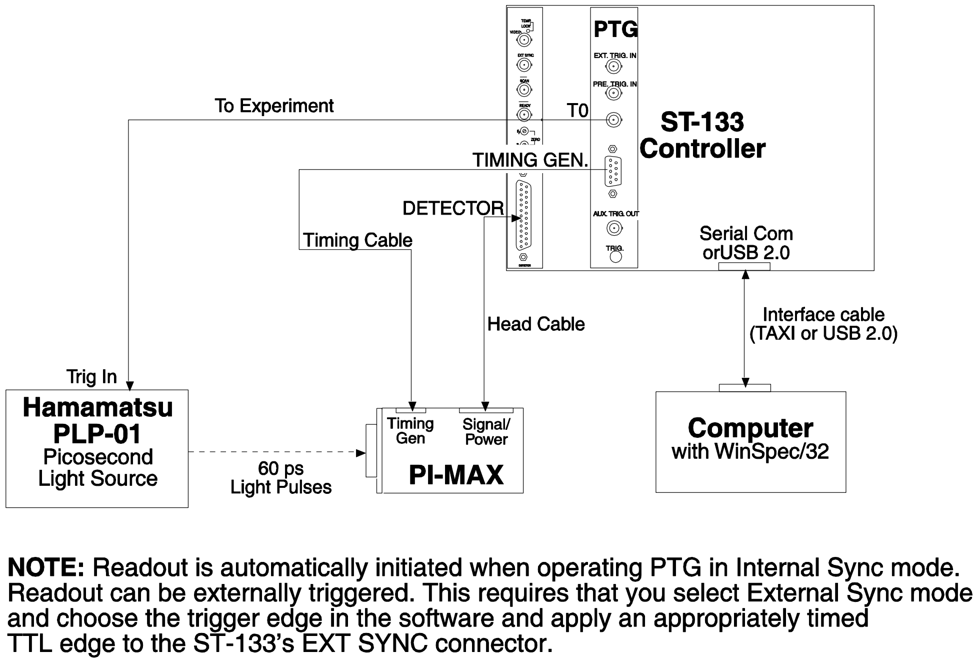

Figure 32. PTG Fast Gating Experiment Block diagram

The WinSpec/32 software's sequential gating function was used to increment the delay to the PI-MAX gate in 50 ps steps. As a result, with respect to the applied light pulses, the PI-MAX was gated 50 ps later with each repetition. The data from each pulse was collected and displayed in a 3-D plot with time on the Z-axis. By sliding the coincidence time of the gate and applied light pulses in this manner, a plot was produced that accurately characterized the temporal profile of the PI-MAX fast gate function. The measurement results are shown below. FWHM on the gate was 1.6 ns and the FW was measured at 2 ns.

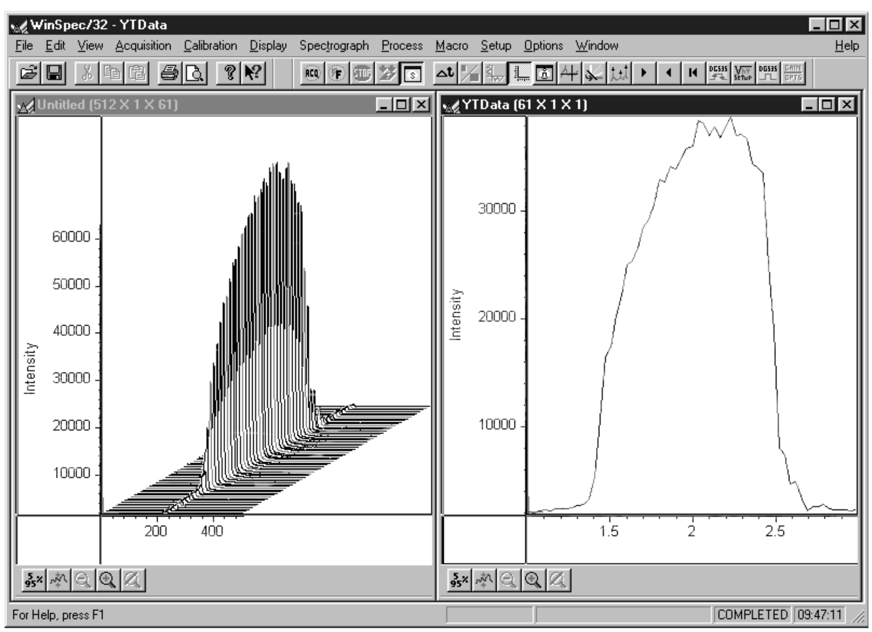

Figure 33. Fast Gating Measurement Results

MCP Bracket Pulsing

Introduction

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* keeps the MCP biased OFF except for an interval that brackets the timing of the photocathode gate as shown in Figure 34. 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-MAX, however, when bracket pulsing is ON, the MCP is biased OFF until just before the photocathode is gated ON. The MCP is then biased ON and remains biased ON until just after the photocathode is biased OFF.

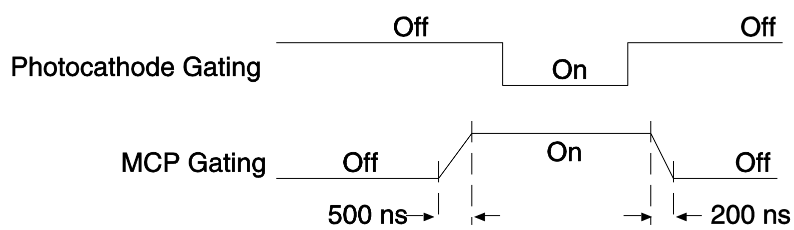

Figure 34. Timing: Bracket Pulsing

Traditionally, intensified detectors discriminated against background signal by gating the photocathode. Although this technique yields very high peak Off/On ratios, on the order of 5×10^6:1 in the visible, background signal can still prove troublesome in low-duty factor measurements, particularly in the UV region where the rejection is only ~10^4 :1. By bracket pulsing the MCP off (in addition to photocathode gating), the on/off ratio of the PI-MAX 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.

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

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. 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.

Bracket Pulsing in Nanosecond Pump Probe Experiments

Some nanosecond pump-probe experiments combine a nanosecond or faster pump with a flashlamp 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% of 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.

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 (Raleigh, MIE, Raman) or unwanted fast fluorescence. Because these usually fall below the MCP bracket pulsing 1 µs delay restriction, these measurements cannot be improved by MCP bracket pulsing in the PI-MAX.

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 is very much slower than 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 500 ns to accomplish coincidence at the detector. MCP bracketing should only be used in experiments where it is going to make a difference.

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-MAX.

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 much slower than photocathode gating (500 ns is required to gate the MCP on and another 200 ns 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 1 µs.

Note: The 1 µs restriction does not apply when you are using a PTG with Anticipator mode selected or when you are using a PTG, a pre-trigger is available, and the Pre-Trigger mode is selected.

Setup

MCP Bracket pulse implementation in a system having a PTG is accomplished by selecting **Bracket Pulsing ON** from the host software and selecting the **Bracket Start** parameter appropriate to your experiment (see choices below). The Timing Gen cable carries the signal that gates the MCP on and off if bracket pulsing has been turned on. Figure 35, page 88, is a timing diagram for a PTG that has been set up for bracket pulsing with a "Main" bracket start. Note that ***the insertion delay is 25 ns instead of the 85 ns insertion delay characteristic to the DG535.***

The four Bracket Start choices are:

- **Main:** Main times the bracket start from the main trigger (either an external or an internal trigger). Select this if the event of interest will occur at least 1 µs after the main trigger (the 1 µs includes the 500 ns required to turn the MCP fully on).
- **Main+Burst:** Select this if Burst mode is active. Brackets an entire burst but not the individual pulses within a burst.
- **Pre-Trigger:** Allows you to capture an event that would otherwise occur while the MCP was turning on. This selection requires that, in addition to the main trigger at **Ext Trig In**, you trigger the PTG by a pulse applied to the **Pre-Trig In** BNC. The pre-trigger must be at least 525 ns before the main trigger. After an insertion delay of approximately 25 ns, the MCP will be gated on before the main trigger occurs. The main trigger plus the gate delay and width parameters determine the photocathode gating and the MCP turn off. Because the MCP is gated on earlier, it is on for a longer period of time and therefore there is a slight loss of on/off ratio. However, you would be able to capture a non-repetitive event.
- **Anticipator:** Select this if the experiment is repetitive, driven by an external trigger at a constant frequency, and the event of interest would occur before the MCP has fully turned on. It is critical that the trigger pulse be as jitter free as possible, since the anticipator circuit will look at the pulse repetition rate (for the

first pulse to pulse period), and then anticipate each of the subsequent external triggers in the series. In this way, the bracketing pulse is timed to lead the photocathode gate pulse by the anticipate time entered in the Anticipate By field. The on/off ratio in the UV is retained.

For proper operation, the bracketing pulse must begin at least 500 ns before the gate pulse. The minimum Anticipator Time is 500 ns (or the minimum PI-MAX bracket lead-time from EEPROM) minus the minimum Gate Delay time. For example, with a minimum Gate Delay time of 200 ns, the minimum Anticipator time would be 300 ns.

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

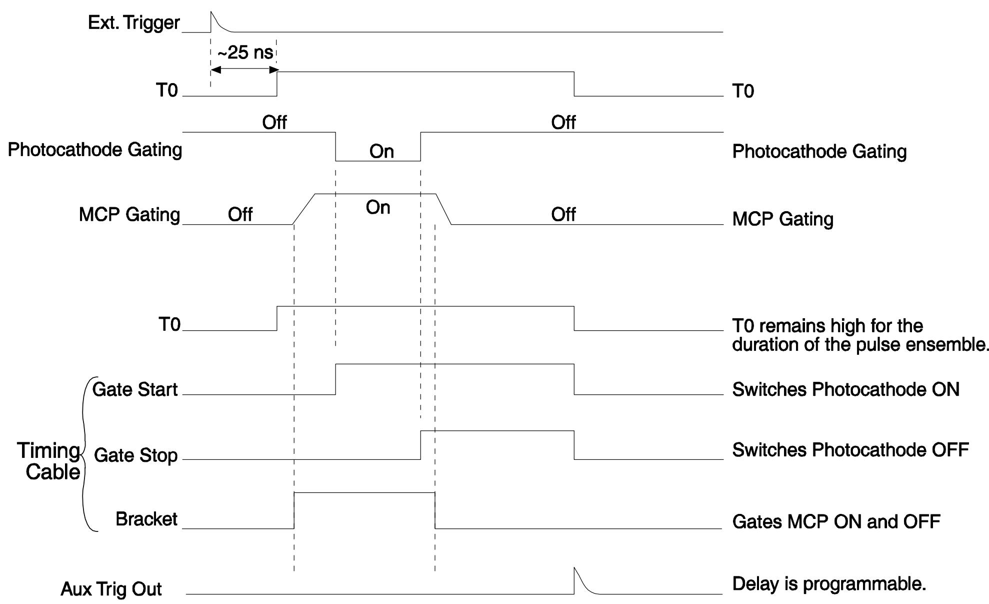

Figure 35. PI-MAX Timing for MCP Bracket Pulsing with PTG Timing Generator

MCP Gating

Introduction

MCP gating is only available with the PI-MAX$_{MG}$ system. This gating mode (not to be confused with MCP bracket pulsing) provides you with 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-MAX$_{MG}$ 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. 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-MAX. Quantitatively, the propagation delay of the PI-MAX itself is in the 40 ns range compared to 10-12 ns for a standard PI-MAX. Note that the PTG propagation delay is in addition to the 40 ns. Minimum FWHM for a PI-MAX$_{MG}$ system is in the 8 to 15 ns range, compared to 1.5 ns to 2 ns for a standard PI-MAX. Pulse repetition rate is limited to 1 kHz.

Setup and Operation

The PI-MAX$_{MG}$ is set up in the same way as a standard PI-MAX and is compatible with the PTG (preferred) and the DG535 timing generators. Note that with a PTG, a width setting of 37 ns produces a gate width of 37 ns because the gate width selected with the PTG is the optical FWHM.

1. Start with **Shutter Mode** operation if possible, to get initial operation, focus, etc. (see Chapter 4, *First Light).*
2. Then, switch to **Gate Mode** and a relatively long gate to acquire the phenomenon of interest.
3. Finally, narrow down the gate to the desired operation.

When possible in the experiment, it is a good idea to use bracket pulsing to limit the photocathode ON time. The required “lead time” or pretrigger time for the photocathode bracket pulse is 300 ns (compared to 500 ns for a standard PI-MAX MCP bracket pulse).

Note: Pulse repetition rate is limited to 1 kHz.

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.

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 PTG. 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-MAX. The spectrum would then be intensified and applied to the PI-MAX’s CCD array.

Cabling for MCP Gated Operation

Figure 36 illustrates the cabling for an MCP gated experiment using a PTG*. The laser trigger output is applied to the **Ext. Trig. In** connector of the PTG to initiate the timing sequence. The Start/Stop outputs of the PTG are applied to the PI-MAX via the **Timing Gen** cable to gate the MCP on and off. This cable also carries the signal that gates the photocathode on and off if bracket pulsing has been selected. Another timing generator output is fed through the back plane to inhibit readout while the timing generator is busy. Finally, to prevent artifacts from the laser from degrading the data, it is essential that the timing generator be inhibited during each readout. The handshake for this inhibiting function is also routed through the backplane. The PTG parameters are set from the computer by the application software.

Other system cabling would include the Detector-Controller cable that interconnects the PI-MAX and the controller and the TAXI cable between the controller and the computer.

* Requires ver 2.4 or later WinView/32 or WinSpec/32 software.

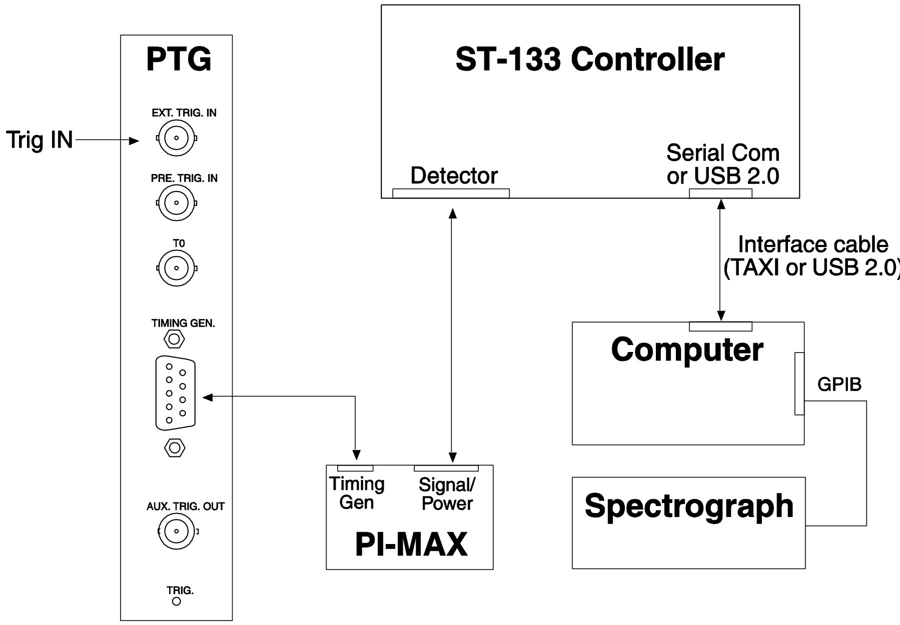

Figure 36. MCP Gated Operation Cabling

Figure 37 is a timing diagram for a PTG. Note that ***the insertion delay is 25 ns instead of the 85 ns insertion delay characteristic to the DG535.***

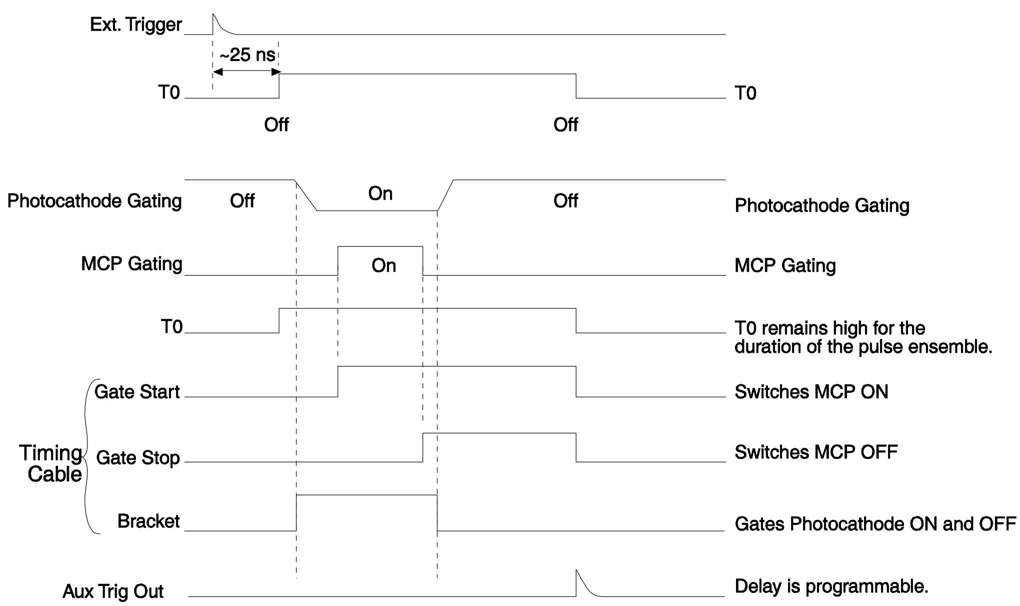

Figure 37. PI-MAX Timing in MCP Gated Operation with PTG Timing Generator

500 ps Gating Option

The 500 ps Gating Option, available for PI-MAX detectors with fast gate RB intensifiers, uses the PTG for timing. Please refer to the following information when in setting up your system for this option:

1. Enable the 500 ps gating option by selecting the "**Enable Fast Pulse Option**" checkbox on the **Experiment Setup|Main** tab (see Figure 38). Wait about 10 minutes before taking data to ensure that the acquired data will be valid.

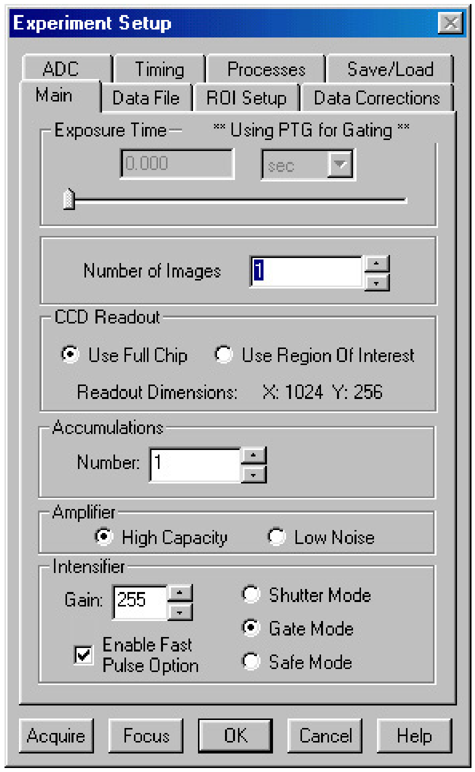

Figure 38. Experiment Setup|Main tab

2. When setting up the pulser, select the **PTG** as the active pulser.
3. When setting up triggers, the maximum trigger frequency is 2000 Hz.

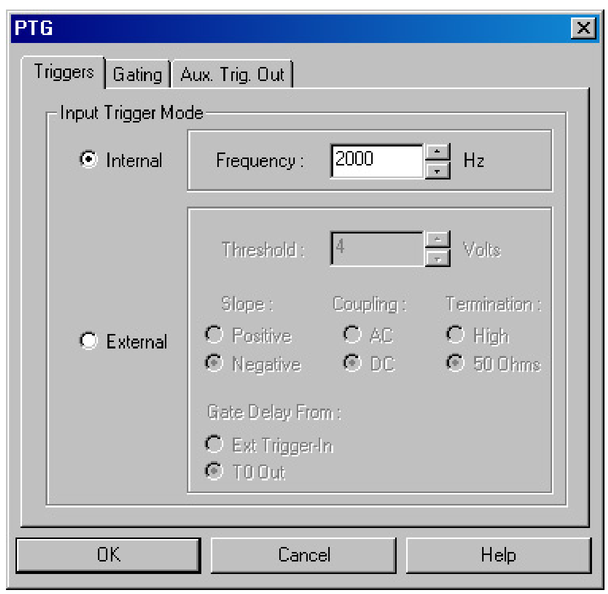

Figure 39. PTG|Triggers tab

4. After setting the trigger frequency, set the gating parameters. When the 500 ps option is enabled, you will see "2 ns Board Is Enabled" on the gating setup dialogs (for example, on the Repetitive Gating dialog in Figure 40).

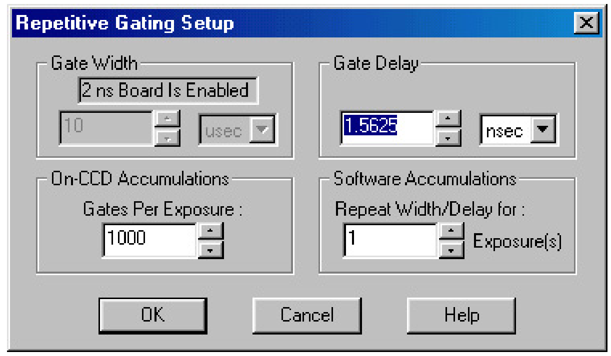

Figure 40. Repetitive Gating dialog

5. Before taking data, verify that about 10 minutes has elapsed since you enabled the Fast Pulse Option. This will ensure that the acquired data will be valid.

Additional Experiments

Introduction

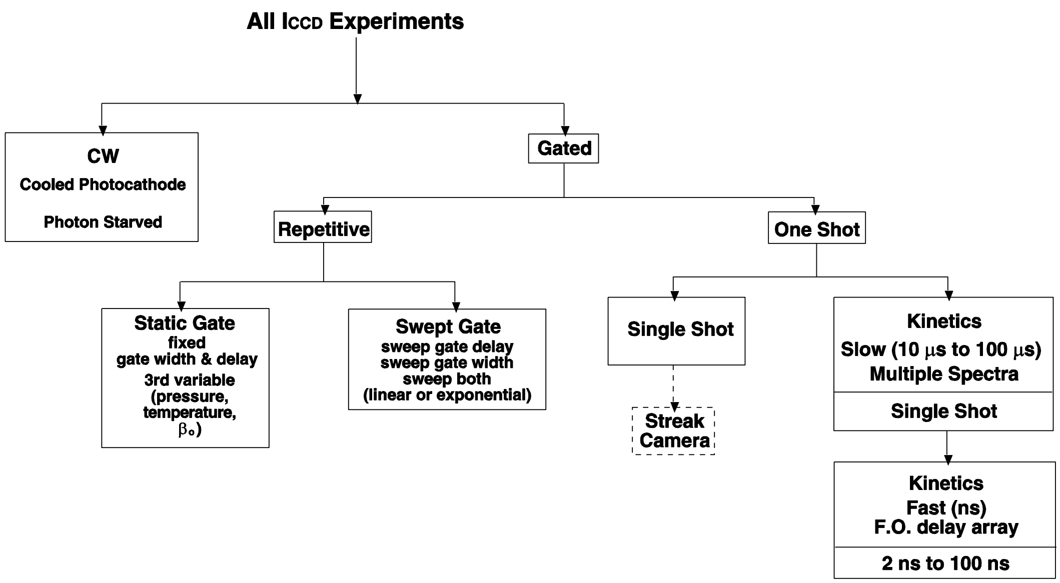

Figure 41. Experiments with the PI-MAX

Figure 41 illustrates the kinds of experiments that can be performed with a PI-MAX detector and PTG. Of the many gated measurements that can be performed with a PI-MAX and PTG, 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. Some variable in the experiment such as 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.

The next section provides step-by-step instructions, along with diagrams and screen shots, for setting up and performing a Swept Gate experiment with fixed Gate Width and variable Gate Delay (type Repetitive-Sequential 1).

Procedure for Setting up and Performing a Swept Gate Experiment (Fixed Width, Variable Delay)

This experiment is an attempt to time-resolve a Xenon light flash from a commercially available strobe light. Since the strobe does not have a "pretrigger" out, an electrical trigger is generated by using a photodiode. Output from the photodiode is connected to the **Ext. Trig.** BNC of the PTG (Figure 42). Then perform the steps that follow.

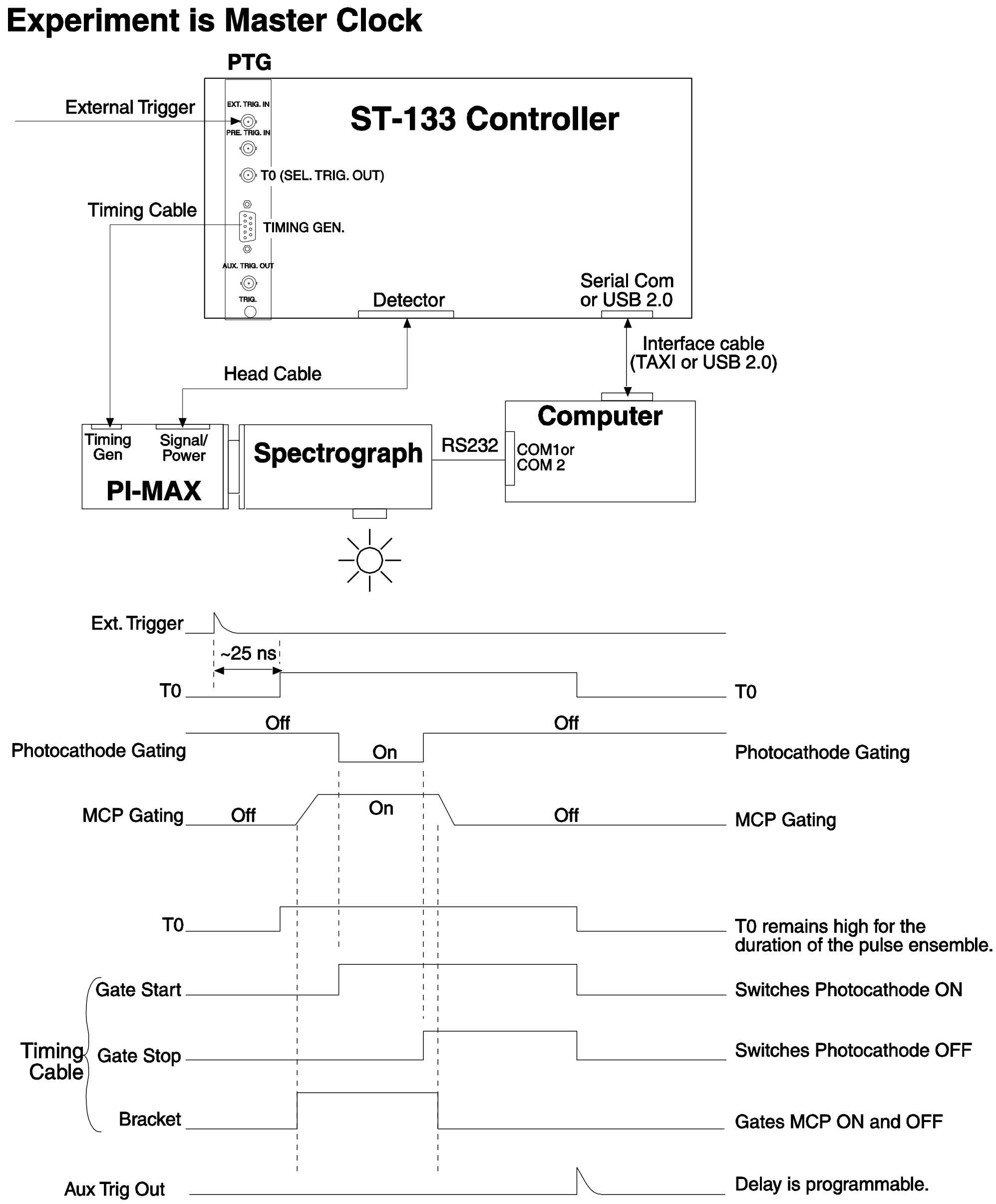

Figure 42. Experiment is Master Clock: Hardware Setup and Timing Diagram

Experiment as Master Clock

The following procedure uses the experiment as the master clock and therefore refers to connections as shown in Figure 42.

1. Switch on the equipment and start the WinX application software (Ver. 2.4 and higher).

2. Choose the appropriate camera/controller in the **Setup|Hardware|Hardware Setup** dialog. The screen should resemble Figure 43, which shows the setup for a Thomson 512 x 512 full frame camera.

   a. Choose **High Speed PCI** or **PCI (Timer)** on the Interface tab and enter the I/O Address and the Interrupt Level, if appropriate. *See Figure 43.*

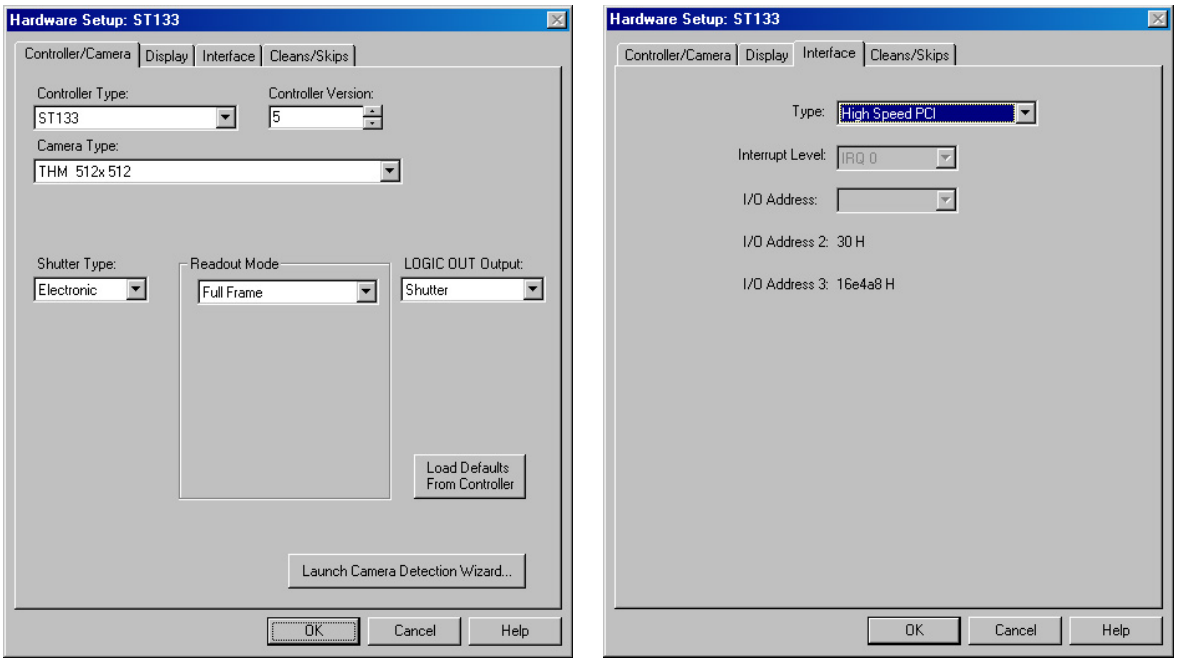

Figure 43. Hardware Setup: Controller/ Camera and Interface tabs

   b. Click on “Load Default Values” on the Cleans/Skips tab.

   c. Set the detector temperature by selecting "Detector Temperature" on the Setup menu, entering the Target Temperature information, clicking on "Set Temp" and then clicking on "OK". You may want to refer to the WinView/32 or WinSpec/32 manual, as appropriate.

3. If you have a spectrograph, set the spectrograph properties by using the menu items on the "Spectrograph" menu (WinSpec/32 only). If the spectrograph you will be using has not been installed, first click on "Install/Remove Spectrograph" and do so before setting the properties. Figure 44 shows the WinSpec/32 sequence for an Action 300I spectrograph.

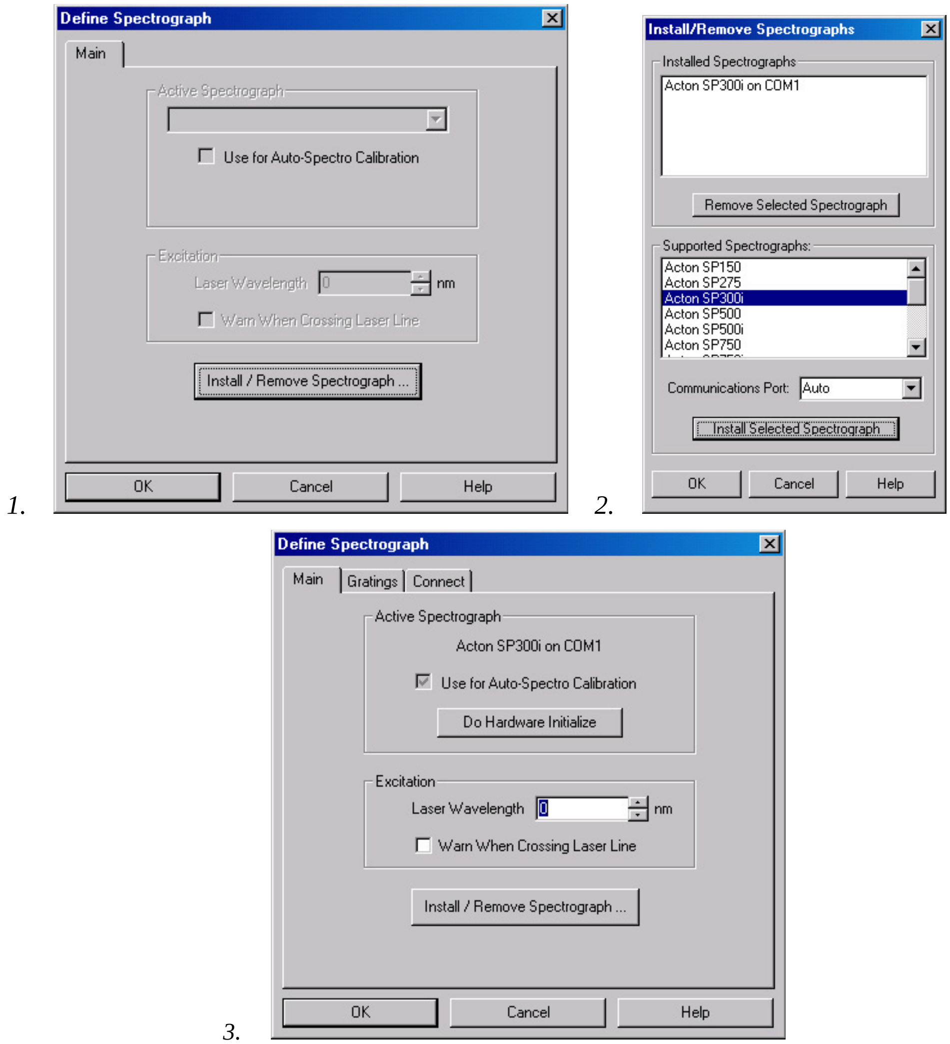

Figure 44. Define Spectrograph and Install/Remove Spectrographs dialogs

4. After you have installed and defined the spectrograph, move the grating to the desired wavelength.

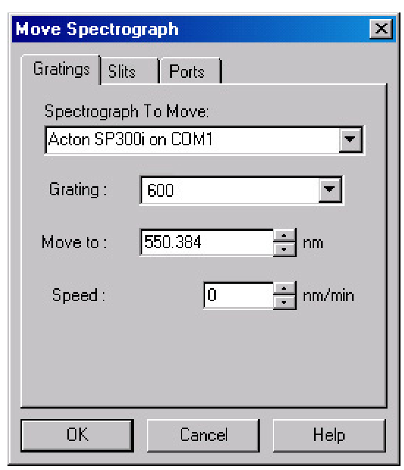

Figure 45. Move Spectrograph dialog

5. At this point, it is a good practice to make sure that the camera is focused by running it in **Free Run** mode. This requires that you set the experiment parameters on the Experiment Setup tabs *(refer to Figure 46 and Figure 47).* On the **Experiment Setup|Main** tab, choose **Shutter Mode**, set a value between 0 and 255 for MCP gain, and set the appropriate integration time. On the Timing tab, select **Free Run** and **Fast Mode**. On the **ADC** tab, select the appropriate ADC type. On the **ROI Setup** tab, select the appropriate ROI.

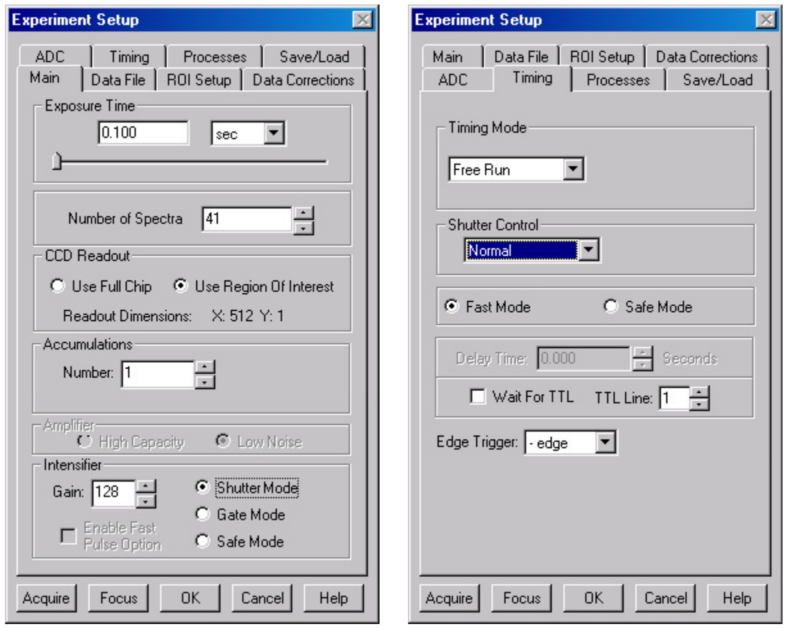

Figure 46. Experiment Setup: Main and Timing tabs

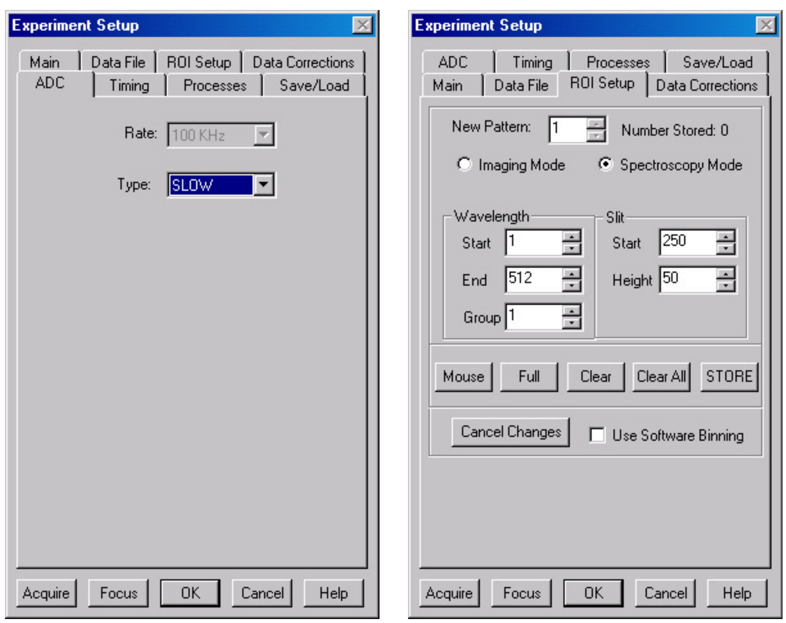

Figure 47. Experiment Setup: ADC and ROI Setup tabs

6. Because there is a risk of overloading the camera in **Shutter Mode**, make sure that the room or ambient illumination is low (i.e., you have difficulty seeing in the room).

7. After setting the parameters and making sure the ambient light level is low, click on **Focus**.
8. 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 on “Yes” and the camera will begin acquiring data.
9. After you make sure that the camera is seeing in **Free Run** mode, stop data acquisition.
10. Set up the pulser (PTG). The following figures show typical examples of the screens you would use to set up the PTG.

    a. After selecting the PTG as the active pulser, click on "Setup PTG…". Define the external trigger on the **Triggers** tab. *See Figure 48.*

    b. On the **Gating** tab, select **Sequential** as the Active Mode and then click on "Setup…". For this experiment both Burstmode and Bracket Pulsing are OFF. *See Figure 48.*

    Note: The **Gate Delay From:** choice will only appear if you have checked "**Use NVRAM Calibration (if present)**" on the Get/Set Parameter and the PTG Get/Set Parameter dialogs (accessed from the **Diagnostics** menu). The NVRAM calibration is the factory calibration and will give you the most accurate timing information gate width and delay.

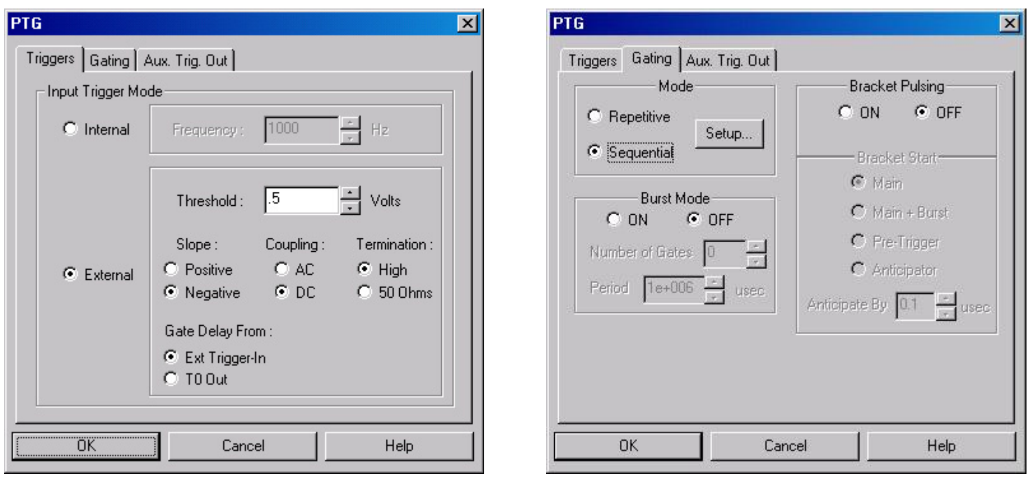

Figure 48. PTG: Triggers and Gating tabs

    c. Click on "Setup…" and define the pulse sequence on the Sequential Gating Setup dialog. *See Figure 49.*

    - Enter the number of spectra to be acquired (in this case, 41).
    - Select "Fixed Increment".
    - Enter the start and end times for the gate width. (Since this experiment requires a fixed gate width these values will be the same.)
    - Enter 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.) Note that the minimum gate delay for T0 is 1.5625 ns.

- Then select the number of exposures (in this case, 1 exposure).
- To check the gate delay for each of the 41 spectra, click on "View Width/Delay Sequence."

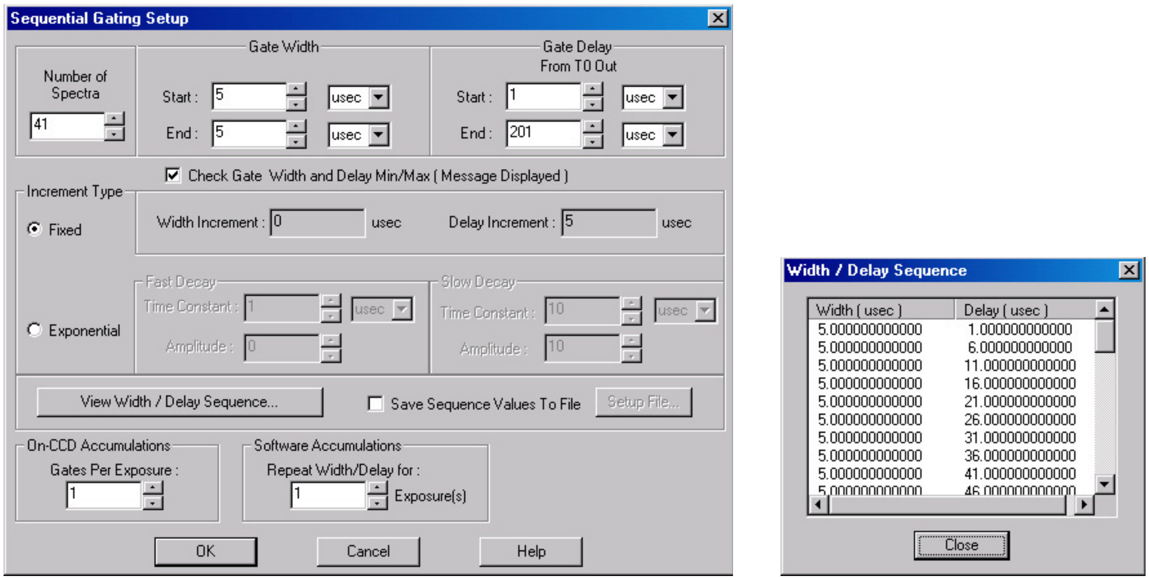

Figure 49. Sequential Gating Setup and Width/Delay Sequence dialogs

d. If you are using the Aux. Trig. Out signal from the PTG to trigger a piece of equipment, then enter the Auxiliary Trigger Out delay time on the **Aux. Trig. Out** tab. *See Figure 50.*

Figure 50. Aux. Trig. Out tab

e. Click on **OK** to program the pulser/timing generator.

11. Set up the experiment parameters from the Experiment Setup dialog.

a. On the **Timing** tab, change the timing as shown in Figure 51.

b. On the **Main** tab, enter the exposure time, gain and switch to **Gate Mode**. The number of spectra will be automatically set depending on the number entered on the Sequential Gating Setup dialog (Figure 49).

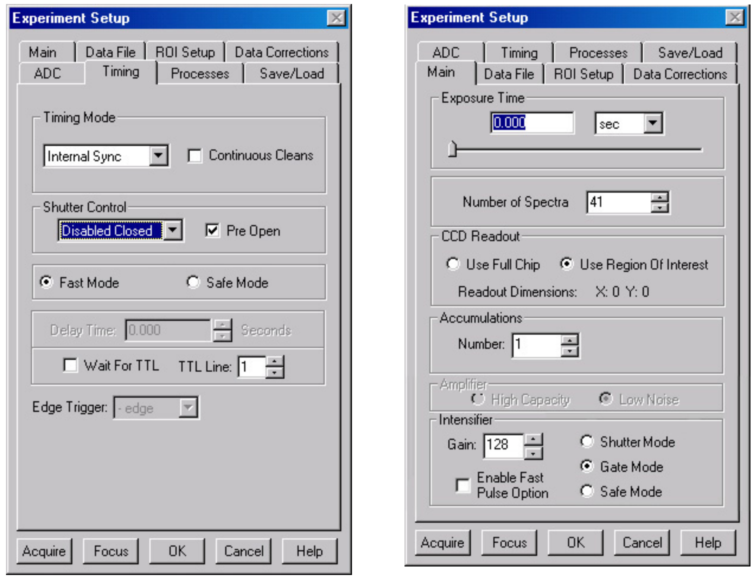

Figure 51. Experiment Setup: Timing and Main tabs

Note: 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 than it is in **Shutter Mode**, but the risk of damaging overload from intense light sources such as lasers remains.

12. After verifying all connections and equipment readiness, click on **Acquire** to begin acquiring the spectra (or images).

13. Figure 52 displays the 3-D graph for a “Sequential-Repetitive" experiment with Fixed Width and Variable Delay (as set in Figure 48 and Figure 49).

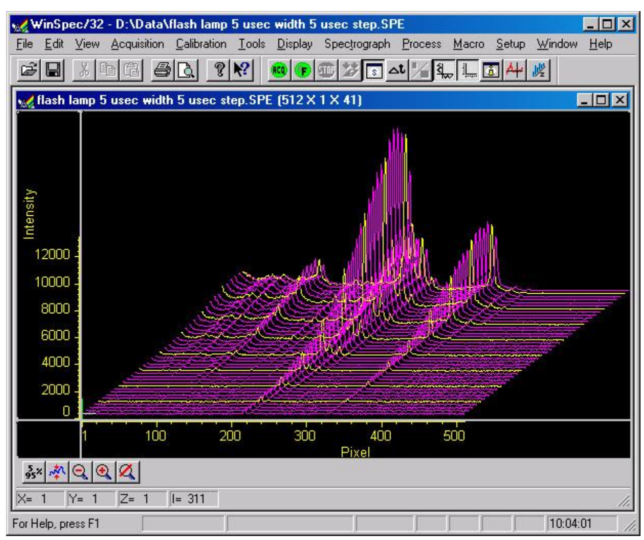

Figure 52. Experiment Results in 3-D

PTG as Master Clock

If you have a light source that has a "Trigger In", the PTG can be used as the Master clock (cable connections shown in Figure 53). The setup procedure is much the same as that given for the "Experiment as Master Clock". The differences are that a cable is connected between the PTG's T0 BNC and the light source (experiment) for triggering the event and that the 25 ns propagation delay for the External Trigger is no longer a factor.

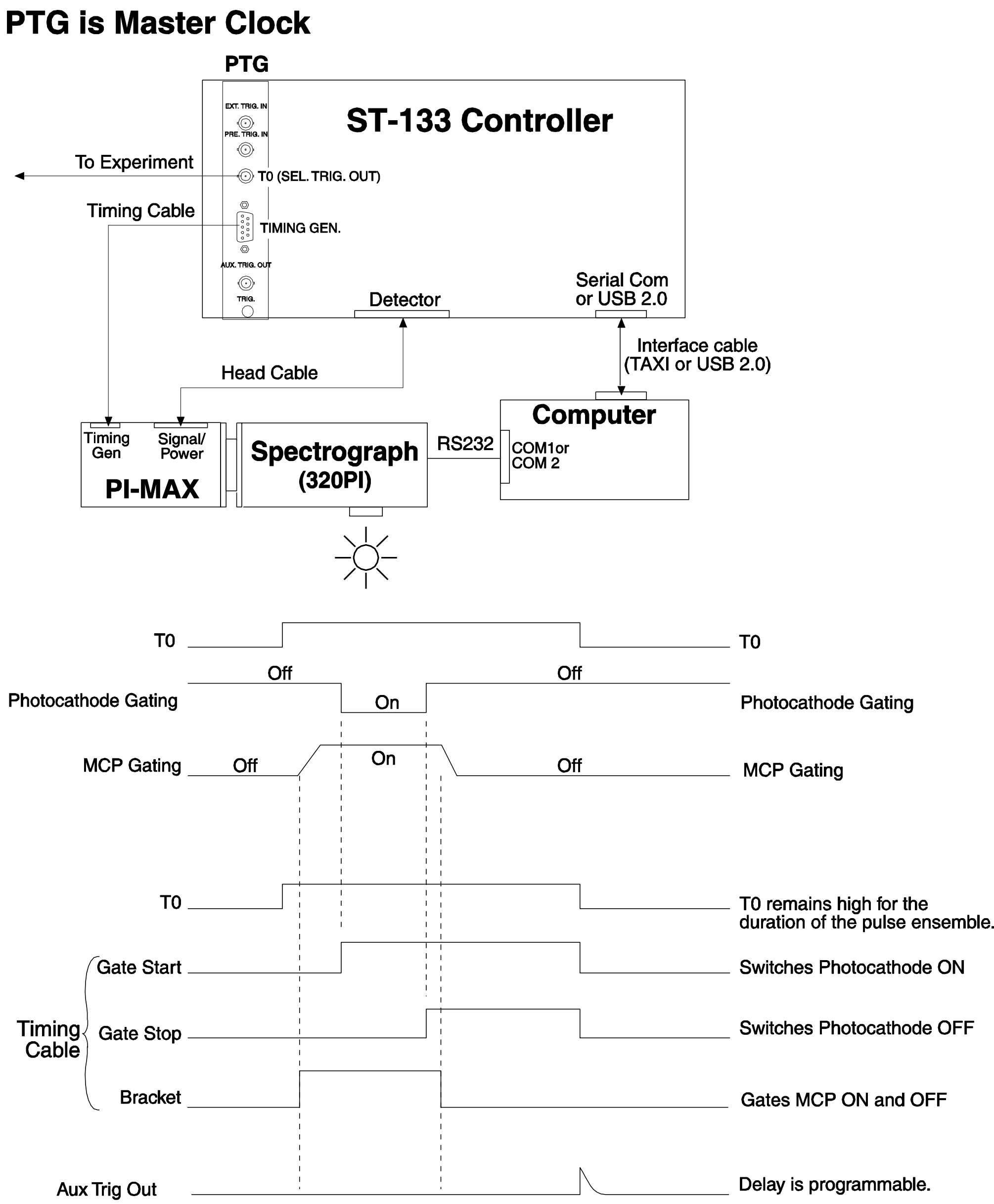

Figure 53. PTG is Master Clock: Hardware Setup and Timing Diagram

Procedure for Setting up and Performing a Single Shot Experiment

A single shot experiment offers only 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 of the experiment is shown in Table 6 below. This information is important in order to choose the correct length fiber-optic cable.

Delay Source	Delay (ns)	Total Delay (ns)	Fiber-Optic Cable Length
Photodiode (light -> TTL pulse)	2	55	A minimum of 38 ft of fiber-optic cable is required.
Photodiode -> PTG (2 ft BNC cable)	3		
PTG	25		
PTG -> PI-MAX (6 ft cable)	10		
PI-MAX	15		

Table 6. Single Shot Experiment Time Budget

In this experiment, the cables are kept as short as possible to minimize the length of the fiber-optic cable required.

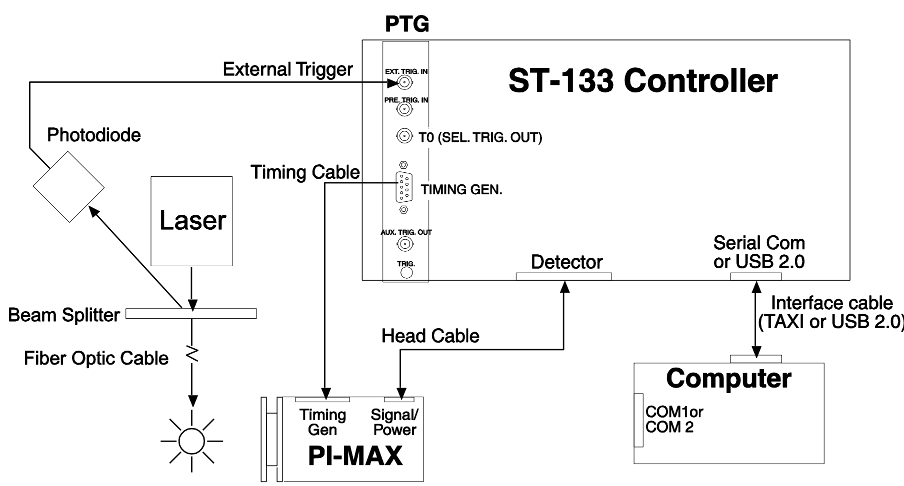

Figure 54. Single Shot: Hardware Setup

After setting up the appropriate hardware, as shown in Figure 54, default values for "Cleans and Skips" are loaded (Figure 55). If the CCD has to wait more than a few seconds for the external trigger, it is advisable to increase the number of cleans.

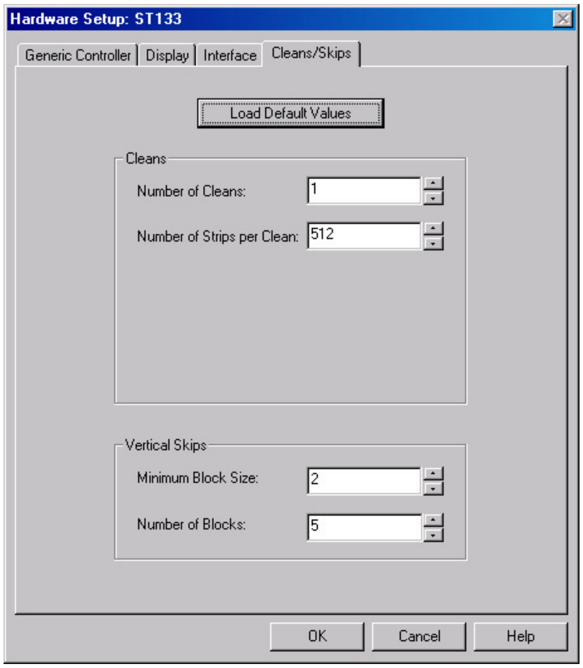

Figure 55. Cleans and Skips: Default Values Loaded

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 (Figure 56).

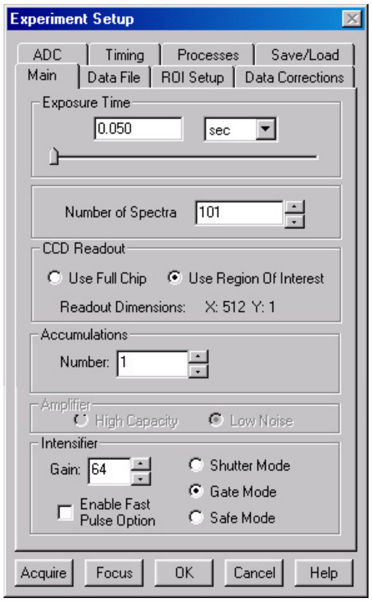

Figure 56. Experiment Setup: Gain Selected

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).

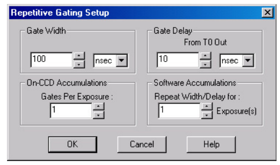

Figure 57. Repetitive Gating Setup: 100 ns Width, 10 ns Delay

Figure 58 shows the result of the experiment. Figure 59 shows the peak obtained by binning, in the vertical direction, the entire region around the fluorescence spot.

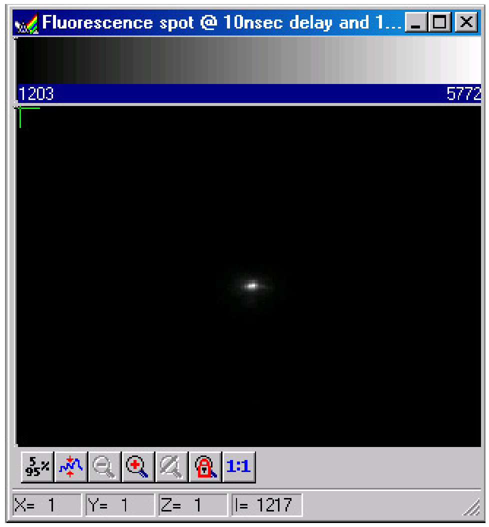

Figure 58. Single Shot Result: Fluorescence Spot, 100 ns Width, 10 ns Delay

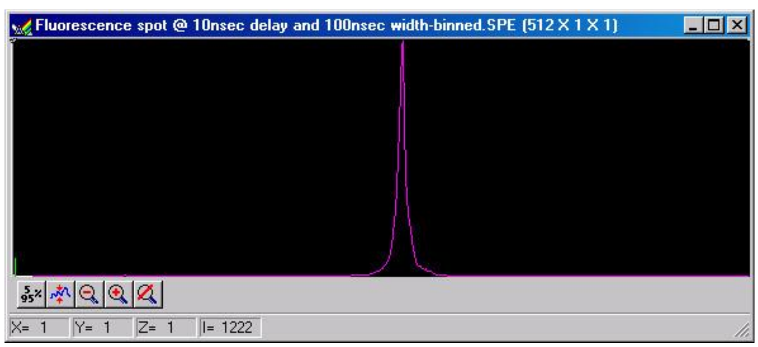

Figure 59. Single Shot Result: Fluorescence Spot, 100 ns Width, 10 ns Delay, Binned Vertically

Procedure for Setting up and Performing a Swept Gate Experiment (Variable Width, Variable Delay):

The sequence of steps for a Swept Gate experiment with variable width and delay is similar to the Swept Gate experiment with fixed width and variable delay but with the following exception:

- In addition to entering differing start and end values for the Gate Delay, you would also enter differing start and end values for the Gate Width.

Procedure for Setting up and Performing a Static Gate Experiment (Fixed Width, Fixed Delay)

The sequence of steps for a Static Gate experiment is similar to the Swept Gate experiment but with the following exceptions:

- The Active Mode, selected in Step 10b, would be **Repetitive**.
- The Gate Width and Gate Delay values would be entered in the dialog shown below. Note that the minimum gate delay from T0 is 1.5625 ns:

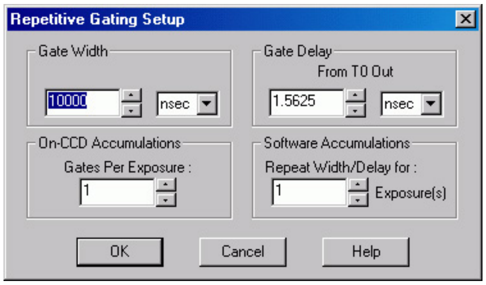

Figure 60. Repetitive Gating Setup dialog

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Chapter 8
Gated Operation with a DG535

An Inhibit option must be installed in the DG535 before it can be used to for gating the PI-MAX. Contact Princeton Instruments Customer Support for information on how to install/enable the DG535 Inhibit function.

Introduction

This chapter discusses gated operation with a DG535 timing generator and aspects of operation of the PI-MAX not covered in Chapter 4, *First Light*. We additionally suggest that you review Chapter 11, *Tips and Tricks*, which contains information that should prove helpful in getting good results in more complex measurements.

Gate Mode operation is more complex than **Shutter Mode** operation because of the additional cabling and timing considerations that apply. However, it is in gated operation that the PI-MAX achieves its maximum power and utility, able to recover extremely faint fast signals in the presence of large ambient light levels.

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 both fall in a valid gate width and in a valid exposure time. Many gate pulses can be placed into one exposure time at random 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 ≤ 2 ns FWHM (full width at half maximum) 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-MAX's MCP bracketing feature can be used to extend the On:Off ratio to 10^6:1.

Precautionary Measures

WARNING

Intensified CCD detectors, such as the PI-MAX, 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. In **Shutter Mode** operation, it will be necessary to keep the lab lighting be subdued when working with an intensified detector. If a sustained alarm indication occurs when the controller is turned on, either completely cover the intensifier to reduce the light to halt the overload condition, or reduce the laboratory illumination still further until safe operating conditions are established.

Intensifier Modes and Safety

The Experiment Setup **Main** screen allows selection of three modes, **Shutter Mode**, **Gate Mode** and **Safe Mode**. In **Shutter Mode** operation, the photocathode is biased on continuously during the exposure time and the room illumination must be subdued to prevent an overload alarm from occurring. In **Gate Mode**, the photocathode is biased on only during the time 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. Intense light sources in gated experiments can cause spot damage that would be undetected by the alarm circuit. In **Safe Mode**, the photocathode is continuously biased OFF and the intensifier is as safe as it can be.

Alarm

To reduce the risk of detector damage, the PI-MAX 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 **MCP On/Off** switch (on the back of the PI-MAX) to the **OFF** position. Cover the detector window and only switch the **MCP On/Off** 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.

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

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.

* The Gate pulse is produced inside the PI-MAX from the Start and Stop signals supplied by the Timing Generator.

DG-535 and Gate Mode Overview

For gate mode operation with a DG535 Timing Generator, External Sync with PreOpen timing must be selected (**Acquisition|Experiment Setup…|Timing** tab). A "frame cycle" is initiated by the **D** output of the DG535 that must be applied to the **Ext Sync** input of the ST-133. Without this connection and mode selection, an exposure and readout cannot occur.

A frame cycle consists of an "exposure" followed by a readout. The "exposure" defines the time "space" in which the data gets collected. If, as is generally the case, you want the readout to begin as soon as possible after **Ext Sync** is applied, set the **Exposure Time** to **Zero** and the **Shutter Type** (WinView/32 or WinSpec/32 Hardware Setup) to **None** (the latter setting removes the shutter compensation time, another source of delay).

The **Accumulations** and **Images** parameters (**Acquisition|Experiment Setup…|Main** tab) govern how the data will be processed and whether any given Ext Sync signal will initiate a controller cycle or be ignored. Integrating multiple events on the CCD really brings the power of the PI-MAX 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).

Examples:

1. If you want to acquire 5 separate images, set the ET=0, Number of Images (or Spectra)=5, and Accumulations=1.
2. If you want to acquire single image that is the sum of integration during 5 gate pulses, set the ET so that it is long enough to encompass 5 gate pulses, Number of Images (or Spectra)=1, and Accumulations=1.

Timing Modes

The Timing mode determines when and how the data will be read out. Table 7 shows the possible Timing Mode and Shutter Control combinations when operating in Gate Mode. As shown in the table, the following timing modes are available: **External Sync** and **External Sync with Continuous Cleans.**

Timing Mode	"Shutter" Control	Ext Trigger Input
External Sync	PreOpen	Ext Sync BNC
External Sync with Continuous Cleans	PreOpen	Ext Sync BNC

Table 7. Timing Mode, Shutter Control, and Ext. Trigger Input when a DG535 is the Timing Generator

External Sync

External synchronization uses the External Sync trigger from the DG535's **D** output to determine when the data is readout of the array (Exposure Time = 0 s.) or when the exposure time will begin (Exposure Time > 0 s.). Because of pulser constraints, External Sync mode must always be used with the PreOpen shutter mode, which ensures that the DG535 is not "Inhibited" from gating the photocathode while the array is ready to integrate signal.

The timing diagrams below show the sequence of events for a 0 second exposure time and for an exposure time greater than 0 seconds. When the exposure time is set to 0 seconds (**Acquisition|Experiment Setup…|Main**) and External Sync PreOpen is selected, the gating determines the actual time (t_{exp}) that the array will be exposed to incoming signal.

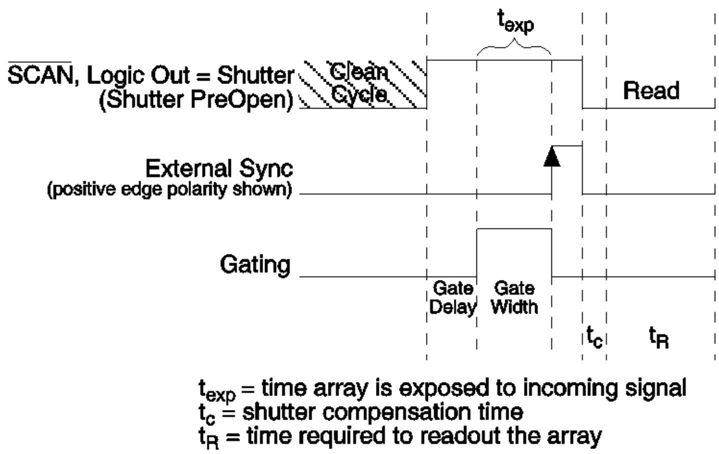


Figure 61. DG535: External Sync, PreOpen, Exposure Time = 0 s.

When the exposure time is set to something other than 0 (**Acquisition|Experiment Setup…|Main**) and External Sync PreOpen is selected, the start of the exposure time is controlled by the External Sync trigger, and one or more gates may occur during the exposure time depending on the gating parameters set up for the DG535 (**Setup|Pulsers…|DG535**).

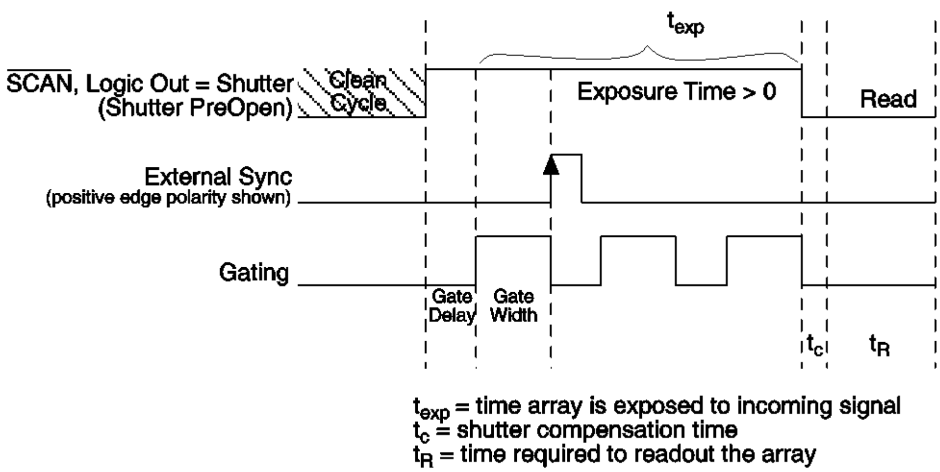


Figure 62. DG535: External Sync, PreOpen, Exposure Time > 0 s.

External Sync with Continuous Cleans

External synchronization can also use a function called Continuous Cleans (represented by CC in the figure below). In addition to the standard "cleaning" of the array, which occurs after the controller is enabled, Continuous Cleans will remove any charge that integrates on the array after the Start Acquisition command has been sent to the ST-133 until the moment the External Sync pulse is received. As mentioned earlier in the manual, values continuous cleans are entered on the **Setup|Hardware …|Cleans/Skips** tab. If the CCD has to wait more than a few seconds for the external trigger, it is advisable to increase the number of cleans.

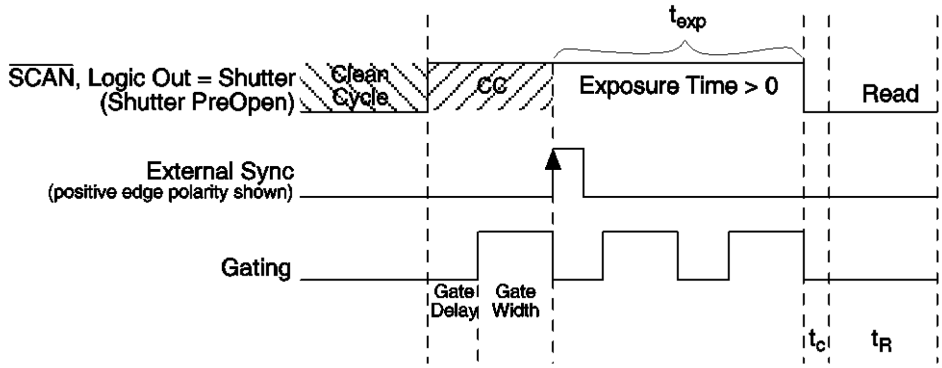


Figure 63. DG535: External Sync, PreOpen, Cont. Cleans, Exposure Time > 0 s.

DG535 Gating Setup

In the WinX application, trigger, gating, and communication port parameters for the DG535 are defined via the **Setup|Pulsers|DG535** dialog. The **Triggers** tab card allows you to indicate whether the DG535 will use an internal trigger (occurring at X frequency) to initiate an Ext. Sync trigger from its **D** output or whether the trigger source will be a signal input at its **Trig IN** input.

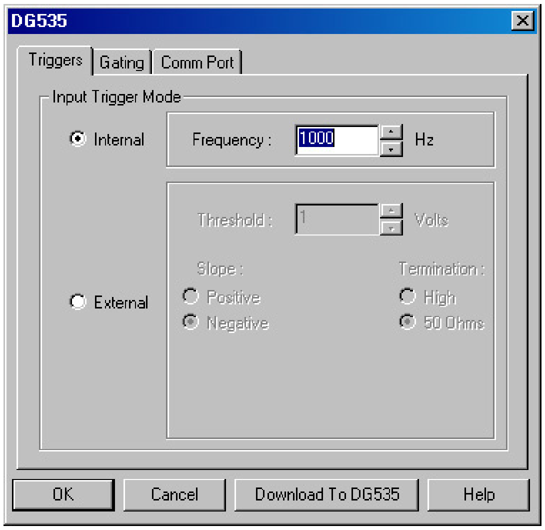


Figure 64. DG535 Triggers tab

Gating parameters are set up via the **Gating** tab card and via the Repetitive Gating Setup and Sequential Gating Setup dialogs that are accessed from this tab card. With repetitive gating the gate width and gate delay are constant for the specified number of exposures. With sequential gating either or both gate width and gate delay change as images or spectra are acquired.

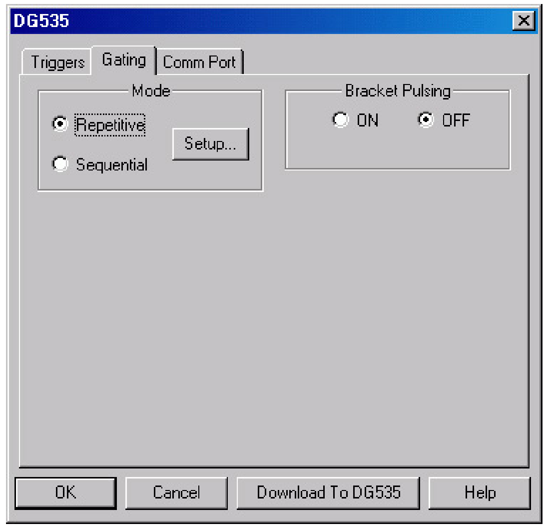


Figure 65. DG535 Gating tab

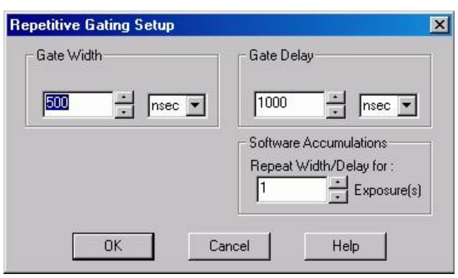


Figure 66. DG535 Repetitive Gating Setup dialog

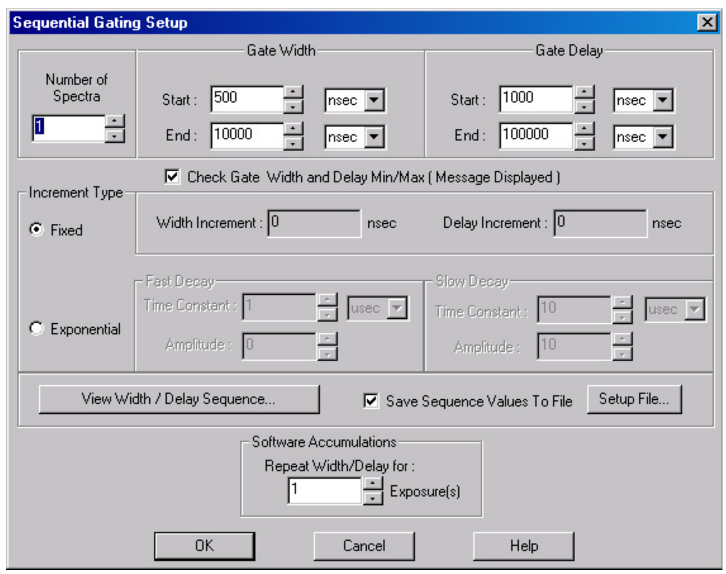


Figure 67. DG535 Sequential Gating Setup dialog

The DG535 parameters for communicating with the host computer are set up or changed on the **Comm Port** tab card. Select GPIB for the port type and select the port address. The Port address setting determines which GPIB address the computer will use in communications with the DG535 Pulser. Selections include 1 through 30 plus Demo, which allows the DG535 software routines to be exercised even though a DG535 is not connected. The selected address must match the one selected at the DG535 and the default value is 15. After you select the correct COM port, click on the Initialize Port button to initialize it.

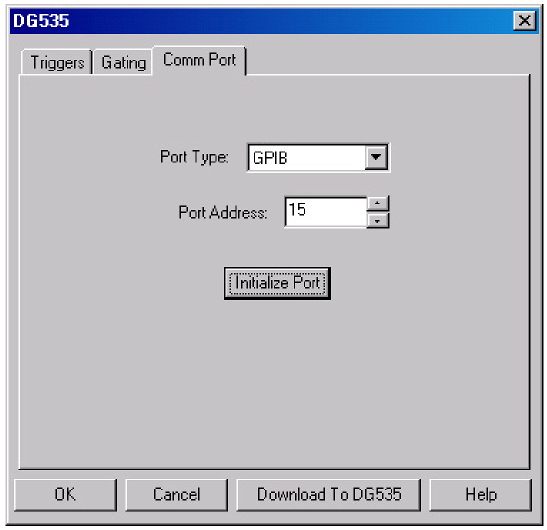


Figure 68. DG535 Comm Port tab

Fast Gating

A particularly noteworthy feature of the PI-MAX is its ability to gate in as little as 2 ns or less when the PI-MAX has been configured with a fast gate intensifier. The camera's exceptional gating performance can be easily demonstrated with a straightforward experimental setup.

The following fast-gated experiment was performed using the PI-MAX camera with the fast-gate option and operated in conjunction with Princeton Instruments' WinSpec/32 software, a Hamamatsu PL0-01 Picosecond Light Source, and a DG535). Other equipment included a computer and an ST-133 Controller. To do the experiment, 60 ps pulses from the Hamamatsu Light Source triggered from the timing generator were applied to the PI-MAX and a gated measurement was performed.

Sequential Gating Setup

Number of Spectra: 61
Start Gate Width: 2 ns
End Gate Width: 2 ns
Start Gate Delay: 102 ns
End Gate Delay: 105 ns
Increment Type: Fixed
Delay Increment: 0.05 ns

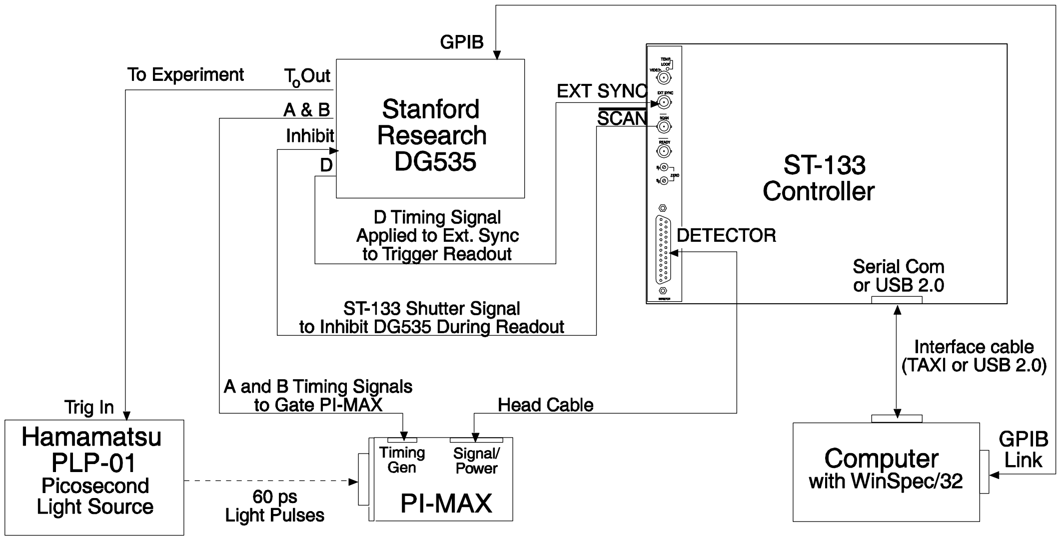


Figure 69. DG535 Fast Gating Experiment Block Diagram

In both setups, the WinSpec/32 software's sequential gating function was used to increment the delay to the PI-MAX gate in 50 ps steps. As a result, with respect to the applied light pulses, the PI-MAX was gated 50 ps later with each repetition. The data from each pulse was collected and displayed in a 3-D plot with time on the Z axis. By sliding the coincidence time of the gate and applied light pulses in this manner, a plot was produced that accurately characterized the temporal profile of the PI-MAX fast gate function. The measurement results are shown below. FWHM on the gate was 1.6 ns and the FW was measured at 2 ns.

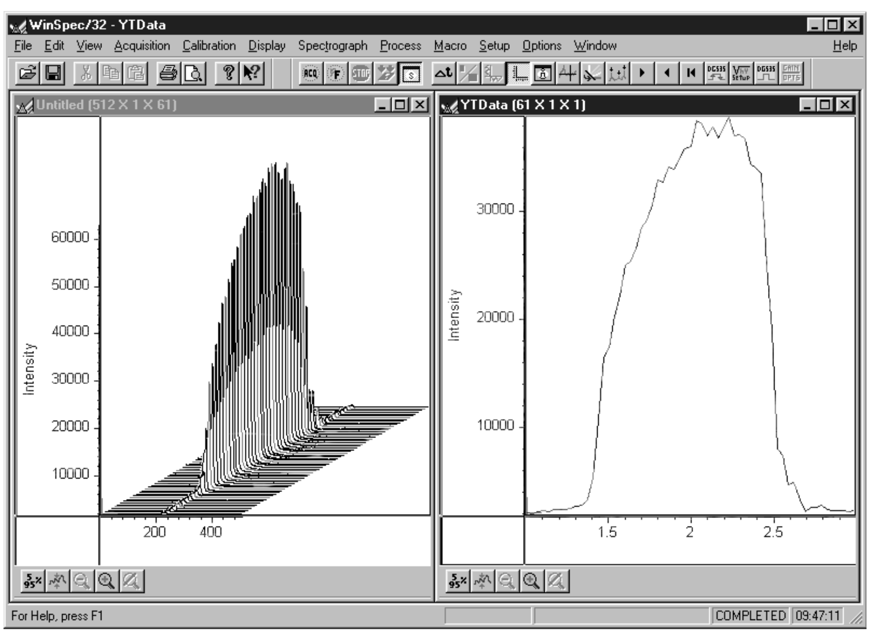


Figure 70. Fast Gating Measurement Results

MCP Bracket Pulsing

Introduction

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* keeps the MCP biased OFF except for an interval that brackets the timing of the photocathode gate as shown in Figure 71. 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-MAX, however, when bracket pulsing is ON, the MCP is biased OFF until just before the photocathode is gated ON. The MCP is then biased ON and remains biased ON until just after the photocathode is biased OFF.

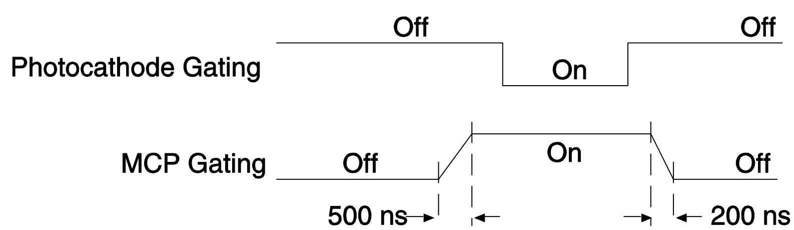


Figure 71. Timing: Bracket Pulsing

Traditionally, intensified detectors discriminated against background signal by gating the photocathode. Although this technique yields very high peak Off/On ratios, on the order of 5×10^6:1 in the visible, background signal can still prove troublesome in low-duty factor measurements, particularly in the UV region where the rejection is only ~10^4 :1. By bracket pulsing the MCP off (in addition to photocathode gating), the on/off ratio of the PI-MAX 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.

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

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. internal combustion engine), its lifetime can be many ms, 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 not 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 ms 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.

Bracket Pulsing in Nanosecond Pump Probe Experiments

Some nanosecond pump-probe experiments combine a nanosecond or faster pump with a flashlamp 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% of 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.

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 (Raleigh, MIE, Raman) or unwanted fast fluorescence. Because these usually fall below the MCP bracket pulsing 1 µs delay restriction, these measurements cannot be improved by MCP bracket pulsing in the PI-MAX.

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 is very much slower than 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 500 ns to accomplish coincidence at the detector. MCP bracketing should only be used in experiments where it is going to make a difference.

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-MAX.

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 much slower than photocathode gating (500 ns is required to gate the MCP on and another 200 ns 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 1 µs.

Setup

Implementing bracket pulsing involves selecting the function in software (Figure 72) ***and*** applying the DG535's **C⎍D** output via the **C+D-Gen II/A+B-Gen III** cable to the PI-MAX **Timing Gen** connector. The precise timing required to implement the function is automatically set according to photocathode gate width and delay, with the limitation that bracket pulsing should be deselected (or the **C+D-Gen II/A+B-Gen III** cable disconnected) if the delay between the trigger and the gate pulse is less than 1 µs. *This limit is imposed by the relatively slow on/off time of the bracket pulse function. It takes 500 ns to gate the MCP on and another 200 ns to gate it off.*

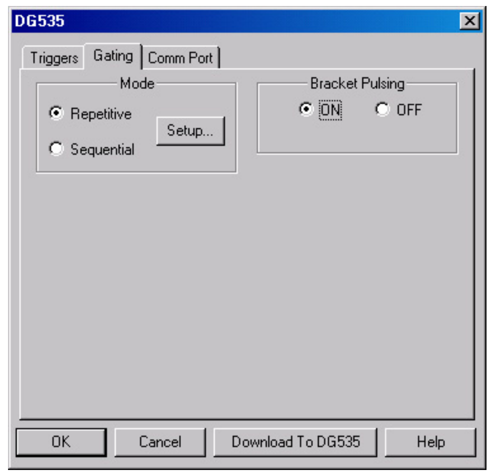


Figure 72. Gating tab

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

MCP Gating

Introduction

MCP gating is only available with the PI-MAX$_{MG}$ system. This gating mode (not to be confused with MCP bracket pulsing) provides you with 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-MAX$_{MG}$ 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. 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-MAX. Quantitatively, the propagation delay of the PI-MAX itself is in the 40 ns range compared to 10-12 ns for a standard PI-MAX. Note that DG535 propagation delay is in addition to the 40 ns.

Minimum FWHM for a PI-MAX$_{MG}$ system is in the 8 to 15 ns range, compared to 1.5 ns to 2 ns for a standard PI-MAX. Pulse repetition rate is limited to 1 kHz.

Setup and Operation

The PI-MAX$_{MG}$ is set up in the same way as a standard PI-MAX and is compatible with the DG535 and the PTG (preferred) timing generators. The cables used for a standard PI-MAX are used for the PI-MAX$_{MG}$. Note that when using the DG535, the set value of gate width is significantly larger than the optical FWHM. Typically, a width setting of 37 ns produces a FWHM in the range of 7 to 9 ns.

1. Start with **Shutter Mode** operation if possible, to verify initial operation, to focus, etc.
2. Then, switch to **Gate Mode** and a relatively long gate to acquire the phenomenon of interest.
3. Finally, narrow down the gate to the desired operation.

When possible in the experiment, it is a good idea to use bracket pulsing to limit the photocathode ON time. The required "lead time" or pretrigger time for the photocathode bracket pulse is 300 ns (compared to 500 ns for a standard PI-MAX MCP bracket pulse).

Note: Pulse repetition rate is limited to 1 kHz.

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.

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 DG535. 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-MAX. The spectrum would then be intensified and applied to the PI-MAX's CCD array.

Cabling for MCP Gated Operation

Figure 73 illustrates the cabling for this experiment using a Stanford Research DG535 Timing Generator. The laser trigger output is applied to the **Trig. In** connector of the DG535 to initiate the timing sequence. The **A** and **B** edge outputs of the DG535 gate the MCP on and off. The **C⎍D** pulse output gates the photocathode on and off if bracket pulsing* has been selected. These three signals, **A**, **B**, and **C⎍D**, are applied to the PI-MAX **Timing Gen** connector. Another timing generator output, **D**, is applied to the **Ext. Sync** input of the controller to initiate readout. Finally, to prevent artifacts from the laser from degrading

* Bracket pulsing is not available for camera's having a Gen III Intensifier. Also, if the camera has a Gen III Intensifier, for proper operation, it is the **A⎍B** DG535 output that must be connected to the camera **Timing Gen** connector and not the **C⎍D** DG535 output.

the data, it is essential that the timing generator be inhibited during each readout. This is accomplished by connecting the controller's **Shutter** output signal (provided at ST-133's $\overline{\text{SCAN}}$ output) to the **Inhibit** input of the DG535. The DG535 parameters are set from the computer by the application software.

Other system cabling would include the Detector-Controller cable that interconnects the PI-MAX and the controller, the TAXI cable between the controller and the computer, and the GPIB link between the computer and the DG535.

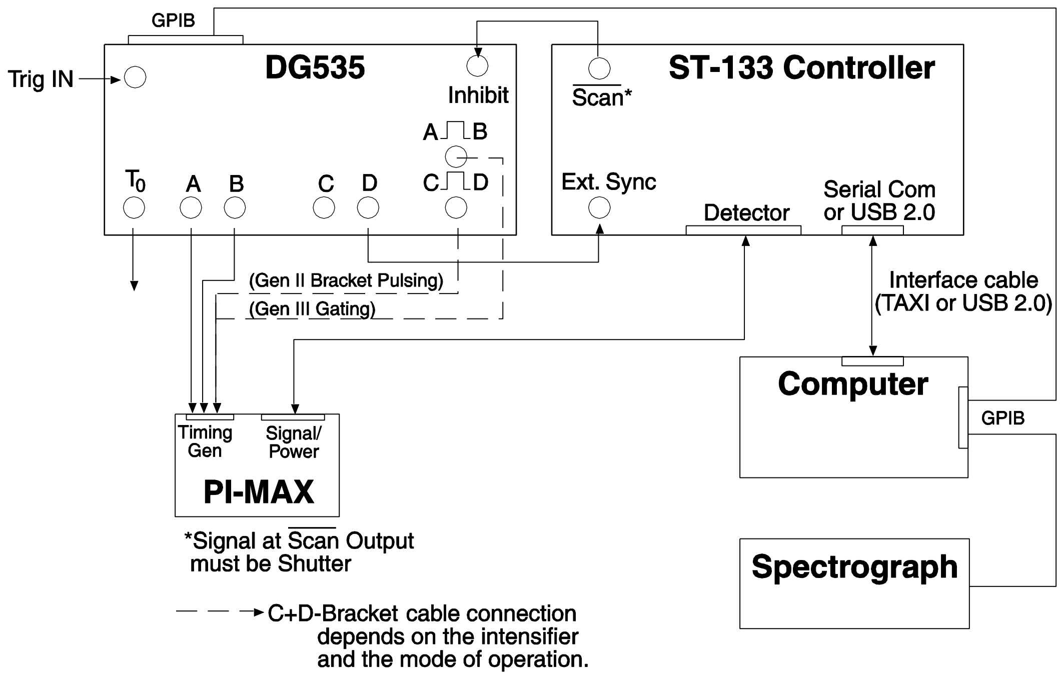


Figure 73. MCP Gated Operation Cabling

Figure 74 is a timing diagram for a DG535. A diagram of the PTG timing would be similar, the principal difference being that ***the insertion delay would be 25 ns instead of the 85 ns insertion delay characteristic to the DG535.***

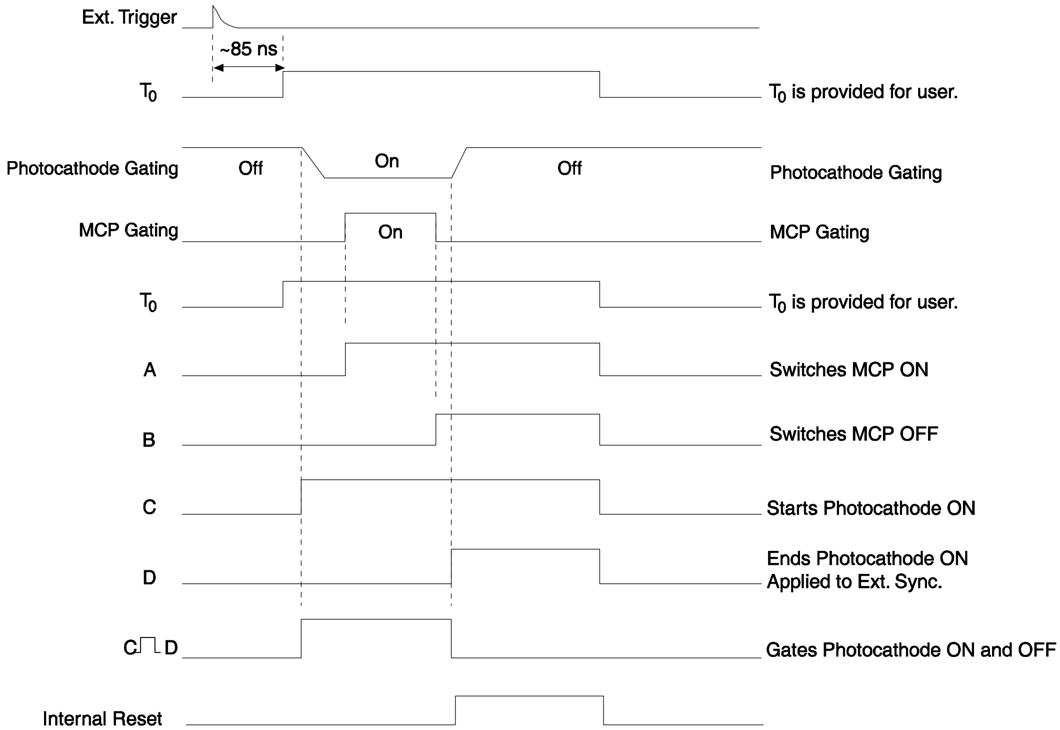


Figure 74. PI-MAX Timing in MCP Gated Operation with DG535 Timing Generator

Chapter 9
Kinetics Operation

> ***Notes:***
>
> 1. Kinetics operation requires that the Kinetics option has been installed in the Controller. If the communication protocol is USB 2.0, kinetics operation is supported by WinView/WinSpec Version 2.5.18.1 or higher.
> 2. Kinetics operation is not supported by Interline CCDs (PI-MAX2:1003).

Introduction

Charge can be shifted on the surface of a CCD array much faster than it can be read out. If only a small area of a CCD is illuminated, the charge from several exposures can be shifted along the surface, in much the same way that a long strip of film is passed through a traditional photographic camera to record a series of images. Instead of moving the film, the camera moves only the charge along the surface of the array, and this makes it very fast. Refer to ***"Readout of the Array"***, beginning on page 60, for more information about charge shifting and array readout.

Masking

For Kinetics operation, a portion of the photocathode on the intensifier must be masked so it can be used as a storage area. The masking can be accomplished via a mechanical or an optical mask at the photocathode or entrance slit. (One form of optical masking uses multiple fiberoptic cables with differing lengths for time delay.) If the open area is small relative to the storage area, quite a few images can be acquired in rapid succession, for example with 50 open rows and 256 rows masked, 5 images can be acquired in a total of approximately 1.2 ms.

Shutter Mode and Kinetics

Introduction

In Shutter Mode, kinetics operation can be run in Free Run, can take a series of images initiated by a Single Trigger, or can take a single image for each trigger in a series of triggers.

Free Run

In Free Run Kinetics mode, the ST-133 takes a series of images, each with the exposure time set through the software, with only a few microseconds between images. The exact number of images depends on the Window Size you select on the **Hardware Setup|Controller/Camera** tab. Window Size is the number of rows allocated for an image subframe. The number of subframes is the number of pixels perpendicular to the shift register divided by the Window Size. The time required to shift a subframe under the mask is determined by the Vertical Shift rate (specified in μs/row) multiplied by the Window Size.

Example: Assuming an array with 512 rows, specifying a Window Size of 32 would result in 16 subframes.

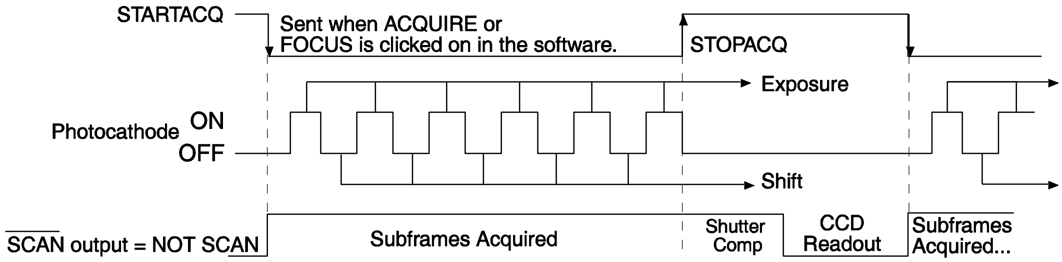


Figure 75. Kinetics in Shutter Mode: Free Run Timing Diagram

Single Trigger

Single Trigger Kinetics mode takes an entire series of image subframes with each External Trigger Pulse (applied at the Ext. Sync BNC on the ST-133). When the External Sync occurs after the Start Acquisition (STARTACQ) command, the photocathode is biased on for the exposure time set in the software. The photocathode is biased off at the end of the exposure time, and the subframe is shifted. The photocathode is biased on again and the cycle repeats until the subframes have been acquired. At that point, the photocathode is biased off, the shutter compensation time elapses, and the CCD is read out at normal speeds. Once the readout is complete the camera is ready for the next set of subframes of exposures. The number of subframes in a series is based on the number of rows on the CCD divided by the Window Size.

Single trigger timing is shown in Figure 76, where a single External trigger pulse is used to collect a burst of 6 subframes.

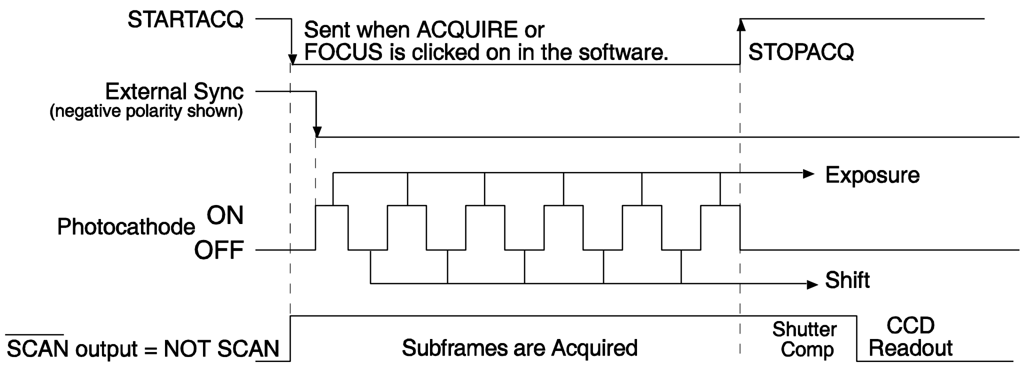


Figure 76. Kinetics in Shutter Mode: Single Trigger Timing Diagram

Multiple Trigger

Multiple Trigger Kinetics takes a single image in the series for each External Sync pulse received by the ST-133. When the first External Sync occurs after the Start Acquisition (STARTACQ) command, the photocathode is biased on for the exposure time set in the software. The photocathode is biased off at the end of the exposure time, the subframe is shifted, and the camera waits for the next pulse to arrive. It then repeats the cycle until all of the subframes have been acquired. At that point, the photocathode is biased off and CCD frame readout begins. Once the frame has been read out, the camera is ready for the next series of subframes. The number of subframes in a series is based on the number of rows on the CCD divided by the Window Size.

Multiple trigger timing is shown in Figure 77, where a series of 6 subframes is collected with 6 External Sync pulses.

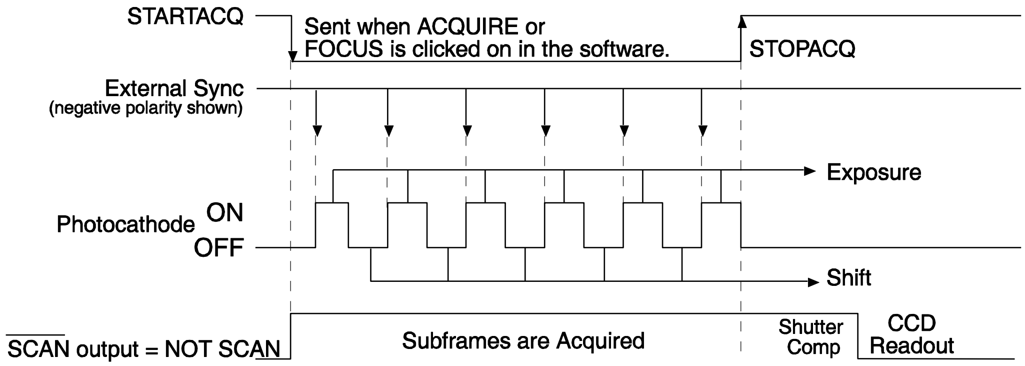


Figure 77. Kinetics in Shutter Mode: Multiple Trigger Timing Diagram

Array Readout

Kinetics operation uses the CCD to store a limited number of images in rapid succession. The time it takes to shift each line on the CCD is as short as a few microseconds, depending on the CCD. Therefore, the time between images can be as short as a few hundred microseconds.

Returning to our 4 × 6 CCD example, in this case 2/3 of the array is masked, either mechanically or optically. The shutter opens to expose a 4 × 2 region. While the shutter remains open charge is quickly shifted just under the mask, and the exposure repeated. After a third image is collected the intensifier is gated OFF and the CCD is read out. Since the CCD can be read out slowly, very high dynamic range is achieved. Shifting and readout are shown in Figure 78.

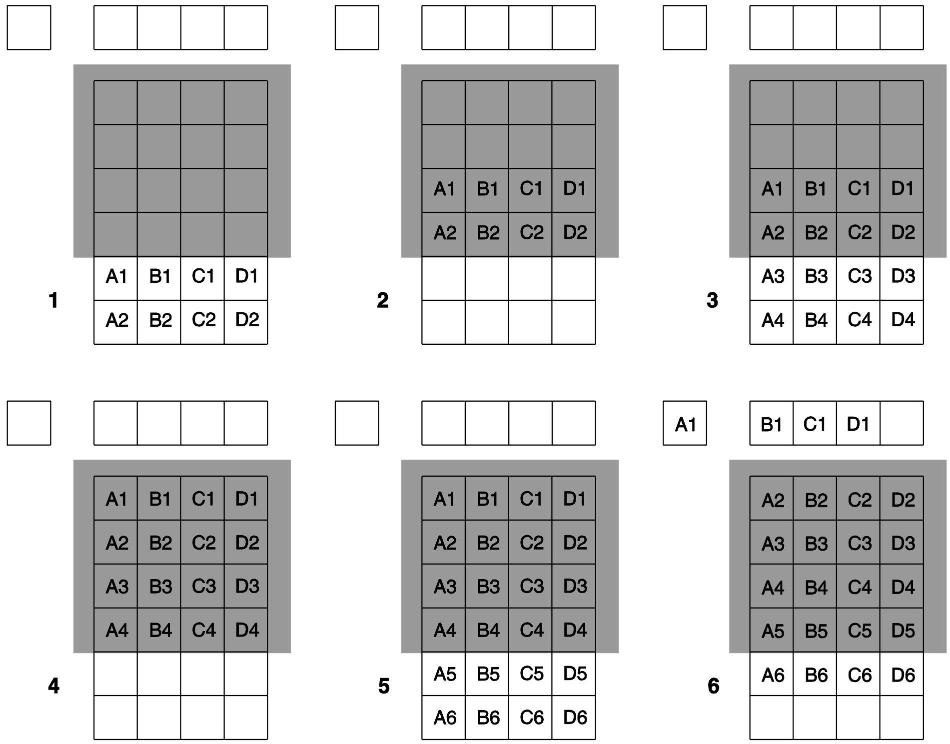


Figure 78. Kinetics Readout

PTG Burst Mode

A PTG configured to run in Burst Mode will generate a short burst of very rapid gate pulses. The pulse burst can be driven from an external trigger or from the internal oscillator. The maximum number of pulses is duty cycle limited but a good rule of thumb is 50 pulses/burst.

Burst mode is supported in the PI-MAX 512*, 1k, and 1024 RB/SB/UV/HQ models. The maximum burst mode repetition rate depends on the model and the intensifier. In the 1024 series of detectors, the maximum burst repetition rate is 250 kHz (minimum burst period = 4 µs) For the 512 and 1K series of detectors, the maximum burst repetition rate depends on the intensifier as in Table 8.

* Burst mode is not supported in the PI-MAX 512 detectors with Gen II (SB Slow Gate, RB Slow Gate) intensifiers.

Intensifier	Max. Burst Mode Repetition Rate	Minimum Burst Period	Minimum Gate Width
Gen II			
RB Fast Gate	500 kHz	2 µs	>5 ns
SB Fast Gate	500 kHz	2 µs	>5 ns
UV	500 kHz	2 µs	>5 ns
RB Slow Gate	N/A	N/A	N/A
SB Slow Gate	N/A	N/A	N/A
Gen III			
HQ	50 kHz	20 µs	>5 ns
HQ Blue	50 kHz	20 µs	>5 ns

Table 8. Burst Mode Repetition Rate for PI-MAX 512 and PI-MAX 1k Models

One Shot Experiments

One shot experiments can also be performed in the kinetics mode. Two different kinds of kinetics modes, ***slow*** and ***fast***, are provided. In the slow kinetics mode the time scale is on the order of 10 to 100 µs per image or spectra. In the fast kinetics mode the time scale is in the 2 to 100 ns range. In the slow kinetics case, a small strip on the CCD array is used for integration of the light signal. The remainder of the array is masked off, either through the optics or through a physical mask in front of the camera and the masked portion of the chip is used as its own storage register. The data-acquisition speed is limited by how fast a row of information on the CCD can be physically shifted. For example, if the vertical shift speed is three microseconds per row and the strip is five rows tall, it will be possible to get a fresh spectrum every 15 µs. In the case of a chip that's 256 pixels tall, it will be possible to get 50 spectra on the chip before it is completely filled, at which point it can be read out as an image.

In a fast kinetics experiment, a fiber optic delay line can be used to provide the timing. For example, you might have ten fibers, with the first fiber being 7 ft long, the second fiber 14 ft long, the third fiber 21 ft long, etc., up to the last fiber, which would be 70 ft long. The optical delay differences provided by each of those fibers is approximately 10 ns. If the fibers were aligned at the entrance slit of the spectrograph, and gated once, ten snapshots in time, each one separated from the one above it by 10 ns, would be produced.

Gate Mode Experiments - Examples

The combination of PTG and PI-MAX offers numerous possibilities in Kinetics mode. But in all combinations **underlying objective is to synchronize intensifier gate to CCD shifting** and to capture the time resolution of the event on the CCD. Presented below, are two experiment scenarios that can be carried out with this instrumentation. User is responsible for masking the intensifier (e.g., through Spectrograph/fiber optic combination).

<u>Experiment 1: Single Trigger</u>

A single trigger arrives from user's experiment or is internally generated by the PTG. The PTG generates multiple triggers (burst) based on that trigger. These triggers are used to synchronize both the intensifier and the CCD shift. Figure 79 is a timing diagram for Experiment 1.

Hardware Connections

- User's trigger pulse connected to Ext. Trig. In of PTG (optional)
- Aux. Out BNC of PTG connected to Ext. Sync. of ST-133

PTG Settings

- **Trigger:** External or Internal
- **Pulsing:** Continuous with constant Delay and constant Width, Burst Mode (Number of pulses, period)
- **AUX:** delay is longer than Gate Width + Delay, but shorter than Burst period

Experiment Setup Settings

- **Main:** Gate Mode
- **Timing:** Single Trigger**,** +edge, disable Continuous Cleans, Shutter Control is disabled open.

Conditions

- Gate Delay + Gate Width <= AUX delay
- Burst period >=AUX delay + shift time*
- Number of burst pulses >= Total number of Kinetic shifts

(* Shift time can be calculated by vertical shift rate and number of rows used in kinetic shifting.
For PI-MAX 1024→ vertical shift rate is 30µs/row (PI-MAX 512 → 1.6µs/row).
If 10 rows are used in kinetic shift →Total shift time = 10*30µs = 300µs)

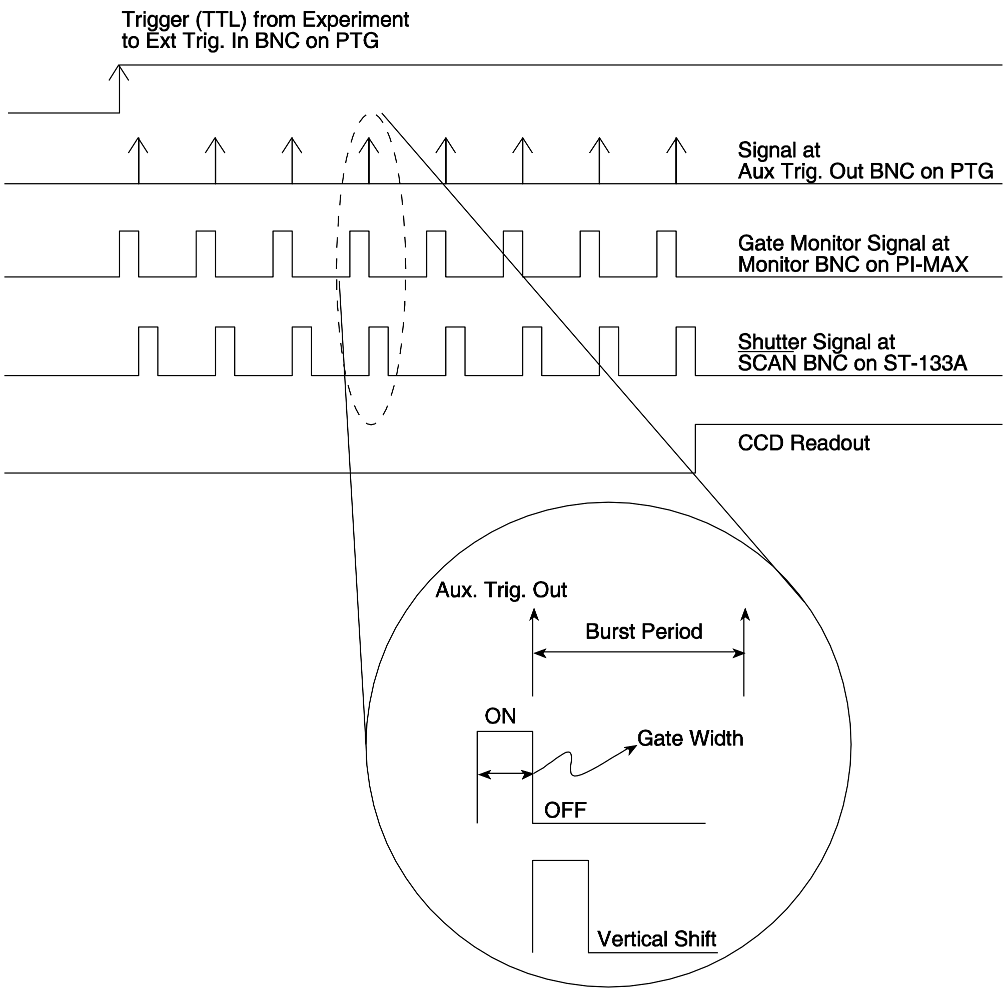


Figure 79. Timing Diagram: Experiment 1

Experiment 2: Multiple Trigger

A trigger, either internal or external, is required for each vertical shift "window" of the CCD. The PTG generates the gate pulse and an internal sync for each incoming trigger. The CCD vertical shift is driven by the internal sync of the PTG. Figure 80 is a timing diagram for Experiment 2.

Hardware Connections

- User's trigger pulse connected to Ext. Trig. In of PTG (optional)

PTG Settings

- **Trigger:** External or Internal
- **Pulsing:** Continuous with constant Delay or constant Width

Experiment Setup Settings

- **Main:** Gate Mode
- **Timing:** Multiple Trigger**,** -edge, disable Continuous Cleans, Shutter Control is disabled open.

Conditions

- Gate Delay + Gate Width <= Internal Frequency

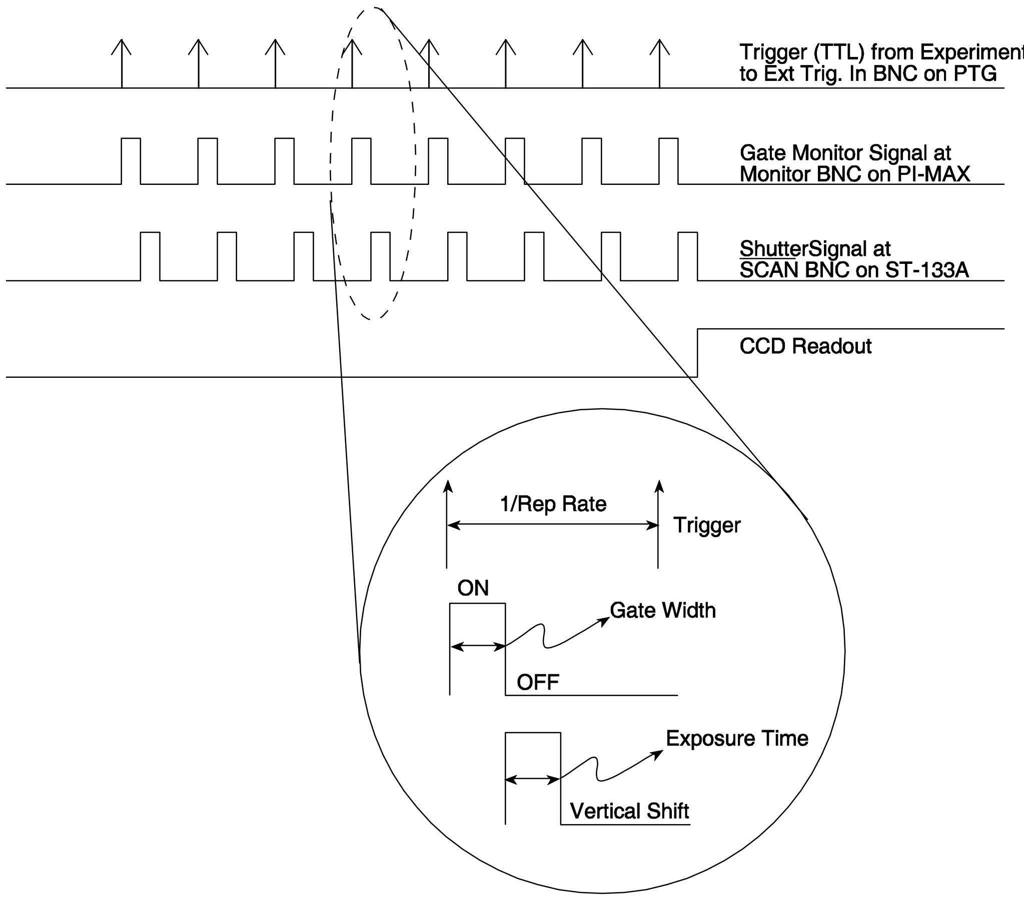


Figure 80. Timing Diagram: Experiment 2

Chapter 10

PI-MAX2 DIF Camera (Double Image Feature)

Introduction

This chapter assumes a basic understanding of the operation of the PI-MAX2 and PTG in Gate Mode using the WinX application software (WinView/32 or WinSpec/32). Please refer to Chapter 7 of this manual if you do not feel confident with the basic operation of the PI-MAX and PTG in Gate mode.

The purpose of the PI-MAX2 DIF system is to acquire a pair of gated images in rapid succession. The time between frames can be as short as 2 µs with exposure times as short as 5 ns. The DIF capability is ideally suited to capturing rapidly evolving events. These experiments will fall into one of two broadly applicable categories: single trigger and dual trigger experiments. Single trigger experiments involve a single impulse event that evolves over time such as a laser-induced plasma or luminescence decay. Dual trigger experiments involve two impulses separated in time such as double laser pulse velocimetry measurements.

Requirements

The following requirements must be met for DIF operation:

- the PI-MAX2 must use an interline CCD,
- the controller must have a High Speed PCI Interface (TAXI) board and a PTG board installed, and
- the entire system must be set up for DIF operation at the factory.

In addition to these requirements, it is recommended that the intensifier have a fast decay phosphor (P46 or P47). Since DIF operation involves acquiring images in rapid succession, phosphor persistence can become the limiting factor in the rate of image acquisition.

The WinX application software (version 2.5.16 or later) can control the DIF functionality of the PI-MAX2 and provides full access to the two DIF timing modes: single trigger and dual trigger.

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 is read out.

Timing Modes

In the WinX application software, the timing modes available in the **Acquisition|Experiment Setup…|Timing** tab are different from those in standard intensified systems. The available timing modes are:

Single Trig. Mode: two shot, one trigger for both shots.

Dual Trig. Mode: two shot, each shot requires a trigger.

The trigger(s) can be generated by an external source attached to the PTG or the PTG can generate the trigger(s) internally. When using a PTG internal trigger, the experiment will normally be triggered by a signal from the ST-133. Typically, the rising edge of T0, from the PTG, is used.

Single Trigger Mode

The Single Trigger Mode only requires a single trigger to initiate the acquisition of both images of the DIF operation. The Single Trigger Mode uses the Burst Mode feature of the PTG to acquire two images from a single trigger event. On the **Gating** tab of the Pulse dialog, the Burst Mode should be turned on. The Number of Pulses must be set to 2, and the time between the images is set by the Burst Period. It is very important that the Burst Period be large enough to accommodate the gate width, gate delay, and phosphor decay time. To set the gate width and delay, select Repetitive Mode from the **Gating** tab of the Pulse dialog and then click on the Setup button.

Note: Sequential Mode will not create different gate width and delay for the two images in Single Trigger Mode due to Burst Mode selection.

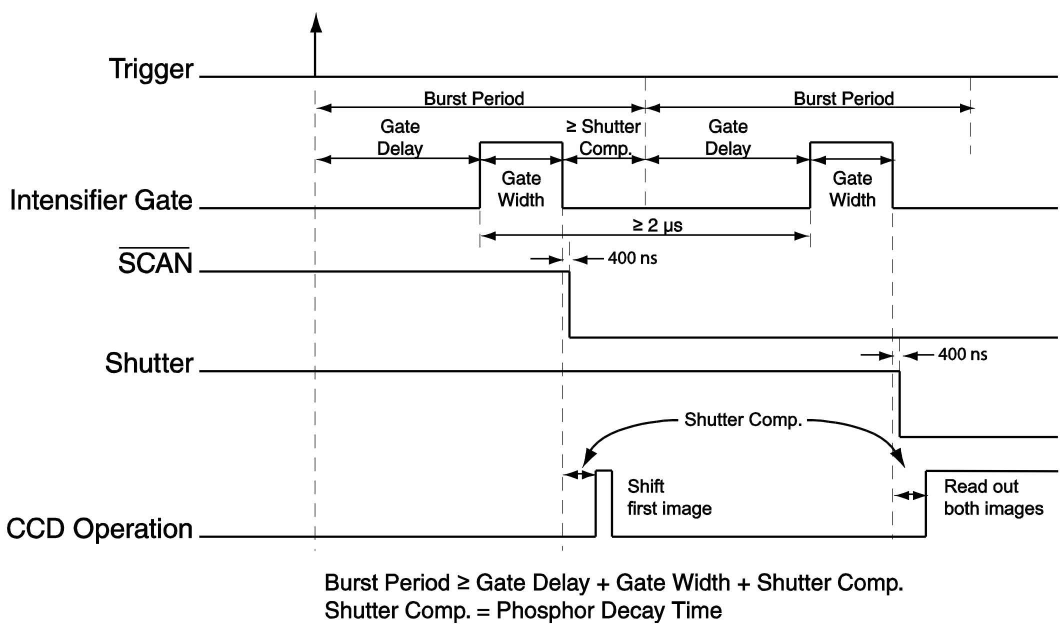


Figure 81. DIF Operation: Single Trigger Timing Diagram

Dual Trigger Mode

The Dual Trigger Mode requires two triggers to acquire both images of the DIF operation. The PTG will control the gating of the intensifier for both images. To make the gate width and delay the same for both images, select Repetitive Mode from the **Gating** tab of the Pulser dialog then click the Setup button to set the values. To make the gate width and delay different for each pulse, select Sequential Mode from the **Gating** tab of the Pulse dialog, then click the Setup button to set the values. The Number of Images should be set to 2, and the first image will use the starting values for gate width and delay while the second image will use the ending values.

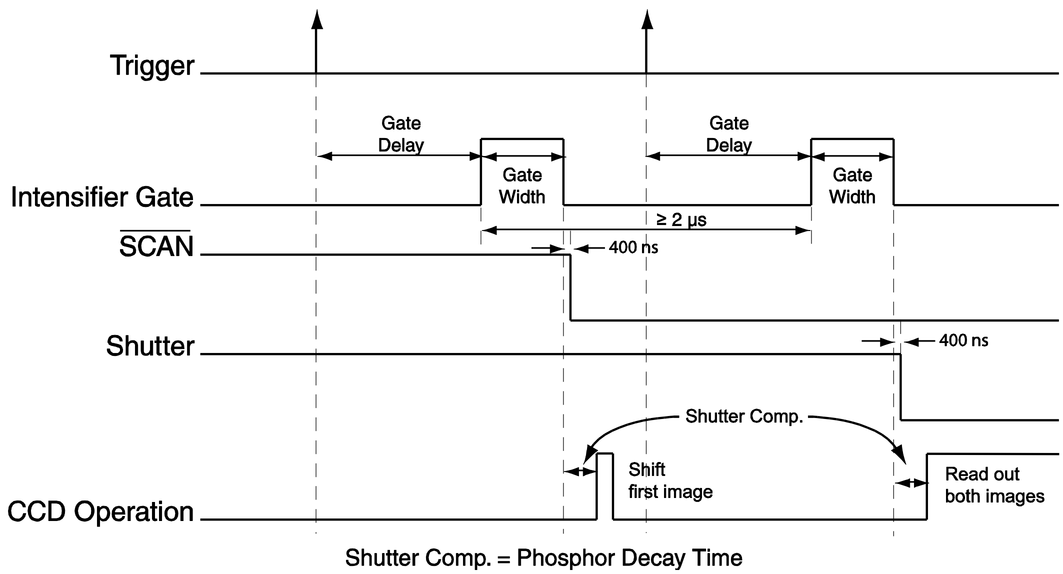
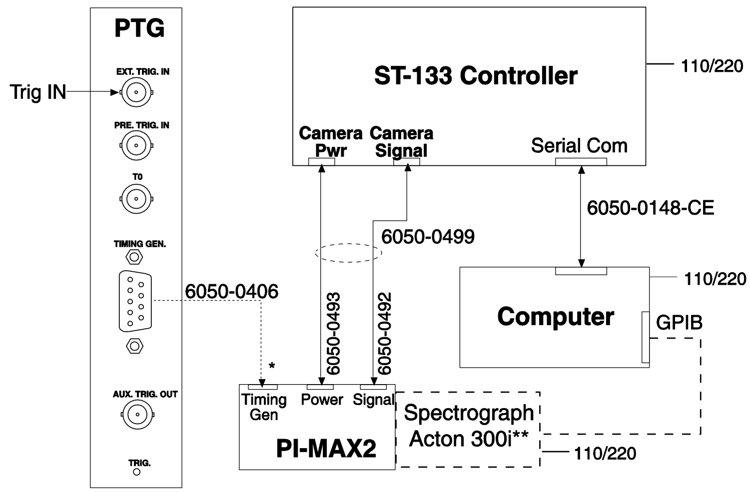


Figure 82. DIF Operation: Dual Trigger Timing Diagram

Setup

Hardware



* In current systems, the Timing Gen. cable can remain connected during Shutter Mode operation. Older systems may require that it be disconnected.
** Spectrograph connection is optional.

Figure 83. System Diagram: DIF Operation

Software

For the purposes of this setup, it is assumed that you are using WinX application software (either WinView/32 or WinSpec/32) to control the system.

Operation

The operation of the PI-MAX2 in DIF mode is similar to the standard operation of a PI-MAX2 with PTG. There are only a few differences due to the special timing modes of DIF, and they will be outlined here. Because there are two timing modes in DIF operation, there are two procedures for setting up the experiment.

Single Trigger Mode

1. The first requirement is that the PI-MAX2 camera be aligned and focused on the area of interest in the experiment. This is best accomplished while the PI-MAX2 is operating in Interline mode (i.e., before switching to DIF mode). The procedure for initial focus is outlined in Chapter 4: First Light.

2. After the alignment and focus, the PI-MAX2 system needs to be put into DIF mode. Select **Hardware** from the **Setup** menu to open the Hardware dialog. Under Readout Mode, select **DIF** and then click **OK**.

3. The PI-MAX2 must be set to Gate mode for the intensifier to operate properly. Either click on the **Gate mode** button on the Custom Toolbar or select **Gate mode** on the **Acquisition|Experiment Setup…|Main** tab.

4. Now the PTG needs to be programmed to match the experiment. On the **Setup** menu, select **Pulser** and click on **Pulser Setup** (or click the **Pulser Setup** button in the Custom Toolbar).

a. In the **Pulser** dialog, select the **Trigger** tab. The PTG can be triggered by an external trigger signal such as a TTL (typical settings for a TTL trigger might be: 1.7 V, positive edge, DC, 50 Ohm) or a photodiode (typical settings for a photodiode might be: 8.0 V, positive edge, DC, high Z), or the PTG can use its own internal clock to trigger the experiment. Select the appropriate one for your experiment. In either case, the trigger frequency should be slow enough so that the period between triggers is longer than the entire DIF experiment. For example, if the Burst Period is 6 µs, then the trigger frequency should be 8333 Hz [1 / (2 * 6 µs)].

b. Now select the **Gating** tab. In the Burst Mode section, turn Burst Mode on. Set the Number of Pulses to 2. The Burst Period must be set to a value that is greater than Gate Width + Gate Delay + Phosphor Decay. Ensure that the Gating is set to Repetitive, and then click on the **Setup** button to set the appropriate gate width and delay.

c. At the bottom of the **Pulser Setup** dialog, click **OK** to download the gating sequence to the PTG.

5. The CCD parameters need to be set to the appropriate values for DIF operation. Select **Experiment Setup** from the **Acquisition** menu.

   a. In the **Timing** tab, select **Single Trig. Mode**.

   b. In the **Main** tab, verify that the Number of Images is 2 and the Intensifier is in Gate Mode.

   c. When the experiment is ready, click the **Acquire** button to start the image acquisition.

Dual Trigger Mode

1. As with Single Trigger Mode, the PI-MAX2 camera must first be aligned and focused on the area of interest in the experiment. This is best accomplished while the PI-MAX2 is operating in Interline mode (i.e., before switching to DIF mode). The procedure for initial focus is outlined in Chapter 4: First Light.

2. The PI-MAX2 system needs to be put into DIF mode. In the **Setup** menu, open the **Hardware** dialog. Under Readout Mode, select **DIF** and then click **OK**.

3. The PI-MAX2 must be set to Gate mode for the intensifier to operate properly. Either click on the **Gate** mode button on the Custom Toolbar or select **Gate mode** on the **Acquisition|Experiment Setup…|Main** tab.

4. Now the PTG needs to be programmed to match the experiment. In the **Setup** menu, select **Pulser** and click on **Pulser Setup** (or click the **Pulser Setup** button in the Custom Toolbar).

   a. In the Pulser dialog, select the **Trigger** tab. The PTG can be triggered by an external trigger signal such as a TTL (typical settings for a TTL trigger might be: 1.7 V, positive edge, DC, 50 Ohm) or a photodiode (typical settings for a photodiode might be: 8.0 V, positive edge, DC, high Z), or the PTG can use its own internal clock to trigger the experiment. Select the appropriate one for your experiment. In either case, the trigger frequency should be slow enough so that the period between triggers is longer than the Gate Delay + Gate Width + Phosphor Decay time.

b. Now select the **Gating** tab. If the experiment can use the same gate width and delay for both frames, then select **Repetitive**, and click on the **Setup** button to set the appropriate gate width and delay. If the experiment requires different gate widths or delays for each frame, then select **Sequential** and click on the **Setup** button to set the appropriate gate widths and delays. The number of images should be set to 2, the gate width and delay for the first frame should be set as the starting values, and the width and delay for the second frame should be set as the ending values.

c. At the bottom of the **Pulser Setup** dialog, click **OK** to download the gating sequence to the PTG.

5. The CCD parameters need to be set to the appropriate values for DIF operation. Select **Experiment Setup** from the **Acquisition** menu.

   a. On the **Timing** tab, select **Dual Trig. Mode**.

   b. On the **Main** tab, verify that the **Number of Images** is **2** and the **Intensifier** is in **Gate Mode**.

   c. When the experiment is ready, click the **Acquire** button to start the image acquisition.

Tips and Tricks

Experiments using the DIF feature of the PI-MAX2 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-MAX2 has a Gate Monitor signal on the back of the camera head which is very useful for seeing when the two image exposures occur during the course of the experiment. The use of the Gate Monitor and an oscilloscope is discussed in more detail in Chapter 11: Tips and Tricks.

- The short time between the two images in DIF requires an intensifier with a fast phosphor. P46 phosphor as a decay time of ~ 2 µs, that 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 Shutter Compensation 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 Shutter Compensation Time to allow the phosphor more time to decay before shifting the image. If residual image is not an issue, then Shutter Compensation Time can be shortened to decrease the time between the two DIF images.

Chapter 11

Tips and Tricks

Introduction

In Chapters 4 and 7, 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.

Overexposure Protection

WARNING Image intensified detectors such as the PI-MAX can be *destroyed* if exposed to excessive light levels. 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 **MCP On/Off** switch (on the back of the PI-MAX) 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 continuously, 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.

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, see the ***"Alarm"*** discussion on page 82.

Signal Delay

Introduction

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.

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-MAX, ST-133, and a pulse generator (PTG or DG535), 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.

PTG

Signal Delay

- **Cable Delay from External Timer to Laser:** 10 ns (6 ft cable is assumed)
- **Delay (at laser); Trigger to Laser Pulse:** 50 ns
- **Delay; Laser Pulse to Sample:** 10 ns
- **Delay; Fluorescence Signal to Detector:** 45 ns

Total Signal Delay: 115 ns

Gate On Delay

- **Cable Delay from External Timer to PTG:** 15 ns (10 ft cable is assumed)
- **PTG Insertion Delay; Trigger to Start of Gate Open Pulse:** 25 ns
- **Cable Delay from PTG to Detector:** 22 ns (15 ft cable is assumed)
- **Detector Insertion Delay:** 15 ns

Total Gate On Delay: 77 ns

DG535

Signal Delay

- **Cable Delay from External Timer to Laser:** 10 ns (6 ft cable is assumed)
- **Delay (at laser); Trigger to Laser Pulse:** 50 ns
- **Delay; Laser Pulse to Sample:** 10 ns
- **Delay; Fluorescence Signal to Detector:** 45 ns

Total Signal Delay: 115 ns

Gate On Delay

- **Cable Delay from External Timer to DG535:** 15 ns (10 ft cable is assumed)
- **DG535 Insertion Delay; Trigger to Start of Gate Open Pulse:** 85 ns
- **Cable Delay from DG535 to Detector:** 10 ns (6 ft cable is assumed)
- **Detector Insertion Delay:** 15 ns

Total Gate On Delay: 125 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.

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.

The PI-MAX **Monitor** BNC connector provides a pulse which, although delayed with respect to the actual intensifier photocathode gating by 4-6 ns, quite accurately indicates the intensifier photocathode gating time. 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.

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. *This is not necessarily always the case. Digital oscilloscopes can display signals that occur before the trigger*.

For even more precise measurement of the gate time, one can use the noise burst on the Pulse Monitor output. The “noise” is actually induced voltage resulting from the fast rise time gate pulse and is within ~2 ns of the true optical gate.

Adjusting the Signal Delay

The PTG and DG535 give 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 for the PTG; 85 ns for the DG535), 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.

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.

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.

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 Pretrigger Output, it can be used to trigger the timing generator. If the interval between the Pretrigger and the laser output is long enough, the timing generator delay can then be adjusted to catch the laser pulse following each pretrigger. If the interval between the Pretrigger and the laser output isn't long enough to accommodate all the 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 doesn't have a Pretrigger 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.

Triggered Lasers

Timing Generator as Trigger Source: Using the PTG's **T0** signal or the DG535's **T0** output to trigger the laser allows you to get rid of the propagation delay for the External Trigger (25 ns for PTG and 85 ns for DG535) and to set up all timing relative to **T0**. 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), cabling from the ST-133 to the PI-MAX (1.5 ns/ft), the PI-MAX's internal delay (15 ns), and the minimum allowable gate delay (21 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 Pretrigger 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 pretrigger, 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.

Jitter

Jitter, 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 pretrigger. 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."

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 PTG,*** the timing generator is inhibited internally by the Controller. ***With a DG535,*** it is necessary to connect a cable from the **Shutter**[*] output signal (provided at the ST-133's $\overline{\text{SCAN}}$ Output) to the **Inhibit** input of the DG535 (requires that the DG535 have the Inhibit Option installed).

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

[*] NOT SCAN and SHUTTER are two different signals and must be set by jumper or software.

sharp image on the photocathode of the intensifier. The ability of the lens to do this well depends on a number of factors, as follows.

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/).

Resolution

This is a measure of the sharpness of the lens, that is, of its ability to resolve two closely spaced lines. Resolution is commonly expressed as the Modulation Transfer Function (MTF), which specifies the number of line pairs per mm that can be resolved for a given valley depth between the two lines of each pair. In comparing the MTF of two systems, it is important that the specified valley depth for both be the same. For any real lens, resolution is a function of f/#, with maximum sharpness most often occurring at some mid-range value. Thus, a lens which offers f/# settings from f/ 2.8 to f/22 will probably be sharpest at f/8 or f/11. For this reason, even though focusing may be more sensitive at maximum aperture, actual data acquisition should be done with a mid-aperture setting.

When working with an intensified camera though, keep in mind that the resolution limit will ordinarily be determined by the intensifier, not the lens, and light gathering power becomes the principle concern for the lens.

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 (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.

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 30 minutes for the detector temperature to completely stabilize. Then try taking a few dark charge readings with the detector operated with the MCP On/Off 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. 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. Every device has been thoroughly tested to ensure its compliance with Princeton Instruments' demanding specifications.

Temperature Lock

If the PI-MAX 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. See ***"Temperature Control"***, page 57.

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.

Intensifier Alarm

To reduce the risk of detector damage, PI-MAX detectors are 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 temporarily disabled. Toggle the **MCP On/Off** switch on the back of the PI-MAX to the **OFF** position. Cover the detector window and only switch the **MCP On/Off** 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.

Some controllers may also provide an audible alarm, indicating the same over-threshold condition as the detector alarm. Note that it is normal for the alarm to sound momentarily when the system is turned on.

Caution

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

Preamplifier Output Mode

PI-MAX detectors with the Thomson 512 × 512 chip have two auto-selected output nodes. Node selection is done automatically from software depending on the A/D converter speed. This allows performance to be optimized for a FAST converter (1 MHz) or for a SLOW one (500 kHz or slower but with superior noise performance). This feature enhances the PI-MAX's ability to provide outstanding performance in a wide variety of applications.

Note that the node selection reverses the direction of data readout. When **Slow** is selected, data readout begins with the longer (red) wavelength pixels and progresses to the shorter (blue) wavelengths. When **Fast** is selected, the shorter wavelength pixels are read out first. In imaging, the effect is to reverse the image. These reversal effects are automatically accommodated by the software and are transparent to the user. When the image or spectrum is saved, the data will be in the order displayed *at the computer*.

Note: The order of the data at the ST-133's **Video Output** connector will always depend on the selected node. This reversal will be evident in the video monitor display and cannot be accommodated. Again, as explained in the preceding paragraph, the display at the computer is automatically corrected in software.

Chapter 12
Microscopy Applications

Introduction

This chapter discusses the setup and optimization of your digital imaging system as applied to microscopy.

Since scientific grade cooled imaging systems are usually employed for low light level microscopy, the major goal is to maximize the light throughput to the camera. In order to do this, the highest Numerical Aperture (NA) objectives of the desired magnification should be used. In addition, you should carefully consider the transmission efficiency of the objective for the excitation and emission wavelengths of any fluorescent probes employed. Another way to help maximize the transmission of light is to choose the camera port that uses the fewest optical surfaces in the pathway, since each surface results in a small loss in light throughput. Often the trinocular mount on the upright microscope or the bottom port on the inverted microscope provide the highest light throughput. Check with the manufacturer of your microscope to determine the optimal path for your experiment type.

A rule of thumb employed in live cell fluorescence microscopy is “if you can see the fluorescence by eye, then the illumination intensity is too high”. While this may not be universally applicable, it is a reasonable goal to aim for. In doing this, the properties of your camera should be considered in the design of your experiments.

Hardware binning can also be used to increase sensitivity. If sufficient detail will be preserved, you can use 2×2 binning (or higher) to increase the light collected at each “super-pixel” by a factor of four or more. This will allow you to reduce exposure times, thereby increasing temporal resolution and reducing photodamage to the living specimen.

Another way to minimize photodamage to biological preparations is to synchronize a shutter on the excitation pathway to the intensifier gate/shutter on the camera. This will limit exposure of the sample to the potentially damaging effects of the excitation light.

Mounting the Camera on the Microscope

The camera is connected to the microscope via a standard type mount coupled to a microscope-specific adapter piece. There are two basic camera mounting designs: the F-mount and the C-mount. The F-mount uses a tongue and groove type mechanism to align the camera with an adapter, while the C-mount employs a standard size thread to connect to the adapter. Either or both types could be available for a specific camera model.

F-Mount

For a camera with the F-mount type design, you will need two elements to mount the camera on your microscope. The first element is a Diagnostic Instruments Relay Lens. This lens is usually a 1× relay lens that performs no magnification. Alternatively, you may use a 0.6× relay lens to partially demagnify the image and to increase the field of view. There is also a 2× relay lens available for additional magnification. The second element is a microscope specific Diagnostic Instruments Bottom Clamp. Table 9 lists the bottom clamps routinely used with each of the microscope types. They are illustrated in Figure 84. If you think that you have received the wrong type of clamp, or if you need a clamp for a microscope other than those listed, please contact Princeton Instruments.

Microscope Type	**Diagnostic Instruments Bottom Clamp Type**
Leica DMR	L-clamp
Leitz All types	NLW-clamp
Nikon® Optiphot, Diaphot	O-clamp
Olympus BH-2, B-MAX, IMT-2	V-clamp
Zeiss Axioscope, Axioplan, Axiophot	Z-clamp
Zeiss Axiovert	ZN-clamp

Table 9. Bottom clamps for different type microscopes

To assemble the pieces, first pick up the camera and look for the black dot on the front surface. Match this dot with the red dot on the side of the relay lens. Then engage the two surfaces and rotate them until the F-mount is secured as evidenced by a soft clicking sound. Now, place the long tube of the relay lens into the bottom clamp for your microscope, securing the two together with the three setscrews at the top of the clamp as shown in Figure 85. This whole assembly can now be placed on the microscope, using the appropriate setscrews on the microscope to secure the bottom clamp to the output port of the microscope.

The F-mount is appropriate for any trinocular output port or any side port. When mounting the camera perpendicular to the microscope on the side port, we recommend that you provide some additional support for your camera to reduce the possibility of vibrations or excessive stress on the F-mount nose. Princeton Instruments ***does not*** advise using an F-mount to secure the camera to a bottom port of an inverted microscope due to possible failure of the locking mechanism of the F-mount. *Contact the factory for information about a special adapter for operating in this configuration.*

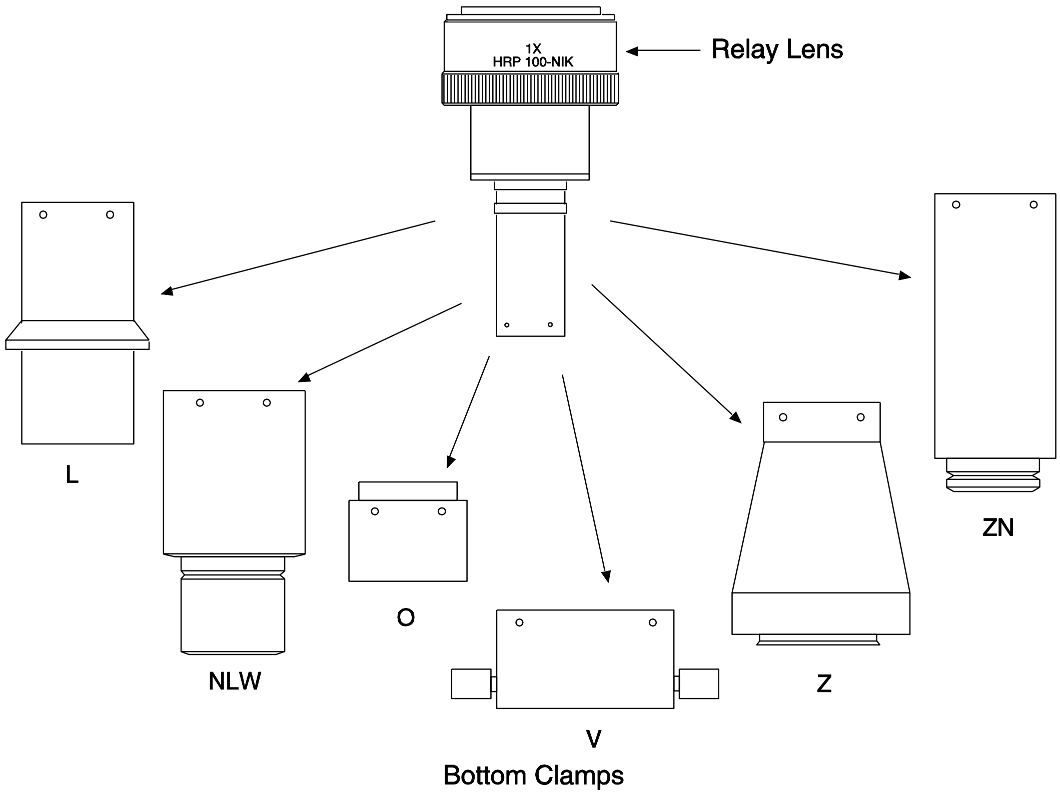


Figure 84. Diagnostic Instruments F-mount adapters

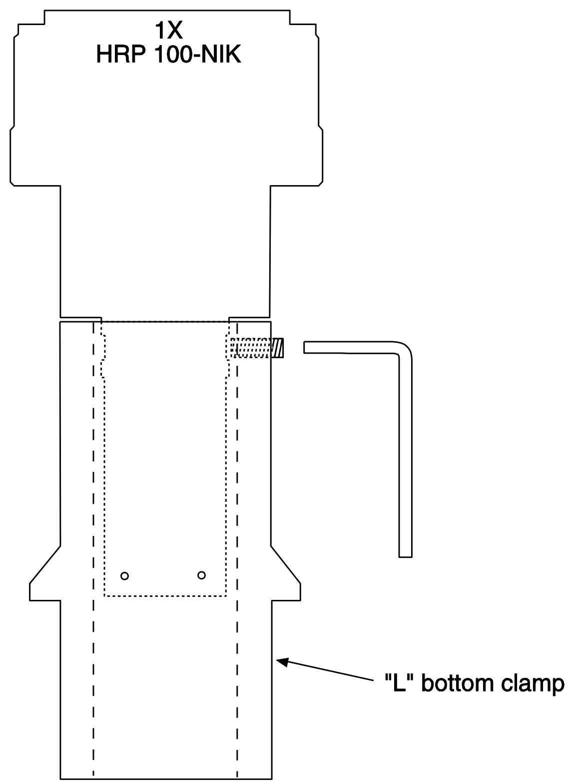


Figure 85. Bottom clamp secured to relay lens

C-Mount

For a camera equipped with a C-mount thread, use a standard C-mount adapter supplied by the microscope manufacturer to attach the camera to the microscope. *If you don't have an adapter, you can obtain one through your microscope distributor or you obtain dealer information from Diagnostic Instruments at its website at www.diaginc.com.*

The adapter can be screwed into the camera and then the assembly can be secured to the microscope using the standard setscrews on the microscope. The camera can be mounted on the trinocular output port, the side port or the bottom port of the inverted microscope. When mounting the camera perpendicular to the microscope on the side port, we recommend that you provide some additional support for your camera to reduce the possibility of vibrations or excessive stress on the C-mount nose. For the bottom port of the inverted microscope, the C-mount is designed to support the full weight of the camera, however, you may wish to provide some additional support for the camera since the detector is in a position where it could be deflected by the operator's knee or foot. This kind of lateral force could damage the alignment of the nose and result in sub-optimal imaging conditions.

Most output ports of the microscope do not require additional optical elements to collect an image, however, please check with your microscope manual to determine if the chosen output port requires any relay lens. In addition, all optical surfaces should be free from dust and finger prints, since these will appear as blurry regions or spots and hence degrade the image quality.

Operation

Xenon or Mercury Arc Lamp Precautions

WARNING

Before You Start, if your system includes a microscope Xenon or Hg arc lamp, it is **CRITICAL** to turn off all electronics adjacent to the arc lamp, especially your digital camera system and your computer hardware (monitors also), before turning on the lamp power.

Powering up your microscope Xenon or Hg lamp causes a large EMF spike to be generated that can cause damage to electronics that are running in the vicinity of the lamp. We advise that you place a clear warning sign on the power button for your arc lamp reminding all workers to follow this procedure. While Roper Scientific has taken great care to isolate its sensitive circuitry from EMF sources, we cannot guarantee that this protection will be sufficient for all EMF bursts.

Focusing the Microscope

1. Direct all of the light to the eyepieces
2. Focus on the target, set up Koehler illumination and adjust the condenser to match the objective, all in the transmitted light mode (as per the instructions provided by your microscope manufacturer).
3. Decrease the transmitted light intensity to a level that is low, but still sufficient to allow visualization by eye.
4. Redirect the light to the camera port.

Adjusting the Parfocality of the Camera

To adjust the parfocality on an F-mount system, begin collecting images with a short exposure time and focus the light on the camera by rotating the ring on the Diagnostic Instruments relay lens without touching the main focusing knobs on the microscope.

While adjusting parfocality, you will need to acquire images rapidly to minimize the delay between the time a setting is changed and the time when the effect of the change can be observed. The specifics of how to proceed will vary according to the application software.

In the WinX application software, select Acquisition, **Video Focus**. Begin with an exposure time of 0.1 s. Then use **Focus** to begin data acquisition and **Stop Acquisition** to end it when you are finished focusing. *See your WinView/32 or WinSpec/32 manual for additional information.*

In IPLab, begin by selecting Set Camera from the Ext. menu. Set the dialog to Asynchronous, 100 ms exposure, and 2 cleans. Establish Focus mode operation by selecting Focusing from the Ext. menu. Set this dialog to 0.1 pixel seconds, 0-256 gray scale, and 1×. Press Start Camera to begin focusing and Stop Camera when finished. *See your IPLab manual for additional information.*

Many PI cameras, both F-mount and C-mount, also make provision for extending the focus range by providing a focus adjustment on the camera lens mount. If necessary, this focus can be changed to bring the image into range of the relay lens or other microscope focus adjustment.

Imaging Hints

Determine the gray levels of the image by placing the cursor within the image and monitoring the values shown. For optimal image quality of a 12-bit image, the highest value in the field should be near 4000 counts but not at 4095 (which is saturating). You may increase the number of counts by increasing your exposure, increasing the intensifier gain, or by increasing the amount of light illuminating the specimen.

Note that adjusting the intensifier gain also affects the dark charge of the intensifier (EBI). To properly perform background subtraction a background must therefore be measured at each intensifier gain setting.

Fluorescence

Once you have acquired a suitable image in transmitted light mode, you may switch to fluorescence mode.

In fluorescence mode you generally want to minimize the bleaching of your sample, usually achieved by placing several neutral density filters in the excitation pathway to minimize the illumination intensity. There will always be a trade-off here; when you maximize signal quality by increasing the illumination intensity, you need to consider whether your preparation can tolerate these conditions. In general, it is better to expose longer with a lower intensity than to expose for a shorter time with a higher intensity; nevertheless, your experimental conditions will dictate which path you take.

In fluorescence measurements you may not wish to maximize the gray levels in the image, since this may cause bleaching of the dye or photodamage to the cell. Maintain the minimum exposure required to get a sufficiently high quality image.

If the scaling on the image does not appear good to the eye, you may use additional scaling features available in the software. See your software manual for information on how to properly use the contrast enhancing features of the program.

Microscopes and Infrared Light

Microscope optics have very high transmission efficiencies in the infrared region of the spectrum. Since the light sources are very good emitters in the infrared, some microscopes are equipped with IR blockers or heat filters to prevent heating of optical elements or the sample.

For those microscopes that do not have the better IR blockers, the throughput of infrared light to the camera can be fairly high. In addition, while the eye is unable to see the light, some PI cameras are very efficient in detecting infrared wavelengths. As a result, the contaminating infrared light will cause a degradation of the image quality due to a high background signal that will be invisible to the eye. Therefore, it is recommended that you add an IR blocker prior to the camera if you encounter this problem with the microscope.

Chapter 13

TTL Control

Fully supported by WinSpec Version 2.5 when the communication protocol is TAXI (PCI), this feature is not supported when the protocol is USB 2.0.

Introduction

Princeton Instrument's WinView/32 and WinSpec/32 software packages incorporate WinX32 Automation, a programming language that can be used to automate performing a variety of data acquisition and data processing functions, including use of the TTL In/Out functions. WinX32 Automation can be implemented in programs written in Visual Basic. See the WinX32 documentation for more detailed information.

The TTL lines are made available through the TTL IN/OUT connector on the rear of the ST-133 Controller. This connector provides 8 TTL lines in, 8 TTL lines out and an input control line. Figure 86 illustrates the connector and Table 11 lists the signal/pin assignments.

TTL In

The user controls the 8 TTL Input lines, setting them high (+5 V; TTL 1) or low (0 V; TTL 0). When the lines are read, the combination of highs and lows read defines a decimal number which the computer can use to make a decision and initiate actions as specified in the user's program. If a TTL IN line is low, its numeric value is 0. If a TTL IN line is high, its numeric value is as follows.

TTL IN	Value	TTL IN	Value
1	1	5	16
2	2	6	32
3	4	7	64
4	8	8	128

This coding allows any decimal value from 0 to 255 to be defined. Thus, as many as 256 different sets of conditions can be specified, at the user's discretion, using the TTL IN lines. *Any unused lines will default to TTL high (+5 V).* For example, to define the number three, the user would simply set the lines TTL IN 1 and TTL IN 2 both high (+5 V). It would be necessary to apply TTL low to the remaining six lines because they would otherwise default to TTL high as well.

TTL IN	Value	TTL IN	Value
1	High (1)	5	Low (0)
2	High (2)	6	Low (0)
3	Low (0)	7	Low (0)
4	Low (0)	8	Low (0)

Table 10 illustrates this coding for decimal values 0 through 7. Obviously this table could easily be extended to show the coding for values all the way to 255.

Decimal Equiv.	TTL IN/OUT 8 1= dec 128	TTL IN/OUT 7 1=dec 64	TTL IN/OUT 6 1=dec 32	TTL IN/OUT 5 1=dec 16	TTL IN/OUT 4 1=dec 8	TTL IN/OUT 3 1=dec 4	TTL IN/OUT 2 1=dec 2	TTL IN/OUT 1 1=dec 1
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1
2	0	0	0	0	0	0	1	0
3	0	0	0	0	0	0	1	1
4	0	0	0	0	0	1	0	0
5	0	0	0	0	0	1	0	1
6	0	0	0	0	0	1	1	0
7	0	0	0	0	0	1	1	1

Table 10. Bit values with decimal equivalents:
1 = High,
0 = Low

Buffered vs. Latched Inputs

In controlling the TTL IN lines, users also have the choice of two input-line states, *buffered* or *latched*. In the buffered state, the line levels must remain at the intended levels until they are read. With reference to the preceding example, the high level at TTL IN 1 and TTL IN 2 would have to be maintained until the lines are read. In the latched state, the applied levels continue to be available until read, even if they should change at the TTL In/Out connector.

This control is accomplished using the EN/CLK TTL input (pin 6). If EN/CLK is open or high, *buffered* operation is established and the levels reported to the macro will be those in effect when the READ is made. With reference to our example, if pin 6 were left unconnected or a TTL high applied, TTL IN 1 and TTL IN 2 would have to be held high until read. If, on the other hand, EN/CLK were made to go low while TTL IN 1 and TTL IN 2 were high, those values would be *latched* for *as long as EN/CLK remained low*. The levels actually present at TTL IN 1 and TTL IN 2 could then change without changing the value that would be read by software.

TTL Out

The state of the TTL OUT lines is set from WinView/32 or WinSpec/32. Typically, a program monitoring the experiment sets one or more of the TTL Outputs. Apparatus external to the ST-133 interrogates the lines and, on detecting the specified logic levels, takes the action appropriate to the detected condition. The coding is the same as for the input lines. There are eight output lines, each of which can be set low (0) or high (1). The combination of states defines a decimal number as previously described for the TTL IN lines.

Pin #	Assignment	Pin #	Assignment
1	IN 1	14	IN 2
2	IN 3	15	IN 4
3	IN 5	16	IN 6
4	IN 7	17	IN 8
5	GND	18	GND
6	EN/CLK	19	Reserved
7	(future use)	20	GND
8	GND	21	OUT 2
9	OUT 1	22	OUT 4
10	OUT 3	23	OUT 6
11	OUT 5	24	OUT 8
12	OUT 7	25	GND
13	Reserved		

Table 11. TTL In/Out Connector Pinout

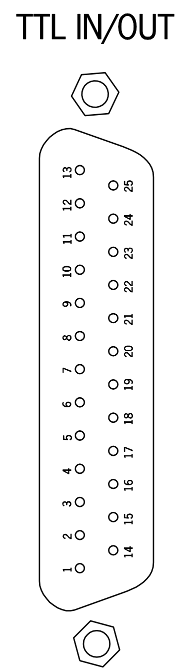


Figure 86. TTL In/Out Connector

TTL Diagnostics Screen

Note that WinView/32 and WinSpec/32 provide a TTL Diagnostics screen (located in under *Hardware Setup - Diagnostics)* that can be used to test and analyze the TTL In/Out lines.

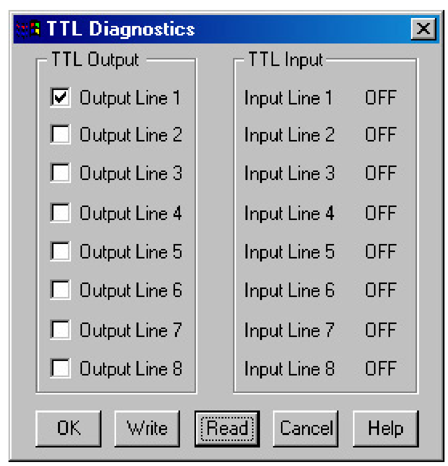


Figure 87. TTL Diagnostics dialog

Hardware Interface

A cable will be needed to connect the TTL In/Out connector to the experiment. The design will vary widely according to each user's needs, but a standard 25-pin female type D-subminiature connector will be needed to mate with the TTL In/Out connector at the ST-133. The hardware at the other end of the cable will depend entirely on the user's requirements. If the individual connections are made using coaxial cable for maximum noise immunity (recommended), the center conductor of the coax should connect to the proper signal pin and the cable shield should connect to the nearest available ground (grounds are conveniently provided at pins 5, 8, 18 and 20). Connector hardware and cables of many different types are widely available and can often be obtained locally, such as at a nearby electronics store. A list of possibly useful items follows. Note that, although the items listed may be appropriate in many situations, they might not meet your specific needs.

- 25-pin female type D-subminiature solder type connector (Radio Shack part no 276-1548B).
- RG/58U coaxial cable.
- Shielded Metalized hood (Radio Shack part no 276-1536A).
- BNC connector(s) type UG-88 Male BNC connector (Radio Shack part no 278-103).

Example

Suppose you needed to build a cable to monitor the line TTL OUT 1. One approach would be to build a cable assembly as described in the following paragraphs. This procedure could easily be adapted to other situations.

1. Begin with a 25-pin female type D-subminiature solder type connector (Radio Shack part no 276-1548B). This connector has 25 solder points open on the back.
2. Referring to Table 11 note that pin 8 = GND and pin 9 = TTL OUT 1.
3. Using coaxial cable type RG/58U (6 feet length), strip out the end and solder the outer sheath to pin 8 (GND) and the inner line to pin 9 (TTL OUT 1). Then apply shielding to the lines to insulate them.
4. Mount the connector in a Shielded Metalized hood (Radio Shack part no 276-1536A).
5. Build up the cable (you can use electrical tape) to where the strain relief clamp holds.
6. Connect a BNC connector (UG-88 Male BNC connector) to the free end of the cable following the instructions supplied by Radio Shack on the box (Radio Shack part no 278-103).
7. To use this cable, connect the DB25 to the TTL In/Out connector on the back of the ST-133 controller.
8. To check the cable, start WinView/32 or WinSpec/32 and open the TTL Diagnostics screen (located under *Hardware Setup - Diagnostics*). Click the **Write** radio button. Then click the **Output Line 1** box. Next click the **OK** button to actually set TTL OUT 1 high. Once you set the voltage, it stays until you send a new command.
9. Measure the voltage at the BNC connector with a standard voltmeter (red on the central pin, black on the surrounding shielding). Before clicking **OK** at the TTL Diagnostics screen you should read 0 V. After clicking **OK** you should read +5 V.

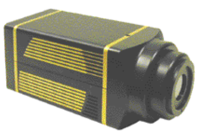
Note that adding a second length of coaxial cable and another BNC connector would be straightforward. However, as you increase the number of lines to be monitored, it becomes more convenient to consider using a multiple conductor shielded cable rather than individual coaxial cables.

Chapter 14
System Component Descriptions

Introduction

PI-MAX is an advanced intensified CCD (ICCD) camera system used for low light and time resolved applications. It consists of an imaging (square) or spectroscopy (rectangular) format CCD coupled to Generation II (PI-MAX RB, SB, UV) or Generation III (PI-MAX HQ) intensifiers. The operation of the camera system is under complete control of WinView/32 (Imaging) or WinSpec/32 (Imaging and Spectroscopy) software packages. In pulsed/gated experiments, where the camera needs to be synchronized to a light source such as laser, an integrated Programmable Timing Generator™ (PTG) or an external delay generator (e.g., DG535 from Stanford Research Systems) is used.

PI-MAX Camera



Mount Adapters

The nose at the front end of the PI-MAX camera is designed to accept three types of mount adapters: C-mount, F-mount, and Spectroscopy-mount. The PI-MAX is supplied with the mount adapter specified when the system was ordered. For more information about these mount adapters, refer to Appendix D for C- and F-mount adapters and refer to Appendix E for spectroscopy-mount adapters and spectrograph adapters.

Switches, Connectors and Indicators

Power/Signal connector: (standard PI-MAX) 25-pin D connector; connects to Controller cable (6050-0336); other end of cable connects to Detector connector of ST-133 Controller. See Figure 88.

Signal connector: (PI-MAX2) 40-pin connector; connects to Signal cable (6050-0492); other end of cable connects to Signal connector of ST-133 Controller. See Figure 89.

Power connector: (PI-MAX2) 15-pin D connector; connects to Power cable (6050-0493); other end of cable connects to Camera Pwr connector of ST-133 Controller. See Figure 89.

Timing Gen connector: 9-pin D connector; allows connections between PI-MAX and the Timing Generator (PTG or Stanford Research DG535).

Figure 88. PI-MAX Rear Panel

Signals applied through this cable control the photocathode gating and MCP bracket pulsing.

MCP On/Off switch: This switch biases the intensifier photocathode ON or OFF. When the MCP On/Off 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 MCP On/Off switch setting.*

When the MCP On/Off switch is set to **OFF**, then the photocathode cannot be turned on from software.

Figure 89. PI-MAX2 Rear Panel

Caution It is advisable to set the MCP On/Off switch to **OFF** as a fail-safe measure if the PI-MAX is left ON but unused for a period of time.

Water ports: (standard PI-MAX) Two standard ¼″ size brass fittings for circulating water coolant are located on the back panel. Either port may be used as the inlet. ***The water cannot be chilled.*** A closed circulator such as the PI model CC-100 circulating water at laboratory ambient temperature should be used. *See "**Temperature Control**", page 57 for additional information.*

Note: Although circulating water will extend the PI-MAX's cooling capabilities, it is not necessary. Most of the PI-MAX cooling is provided by the fan. With regard to the procedures in this chapter, there is no need for circulating water coolant.

Monitor connector: BNC port for TTL logic 1 pulse delayed 4-6 ns with respect to photocathode gating. Delay in 2 ns mode is not specified. *Cable delay, ~1.5 ns/ft, will be in addition to the delay at the connector.*

Note: Operation of Monitor output with ≤6 ns gating cannot be guaranteed.

Excess Rep Rate: Red LED lights to warn of excessive repetition rate. Must be off for proper operation.

Note: Excess Rep Rate LED is not activated by MCP bracket pulsing; MCP bracket repetition rate limit is 5 kHz.

Trig: Green LED flashes each time PI-MAX is triggered. Glows steadily at high repetition rates.

Note: In gated operation, the green **TRIG** LED indicator flashes each time the PI-MAX is triggered. In early units, however, the light may not flash with very short gate times. The exact gate width at which this occurs varies from unit to unit but typically this occurs at ~15 ns. This trigger detection aberration has no affect whatsoever on the unit's ability to make measurements with narrow gate widths. The PI-MAX continues to gate normally and data acquisition continues to take place in the usual manner.

Note that actual triggering can still be readily determined by either of two methods. First, the Timing Generator, whether a PTG or a DG535, has its own **Trigger** LED indicator. As long as triggering continues to be indicated at the Timing Generator, the user can be reasonably confidant that the PI-MAX is triggering properly. Second, the signal at the PI-MAX **Monitor** output can be observed with a fast oscilloscope. Although the Monitor signal won't be able to make the full logic level at the shortest attainable gate times, its presence can be easily verified, indicating that proper triggering is taking place.

Fan: Ventilation fan that runs continuously to remove heat generated by the thermoelectric cooler and the electronics. Air is drawn into the camera through the side ventilation slots, picks up the heat from the electronics and the cooler, and is then exhausted through the back panel grill.

Thermoelectric Cooler: The thermoelectric (TE) cooler is mounted to the heat removal block. With air-cooling alone, at an ambient temperature of 25°C, temperature lock at -20° will generally occur within ten to twenty 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.

ST-133 Controller

Electronics: The ST-133 controller is a compact, high performance CCD Camera Controller for operation with Princeton Instruments brand* cameras. Designed for high speed and high performance image acquisition, the ST-133 offers data transfer at speeds up to 5 megapixel per second and standard video output for focusing and alignment. A variety of A/D converters are available to meet different speed and resolution requirements.

In addition to containing the power supply, the controller contains the analog and digital electronics, scan control and exposure timing hardware, and controller I/O connectors, all mounted on user-accessible plug-in modules. This highly modularized design gives flexibility and allows for convenient servicing.

* The ST-133 controller must be factory configured for operation with an LN detector. For this reason, a controller purchased for operation with an LN detector can only be used with an LN detector. Similarly, a controller purchased for operation with a TE detector ***cannot*** be used with an LN detector.

POWER Switch and Indicator: The power switch location and characteristics depend on the version of ST-133 Controller that was shipped with your system. In some versions, the power switch is located on the on the front panel and has an integral indicator LED that lights whenever the ST-133 is powered. In other versions, the power switch is located on the back of the ST-133 and does not include an indicator LED. Figure 90 shows the two locations.

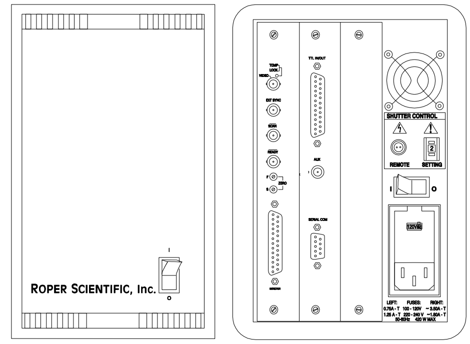


Figure 90. Power Switch Location (ST-133A and ST-133B)

Rear Panel Connectors: There are three controller board slots. Two are occupied by the plug-in cards that provide various controller functions. The third, covered with a blank panel, is reserved for future development. The left-most plug-in card is the Analog/Control module. Adjacent to it is the Interface Control module. Both modules align with top and bottom tracks and mate with a passive back-plane via a 64-pin DIN connector. For proper operation, the location of the modules should not be changed. Each board is secured by two screws that also ground each module's front panel. The connectors and functions located on the rear panel are further are described on the following page. Removing and inserting boards is described in Chapter 15, pages 179-180.

WARNING! To minimize the risk of equipment damage, a module should ***never*** be removed or installed when the system is powered.

The **Analog/Control Module**, which should always be located in the left-most slot, provides the following functions.

- Pixel A/D conversion
- CCD scan control
- Exposure control
- Timing and synchronization of readouts
- Temperature control
- Video output control

The **Interface Control Module**, which should always be located in the center slot, provides the following functions.

- TTL in/out Programmable Interface
- Communications Control (TAXI or USB 2.0 protocol)

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

Standard PI-MAX Controller Rear Panel Features: The descriptions of the rear panel connectors are keyed to the accompanying figure. Depending on your system, either the TAXI or the USB 2.0 Interface Control Module will be installed in the second from the left slot (as you face the rear of the ST-133). In the Figure 91, the TAXI module is shown in that position. The Fuse/Voltage label will be above or below the Power Module.

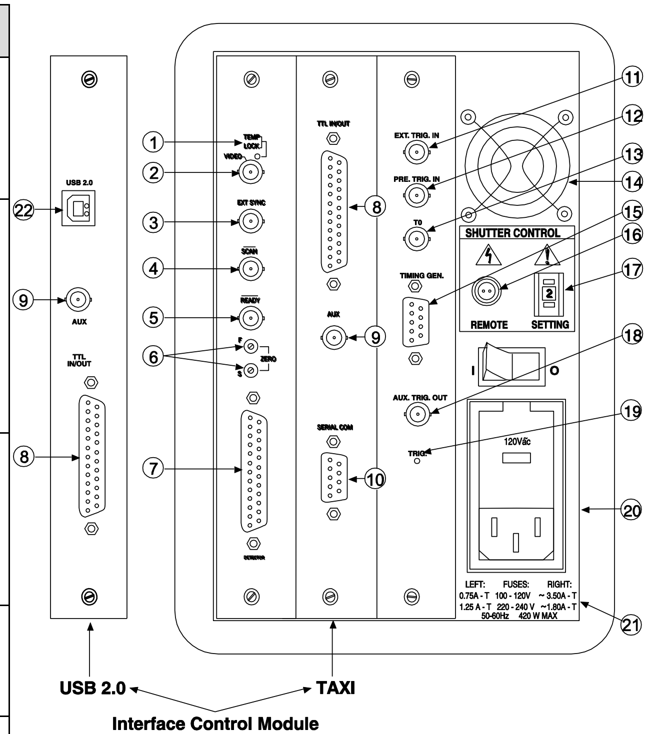


Figure 91. ST-133 (Standard) Rear Panel Callouts

#	Feature
1	**Temperature Lock LED:** Indicates that the temperature control loop has locked and that the temperature of the CCD array will be stable to within ± 0.05°C.
2	**Video/Aux Output:** If labeled Video, composite video output is provided at this connector. The amplitude is 1 V pk-pk and the source impedance is 75 Ω. Note that video output is not currently supported under USB 2.0. If labeled Aux, this output is reserved for future use.
3	**External Sync Input:** TTL input that has a 10 kΩ pullup resistor. Allows data acquisition and readout to be synchronized with external events. Through software, positive or negative (default) triggering can be selected.
4	**SCAN Output:** WinView/32 (ver. 2.4 and higher) software selectable NOT SCAN or SHUTTER signal. Default is SHUTTER.
5	**READY Output:** Initially HIGH. Changes state on completion of cleaning cycles before the first exposure.
6	**Zero Adjustment:** Bias potentiometers control the offset values of the Fast (F) and Slow (S) A/D converters. Preadjusted at factory. If potentiometers are not present, bias may be software-settable.
7	**Detector Connector:** Transmits control information to the camera and receives data back from the camera via the Detector-Controller cable.
8	**TTL In/Out:** User-programmable interface with eight input bits and eight output bits that can be written to or polled for additional control or functionality. Output is not currently supported under USB 2.0. See Chapter 13.
9	**AUX Output:** Reserved for future use.
15	**Timing Gen.:** Gate Start/Stop and Bracket signals are provided at this connector. *This output **must** be cabled to the PI-MAX **Timing Gen** connector.*
16	**Remote Shutter Connector:** Unless the PI-MAX system is powering a slit shutter for a spectrograph, this connector can be ignored.
17	**Shutter Setting Selector:** Sets the shutter hold voltage. Unless the PI-MAX system is powering a slit shutter for a spectrograph, this functionality can be ignored.
18	**Aux. Trig. Out:** AC-coupled variable delay trigger output for synchronizing other system components with PTG. The host software sets the Delay Time of this output with respect to the PTG trigger time. *This output does not need to be connected to the PI-MAX.*

#	Feature	#	Feature
10	**Serial COM Connector:** Provides two-way serial communication between the controller and the host computer.	19	**Trig. LED:** Trigger indicator. A 100 ms flash is produced each time the PTG triggers. With repetition rates faster than 10 Hz, indicator glows continuously.
11	**Ext. Trig. In.:** When external triggering is selected in the software, the PTG will be triggered by an externally derived trigger pulse applied to this input. The threshold (range ±5 V), slope, coupling mode (AC or DC), and input impedance (High or 50 Ω) are selectable in software.	20	**Power Module:** Contains the power cord socket and two fuses. Depending on the ST-133 version, the power switch may be located directly above the power module.
12	**Pre. Trig. In:** TTL level used only to start a bracket pulse.	21	**Fuse/Voltage Label:** Displays the controller's power and fuse requirements. This label may appear below the power module.
13	**T0** TTL Trigger output coincident with PI-MAX gate. *This output does not need to be connected to the PI-MAX.*	22	**USB 2.0 Connector:** Provides two-way serial communication between the controller and the host computer. Uses USB 2.0 protocol.
14	**Fan:** Cools the controller electronics. Runs continuously when the controller is turned on.		

PI-MAX2 Controller Rear Panel Features: The descriptions of the rear panel connectors are keyed to the accompanying figure. The TAXI Interface Control Module is installed in the second from the left slot (as you face the rear of the ST-133). The Fuse/Voltage label will be above or below the Power Module.

#	Feature
1	**Temperature Lock LED:** Indicates that the temperature control loop has locked and that the temperature of the CCD array will be stable to within ± 0.05°C.
2	**Aux Output:** This output is reserved for future use.
3	**External Sync Input:** TTL input that has a 10 kΩ pullup resistor. Allows data acquisition and readout to be synchronized with external events. Through software, positive or negative (default) triggering can be selected.
4	$\overline{\text{SCAN}}$ **Output:** WinView/32 (ver. 2.4 and higher) software selectable NOT SCAN or SHUTTER signal. Default is SHUTTER.
5	$\overline{\text{READY}}$ **Output:** Initially HIGH. Changes state on completion of cleaning cycles before the first exposure.
6	**Camera Signal Connector:** Transmits control information to the camera and receives data back from the camera via the Signal cable (6050-0492).
7	**Camera Power Connector:** Transmits power to the camera from the Controller via the Power cable (6050-0493).
8	**TTL In/Out:** User-programmable interface with eight input bits and eight output bits that can be written to or polled for additional control or functionality. Output is not currently supported under USB 2.0. See Chapter 13.
9	**AUX Output:** Reserved for future use.
10	**Serial COM Connector:** Provides two-way serial communication between the controller and the host computer.

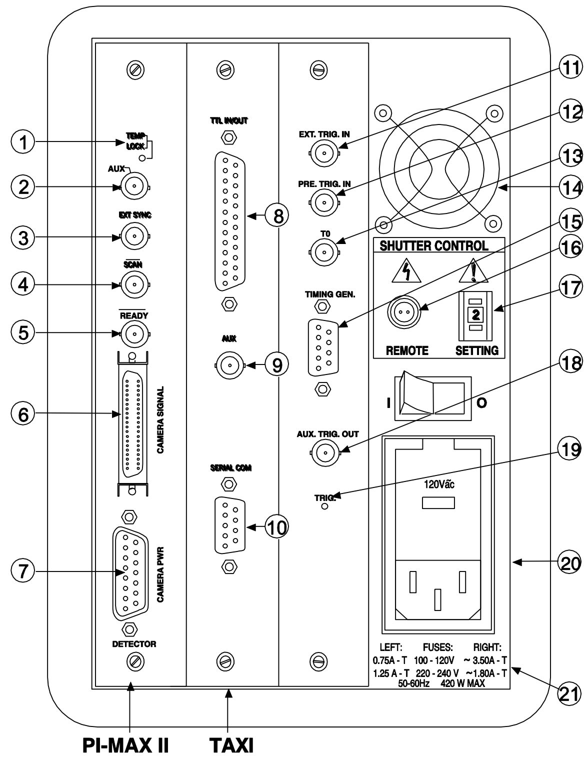


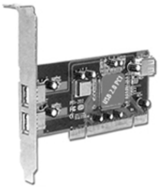
Figure 92. ST-133 (PI-MAX2) Rear Panel Callouts

#	Feature
14	**Fan:** Cools the controller electronics. Runs continuously when the controller is turned on.
15	**Timing Gen.:** Gate Start/Stop and Bracket signals are provided at this connector. *This output **must** be cabled to the PI-MAX2 **Timing Gen** connector.*
16	**Remote Shutter Connector:** Unless the PI-MAX2 system is powering a slit shutter for a spectrograph, this connector can be ignored.
17	**Shutter Setting Selector:** Sets the shutter hold voltage. Unless the PI-MAX2 system is powering a slit shutter for a spectrograph, this functionality can be ignored.
18	**Aux. Trig. Out:** AC-coupled variable delay trigger output for synchronizing other system components with PTG. The host software sets the Delay Time of this output with respect to the PTG trigger time. *This output does not need to be connected to the PI-MAX2.*

#	Feature	#	Feature
11	**Ext. Trig. In.:** When external triggering is selected in the software, the PTG will be triggered by an externally derived trigger pulse applied to this input. The threshold (range ±5 V), slope, coupling mode (AC or DC), and input impedance (High or 50 Ω) are selectable in software.	19	**Trig. LED:** Trigger indicator. A 100 ms flash is produced each time the PTG triggers. With repetition rates faster than 10 Hz, indicator glows continuously.
12	**Pre. Trig. In:** TTL level used only to start a bracket pulse.	20	**Power Module:** Contains the power cord socket and two fuses. Depending on the ST-133 version, the power switch may be located directly above the power module.
13	**T0** TTL Trigger output coincident with PI-MAX2 gate. *This output does not need to be connected to the PI-MAX2.*	21	**Fuse/Voltage Label:** Displays the controller's power and fuse requirements. This label may appear below the power module.

Interface Card

PCI Card: This interface card is required when the system interface uses the TAXI protocol rather than USB 2.0. The PCI card plugs-into the host computer's motherboard and provides the serial communication interface between the host computer and the ST-133. Through WinView/32 or WinSpec/32, the card can be used in either **High Speed PCI** or **PCI(Timer)** mode. **High Speed PCI** allows data transfer to be interrupt-driven and can give higher performance in some situations. **PCI(Timer)** allows data transfer to be controlled by a polling timer.



USB 2.0 Card: This interface card is required when the system interface uses the USB 2.0 protocol rather the TAXI protocol and the computer does not have native USB 2.0 support. The USB 2.0 card plugs-into the host computer's motherboard and provides the communication interface between the host computer and the ST-133. The USB 2.0 PCI card (70USB90011) by Orange Micro is recommended for desktop computers; the SIIG, Inc. USB 2.0 PC Card, Model US2246 is recommended for laptop computers. See www.orangemicro.com or www.siig.com , respectively, for more information.

Pulser

PTG: The ***optional*** Princeton Instruments Programmable Timing Generator (PTG) is a plug-in module designed for operation in the ST-133. Incorporating the Timing Generator into the Controller in this manner allows pulsed operation of the PI-MAX Intensified Camera in pulsed measurements without the inconvenience and expense of a separate timing generator.

DG535: The ***optional*** Stanford Research DG535 Digital Delay and Pulse Generator can provide four precisely timed logic transitions or two precisely controlled pulses. The four digitally controlled time intervals may be programmed from the front panel or via the GPIB Interface. Front panel BNCs provide high slew rate outputs for TTL, ECL, NIM or continuously adjustable levels. The outputs may be set to drive either 50 ohm or high impedance loads. The high accuracy (1 ppm), precision (5 ps), wide range (0 to 1000 s), and low jitter (50 ps) make the DG535 the ideal solution to many difficult timing problems.

DG535s for use with a PI-MAX system should have **Inhibit** available at the front panel. *The Inhibit function is enabled in units purchased from Princeton Instruments.* All DG535s have the inhibit function; it's just not brought out to the front panel in standard units. The modification to make Inhibit available at the front panel is straightforward. A customer-owned DG535 can be easily modified by a qualified technician to implement the **Inhibit** Option. This can be done in the field or at the factory. Contact *Princeton Instruments* for details. *See page 232 for contact information.*

Spectrograph

The 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. For mounting instructions, see Appendix E**, *Spectroscopy-Mount and Spectrograph Adapters***, beginning on page 203.

Cables

The cables listed below may be supplied with the PI-MAX or PI-MAX2 system.

PI-MAX-Controller:

Standard PI-MAX: The standard 15' (4.6 m) cable (6050-0336) has DB-25 connector with slide-latch locking and screw-post hardware. This cable connects the **Power/Signal** connector on the back of the PI-MAX to the **Detector** connector on the back of the ST-133.

PI-MAX2: The standard 15' (4.6 m) cable set (6050-0499) has two cables. One cable (6050-0492) interconnects the **Signal** and the **Camera Signal** connectors on the PI-MAX2 and the ST-133, respectively. The other cable (6050-0493) interconnects the **Power** and the **Camera Pwr** connectors on the PI-MAX2 and the ST-133, respectively.

Computer Interface Cable: Depending on the system configuration, either a USB or a TAXI cable will be shipped.

TAXI: The standard 25' (7.6 m) cable (6050-0148-CE) has DB-9 Male connectors with screw-down locking hardware. The TAXI (Serial communication) cable interconnects the **Serial Com** connector on the rear of the ST-133 with the PCI card installed in the host computer. In addition to the standard length, this cable is available in 10', 50', 100', and 165' lengths. Also available are fiber optic adapters with fiber optic cables in 100, 300, and 1000 meter lengths.

USB 2.0: The standard 16.4' (5 m) cable (6050-0494) has USB connectors that interconnect the **USB 2.0** connector on the rear of the ST-133 with a USB card installed in the host computer.

PI-MAX to PTG: This 15' cable (6050-0406) is ***required*** if the system includes a PTG. This cable interconnects the **Timing Gen** connector on the PTG module with the **Timing Gen** connector on the PI-MAX.

PI-MAX to DG535: This 6' cable (6050-0385) is required if the system includes a DG535. This cable assembly includes a Filter (2550-0347) for CE-compliance. The cable connects via the Filter to the DB9 **Timing Gen** connector on the back of the PI-MAX, and to the **A**, **B**, and **C⎍D** (or **A⎍B** depending on the intensifier type) BNC connectors of the DG535. The cable branches into three BNC cables, one labeled **A Start**, one labeled **B Stop**, and the third **C+D Gen II/A+B Gen III**.

Gen II Notes:
1. When this cable is left unconnected, the MCP will be biased continuously ON. Normal photocathode gating will remain functional.
2. Leave this cable unconnected if the delay between trigger in and the gate pulse is less than 1 µs.

For proper operation of a Gen III Intensified camera when gating, connect the **C+D-Gen II/A+B-Gen III** cable to the DG535 **A⎍B** BNC connector.

Gen III Note: Bracket pulsing is not allowed with Gen III Intensifiers. These Intensifiers do not respond in the UV, negating any possible advantage to bracket pulsing.

DG535 to Computer: This 4 meter cable (6050-0170) is required if the system includes a DG535. This is a standard IEEE 488 GPIB cable. It connects the **IEEE-488 GPIB Std Port** connector on the back of the DG535 to the interface connector of the computer's IEEE-488 GPIB Interface card. The DG535 parameter values are set by sending commands to the DG535 from the computer via the application software (WinView/32 or WinSpec/32). *Note that local vendors may be able to supply the GPIB cable.*

DG535 to Controller BNC cables:

- Cable connects BNC **D** output of the DG535 to the Controller's **Ext. Sync** input. Tells the Controller to initiate an expose-readout cycle.
- Cable connects the Controller's **Shutter** output signal (provided at ST-133's **SCAN** Output) to the **Inhibit** input of the DG535 (must be equipped with inhibit option). Inhibits the DG535 (and thus PI-MAX gating) during readout.

  Note that BNC cables may be available from local vendors. It is generally a good idea to have spare BNC cables on hand.

Other Cables

Other cables may also be required depending on the system requirements. For example, there may be a BNC cable from the laser pre-trigger output or other master timing source to the **Trig In** BNC connector of the DG535. Note also that the DG535 provides a **T0** output that, although not required by the PI-MAX or Controller, could be used to trigger or gate other system components. If the system includes a computer-controlled spectrograph, an additional cable would be required to connect the spectrograph with the computer.

Application Software

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

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

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

User Manuals

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

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

Chapter 15
Troubleshooting

CAUTION! If you observe a sudden change in the baseline signal you may have excessive humidity in the vacuum enclosure of the camera. Contact the factory for information on having the camera vacuum repumped.

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

Introduction

The following issues have corresponding troubleshooting sections in this chapter.

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.

Alarm Sounds Continuously

Immediately reduce the light entering the camera. This can be done by switching **MCP ON/OFF** switch on the back of the PI-MAX to "**OFF**" until you lower the source illumination, by 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 be lowered.

If the alarm sounds continuously even when the illumination level is adequately low, switch the **MCP ON/OFF** to "**OFF**" and turn the ST-133 off. Then contact the factory: this may indicate intensifier damage or another situation that requires immediate attention.

Baseline Signal Suddenly Changes

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 intensifier 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 Princeton Instruments or an authorized service facility of Princeton Instruments.

Camera Stops Working

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

- Turn off all AC power.
- Verify that all cables are securely fastened and that all locking screws are in place and all slide latches are in the latched position. For instructions on operating the slide latch locking mechanism, see ***"Securing the Detector-Controller Cable Slide Latch"***, page 181.
- Check for a burned-out fuse in the Controller power module. For information about changing a fuse, see ***"Changing the ST-133 Line Voltage and Fuses"*** on page 168.
- Correct any apparent problems and turn the system on.
- If the system still does not respond, contact Customer Support.

Camera1 (or similar name) on Hardware Setup dialog

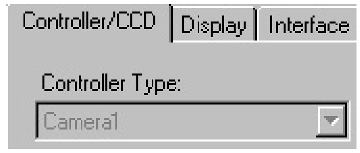


Figure 93. Camera1 in Controller Type (Camera Name) Field

If you see a default name such as Camera1 on the **Setup|Hardware|Controller/CCD** tab, you may want to change it since this name is not particularly descriptive. Such a change is made by editing the PVCAM.INI file that is generated by Camera Detection wizard (or by the RSConfig.exe if you have software version 2.5.19.0 or earlier).

To change the default Camera Name:

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

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

2. Change the "Name=" entry to something more meaningful for you (for example, ST133USB - to indicate that this is a PVCAM-based system using an ST-133 with a USB 2.0 interface) and save the edited file.

   [Camera_1]
   Type=1
   Name=ST133USB
   Driver=apausb.sys
   Port=0
   ID=523459

3. The new camera name will now appear in the **Controller Type** (**Camera Name)** field.

Changing the ST-133 Line Voltage and Fuses

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

WARNING! Use proper fuse values and types for the controller and detector to be properly protected.

To Change Voltage and Fuse Configuration:

WARNING! Before opening the power module, turn the Controller OFF and unplug the power cord.

1. As shown in Figure 94, place the flat side of a flat bladed screwdriver parallel to the back of the Controller and behind the small tab at the top of the power module, and twist the screwdriver slowly but firmly to pop the module open.
2. To change the voltage setting, roll the selector drum until the setting that is closest to the actual line voltage is facing outwards.
3. Confirm the fuse ratings by removing the two white fuse holders. To do so, simply insert the flat blade of the screwdriver behind the front tab of each fuse holder and gently pry the assembly out.

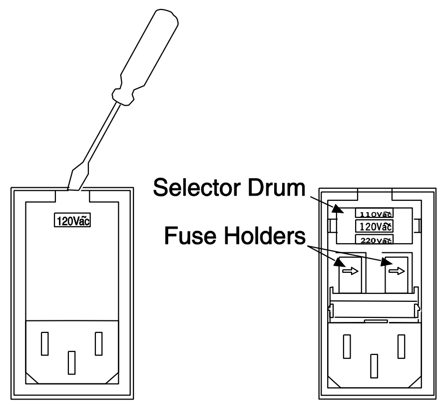


Figure 94. Power Input Module

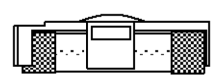


Figure 95. Fuse Holder

4. Refer to the Fuse/Voltage label (above or below the Power Module) to see which fuses are required by the selected voltage. If the Controller power switch is on the back of the ST-133, the Fuse/Voltage label is located below the Power Module.
5. After inspecting and if necessary, changing the fuses to those required by the selected voltage, reinstall the holders with the arrow facing to the right.
6. Close the power module and verify that the correct voltage setting is displayed.
7. Verify that the Controller power switch is in the OFF position and then plug the power cord back into the power module.

Controller Is Not Responding

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

- If the Controller 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 Controller OFF. Follow the interface card installation instructions in Chapter 3 and cable the interface card to the "High Speed Serial" port on the rear of the camera. Then do a "Custom" installation of WinSpec/32 or WinView/32 with the appropriate interface component selected: "PCI Interface" or "ISA Interface", depending on the interface card type. 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 "High Speed Serial" port on the rear of the camera, close the application program and turn the Controller OFF. Check the cable connections and secure the slide latches if the connections are loose.
- If the interface card was installed after the WinX application software has been installed, close the application program and do a "Custom" installation of WinSpec/32 or WinView/32 with the appropriate interface component selected: "PCI Interface" or "ISA Interface", depending on the interface card type. Be sure to deselect the interface component that does not apply to your system.

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.

Data Overrun Due to Hardware Conflict message

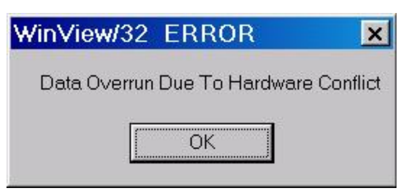


Figure 96. Data Overrun Due to Hardware Conflict dialog

If this dialog appears when you try to acquire a test image, acquire data, or run in focus mode, check the CCD array size and then check the DMA buffer size. A large array (for example, a 2048x2048 array), requires a larger DMA buffer larger setting than that for a smaller array (for example, a 512x512 array).

To change the DMA buffer setting:

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

Data Overrun Has Occurred message

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

1. Minimize the number of programs running in the background while you are acquiring data with the WinX application software (WinView/32 or WinSpec/32).
2. Run data acquisition in Safe Mode.
3. Add memory.
4. Use binning.
5. Increase the exposure time.
6. Defragment the hard disk.
7. Update the Orange Micro USB 2 driver. See ***"To Update the OrangeUSB USB 2.0 Driver:"***, page 40.

If the problem persists, your application may be USB 2.0 bus limited. Since the host computer controls the USB 2.0 bus, there may be situations where the host computer interrupts the USB 2.0 port. In most cases, the interrupt will go unnoticed by the user. However, there are some instances when the data overrun cannot be overcome because USB 2.0 bus limitations combined with long data acquisition times and/or large data sets increase the possibility of an interrupt while data is being acquired. If your experiment requirements include long data acquisition times and/or large data sets, your application may not be suitable for the USB 2.0 interface. Therefore, we recommend replacement of the USB 2.0 interface module with our TAXI interface module and Princeton Instruments (RSPI) high speed PCI card. If this is not the case and data overruns continue to occur, contact Customer Support (see page 232 for contact information).

Demo is only Choice on Hardware Wizard:Interface dialog (Versions 2.5.19.0 and earlier)

If RSConfig.exe has not been run and there is not an installed Princeton Instruments (RSPI) high speed PCI card, the Hardware Wizard will only present the choice "Demo" in the Interface dialog (Figure 97). Clicking on **Next** presents an "Error Creating Controller. Error=129." message, clicking on **OK** presents "The Wizard Can Not Continue Without a Valid Selection!" message, clicking on **OK** presents the Interface dialog again.

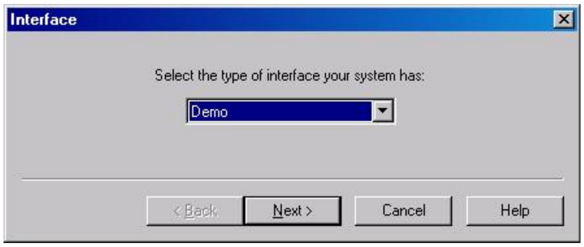


Figure 97. Hardware Wizard: Interface dialog

At this point, you will need to exit the WinX application software (WinView/32 or WinSpec/32) and run the RSConfig.exe program, which creates a file called PVCAM.INI. This file contains information required to identify the interface/camera and is referenced by the Hardware Wizard when you are setting up the WinX application software with USB for the first time:

1. If you have not already done so, close the WinX application software.
2. Make sure the ST-133 is connected to the host computer and that it is turned on.
3. Run RSConfig from the **Windows|Start|Programs|PI Acton** menu or from the directory where you installed the WinX application software.
4. When the RSConfig dialog (Figure 98) appears, you can change the camera name to one that is more specific or you can keep the default name "Camera1". When you have finished, click on the **Done** button.

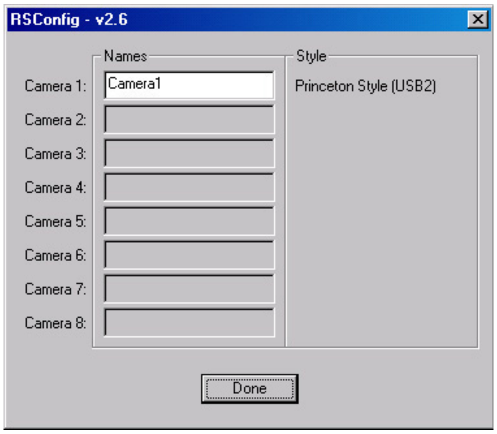


Figure 98. RSConfig dialog

5. You should now be able to open the WinX application software and, from **Setup|Hardware…,** run the Hardware Wizard.
6. When the PVCAM dialog (Figure 99) is displayed, click in the **Yes** radio button, click on **Next** and continue through the Wizard. After the Wizard is finished, the **Controller/Camera** tab card will be displayed with the **Use PVCAM** checkbox selected. You should now be able to set up experiments and acquire data.

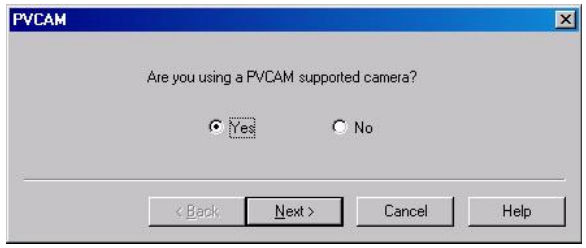


Figure 99. Hardware Wizard: PVCAM dialog

Demo, High Speed PCI, and PCI(Timer) are Choices on Hardware Wizard:Interface dialog (Versions 2.5.19.0 and earlier)

If there is an installed Princeton Instruments (RSPI) high speed card in the host computer and you want to operate a camera using the USB 2.0 interface, the PVCAM.INI file (created by RSConfig.exe) must exist and the USB 2.0 supported camera must be [Camera_1]. PVCAM.INI, which contains information required to identify the interface/camera, is referenced by the Hardware Wizard when you are setting up the WinX application software (WinView/32 or WinSpec/32) with USB for the first time. If the Wizard did not find a PVCAM.INI file or if RSConfig.exe was run but the USB 2.0 camera is [Camera_2] in the PVCAM.INI file, "Demo", "High Speed PCI", and "PCI(Timer)" will be selectable from the Wizard's Interface dialog.

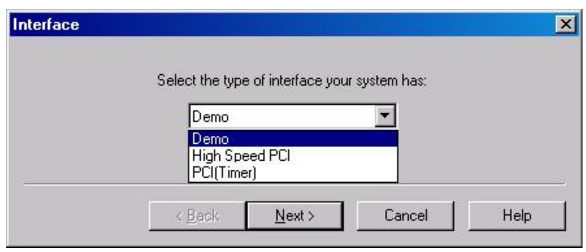


Figure 100. Hardware Wizard: Interface dialog

At this point, you will need to run the RSConfig.exe program:

1. If you have not already done so, close the WinX application software.
2. Make sure the ST-133 is connected to the host computer and that it is turned on.
3. Run RSConfig from the **Windows|Start|Programs|PI Acton** menu or from the directory where you installed the WinX application software.
4. When the RSConfig dialog (Figure 101) appears, you can change the camera name to one that is more specific or you can keep the default name "Camera2". When you have finished, click on the **Done** button. You will next edit the generated PVCAM.INI file.

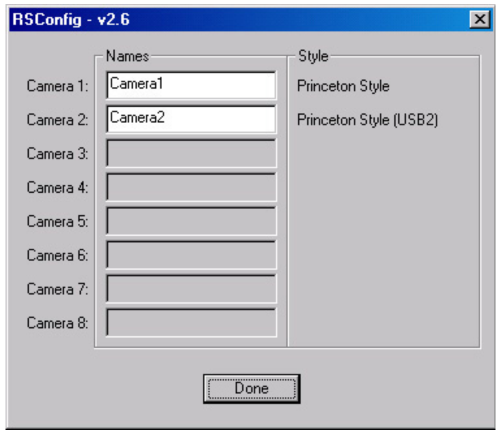


Figure 101. RSConfig dialog: Two Camera Styles

5. Using **Notepad** or a similar text editor, open PVCAM.INI, which is located in the Windows directory (C:\Windows, for example).

If the contents of the file look like:	Change the headings so the contents now look like:
[Camera_1] →	[Camera_2]
Type=1	Type=1
Name=Camera1	Name=Camera1
Driver=rspipci.sys	Driver=rspipci.sys
Port=0	Port=0
[Camera_2] →	[Camera_1]
Type=1	Type=1
Name=Camera2	Name=Camera2
Driver=apausb.sys	Driver=apausb.sys
Port=0	Port=0

Note: The [Camera_#] must be changed so the camera supported by the USB interface will be recognized (the USB driver is "apausb.sys"). For consistency, you may also want to change the camera names.

6. Save the file. With the ST-133 connected and on, open the WinX application software.

7. Run the Hardware Wizard.

8. When the PVCAM dialog (Figure 102) is displayed, click in the **Yes** radio button, click on **Next** and continue through the Wizard. After the Wizard is finished, the **Controller/Camera** tab card will be displayed with the **Use PVCAM** checkbox selected. You should now be able to acquire data.

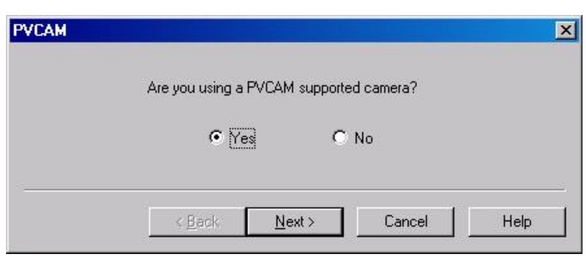


Figure 102. Hardware Wizard: PVCAM dialog

Detector Temperature, Acquire, and Focus are Grayed Out (Versions 2.5.19.0 and earlier)

These functions and others will be deactivated if you have installed a camera being run under USB 2.0 and have opened the WinX application software (WinView/32 or WinSpec/32) without having first turned on the ST-133. They will also be deactivated if you have installed a camera being run under USB 2.0 and a Princeton Instruments high speed PCI card was also detected when RSConfig.exe was run.

1. Check to see if the ST-133 is connected to the host computer and is turned on. If it is not connected or is connected but not turned on, go to Step 2. If it is connected and on, go to Step 3.
2. Close the WinX application, verify that the ST-133 is connected to the host computer, turn on the ST-133, and reopen the WinX application. The formerly grayed out functions should now be available.
3. If the ST-133 is connected and on, the USB 2.0 camera may not be listed as Camera 1 in the PVCAM.INI file.
4. Run RSConfig.exe (accessible from the **Windows|Start|Programs|PI Acton** menu). If the USB 2.0 camera is listed as Camera 2 (Princeton Style (USB2) in Figure 103), you will have to edit the PVCAM.INI file.

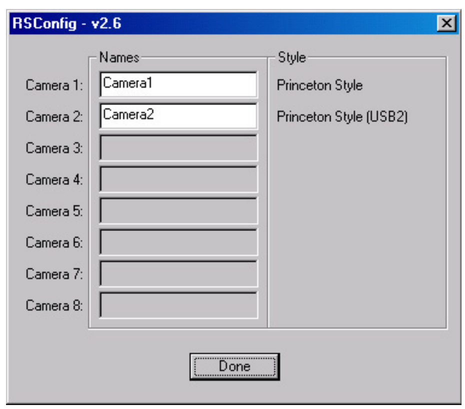


Figure 103. RSConfig dialog: Two Camera Styles

5. Using **Notepad** or a similar text editor, open PVCAM.INI, which is located in the Windows directory (C:\Windows, for example).

If the contents of the file look like:		Change the headings so the contents now look like:
[Camera_1] Type=1 Name=Camera1 Driver=rspipci.sys Port=0	→	[Camera_2] Type=1 Name=Camera1 Driver=rspipci.sys Port=0
[Camera_2] Type=1 Name=Camera2 Driver=apausb.sys Port=0	→	[Camera_1] Type=1 Name=Camera2 Driver=apausb.sys Port=0

Note: The [Camera_#] must be changed so the camera supported by the USB interface will be recognized (the USB driver is "apausb.sys"). For consistency, you may also want to change the camera names.

6. Save the file. With the ST-133 connected and on, open the WinX application software. The formerly grayed out functions should now be available.

Error Creating Controller message

This message may be displayed if you are using the USB 2.0 interface and have not run the RSConfig.exe program (see previous topic), if the PVCAM.INI file has been corrupted, or if the ST-133 was not turned on before you started the WinX application software (WinView/32 or WinSpec/32) and began running the Hardware Wizard.

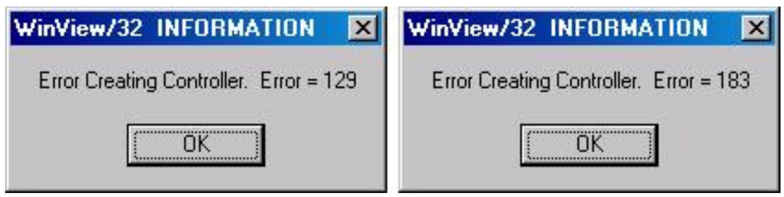


Figure 104. Error Creating Controller dialog

Error 129: Indicates that the problem is with the PVCAM.INI file. Close the WinX application software (WinView/32 or WinSpec/32), run RSConfig, make sure the ST-133 is on, reopen the WinX application software, and begin running the Hardware Wizard.

Error 183: Indicates that the ST-133 is off. If you are running the Hardware Wizard when this message appears, click on **OK**, turn on the ST-133, and, on the PVCAM dialog, make sure **Yes** is selected and then click on **Next**. The Hardware Wizard should continue to the Controller Type dialog.

Error Occurs at Computer Powerup

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.

Caution Since interrupts and DMA channels cannot be shared, make sure no other boards in your computer use this interrupt or these DMA channels.

Conflicts

One of the many advantages that PCI offers over ISA is that the whole issue of address and interrupt assignments is user transparent and under BIOS control. As a result, users typically do not have to be concerned about jumpers or switches when installing a PCI card. Nothing more should be required than to plug in the card, make the connections, and operate the system. As it turns out, however, in certain situations conflicts may nevertheless occur and user intervention will be required to resolve them.

Typical PCI motherboards have both ISA and PCI slots and will have both PCI and ISA cards installed. In the case of the ISA cards, the I/O address and Interrupt assignments will have been made by the user and the BIOS will not know which addresses and interrupts have been user assigned. When a PCI card is installed, the BIOS checks for available addresses and interrupt levels and automatically assigns them so that there are no *PCI* address or interrupt conflicts. However, because the BIOS doesn't know about the user-assigned ISA I/O address and interrupt level assignments, it is possible that a PCI card will be assigned an address or interrupt that is already assigned to an ISA card. If this happens, improper operation will result. Specifically, the problems could range from erratic operation under specific conditions to complete system failure. If such a conflict occurs, because the user has no control over the PCI address and interrupt assignments, there will be no recourse but to examine the ISA assignments and change them to values that do not conflict. Most (but by no means all) ISA cards make provision for selecting alternative I/O addresses and interrupt levels so that conflicts can be resolved. Software is available to help identify specific conflicts.

The following example may serve to illustrate the problem. Suppose you had a system with an ISA network card, a PCI video card and an ISA sound card. Further suppose that you were then going to install a PCI Serial Buffer card. Before installing the PCI Serial card, the I/O address and interrupt assignments for the installed cards might be as indicated in Table 12.

Slot Type	Status	I/O Address	Interrupt
1 (ISA)	ISA Network Card	200-210	11
2 (PCI)	PCI Video Card	FF00-FFFF	15
3 (ISA)	ISA Sound Card	300-304	9
4 (PCI)	Empty	N/A	N/A

Table 12. I/O Address & Interrupt Assignments before Installing Serial Card

As shown, there are no conflicts, allowing the three peripheral cards to operate properly. If the PCI Serial card were then installed, the BIOS would interrogate the PCI cards and may reassign them new address and interrupt values as follows.

Slot Type	Status	I/O Address(s)	Interrupt
1 (ISA)	ISA Network Card	200-210	11
2 (PCI)	PCI Video Card	FE00-FEFF	11
3 (ISA)	ISA Sound Card	300-304	9
4 (PCI)	Princeton Instruments (RSPI) PCI Serial Card	FF80-FFFF	15

Table 13. I/O Address & Interrupt Assignments after Installing Serial Card

As indicated, there is now an interrupt conflict between the ISA Network Card and the PCI Video card (both cards have been assigned Interrupt 11), causing the computer to no longer function normally. This doesn't mean that the PCI Serial card is defective because the computer stops functioning properly when the Serial card is installed. What it does mean is that there is an interrupt conflict that can be resolved by changing the interrupt level on the conflicting Network card in this example. It is up to the user to consult the documentation for any ISA cards to determine how to make the necessary change.

Note: Changing the order of the PCI cards, that is, plugging them into different slots, could change the address and interrupt assignments and possibly resolve the conflict. However, this would be a trial and error process with no guarantee of success.

Diagnostics Software

Many diagnostics programs, both shareware and commercial, are available to help resolve conflicts. Most often, all that's required is a program that will read and report the address and interrupt assignments for each PCI device in the computer. One such program available from Princeton Instruments' Customer Support department is called PCICHECK. When the program is run, it reports the address and interrupt assignments for the first PCI device it finds. Each time the spacebar is pressed, it moves on to the next one and reports the address and interrupt assignments for that one as well. In a few moments this information can be obtained for every PCI device in the computer. Note that, even though there are generally only three PCI slots, the number of PCI devices reported may be larger because some PCI devices may be built onto the motherboard. A good strategy for using the program would be to run it before installing the PCI Serial card. Then run it again after installing the card and note any address or interrupt assignments that may have changed. This will allow you to easily focus on the ones that may be in conflict with address or interrupt assignments on ISA cards. It might be noted that there are many programs, such as the MSD program supplied by Microsoft, that are designed to read and report address and interrupt assignments, including those on ISA cards. Many users have had mixed results at best using these programs.

Operation

There are no operating considerations that are unique to the PCI Serial card. The card can easily accept data as fast as any Princeton Instruments system now available can send it. The incoming data is temporarily stored in the card's memory, and then transferred to the main computer memory when the card gains access to the bus. The PCI bus arbitration scheme assures that, as long as every PCI card conforms to the PCI guidelines, the on-board memory will never overflow.

Unfortunately, there are some PCI peripheral cards that do ***not*** fully conform to the PCI guidelines and that take control of the bus for longer periods than the PCI specification allows. Certain video cards (particularly those that use the S3 video chip) are notorious in this respect. Usually you will be able to recognize when memory overflow occurs because the displayed video will assume a split-screen appearance and/or the message **Hardware Conflict** will be displayed (WinView/32). At the same time, the LED on the upper edge of the PCI Serial card will light.

Users are thus advised not to take any actions that would worsen the possibility of memory overflow occurring when taking data. In that regard, avoid multitasking while taking data. Specific operations to avoid include multitasking (pressing ALT TAB or ALT ESC to start another program), or running a screensaver program.

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 ADU rms (6 ADU pk-pk). This is on top of offset that typically is about 40 counts. Moisture accumulation produces a coarser noise with many spikes ≥ 30 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 Princeton Instruments or an authorized service facility of Princeton Instruments.

No CCD Named in the Hardware Wizard:CCD dialog (Versions 2.5.19.0 and earlier)

Figure 105. Hardware Wizard: Detector/Camera/CCD dialog

If you have installed a USB 2.0 Interface Module in your ST-133, a blank field may be displayed in the Detector/Camera/CCD dialog (Figure 105) if the ST-133 controller was made before January 2001. Earlier versions of the ST-133 did not contain non-volatile RAM (NVRAM), which is programmed with information about the controller and the camera. PVCAM, the program under which the Princeton Instruments USB works, retrieves the information stored in NVRAM so it can enter specific camera characteristics into the WinX application software..

Check the serial label on underside of your controller. If the first five characters are D1200 (December 2000) or earlier (J0797 or July 1997, for example), contact Customer Support to find out about an NVRAM controller upgrade.

Program Error message

Figure 106. Program Error dialog

This dialog may appear if you have tried to acquire a test image, acquire data, or run in focusing mode and the DMA buffer size is too small. A large array (for example, a 2048x2048 array), requires a larger setting than that for a smaller array (for example, a 512x512 array).

To correct the problem:

1. Click on **OK**.
2. Reboot the WinX application software (WinView/32 or WinSpec/32).
3. Note the array size (on the **Setup|Hardware|Controller/CCD** tab or the **Acquisition|Experiment Setup|Main** tab Full Chip dimensions). If your

camera contains a large array (such as a 2048x2048 array), and the DMA buffer size is too small, there will not be enough space in memory for the data set.

4. Open **Setup|Environment|Environment** dialog.
5. Increase the DMA buffer size to a minimum of 32 Mb (64 Mb if it is currently 32 Mb or 128 Mb if it is currently 64 Mb), click on **OK**, and close the WinX application software.
6. Reboot your computer.
7. Restart the WinX application software and begin acquiring data or focusing. If you see the message again, increase the DMA buffer size.

Removing/Installing a Plug-In Module

The ST-133 Controller has three plug-in slots. The Analog/Control module (leftmost slot when the controller is viewed from the rear) and the Interface Control module (either a TAXI or a USB 2.0 compatible module in the middle slot) are always provided. The third slot, however, is covered with a blank panel unless a PTG module has been installed in the ST-133.

If a module is ever removed for any reason, internal settings should ***not*** be disturbed. Changing a setting could radically alter the controller's performance. Restoring normal operation again without proper equipment and guidance would be very difficult, and it might be necessary to return the unit to the factory for recalibration.

Note: If you have an installed PTG and are changing from one interface type to another (TAXI to USB 2.0 or USB 2.0 to TAXI), contact Customer Support for specific changeover instructions. See page 232 for contact information.

WARNINGS!

1. Always turn the Controller OFF before removing or installing a module. If a module is removed or installed when the controller is powered, permanent equipment damage could occur which would not be covered by the warranty.
2. Before handling any boards, take precautions to prevent electrostatic discharge (ESD). The modules are susceptible to ESD damage. Damage caused by improper handling is not covered by the Warranty.

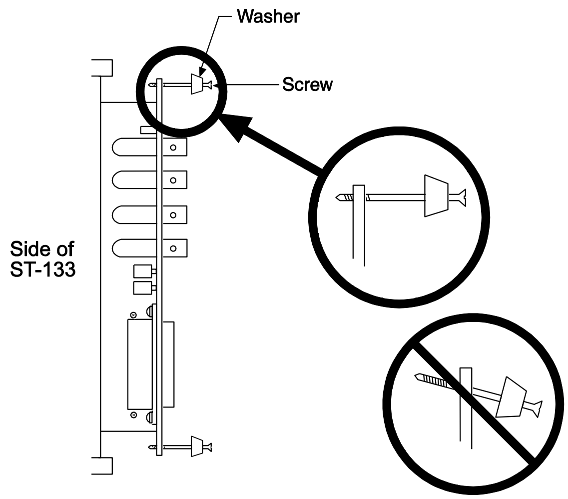


Figure 107. Module Installation

To Remove a Module:

1. Verify that the Controller has been turned OFF.
2. Rotate the two locking screws (one at the top of the module and one at the bottom) counterclockwise until they release from the chassis.
3. Then, grasp the module and pull it straight out.
4. Set the module aside in a safe place. If you are replacing it with another module, as in the case of exchanging a TAXI module for a USB 2.0 module, you may be able to use the packaging from the new module to store the old module. This packaging is usually an antistatic bag that will protect the module components from electrostatic discharge.

To Install a Module:

Installing a module is a bit more complex because you first have to be sure the locking screws are aligned correctly. The following procedure is suggested.

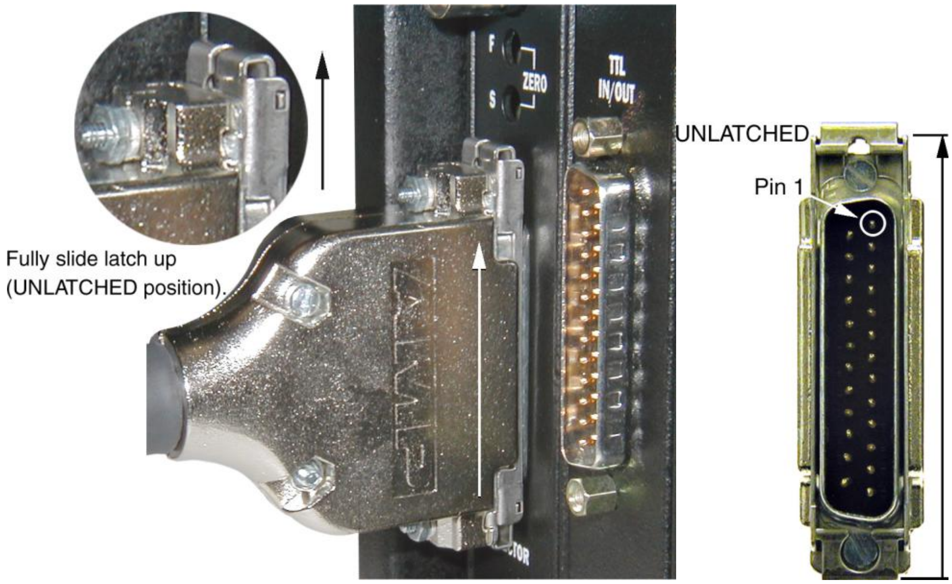
1. Verify that the Controller has been turned OFF.
2. Remove the replacement module from its antistatic packaging. This packaging is designed to protect the module components from electrostatic discharge.
3. Rotate the two locking screws counterclockwise until the threads on the screws engage those of the module panel. *See Figure 107.* By doing this, the screws will be perfectly perpendicular to the module panel and will align perfectly when the module is inserted.
4. Insert the module so the top and bottom edges of the board are riding in the proper guides.
5. Gently but firmly push the module in until the 64-pin DIN connector at the back of the module mates with the corresponding connector on the backplane, leaving the module panel resting against the controller back panel.
6. Rotate the two locking screws clockwise. As the screws are rotated, they will first disengage from the module panel threads, and then begin to engage those of the bracket behind the controller panel.

WARNING! Tighten the screws to where they are just snug. Do ***not*** tighten them any further because you could easily bend the mating bracket.

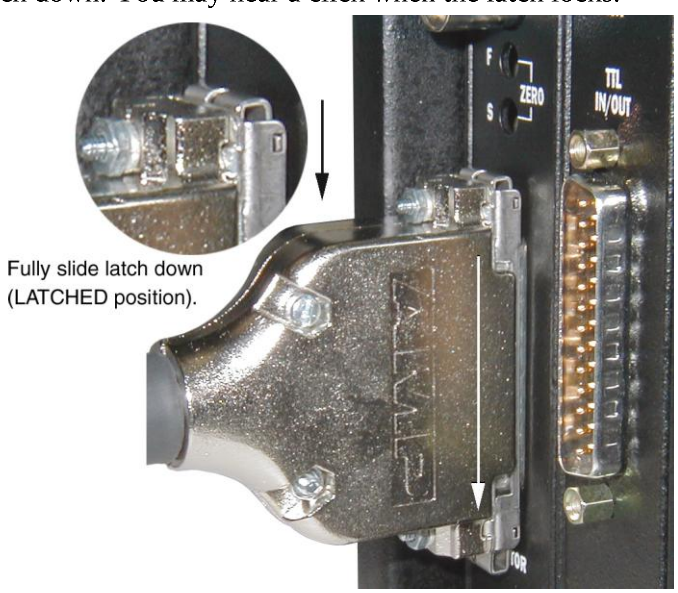
Securing the Detector-Controller Cable Slide Latch

Some Princeton Instruments Detector-Controller cables use a slide latch to secure the Detector-Controller cable to the DETECTOR connector on the back of the ST-133. Incorrectly plugging this cable into the connector and improperly securing the slide latch may prevent communication with the PI-MAX (the camera may appear to stop working).

1. Before trying to plug in the cable, slide the latch up (toward Pin 1). Then, plug the cable into the DETECTOR connector on the ST-133.



2. Slide the latch down. You may hear a click when the latch locks.



3. Verify that the connector is fully secured.

If you are having trouble sliding the latch, slightly pull the connector out and then slide the latch into its locked position.

Serial violations have occurred. Check interface cable.

Figure 108. Serial Violations Have Occurred dialog

This error message dialog will appear if you try to acquire an image or focus the camera and either (or both) of the following conditions exists:

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

To correct the problem:

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

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

Temperature Lock Cannot be Achieved or Maintained

Possible causes could include:

- High ambient temperature.
- Airflow through the camera is blocked.
- The camera fan is not running.
- Coolant flow rate is too slow.
- The connectors on the Detector-Controller cable need to be secured.
- The target array temperature is not appropriate for your particular camera and CCD array.
- You are trying to operate at a temperature colder than the specified limit. TE-cooled cameras have a thermal-protection switch that shuts off the cooler circuits if the internal temperature exceeds a preset limit. Typically, camera operation is restored automatically in about ten minutes. Although the thermo-protection switch will protect the camera, it is advisable to power down and correct the operating conditions that caused the thermal-overload.

Appendix A
Specifications

ATTENTION The following specifications are ***subject to change***. Contact the factory or go to www.princetoninstruments.com for the latest information on performance, options, and accessories.

General

CCD Array	Well Capacity	Read Noise	Sensitivity
Marconi (EEV) CCD30-11 1024 × 256: full frame, 26 × 26 µm pixels	500 ke^- for single pixel; 1.2 Me^- with binning	8 e^- rms @ 100 kHz; 15 e^- rms @ 1 MHz	Software selectable; 1 to 80 ADU/photoelectron
Thomson 7895 512 × 512: 19 × 19 µm pixels (effective size 24 × 24)	450 ke^- for single pixel; 1.2 Me^- with binning	<8 e^- rms @ 100 kHz; <35 e^- rms @ 1 MHz; <50 e^- rms @ 5 MHz	Software selectable; 1 to 80 ADU/photoelectron (standard PI-MAX), 4 to 300 ADU/photoelectron (PI-MAX2)
Marconi CCD47-10 1024 × 1024: 13 × 13 µm pixels	100 ke^- for single pixel	<8 e^- rms@ <100 kHz; 11 e^- rms @ 1 MHz	Software selectable; 6 to 80 ADU/photoelectron
Kodak 1003M 1024 × 1024: interline, 12.8 × 12.8 µm pixels	130 ke^- for single pixel	<11 e^- rms @ 1 MHz; <16 e^- rms @ 5 MHz	Software selectable; 4 to 300 ADU/photoelectron

Digital Conversion: 16 bits

Image Intensifier: 18 mm or 25 mm

Method of Coupling: 1:1 fiber optics for most models *(1.27:1 for Thomson 512)*

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 simply screws into the PI-MAX nose until it bottoms out. It is then secured by the three locking setscrews, which require a 0.050″ hex key. Available mounts include:

Spectroscopy Adapter: three 120° slots in concentric configuration with 3.6" bolt circles.

F-Mount Adapter:* accepts standard F-mount latching mechanism.

* Similar mount for Canon lenses may also be available. Contact factory for information.

C-Mount (microscopy) Adapter: accepts standard C-mount threaded lenses.

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

Focal Depth (distance from adapter flat to photocathode surface)
Spectroscopy: 0.894"
F-Mount: 46.5 mm
C-Mount: 17.5 mm (0.690")

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
1.27:1 coupling: typically 55 µm spot size FWHM

Gen II High Res Spatial Resolution
1:1 coupling: typically 45 µm spot size FWHM
1.27:1 coupling: typically 40 µm spot size FWHM

Gen III Spatial Resolution
1:1 coupling: typically 42 µm spot size FWHM
1.27:1 coupling: typically 38 µm spot size FWHM

Geometric Distortion: typically < 1 pixel

Sensitivity: Variable intensifier gain adjustment (via software) allows sensitivities from 1-80 counts per photoelectron. Some phosphor choices may result in lower values.

Gating ON/OFF Ratio
Visible (550 nm): 5 x 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: Better than 1% for the upper 95% of range in ungated operation. Slightly non-linear response at lower 5% of range, due to phosphor nonlinearity.

Photocathode Dark Charge (EBI): Red-blue enhanced, < 5 counts/pixel-second; Red-enhanced, < 15 counts/pixel-second

Phosphor Decay: 2 ms P43 standard, 1 µs P46 phosphor is optional

Spectral Range
Gen II: Red-blue enhanced, 180-900 nm; Red enhanced, 360-920 nm

Gen III: HQ, 450-900 nm (3 dB cutoff wavelengths); HQ (Blue), 375-900 nm

Nonuniformity: Typically 12% pk-pk for Gen II 18 mm intensifiers, 16% pk-pk for Gen II 25 mm intensifiers

CCD Cooling: down to -20°C air cooled; supplementary cooling with circulating room-temperature water will enhance cooling performance. Temperatures to -45°C are achievable with supplemental circulating chilled coolant.

> **Note:** See warning in *"Temperature Control"*, page 57 before initiating supplemental water cooling.

Readout Noise: 1-1.5 counts RMS in gated operation (100 kHz).

Computer

Requirements for the host computer depend on the type of interface, TAXI or USB 2.0, that will be used for communication between the ST-133 and the host computer. Those requirements are a listed below according to protocol.

TAXI Protocol:

- AT-compatible computer with 200 MHz Pentium® II (or better).
- Windows® XP or Windows Vista® (32-bit) operating system.
- High speed PCI serial card (or an unused PCI card slot). Computers purchased from Princeton Instruments are shipped with the PCI card installed if High speed PCI was ordered.
- Minimum of 32 Mbytes of RAM for CCDs up to 1.4 million pixels. Collecting multiple spectra at full frame or high speed may require 128 Mbytes or more of RAM.
- CD-ROM drive.
- Hard disk with a minimum of 80 Mbytes available. A complete installation of the program files takes about 17 Mbytes and the remainder is required for data storage, depending on the number and size of spectra collected. Disk level compression programs are not recommended.
- Super VGA monitor and graphics card supporting at least 256 colors with at least 1 Mbyte of memory. Memory requirement is dependent on desired display resolution.
- IEEE-488 GPIB port (required by DG535 Timing Generator, if present). May also be required by Spectrograph.
- Two-button Microsoft compatible serial mouse or Logitech three-button serial/bus mouse.

USB 2.0 Protocol:

- AT-compatible computer with Pentium 3 or better processor and runs at 1 GHz or better.
- Windows XP (with Service Pack 3) or Vista (32-bit).
- Native USB 2.0 support on the motherboard or USB Interface Card (Orange Micro 70USB90011 USB 2.0 PCI is recommended)
- Minimum of 256 Mb of RAM.
- CD-ROM drive.
- Hard disk with a minimum of 80 Mbytes available. A complete installation of the program files takes about 17 Mbytes and the remainder is required for data

storage, depending on the number and size of spectra collected. Disk level compression programs are not recommended.

- Super VGA monitor and graphics card supporting at least 256 colors with at least 1 Mbyte of memory. Memory requirement is dependent on desired display resolution.
- IEEE-488 GPIB port (required by DG535 Timing Generator, if present). May also be required by Spectrograph.
- Two-button Microsoft compatible serial mouse or Logitech three-button serial/bus mouse.

Operating Environment

Storage Temperature: < 55°C

Lab 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.

Lab Humidity: < 50%; non-condensing.

Controller

Controller Type: ST-133

Inputs:

EXT SYNC: TTL input (BNC) to allow data acquisition to be synchronized with external events. Sense can be positive or negative going as set in software. Synchronization and Trigger Modes are discussed in the Shutter Mode and Gated operation chapters.

Outputs:

VIDEO or **AUX**

Video: 1 V pk-pk from 75 Ω, BNC connector. Either RS-170 (EIA) or CCIR standard video as specified when system was ordered. Requires connection via 75 Ω cable that must be terminated into 75 Ω.

Aux: Reserved for future use.

$\overline{\text{SCAN}}$: TTL output (BNC) for monitoring detector status. *Logic output is software-selectable as either NOT SCAN or SHUTTER.* When the logic output is NOT SCAN, it is at a TTL low when CCD is being read; otherwise high. When the logic output is SHUTTER, the output precisely brackets shutter-open time (exclusive of shutter compensation) and can be used to control an external shutter or to inhibit a pulser or timing generator. Default selection is SHUTTER.

$\overline{\text{READY}}$: TTL output (BNC); marks start of *first* exposure. When run is initiated, remains high until completion of cleaning cycles preceding *first* exposure, then goes low and remains low for duration of run.

SERIAL COM: Data link to computer via proprietary cable connected to this 9-pin "D" connector. Cable lengths to 165 feet (50 m) available. An optional fiber optic link is available to extend the distance to ~3300 feet (1 km).

USB 2.0: Data link to computer via USB cable inserted at this connector. Cable length of 5 meters is standard. Other lengths may be available. Contact Customer Service for more information.

TTL I/O: 8 TTL Inputs and 8 TTL Outputs are provided for control via the TTL connector. Refer to Chapter 13, "TTL Control" for more information.

A/D Converters

Standard: 16-bit, 100 kHz readout rate only.

Optional: Dual digitizers with either 100 kHz/1 MHz, 50 kHz/1 MHz, or 1 MHz/5MHz readout rates. Software-selectable. Low-speed operation gives better noise performance; high-speed operation allows faster data acquisition.

Linearity: better than 1%.

Readout noise: 1-1.2 counts RMS on standard controllers.

Shutter Compensation Time

The following numbers apply for a 1 MHz ST-133.

Shutter	Compensation Time
Electronic	6 ms
None	0 ns

Miscellaneous

Dimensions: See Appendix B.

Controller Weight:

ST-133A: 13 lb (5.9 kg)

ST-133B: 12.5 lb (5.7 kg)

Power Requirements: Nominally 100, 120, 220 or 240 VAC. Refer to Fuse/Voltage label on rear of Controller for details. Required DC voltages are generated in the controller. Power to detector is supplied via controller cable.

Environmental Requirements:

Storage temperature: -20° C to 55° C;

Operating temperature: 5ºC to +30ºC; For NTE/NTE 2 Detectors, the operating temperature range over which specifications can be met is 18° C to 23° C

Relative humidity: <50% noncondensing.

TTL Requirements: Rise time ≤ 40 ns, Duration ≥ 100 ns.

Internal Pulser

The PI-MAX incorporates an internal gate pulse generator and high voltage power supply controlled from an external timing generator, either a PTG or a Stanford Research DG535 Digital Delay/Pulse Generator. The DG535 is controlled from the application software via a GPIB link.

Note: A DG535 purchased as part of a PI-MAX system will have the Inhibit input enabled. If you are going to operate the PI-MAX with a DG535 that hasn't had this input enabled, it will be necessary to modify the DG535 as required. The modification is simple and can be easily be made by any qualified technician. Contact the factory for details.

Gating Speed

Fast Gate Intensifier

Gen II 18 mm: <5 ns FWHM in Start/Stop mode
Gen II 25 mm: <7 ns FWHM

Gen III 18 mm: <10 ns FWHM in Start/Stop mode.

Slow Gate 18 mm: <50 ns FWHM

Slow Gate 25 mm: <100 ns FWHM

Fixed Fast: <2 ns FWHM - 18 mm Gen II
<5 ns FWHM - 18 mm Gen III

Propagation Delay: 12 ns. Note that this is only the delay of the internal pulser. The timing generator's insertion delay, 25 ns for the PTG, 85 ns for the Stanford Research DG535, must be considered as well.

Jitter: <100 ps

Maximum Repetition Rate (photocathode)

Sustained: 50 kHz in variable mode; 5 kHz @ 2 ns

Burst: 250 kHz (bursts of 50 pulses)

Maximum Repetition Rate (MCP bracket pulsing): 5 kHz, (drops pulses if input rate exceeds 5 kHz)

Start/Stop Inputs: Both are 0 to +5V rising edges, 50 Ω, compatible with the Stanford Research DG535 and applied via **Timing Gen** connector.

MCP Bracket Pulsing: MCP requires 500 ns to gate On and 200 ns to gate Off.

Note: Bracket pulsing only applies to units having a Gen II Image Intensifier. In the case of units having a Gen III Image Intensifier, bracket pulsing does not apply.

Appendix B

Outline Drawings

Note: Dimensions are in inches and [mm] unless otherwise noted.

PI-MAX/PI-MAX2

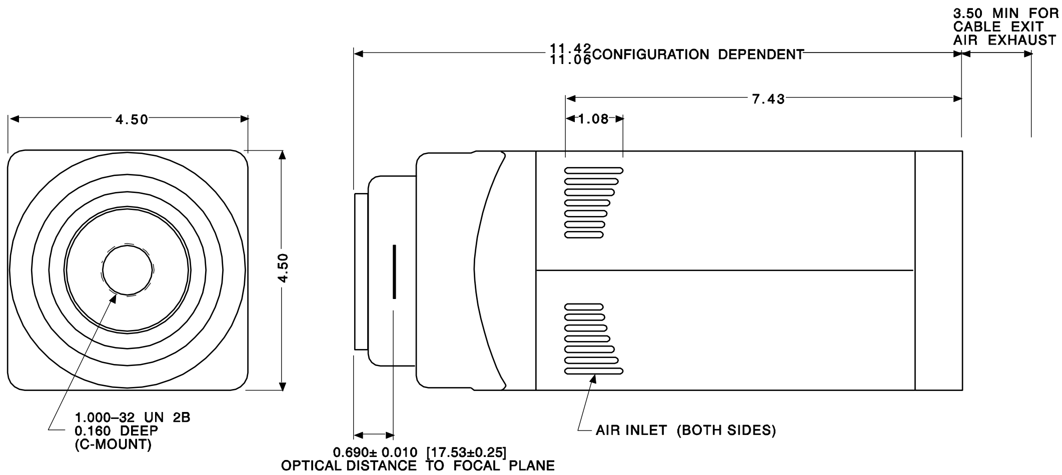


Figure 109. Outline Drawing: PI-MAX/PI-MAX2 with C-mount Adapter

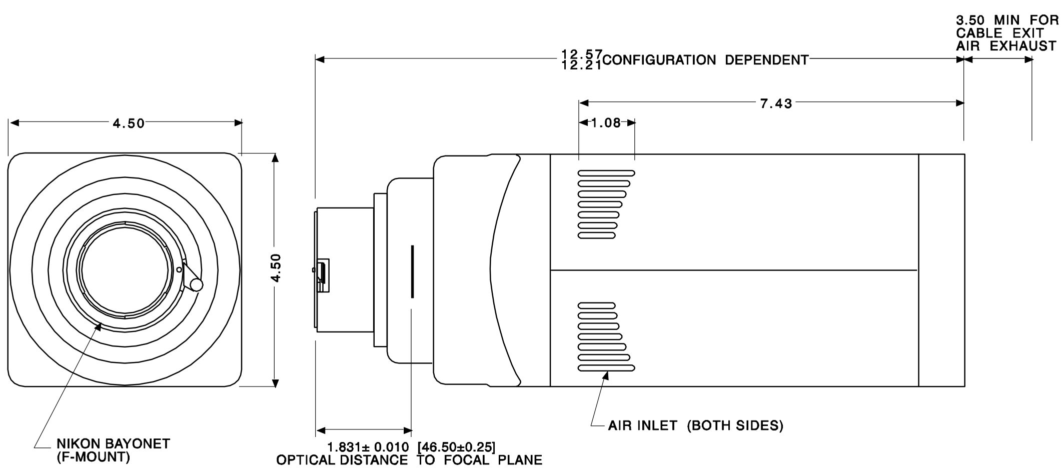


Figure 110. Outline Drawing: PI-MAX/PI-MAX2 with F-mount Adapter

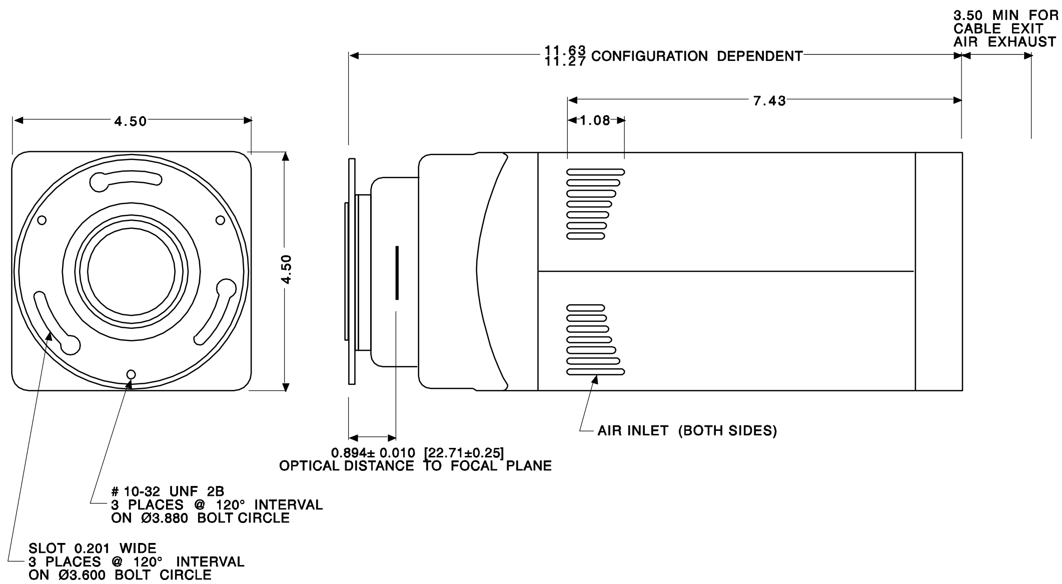


Figure 111. Outline Drawing: PI-MAX/PI-MAX2 with Spectroscopy-mount Adapter

ST-133A Controller

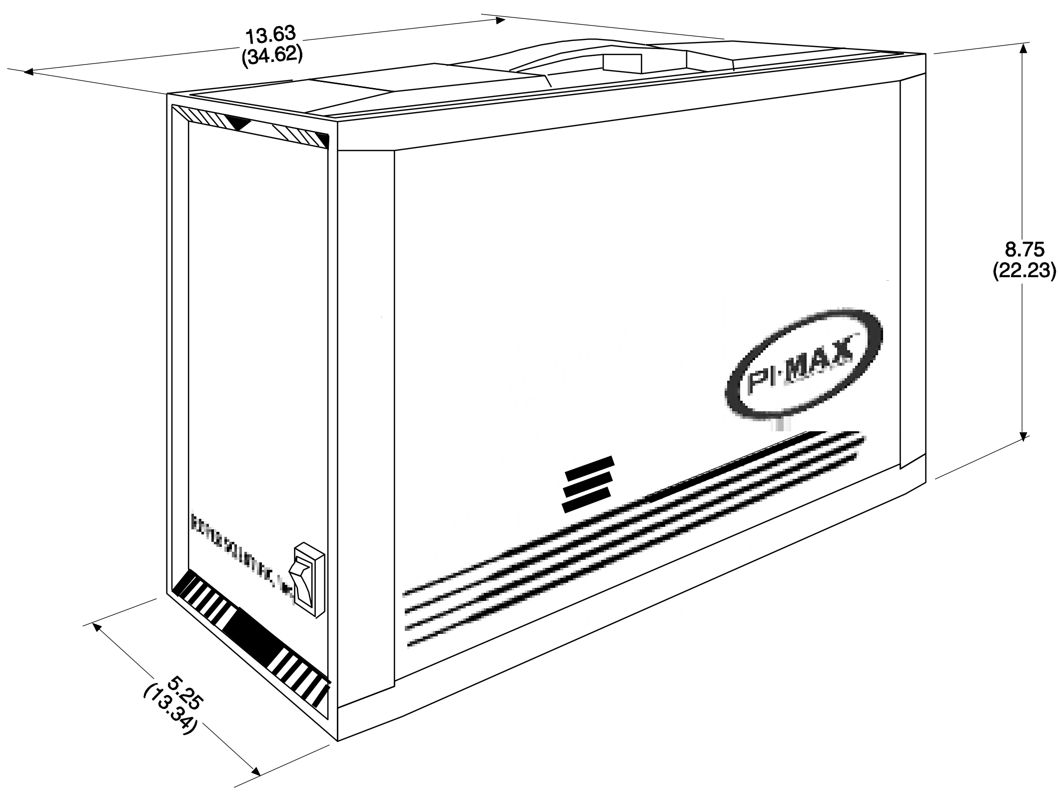


Figure 112. Outline Drawing: ST-133A

ST-133B Controller

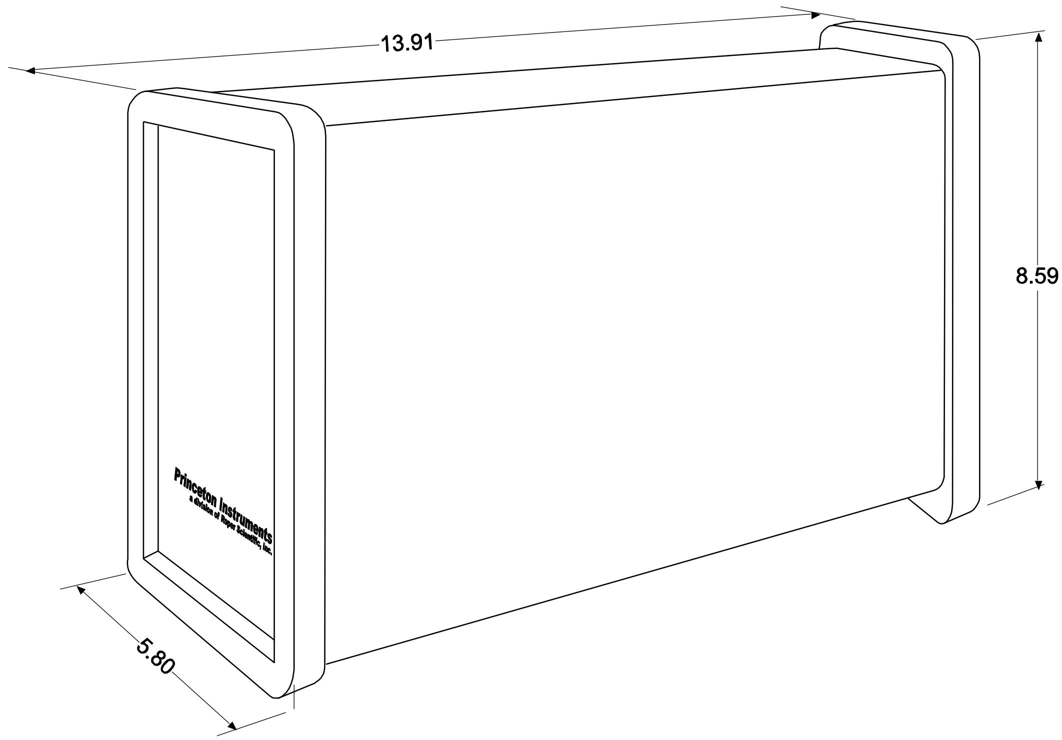


Figure 113. Outline Drawing: ST-133B

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Appendix C
Software

Introduction

The PI-MAX camera requires software control and can be operated with either of two Princeton Instruments WinX application programs, WinView/32 or WinSpec/32. Some camera parameters are controlled via the Controller. Others are controlled via the DG535 Timing Delay Generator, which is required for gated operation of the camera. The software manuals discuss control of the PI-MAX, PTG and DG535 in detail. Nevertheless, the following paragraphs, which delineate the applicable software screens, may prove helpful as a convenient reference.

Camera State

Figure 114. Camera State dialog

In a system having the PI-MAX camera, this dialog appears when the software is booted. It displays the camera's current start-up state and allows you to restore the previous setting.

Keep in Safe Mode: This is the default. Whenever the software is booted, the Safe mode is established, biasing the PI-MAX intensifier’s photocathode off. The intensifier gain and exposure time in effect when the software was last shut down are retained.

Restore to Last Setting: Making this selection followed by clicking on OK will put the camera in the gate mode in effect when the software was last shut down. Thus, clicking on the **Restore to Last Setting** radio button could put the camera in **Safe Mode**, **Shutter Mode** or **Gate Mode**, whichever was the active state at the time of shutdown. In addition, the intensifier gain in effect when the software was shut down is also restored, as is the exposure time.

Once the selection has been made, the user can easily change the gate mode via the Experiment Setup **Main** page. In systems having the PI-MAX camera, the Experiment Setup **Main** page allows the user to directly select **Safe** mode, **Shutter Mode** or **Gate Mode**.

Main tab
(Experiment Setup on Acquisition menu)

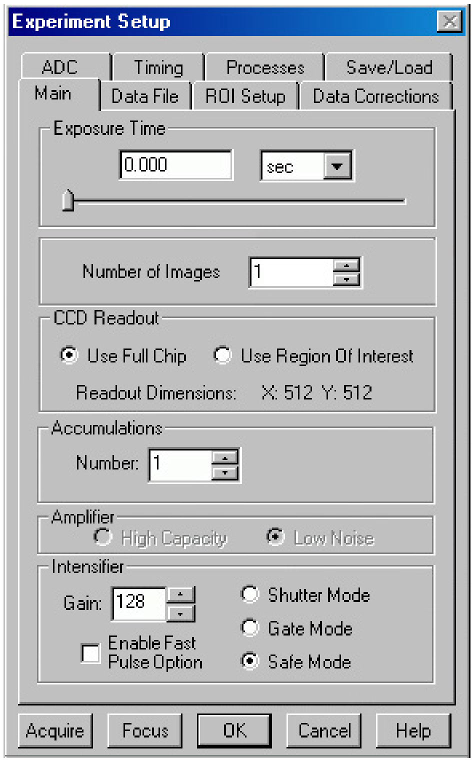

Figure 115. Main tab with PI-MAX camera

The Experiment Setup **Main** tab is used to specify the most essential parameters. These include the Exposure Time, Number of Images, Number of Accumulations and choice of Full Chip or Region of Interest readout. Some of the selections on this page only apply for a PI-MAX camera. With other cameras these selections are not displayed. Selections unique to the PI-MAX include.

Amplifier: If the PI-MAX is equipped with the Thomson 512 × 512 CCD array, either of two amplifier output nodes are automatically selected depending on the A/D speed. The FAST (1 MHz) A/D selection uses the fast node, while the SLOW (500 kHz or slower) A/D uses the slow (low-noise) node. *The default setting is read from non-volatile RAM in the PI-MAX. If the selection is changed, the new setting is written to the non-volatile RAM and becomes the new starting default.*

Fast node: Allows the camera to collect 16-bit images at a readout rate of up to 1 million pixels per second.

Low Noise node: When operating at a lower speed, the camera provides superior noise performance.

Intensifier:

Gain: Sets the intensifier gain when operating with a PI-MAX intensified camera. The range is in arbitrary units from 0 to 255 and the default setting, which will give good results in many applications, is 128.

Shutter Mode: Selecting this radio button biases the PI-MAX photocathode continuously on during the exposure time and off during readout. This mode works with exposure times as short as 5 ms.

Gate Mode: Selecting this radio button puts PI-MAX in Gate mode, in which the photo-cathode is biased on by pulses generated in the DG535.

Safe Mode: Selecting this radio button puts PI-MAX in the Safe mode, in which the photocathode is continuously biased off until either **Shutter Mode** or **Gate Mode** is selected. Note that Safe mode is the turn-on default. *In a system having the PI-MAX camera, when the software is booted, a dialog appears that allows you to change the PI-MAX start-up gate mode.*

Pulsers dialog

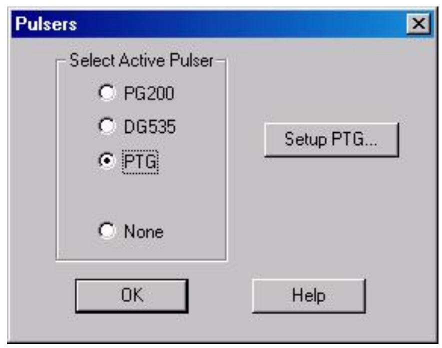

Figure 116. Pulsers dialog

The Pulsers dialog, which opens when **Pulsers** is selected on the Setup menu, allows the user to choose whether the software is configured to run a PG200 Pulser, a PTG module, a DG535 Timing Delay Generator, or no pulser. To the right of the pulser-selection buttons is the **Setup** button that gives access to the pulser setup screens. Select **PTG** or **DG535** for operation with the *PI-MAX* (PG-200 is not compatible with the PI-MAX).

PTG dialog

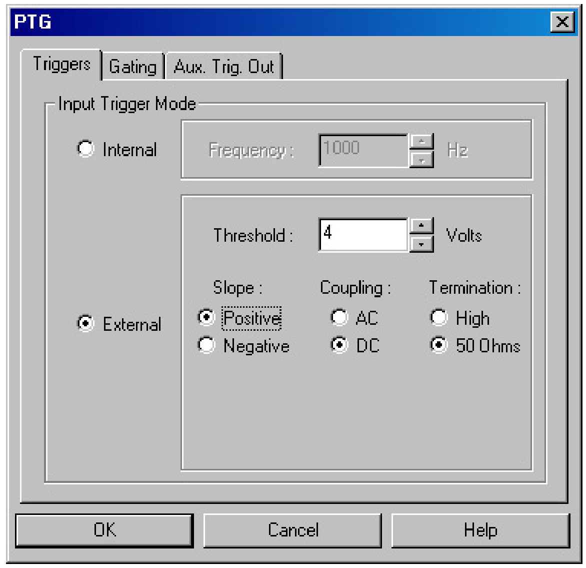

Figure 117. PTG dialog

Operation of the PTG (ProgrammableTiming Generator) becomes available when you select **Pulsers** from the **Setup** menu, next click on the **PTG** radio button and then click on the **Setup PTG** button. This opens the PTG dialog as shown above. Note that pulser support must be selected when installing the WinX application software (WinView/32 or WinSpec/32) for PTG control to be available, and that the intended use of the PTG is for operation in conjunction with the PI-MAX CCD Detector.

The choices provided by the **Triggers**, **Gating**, and **Aux Trig Out** tabs are described in the WinX application software Help topics.

DG535 dialog

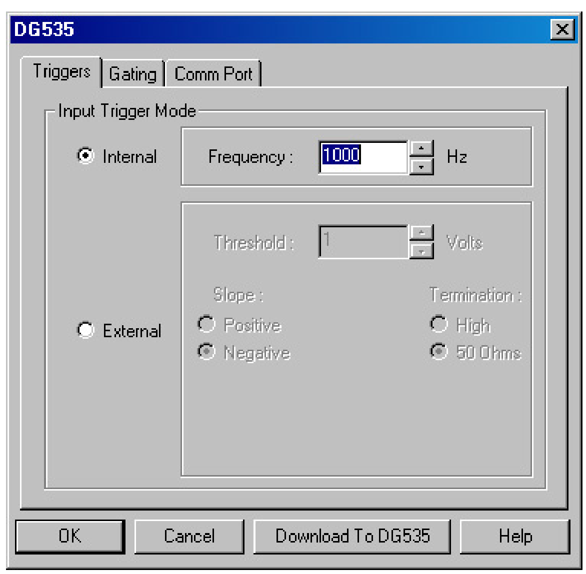

Figure 118. DG535 dialog

Operation of the DG535 Timing Generator becomes available when you select **Pulsers** from the Setup menu, next click on the **DG535** radio button and then click on the **Setup DG535** button. This opens the DG535 dialog as shown above. Note that pulser support must be selected when installing the WinX application software (WinView/32 or WinSpec/32) for DG535 control to be available, and that the intended use of the DG535 is for operation in conjunction with the PI-MAX CCD Detector.

The DG535 parameters are set via the IEEE-488 GPIB link between the computer and the DG535 Pulser. The choices provided by the **Triggers**, **Gating** and **Comm Port** tabs correspond to those provided by the DG535 front panel, and are described in the WinX application software Help topics and in the DG535 manual.

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Appendix D
C-Mount and F-Mount Adapters

Attaching the C-Mount or F-Mount Adapter to the PI-MAX

The PI-MAX is supplied with the lens mount adapter specified when the system was ordered, normally either for a screw-type C-mount lens or for a bayonet type F-mount lens, allowing a lens of the corresponding type to be mounted quickly and easily. If you have multiple mount adapters and you want to change from one adapter type to another: loosen the three setscrews, unscrew the current adapter, screw in the new adapter until it bottoms out, and secure the adapter with the locking setscrews. The focal length distance will automatically be correct to a high degree of precision.

The PI-MAX nose and imaging mounts are illustrated on the following pages.

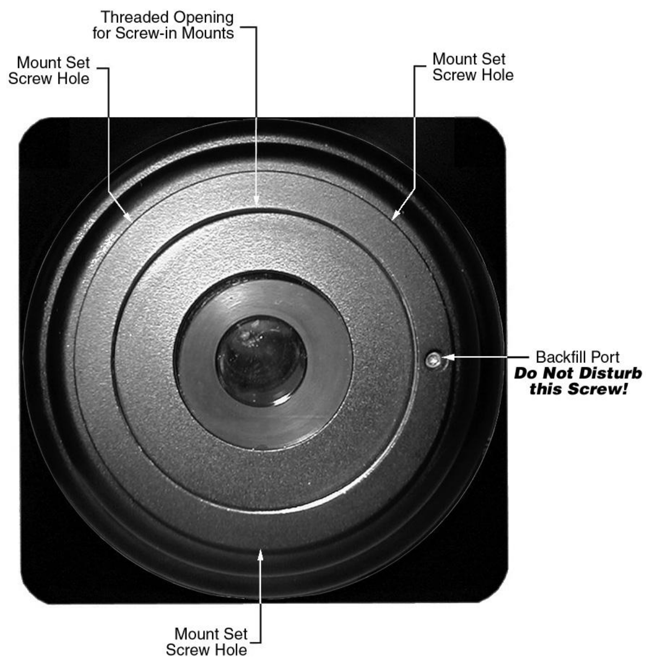

Figure 119. PI-MAX Standard Nose

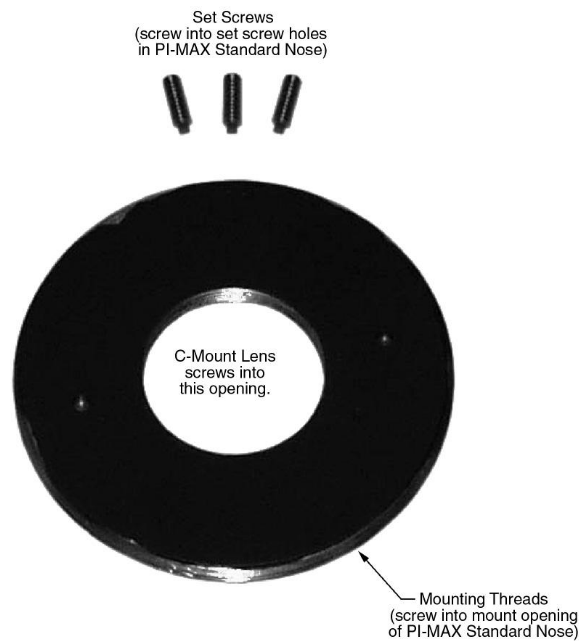

Figure 120. C-Mount Adapter

Figure 121. F-Mount Adapter

Mounting the Lens

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 (Figure 122), locate the large indicator dot on the side of the lens. 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.

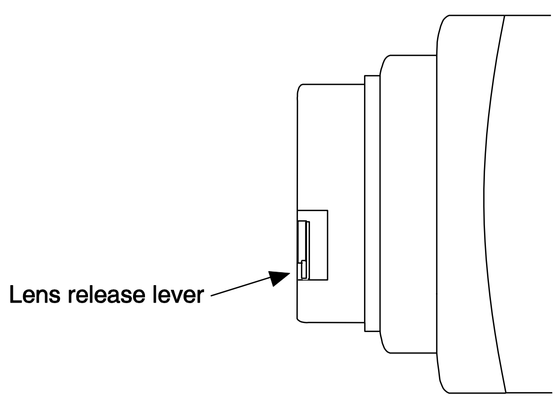

Figure 122. F-mount (Nikon) Lens Adapter

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.

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

Mounting Orientation

The PI-MAX can be mounted at any attitude or angle. The camera can rest on any secure surface. Take care not to block the ventilation openings.

WARNING 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.

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

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. In microscopy applications, it will also be necessary to review the discussions in Chapter 12.

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Appendix E
Spectroscopy-Mount and Spectrograph Adapters

Spectroscopy-Mount Adapter

The PI-MAX is supplied with a spectroscopy-mount adapter if one was specified when the system was ordered. The spectroscopy-mount adapter is simply screwed directly into the nose and then secured by three set screws. If you want to change from one adapter type to another (e.g., C-mount to spectroscopy-mount), loosen the three setscrews, unscrew the current adapter, screw in the new adapter until it bottoms out, and secure the adapter with the locking setscrews. The focal length distance will automatically be correct to a high degree of precision. However, there will be the usual focal depth adjustment and rotational adjustment at the spectrograph input or output.

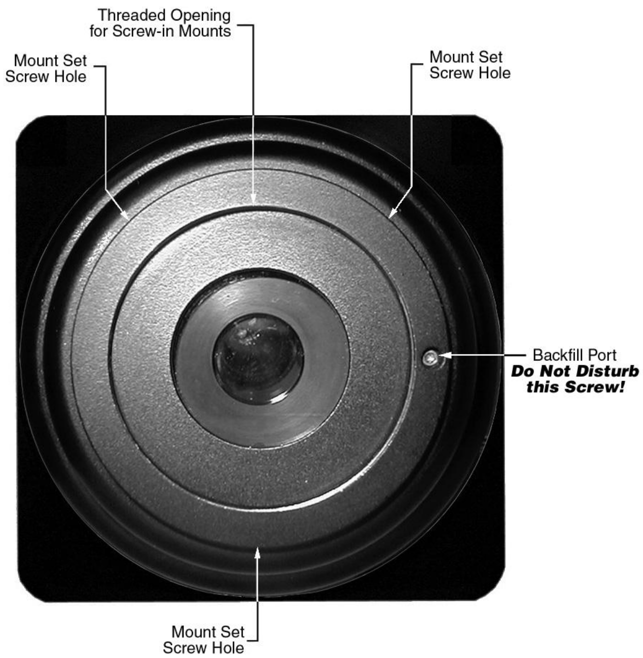


Figure 123. PI-MAX Standard Nose

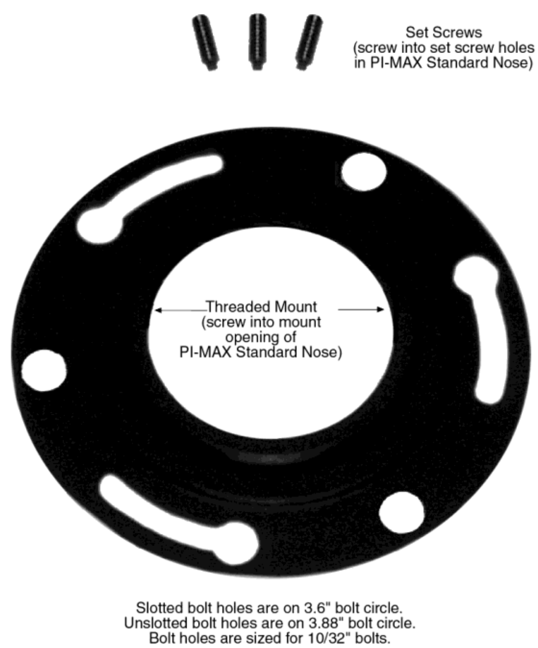


Figure 124. Spectroscopy-Mount Adapter

Spectrograph Adapters

Princeton Instruments offers a variety of spectrograph adapters for mounting a PI-MAX to a spectrograph: Acton (adapters are available for all Acton models), the ISA HR320, ISA HR640, Chromex 250IS, and most instruments that are 1 meter or longer. (If you are not sure of the depth of the exit focal plane, contact the spectrograph manufacturer.)

Mounting the camera to one of these spectrographs typically requires a female Focusing Flange that may be a separate part or an integral part of the spectrograph. Also required is a male Focusing Flange that slides into the female flange to set the focus and which is bolted to the spectroscopy-mount adapter that screws into the PI-MAX nose.

The mounting instructions for spectrograph adapters offered by Princeton Instruments are organized by spectrograph model and adapter kit number. For the appropriate instruction set, see Table 14, page 205, which cross-references these items with the page number.

Note: When mounted to a spectrograph, the text on the back of the PI-MAX should be right side up.

Spectrograph-Detector Focusing

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 an Acton 2300i spectrograph, can be easily adapted to other spectrographs.

1. Mount a light source such as a mercury pen-ray type in front of the entrance slit of the spectrograph. Any light source with line output can be used. *Standard fluorescent overhead lamps have good calibration lines as well.* If there are no “line” sources available, it is possible to use a broad band source such as tungsten for the alignment. If this is the case, use a wavelength setting of 0.0nm for alignment purposes.
2. With the spectrograph properly connected to the controller, turn the power on, wait for the spectrograph to initialize. Then set it to 435.8 nm if using a mercury lamp or to 0.0 nm if using a broadband source.

   Hint: Overhead fluorescent lights produce a mercury spectrum. Use a white card tilted at 45 degrees in front of the entrance slit to reflect overhead light into the spectrograph. Select 435.833 as the spectral line.
3. Set the slit to 25 µm. If necessary, readjust the Exposure Time to maintain optimum (near full-scale) signal intensity.
4. 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.

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

   - **Long focal-length spectrographs such as the Acton 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.

5. 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.

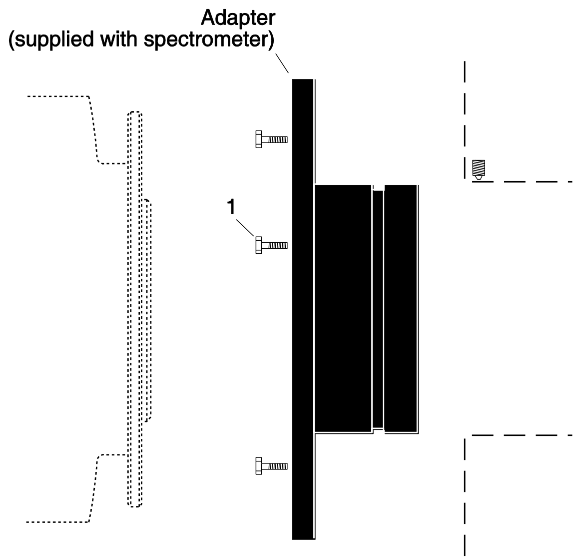
   Alternatively, take an image, display the horizontal and vertical cursor bars, and compare the vertical bar to the line shape on the screen. Rotate the detector until the line shape on the screen is parallel with the vertical bar.

Note: When aligning other accessories, such as 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. do the focus and alignment operations while watching a live image.

Spectrograph	Adapter Kit No.	Page
Acton	Sliding Tube	206
Acton	C-Mount Adapter	207
Chromex 250 IS	7050-0090	208
ISA HR 320	7050-0010	209
ISA HR 640	7050-0034	210
SPEX 270M	7050-0041	211
SPEX 500M	7050-0038	212
SPEX TripleMate	7050-0007	213

Table 14. Spectrograph Adapters

Acton (Sliding Tube)



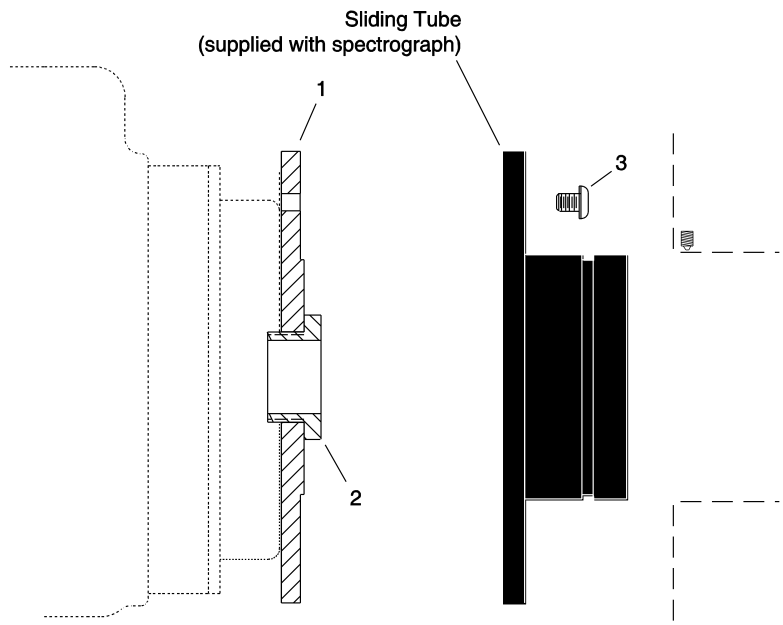
	Qty	P/N	Description
1.	3	2826-0120	Screw, 10-32 × 1/2, Hex Head, Stainless Steel

Assembly Instructions

1. Make sure that the shipping cover has been removed from the detector port on the spectrograph.
2. Loosen the setscrews holding the Acton adapter in the spectrograph and remove the adapter. If there is a spacer plate installed on the adapter, remove it.
3. Leaving 1/4" of thread exposed, mount the three (3) hex head screws to the adapter.
4. Mount the adapter to the detector flange and rotate the adapter so the screw heads are over the narrow end of the slots.
5. Tighten the screws.
6. Gently insert the adapter into the spectrograph and fasten with the setscrews.

Note: Adapter parts are machined to provide a tight fit. It is necessary to rotate the detector back and forth when inserting into the spectrograph adapter. Do not force the two parts of the adapter together, as they can be permanently damaged by excessive force.

Acton (C-Mount Adapter)



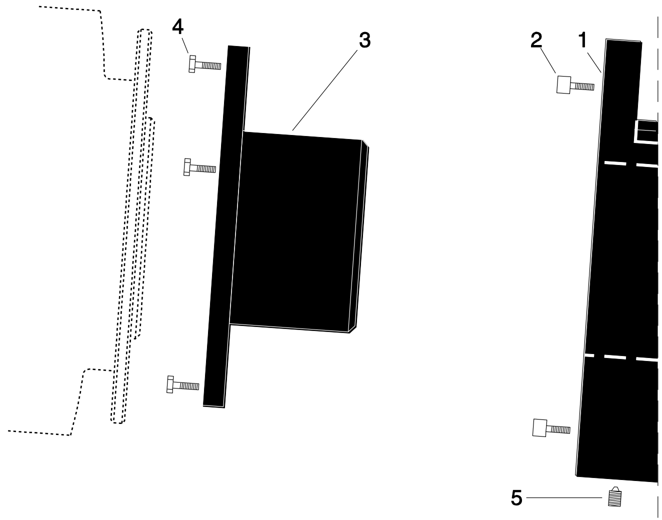
	Qty	P/N	Description
1.	1	8401-071-01	Adapter Plate
2.	1	8401-071-02	Threaded C-Mount Adapter
3.	3	2826-0127	Screw, 10-32 × 1/4, Button Head Allen Hex, Stainless Steel

Assembly Instructions

1. Make sure that the shipping cover has been removed from the detector port on the spectrograph.
2. Loosen the setscrews 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) 1/4" 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.

Note: 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.

Chromex 250 IS



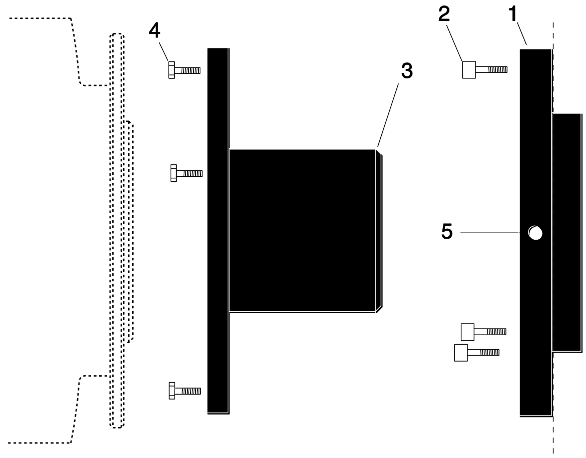
	Qty	P/N	Description
1.	1	2517-0901	Plate, Adapter-Female
2.	4	2826-0283	Screw, 10-32 × 3/4, Socket Head, Stainless Steel, Hex, Black
3.	1	2518-0227	Adapter-Male, ICCD Diode Array
4.	3	2826-0120	Screw, 10-32 × 1/2, Hex Head, Stainless Steel
5.	1	2826-0082	Set Screw, 10-32 × 1/4, Stainless Steel, Allen Hex, Nylon Tip

Assembly Instructions

1. Attach part 1 to the spectrograph wall (dashed line in illustration) with the socket head screws provided.
2. Leaving 1/4" of thread exposed, mount the three (3) hex head screws to part 3.
3. Mount the adapter to the detector flange and rotate the adapter so the screw heads are over the narrow end of the slots.
4. Tighten the screws.
5. Gently insert part 3 into part 1 and fasten with the setscrew.

Note: Adapter parts are machined to provide a tight fit. It is necessary to rotate the detector back and forth when inserting into the spectrograph adapter. Do not force the two parts of the adapter together, as they can be permanently damaged by excessive force.

ISA HR 320



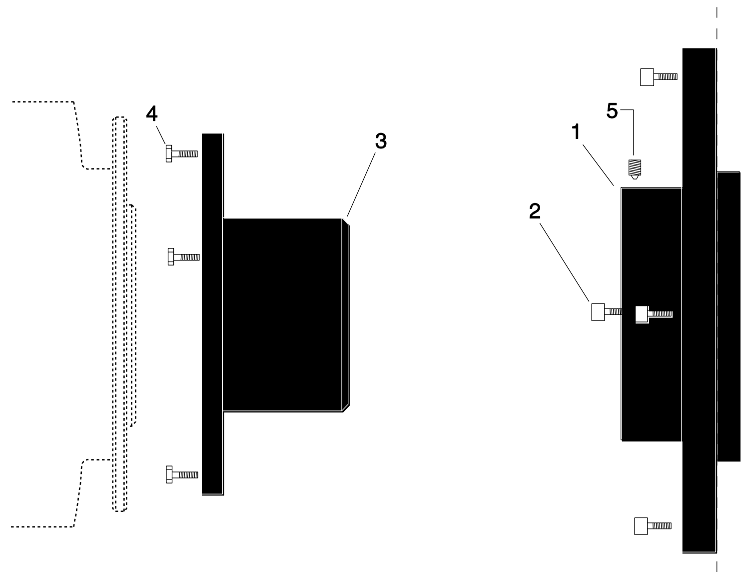
	Qty	P/N	Description
1.	1	2518-0044	Flange-Female, Mechanical, ISA, HR320
2.	3	2826-0053	Screw, 10-32 × 7/16, Socket Head Cap Hex, Stainless Steel
3.	1	2518-0045	Flange-Male, Detector Mate
4.	3	2826-0120	Screw, 10-32 × 1/2, Hex Head, Stainless Steel
5.	1	2826-0082	Set Screw, 10-32 × 1/4, Stainless Steel, Allen Hex, Nylon Tip

Assembly Instructions

1. Attach part 1 to the spectrograph wall (dashed line in illustration) with the socket head screws provided.
2. Leaving 1/4" of thread exposed, mount the three (3) hex head screws to part 3.
3. Mount the adapter to the detector flange and rotate the adapter so the screw heads are over the narrow end of the slots.
4. Tighten the screws.
5. Gently insert part 3 into part 1 and fasten with the setscrew.

Note: Adapter parts are machined to provide a tight fit. It is necessary to rotate the detector back and forth when inserting into the spectrograph adapter. Do not force the two parts of the adapter together, as they can be permanently damaged by excessive force.

ISA HR 640



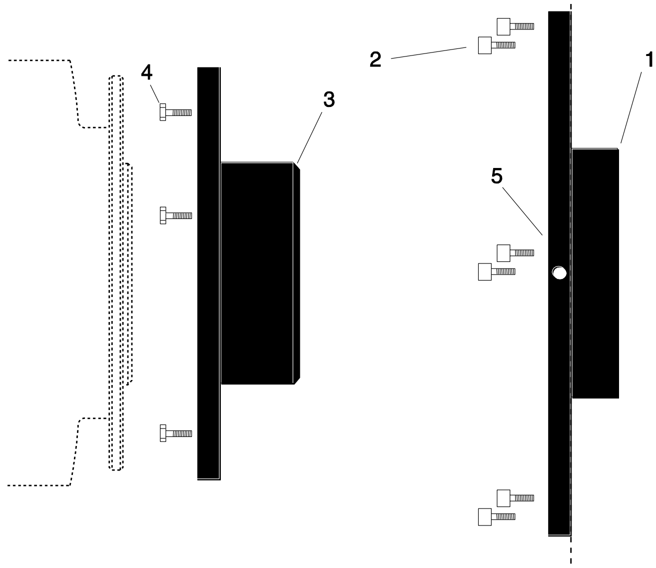
	Qty	P/N	Description
1.	1	2518-0203	Adapter-F, HR-640
2.	4	2826-0144	Screw, M4x.7x14 mm, Socket Head, Hex, Stainless Steel
3.	1	2518-0227	Adapter-Male, ICCD Diode Array
4.	3	2826-0120	Screw, 10-32 × 1/2, Hex Head, Stainless Steel
5.	2	2826-0082	Set Screw, 10-32 × 1/4, Stainless Steel, Allen Hex, Nylon Tip

Assembly Instructions

1. Attach part 1 to the spectrograph wall (dashed line in illustration) with the socket head screws provided.
2. Leaving 1/4" of thread exposed, mount the three (3) hex head screws to part 3.
3. Mount the adapter to the detector flange and rotate the adapter so the screw heads are over the narrow end of the slots.
4. Tighten the screws.
5. Gently insert part 3 into part 1 and fasten with the setscrews.

Note: Adapter parts are machined to provide a tight fit. It is necessary to rotate the detector back and forth when inserting into the spectrograph adapter. Do not force the two parts of the adapter together, as they can be permanently damaged by excessive force.

SPEX 270M



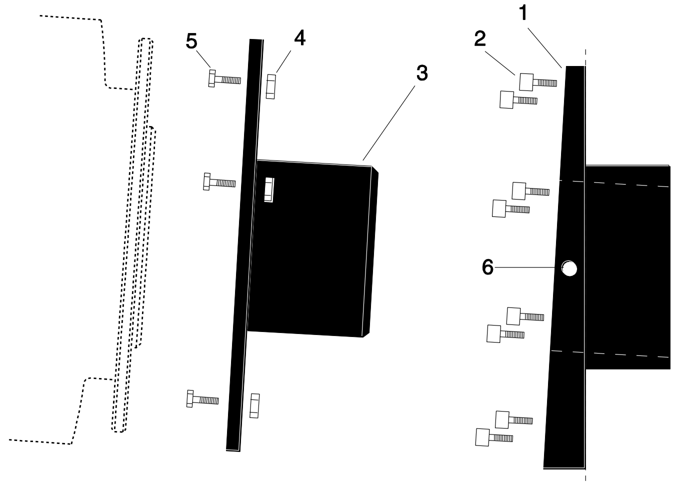
	Qty	P/N	Description
1.	1	2518-0691	Female Adapter Plate, 2.400 ID
2.	6	2826-0068	Screw, 6-32 × 3/8. Socket Head, Hex, Stainless Steel
3.	1	2518-0690	Adapter Male, Focusing, Male, Spec 270
4.	3	2826-0120	Screw, 10-32 × 1/2, Hex Head, Stainless Steel
5.	2	2826-0019	Set Screw 8-32 × 3/16, Hex, Nylon Tip

Assembly Instructions

1. Attach part 1 to the spectrograph wall (dashed line in illustration) with the socket head screws provided.
2. Leaving 1/4" of thread exposed, mount the three (3) hex head screws to part 3.
3. Mount the adapter to the detector flange and rotate the adapter so the screw heads are over the narrow end of the slots.
4. Tighten the screws.
5. Gently insert part 3 into part 1 and fasten with the setscrews.

Note: Adapter parts are machined to provide a tight fit. It is necessary to rotate the detector back and forth when inserting into the spectrograph adapter. Do not force the two parts of the adapter together, as they can be permanently damaged by excessive force.

SPEX 500M



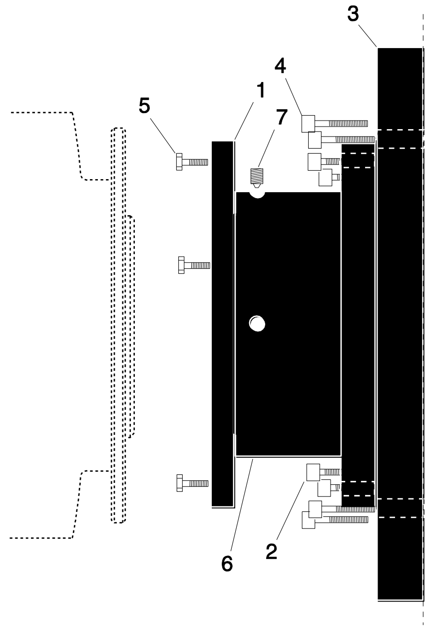
	Qty	P/N	Description
1.	1	2517-0214	Adapter-Female, Spex 500M
2.	8	2826-0170	Screw, 1/4-20 × 0.5L, Low Socket Head Cap
3.	1	2518-0291	Adapter Male, Spex 500M
4.	3	2827-0010	10-32 Nut, Stainless Steel
5.	3	2826-0120	Screw, 10-32 × 1/2, Hex Head, Stainless Steel
6.	2	2826-0055	Set Screw 8-32 × 1/4, Allen Hex, Nylon Tip

Assembly Instructions

1. Attach part 1 to the spectrograph wall (dashed line in illustration) with the socket head screws provided.
2. Leaving 1/4" of thread exposed, mount the three (3) hex head screws and nuts to part 3.
3. Mount the adapter to the detector flange and rotate the adapter so the screw heads are over the narrow end of the slots.
4. Tighten the screws.
5. Gently insert part 3 into part 1 and fasten with the setscrews.

Note: Adapter parts are machined to provide a tight fit. It is necessary to rotate the detector back and forth when inserting into the spectrograph adapter. Do not force the two parts of the adapter together, as they can be permanently damaged by excessive force.

SPEX TripleMate



	Qty	P/N	Description
1.	1	2518-0183	Adapter-Male, ICCD/For Spex TripleMate
2.	4	2826-0128	Screw, 10-32 × 5/8, Socket Head Cap, Stainless Steel
3.	1	2517-0163	Slit Mount, Spex
4.	4	2826-0129	Screw, 1/4-20 × 3/4, Socket Head Cap, Stainless Steel
5.	3	2826-0120	Screw, 10-32 × 1/2, Hex Head, Stainless Steel
6.	1	2518-0185	Adapter-Female, Flange Spex
7.	2	2826-0070	Set Screw, 6-32 × 3/16, Stainless Steel, Allen Hex
	1	2500-0025	O-ring, 2.359x.139, Viton (installed)
	1	2500-0026	O-ring, 2.484x.139, Viton (installed)

Assembly Instructions

1. Mount the whole assembly onto the spectrograph (dashed line in illustration).
2. Leaving 1/4" of thread exposed, mount the three (3) hex head screws to part 1.
3. Mount the adapter to the detector flange and rotate the adapter so the screw heads are over the narrow end of the slots.
4. Tighten the setscrews.
5. Tighten the hex head screws.

Note: Adapter parts are machined to provide a tight fit. It is necessary to rotate the detector back and forth when inserting into the spectrograph adapter. Do not force the two parts of the adapter together, as they can be permanently damaged by excessive force.

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Appendix F

IVUV Detector

Introduction

The Intensified Vacuum UV Detector (IVUV), a variation of the PI-MAX detector, is available in two types. The first type is a sealed-nose version that is backfilled with dry nitrogen only. The second type is an open-nose version that must be purged with dry nitrogen during operation.

WARNING

> Under normal conditions, the front end of the sealed-nose IVUV is sealed and backfilled with dry nitrogen only so there is no danger of damage due to condensation. In the case of an open-nose IVUV, however, the detector must be purged with dry nitrogen during operation. Otherwise catastrophic damage could occur that would not be covered by the Warranty.

Nitrogen Purging of the Detector

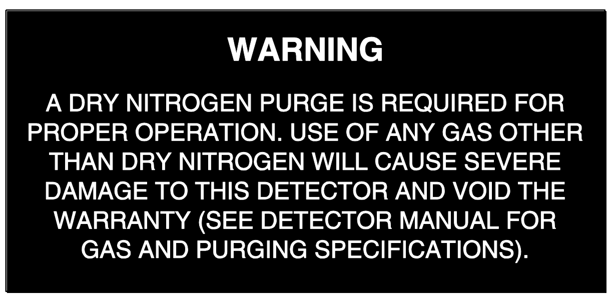

Figure 125. Camera's Purge Warning Label

An IVUV requires continuous purging of the detector with nitrogen while operating cooled. Even if the detector is not powered, it must be purged whenever water or other coolant is circulating, as the possibility of condensation still exists. *See Chapter 3 for additional information concerning circulating coolant.*

WARNING

> *Never* use any gas other than dry nitrogen. Noble gases, such argon or helium, have a low breakdown voltage, which could lead to arcing that could destroy the image intensifier.

Caution

> If the relative humidity in your lab is high, e.g., > 40% do not operate the open-nose detector without purging, *even if you are not cooling the detector!*

Dryness Requirement

The dryness of the nitrogen is critical. The colder the detector is operated, the dryer the gas must be. Also, the longer the detector is operated cold, the drier the gas must be.

WARNING

Be wary of unspecified "dry" gases intended for less demanding applications. Even a 99.9% pure gas can deposit enough water to cause permanent damage to the detector.

As an example, consider an IVUV camera where the CCD temperature is -20°C and where you are using nitrogen with 100 ppm of water vapor. This water vapor will be at dew point and water will condense and freeze on the CCD. Ice will continue to form for as long as this nitrogen flows over the surface of the CCD.

Princeton Instruments recommends that gases with less than 10 ppm water vapor be used. An example is AIRCO compressed nitrogen grade 4.8 (≤3 ppm). Equivalent gases from other quality vendors are also suitable.

Connect the nitrogen source to the nitrogen inlet on the upper surface of the camera nose. Purge the detector for at least 10 minutes at a high rate (1-2 liters/minute). Then lower the rate to 750-1000 ml/minute.

Caution

After you have finished an experiment and have turned off the controller, maintain a gas flow of at least 2 liters/minute for at least 15 minutes. This keeps condensation from forming on the detector until it reaches room temperature.

Backfilling

If a sealed version of the IVUV PI-MAX detector must be backfilled, ***contact the factory*** and arrange to return the detector to the factory where it can be properly flushed, backfilled and resealed again. See page 232 for contact information.

WARNING

Operating a sealed-nose IVUV PI-MAX that is no longer backfilled with dry nitrogen may result in condensation on the array that could cause irreversible damage. Such damage would not be covered by the Warranty.

Appendix G

USB 2.0 Limitations

The following information covers the currently known limitations associated with operating under the USB 2.0 interface.

- Maximum cable length is 5 meters (16.4 feet)
- 1 MHz is currently the upper digitization rate limit for the ST-133 Controller.
- Large data sets and/or long acquisition times may be subject to data overrun because of host computer interrupts during data acquisition.
- USB 2.0 is not supported by the Princeton Instruments PC Interface Library (EZ-DLLS).
- Some WinX (WinView/32 and WinSpec/32) 2.5.X features are not fully supported with USB 2.0. See the table below.

Feature	Supported with USB 2.0 in WinX 2.5.X	Remarks
Demo Port Capability	NO	
DIF		
Kinetics	YES	WinX 2.5.18.1
Reset Camera to NVRAM Defaults	NO	
Temperature Lock Status	YES	WinX 2.5.x doesn't utilize hardware lock status
PTG	YES	
Virtual Chip	NO	
Custom Timing	YES	WinX 2.5.18.1
Custom Chip	YES	WinX 2.5.18.1
Frames per Interrupt	NO	
RS170 (Video Output)	NO	
Online Exposure	NO	
File Information	YES	Not all header info is currently available in WinX 2.5.x through PVCAM
Overlapping ROIs	NO	

Table 15. Features Supported under USB 2.0 *(continued on next page)*

Feature	Supported with USB 2.0 in WinX 2.5.X	Remarks
Macro Record	YES	Macros recorded for non-PVCAM cameras may have to be re-recorded to function
TTL I/O	NO	

Table 15. Features Supported under USB 2.0

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: See **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 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.

CCD Spectral Sensitivity: Coatings applied to the CCD input window can enhance sensitivity in the UV regions. Deep-depletion enhances sensitivity in the NIR.

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 ST-133 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 **Shutter Mode**, the exposure time is set on the **Experiment|Timing** dialog and the photocathode is biased ON for that period.
- In **Gate Mode** with a **PTG**, the exposure time is determined by a PTG pulse ensemble defined by the PTG gating setup.
- In **Gate Mode** with a **DG535**, an ET = 0 setting means that the exposure time will be determined by the External Sync signal. An ET > 0 setting determines the exposure time.

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, i.e. Freerun mode, 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 512x512 array, a full-frame would consist of the entire 512X512 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.

Note: Kinetics Mode results in multiple images/spectra (subframes) collected on a single frame

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.

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-MAX 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.

Input Windows: The intensifier and the CCD array both have input windows.

MgF_2 : 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) and 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-MAX is made possible by switching the intensifier on and off (gating) very rapidly. Typical fast-gate intensifiers have minimum gate widths (FWHM=full width at half-maximum gate pulse) of approximately 2 ns. For slow-gated devices the FWHM is about 50 ns.

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 (see page 85) ratios in the UV region can be improved dramatically (10^7:1).

Intensifier Size: 18 mm dia. and 25 mm dia. 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:

Gen I: 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 .01 lux. Problems included image distortion, short-lived components, and large size.

GenII: 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 Gen I intensifiers however have high resolution, no image distortion, and are small. Can detect images under ambient light intensity as low as .001 lux.

Super Gen II: Gen II devices that employ novel photocathodes with extended spectral range or high QE in a particular wavelength.

Gen III: Gen II 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 devices. Can detect images under ambient light intensify as low as .0001 lux.

Gen IV: Introduced in 1999. No ion barrier film and exhibit enhanced QE, SNR, dynamic range, and high-light-level resolution.

Internal Trigger mode: PTG or DG535 mode where gate pulses are delayed from trigger pulses produced by an internal timer. Delays are programmable in increments of 10 ns instead of 1 ns as they are in **External Trigger** mode.

Kinetics Mode: An optional PI-MAX mode of operation in which most of the CCD is mechanically or optically masked, leaving a small section (i.e., window) open to light. A series of images is rapidly acquired during a single data acquisition period by repeatedly gating the intensifier. The image is collected in the window while the intensifier is gated on, and after it is gated off, the image is shifted on the array to clear the window for the next image. After the entire series is collected, the CCD is readout. Kinetics mode takes advantage of the fact that shifting on the array is much faster than performing a readout.

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.

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-MAX cameras with Gen II intensifiers. 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 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) while P46 offers fast decay for high-repetition rate spectroscopy (3 µs decay). The shutter compensation time (see below), 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, shutter compensation time elapses to allow for phosphor decay, and then the CCD array is readout.

QE: 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 (ROI): 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.

Safe Mode: PI-MAX 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 or **Scanning:** The process of reading out the contents of a CCD array.

Shutter Compensation Time: This is the amount time inserted between the end of the exposure time and the beginning of the array readout. For a PI-MAX, the appropriate choices of **Shutter Type** (**Hardware Setup|Controller/Camera** tab card) are "Electronic" and "None". When "Electronic" is selected, 6 ms is inserted to allow time for the phosphor to decay: this choice is appropriate for a P43 phosphor. No time is inserted when "None" is selected: this choice is appropriate for a P46 phosphor.

Shutter Mode: PI-MAX intensifier mode in which the photocathode is biased on at during the exposure time and is biased off before the array is read out.

Timing Mode: A timing mode determines how data acquisition is synchronized with an experiment. The timing modes associated with a PI-MAX system are: Free Run, External Sync, External Sync with Continuous Cleans, and Internal Sync.

Vertical Shift Time (µs): Reports the speed (in microseconds) 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 and Kinetics modes.

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.

Window Size: Specifies the height of the window for Kinetics mode and should be equal to the height of the unmasked area of the array. This value must be 1 or greater.

Declarations of Conformity

This section of the PI-MAX/PI-MAX2 system manual contains the declarations of conformity for PI-MAX and PI-MAX2 systems. A system includes the PI-MAX or PI-MAX2 camera with a Gen II or Gen III intensifier and an ST-133 Controller with or without PTG boards.

DECLARATION OF CONFORMITY

We,

ROPER SCIENTIFIC

(PRINCETON INSTRUMENTS)

3660 QUAKERBRIDGE ROAD

TRENTON, NJ 08618

Declare under our sole responsibility, that the product

ST-133 CONTROLLER with PTG BOARD and

PI-MAX GEN II/GEN III CAMERA HEADS,

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

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

EN 55011 for Group 1, Class A, 1991,

EN 61326-1, 1997-03 (EN 61000-4-2, EN 61000-4-3, EN 61000-4-4,

EN 61000-4-5, EN 61000-4-6, EN 61000-4-11)

Which follow the provisions of the

CE LOW VOLTAGE DIRECTIVE 73/23/EEC

And

EMC DIRECTIVE 89/336/EEC.

Date: August 7, 2002
TRENTON, NJ

(PAUL HEAVENER)
Engineering Manager

DECLARATION OF CONFORMITY

We,

ROPER SCIENTIFIC

(PRINCETON INSTRUMENTS)

3660 QUAKERBRIDGE ROAD

TRENTON, NJ 08619

Declare under our sole responsibility, that the product

ST-133 CONTROLLER with

PI-MAX GEN II and GEN III CAMERA HEADS,

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

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

EN 55011 for Group 1, Class A, 1991,

EN 50082-1, 1993 (EN 61000-4-2, EN 61000-4-3, EN 61000-4-4)

Which follow the provisions of the

CE LOW VOLTAGE DIRECTIVE 73/23/EEC

And

EMC DIRECTIVE 89/336/EEC.

Date: August 7, 2002
TRENTON, NJ

(PAUL HEAVENER)
Engineering Manager

DECLARATION OF CONFORMITY

We,

ROPER SCIENTIFIC

(PRINCETON INSTRUMENTS)

3660 QUAKERBRIDGE ROAD

TRENTON, NJ 08619

Declare under our sole responsibility, that the product

ST-133 16-BIT 5 MHz CONTROLLER with PI-MAX2 CAMERA,

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

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

EN 61326 for Class A, 1998,

(EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5,

EN 61000-4-6, EN 61000-4-11), EN 61000-3-2:2000, and

EN 61000-3-3:1995,

Which follow the provisions of the

CE LOW VOLTAGE DIRECTIVE 73/23/EEC

And

EMC DIRECTIVE 89/336/EEC.

Date: July 18, 2003

TRENTON, NJ

(PAUL HEAVENER)
Engineering Manager

Warranty & Service

Limited Warranty

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

Basic Limited One (1) Year Warranty

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

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

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

XP Vacuum Chamber Limited Lifetime Warranty

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

Sealed Chamber Integrity Limited 12 Month Warranty

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

Vacuum Integrity Limited 12 Month Warranty

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

Image Intensifier Detector Limited One Year Warranty

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

X-Ray Detector Limited One Year Warranty

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

Software Limited Warranty

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

Owner's Manual and Troubleshooting

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

Your Responsibility

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

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

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

Contact Information

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

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

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

Customer Support E-mail: techsupport@princetoninstruments.com

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

America	1.877.4.PIACTON (877.474.2286)
Benelux	+31 (347) 324989
France	+33 (1) 60.86.03.65
Germany	+49 (0) 89.660.7793
Japan	+81 (3) 5639.2741
UK & Ireland	+44 (0) 28.3831.0171

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

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