

SPECTRUM ONE

Array Detection System

For CCD Detectors

With CCD-3000(V), CCD-3500(V)
Controllers

Part Number 80119 Rev. J

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ABOUT THE MANUALS

You may have more than one manual, depending on your system configuration. To find the manual that has the information you need, these guidelines may help.

- Each manual generally covers a product and the features and accessories peculiar to and/or contained within that product.
- Accessories that can be applied to other products are normally covered by separate documentation.
- Software that is exclusively used with one instrument or system is covered in the manual for that product.
- Software that can be used with a number of other products is covered in its own manual.
- If you are reading about a product that interacts with other products, you will be referred to other documentation as necessary.

INTRODUCTION:

The Spectrum ONE detection systems are a family of array detectors designed and manufactured by Jobin Yvon Inc.

The Spectrum ONE series detectors include cooled Charge Coupled Devices (CCD's), which provide two-dimensional photodetection, and linear Indium Gallium Arsenide (InGaAs) detectors (not discussed in this manual) for spectrometric applications.

The glossary section of this manual starts on page 33. It contains definitions of terms and information about essential topics relating to array detection of spectra. Reading the glossary is recommended.

The Spectrum ONE CCD array detection system is well suited to applications such as:

- Absorption spectroscopy
- Emission spectroscopy
- Moderately low signal level applications
- Raman spectroscopy
- Fluorescence
- Photoluminescence
- Recording spectra from multiple sources or locations that are imaged along the height of the spectrograph entrance slit

OPERATING PRINCIPLES:

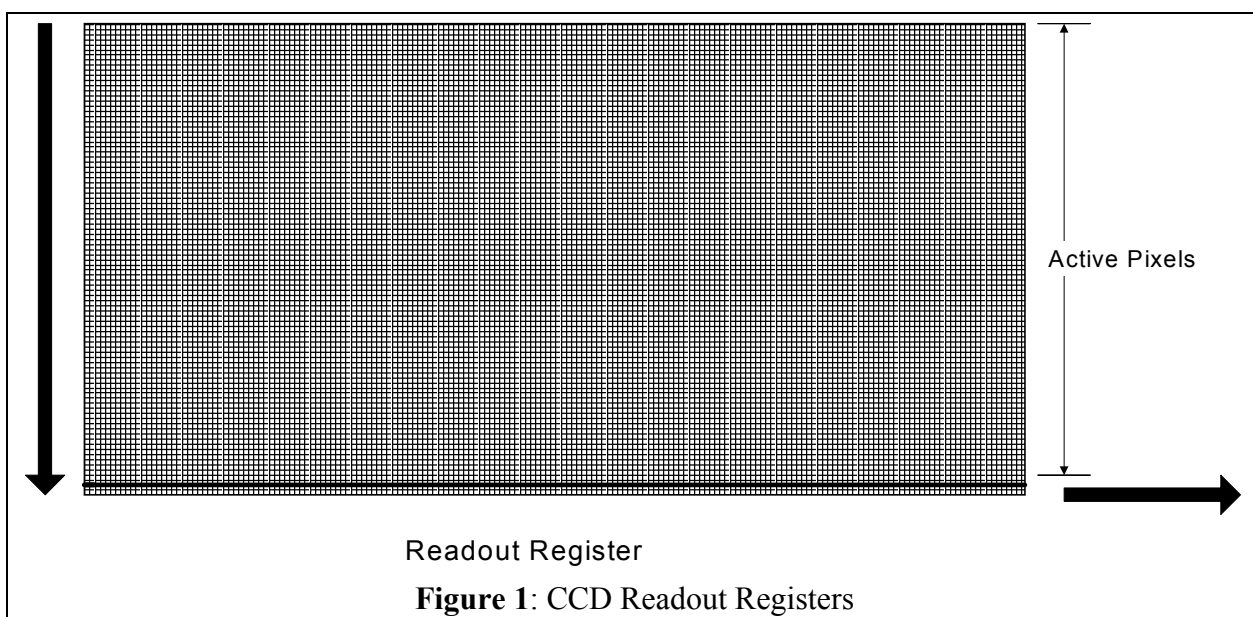
CCD Sensors

CCD detector arrays are essentially large area silicon devices constructed such that the sensing area is divided into a two-dimensional matrix of pixels. Each pixel is an individual detection element, but combination of pixels, or “binning,” is also possible.

When illuminated by opening the shutter, each pixel integrates a charge arising from the photoelectric effect. The charges of adjacent pixels are kept separated by a grid of electrodes that confine the charges by electrostatic force.

At the end of the signal integration time, the shutter is closed. Then the electrode grid voltages are manipulated by control signals from the Detector controller. This will sequentially shuttle the pixel charges row-by-row to the edge of the chip into the readout register, as shown in Figure 1. This is called a parallel shift. The charge is then transferred from the readout register to the ADC (serial shift). Based on the software settings, the Detector controller can cause the readout to be formatted as either individual pixel data points or as areas of several pixels “binned” into superpixels.

The signal from the CCD is processed, amplified and converted to digital data points by electronics in the Detector Controller. The data is then passed from the Detector Controller to the memory of the computer. This allows the software running in the host PC to access it rapidly for further processing and display.



SYSTEM DESCRIPTION AND SPECIFICATIONS:

The Spectrum ONE array detection system consists of a detector head, a detector controller and software. The detector head consists of the array sensor that is actively cooled by Liquid Nitrogen or forced-air circulated thermoelectric cooling. The controller acts as the interface between the detector and the operating computer. Models CCD-3000V and CCD-3500V are functionally identical to models CCD-3000 and CCD-3500, except that the 'V' versions incorporate the TE/PS auxiliary power supply required for the high-performance ATE-CCD heads, and are thus dimensionally larger. Communication is via IEEE-488. A National Instruments brand IEEE-488 GPIB interface is required to run SpectraMax for Windows software.

Caution: Electrostatic discharge (ESD) may damage components of the Spectrum ONE system if proper precautions are not taken. The JY warranty on the Spectrum ONE array detectors does not cover damage to the sensors that arises from any improper handling of the detector including ESD. Proper handling precautions must be taken at all times.

Detector Heads:

The Spectrum ONE array detectors are available with three cooling options: compact "mini" thermoelectrically cooled detectors (MTE series), air-cooled thermoelectrically cooled detectors (ATE series), and cryogenic liquid nitrogen LN₂ cooled detectors. The compact, "mini" thermoelectrically cooled units operate the sensor at less-cool temperatures and thus have higher dark current and are ideal for applications requiring short exposure times. The ATE-series high-performance evacuated units provide an operating temperature that is warmer than the LN₂ cooled heads, but still with a very low dark current performance. No cryogenic cooling fluid is required in the thermoelectrically cooled systems. When the lowest noise and dark level is required, liquid nitrogen (LN₂) provides cryogenic cooling to reduce temperature and therefore dark current to the lowest level possible.

The three types of detector heads are described in more detail in the next section.

Mini-Air-Cooled Thermoelectrically Cooled (MTE) Heads:

Figure 2 shows the compact air-cooled mini Spectrum ONE head. Only select CCD sensors from Jobin Yvon are available in this housing. Typically, the distance between the CCD chip and the external flange is 12.47mm (0.491 inches) for the MTE head. Dimensioned drawings of MTE thermoelectrically cooled housings are provided in Appendix D.

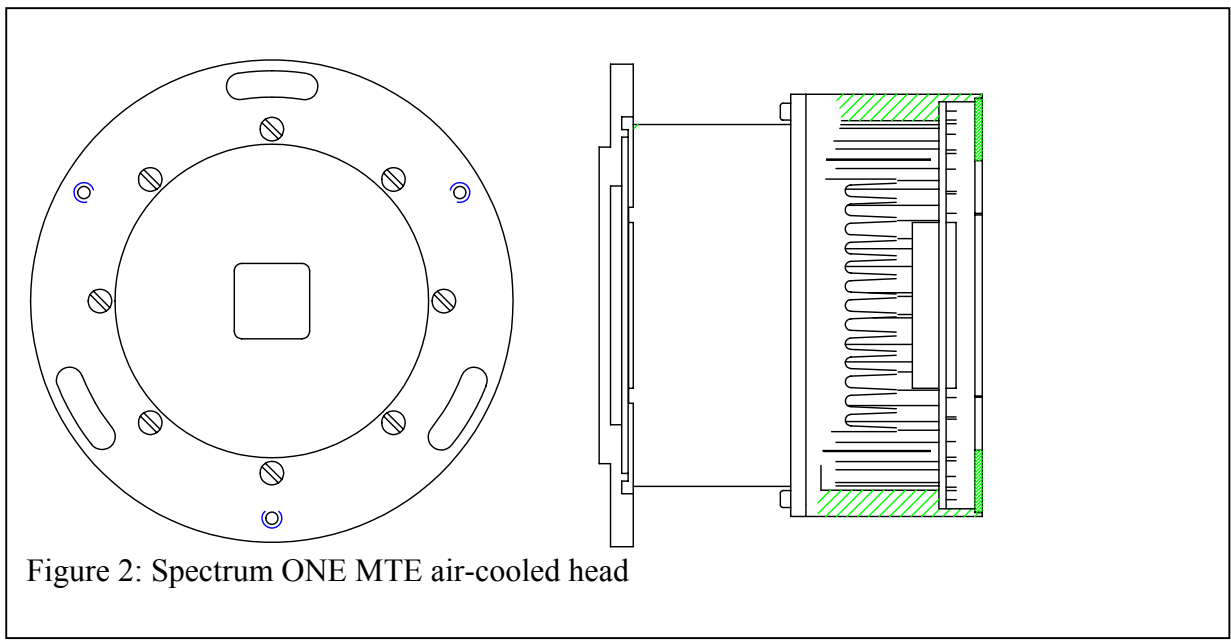


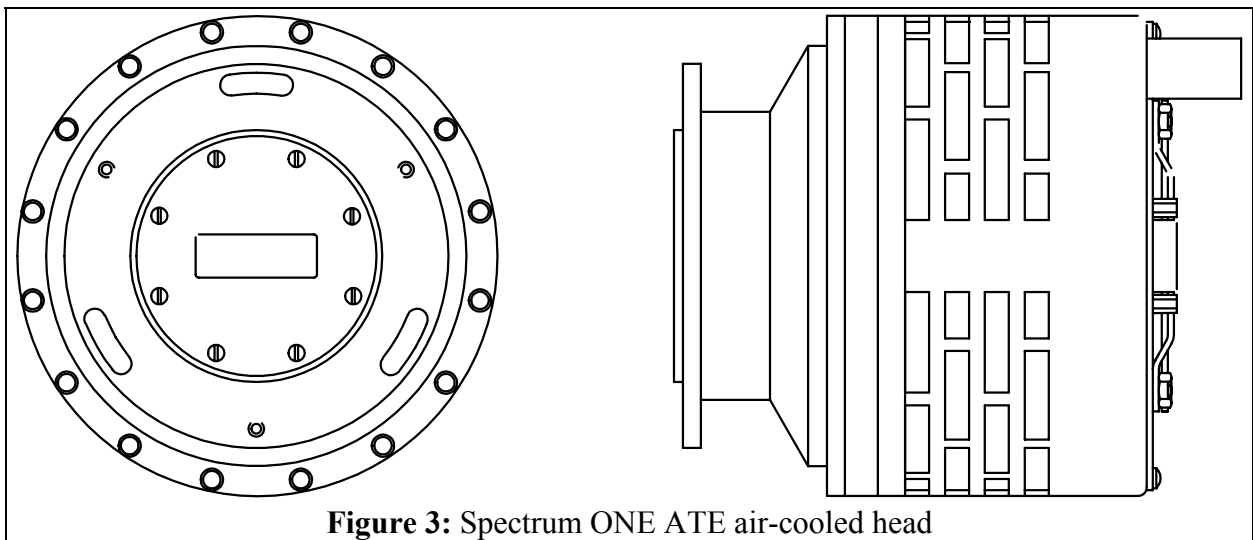
Figure 2: Spectrum ONE MTE air-cooled head

Air-Cooled Thermoelectrically Cooled (ATE) Heads:

The ATE thermoelectrically-cooled array detector heads employ multi-stage Peltier effect cooling devices inside evacuated chambers. Several array chip options are available. These ATE cooled heads can run continuously at their set operating temperature without maintenance. Typically, the distance between the CCD chip and the external flange is 12.57mm (0.495 inches) for the ATE head.

The air-cooled heads require only freely circulating ambient room temperature air to the set temperature. A nominal ambient temperature of 22°C (72°F) is recommended. If the ambient air temperature at the head rises, the heat dissipated from the head will be reduced and the chip temperature will certainly be affected. [The total power dissipation from the head is several watts]. If the head must be mounted inside an enclosure, provide forced ventilation to assure that the temperature in the enclosure is maintained below 35°C (95°F) for best results. If these conditions are not met, the operating temperature will be increased, and the sensor performance will be degraded.

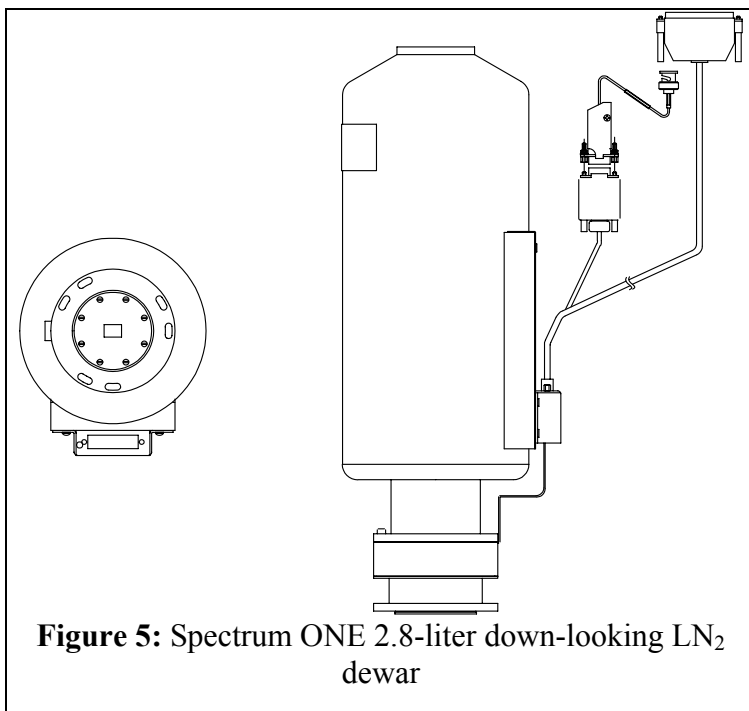
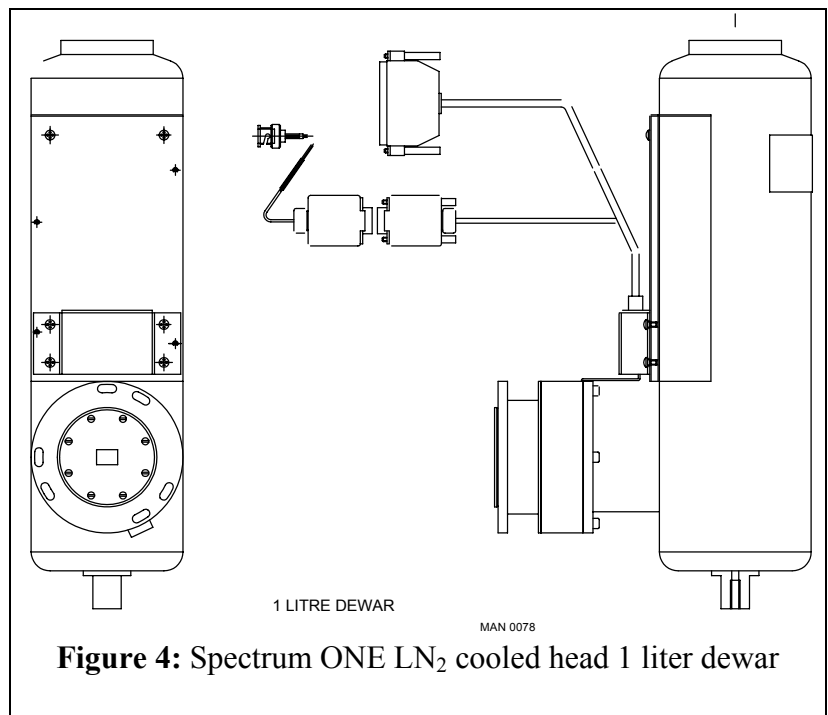
Figure 3 shows a high performance air-cooled Spectrum ONE head. With unrestricted airflow, the heat sink runs nominally 13°C above ambient. If, by airflow restriction or excessive ambient temperature, the heat sink exceeds 60°C, a sensor will signal the Peltier cooler power supply to shut down. In this way, damage to the head is prevented.



LN₂ Cooled Heads:

LN₂ cooled Spectrum ONE heads are mounted in one of three types of liquid nitrogen dewar configurations: Side-looking, down-looking and all-position configuration. In addition, each configuration is available in a 1-liter and a 3-liter capacity.

The standard side-looking dewar for a Spectrum ONE detector is shown in Figure X. Figure X shows the standard down-looking configuration for a Spectrum ONE detector. In both cases, the 1-liter capacity dewars are designed to maintain the array sensor at 140 K for at least 24 hours before refilling with liquid nitrogen. The 2.8-liter dewars require refilling about every 72 hours in a room temperature environment.



An all-position LN₂ dewar is also available for the Spectrum ONE array detectors. In this case, the hold time for the 1-liter capacity dewars is typically 15 hours, while that for the 2.8-liter dewars is typically 26 hours.

The distance between the CCD chip and the external flange is 7.91mm (0.3113 inches). Dimensioned drawings for the different dewars are available in Appendix D.

Liquid Nitrogen Precautions

Warning: Liquid Nitrogen requires special handling, and should be used by trained users only. Review this section carefully before filling the dewar.

Ventilation:

In confined spaces lacking adequate ventilation, nitrogen gas can displace air to the extent that it can cause asphyxiation. Always use and store liquid nitrogen in well-ventilated spaces.

Extreme Cold:

The boiling point of liquid nitrogen at atmospheric pressure is 77.3 K (about -196°C). This extreme cold can cause tissue damage similar to a severe burn. Therefore, exposure of the skin or eyes to the liquid, cold gas, or liquid-cooled surfaces must be avoided.

The liquid should be handled so that it will not splash or spill. Gloves impervious to liquid nitrogen and goggles should be worn when handling the liquid. Feet can be protected by wearing rubber boots, with trousers (without cuffs) on the outside.

Storage and Transfer:

Liquid nitrogen should always be stored in vacuum-insulated containers, which should be loosely covered but not sealed. Covering prevents moisture condensing out of the air to form ice that may cause blockage inside the dewar. Sealing results in pressure buildup. **DO NOT ATTEMPT TO SEAL THE MOUTH OF THE DEWAR!**

The gas-to-liquid volume ratio is about 680:1. All containment vessels must therefore be fitted with exhaust vents to allow evaporating gas to escape safely. If these vents are sealed, pressure will build up rapidly and may result in the fracture of the containment vessel.

LN₂ Filling Instructions:

Using a pressurized storage vessel:

Remove the cap and insulating plug at the top of the detector dewar, insert the fill tube, and let the nitrogen flow into the dewar.

Using a funnel and transfer dewar:

Insure that the funnel has ribs to provide gaps to vent the boiled off vapor inside the camera dewar as the liquid nitrogen is added. Set the funnel into the mouth of the dewar. Pour the liquid nitrogen into the funnel slowly.

The dewar is full when the liquid nitrogen reaches the bottom of the narrow neck of the dewar. A probe such as a clean wooden dowel may be inserted and removed to reveal a frost line indicating the nitrogen level.

Periodic Filling:

The larger, 2.8 liter dewar permits continuous cooled operation of the detector by virtue of its 72-hour hold time. The smaller, 1 liter dewar, with a hold time of 24 hours, is designed for more intermittent operations.

Replace the cap when the dewar is full. The cap is insulated to help extend the interval between fills. It also minimizes moisture condensation into the dewar. The loose fit of the cap prevents pressure buildup in the dewar by allowing evaporating nitrogen to escape.

When filling the dewar, an initial period of nitrogen boiling and overflow occurs until the internal components of the dewar have cooled to liquid nitrogen temperatures. After this initial boil-off period, refill the dewar as needed to extend the cold temperature hold time.

Detector Head Evacuation:

All Spectrum ONE detector heads except the MTE Mini head have a high vacuum chamber that holds the sensor. In the MTE head the chamber is dried and back filled with dry nitrogen at the factory. This chamber, along with other insulating measures, isolates the chip from the ambient temperature. The heads are evacuated or purged at the factory. They are designed to maintain insulating properties for a minimum of one year between pumping or purging cycles. A vacuum leak will result in a decrease in the insulating capability of the head. Thermoelectrically cooled heads will be unable to achieve their rated operating temperatures and the sensors will have high dark currents. LN₂ heads will rapidly consume the liquid nitrogen, and frost may form on the exterior of the dewar. In either case, condensation may form on the array during cool down cycles, degrading optical performance and fostering corrosion. You may notice spreading of light to nearby pixels. Spectral features may become blurred. While rare, the CCD sensor can be physically damaged

If the head cannot maintain operating temperature, contact JY to arrange for re-pumping the vacuum or for re-purging instructions. Any attempts to evacuate the Spectrum ONE head at user locations are not recommended. Some types of vacuum pumps can backstream oil, causing *irreparable damage* to the CCD electronics. In the event of loss of vacuum, please contact the JY Service Department according to the directions given on page 65.

Detector Controllers:

Two controllers are currently available from Jobin Yvon to work with the array detectors: models CCD-3000V and CCD-3500V.

CCD-3000V and CCD-3500V Detector Controllers:

The CCD-3000-series Detector Controller Unit shown in Figure 6 is a compact controller that controls the CCD head based on commands from the computer. This unit supplies power, clocking signals, and biases to the CCD sensor array. The Controller unit, provided with a 166 kHz, 16 bit ADC, also amplifies and digitizes the signal as it is collected from the CCD.

The CCD-3500V controller is identical in functionality and size as the CCD-3000V controller. However in addition to the standard 16 bit, 166 kHz ADC, the CCD-3500V is provided with an additional 14 bit, 3 MHz ADC for high-speed data acquisition. The physical dimensions of the CCD-3000V and CCD-3500V controllers are: 28mm wide x 25mm deep x 18.5mm high (11" wide x 9.75" deep x 7.25" high). The weight of the controller is 21.2 lbs (9.62 kg).

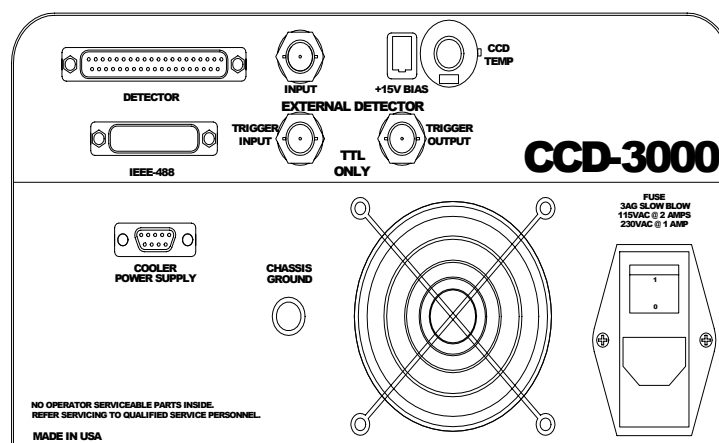


Figure 6. CCD-3000V Controller

Temperature control with CCD-3000V and CCD-3500V Controllers

The temperature control knob is the black knob located on the back panel of the CCD-3000V and CCD-3500V controller, as shown in Figure 6a. This knob is factory set for the optimal performance of your specific CCD and reads in **Kelvin**.

Do not adjust the temperature below the default settings for each type of detector head:

- MTE: 240K (-33 °C)
- ATE: 200K (-73 °C)
- LN: 140K (-133 °C)

If you wish to increase the temperature, you can do so by first unlocking the temperature control knob and then turning 'center control knob' to the desired temperature (refer to the diagram below). Changing the temperature below the recommended level will reduce the quantum efficiency of the chip. Changing the temperature above the recommended value will increase your noise level. A single digit number in the outer ring of the knob indicates hundreds of degrees K, and the two-digit number on the inner circle indicates tens and ones. For example, a reading of 1 on the outer ring and 47 on the inner circle indicates a temperature setting of 147K, equivalent to -126 °C.

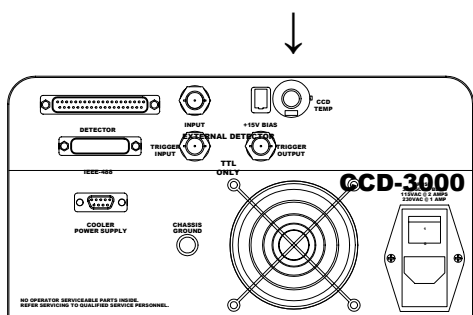


Figure 6a. Temperature knob location on CCD-3000 series controller.

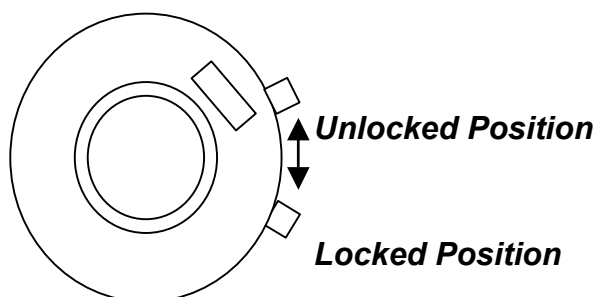


Figure 6b. Example of how to lock knob in position.

Caution: For liquid nitrogen cooled detectors do not set the temperature below 140K. Do not adjust the temperature unless needed. Please contact the Service department if you wish to vary the temperature more than $\pm 10^\circ$ from the original factory setting.

Shutter:

A mechanical shutter is supplied with every Spectrum ONE detection system. A variety of shutters are available from JY, and can be mounted inside or outside the spectrograph, depending on which spectrograph is used. The table below lists some commonly used spectrographs and the shutters with which they are compatible.

Table 1. Shutter information.

Spectrograph	Location	Shutter Part #	Cable Part #
Triax 180/190	Front Only	MSL-TSHCCD	32617 for each shutter BNC to 9-pin
Triax 320 Triax 550	Front (axial) Side (lateral) alone Side (lateral) both	227MCD MSL-TSHCCD MSL-TSCCD2	
500M 750M 1000M 1250M	Front (axial) Side (lateral) alone Side (lateral) both	1425MCD 1425MCD-B 1425MCD-C	
CP140 CP200	External Only	23009030	

Connect the BNC-to-9-pin cable (#32617) to the 9-pin connector on the cable coming from the CCD head. Connect the BNC end of the cable (female) to the male BNC socket on the outside of the shutter mechanism. Contact the JY Service Department for assistance in installing the shutter (see the Service Policy section page 65). See the appropriate spectrograph manual for detailed installation instructions. Note that one shutter and one shutter cable come automatically with the Spectrum ONE CCD system. Additional shutters may be purchased separately.

Software

GPIB Interface

CCD-3000V and CCD-3500V controllers are designed to transfer data via IEEE-488 communication. If using JY software, the user must supply a National Instruments card. The following cards are approved National Instruments GPIB interface boards for use with a PC:

- AT-GPIB/TNT and AT-GPIB/TNT (PNP)
- PCI-GPIB; NI P/N 777158-51 (JY P/N 973027, includes 2m IEEE-488 cable)
- PCMCIA-GPIB IEEE-488; NI P/N 777157-02 (JY P/N 973009, includes 2m IEEE-488 cable)

JY offers these National Instruments boards in our sales catalog for your convenience. Many alternate vendor boards can function in SIMILAR fashion. As we **cannot support** or **guarantee** reliable communications with other boards and software, we **require** that you use the National Instruments products described above. Please contact the Service department at JY if you have a newer version of a National Instruments board and for the latest compatibility information.

CCD Disk

Included with you SpectrumONE system is a disk containing the data files required for correct operation of your system. These files include factory calibration files for your detector, and must not be modified.

Software:

A variety of software options are available from Jobin Yvon to operate the Spectrum ONE array detector system. Complete control over every aspect of the detector and powerful data acquisition routines are available in SpectraMax for Windows. Please refer to the documentation provided with the software shipped with the system. A Software Development Kit (SDK) is also available, as well as LabVIEW VIs.

Jobin Yvon is committed to continuous development and improvement of software. To the extent possible, new software options are developed with backward compatibility. In this way, normally an existing system can be upgraded as new software is developed. Please contact JY periodically to check on current software upgrade options.

INSTALLATION: UNPACKING AND INSPECTION

1. Verify that all items listed are contained in the shipping package and inspect for damage:
 - a. CCD-3000v or CCD-3500v controller
 - b. CCD detector head
 - c. Instrument cable (P/N 35872 Rev. E: black divided cable with 36-pin male end to controller, 25-pin female end to detector head and 9-pin male end to shutter cable)
 - d. Shutter cable (P/N 36217 Rev. A: BNC to 9-pin female cable)
 - e. AC power cord
 - f. This Manual (P/N 80119)
 - g. Thermoelectric cooling cable for MTE and ATE units (P/N 37661: 9-pin gray cable male-female)
 - h. Optional: IEEE 488 GPIB cable (P/N CCA-2M488)
 - i. Optional: IEEE card, as ordered.
 - j. Optional: CCD flange
2. Unpack your SpectrumONE CCD system.
3. Review the diagrams shown in figures 7a and 7b.

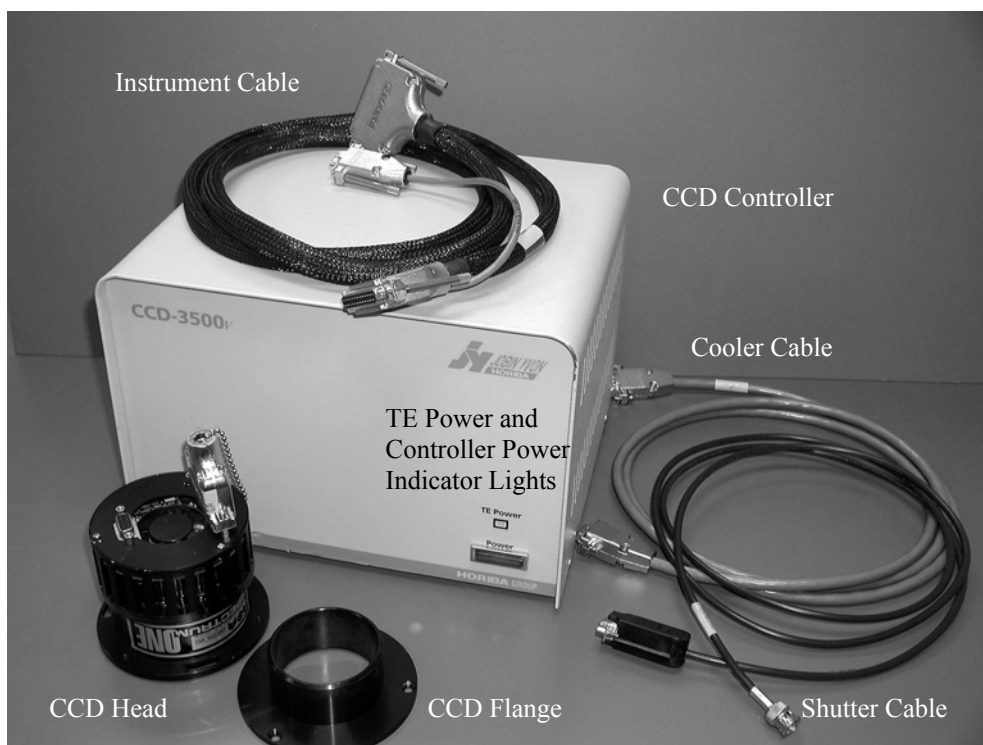


Figure 7a. Front view of CCD controller, with labeled parts.



Figure 7b. Rear view of CCD3000V controller, with labeled parts.

Instrument Connections and Installation

Software:

The controlling software must be configured for the CCD and installed properly in order for the Spectrum ONE detector to operate. When the system is ordered with the computer, the software will be installed and tested at the factory. In those cases where the user must install the software, the configuration files for the system are provided on the installation diskettes or on a CD-ROM. Simply follow the installation directions in the manual provided with the software.

NOTE: When configuring the software to work with the CCD-3000V or CCD-3500V controllers using SpectraMax for Windows software, the IEEE 488 address of the controller must be set to 5.

Mechanical Installation:

A Spectrum ONE array detector can be fitted to any Spex or Jobin Yvon monochromator that can be equipped with a spectrograph exit port. If a spectrograph port is already installed, note the mask on the face of the detector before mounting. This mask is offset to one side to accommodate the tilt of the focal plane without vignetting.

1. Remove the protective plastic cap from the front flange of the detector head.
2. Prepare the monochromator for mounting of the detector by loosening the mounting screws on the multichannel adapter mount (see monochromator manual for instructions, or consult factory for assistance).
3. Carefully pick up the detector head with the Spectrum ONE label facing up. The sensor should be aligned along the optical axis of the monochromator.
4. Tighten the mounting screws so that the detector head is securely positioned at the focal plane of the monochromator. This adjustment will be fine-tuned in the section on Focusing and Alignment.

Note: A number of array adapters are available for the array detectors when working with the TRIAX series of spectrographs. These arrays are optimized to give the best resolution or the best imaging. The adapter consists of two sections, one of which fits into the other. With any MAI-T adapter mount the snout to the detector head using three 8-32 flat head bolts. Slide the flange into the adapter and clamp the flange down using the 6-32 clamping screw. Refer to the TRIAX manual for more detailed instructions.

Electrical Connections:

1. Connect AC power cord to CCD controller into using a surge protector, but **do not turn the unit on.**
2. With the power off, connect the host computer to the CCD controller using IEEE-488 (GPIB) cable. Figure 8 shows a wiring diagram for a TE cooled CCD, with optional trigger connections.
3. Plug the detector cable (P/N 35872) in the back of the controller using 37-pin connector.
4. Remove the 25-pin grounding connector (P/N 36430) from the CCD head and immediately plug in the instrument cable (P/N 35872).

NOTE: To prevent Electrostatic Discharge (ESD) damage, insert grounding plug into connector on detector head whenever CCD head is disconnected.

5. Connect the BNC-to-9-pin cable (P/N 36217) to the 9-pin branch on the cable coming from the CCD head (P/N 35872).
6. For internally mounted shutters, connect the BNC end of cable (P/N 36217) to the BNC connection inserted through the CCD Adapter directly under the CCD head. For the externally mounted shutter, connect the BNC end to the BNC connector on the outside of the shutter mechanism.
7. For TE Cooled CCDs: Connect thermoelectric cooler on the CCD head to power supply on the back of the CCD controller with the 25-pin cable (p/n 37661).

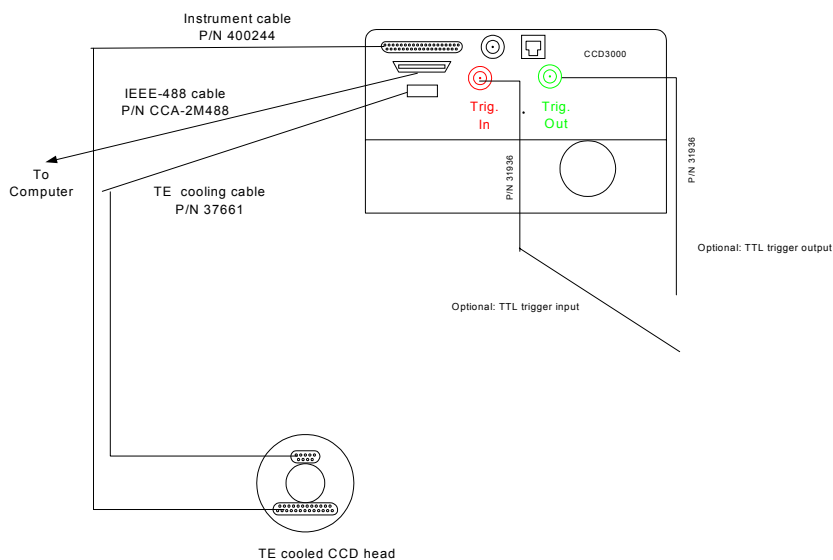


Figure 8. Wiring diagram for Spectrum ONE CCD detector.

Note: Once the software, mechanical connections and electrical connections have been installed, you may continue with the Operation section.

Warranty Disclaimer:

The sensor head, the Detector Interface Unit and the computer are very sensitive to electrostatic discharge (ESD). ESD precautions must be followed.

The installer should stand on a conductive mat and wear a grounded wrist strap during installation. The computer must be turned off, but its power cord should be connected to a grounded outlet to take advantage of the outlet ground.

Always turn the power off to all components before connecting or disconnecting any cables.

Before inserting a connector, touch the connector shell to the component case to discharge any accumulated static charge.

OPERATION

Powering up

NOTE: To prevent Electrostatic Discharge (ESD) damage, insert the grounding plug into the connector on the detector head whenever the CCD head is disconnected.

1. Connect all cables as described in on page 22 in the Installation section
2. Turn on the controller. A red power light on the front of the controller lights up to indicate the unit is turned on.
 - ♦ If the CCD is TE-cooled, you should hear the fan on the back of the CCD Head start and the TE Status LED on the CCD controller should turn green.
 - ♦ If CCD is LN₂-cooled, carefully fill the dewar with LN₂ according to the procedure in the next section
 - ♦ In 30 - 40 minutes, the chip temperature should stabilize for optimum performance.
3. Verify that the monochromator, computer and any other supporting equipment are connected to AC power.
4. Turn on the computer and start the software
5. After 20 minutes check the temperature according to the appropriate instructions given in the software manual. Monitor the temperature until the detector has reached its target temperature. Then you may proceed to the next section.
6. Note: For LN₂ heads, it will take approximately 30 to 40 minutes from the beginning of cooling the detector until it reaches its target temperature. Thermoelectrically cooled heads will reach operating temperature in 15-20 minutes. This time will also vary depending on the size of the chip. Note that for best results in the most demanding measurements, it is best to allow 60 to 90 minutes for the CCD chip to stabilize completely.

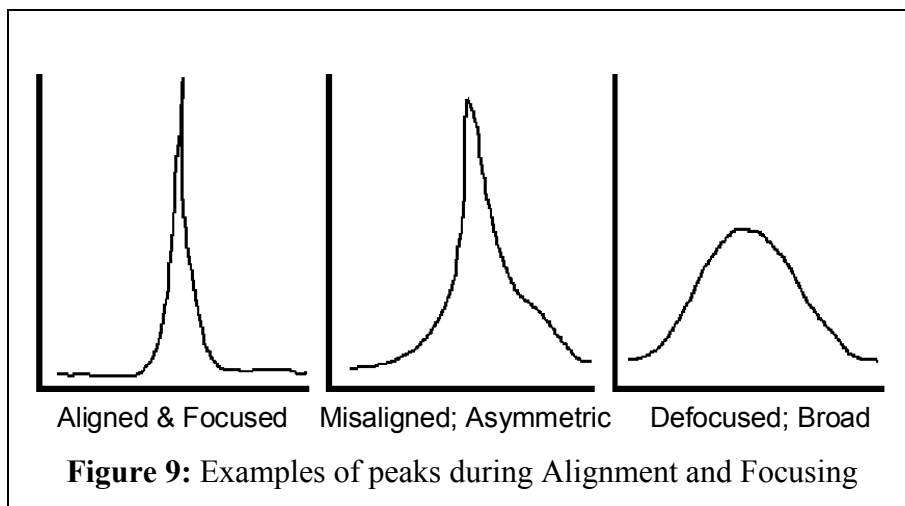
CCD focus and alignment on monochromator

The SpectrumONE CCD detector can be mounted on most standard imaging monochromators. Consult your monochromator manual to determine the correct way to mount the detector. Before starting this procedure, make sure that:

- Software is running
- CCD detector head is properly mounted on monochromator
- CCD detector is cooled to correct operating temperature

Procedure:

- 1) Attach a spectral line source, such as a mercury lamp, to the instrument entrance slit. Reduce the slit width to make the image of the slit as narrow as possible on the detector. This will allow determination of the best focus.



- 2) Select real time data acquisition mode in the software, displaying signal intensity as a function of pixel position. Make sure that the sensor parameters (pixel format, pixel size) in the screen agree with those of your actual sensor.
- 3) Set the "Integration Time" to 0.1 second or less, and select continuous spectrum acquisition.
- 4) Observe the spectra. A focused, aligned CCD will provide a distinct peak, generally symmetrical to the limits of the design of the spectrometer, of large amplitude. The peak should be less than or equal to 5 pixels wide across the Full Width of Half the Maximum height (FWHM). Excessive asymmetry of the peak is a sign that the slit image is not aligned to the pixel columns; diminished shape and magnitude are symptomatic of defocusing. (Figure 9)

- 5) Loosen the array adapter. Adjust the CCD sensor plane position by moving the head in and out with respect to the exit port. (The CCD plane is approximately 9.5 mm, or 3/8", behind the mating surface of the detector head's mounting flange.) The CCD orientation is adjusted by rotating the detector head clock-wise or counter-clockwise in the exit port.
- 7) Verify that the alignment is proper by acquiring an image. When the output is imaged, alignment results in an upright, sharp image of the spectral diffraction pattern on the computer. Note that the dispersion should be at right angles to the upright image; any angling indicates a potential problem with grating adjustments.
- 4) Lock the array adapter in place once the CCD has been aligned and focused.
- 5) Change the software parameters to display signal intensity as a function of wavelength.
- 6) Acquire a spectrum and verify that the spectral peaks are properly calibrated.
- 7) See software manual for additional information, and monochromator manual to recalibrated peak positions, if required. This is sometimes referred to as linearization of the system.
- 8) If you are using SpectraMax for Windows, see Appendix F for a detailed procedure for focusing, alignment and linearization of your Spectrum ONE CCD.

Other Modes of Data Acquisition

The versatile Spectrum ONE detection system with CCD-3000v and CCD-3500v controllers allow a variety of data acquisition modes:

- ◆ Standard spectral acquisition
- ◆ Multiple accumulation mode—multiple spectra can be averaged or summed
- ◆ Blast mode—A single experiment can be setup to be run a series of acquisitions sequentially, with pre-programmed delay time and integration time, and choice of flushing the chip between acquisitions or not, and choice of closing the shutter between acquisitions or not.
- ◆ Fast Kinetics/Burst Mode—A single experiment can be set up in which only the top portion of the chip is used for data acquisition and the rest is used for storage. This mode allows faster data acquisition than a standard acquisition, but requires special optics.
- ◆ Triggered experiments—The CCD-3000v and CCD-3500v controllers can accept a TTL input trigger, and can also generate a TTL output trigger.

Powering Down and Disassembly of System

1. Turn off software.
2. Turn off power switch on controller. It is safe to leave all cables connected while detector is not in use.
3. **To disassemble a system with a TE cooled detector**, remove the TE cooler cable first from the detector head and then from the controller.
4. Remove the instrument cable from the detector head and immediately connect the protector plug in its place to prevent ESD damage.
5. Remove the other end of the instrument cable from the controller.
6. To mechanically remove the detector head from the monochromator, loosen the mounting screws and carefully pull the detector towards you, out of the mount. This is the reverse of the installation procedure.
7. Replace the plastic protector cap on the front flange of the detector.
8. Unplug the controller from the AC power.
9. **To disassemble a system with a LN₂ cooled detector, first make sure the liquid nitrogen has evaporated from the dewar (approximately 24 hours from fill time; consult factory for assistance).**
10. Then continue with steps 4 – 8.

Triggering with CCD-3000V and CCD-3500V Controllers

(See also Appendix G)

The Spectrum ONE CCD-3000V and CCD-3500V Detection Systems have both input and output TTL trigger functions. Both can be enabled via the software. Note: the fastest triggering rate possible is 50 Hz for experiments using a mechanical shutter. For experiments without a shutter, the fastest triggering rate compatible with the controller is 3KHz. Two hardware triggers are available as BNC receptacles on the back of the controller: one for input and one for output.

The CCD-3000V and CCD-3500V controllers have two external trigger ports: TRIGGER INPUT and TRIGGER OUTPUT. If SpectraMax for Windows software is used with Triggers Enabled, when the controller is ready to acquire, the TRIGGER OUTPUT line is moved high and the controller waits for a positive pulse from the TRIGGER INPUT to start the acquisition. When an input pulse is received, the output line is moved low until the controller is ready for the next acquisition. The triggers can also be controlled via a user-programmed interface (See programming manual for more information).

Triggering can be activated at the start of each experiment or at the start of each acquisition during the course of one experiment.

1. Input Trigger Parameters

- a. Input Trigger On Start—The experiment will start as soon as the CCD controller receives a TTL high signal. If the controller receives multiple input triggers, only the first one will have any effect on the experiment.
- b. Input Trigger Per Acquisition—In a multiple acquisition experiment (such as an experiment where Multiple Accumulations or Blast Mode is selected), sometimes it is desirable to wait for a trigger to start each acquisition. In this case each acquisition will start only after the CCD controller receives a TTL high signal.

2. Output Trigger Parameters—The TTL output from the Trigger Out BNC port on the CCD controller will stay high for the duration of the software-specified integration time.
3. If you are using SpectraMax for Windows software, see Appendix G for a more detailed discussion of triggering with the CCD-3000V and CCD-3500V controllers.

System Requirements

A. CCD-3000V and CCD-3500V Controller Electrical Specifications:

Parameter	CCD-3000V	CCD-3500V, User Selectable Mode	
ADC Precision	16-bit	14-bit	16-bit
Data conversion speed	166KHz	3MHz	166KHz
Dynamic Range	65,535 max	17,545 max	65,535 max
Gain Settings	Gain 1: 2e ⁻ /ct (20 kHz) Gain 2: 6e ⁻ /ct (38 kHz) Gain 3: 12e ⁻ /ct (56 kHz) Gain 4: 24e ⁻ /ct (100 kHz)	5e ⁻ /ct	Same options as CCD-3000V
External Trigger In	TTL, programmable	TTL, programmable	
External Trigger Out	TTL, fixed	TTL, fixed	
Input Line Voltage	100/120/230 VAC (configured at purchase)	100/120/230 VAC (configured at purchase)	
Input Line Frequency	50/60 Hz	50/60 Hz	
Communication Protocol	GPIB/IEEE-488	GPIB/IEEE-488	
Exposure time	5ms minimum, maximum depends on sensor	5ms minimum, maximum depends on sensor	

B. Environmental Requirements for detector heads and controllers

Parameter	Value
Ambient Temp./Humidity	60 °F to 85 °F (16 °C to 29 °C)/25-55% Relative Humidity
Storage Temp./Humidity	-20 °C to + 50 °C/95% Relative Humidity maximum

C. Mechanical specifications

Parameter	Value
Typical Sensor Operating Temperature	
LN ₂ head	-133°C
ATE head	-55°C
MTE head	-30°C
Optical Distance from sensor to front flange	
LN ₂ head	0.791mm (0.3113")
ATE head	12.57mm (0.495")
MTE head	12.47mm (0.491")
Controller Dimensions	28mm wide x 25mm deep x 18.5mm high (1.1" wide x 0.975" deep x 0.725" high)
Controller Weight	21.2 lbs (9.62 kg)

Note: All specifications are subject to change without notification.

Troubleshooting:

The Spectrum ONE detection system is designed to perform for years with minimal maintenance.

Vacuum: The detector head is evacuated or purged, and eventually will need re-pumping or re-purging. For evacuated heads, the level of vacuum required is beyond the capabilities of mechanical vacuum pumps. User re-pumping is not recommended. The user's responsibility in this regard is simply to monitor the operating temperature on a periodic basis. Refer to the specifications listed on page 32 for the temperature appropriate for each type of CCD head. When the cooling circuitry can no longer maintain the specified temperature, contact the factory for assistance.

Shutter: If the shutter should fail to actuate, contact the factory for assistance.

Noise: If the detection system detects high levels of noise, a grounding strap connected from the detector head to a ground may solve this problem. NEVER disturb the screws that hold the vacuum-sealed flanges together. The best place to attach a ground wire varies depending on the type of head used. For side-looking LN₂ heads, attach a ground wire to the threaded hole at the bottom of the dewar. For down-looking LN₂ heads, use one of the mounting screws on the 25-pin connector. For TE cooled detectors, use one of the mounting screws on the 9-pin connector on the head.

In Case of Power Interruption:

For thermoelectrically cooled heads, restart as normal. For LN₂ cooled heads, if power is interrupted while the detector is cooled the system can be restored to normal operation by performing the following steps:

- Repower the system as usual
- Reinitialize the detector
- Note that the sensor may be at a *lower* than normal operating temperature due to loss of thermostat control while unpowered. Allow enough time for the sensor to return to normal operating temperature.
- Run a series of full area readouts with short integration time. This will flush most trapped charges from the sensor. For most cases, normal operation can be resumed at this point.
- For those cases where very long integration times are used, an increase in dark charge may be noticeable. If the effect does not affect the validity of your data, you may choose to proceed as normal; we recommend to take background spectra at more frequent intervals. If this effect happens to be large compared to the desired signal, the dewar should be allowed to warm to room temperature and then restarted as normal to clear all trapped charges.

If the signal is too noisy:

- Try to increase the strength of the optical signal at the detector.
- Do what you can to eliminate or reduce the non-signal stray light that is allowed to enter the spectrograph entrance slit, whether on the optical axis or not.
- Check for light leaks as suggested under "Background signal too high" in this section.
- Ground loops and electromagnetic interference (EMI) may cause a variety of problems. Refer to Appendix C: System Optimization for more help.
- If turning off the spectrometer power switch reduces noise, rearrange power connections to be sure the spectrometer, source, and detector are tied to the same ground and, if possible, the same power circuit.

APPENDIX A: GLOSSARY

The discussion of detection with charge-coupled devices requires some familiarity with the terminology used. This section includes definitions specific to this context for some familiar terms, as well as several unique terms, abbreviations and acronyms.

ADC

An Analog to Digital Converter (ADC) converts a sample of an analog voltage or current signal to a digital value. The value may then be communicated, stored, and manipulated mathematically. The value of each conversion is generally referred to as a data point.

Advanced Inverted Mode Operation (AIMO)

Advanced Inverted Mode Operation (AIMO) is a mode of operation specific to Marconi (EEV) CCD chips for extremely low dark current operation at TE or warmer operation. A similar process is called MPP.

Backthinning

The depletion layer of a CCD (where the photoelectric effect occurs) is normally partially obscured under the electrode gates, which are formed in layers above the depletion layer. This is due to the constraints of the chip fabrication process. The substrate (or back) of a CCD chip can be etched down to be very thin. Then the chip is mounted so that the signal light is incident on the back rather than the front. Under such illumination, the chance a photon has of reaching the depletion region is greater. Thus, in a backthinned chip (also called back illuminated) the Quantum Efficiency is higher. Backthinned chips are sensitive to etaloning from 700nm to 1100nm (see Etaloning).

Binning

The charges of adjacent pixels can be combined in the readout register cell for that column or row. This combining is called binning. Binning is also the term used when selecting less than the full amount of pixels. Binning enables adjustment of the effective detector height from one pixel up to the full height of the CCD. More than one binned area can exist in a given readout.

Under uniform illumination, the signal level increase is directly proportional to the number of pixels binned. Readout-associated noise is also reduced because the total signal from the binned number of pixels contains the noise from only a single analog-to-digital conversion. Thus, signal to noise ratio is improved.

Binning also enables selective readout of multiple spectra. The signals from several samples can be optically collected simultaneously and imaged into vertically-separated parts of the

imaging spectrograph entrance slit. This will result in vertically separated spectra imaged across the CCD. By binning the heights of these spectra, each binned area can be captured as a separate spectrum in the same readout cycle. The dark signal from unused pixels between the spectra can be discarded. Signal/Noise is improved by discarding dark signal from non-illuminated pixels.

Charge Coupled Device

The CCD is a solid-state photodetector array made silicon. It is essentially one continuous photosensitive material. Individual pixels or picture elements are defined by a grid of usually three electrode gates in the X and Y directions. The charge is collected of under the gate with the greatest potential. During the readout cycle, the voltages applied to the gate electrodes are manipulated to move the charge across the pixels to the output register at the edge of the array. In contrast, PMTs and other single channel detectors can measure only one intensity at a time. PDA detectors measure both intensity and position (wavelength). The CCD simultaneously measures intensity, X-position (wavelength) and Y position (slit height) differences projected along the spectrograph image plane.

Charge Transfer Efficiency (CTE)

The percentage of charge moved from one pixel to the next is the charge transfer efficiency. The CCD has a high CTE if the pixels are read out slowly. As the speed at which the charge is transferred is increased, increasing amounts of the charge is left behind. The residual charge combines with the charge of the next pixel as it is moved into the cell. Therefore, using too high a transfer rate deforms the image shape; it smears the charge over the pixels that follow in the readout cycle. Temperature also affects CTE. Under normal operation the CTE is approximately 99.9995%. Below -140°C the movement of the charges becomes sluggish, and, again, the image becomes smeared.

Correlated Double Sampling (CDS)

This is a technique used to increase the signal to noise ratio of each data point detected. Minute charges are unavoidably retained in the readout register between one sample and the next. Even though the readout register is reset after each point is read, some charge will persist. At the extremely low signal levels that are typical for cooled CCD detection, these charges are significant. By sampling this retained charge, amplifying and inverting it, it can be canceled by combining it with the actual signal which is amplified, but not inverted. The combined signal is then passed to the ADC to be processed as a data point. This process ensures that only the charge due to the signal in each pixel is measured, allowing wide changes in dynamic range between adjacent pixels to be accurately recorded. Faster and less accurate methods include single sampling methods like Clamp and Sample.

Cosmic Ray Events

Cosmic Rays are high-energy particles from space, mostly from the sun. Although they penetrate all detectors, dark current usually masks their effect. The dark signal of an LN₂

cooled CCD is so low that cosmic rays will be detected. In the active area of a typical array, about 5 events per minute per cm² may occur. Compared to very weak signals, detected cosmic ray events can be quite distracting. The CCD chips of different manufacturers have slightly different sensitivity to Cosmic Rays. To minimize the effects of cosmic rays, one can use the smallest section of the chip that the experiment allows, and use the least integration time possible. **Variable Gain** can help to reveal weak signals. Mathematical treatment of the data can also be used to remove the spurious spikes in spectra. Refer to the software manual for more about cosmic ray spike removal.

Dark Signal

Dark signal is generated by thermal agitation. This signal is directly related to exposure time and increases with temperature. The dark signal doubles with approximately every 7°C increase in chip temperature. The more the dark signal, the less dynamic range will be available for experimental signal. This signal accumulates for the entire time between readouts or flushes, regardless of whether the shutter is open or closed. Dark signal is also generated during the charge transfer cycles of the CCD. The problem is not necessarily the dark signal, but the noise in measuring the signal that adversely affects the data.

Dark Signal Nonuniformity (DSNU)

Dark signal nonuniformity (DSNU) is the peak-to-peak difference between the dark signal generation of the pixels on a CCD detector in a dark exposure.

Dynamic Range

The **Dynamic Range** is the ratio of the maximum and minimum signal measurable. The dynamic range of the chip can be greater than that of the assembled system, which is limited by the ADC. A 16-bit ADC limit is 65,535 ($2^{16}-1$) counts in the dynamic range. A 14-bit ADC is limited to a dynamic range of 16,383 counts. **Variable Gain** can be used to shift the ADC range to match the potential well capacity, or to extract statistical noise in the baseline of a given spectral measurement. In this way, stronger or weaker signals can be accommodated with optimal Dynamic Range.

On a pixel-by-pixel basis, the most intense detectable signal, the saturation level, is the lesser of either the **Potential Well Capacity** of the pixel or the ADC maximum limit. When pixels are binned, individual pixels within a binned area may saturate if the intensity is concentrated. Also, the well capacity of the readout register will limit the total signal that can be binned from a given row or column of a binned area.

Dynamic range = $\frac{\text{Full well capacity of readout register of individual pixel}}{\text{Readout noise of detector}}$
of a CCD

The weakest detectable signal is limited by the quadrature sum of all noise sources. The Maximum signal is the largest signal less the dark bias.

Electrons/Count:

Electrons per count is a gain value indicating how many electrons it takes to be identified by the ADC as the smallest measurable unit, or *count*.

Etaloning

When a very thin piece material is used as an optical component, multiple interference patterns may be observed. This effect is called **Etaloning**. When the thickness of the material is on the order of the wavelength of light passed through, etaloning may prevent the detector from distinguishing an actual signal from the interference pattern. Etaloning is problematic with backthinned CCD chips in the wavelength range 700nm to 1100nm.

Felgett's Advantage:

Multichannel detection provides an improvement in signal to noise ratio, as compared to single channel (scanned) spectral detection. Because the multichannel detection acquires a number of spectral elements simultaneously, the S/N is improved by a factor proportional to the square root of the number of channels acquired given the experiment times are equal.

Flush

To reduce noise and maximize dynamic range at the CCD, the dark charge that has accumulated on the chip can be rapidly removed by flushing. The effect of flushing the array is similar to a readout cycle in that the charges are cleared from the pixels. A flush is much faster than a frame readout since it dumps the charges without conversion. Flushing is only necessary when there is an appreciable time between readouts.

Full Well Capacity

Full well capacity is the measure of how much charge can be stored in an individual pixel. This specification varies for each chip type. It depends on the doping of the silicon, architecture and pixel size. The quantum well capacity is usually around 300,000 electrons. The greater the well, the greater the **Dynamic Range**. A chip with a larger full well capacity can record a higher signal level before saturating. See also **Variable Gain**.

The imaging section full well is usually 3 – 10 times smaller than the transfer wells in a spectroscopic array.

Gain

Gain is the conversion between electrons generated in the CCD to counts reported in the software. Gain is typically set to be just below the read noise for most low light measurements, or set to take advantage of the full dynamic range for larger signals. Typically, because CCDs are extremely low noise devices, meaningful gains as low as 1 –2 electrons per count can be achieved. See also **Variable Gain**.

Linearity

When photo response is linear, if the light intensity doubles, the detected signal will double in magnitude as well. Nonlinear response at medium to high intensities is usually due to

amplifier problems, and at very low light levels poor charge transfer efficiency. A CCD's response is linear, once the bias is subtracted. Another definition of linearity is applied to the spectral positioning accuracy or tracking error of a spectrometer drive mechanism, as a single wavelength is viewed at different positions across the chip.

Multi Phase Pinning (MPP)

Multi Phase Pinning (MPP) is a mode of operation specific to certain CCD brand names (Marconi, Hamamatsu, SITe, for example) for extremely low dark current operation. See also AIMO.

Noise

Noise is common to all detectors. The total amount of signal that exists is less important than the ratio of signal magnitude to noise magnitude (S/N). With a high signal to noise ratio a signal peak can be discerned even though signal counts per second may be low. The noise components for CCD arrays are as follows:

- **Amplifier Noise:** Some noise is introduced in the process of electronically amplifying and conditioning the signal read from the detector before conversion to a digital value. Part of **Readout Noise**.
- **Conversion Noise:** During the conversion of an analog signal to a digital data point some electronic noise is introduced, statistical variations occur in the least significant bit of the converted data. Part of **Readout Noise**.
- **Dark Noise:** The detector will integrate a thermally generated **Dark Signal (dark current)** at all times, whether light is reaching the detector or not. Most of the dark current signal is a steady state level that can be subtracted, and so will not ultimately contribute to the noise. However, a component of **Dark Current** is **Dark Noise** due to statistical variations in the Dark Current. The Dark Noise component increases as the square root of the Dark Current. Dark Current, and therefore Dark Noise, can be reduced by cooling. The LN₂ cooled CCD is one of the least noisy detectors available, with less than one electron/pixel/hour of dark signal. If the signal level is below saturation, increasing the signal integration time per readout will minimize the effect that dark noise has on the acquired signal. If the signal level is too high, summing multiple reads can give similar improvement. (See **Readout Noise** below.)
- **Readout Noise:** The electronic noise impressed on the signal during the readout and digitizing of the signal. For convenience, usually all of the noise associated with resetting, amplifying, and converting the signal are considered as readout noise. When averaging signal by acquiring over a long interval of time, increasing the signal integration time per readout rather than summing multiple readouts is preferred. This will proportionately reduce the readout noise component in the acquired signal. However, the integration time must be short enough to prevent saturation of any individual pixels and to keep the digital signal for any data point below the ADC limit.
- **Reset Noise:** Following pixel or bin readout, the readout register is reset to a level approaching zero charge. **Reset Noise** is the non-uniformity in the resetting. This is canceled by **Correlated Double Sampling**. Part of **Readout Noise**.
- **Shot Noise:** This is due to the random statistical variations of light. It includes both experimental and dark signal components. Shot noise is equal to the square root of the number of electrons generated. Its effect can be minimized by increasing signal intensity, signal integration time, or summing a number of readouts.

Photoelectric Effect

Some materials respond to light by releasing electrons. When light of sufficient energy hits a photosensitive material, an electron is freed from being bound to a specific atom. Such materials include the P-N junctions of the silicon photodiodes used in CCD arrays. The energy of the light must be greater than or equal to the binding energy of the electron to free an electron. The shorter the wavelength, the higher the energy the light has.

Photoelectron

A photoelectron is an electron that is released through the interaction of a photon with the active element of a detector. The photoelectron could be released either from a junction to the conduction band of a solid-state detector, or from the photocathode to the vacuum in a PMT. A photoelectron is indistinguishable from other electrons in any electrical circuit.

Photo Response NonUniformity (PRNU)

PRNU is the peak-to-peak difference in response between the most and least sensitive elements of an array detector, under a uniform exposure giving an output level of $V_{\text{Sat}}/2$. These differences are primarily caused by variations in doping and silicon thickness.

Quantum Efficiency (QE)

The efficiency of the photoelectric effect of a detector can be quantified. The quantum efficiency of a detector is the ratio of number of photoelectrons produced to the number of photons impinging on a photoactive surface. A QE of 20% would indicate that one photon in five would produce a distinguishable photoelectron. CCD's are made of silicon, which has a high QE, about 45-50% at its peak at 750 nm. The quantum efficiency of a detector is determined by several factors. These include the material's intrinsic electron binding energy or band gap, the reflectivity of the surface, the thickness of the surface, and energy of the impinging photon (h). The QE varies with the wavelength of incident light. Standard CCD's typically have a peak QE of about 50%. Back thinned CCD's may peak at about 85%. The QE at short wavelengths can be improved by coating with fluorescent dye that converts UV light to longer wavelengths where the quantum efficiency of the chip is higher. The true goal of QE is ultimately improved S/N, and some times maximizing the QE is not the best method for achieving this goal.

Readout Time

The **Readout Time** of a CCD is the interval required to move the charges from their locations in the array to the readout registers, sample the charges, amplify them and convert them to data points. The correlated double sampling readout technique requires more time per pixel than other less accurate methods. Faster ADCs can reduce the readout time at the cost of more noise and/or less dynamic range.

Responsivity

Responsivity is the ratio of output energy to corresponding exposure ($\mu\text{J}/\text{cm}^2$). Technically it is measured at $V_{\text{Sat min}}/2$ under specified conditions of illumination, readout rate, and temperature. Typically, CCDs specify QE, counts, and gain (measured in electrons per count) instead of responsivity.

Saturation Level

The maximum signal level that can be accommodated by a device is its saturation level. At this point, further increase in input signal does not result in a corresponding increase in output. This term is often used to describe the upper limit of a detector element, an amplifier, or an ADC.

Spectral Response

Most detectors will respond with higher sensitivity to some wavelengths than to others. The spectral response of a detector is often expressed graphically in a plot of responsivity or QE versus wavelength.

UV Overcoating (Enhancement)

The depth of penetration into silicon is very shallow for UV light. With this shallow penetration, the probability of a UV photon penetrating to the depletion zone is less than for longer wavelength photons. Thus the QE is lower in the UV than in the visible and NIR. By coating the chip with a fluorescent dye that converts UV light to longer wavelengths, the probability of photon detection is increased. Lumogen is a phosphor coating used for UV enhancement.

Variable Gain

Variable Gain is the ability to match the range of the ADC to the usually larger range of the CCD without losing valuable information.

Signal can be extracted from the noise baseline by statistical treatment. Oversampling of this noise will make this extraction more accurate, so the gain can be electronically adjusted to quantize this small signal at high resolution, typically 1 or 2 electrons per count. Since stronger signals saturate the ADC quicker, low electrons per count is considered high gain (a small signal produces a large response).

Conversely, large optical signals can tax the full dynamic range available on the chip, which may be in excess of the ADC dynamic range. In this case, a lower gain of typically 4 – 6 electrons per count will report a smaller count value versus a high gain setting, and allow the range of the ADC to cover the maximum charge of the CCD. Statistical information in the baseline is generally not the limiting factor of an acquisition with full range signals present, and thus can be traded off without penalty.

APPENDIX B: AC POWER SELECTION AND FUSING

The power input module combines the line voltage selection, fuse holder, on / off (1 / 0) switch and power line cord entry into one compact unit. If you suspect a fuse needs replacement, understand first why the fuse failed to avoid consequent damage to the system. Contact the factory for assistance.

<u>Circuit</u>	<u>Line Voltage</u>	<u>Fuse rating (3AG type)</u>
Input Power	100 VAC	2 Amp slow blow
	120 VAC	2 Amp slow blow
	220 VAC	1 Amp slow blow
	240 VAC	1 Amp slow blow
Shutter Fuse (internal)	N/A	1 Amp fast blow

APPENDIX C: SYSTEM OPTIMIZATION

After completing the installation, some applications demand special attention to assure that the detection system is yielding the best possible signal to noise ratio. The following topical discussions may be helpful in extracting optimal performance from the system.

Optical Optimization:

In many cases, it may be a simple matter to increase signal strength at the detector by increasing optical power at the source. Reducing losses by improving optical coupling from the source to the sample and/or from the sample to the spectrograph entrance slit can also yield dramatic results.

Try to reduce the possibility of stray light entering the system. Check for light leaks by darkening the room or by covering any open segments of the optical system. Use an opaque black cloth to cover portions of the system. Further isolation of leaks may be possible by shining a flashlight at suspected portions of the optical system while monitoring the signal.

Spatial Optimization:

Often the optical signal of interest that is imaged on to the array occupies only part of the total array area. With the Spectrum ONE CCD, there is no need to collect signal from the unused area. With Area selection, one may select a reduced portion of the CCD active area, and reduce the dark signal and associated noise from the unused area. Susceptibility to cosmic rays will be reduced proportionately as well. The best way to match the portion where the signal is located is to acquire a full-chip image of the signal. If the actual signal is too weak, try to approximate the signal using the exact same collection optical setup, but substitute a brighter signal. Refer to the software manual for instructions on defining the active area(s).

Reducing the Number of Conversions:

Each time an analog to digital conversion is made, some noise is introduced. For spectra that are imaged as essentially vertical slit images on the array, the pixels illuminated in their vertical columns can be binned into superpixels, to be combined before conversion to data points. Likewise, when spectral resolution is not a limiting factor, the signals can also be horizontally binned into two-dimensional superpixels. The limit on this is that the combined signal intensity for the most intense superpixel should not exceed the ADC limit. Refer to the software manual for instructions about binning.

Increasing integration time per readout will improve the S/N by decreasing the overall read noise.

However, when signal levels in some pixels are at or near the saturation level, acquiring a series of spectra using integrations of shorter duration and summing them digitally provides a means to avoid saturation. This method takes advantage of Fellgett's advantage, by which the S/N improves by a factor of the square root of the number of acquisitions.

Environmental Noise Reduction:

Because of the extreme low internal noise characteristics of the liquid nitrogen and thermo-electrically cooled sensors, special precautions to minimize noise pickup from external sources is required.

Important: Do not place a computer monitor on or near the Controller. The because of the extreme sensitivity of the signal electronics required to take full advantage of the sensor's low noise, electromagnetic noise radiated by the monitor may be picked up. This may be seen in the spectral data as an increase in read-out noise.

Although shielded, the detector head and cables can still be sensitive to electromagnetic fields. For best results the detection system should be isolated from devices generating such fields.

- Electromagnetic interference (EMI) from a variety of sources may be picked up by the sensitive input channels. Try isolating any other apparatus suspected to be a noise source by turning it off while monitoring the CCD signal in real time. If possible, connect them to power circuits separate from the detector controller.
- Note that the room lights may radiate EMI based on the (50 or 60 Hz) power line frequency. A battery-powered flashlight will not.
- If turning off the spectrometer power switch reduces noise, rearrange power connections to be sure the spectrometer, source, and detector are tied to the same ground and, if possible, the same power circuit.
- A redundant grounding strap connected from the detector to a centrally located system ground may help. The binding post on the CCD-3000V and CCD-3500V rear panel adjacent to the power input module is provided as a chassis ground point. Ground loops and electromagnetic interference can be challenging problems. The best place to attach a ground is usually discovered by a trial and error process. In extreme cases, the best approach is to patiently experiment by trying various combinations of grounding connections. As a general rule, try to keep ground wires short, make tight connections, and avoid painted, coated, and anodized surfaces when possible. Consider a "star ground" of redundant ground wires radiating from a single, central location, preferably connected to a grounded metal table surface under the system.

- Adding redundant ground wires to various points in the system sometimes helps. Guard against the creation of ground loops that may occur when power grounds and signal grounds are connected. Also keep digital grounds and their typical high frequency noise separate from signal ground.
- In extreme cases, such as working with or around high powered pulsed lasers or other high energy apparatus, it may be helpful to construct RFI / EMI shields or cages to contain the noise at its source, or to isolate the detection system from the noise. In these cases, colleagues who are working with a similar apparatus may be your best resource for noise control suggestions.

Should the detection system detect high levels of noise, a grounding strap connected from the detector head to a ground may help. It is important to avoid disturbing the screws that hold the vacuum-sealed flanges together. The best place to attach a ground varies depending on the type of head used. For side looking LN₂ heads, use the threaded hole at the bottom of the dewar. For down-looking LN₂ heads, use one of the mounting screws on the 25-pin connector. For water or air cooled, use one of the mounting screws on the 9-pin connector on the head.

Setting CCD gain with a CCD-3000 series controller:

To take full advantage of the dynamic range of the CCD sensor, the CCD-3000 series controller is provided with 4 different gain settings. Four options are available: Gain 1 (typically 2 electrons/count), Gain 2 (typically 6 electrons/count), Gain 3 (typically 12 electrons/count) and Gain 4 (typically 24 electrons/count). See the software manual for specific instructions on how to change the gain.

Selecting the ADC and Setting ADC gain with a CCD-3500 series controller:

The CCD-3500 series controllers offer two speeds of ADC, each with its own gain options. Four options are available with the 16-bit ADC: Gain 1 (typically 2 electrons/count), Gain 2 (typically 6 electrons/count), Gain 3 (typically 12 electrons/count) and Gain 4 (typically 24 electrons/count). With the 14-bit ADC, one option is available: Gain 1 (typically 5 electrons/count).

APPENDIX D: INTERFACE DRAWINGS:

Note: The Bolt patterns on the LN₂ version mounting flanges have six through-hole slots, so that the detector can be mounted in either of 2 orientations by selecting the group of 3 slots (with an angle of 120° between them). Adjacent slots have an angle of 30° between them. A second flange variation found on TE units uses three threaded holes and three through-hole slots to allow maximum mounting flexibility. The three slots/ threaded holes and mechanical dimensions conform to the accepted 'OMA' flange pattern.

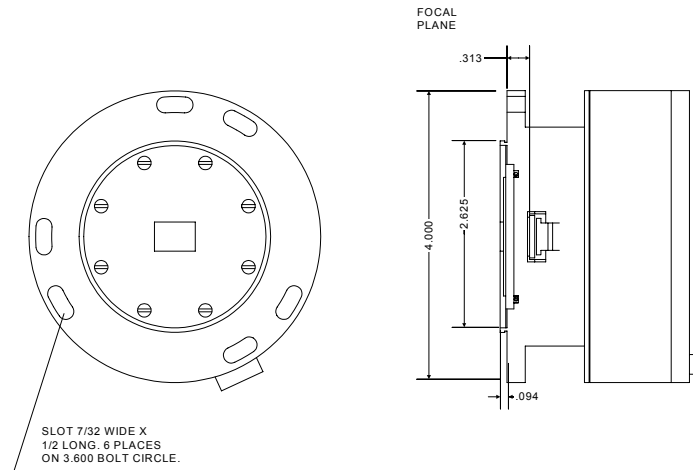


Figure 10: LN₂ Head Mounting Flange

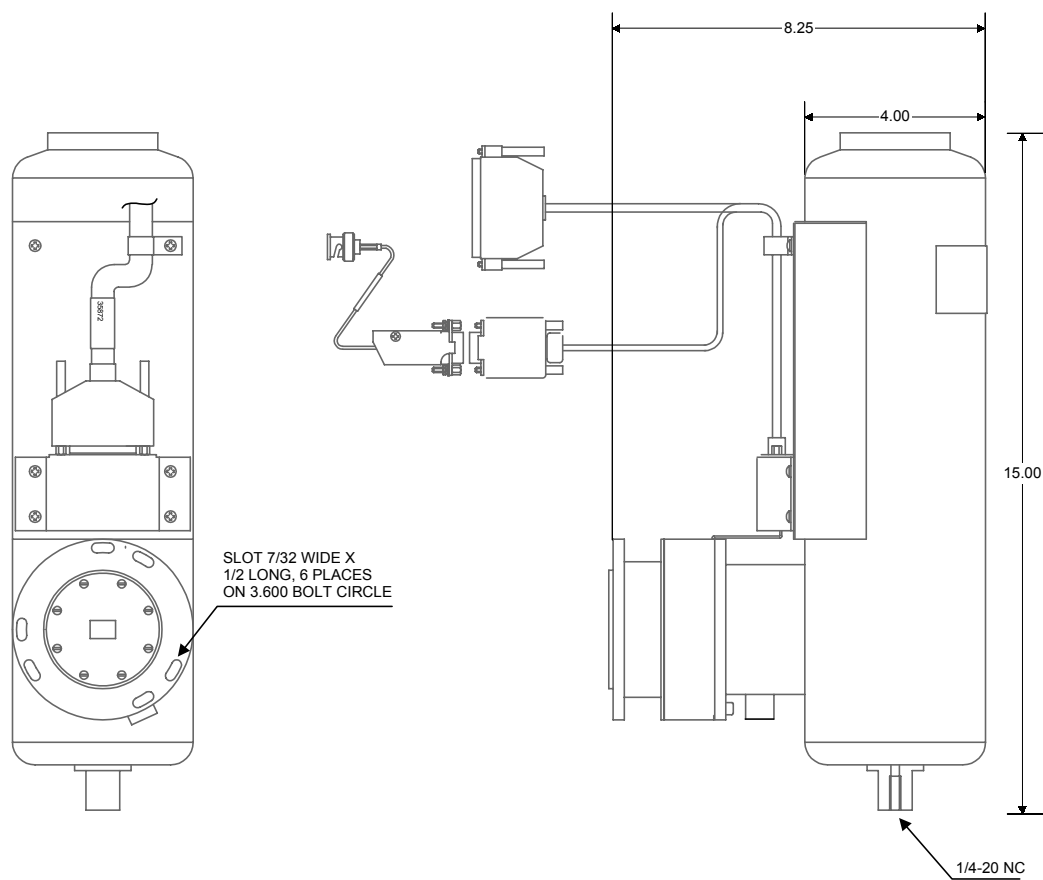


Figure 11: 1 Liter Side Mount LN₂ Dewar for CCD detectors

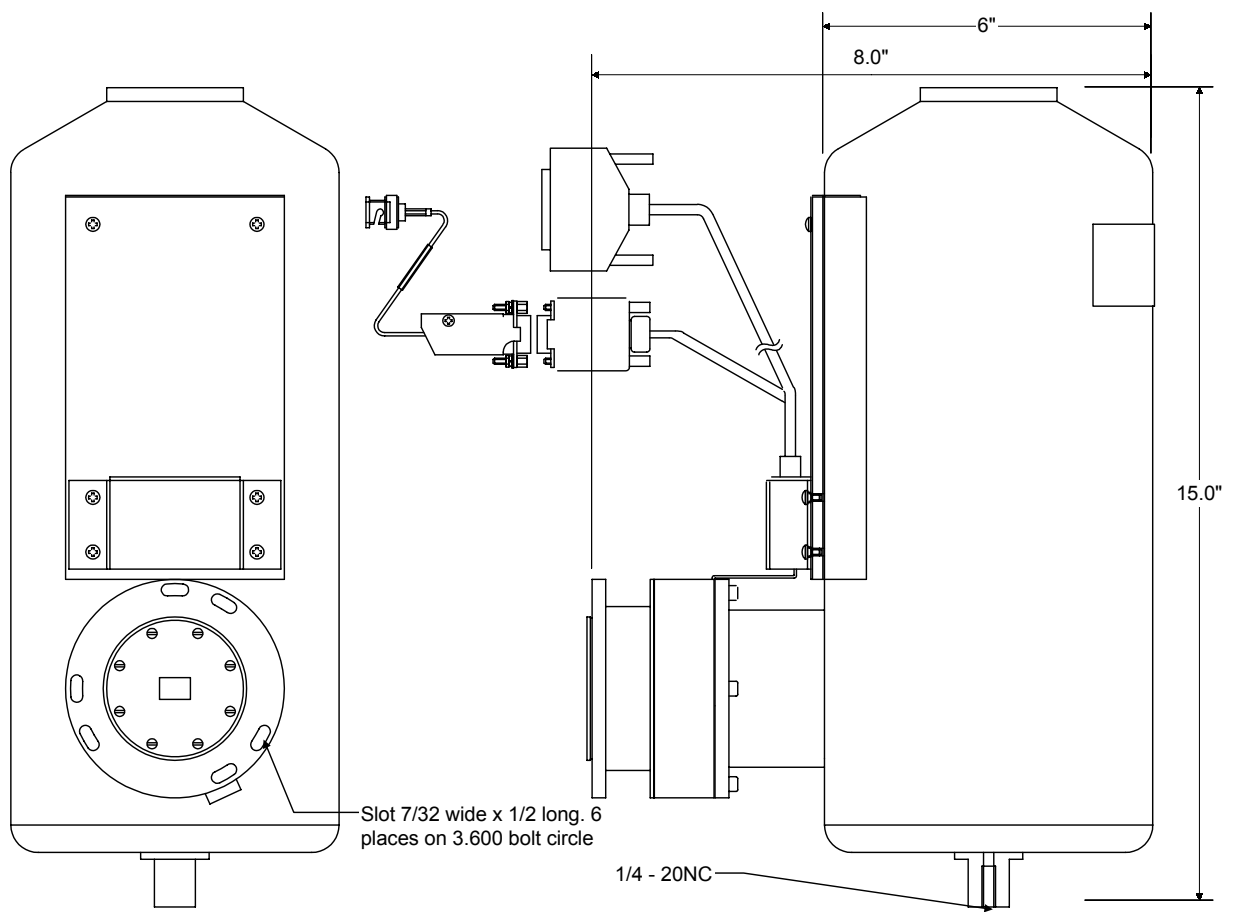


Figure 12: 2.8 Liter Side - Looking LN₂ Dewar for CCD detectors

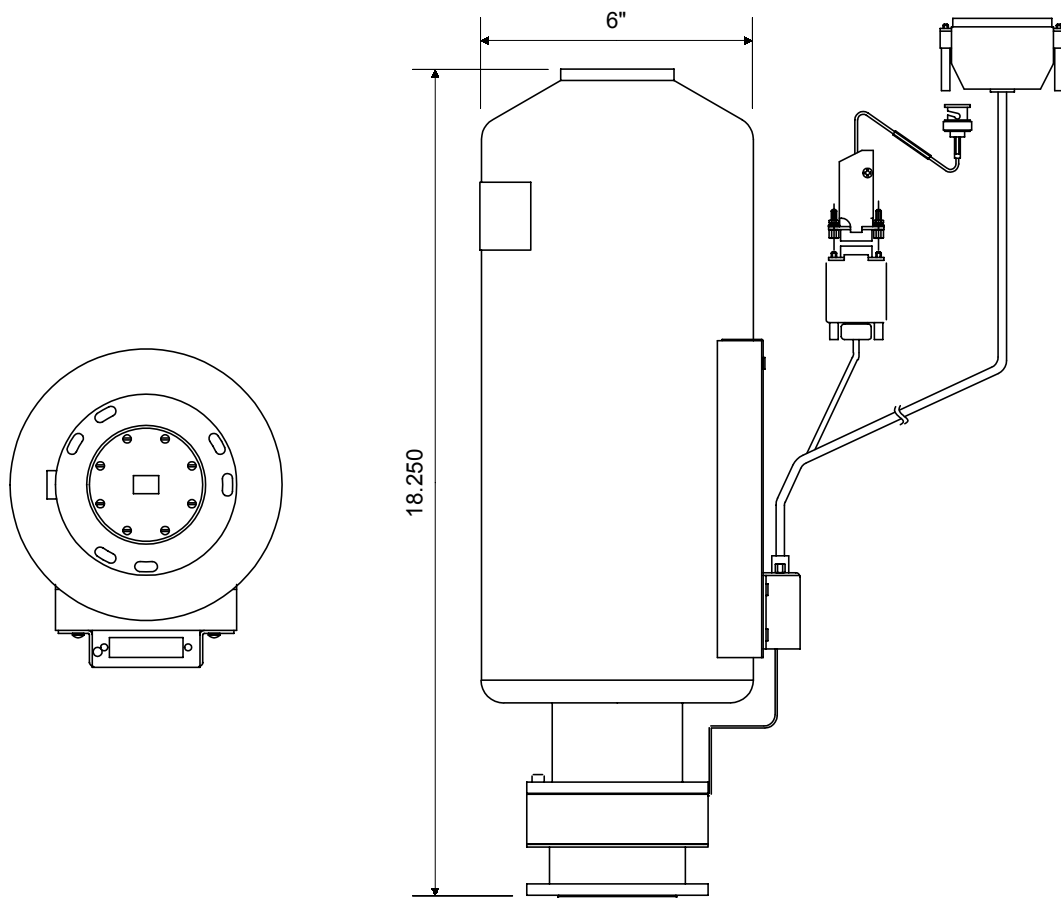


Figure 13: 2.8 Liter Down - Looking LN₂ Dewar for CCD detectors

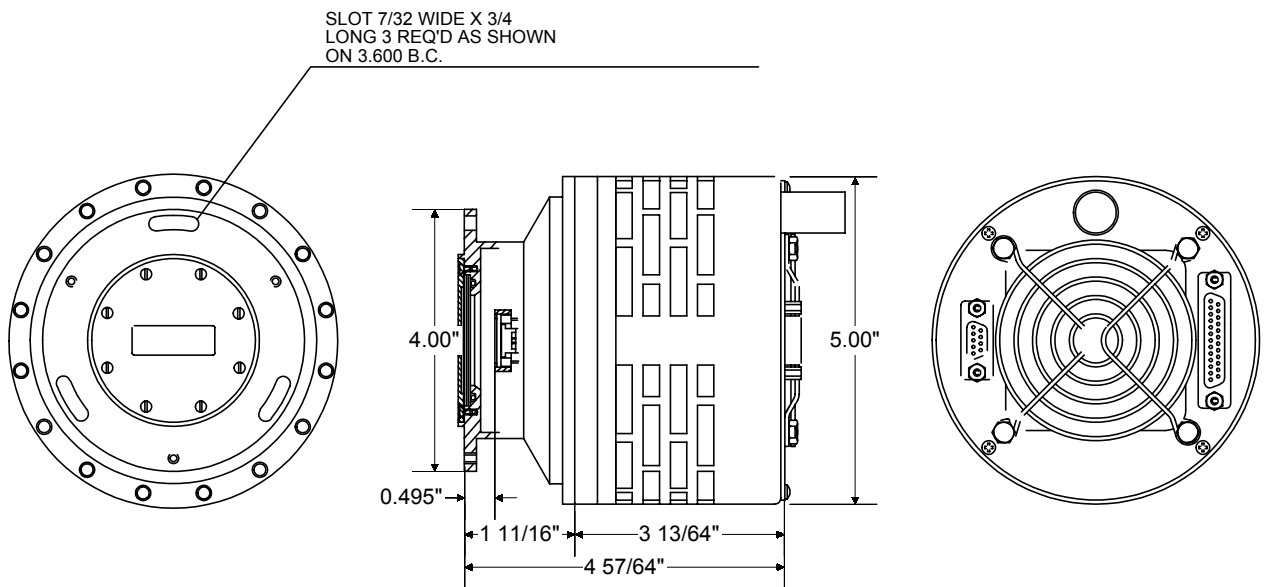


Figure 14: Air Cooled TE CCD Head

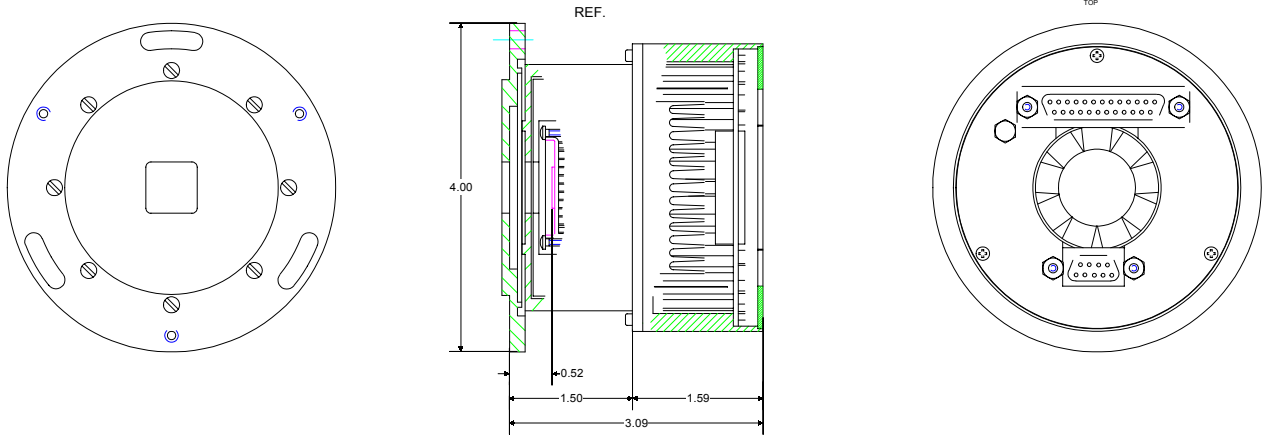


Figure 15: Mini-TECCD interface

APPENDIX E: SHUTTER OPTIONS

Shutter models 225MCD or 227MCD for the 270M, TRIAX180, TRIAX190, TRIAX320 and TRIAX550 spectrographs.

Important: On shutters using a BNC cable for the shutter signal, the shell of the cable is NOT ground. While protected by a fuse, failure to isolate this connector can cause damage to the CCD, controller, or equipment contacted by the cable.

The 225MCD shutter mounts outside on the axial (front) or lateral (side) entrance slit. Alternatively, the model 227MCD mounts inside the front axial entrance port. See the appropriate spectrograph manual for detailed installation instructions.

Connect the BNC-to-9-pin cable to the 9-pin connector on the cable coming from the CCD head. For the externally mounted 225MCD shutter, connect the BNC end to the BNC connector on the outside of the shutter mechanism. For internally mounted 227MCD shutters, connect the BNC end to the BNC connection inserted through the purge port.

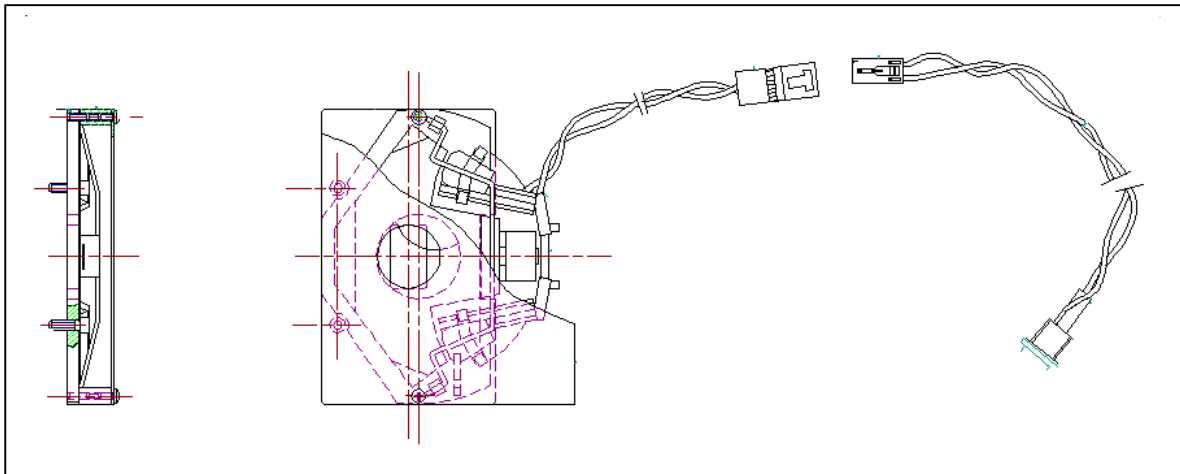


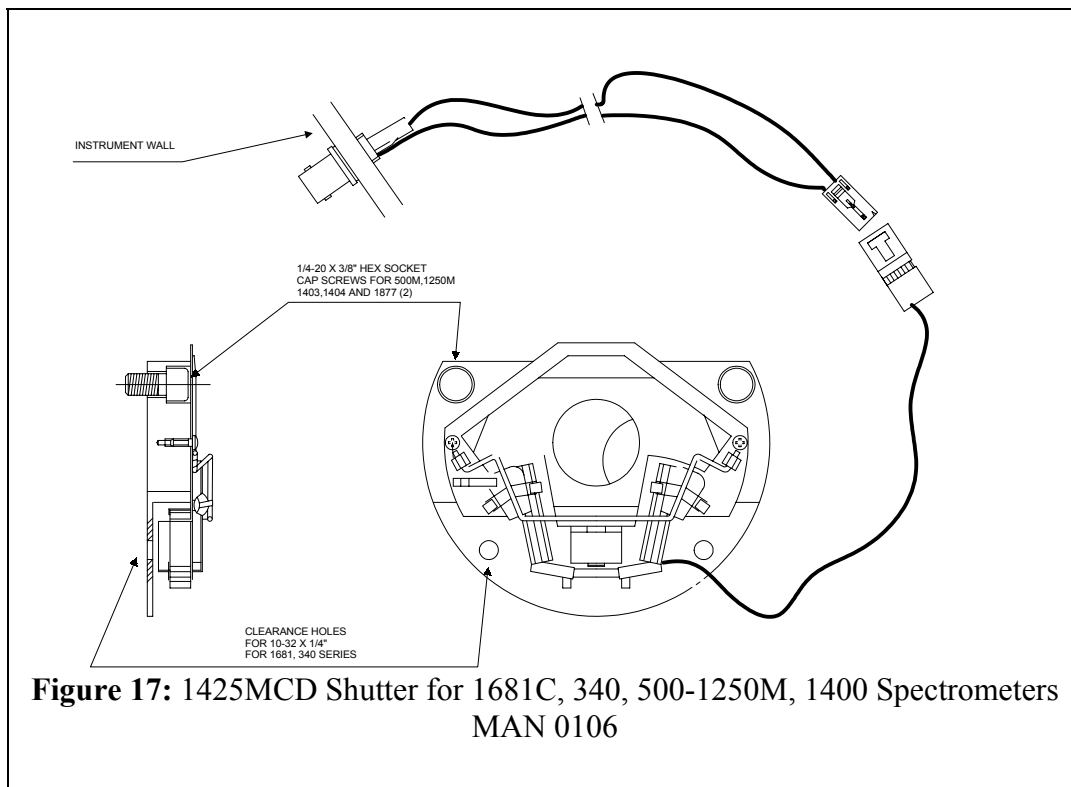
Figure 16. Shutter model 227MCD diagram.

Shutter model 1425MCD(-series), for the 1681C, 340E/S, 500M, 750M, 1000M, 1250M, 1269, 1403, and 1404 Spectrometers.

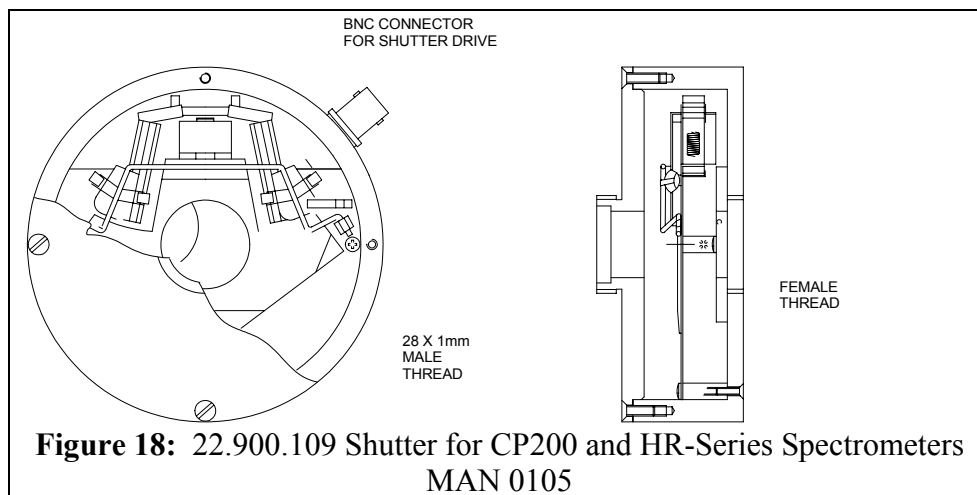
Mount the model 1425MCD (See figure 15) shutter internally on the axial (front) slit. For the 1000M and 1250M, it can also be mounted internally on the lateral (side) entrance slit. For the lateral (side) entrance of the 500M or 750M, use the 1425MCD-B. For dual entrance spectrometers, if shutters are required at both entrances, choose the correct shutter for the lateral slit, and add a 1425MCD-C for the axial slit. For all listed spectrometers *except* the 1681C and 340E, use two 1/4 -20 capscrews to attach the shutter support to the inside of the instrument wall. For the 1681C and 340E, use two 10-32 screws, and mount the shutter vertically, to avoid interference with the light baffle.

Remove the plug from the purge port/tapped hole of the spectrometer, and using the wired BNC connector, screw the threaded end of the BNC connector into the purge port such that the wire hangs inside. Route the wires avoiding the optical path and moving parts inside the spectrometer. Connect the wiring from the shutter to the BNC connector.

Connect the 36217 BNC-to-9-pin connector cable to the BNC connector just installed, and to the 9-pin connector on the 35872 cable coming from the CCD head. The BNC connector must not be grounded.



Shutter model 22.900.109, for the CP200, HR320, THR640, THR1000, & THR1500 Spectrometers



Screw the shutter onto the 28 mm threaded adapter on the entrance slit of the spectrometer.

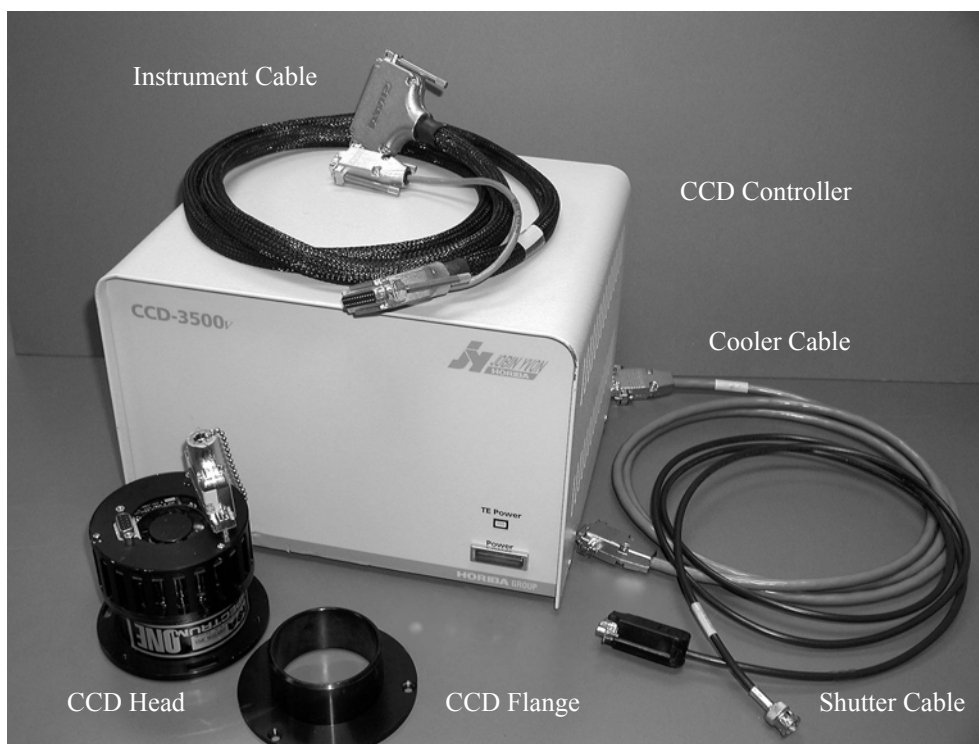
Connect the 32617 BNC-to-9-pin connector cable to the BNC connector on the shutter and to the 9-pin connector on the branch of the 35872 cable to the CCD head.

For all other monochromators contact the JY Service Department for assistance in shutter selection and installation.

APPENDIX F: QUICK CCD START-UP WITH TRIAX SPECTROMETERS

The Spectrum One CCD detector system consists of a detector head, a detector controller unit, and SpectraMax software. A multichannel port on the TRIAX and a shutter are also necessary for the CCD operation, and may or may not be included with your ordered system. Check if all of the following components are present before attempting quick start:

- ◆ CCD controller
- ◆ CCD detector
- ◆ Instrument cable (P/N 35872: black divided cable, with 37-pin connector on one end and 25-pin and 9-pin connectors on the other).
- ◆ AC power cord
- ◆ Shutter
- ◆ Shutter cable (P/N 36217: BNC-to-9-pin cable)
- ◆ TE-cooling cable (P/N 37661: 9-pin gray cable) is included for thermoelectrically (TE) cooled CCDs
- ◆ IEEE-488 (GPIB) interface and cable (National Instruments brand required for SpectraMax for Windows operation)
- ◆ SpectraMax for Windows software



Hardware Installation:

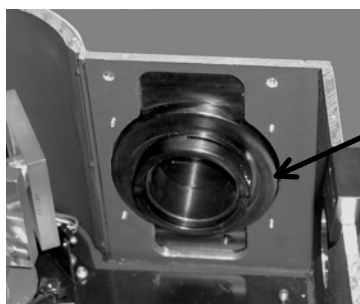
Always turn the power off to all components before connecting or disconnecting any cables to avoid electrostatic discharge.

The computer must be connected to a grounded outlet to protect against static discharge.

Before inserting an electrical cable connector, touch the connector shell to the component case to discharge any accumulated static charge.

Example: TRIAX spectrometer:

1. Install SpectraMax for Windows on your computer according to the instructions in the SpectraMax for Windows manual.
2. Verify that power is off in all components of the system including the computer.
3. Open top cover of the TRIAX and loosen the screw inside CCD port.



CCD
Mounting
Screw

4. If the shutter is not mounted already, mount shutter to the appropriate entrance slit according to the CCD manual.
5. Connect the adapter (P/N 350433) to the CCD head with 3 screws. (This part comes with the JY multichannel array adapter that replaces the Triax exit slit for use with a CCD and usually has been already attached to the detector head).
6. Insert CCD adapter, making sure the Spectrum ONE label is facing directly upward in TE cooled detectors and the dewar opening is facing up in LN₂ CCDs. The array flange adaptor should be just inside the outer wall of the Triax as a first approximation of the correct focal position.

Electrical Connections:

7. Connect AC power cord to CCD controller into using a surge protector, but **do not turn the unit on!**
8. With the power off, connect the host computer to the CCD controller using IEEE-488 (GPIB) cable.
9. Plug the detector cable (P/N 35872) in the back of the controller using 37-pin connector.
10. Remove the 25-pin grounding connector (P/N 36430) from the CCD head and immediately plug in the instrument cable (P/N 35872).

NOTE: To prevent Electrostatic Discharge (ESD) damage, install the grounding plug into the CCD head connector whenever the CCD head is disconnected from the CCD3xxx-series controller.

11. Connect the BNC-to-9-pin shutter cable (P/N 36217) to the 9-pin branch on the cable coming from the CCD head (P/N 35872).
12. For internally mounted shutters, connect the BNC end of cable (P/N 36217) to the BNC connection inserted through the CCD Adapter directly under the CCD head. For the externally mounted shutter, connect the BNC end to the BNC connector on the outside of the shutter mechanism.
13. For TE Cooled CCDs: Connect thermoelectric cooler on the CCD head to power supply on the back of the CCD controller with the 25-pin cable (p/n 37661).
14. Turn on the controller. A red power light on the front of the controller lights up to indicate the unit is turned on.
 - ◆ If the CCD is TE-cooled, you should hear the fan on the back of the CCD Head start and the TE Status LED on the CCD controller should turn green.
 - ◆ If CCD is LN₂-cooled, carefully fill the dewar with LN₂.
 - ◆ In 20-30 minutes chip should reach specified temperature and optimum performance.
15. Replace the top cover of the TRIAX without inserting any screws.
16. Make sure that TRIAX is connected to AC power and the computer and turn the controller and the computer On. Start SpectraMax and load Mono1+CCD layout.
17. Open Virtual Instrument Setup, click on CCD picture to open ADC Gain window. Click twice on Shutter button to open and close the shutter. If you do not hear the shutter, refer to Troubleshooting Section.
18. Close Virtual Instrument Setup, open Main window to select Real Time Display from Collect menu. You are ready for Alignment and Focusing of the CCD.

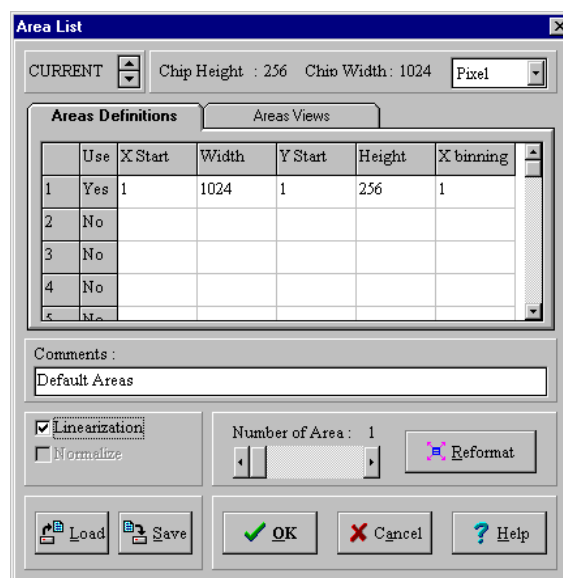
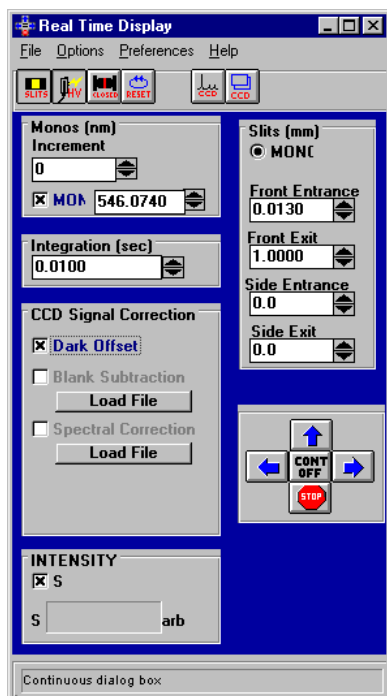
Focusing and Alignment:

Once the Spectrum ONE head is mounted and the system connected, the position of the head must be adjusted so that the sensor lies at the instrument focal plane, and that the spectral slit images are aligned with the pixel columns.

The head must first be cooled to near operating temperature before the detector can be focused and aligned.

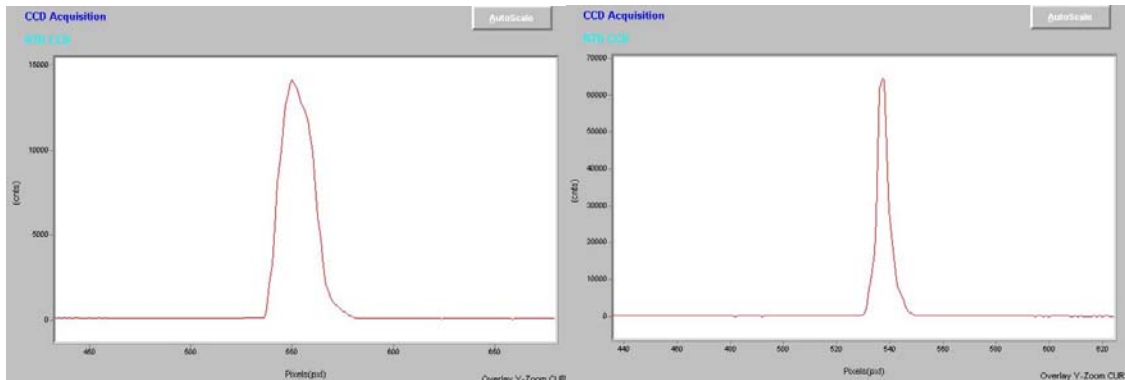
With SpectraMax for Windows software:

1. Attach a spectral line source, such as a mercury lamp, to the instrument entrance slit.
2. Reduce the slit width to 13 μm in RTD mode to make the image of the slit as narrow as possible on the detector and close height limiter to 1 mm.
3. In RTD window open Area List and press the Reformat button to make sure that the sensor parameters (pixel format, pixel size) in the RTD screen agree with those of your actual sensor. Uncheck linearization to display X-axis in pixels.
4. Set monochromator position to a known emission wavelength, i.e. Hg line at 546.074 nm.
5. Set the "Integration Time" to 0.1 second or less, and select Continuous spectrum acquisition on Spectrometer Step Control. After receiving a moderately high signal, stop acquisition.



6. Turn Autoscale off in the display screen.
7. Zoom In on the central peak and scale it in Y-direction.

Observe the spectra while moving the detector head in and out of the adapter flange. Excessive asymmetry of the peak is a sign that the slit image is not aligned to the pixel columns; diminished shape and magnitude are symptomatic of defocusing. A focused, aligned CCD will provide a distinct peak of large amplitude and narrow half-width. In certain high-grating-angle systems, symmetry will not be an indicator of best focus, due to the physics of the optical system.

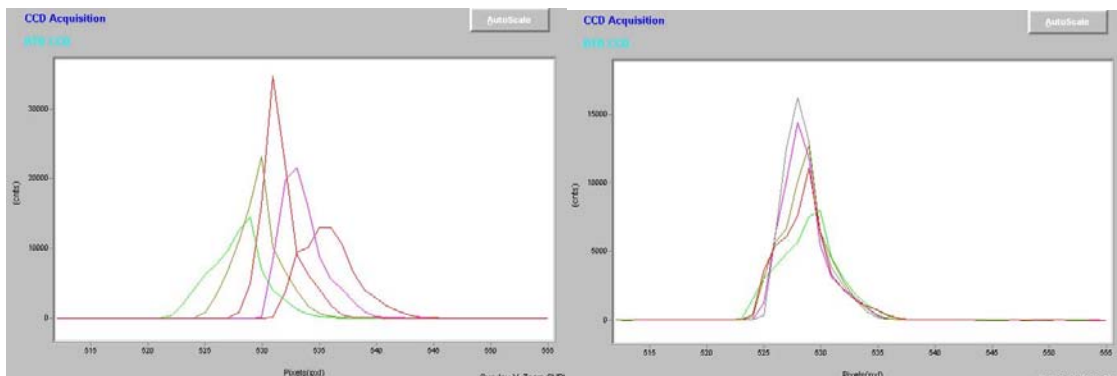


Misaligned and unfocused CCD

Aligned CCD

These spectra were obtained on a TRIAX 190 equipped with a CCD chip (1024x256).

8. Adjust the CCD sensor plane position by moving the head in and out with respect to the exit port until the signal is maximized. The peak should be less than or equal to 4 pixels wide across the Full Width at Half the Maximum height (FWHM).
9. The CCD orientation is adjusted by rotating the detector head to the right or left in the focal plane. Open the height limiter to its full size to fully illuminate the chip.
10. In RTD window open Area List and reformat chip into 5 areas. Acquire continuous spectra while rotating the detector head. When aligned, the 5 spectra overlap and have similar intensity. Each individual spectrum should be less than 5 pixels wide at FWHM.

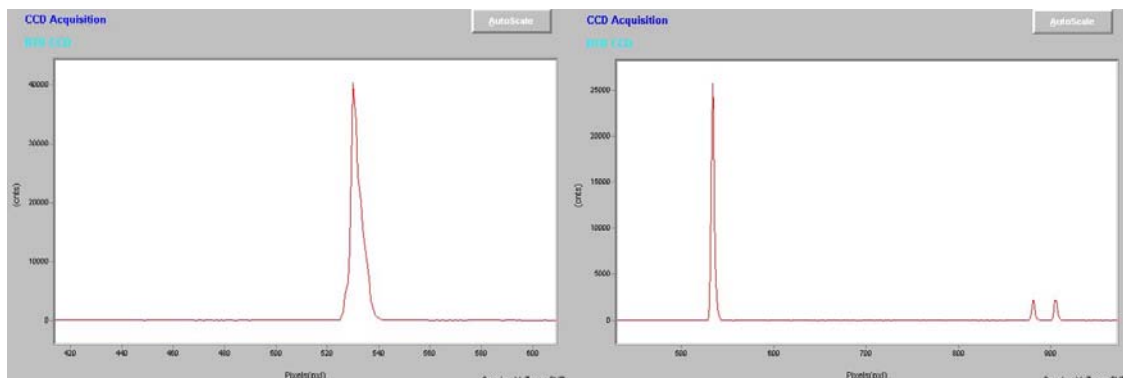


Misaligned CCD

Aligned CCD

These spectra were obtained on a TRIAX 190 equipped with a CCD chip (1024x256).

11. Tighten the array adapter once the CCD has been focused and aligned.
12. Reformat chip to full area and check the peak FWHM again.

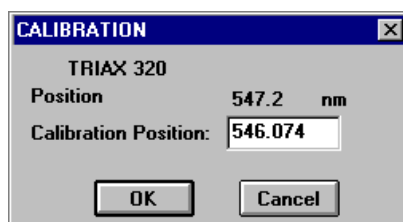


Focused and aligned CCD chip showing mercury lines at 546.074 nm (green) and doublet at 576.96 and 579.06 nm. These spectra were obtained on a TRIAX 190 equipped with a MTE-CCD (1024x256).

SpectraMax for Windows Calibration Procedure:

The following procedure should be applied only if the observed and theoretical values differ less than 2 nm. Otherwise, please, call Service for help with Hardware Configuration and Control.

1. Start acquisition in RTD mode with linearization off.
2. Changing center wavelength, place calibration peak (Ex., 546.074 nm) at the center of the chip. Make note of the monochromator position corresponding to the center of the array.
3. Close RTD mode and open Virtual Instrument Setup. Open Grating sub-menu and click Calibrate.
4. Type the correct peak value and press OK.



5. Re-run the experiment with new offset and check if the peak maximum falls at the middle of the chip.
6. Run acquisition over a wavelength range exhibiting several peaks with linearization mode on. Check if the peak wavelengths are within instrument specifications (± 0.3 nm) over the width of the chip. If the values are over the specified accuracy, the CCD needs to be linearized.

SpectraMax for Windows Linearization Procedure:

The monochromator center wavelength must be properly calibrated before running the linearization program.

1. Select **Linearization** from the *Collect* menu on the **Experiment/Post Processing** screen.
2. Write down or otherwise Save the original values for your instrument as displayed at the start.
3. Choose **Multi/Scans/One Peak** to use a single line across the width of the chip
4. Select **Define Experiment**.
5. If using a single line of a light source, such as the 547.074 nm line of a Hg lamp, select *Multi Scans/One Peak* to take five spectra of the line displaced to different locations across the chip.
 - ◆ Reformat CCD Areas to use the entire chip.
 - ◆ Make sure Linearization box is not checked.
 - ◆ Click on *OK* to close CCD Areas dialog box.
 - ◆ Click on *CCD Regions to Open Positions/Range Modes* dialog box.
 - ◆ Select **Position Mode**
6. Five different spectra are taken with a single peak falling on different areas of the chip for each spectrum.
 - ◆ Set *Nb Regions* to five.
 - ◆ Enter the Center position of the third region to 546.074 nm.
 - ◆ Take the difference of the “From” and “To” positions and divide by five to get an increment “*i*” that will allow five positions to be defined so that the maximum amount of the chip is used in the linearization process.
 - ◆ Set the Center of the second region to the Center position of the third region minus the increment “*i*” calculated above.
 - ◆ Set the Center of the first region to the Center position of the second region minus the increment “*i*” calculated above.
 - ◆ Set the Center of the Fourth region to “To” position of Region 3 plus the increment “*i*” calculated above.
 - ◆ Set the Center of the Fifth region to “To” position of Region 4 plus the increment “*i*” calculated above.
 - ◆ Please check that all regions have the same integration time and Click *OK* to close the dialog.

11. A dialog box will appear requesting the calibration wavelengths. Enter 546.074 nm for green mercury line. **SpectraMax** will calculate new values for the OUTPUT_FOCAL_LENGTH and FOCAL_PLANE_ANGLE and display them on the screen.

Note: Check the values before allowing SpectraMax to update INI. The focal length should be approximately correct for the instrument being used.

12. Click on the check box to accept the values and write them to the appropriate .INI files. Close and exit all **SpectraMax** applications.
13. Restart **SpectraMax** and the changes will take effect. Verify the linearization and repeat is necessary.

APPENDIX G: TRIGGERING WITH THE CCD-3000V AND CCD-3500V DETECTION SYSTEMS AND SPECTRAMAX FOR WINDOWS

The Spectrum ONE CCD-3000V and CCD-3500V Detection Systems have both input and output TTL trigger functions. One hardware input trigger can be configured in the software. Note: the fastest triggering rate possible is 50 Hz for experiments using a mechanical shutter. For experiments without a shutter, the fastest triggering rate compatible with the controller is 3KHz. Two hardware triggers are available as BNC receptacles on the back of the controller: one for input and one for output.

To enable triggering using SpectraMax for Windows, the following procedure can be used:

1. Open the CCD Experiment Acquisition window.
2. Click on the box labeled “Trigger” as shown in Figure 1.

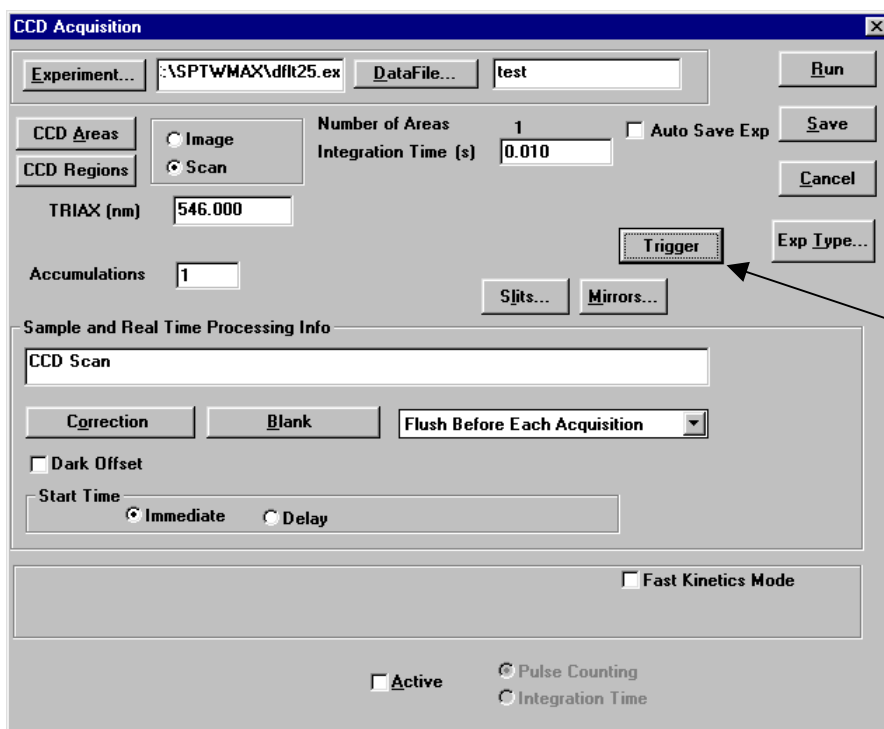


Figure 1. Trigger functionality can be selected in the CCD Acquisition window by clicking on the “Trigger” box.

3. A Trigger Setup window will appear, as shown in Figure 2.

4. Click on the “Enable” button to activate Input Trigger.

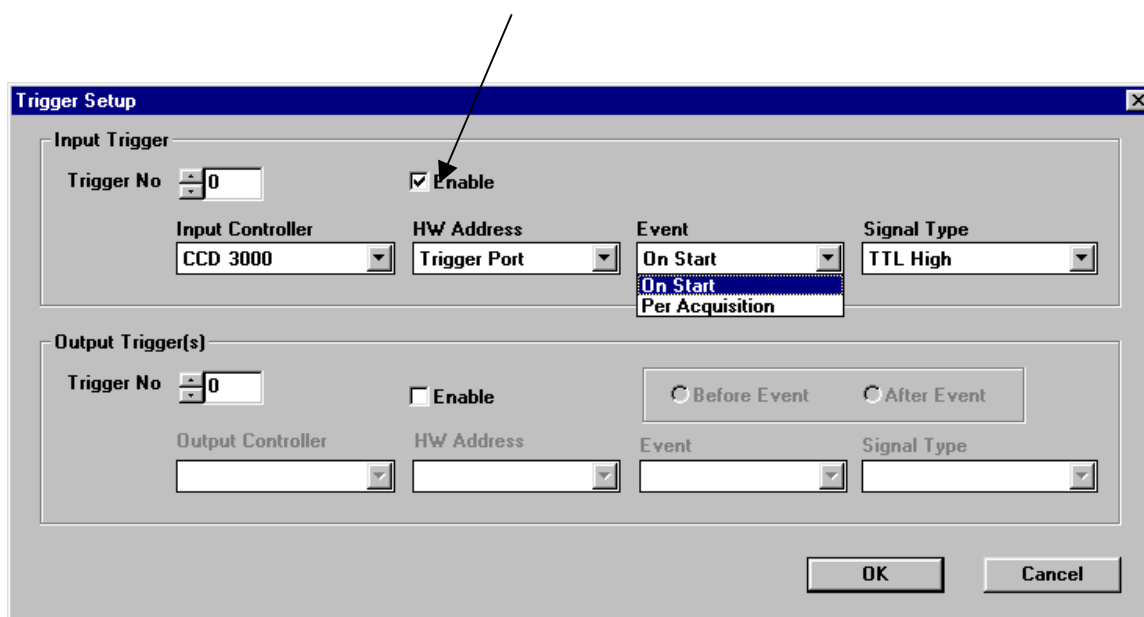


Figure 2. The Trigger Setup window allows the user to activate TTL trigger inputs and outputs. Here, the Input Trigger function is enabled.

- ◆ Input Trigger Parameters

1. Input Trigger On Start—The experiment will start as soon as the CCD controller receives a TTL high signal. If the controller receives multiple input triggers, only the first one will have any effect on the experiment.
2. Input Trigger Per Acquisition—In a multiple acquisition experiment (such as an experiment where Multiple Accumulations or Blast Mode is selected), sometimes it is desirable to wait for a trigger to start each acquisition. In this case each acquisition will start only after the CCD controller receives a TTL high signal.

- ◆ Output Trigger Parameters—The TTL output from the Trigger Out BNC port on the CCD controller will stay high for the duration of the software-specified integration time.

SERVICE POLICY:

If you need assistance in resolving a problem with your instrument, contact our Customer Service Department directly, or if outside the United States, through our representative or affiliate covering your location.

Often it is possible to correct, reduce, or localize the problem through discussion with our Customer Service Engineers.

All instruments are covered by a warranty. The warranty statement is printed on the inside back cover of this manual. Service for out-of-warranty instruments is also available, for a fee. Contact JY or your local representative for details and cost estimates.

If your problem relates to software, please verify your computer's operation by running any diagnostic routines that were provided with it. If there is a support diskette provided, refer to the manual for that diskette, and follow the troubleshooting procedures. Be ready to provide version numbers for the DOS that you are using, as well as the software version and firmware version of any controller or interface options in your system. The software version can be determined by reading the version from the welcome panel that is displayed when the software is loaded. Or select the software name at the right end of the menu bar and click on "About" to view the same panel. Also knowing the memory type and allocation, and other computer hardware configuration data from the PC's CMOS Setup utility may be useful.

In the United States, customers may contact the Customer Service department directly:

- By phone at (732) 494-8660 ext. 185
- The Service fax numbers are: (732) 549-9309 for the Optical Spectroscopy Division (OSD), 549-2571 for the Raman Group and 549-5157 for the Fluorescence Group
- E-mail us at Systems@jyhoriba.com
- Or you may write to:
Jobin Yvon, Inc.
Customer Service (Specify OSD, Raman or Fluorescence)
3880 Park Avenue
Edison, N.J. 08820 U.S.A.

From other locations worldwide, contact the representative or affiliate for your location.

If an instrument or component must be returned, the method described on the following page should be followed to expedite servicing and reduce your downtime.

Return Authorization:

All instruments and components returned to the factory must be accompanied by a Return Authorization Number issued by our Customer Service Department.

To issue a Return Authorization number, we require:

- The model and serial number of the instrument
- A list of items and/or components to be returned
- A description of the problem, including operating settings
- The instrument user's name, mailing address, telephone, and fax numbers
- The shipping address for shipment of the instrument to you after service
- Your Purchase Order number and billing information for non-warranty services
- Our original Sales Order number, if known
- Your Customer Account number, if known
- Any special instructions

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