TriVista® System

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Princeton Instruments

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Table of Contents

Figures

Tables

Introduction

Thank you

Thank you for your purchase of the Princeton Instruments TriVista® system. TriVista is a triple spectrograph that offers the highest spectral resolution and extreme stray light rejection required for Raman, photoluminescence, and other applications in UV, VIS, and NIR spectral ranges. Its unique optical design (patent pending) allows easy switching between additive and subtractive modes and it can be easily reconfigured to work as a double or a single spectrometer.

This Manual

This instruction manual is intended to assist you in set-up and operation of your new TriVista system. Even if you are an experienced user of spectroscopic equipment, we suggest that you review the manual to insure proper setup and operation. If you have any questions about the information contained in this manual, please feel free to contact the Princeton Instruments customer support.

At times, the procedures and instructions will refer you to other documents for detailed information regarding setup and operation. Detailed information about the WinSpec software package used to operate the system can be found in its own manual. Detailed information about CCD detectors, PMTs, and accessories can be found in the instructions or manuals supplied with these devices.

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Chapter 1
TriVista Description

1.1 Overview

At the heart of TriVista® are industry leading Acton Research Corporation spectrometers. They are known for superb resolution, stray light rejection, excellent imaging and ruggedness. The TriVista can operate from 185 nm to 2.2µm. Spectral resolution can reach 4 picometers in the VIS spectral range (500 nm). And — extreme stray light rejection allows Raman spectra to be captured as close as 5 wave numbers from the Rayleigh line.

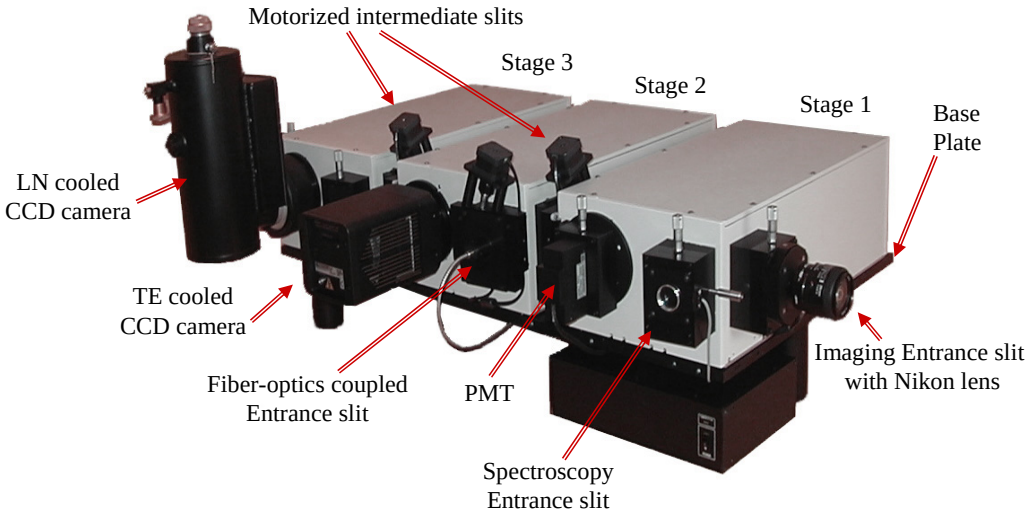

Figure 1. Possible TriVista Components

The thoughtful design of TriVista enables it to run a wide variety of spectroscopy applications from UV Raman to photoluminescence. It incorporates the powerful ***EasySwitch*** feature (patent pending) to switch between additive and subtractive modes with a simple mouse-click. It can also be easily reconfigured as a single, double, or triple spectrometer without removing any of the components from the pre-aligned baseplate.

1.2 TriVista Models

We offer three (3) basic TriVista models: TriVista 555, TriVista 557, and TriVista 777. These models differ by the focal length of their stages, which in turn affects the resolution of the instrument. The table below lists the focal lengths of the stages for all of the TriVista models.

Stage	Focal Distance		
	TriVista 555	**TriVista 557**	**TriVista 777**
1st stage	500 mm	500 mm	750 mm
2nd stage	500 mm	500 mm	750 mm
3rd stage	500 mm	750 mm	750 mm

Table 1. TriVista Models: Stages vs. Focal Distance

1.3 Stage Description

Both 500 mm and 750 mm TriVista stages have the same Czerny-Turner design. Each stage features two (2) entrance slits and two (2) exit slits (see Figure 2). The Front exit of each stage is suitable for mounting a CCD or a PDA array detector.

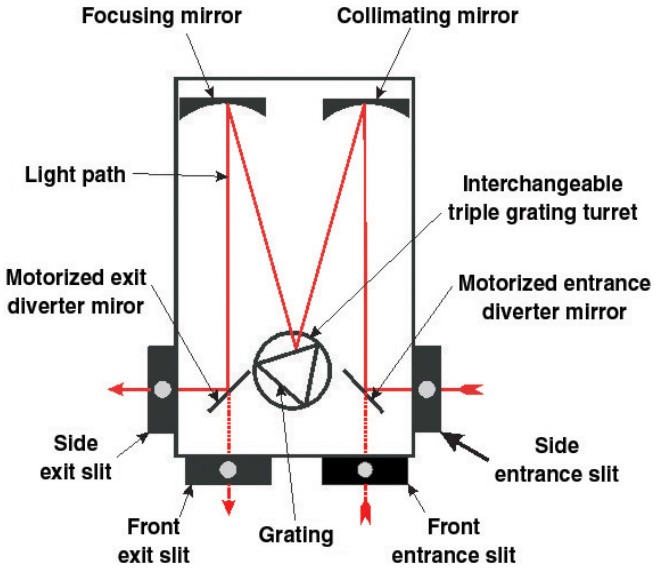

Figure 2. 500 mm Spectrograph/750 mm Spectrograph Components

Focal Plane

The focal plane size is 27 mm wide x 14 mm high.

Mirrors

TriVista stages feature motorized entrance and exit mirrors. Mirrors move out of the way and safely park on the side when you choose front entrance or front exit slit, but they move back and divert your light beam when you choose side entrance or side exit slit. You have full control over mirror position from software, so you do not have to open spectrometer cover to move a mirror.

Sliding Tube (for mounting CCD or PDA Detector)

500 mm Stage: Incorporates exclusive o-ring sealed sliding tube with unique 3-point focus stop/fine focus adjustment mechanism.

750m Stage: Incorporates exclusive o-ring sealed sliding tube with unique split clamp.

Astigmatism-Corrected Optics

The TriVista stages incorporate cylindrical field correction introduced by aspheric optics which brings the tangential and sagittal focal planes together, thereby removing astigmatism. In spectroscopy applications, reduced astigmatism significantly improves resolution of the instrument. In multi-fiber applications, a single fiber introduced at the entrance slit is faithfully reproduced at the detector as a point image of roughly the same size as fiber itself.

Triple Grating Turret

Quite often it becomes necessary to select two or three gratings to achieve efficient light throughput over a broad spectral region. The TriVista stages are all equipped with multiple grating turrets as a standard feature. Turrets make grating change an easy computer-controlled operation which also reduces the risk of handling the delicate gratings. Synchronous turret movements are software-controlled and there is an easy software correction of any Zero Offset drifts.

All gratings are pre-aligned and since up to 3 turrets can be supplied per stage, you could have up to 9 gratings per stage

Digital Scan Drive

The TriVista features 32-bit microprocessor controlled direct digital scanning (DDS) system. The direct digital grating scan mechanism has full wavelength scanning capabilities. The drive step size is 0.0025 nm (nominal). The turret can rotate 360 degrees. Each 1 degree of turret rotation is divided into 12,800 steps of stepping motor. The theoretical angular tolerance of turret positioning is ± 1 step or ± 1/12,800 degrees.

USB Interface

Built-in USB 1.1 interface that includes one (1) USB 1.1 connector and one (1) USB hub per stage. A minimum of three (3) USB cables (Type A to Type B) are supplied with the TriVista.

1.4 TriVista Assembly

Base Plate

The critical issue of TriVista assembly is the proper optical alignment between stages. To ensure that the alignment will be long lasting and insensitive to minor vibrations and mechanical disturbances, all three (3) stages are mounted on a common, rugged base plate, standing on its own feet.

Motorized Intermediate Slits

While switching between different modes of TriVista operation, the width of intermediate slits between stages usually changes to adapt to the new experimental conditions.

In order to make this procedure quick and precise, we designed motorized slits that can be opened with great precision from 10 µm to 12 mm with 5 µm increments. Two motorized intermediate slits join together the optical paths of all three (3) stages.

The slit motors are only energized when you send the command via the software to control the designated slit. When the power to a spectrograph is turned off, the slits remain in the position to which they were last set. This position is stored in nonvolatile memory allowing slit position to be maintained with power on or off.

1.5 Key Features of TriVista

- Fully compatible with high performance Princeton Instruments CCD (Spec-10 and PIXIS®), ICCD (PI-MAX), and InGaAs (OMA-V) detectors
- Highest spectral resolution of <0.004 nm
- Extreme stray light rejection: Capture Raman spectra as close as 5 cm^{-1} from the Rayleigh line
- Wavelength range from 185 nm to far IR with a wide choice of gratings
- Triple-grating turret for fast and easy switching between gratings
- Interchangeable turrets - up to three (3) different turrets can be used on each stage (a total of 9 gratings)
- ***EasySwitch*** feature to easily switch between additive and subtractive modes just with a mouse-click
- Can operate as three individual spectrometers, a combination of single and double spectrometers, or as a triple spectrometer.
- Multiple entrance slits can be coupled with microscope, fiber optics, lenses, or sample chambers.
- Multiple exit slits are suitable for the installation of CCDs, linear arrays, and single point detectors at any stage

Chapter 2
Specifications

2.1 General Specifications

Optical

Optical Design: Imaging Czerny-Turner design with **original polished** aspheric mirrors (500 mm spectrograph); Imaging Czerny-Turner design (750 mm spectrograph).

Mirror Operating Range: 185 nm to the far infrared with available gratings and accessories

Optical Paths: 90º; 180º; and multi-port:

Focal Plane Size: 27 mm wide x 14 mm high (500 mm); 25 mm wide x 14 mm high (750 mm)

Gratings

Mechanical Scan Range: Refers to the *mechanical rotation capability* (not the "operating" or "optimum range") of a grating drive system with a specific grating installed.

Groove density, g/mm	Up to, nm	Up to, Abs. cm^{-1}	Up to, eV
600	2500	4000	0.50
750	2000	5000	0.62
900	1667	6000	0.74
1100	1364	7333	0.91
1200	1250	8000	0.99
1800	833	12000	1.49
2400	625	16000	1.99
3600	417	24000	2.98

Table 2. Mechanical Range of Gratings

Grating Efficiency: Refer to Appendix G for efficiency curves for the available gratings.

Linear Dispersion: Refer to Appendix A for dispersion tables

Spectral Resolution: Refer to Appendix A for resolution tables

Grating Change Time: Less than 20 seconds (via software control)

Turrets

Turret Type: Interchangeable triple grating turret with holders for 3 gratings (depending on your need 1, 2 or 3 gratings can be installed).

Turret Drive System: 32-bit microprocessor controlled direct digital scanning (DDS) system.

Drive Step Size (nominal): 0.0025 nm

Scan Linearity: Scans linear with respect to wavelength

Turret Interchange Time: ≈ 10 minutes (manual changeover from one turret to another)

2.2 General Mechanical and Electrical Specifications

CCD Focus Arrangement

500 mm spectrograph: Exclusive O-ring sealed sliding tube with unique 3-point focus stop/fine focus adjustment mechanism

750 mm spectrograph: Exclusive O-ring sealed sliding tube with unique split clamp

Manual Slits

Micrometer adjustable from 10 µm to 3 mm wide. Standard slit heights: 4 mm and 14 mm

Motorized Slits

Micrometer adjustable from 10 µm to 12 mm wide with 5 µm increments.

Computer Interface

Operating System: Windows ME, NT, 2000 or XP.

TriVista:

USB: Requires only one USB 1.1 connection to computer. All 3 stages and the SpectraHub electronics are connected by USB-Hubs, which are placed at backside of the stages.

RS232: For RS232 control, a terminal or RS232 computer port must be set up as follows: 9600 baud, 8 data bits, no parity, 1 start bit, 1 stop bit. Additionally, an RS232 cable is required. See Appendix G for RS232 cable pinout information.

CCD Detector: Depending on the detector design, requires one free PCI interface or one free USB2 interface.

Overall Dimensions

TriVista 555: 3.23 ft long (985 mm) 1.97 ft wide (600 mm) 1.15 ft high (350 mm)

TriVista 557: 3.44 ft long (1050 mm) 2.62 ft wide (800 mm) 1.15 ft high (350 mm)

TriVista 777: 3.44 ft long (1050 mm) 2.62 ft wide (800 mm) 1.15 ft high (350 mm)

Weight

TriVista 555: ≈ 225 lb (102 kg)

TriVista 557: ≈ 250 lb (113 kg)

TriVista 777: ≈ 260 lb (118 kg)

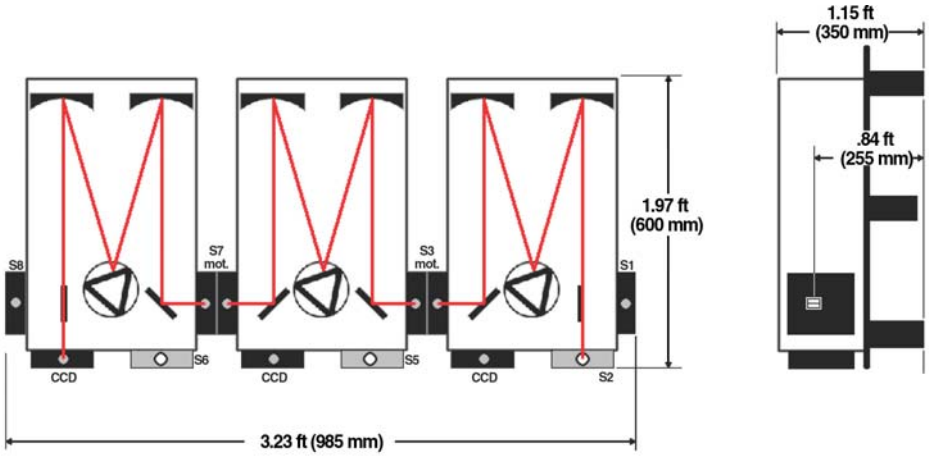

Figure 3. TriVista 555 Dimensions

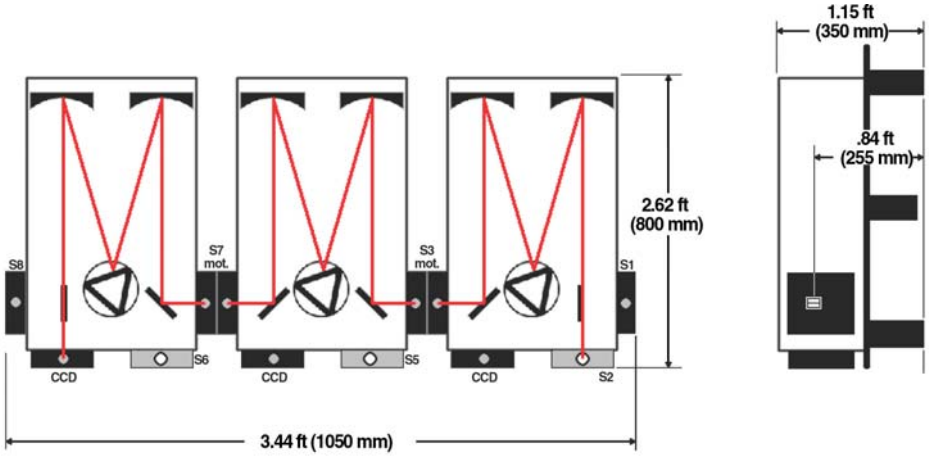

Figure 4. TriVista 557 and TriVista 777 Dimensions

2.3 Spectrometer Specifications

The following specifications are for TriVista systems.

System	TriVista 555		TriVista 557		TriVista 777	
Mode	additive	subtractive	additive	subtractive	additive	subtractive
Focal Length (mm)	1.500	500	1.750	750	2.250	750
Grating Size (mm)	68x84	68x84	68x84*	68x84*	68x68	68x68
Transmission (%)	15	15	15	15	15	15
Aperture	F/5.9	F/5.9	F/5.9**	F/5.9**	F/9.8	F/9.8
Linear Dispersion (nm) * **	0.30	0.90	0.26	0.60	0.20	0.60
Linear dispersion (cm^{-1}) * **	12	36	10.4	24	8	24
Bandpass over 20 mkm pixel (nm) * **	0.006	0.018	0.005	0.012	0.004	0.012
Bandpass over 20 mkm pixel, (cm^{-1}) * **	0.24	0.72	0.20	0.48	0.16	0.48

Table 3. TriVista System Specifications

* The 3rd stage has 68 x 68 µm gratings.

** Aperture of the 3rd stage is F/9.8

*** Calculated for triple configuration at 500 nm central wavelength; all slits are 10µm; all gratings are 1800 g/mm

Chapter 3
System Setup

3.1 Introduction

Upon receiving a TriVista system, you need to perform the following steps:

A. Unpack and inspect the TriVista system

B. Locate a place for the TriVista

C. Place the TriVista on optical table

D. Call your local sales representative to schedule an installation date.

The instructions that follow explain how to perform these steps. Please, carefully read the instructions.

A. Unpack and Inspect the TriVista system

Report any damage immediately to the carrier and to Princeton Instruments Corporation. Save all packing material.

Carefully unpack and examine the TriVista and any accessories purchased. The standard system components are:

- **TriVista:** Three (3) spectrograph stages mounted on a fixed baseplate. Includes five (5) manual entrance and exit slits, two (2) motorized intermediate slits, interchangeable triple turrets, pre-aligned and pre-focused gratings, and motorized entrance and exit mirrors on each stage
- **Power Supplies:** Three (3) AC-DC power supplies with line cords
- **USB Cables:** Three (3) USB 1.1 or USB 2.0 cables
- **Software and Manuals CD for:**

  S&I Spectroscopy & Imaging GmbH Triple Raman System Software

  Princeton Instruments WinSpec/32 Software

  Acton Research Corporation SpectraPro Monochromator Control Software
- **Paper Manuals:**

  WinSpec Software User Manual

  TriVista User Manual

Optional system components are:

- **Princeton Instruments detector system:** Spec-10, PIXIS, OMA-V, PI-MAX

- **PMT system:** SI (200-1100 nm), InGaAs (800-1700 nm), PbS (1100-2500 nm), InSb (1500-5000 nm)
- **Wide range of accessories:** Filter wheels, lenses, motorized slits, fiber optics, sample chambers, macro chambers, light sources, and more

B. Locate a Place for the TriVista

- The location should allow convenient access to entrance and exit slits and safe access to laser beam(s).
- Laser height should match the height of the TriVista entrance slit (refer to the Appendix B).
- Make sure that the chosen location will allow you to operate TriVista for a long period of time. We can not guarantee the best performance if TriVista was removed from its initial location. TriVista has a rugged and reliable design and can withstand slight vibrations and small accidental disturbances. Even so, it is a high-precision optical instrument and such possible future events as lifting the system and moving it to another location may disturb the alignment. For this reason we strongly recommend that you carefully choose the initial TriVista location.

C. Place the TriVista on Optical Table

TriVista needs to be installed on a leveled optical table. Please, refer to the Chapter 2 "Specifications" to see the overall dimensions of your system. This will give you an idea of the size of the optical table required. Allow some additional space for mounting detectors, placing collection optics and sample chamber(s) (if any). Also consider whether it is practical for you to mount your laser or other light source on the same table.

If you do not have an access to optical table, use any vibration protected and well-leveled support with a flat surface.

D. Call your local sales representative to schedule an installation date.

If you do not have an installation date by now, please call your local sales representative to schedule it at your convenience. Our qualified personnel will arrive at your site and perform a full installation of TriVista and train you in its operation. Installation and training usually takes 3-4 days, so Mondays and Tuesdays are the best days to schedule the beginning of your installation.

3.2 Typical System Layout

- After a TriVista is set up by Princeton Instruments/ Acton representatives, its layout typically looks like one of the two diagrams below.

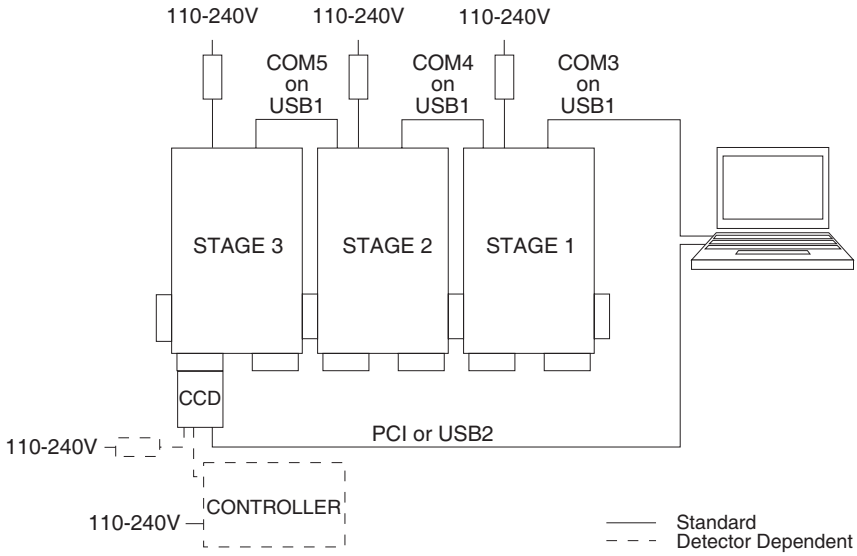

Figure 5. Connection Diagram for CCD Detector

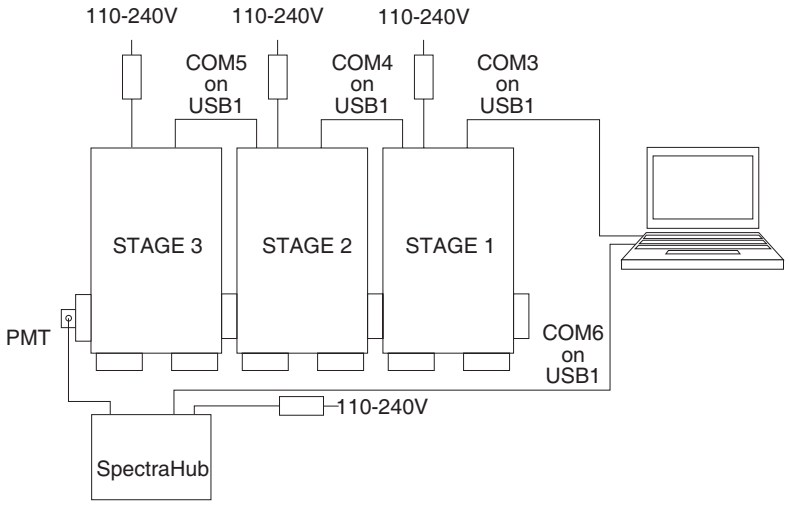

Figure 6. Connection Diagram for PMT

- The back of each spectrometric stage has a connection panel which looks like this:

Figure 7. Spectrograph Cable Connections

FILTER	Filter driver connection for ARC FA-448 Filter Wheel.
SHT TTL	SHT TTL connection for TTL control of shutter.
DSP	Not Used.
READY	Ready light is on when the instrument is ready to operate. (Green light comes on after the instrument initializes. Yellow = busy)
COM	Com light flashes when communicating with the computer.
USB	USB 1.1 connection.
USB HUB	USB Hub 1.1 compatible.
RS-232	RS-232 connection to computer (normally not used).
POWER	Power connection +5 and +24 Volts

- The following communication cables are used:

  1. **USB is the standard cable:** 3650-USB-06 USB Cable Type A to Type B.
  2. **If USB cannot be used:** RS232-compatible 9-pin female (DB9S) connector to 9-pin male connector (DB9P).

     Note: A terminal or RS232 computer port must be set up as follows: 9600 baud, 8 data bits, no parity, 1 start bit, 1 stop bit.

  In addition, a power cable and power supply are also shipped with the system. Refer to Appendix G for the Power connector pinout table and diagram.

3.3 Configurations

The TriVista spectrometer can be used in single, double and triple configurations. Single configuration (Figure 8) means all three stages can be used simultaneously and independently for three different projects. This is highly practical but quite rare situation. Most often TriVista is utilized as a double or triple system (Figure 9 or Figure 10). In these cases, light beam sequentially passes through 2 or 3 stages and the gratings of the involved stages coherently move together with very high precision. Two most common reasons why people use double or triple system instead of a single spectrometer are *high spectral resolution* and *high stray light rejection*. These two effects can be achieved in different modes of TriVista operation:

1. Additive mode gives high spectral resolution and high linear dispersion.
2. Subtractive mode gives high stray light rejection.

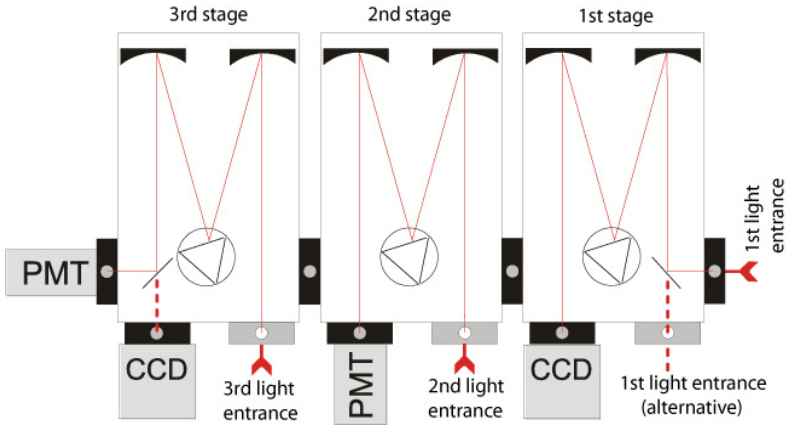

Figure 8. Single Configuration

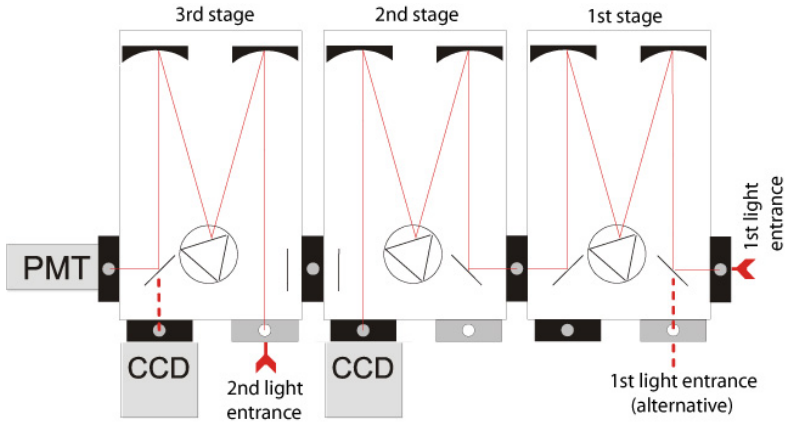

Figure 9. Double Configuration

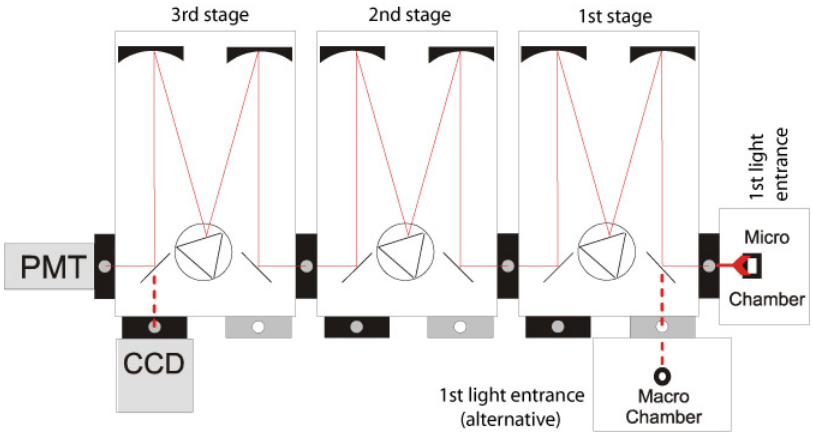

Figure 10. Triple Configuration

3.4 Additive and Subtractive Modes

3.4.1 Additive Mode

In this mode gratings on all 3 stages of spectrometer contribute to positive light dispersion (Figure 11). Polychromatic light enters the first stage of the instrument through the slit S_1. Grating G_1 disperses the light. Slit $S_{1,2}$ acts as a bandpass filter. It allows only a small portion of spectral range to pass through to the second stage and to be further dispersed on the grating G_2. Light passing through the slit $S_{2,3}$ is dispersed for a third time on the grating G_3 and is projected on detector D.

The dispersion of TriVista in additive mode is defined by adding dispersions of each stage. If all three stages have the same gratings and focal lengths, the dispersion is simply equal to the triple dispersion of any of its single stages. Let us consider TriVista555 as an example where 1800 g/mm gratings are used on each stage. A single 500 mm stage with a 1800 g/mm grating has a nominal linear dispersion of 0.9 nm/mm. In the triple additive mode, linear dispersion of the TriVista555 approximately equals 0.3 nm/mm in the visible spectral range.

While working with a CCD detector in additive mode slits $S_{1,2}$ and $S_{2,3}$ have to be opened relatively wide to allow spectral coverage of the whole CCD. Broad slit width inevitably contributes to excessive stray light. When working with a PMT slit $S_{2,3}$ theoretically can be kept as narrow as 10 µm. (Practically, we would advise using slits below 30-50 µm with caution because of low light throughput and limitations of turret positioning precision.) If you are using a PMT in triple additive mode, high resolution and high stray light rejection can be achieved simultaneously. However, the disadvantage of working with a PMT is the time-consuming scanning in order to record a wide spectral range.

3.4.2 Subtractive Mode

Excellent stray light rejection with CCD detector can be achieved in subtractive mode. In this mode, the first and the second stages of spectrometer work as a tunable bandpass filter to allow only the desired portion of spectrum to pass through. At the same time, the third stage projects this spectrum it on the CCD (see Figure 12). A polychromatic light enters the first stage through the entrance slit S_1 and is dispersed by the grating G_1. Slit $S_{1,2}$ again acts as a bandpass filter passing only the light between wavelengths λ_1 and λ_2. The grating G_2 recombines all the dispersed light and focuses it into the middle of the slit $S_{2,3}$ producing again a polychromatic light limited to the spectral range between wavelengths λ_1 and λ_2. Grating S_3 disperses this light and projects it on the detector.

Slit $S_{1,2}$ in subtractive mode is usually relatively wide opened to allow desirable spectral range λ_1-λ_2 to pass through. But the slit $S_{2,3}$ is normally very narrow which assures high stray light rejection.

The groove density of gratings G_1 and G_2 in subtractive mode should match so their dispersive actions totally cancel each other. The first and the second stages of TriVista act as a very sharp bandpass filter allowing for Raman measurements very close to the laser line. In this case, the spectral resolution of TriVista is entirely defined by the spectral resolution of the third stage, depending on slit $S_{2,3}$ width, grating S_3 groove density, and the third stage focal length.

It is possible to use CCD or PMT detector with TriVista working in subtractive mode. Though, the CCD type is preferable because of reduced time required to take measurements.

3.4.3 EasySwitch between Additive and Subtractive Modes

TriVista software offers an easy way to switch between additive and subtractive modes just by mouse-clicking. The physical mechanism behind this switch is changing direction of grating rotation. In additive mode both gratings S_1 and S_2 synchronously rotate clockwise adding dispersion to each other. In subtractive mode grating S_1 rotates clockwise but the grating S_2 synchronously rotates counter-clockwise precisely canceling dispersive action of the grating S_1.

Modes	Double Additive	Double Subtractive	Triple Additive	Triple Subtractive
Primary function	High resolution	Tunable bandpass filter	Best resolution	Best stray light rejection

Table 4. Primary Functions of TriVista modes

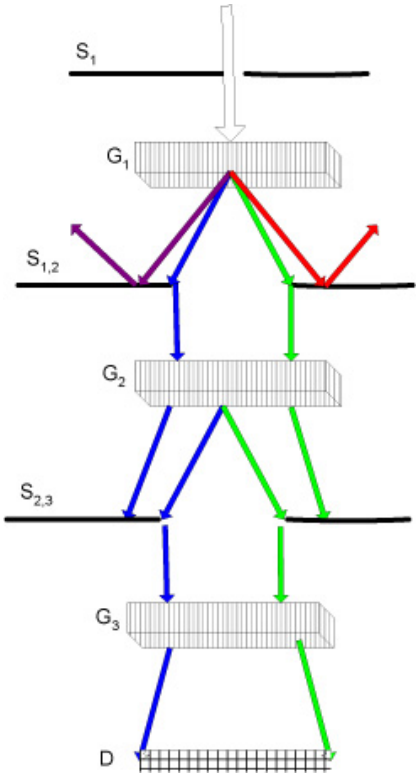

Figure 11. Additive Mode

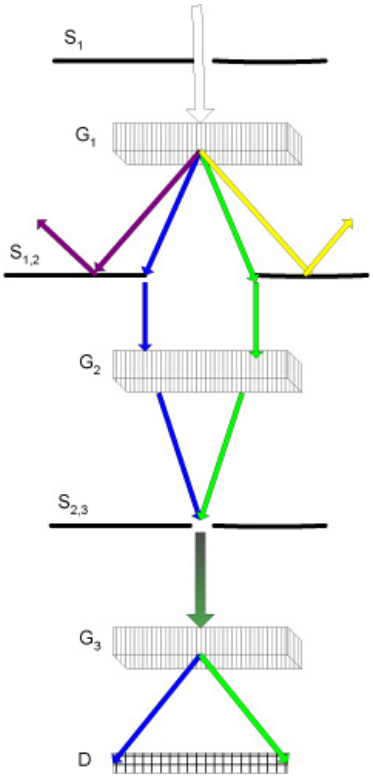

Figure 12. Subtractive Mode

3.5 Central Wavelength Position (for single stage only)

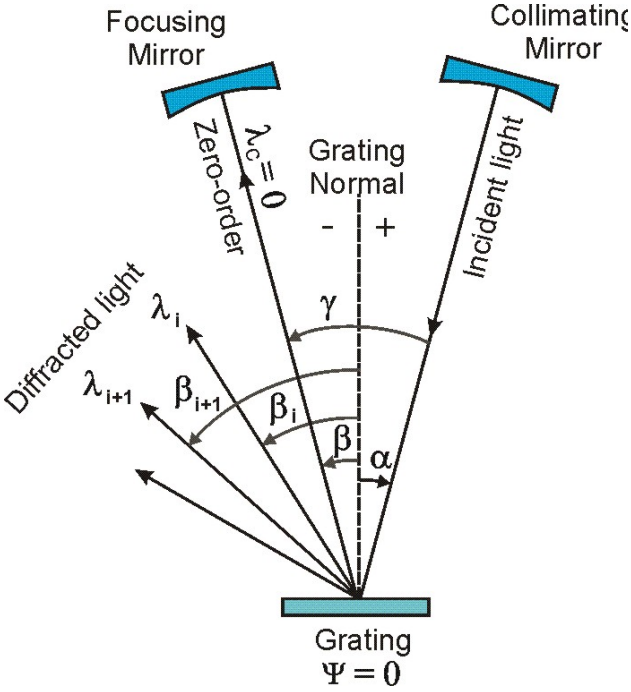

Figure 13. Grating is in Zero-order Position (works like a mirror)

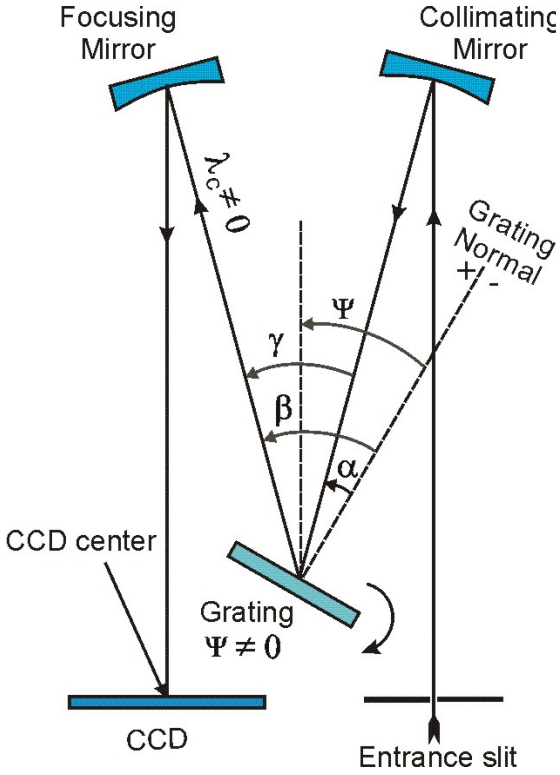

Figure 14. Grating stopped at about 30° Clockwise relative to Zero-order Position

After a polychromatic (white) beam of light passes through spectrometer entrance slit, it hits the collimating mirror (see Figure 2 on page 12). Collimated light falls on the grating surface at the incidence angle α (see Figure 13). The grating disperses this white light into multiple wavelengths in multiple orders of dispersion. Each wavelength λ_i is diffracted at a certain angle β_i. The wavelength reaching the center of CCD is called the *central wavelength* λ_C. Correlation between central wavelength λ_C, incidence angle α and diffraction angle β is expressed by the basic grating equation:

$$10^{-6} \cdot m \cdot N \cdot \lambda_C = \sin(\alpha) + \sin(\beta) \quad (1),$$

where m is order of dispersion; N is grating density [groove/mm]; λ_C is the central wavelength [nm]; 10^{-6} is a factor adjusting the difference between nm and mm units used.

All TriVista stages use Czerny-Turner spectrometer design with fixed *inclusion angle* γ (Figure 13). For 500 mm stage γ = 17.17°; For 750 mm stage γ = 13.10°. In general, inclusion angle γ is the difference between diffraction angle β of the central wavelength and incidence angle α:

$$\gamma = \beta - \alpha = \text{const} \quad (2).$$

At this point you will need to remember the conventional rule of signs. Angle is considered to be positive if it lies at the same side from the grating normal as the incident light beam. And it is negative if it is on the opposite side. In Figure 13 diffraction angle β and inclusion angle γ are negative and the incidence angle α is positive.

Figure 13 shows the situation when grating is located in zero position (grating rotation angle ψ = 0). Grating normal is directed towards the middle point between collimating and focusing mirrors and absolute values of incidence angle α and diffraction angle β are equal (taking into account the rule of signs β = - α). In this position grating works as a mirror and the zero-order wavelength $\lambda_C = 0$ is situated at the center of CCD.

Now consider that we start slowly rotating the grating clockwise increasing the grating angle ψ. Then gradually increasing wavelengths (λ = 100, 200, 300 nm etc.) will come through the CCD center. Figure 14 shows the grating stopped at the angle of about 30° clockwise relative to the zero-order position. If you want to position wavelength λ_C at the CCD center the grating rotation angle ψ can be calculated by the equation:

$$\psi = \arcsin\left(\frac{m \cdot N \cdot \lambda_C}{2 \cdot 10^6 \cdot \cos\left(\frac{\gamma}{2}\right)}\right) \quad (3),$$

where m is order of dispersion; N is grating density [groove/mm]; λ is the central wavelength.

The incidence angle α and diffraction angle β of the central wavelength can be calculated:

$$\alpha = \psi - \frac{\gamma}{2} \quad (4);$$

$$\beta = \psi + \frac{\gamma}{2}.$$

All these equations are listed solely to demonstrate the basic concepts and show how grating works and what happens when it rotates. In reality you don’t have to calculate anything. The only thing you will have to do is to plug in the number for the central wavelength and TriVista software will calculate grating rotation angles ψ for all stages and precisely position each grating.

3.6 Wavelength Positioning across CCD (for single stage only)

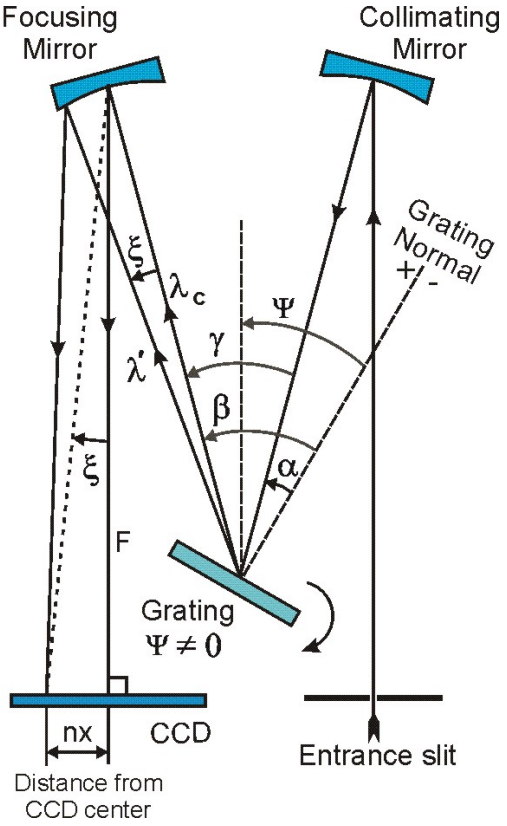

Figure 15. Wavelengths across CCD

A CCD consists of many small light detection elements – pixels. The most common CCD widths are 512, 1024, 1340 or 2048 pixels, but some of them can be up to 6000 pixels wide. Finding the central wavelength λ_c simply means to determine what wavelength is going to illuminate the single central pixel. What about all other pixels?

3.6.1 When CCD Focal Plane is perpendicular to Central Wavelength Beam

A grating simultaneously diffracts all possible individual wavelengths and spreads them in all possible directions. Some part of this spectrum reaches the CCD. Wavelength λ', which illuminates the CCD not exactly at the center, is diffracted at an angle different from the central diffraction angle β by the small angle ξ (Figure 15).

$$\beta' = \beta + \xi \quad (5).$$

The distance from the CCD center to the point where λ' hits the CCD can be calculated as the number of pixels n multiplied by the single pixel width x:

$$d = n \cdot x \quad (6).$$

Focal length F of Czerny-Turner spectrograph is the distance between the optical center of the focusing mirror and the center of CCD. Then tangent of ξ can be found:

$$\tan(\xi) = \frac{n \cdot x}{F} \quad (7a).$$

From which we can find angle ξ itself:

$$\xi = \text{acrtan}\left(\frac{n \cdot x}{F}\right) \quad (7b).$$

Taking the basic grating equation (1) and using equations (4), (5) and (7b) we can find the wavelength λ' [nm] which illuminates the n-th pixel from the CCD center:

$$\lambda' = \frac{\sin(\alpha) + \sin(\beta')}{10^{-6} \cdot m \cdot N} = \frac{\sin(\alpha) + \sin(\beta + \xi)}{10^{-6} \cdot m \cdot N} = \frac{\sin\left(\psi - \frac{\gamma}{2}\right) + \sin\left(\psi + \frac{\gamma}{2} + \arctan\left(\frac{n \cdot x}{F}\right)\right)}{10^{-6} \cdot m \cdot N} \quad (8),$$

where ψ is the grating rotation angle which can be found from the equation (3); γ is the inclusion angle of spectrograph; n is the number of pixels from the CCD center; x is the single pixel width [mm]; F is the spectrograph focal length [mm]; m is the dispersion order; N is the grating density [g/mm].

3.6.2 When CCD Focal Plane tilted from Perpendicular Position

All previous calculations were made in assumption that CCD focal plane is strictly perpendicular to the central wavelength beam. In many cases spectrometers are designed in a way that the CCD focal plane is tilted by the angle δ relative to the perpendicular position (Figure 16). As a matter of fact, when proper alignment is maintained CCD focal plane for 500 mm stages of TriVista is absolutely perpendicular to the central wavelength (δ = 0) while 750 mm stages have tilt of δ = -0.68°.

Figure 17 gives more clear visual perception of the CCD tilt effect. Now the distance from the CCD center to the n^{th} pixel can be calculated taking angle δ into consideration:

$$d = n \cdot x \cdot \cos(\delta) \quad (9).$$

Focal length F increases by a small increment of ΔF = n·x·sin(δ). Then tangent of ξ can be now found:

$$\tan(\xi) = \frac{n \cdot x \cdot \cos(\delta)}{F + n \cdot x \cdot \sin(\delta)} \quad (10a).$$

From which we can find angle ξ itself:

$$\xi = \text{acrtan}\left(\frac{n \cdot x \cdot \cos(\delta)}{F + n \cdot x \cdot \sin(\delta)}\right) \quad (10b).$$

Calculating ξ, don't forget to use the same units, say, [mm] for both focal length F and pixel width x. Now we can find which wavelength λ' illuminates the n^{th} pixel from the CCD center taking into account CCD angle δ.

$$\lambda' = \frac{\sin\left(\psi - \frac{\gamma}{2}\right) + \sin\left(\psi + \frac{\gamma}{2} + \arctan\left(\frac{n \cdot x \cdot \cos(\delta)}{F + n \cdot x \cdot \sin(\delta)}\right)\right)}{10^{-6} \cdot m \cdot N} \quad (11).$$

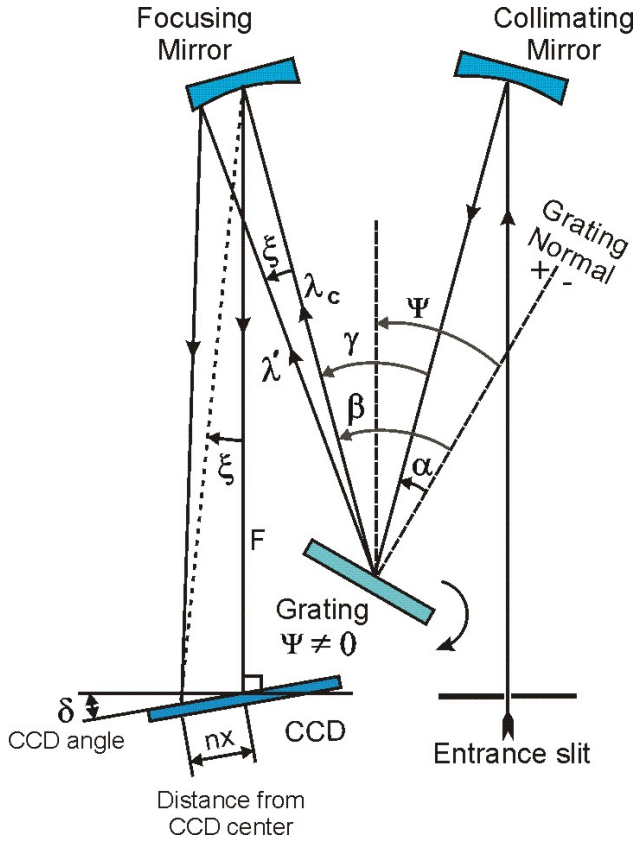

Figure 16. CCD Focal Plane tilted by Angle δ relative to the Perpendicular Position

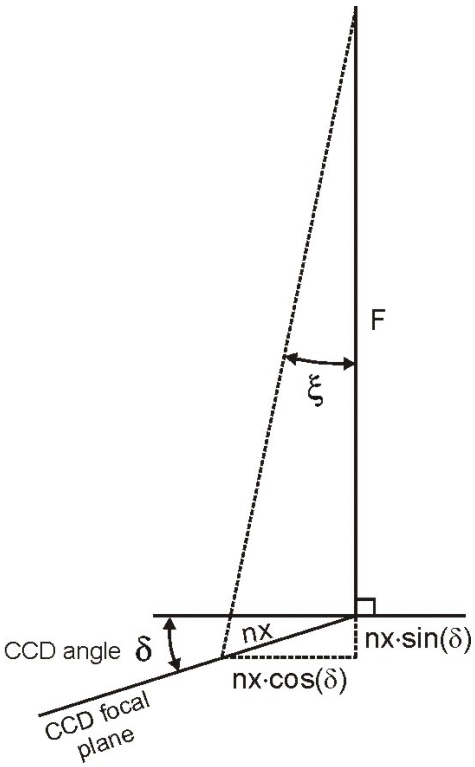

Figure 17. CCD Tilt Effect

3.7 Linear Dispersion

Linear dispersion for a single stage defines how well wavelengths are spatially spread across the focal plane of CCD. It is usually measured in nm/mm or cm^{-1}/mm. For example, if the full width of CCD is 25 mm, the central wavelength is 400 nm, the leftmost pixel "sees" wavelength λ = 300 nm and the rightmost pixel "sees" wavelength λ = 500 nm, then the linear dispersion across CCD is D = (500-300)/25 = 8 nm/mm (Figure 18). This example gives an idea of what the linear dispersion is but it is very simplified. For a single stage spectrometer at the center wavelength linear dispersion is calculated:

$$D = \frac{d\lambda}{dx} = \frac{10^6 \cdot \cos(\beta)}{m \cdot N \cdot F} \quad (12),$$

where β is the diffraction angle of central wavelength; m is order of dispersion; N is grating density [groove/mm]; F is a spectrometer focal length [mm].

Diffraction angle β changes with the wavelength, therefore, linear dispersion is actually a non-linear function of wavelength λ and it varies across the CCD. Linear dispersion D increases with λ increase. Figure 19 shows more realistic picture. All numerical data are cited for illustration purposes only but the fact is that linear dispersion at lower wavelengths (normally at the left of the CCD) is smaller than at higher wavelengths. Linear dispersion at the left half of CCD D_L = (400-310)/12.5 = 7.2 nm/mm. Linear

dispersion at the right half of CCD D_R = (510-400)/12.5 = 8.8 nm/mm. Central linear dispersion D_C = (510-310)/25 = 8.0 nm/mm ($D_L < D_C < D_R$).

As you can see, linear dispersion at the central wavelength can be used with a certain precision as an average linear dispersion across the whole CCD.

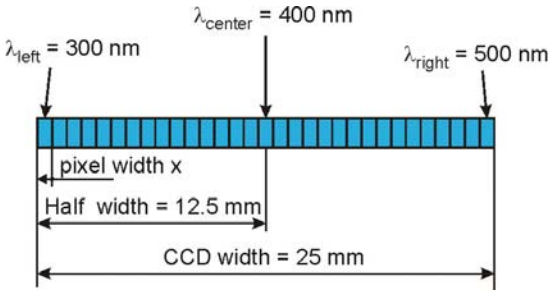

Figure 18. Linear Dispersion across CCD is D = (500-300)/25 = 8 nm/mm

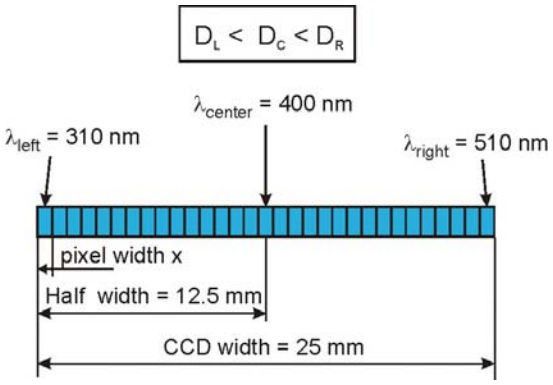

Figure 19. Linear Dispersion differs across CCD

3.7.1 Triple Subtractive Mode

It is very easy to calculate linear dispersion for triple subtractive configuration of TriVista. It always equals to the linear dispersion of the 3rd stage. That happens because dispersive actions of the 1st and the 2nd gratings cancel each other. Therefore, you can use formula (12) directly. Do not forget that it gives you linear dispersion at the central wavelength. Dispersion values at the CCD edges may be slightly different.

3.7.2 Triple Additive Mode

Linear dispersion of triple additive configuration of TriVista is much more sophisticated because the light beam leaving one stage and going to the next one is already dispersed into spectrum. The final linear dispersion is non-linear function of focal lengths, grating groove densities and inclusion angles of all three stages. In general case linear dispersion for TriVista in triple additive configuration is found empirically or calculated with special ray-tracing software. Though, there are a few special cases when linear dispersion for triple additive configuration can be approximately calculated manually:

1. If all TriVista stages are of the same length (555 and 777) and gratings of the same groove density are used, the resulting linear dispersion can be approximately calculated by adding focal length of all stages to the equation (12):

   $$F_{effective} = F_1 + F_2 + F_3 \quad (13),$$

   where F_i is a focal length of i th stage.

2. If gratings of the same groove density are used on all TriVista stages and stages are of different length (TriVista 557), you have to use formula (13) to calculate the effective focal length. Besides you will need to calculate the effective inclusion angle:

   $$\gamma_{effective} = \frac{\gamma_1 \cdot F_1 + \gamma_2 \cdot F_2 + \gamma_3 \cdot F_3}{F_1 + F_2 + F_3} \quad (14),$$

   where F_i is a focal length of i th stage; γ_i is inclusion angle of i th stage.

Remember that these calculations are approximate and can be used for reference purposes only. In Appendix A you can find reference tables with linear dispersion for TriVista 555, 557 and 777 for both additive and subtractive triple configurations at multiple central wavelengths.

3.8 Relative Wavenumbers [cm^{-1}]

Two major spectral units are wavelength λ [nm] and absolute wavenumber ν [cm^{-1}]. Here are the conversion equations between them:

$$\nu_{cm^{-1}} = \frac{10^7}{\lambda_{nm}} \quad (15a);$$

$$\lambda_{nm} = \frac{10^7}{\nu_{cm^{-1}}} \quad (15b).$$

The conversion factor 10^7 was added because 1 cm = 10^7 nm.

TriVista is often used for Raman measurements where spectral peak position is normally expressed not in absolute units but in units relative to the laser wavelength. *Relative wavenumber* Δν is a difference in absolute wavenumbers between laser wavelength and the spectral peak of interest. *Relative wavelength* Δλ is a difference in nm between laser wavelength and the spectral peak of interest. Relative wavenumber Δν [cm^{-1}] and relative wavelength Δλ [nm] positions of a spectral peak can be calculated using the following equations:

$$\Delta\nu = \left(\frac{1}{\lambda} - \frac{1}{\lambda + \Delta\lambda}\right)\cdot 10^7 \quad (16a);$$

$$\Delta\lambda = \left(\frac{1}{\nu - \Delta\nu} - \frac{1}{\nu}\right)\cdot 10^7 \quad (16b),$$

where λ is laser wavelength [nm]; Δλ is relative wavelength position of a spectral peak [nm]; ν is laser absolute wavenumber [cm^{-1}]; Δν is relative wavenumber position of a spectral peak [cm^{-1}].

Equation (16b) can be used to calculate linear dispersion in relative wavenumbers per mm [cm^{-1}/mm]. In this case laser wavelength λ in equation (16b) should be substituted with the central wavelength and the relative wavelength Δλ is substituted with linear dispersion value in [nm/mm]. Appendix A shows linear dispersion for TriVista 555, 557 and 777 in both [nm/mm] and [cm^{-1}/mm] units.

3.9 Spectral Coverage and Spectral Resolution

3.9.1 Spectral Coverage

Linear dispersion leads us to the concept of CCD *spectral coverage* which simply defines what portion of spectrum illuminates the CCD. Both Figure 18 and Figure 19 show spectral coverage S of 200 nm over the 25 mm CCD width:

$S = \lambda_{max} - \lambda_{min} = 500 - 300 = 510 - 310 = 200$ nm.

Spectral coverage is a function of the linear dispersion D and CCD width W:

$$S = D \cdot W \quad (17).$$

As we mentioned earlier it can be approximately calculated by multiplying central linear dispersion by full CCD width. Using numerical data from Figure 19, we can calculate approximate spectral coverage:

$S = D_C \cdot W = 8 \cdot 25 = 200$ nm.

The exact spectral coverage can be found from equation (11). It will be equal to the difference between wavelengths of the leftmost and rightmost pixels on CCD.

3.9.2 Pixel Bandpass

CCD consists of pixels of finite width x. Each pixel is actually illuminated by very narrow but finite spectral range. We can even define the wavelengths at the left and right edges of each pixel. But they usually do not have any practical value. The really important parameter we want to know is wavelength at the center of an n^{th} pixel (from the CCD center) which you can calculate using equation (11). Another important parameter is the difference between wavelengths at the left and right edges of the pixel which is called *pixel bandpass*. The average pixel bandpass can be calculated by multiplying linear dispersion at the CCD center by pixel width x:

$$B = D_C \cdot x, \quad (16)$$

where D is linear dispersion [nm/mm]; x is pixel width [mm].

For example, if your CCD pixel size is 20 μm (0.020 mm) and the central dispersion D_C = 8 nm/mm then 1 pixel will cover spectral range $B = 8 \cdot 0.020 = 0.16$ nm.

Pixel bandpass can be viewed as the ultimate spectral resolution of multi-channel spectroscopy system limited by both linear dispersion of spectrograph and the pixel size of detector.

3.9.3 FWHM Spectral Resolution

Consider that if two closely spaced spectral lines are projected on two adjacent CCD pixels one could not tell if there is actually one or two peaks. In reality, it takes at least 2.5-3 CCD pixels to resolve two close peaks. The formal rule says that two peaks are spectrally resolved when the maximum of one peak corresponds to the minimum of another peak (Figure 20).

Every peak width is wide at the bottom and has zero width at the top. The peak width at exactly the middle of its height H is called Full Width Half Maximum (FWHM) and is often used as a measure of practically achieved spectral resolution. FWHM takes into consideration all optical aberrations and such spectrograph settings like entrance slit width. FWHM can be expressed in CCD pixels or nm and is used for characterizing spectral resolution of an instrument. Note that most spectral lines from the real world are quite wide on their own and they can’t be used to judge the instrument performance. To measure FWHM intrinsic to the TriVista system only such light sources as good quality single-mode laser or calibration mercury lamp should be used since their spectral lines are very thin.

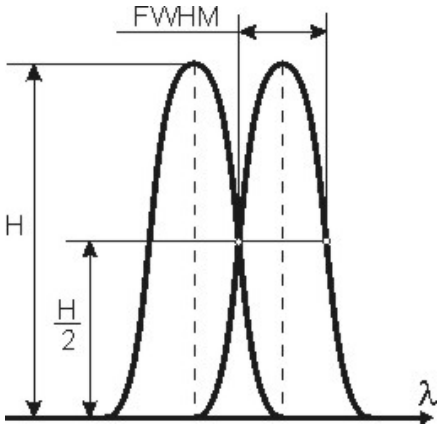

Figure 20. FWHM Illustration

3.10 Spectral Coverage of CCD in Triple Configuration

TriVista system comes with the choice of dispersive gratings corresponding to the range of your applications. When you use multi-channel detector (CCD or PDA) in triple configuration it is not obvious that you are always getting full CCD coverage like you would expect in single configuration. To get full CCD coverage you have to make *the right choice of gratings on all three stages and set appropriate widths for the two intermediate slits*. Different approaches apply for triple additive and triple subtractive configurations.

Note: The 1st intermediate slit is treated as the 2nd stage entrance slit and the 2nd intermediate slit is treated as the 3rd stage entrance slit (Figure 21).

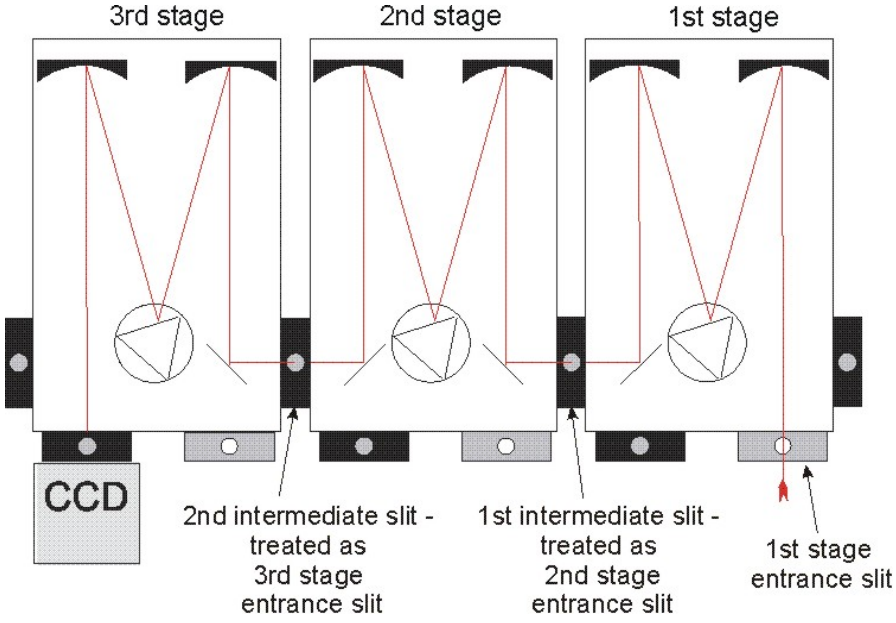

Figure 21. Intermediate Slits treated as Entrance Slits

3.10.1 Triple Subtractive Configuration

Triple subtractive configuration is intended for measurements requiring the best stray light rejection. To allow this happening we need to keep the 1st stage entrance slit and the 2nd intermediate slit very narrow (usually 30-100 μm). But the 1st intermediate slit should be normally opened to 1-12 mm to allow wide enough bandpass (range of spectrum) to pass through.

Note: In subtractive mode it is extremely important to choose exactly the same gratings on the 1st and the 2nd stages so their dispersive actions would precisely cancel each other!

Let us consider a few practical examples of how to choose combination of gratings and slit widths for TriVista 555 with 25mm wide CCD. In all examples we use central wavelength λ = 600nm in the first order dispersion. Numerical values for linear dispersion are taken from table in Appendix A. Table 5 shows TriVista setup parameters and their effect on fullness of CCD spectral coverage.

Example	1	2	3
Stage 1			
Entrance slit, μm	30	30	30
Bandpass, nm	∞ (White)	∞ (White)	∞ (White)
Grating, g/mm	900	900	900
Linear dispersion, nm/mm	2.02	2.02	2.02
Stage 2			
1st intermediate slit, mm	3	12	12
Bandpass	6.06 (Spectrum)	24.24 (Spectrum)	24.24 nm (Spectrum)
Grating, g/mm	900	900	900
Linear dispersion, nm/mm	-	-	-
Stage 3			
2nd intermediate slit, μm	30	30	30
Bandpass, nm	6.06 (White)	24.24 (White)	20.75 (White)
Grating, g/mm	900	900	1800
Linear dispersion, nm/mm	2.02	2.02	0.83
CCD coverage, mm	3	12	25

Table 5. CCD Coverage in Triple Subtractive Configuration for TriVista 555 (using 600 nm central wavelength in the first order of dispersion)

Example 1.

In the first example, we choose equal gratings of 900 g/mm on all three stages of TriVista 555. The 1st stage entrance slit and the 2nd intermediate slit are set to 30 μm to ensure the best stray light rejection. The 1st intermediate slit is opened to 3 mm (3000 μm).

Note: To increase light throughput, it is practical in many cases to keep the 1st stage entrance slit and the 2nd intermediate slit widths at 50-70 μm. This does not affect CCD coverage but slightly degrades FWHM spectral resolution.

Signal coming through the 1st stage entrance slit represents a white light with a mix of all possible wavelengths. That's why we identified it as "∞ (White)". After the 1st stage this light is dispersed by 900 g/mm grating into the spectrum with the linear dispersion 2.02 nm/mm (see dispersion data in Appendix A for TriVista 555 in subtractive mode with 900 g/mm grating on the third stage at central wavelength 600 nm). This spectrum is projected onto the 1st intermediate slit. Since the width of the slit is 3 mm the bandpass of $3 \cdot 2.02 = 6.06$ nm will pass through to the 2nd stage. Grating on the 2nd stage works in subtractive mode. The 6.06 nm wide bandpass converges back into the narrow beam of white light which passes through the middle of the second intermediate slit. Light leaving the 2nd stage and entering the 3rd stage doesn't have any linear dispersion characteristic. It is essentially the white light composed of narrow 6.06 nm bandpass. On the 3rd stage this white light is dispersed again by 900 g/mm grating with 2.02 nm/mm linear dispersion before reaching CCD focal plane. Since the total bandpass is 6.06 nm it means only 6.06/2.02 = 3 mm in the center of CCD will be illuminated. Remembering that our center wavelength was 600 nm we are able to see the bandpass approximately between 597 to 603 nm. Since dispersion is non-linear across the CCD the spectral boundaries will be slightly different.

Example 2.

Using the same configuration from the Example 1, we will open the 1st intermediate slit to the full 12 mm width. Following the logic of the Example 1 we will obtain $12 \cdot 2.02 = 24.24$ nm bandpass entering the 3rd stage which will allow illuminating 12 mm of the central CCD area (see Table 5).

You may also notice that in both examples the width of CCD illumination was nothing else but projection of the 1st intermediate slit width. This happened because we were using gratings of the same groove density on all three stages.

Example 3.

Let us leave the 1st intermediate slit to be fully opened to 12 mm. It will give us the same 24.24 nm bandpass entering the 3rd stage. But now we change the 3rd stage grating from 900 g/mm to 1800 g/mm. This grating has linear dispersion 0.83 nm/mm. Therefore, 24.24/ 0.83 = 29.20 mm can be potentially illuminated. Though, the useful spectral coverage will be only 25 mm which corresponds to our full CCD width. This will cut the bandpass projected on CCD from 24.24 nm to $24.24 \cdot 25/ 29.20 = 20.75$

3.10.2 Triple Additive Configuration

Triple additive configuration is used primarily for taking spectra with high spectral resolution since focal length of all three stages is added together. In this configuration both intermediate slits should be wide opened. Normally the 2nd intermediate slit is opened wider then the 1st one.

Let us consider a few practical examples of how 25 mm wide CCD is illuminated using TriVista 555 in triple additive configuration. In all examples we use central wavelength λ = 600 nm in the first order dispersion. Numerical values for linear dispersion are taken from the table in Appendix A.

Example	1	2	3
Stage 1			
Entrance slit, μm	30	30	30
Bandpass, nm	∞ (White)	∞ (White)	∞ (White)
Grating, g/mm	900	900	900
Linear dispersion, nm/mm	2.02	2.02	2.02
Stage 2			
1st intermediate slit, mm	3	6	6
Bandpass, nm	6.06 (Spectrum)	12.12 (Spectrum)	12.12 (Spectrum)
Grating, g/mm	900	900	900
Linear dispersion, nm/mm	1.01	1.01	1.01
Stage 3			
2nd intermediate slit, mm	6	12	12
Bandpass, nm	6.06 (Spectrum)	12.12 (Spectrum)	12 (Spectrum)
Grating, g/mm	900	900	1800
Linear dispersion, nm/mm	0.67 nm/mm	0.67 nm/mm	0.48 nm/mm
CCD coverage, mm	9.04	18.09	25

Table 6. CCD coverage in Triple Additive Configuration for TriVista 555 (using 600 nm central wavelength in the first order of dispersion)

Example 1.

In the first example we again choose equal gratings of 900 g/mm on all three stages. Entrance slit on the 1st stage is set to 30 μm to ensure the best spectral resolution. The 1st intermediate slit is opened to 3 mm (3000 μm) and the 2nd intermediate slit is opened to 6 mm (6000 μm).

Signal coming through the 1st stage entrance slit represents a white light with a mix of all possible wavelengths. That's why we indicated it as "∞ (White)". After the 1st stage this light is dispersed by 900 g/mm grating into the spectrum with the linear dispersion 2.02 nm/mm. This spectrum is projected onto the 1st intermediate slit. Since the width of the slit is 3 mm the bandpass of $3 \cdot 2.02 = 6.06$ nm will pass through to the 2nd stage. Grating on the 2nd stage works in additive mode. Focal lengths of the 1st and the 2nd stages add together and the linear dispersion on the 2nd stage becomes 1.01 nm/mm. The 6.06 nm bandpass is therefore spreading over 6.06/1.01 = 6 mm. This is the reason we have chosen the 2nd intermediate slit to be 6 mm wide. If we would decrease its width, say, to 3 mm it would cut the bandpass from 6.6 to 3.03 nm. If we would open it wider then 6 mm it would allow additional stray light to pass through without any real benefit to bandpass widening and CCD coverage.

The 3rd stage focal length adds up and the linear dispersion on the 3rd stage increases to 0.67 nm/mm. The bandpass of 6.06 nm illuminates 6.06/0.67 = 9.04 mm of the center CCD area.

Example 2.

In this example we will use the same system as in the Example 1 but will open the 1st and the 2nd intermediate slits to 6 and 12 mm correspondingly. The 1st stage linear dispersion 2.02 nm/mm allows bandpass of $6 \cdot 2.02 = 12.12$ nm to pass through to the 2nd stage. The 2nd stage linear dispersion 1.01 nm/mm spreads the same bandpass over the 12.12/1.01 = 12 mm width of the second intermediate slit. The 3rd stage linear dispersion 0.67 nm/mm illuminates 12.12/0.67 = 18.09 mm of CCD center area.

Example 3.

We will use the system from the Example 2 when intermediate slits are opened to 6 and 12 mm. On top of that we will use 1800 g/mm grating on the 3rd stage. The linear dispersion on the 3rd stage is 0.48 nm/mm. Therefore bandpass of 12.12 nm passing from the 2nd to the 3rd stage can potentially illuminate 12.12/0.48 = 25.25 mm. The useful coverage will be only 25 mm which corresponds to our full CCD width. This will cut bandpass projected on CCD from 12.12 nm to $12.12 \cdot 25 / 25.25 = 12$ nm.

3.10.3 Summary

All these examples demonstrate the principles of how to select the correct TriVista configuration to illuminate the whole CCD width:

1. In triple subtractive configuration, open the 1st intermediate slit to the full 12 mm width. On the 1st and 2nd stages use gratings of the same groove density. On the 3rd stage use grating of double groove density.
2. In triple additive configuration, open the 1st intermediate slit to 6 mm, the 2nd intermediate slit to 12 mm. On the 1st and 2nd stages use gratings of the same groove density. On the 3rd stage use grating of double groove density.

If you use a CCD or PDA of considerably different width or have a TriVista 557, you will need to accommodate the described above principles to your situation by playing with grating density and intermediate slit widths.

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Chapter 4
Operation

4.1 Turning the System ON and OFF

To assure smooth operation of the system and to avoid any possible hardware or software conflicts, the following sequences of operations should be strictly observed while turning the system **ON** and **OFF**.

Turning the system ON

When you are turning TriVista ON:

1. Turn power to PC, spectrometer stages and detectors **ON**.
2. Start WinSpec.
3. Start S&I software.
4. Set up software configuration (see Chapter 5 – Software).
5. Start data acquisition.

Turning the system OFF

The reversed procedure is true for turning the system OFF:

1. Stop data acquisition.
2. Close S&I software.
3. Close WinSpec.
4. Turn power to PC, spectrometer stages and detectors OFF.

Spectrometer stages in standby mode consume negligible amount of electric power and you can leave them powered ON all the time unless you are not planning to use TriVista in a month or two. No damage will occur to the stages if they stay ON for a long period of time. You also may leave the detector powered ON all the time if you use it on a daily basis. However, it is better to turn detector power OFF you are not planning on using it in the next 3-4 days.

Note: If for some reason you happened to turn your detector power **OFF** while software is still running and then turn your detector power **ON**, you might need to restart your PC and follow the procedure for turning the system **ON** from the very beginning.

4.2 Manual Slit Width Adjustment

Unless you specifically ordered additional motorized slits your, TriVista system should have five (5) manual slits. Four of them are installed on the entrance slits of the 3 stages and the 5th one serves as the exit slit for the 3rd stage. Each manual slit contains two bilateral razor-sharp jaws. They are set strictly parallel and the distance between them is precisely calibrated at the factory to allow controlled amount of light to enter or exit TriVista stages. Always check the widths of manual slits before starting your experiment.

The slit width of each bilateral slit assembly (Acton 716 type) is adjustable from 0.010 millimeters to 3 millimeters (10 µm to 3,000 µm) by a micrometer located on the top of

the slit housing. The micrometer knob is graduated in 0.010 millimeter (10 µm) increments.

Each full clockwise revolution of the micrometer knob increases the slit width 0.25 millimeters (250 µm). For maximum reproducibility, the slit width should be set in a clockwise direction (increasing slit widths) each time it is changed. Refer to the drawing below.

The micrometer knob should not be rotated below a reading of 0.00 or above 3.00. A micrometer setting of less than 0.010 millimeters (10 µm) should not be used, because a stop is provided to prevent the slit jaws from contacting each other.

WARNING Damage may be done if slit jaws are opened wider than 3.0 mm.

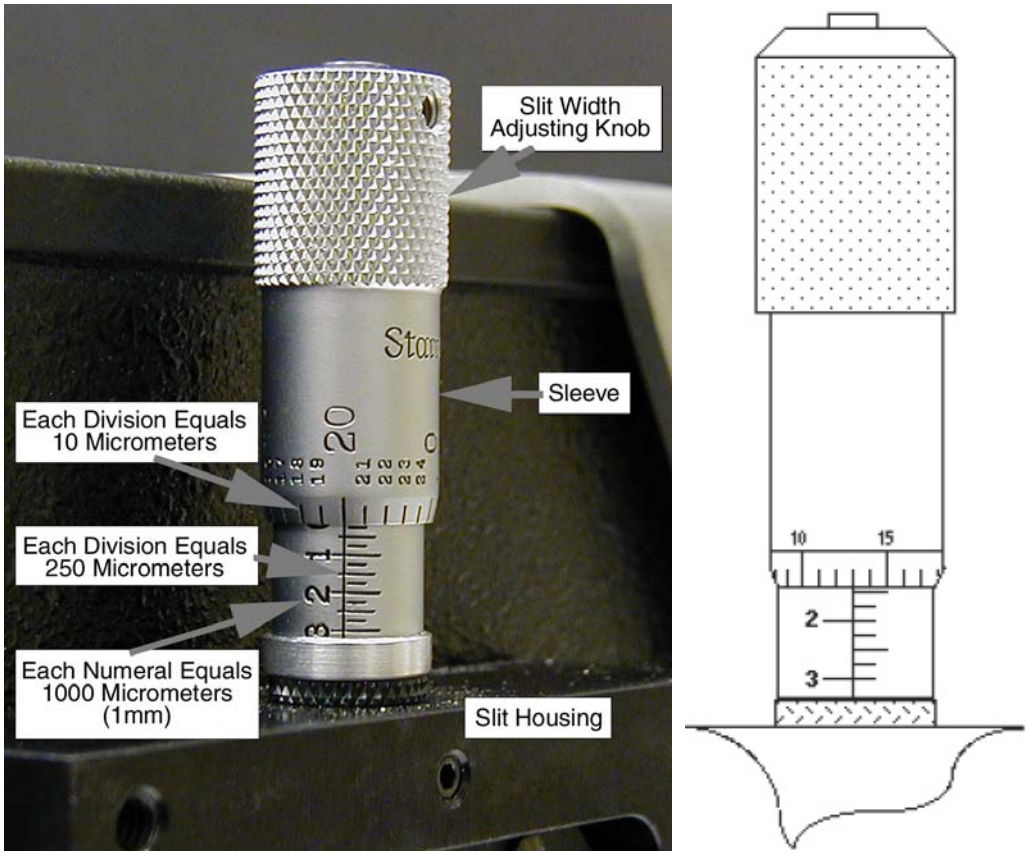


Figure 22. Slit width settings of 0.200 mm and 1.38 mm.

4.3 Focusing and Alignment of Array Detectors

If you have questions on how to mount your array detector (CCD or OMA-V) onto a spectrometer, please refer to the detector's system manual. Here, we provide guidance on how to align and focus a detector that has already been mounted.

The detector mounting adapter provides two degrees of freedom - focus and vertical alignment. For focusing, you slowly slide the detector in and out of the spectrometer. At the same time, you are watching on the monitor for changes in peak width and intensity.

For vertical alignment, you rotate the detector, again, adjusting for the optimum peak shape. The detailed procedure follows.

1. Mount a light source such as a mercury pen-ray type in front of the entrance slit. The spectrum of a mercury-argon calibration lamp is provided in Appendix H. This lamp is good for calibration in the wide UV-NIR range.

   Any light source with line output can be used. Standard fluorescent overhead lamps have good calibration lines at 435.833 nm, 546.073 nm, and a doublet 576.96 and 579.066 nm 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 0.0 nm for alignment purposes.

2. With the spectrograph properly connected to the computer, turn the power ON and wait for the spectrograph to initialize. Then set it to 435.833 nm if using a mercury lamp or to 0.0 nm if using a broadband source, or another wavelength corresponding to a spectrum produced by another "line" 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 spectrometer. Select 435.833 as the spectral line.

3. Set the entrance slit to 20 µm.

4. Set the Exposure Time of the array to a convenient value somewhere in the range of 0.01 s to 1 s, making sure the detector is not overfilled.

5. Run the Detector in live mode and watch the display on the monitor.

   Hint: If using WinSpec/32, simply select FOCUS with Freerun and Safe Mode timing selected. You can also go to Process menu of WinSpec and click on Focus Helper. Select Helper Active and Full report, Set width to 10-20 and press Ok. Run Focus mode. Click on the spectral peak you are working with. Focus helper will show the screen with the FWHM resolution of your peak. Focusing your detector basically means you need to obtain the sharpest peak with FWHM as narrow as possible.

6. Loosen the detector mounting flange.

   500 mm stage: Use a 3/32" Allen wrench to loosen the two (2) #10-32 set screw (approximately 2 turns) located on the top and side of the front plate. On the 1st and 2nd stages of TriVista, the side set screw is not accessible. Use the top set screw only.

   > The set screws must be loose when turning the thumb wheel adjustment, or severe damage will occur. The distance between the edge of the array detector mounting flange and the instrument MUST NOT exceed .33".

   750 mm stage: Loosen the split clamp.

7. Slowly slide the detector IN or Out until the sharpest image or line is achieved.

8. Move the thumbwheel (500 mm stage) or the thumb focus-stop screw (750 mm stage) until it just makes contact with the detector mounting flange. This enables you to rotate the detector without changing the focus position.

   Hint: The 500 mm stage thumbwheel adjustments may be used to precisely position the detector (1/8th of a turn changes the detector position by approximately 1/10th of a millimeter).

9. Rotate the detector until the light source image is vertical on the CCD or until the best focus is achieved if a diode array is used. 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.
10. After achieving the best vertical alignment, secure the detector mounting flange.

    500 mm stage: Ensure the array detector mounting flange is in contact with the thumb wheel and the two (2) push screws. Tighten the #10-32 set screw on the top of the front plate first, and then tighten the one on the side to secure the detector.

    750 mm stage: Tighten the split clamp to secure the detector.

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.

4.4 Turret Interchange

Read and follow the instructions in this section only if you ordered more then one turret on each stage of TriVista. Otherwise, you never have to interchange turrets.

The 500 mm stage is supplied with one kinematically mounted triple grating turret assembly, but you may order up to three (3) grating turrets for each stage. If experimental conditions are changed from, for example, UV to NIR, it is most likely that the grating turret on each stage will need to be changed. Label your turrets (for example, with the Stage number and spectral range used) and make sure you install the correct grating turret in the correct stage. Only the grating turrets for the same stage are interchangeable without realignment.

CAUTION

1. The optical surfaces in the spectrograph are extremely delicate and can be permanently damaged by contact with solid objects as well as with most liquids and aeorsols.
2. ***DO NOT TOUCH optical surfaces with anything.*** Wear thin protective powderless gloves to minimize damage from body oils if you accidentally touch any optical surface, especially the grating.
3. Avoid talking or sneezing near optical surfaces. Do not breathe directly on them.

The following procedure is recommended for interchanging grating turrets. Observe proper optical handling procedures.

1. Locate the storage container with the new grating turret to be installed.
2. Become familiar with the components as labeled on Figure 23, Figure 24, and Figure 25.
3. Scan the instrument to grating #1 and the **highest** wavelength position permissible by the mechanical scan range (see Chapter 2 for specific numbers).
4. Remove the screws from the spectrograph access cover and remove the access cover. Become familiar with the grating turret and its components.

5. Locate a 9/64 ball end hex wrench. Refer to Figure 25 and with the 9/64 ball end hex wrench, loosen the turret clamping screw #1.

   NOTE: All 3 turret clamping screws are captive.

6. Loosen the turret clamp screw #2 and then #3.
7. Use extreme care so as not to touch the grating surfaces and grasp the top plates of the grating turret, refer to Figure 24. Lift the grating turret straight up off the grating spindle assembly. If the turret cannot be lifted up, assure the 3 clamping screws are disengaged from the grating spindle assembly.
8. Place the removed grating turret assembly on a clean surface.
9. Remove the plastic cover from the grating turret storage container. Loosen the 3 grating turret clamping screws. **NOTE:** These screws are captive.
10. Carefully grasp the grating turret by the top plates.
11. Locate the grating turret # on the grating turret assembly. Assure the monochromator is at grating #1 and at **highest** wavelength position. Refer to Figure 23 and place the grating turret on the grating spindle with the turret # located as shown.
12. Assure the turret is properly seated, the ball in the cone hole and the rod in the vee groove.
13. Lightly tighten clamp screw #1, then #2 and #3.

    NOTE: To assure maximum reproducibility, the clamping screws must be tightened in this sequence and to 3 inch pounds of torque.

14. Tighten screw #1, to 3 inch pounds of torque, then #2 and #3. The grating turret is now installed.
15. Place the access cover on the monochromator. Replace and tighten all of the cover screws.
16. Install the removed grating turret into the storage container and tighten the 3 clamp screws. Replace the plastic cover.

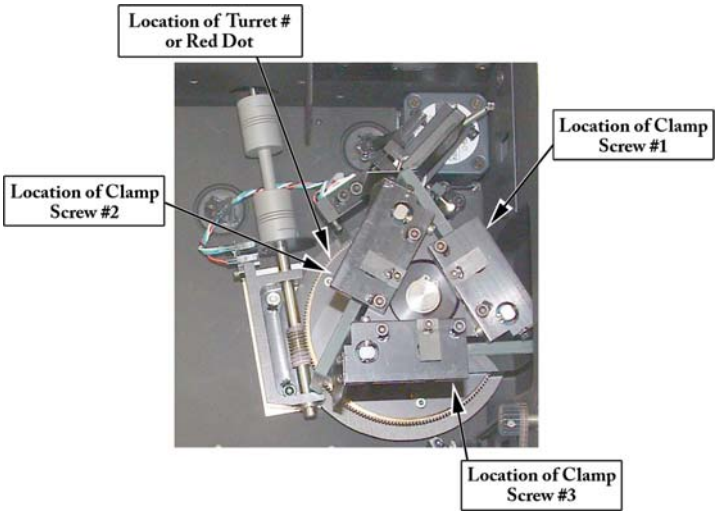


Figure 23. Location of Turret # (or Red Dot) and Clamp Screws

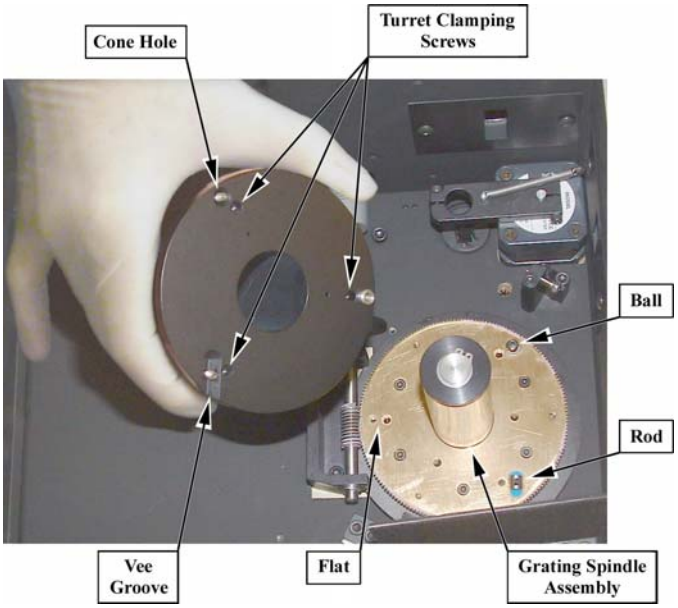


Figure 24. Location of Grating Spindle Assembly

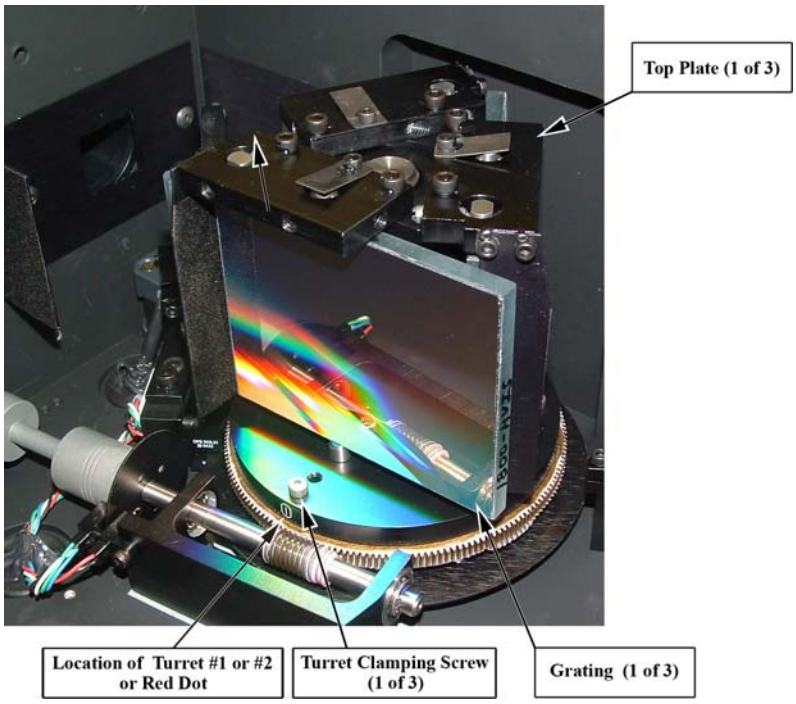


Figure 25. Location of Turret Clamping Screw

4.5 Stokes/Anti-Stokes Laser Stop Mask

To simultaneously obtain Stokes and Anti-Stokes Raman signal (Figure 26), we offer a laser mask which can be installed on 1st , 2nd or both intermediate slits. The laser mask is a very thin metal bar positioned precisely in the middle of the slit which mechanically blocks the laser light. For more versatility, the laser stop mask has 4 options - three bars of different width (150, 300, 600 µm) and the open space to allow Raman signal to pass unblocked through the intermediate slit (Figure 27). The laser stop mask is set on a sliding strip for changing between 4 options and precise positioning. Figure 28 demonstrates the motorized intermediate slit with the laser stop mask set at the 150 µm width bar. Figure 29 shows the mask in the opened position. Besides the standard laser mask, we can also provide one with 250µm, 500µm and 1 mm wide bars.

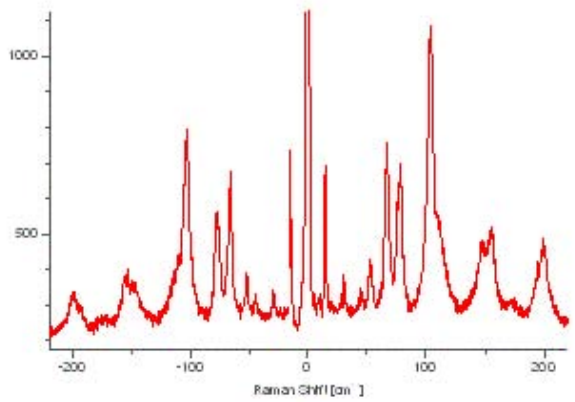


Figure 26. Stokes/Anti-Stokes Spectrum

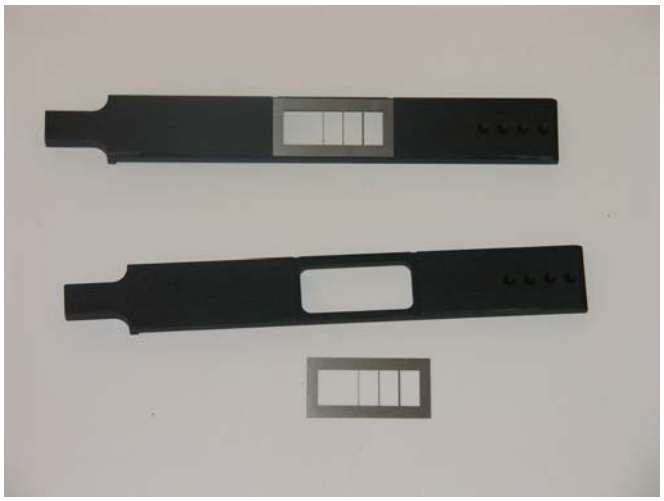


Figure 27. Sliding Strip with Laser Stop Mask

Figure 28. Intermediate Slit with 150 µm Laser Stop

Figure 29. Intermediate Slit with Open Laser Stop

4.6 Universal Macro-Chamber

Our optional universal Macro-Chamber is intended for Raman measurements of solid, liquid and gaseous samples. Large volume of the chamber allows it to handle samples in a wide range of sizes and geometry. Samples can be irradiated at all possible angles, including illumination from the bottom which allows you to maximize Raman signal intensity. A lot of additional Raman accessories can be installed within the chamber so you could flexibly adjust conditions of your experiment. Macro-Chamber consists of two parts – Sample chamber and Entrance optics chamber (Figure 30).

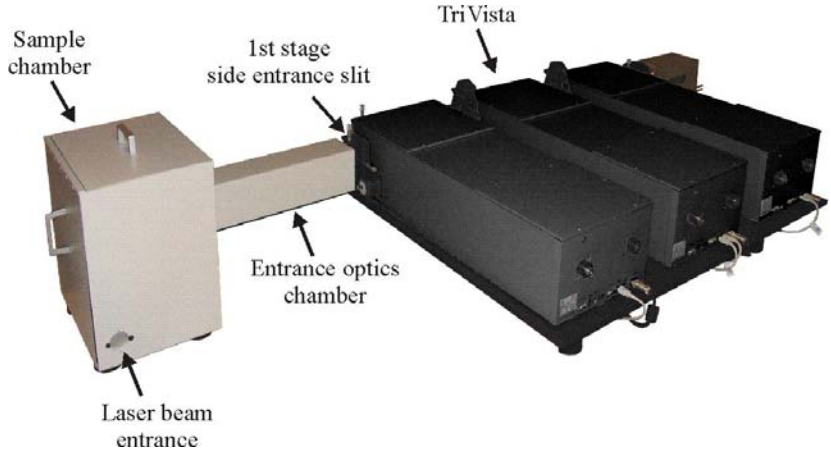


Figure 30. Universal Macro-Chamber

The laser beam is introduced into the Sample chamber through the small orifice at the bottom. Mounting rail is installed by the laser beam entrance (Figure 31) to accommodate all sorts of filters, polarizers or power analyzer. The system of adjustable mirrors (XYZ and rotation) diverts laser beam towards the sample. The adjustable focusing lens (XYZ) helps focusing laser beam on the desirable spot on the surface or inside the sample. The XYZ adjustable sample holder can accommodate sample with dimensions of up to 10” (25 cm).

Scattered light is collected with f/2 collection lens 2" (50 mm) in diameter and is sent to the Entrance optics chamber (Figure 32). Collected light is passed through the iris aperture to reject stray light and collimated by collimating lens 1.5" (38 mm) in diameter installed on top of the mounting rail. Focusing lens 1.5" (38 mm) focuses Raman signal on the side entrance slit of the 1st stage of TriVista. It is technically possible to install Macro-Chamber on the front entrance slit of TriVista. Between collimating and focusing lenses where collected light is collimated you can install another slit for additional stray light suppression, polarization analyzer/scrambler and all sorts of 1.5" filters, including Notch filter. With Notch filter installed you can use the 1st stage of TriVista as a single spectrometer and change between Single and Triple configuration without even touching your sample. Optics of Macro-Chamber allow handling lasers with different excitation wavelengths from UV to NIR.

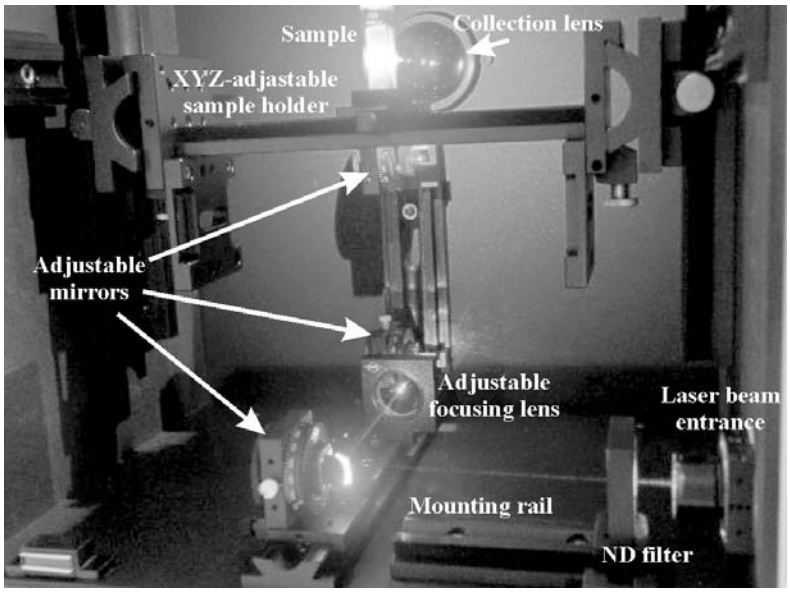


Figure 31. Inside Sample chamber

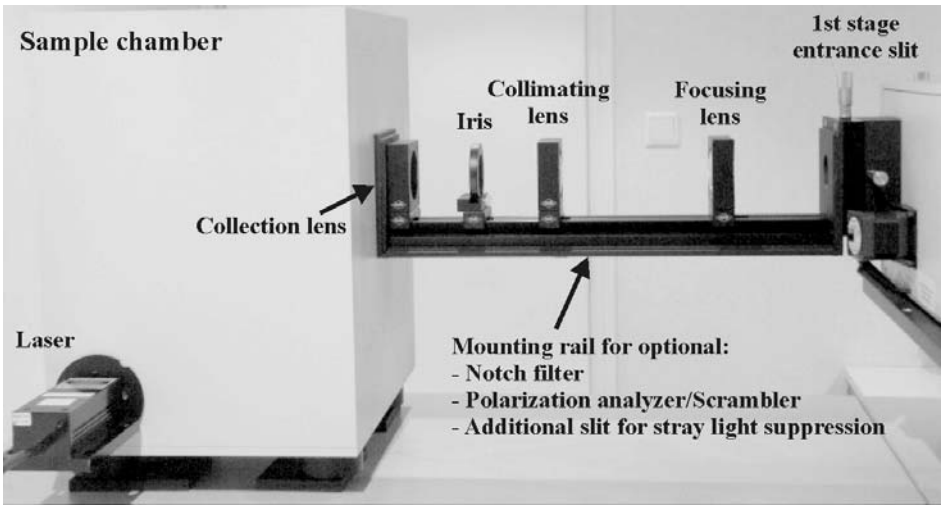


Figure 32. Entrance optics chamber

4.7 Micro-Raman Assembly

If you have ordered our optional Micro-Raman assembly you can run Raman samples using conventional microscope. It gives you power to analyze microscopic quantities of newly produced or scarce substances by Raman spectroscopy or analyze different spots of macroscopic samples under microscope. Depending on your order you might have standard or confocal microscope, upright or inverted configuration or option with software controlled XYZ Mapping.

To achieve best flexibility of the system the standard setup utilizes optical fiber coupling (Figure 33). For special demands like UV excitation or multiple laser wavelengths you might have direct mounting of the laser on a microscope and direct coupling between microscope and the 1st stage of TriVista. It is also possible to substitute manual entrance slit to the motorized one to achieve full control over the TriVista functions.

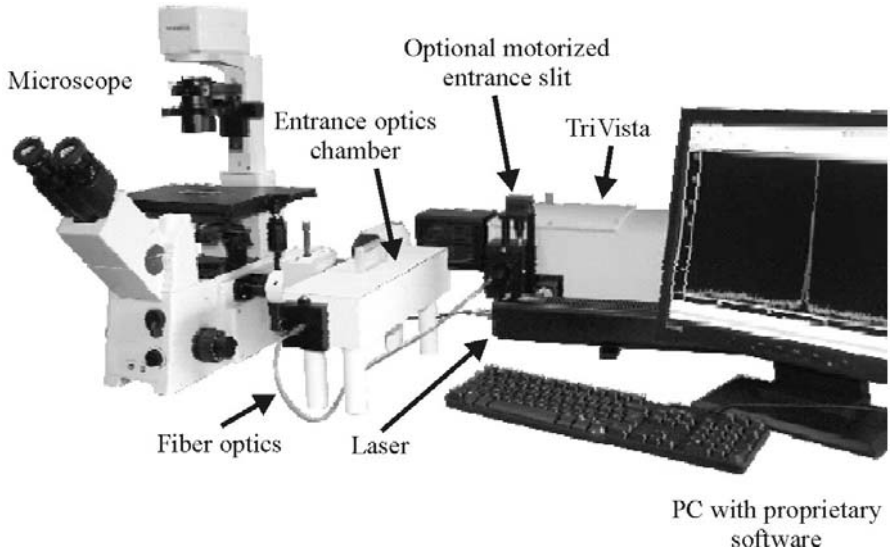


Figure 33. Fiber-optically Coupled Macro-Raman Assembly based on Olympus BX 51

The Micro-Raman assembly is based on the Olympus BX51 or IX71 microscope, an upright or inverted configuration. The confocal Raman microscope option offers a spatial resolution on micron scale. The software-driven XYZ stage enables automated 3D mapping and also has an auto focus option.

The microscope is directly attached to the Entrance optics chamber, which has design very similar to the Entrance optics chamber used with Macro-Chamber (see Figure 32). This chamber may incorporate a Notch Filter (needed with single spectrometer configuration only) and may contain additional optics like Interference filter, ND filter, etc. Modular design of the Entrance optics chamber allows handling lasers with different excitation wavelengths from UV to NIR.

4.8 Mounting Accessories to the TriVista Slit Assemblies

All TriVista accessories come with their own set of instructions for proper mounting and operation. The instructions below are only general information. Please refer to the individual instructions for detailed information.

The full range of accessories mount directly to the TriVista slit assemblies. A drawing of the standard slit assembly can be found in Appendix B, page 95, to assist you in mounting accessories.

To Mount an Accessory to the Slit:

For detailed instructions, see the instructions supplied with the accessory.

1. Place the accessory directly against the face of the slit body. Light sources normally mount on the entrance slit, detectors on the exit slit. Other accessories such as fiber bundles normally mount on the entrance slit, but are also compatible with the exit slit.
2. Using four (4) 8-32 screws normally provided with the accessory, secure the accessory to the slit body. Screw length depends on the kind of accessory to be mounted.

Light sources fitted with light collection/focusing optics are normally factory aligned to the standard slit.

Note: In some instances with light sources, there is limited access to the bottom two screw holes. In this case, special slotted holes in the light source housing are provided to facilitate mounting of the source to the slit.

Chapter 5
S&I Software

5.1 Introduction

The S&I software was written to obtain an optimized access to all three stages of the TriVista. It is programmed in "Visual Basic" and runs in co-operation with Princeton Instruments' WinSpec software package, which is designed to operate a multitude of CCD, ICCD and InGaAs detectors and allow access to exclusive detector functions. S&I software controls spectrometer functions while WinSpec is used as a DLL and provides data acquisition and setup functions for multi-channel detectors. Since these features are accessed by S&I, WinSpec must always be active when the S&I software is running. WinSpec is not required when data is acquired by a single-channel detector such as a PMT, but the data will be stored in the WinSpec "SPE" format.

Because WinSpec is used as a DLL, only some descriptions of the main functions of WinSpec are included in this manual. For more information, review the WinSpec manual.

5.2 System Interface Settings

During the installation process, the system interface settings were set in the Windows Device manager for the TriVista and the devices mounted to it. If you have not changed the initial setup, go to the next section "Hardware Settings". If you have changed the devices you may need to confirm or change the system interface settings for the new device(s).

Before configuring of the interfaces, make sure the system is physically connected your computer and that the system and devices are turned on. Turn on your computer. For USB (TriVista spectrographs and SpectraHub) and USB2 (Princeton Instruments ST-133 Controller with USB or a PIXIS-type detector), the serial ports can be defined with the Windows Device Manager accessed as shown in the figures that follow. When RS232 is used, the interface is defined by the port-connection.

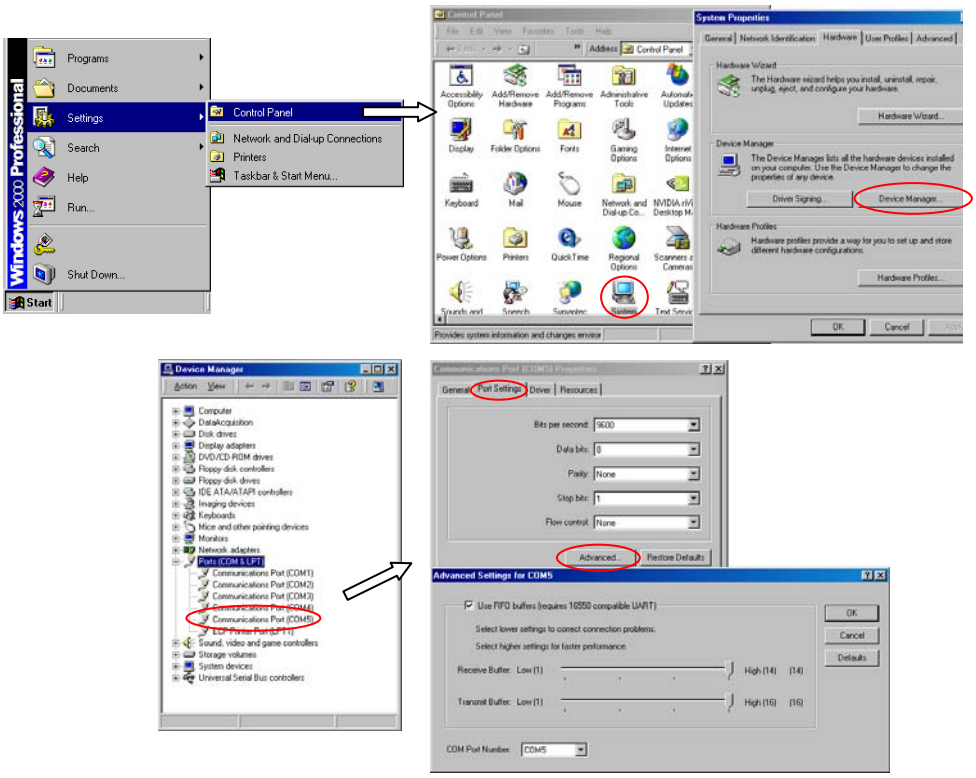


Figure 34. Accessing the Device Manager and Port Settings.

5.3 General Hardware Settings

The first screen you will see after starting the S&I-software is the Measuring window. Because you will be entering, changing, or verifying the TriVista hardware settings, you must click on the Hardware button at the lower left of the window (see Figure 35).

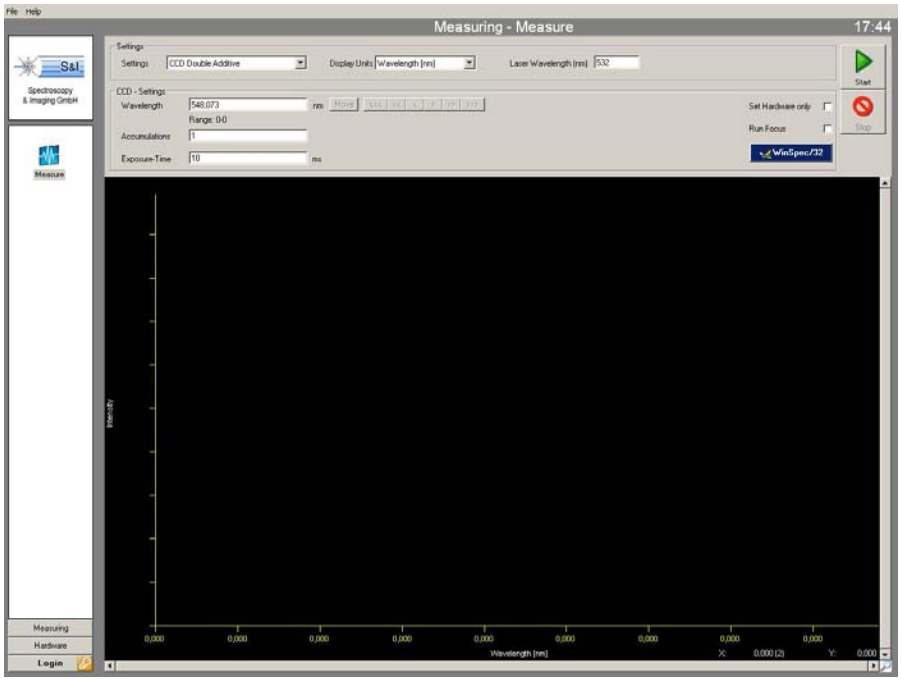


Figure 35. Window Displayed at Startup of the S&I Software

The Hardware window contains the System Settings table (automatically accessed by the program), displays descriptions of the currently selected measuring mode, and shows the current hardware configurations of the three stages.

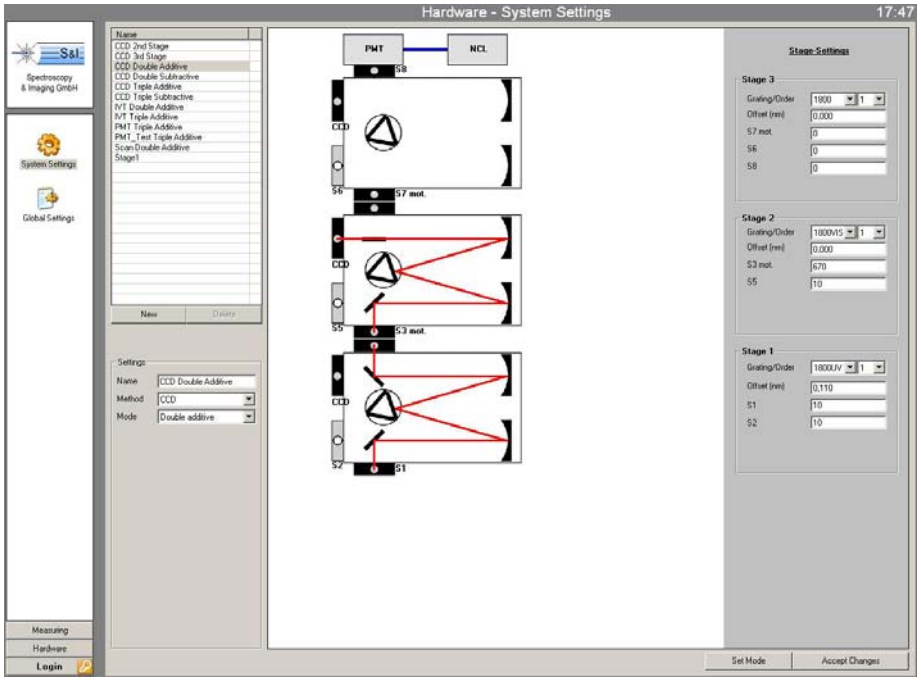
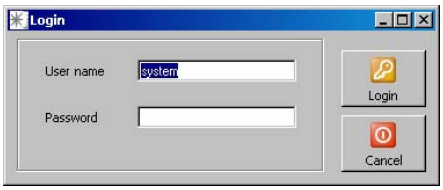


Figure 36. System Settings within the Hardware window

Any of the currently defined modes can be selected and used to acquire data, but changes to hardware settings are password-protected. In order to modify the General Hardware-

Settings, you must login click the "Login" button (in the lower left), enter the password, and then click "Login". After login, two more icons are available in the lefthand panel:



"Monochromator-Settings" and "Mono-Channel-Settings". Click on these icons to access your general Hardware Settings.

Figure 37. Login

5.3.1 Hardware Interfaces

Monochromator Settings

To configure monochromator interfaces click the "Monochromator Settings" icon. The window shown in Figure 38 will appear.

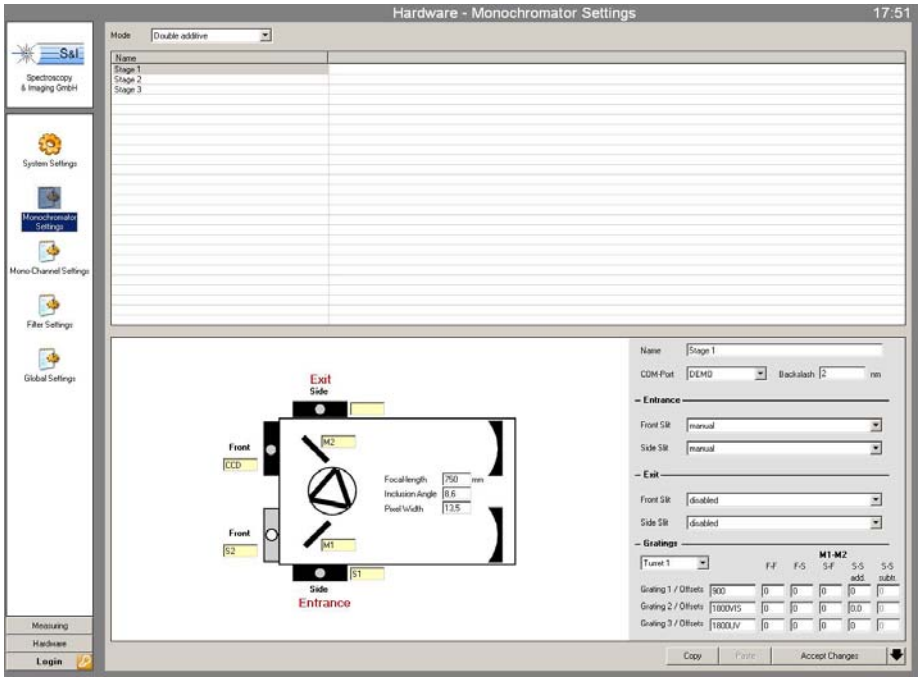


Figure 38. Monochromator Settings window

Each monochromator represents one of the 3 stages on the path of light beam. Select the stage for which you want to assign the COM-port (Figure 39) and choose the mode in which the setting shall be valid (Figure 40). Different modes are described in detail in the "Stage Settings" section, page 64.

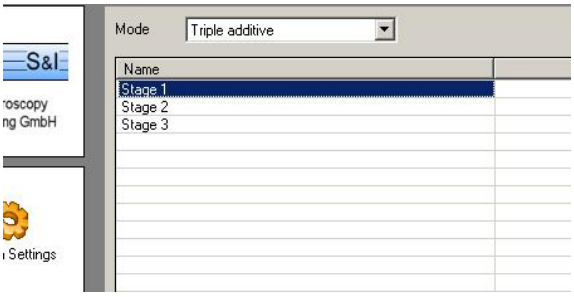


Figure 39. Stage selection

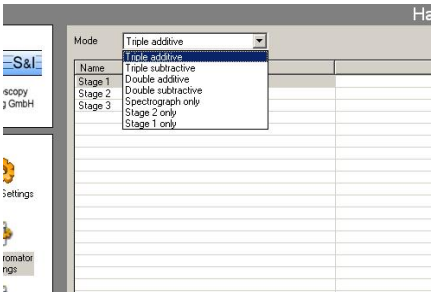


Figure 40. Mode selection

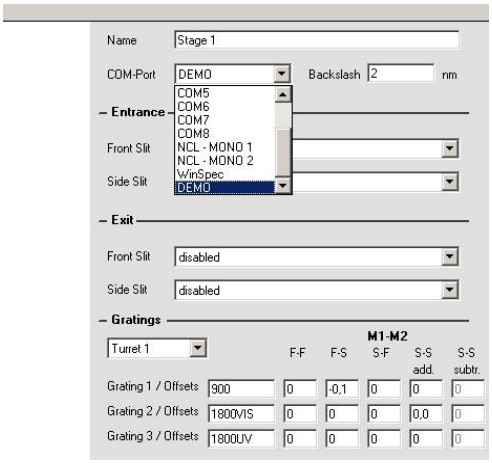


Figure 41. Interface selection

Figure 42. Store Setting with "Accept Changes"

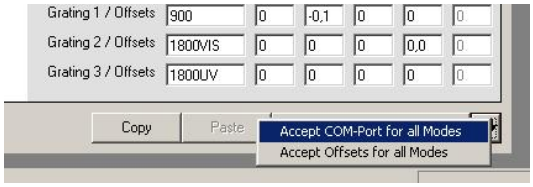


Figure 43. Store Settings for all Modes selection

In the **COM-Port** field (Figure 41) field, choose the same interface as shown in the Windows Device Manager (Figure 34), and save the setting by clicking the "Accept Changes" button in Figure 42.

- If you want to accept the setting of the current stage for all possible modes, click the arrow right of "Accept Changes" and then "Accept COM-Port for all Modes" as shown in Figure 43.
- If you want to deactivate the current stage in any mode, choose the mode and set "COM-port" to "Demo".

MonoChannel Settings

To set the interfaces for the indicator of a monochannel detector click the "Monochannel Settings" icon. The window shown in Figure 44 will appear.

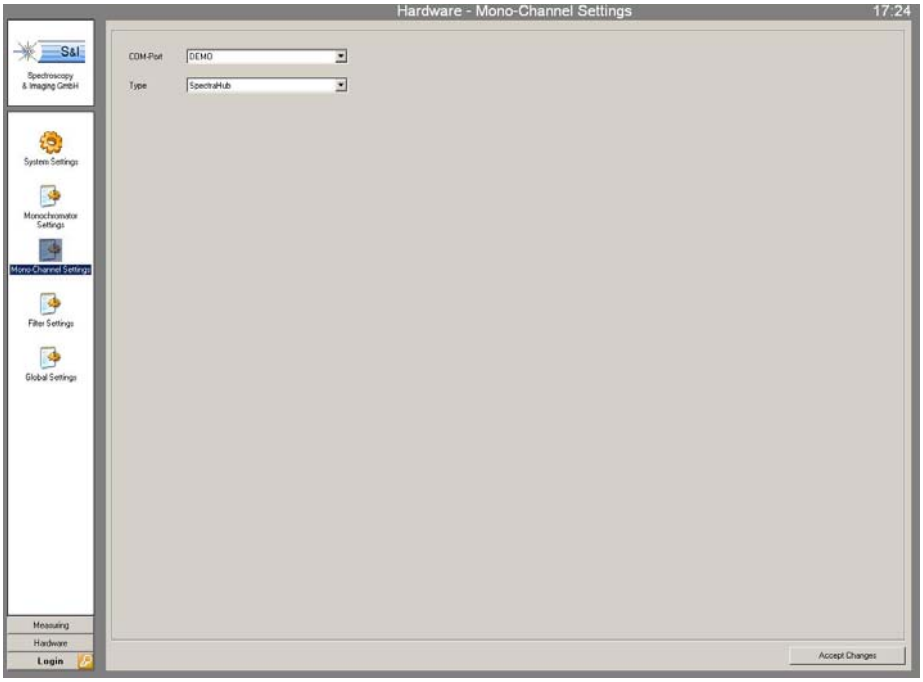


Figure 44. Mono-Channel Settings window

In **Type** field, select the device you use for your PMT. As in "Monochromator Settings", the **COM-Port** selection must match the setting in the Device Manager. If you do not use a PMT, set **COM-Port** to "Demo".

This software is able to perform data-acquisition from the following types of controllers:

- SpectraHub
- NCL
- SR400

5.3.2 Monochromator Settings

After you have selected the communication port, the mode, and type (for PMT), you can configure the TriVista stages. Each spectrometer stage has settings for:

- entrance and exit slits
- turrets and its gratings
- dispersion

All of these settings are part of the "Monochromator Settings" window. Like the settings for the hardware interfaces, the settings for spectrometer configuration are separate for all modes. The only settings that are used for all modes are the grating groove densities.

Slits

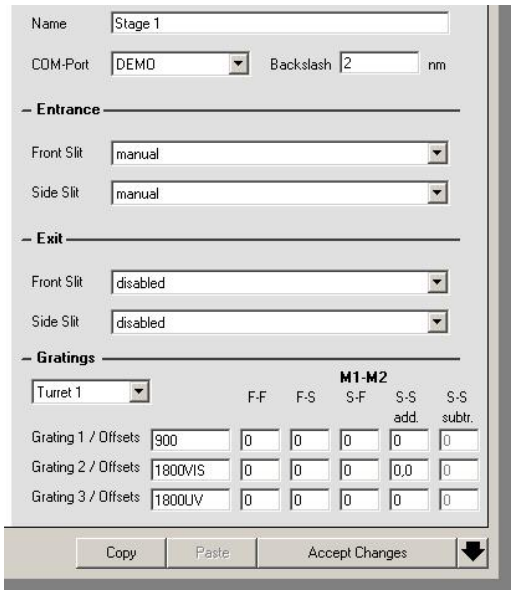


Figure 45. Slit Settings

The settings for the slits can be entered at the right side of the window as shown in Figure 45. Here you can enter if and what kind of slit you use for each entrance and exit. Possible settings are:

- Disabled (no slit placed),
- Manual and
- Motorized.

Caution: Extra care should be taken by configuring intermediate slits. Consider that there is always only one slit between the stages. The second slit which is shown in the software at the same position but at the other stage has to be set to "disabled".

If a motorized slit is used as intermediate slit, retrace through the power and signal feed line to the stage this slit is connected to. The setting "motorized" induces the activation of a slit command field in "system settings". With that field you can control the width of the slit. The same field appears in "Stage Setting" within "System Settings", if the slit is set to "manual", but when the slit is set to "manual" the field can only be used as a comment field.

Turrets and Gratings

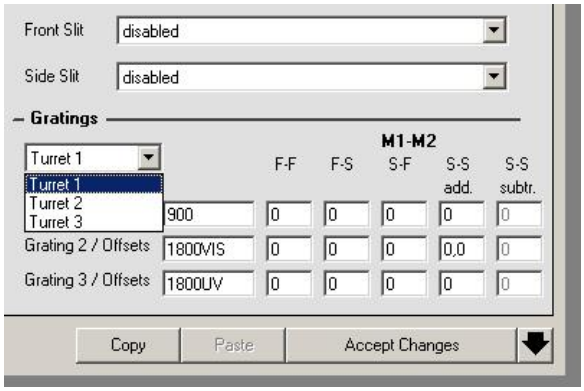


Figure 46. Turrets and Gratings

The turret of each stage can have a maximum of three gratings. Some spectrometers have an option of interchangeable turrets. If a spectrometer has interchangeable turrets, you can choose between different turrets in the hardware setup. Figure 46 shows the setup section for turrets and gratings. Each stage must be set up independently. In the first column right of "Grating # / Offsets" you can enter the dispersion of each grating in grooves per mm. You can also comment the grating with the spectral blaze (for example, "VIS" for visible or "NIR" for near infrared). To find out in which order the gratings are installed on the turret, please run the "Spectra Pro" program and use the "Install Gratings" icon.

If you use several turrets, you will have to physically change the turret and choose the turret number as shown in Figure 46. The fields to the right of the grating setup are the

"Offset-Table". Its use is explained in ***"5.6.1 Offset Table in the 'Monochromator Settings' Window"***, on page 79.

Dispersion

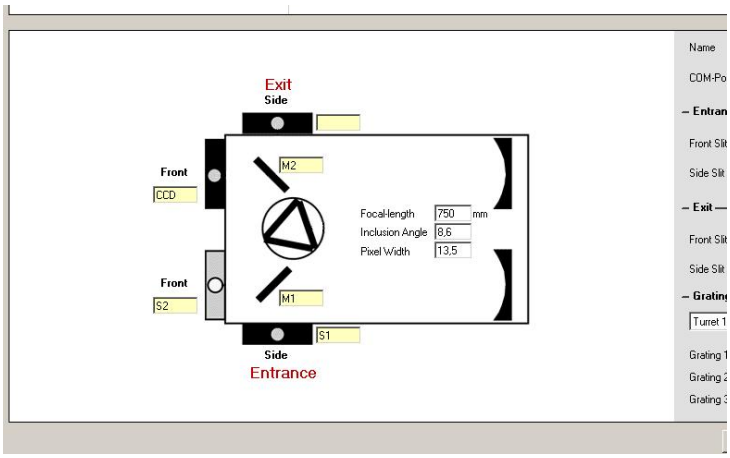


Figure 47. Dispersion Calculation

If a CCD detector is used, the last parameter that has to be configured in "Monochromator Settings" is the calculation of the dispersion on the CCD chip. The spectrometer itself can only execute a movement to a central wavelength. This wavelength is placed at the middle of the CCD chip. The wavelengths beneath the central wavelength have to be calculated by the software from the values for:

- Focal length,
- Inclusion angle and
- Pixel width of the camera.

For a correct calculation of the dispersion on the chip you have to enter these three values into the white fields that are shown in Figure 47.

As you can see, inside of the dispersion setup there are further fields in yellow. These fields can be used for comments on system configuration in "System Settings". Useful comments can be:

- Description of a slit,
- Description of a mirror or
- Position of a CCD camera or PMT

5.4 Generating Different Configurations

After performing the general hardware configuration, you can create different system setups. Through these setups you can define different uses of the TriVista. For example, the use of a PMT detection in triple additive mode, the use of CCD detection with a single spectrometer, and many more configurations.

Use the "System Settings" button (lower left) to switch to the main Hardware window. As shown in Figure 48, you will find a window that is divided into three panels:

- Main setup properties on the left side,
- Illustration of the optical path in the center, and
- Individual stage settings on the right side.

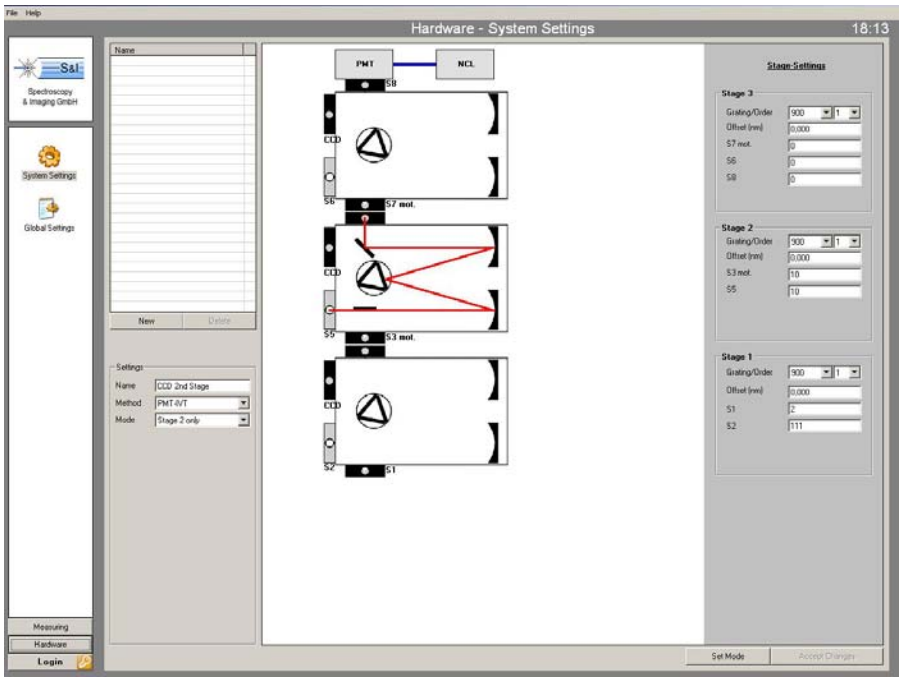


Figure 48. System Settings window

Every configured setup and every change within a setup has to be stored by using the "Accept Changes" button (right, bottom). To activate the stored settings, click on "Set Mode" or start data acquisition in the "Measuring" window.

5.4.1 TriVista Configurations

Each configuration of the system that you have stored can be recalled later by clicking on its name. Figure 49 shows of a list of such configurations. When the system is delivered, some relevant setups are already available in the window. The setups differ from each other in the following ways:

- Mode (Figure 50),
- Method for detection (CCD, PMT), and
- Choice of gratings.

The advantages of using such a list is that the operator can use the system for different applications and that the system can be used by several operators. Furthermore, the different stages can be divided into two or three independent systems, where each system is connected to a different computer.

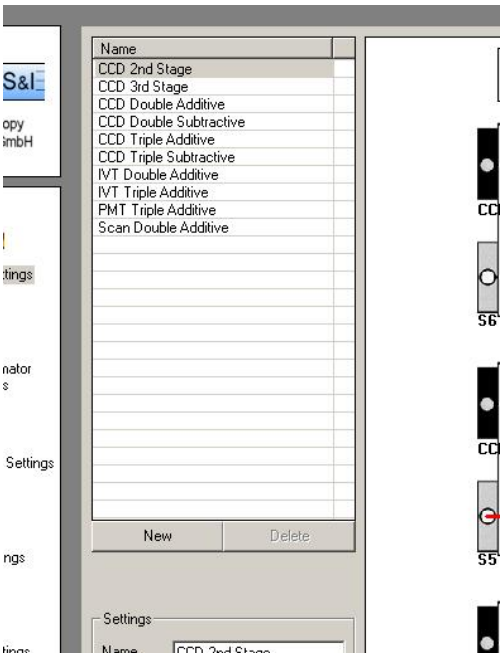


Figure 49. List of TriVista Configurations

CAUTION

To avoid a loss of hardware interfaces, make sure that different operators do not access the same stage. The easiest way to avoid this is to set the interfaces of all stages that are not controlled by the given operator to "Demo".

The TriVista spectrometers can be used in 7 different ways that can be changed through the "Mode" field:

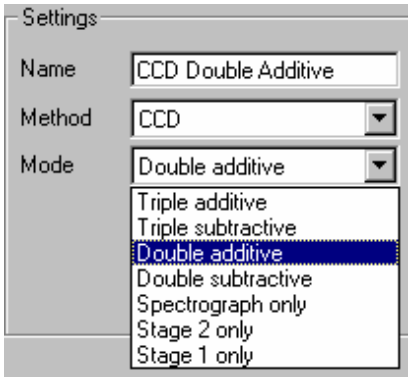


Figure 50. Mode Selection

- Three stages combined for high resolution spectroscopy (**Triple Additive**),
- Three stages combined for Raman-Spectroscopy with a CCD (**Triple Subtractive**),
- The first two stages combined for a doubled dispersion (**Double Additive**),
- The first two stages combined as a narrowband light source (**Double Subtractive**), and
- Each stage as a single spectrometer (**stage 1, 2, or spectrograph (stage 3) only**).

5.4.2 Setting Main Properties

The first step to generate a new device configuration is to set the main properties. Therefore, you click the "New" button and:

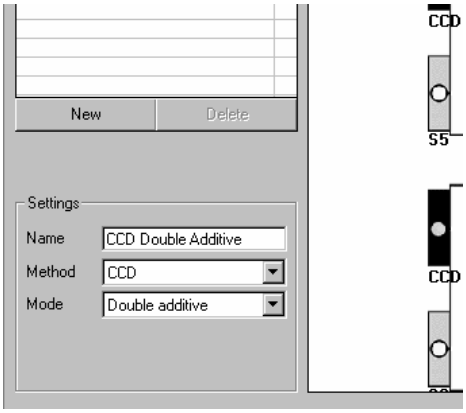


Figure 51. General Settings for a Setup

- Enter a configuration name,
- Select a detection method, and
- Select a mode for the spectrometer system.

Figure 51 illustrates an example of such a configuration, with the name "CCD Double Additive" where a CCD camera is used for light detection and the first two stages work as a double monochromator in additive mode. You can create, use, modify or delete these settings. It is recommended that configuration name will be descriptive enough and reflect system's properties.

The meaning of the possible modes is explained in ***"5.4.1 TriVista Configurations"***, on page 61. You can choose between the following detection methods as shown in Figure 52:

- CCD
- PMT
- PMT-IVT

CCD means that you use a CCD camera at the exit of the system. If you use a photomultiplier, you can choose between PMT and PMT-IVT. With the method PMT it is possible to acquire a spectrum in scanning mode, while with the PMT-IVT you can measure light intensity versus time at one fixed spectral position.

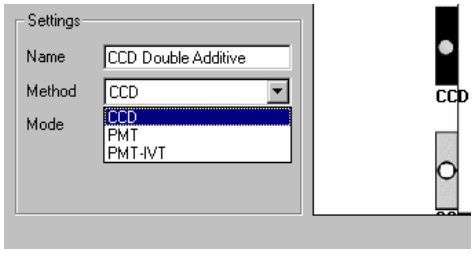


Figure 52. Measurement Methods

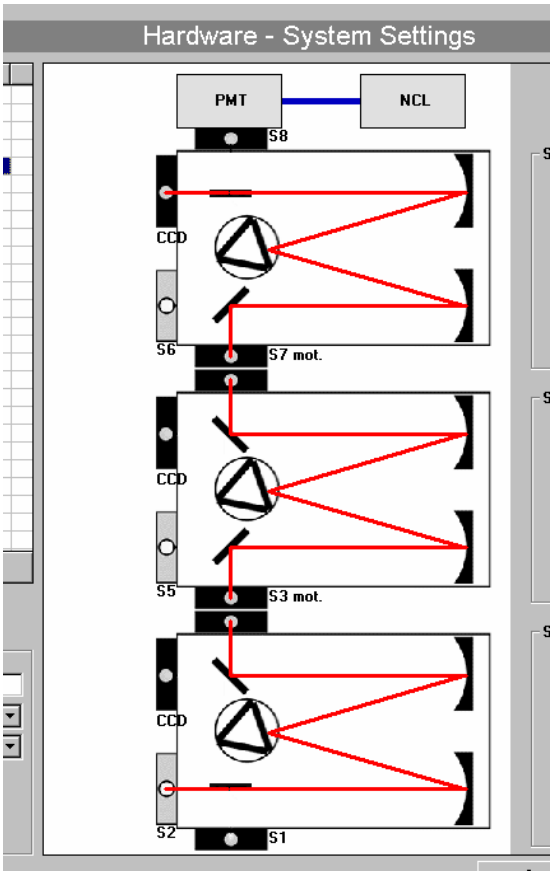


Figure 53. Optical Path

To correctly configure the chosen "Mode", refer to the illustration of the optical path in the middle panel of the "System Settings" window, Figure 53. In this panel it is possible to set the mirrors separately in all stages by clicking the mirrors. Figure 53 shows the mirror-setup for the "Triple Additive" or "Triple Subtractive" mode: The light source enters the system through the front entrance (S2) and leaves it in the third stage through the front exit (CCD). Within the system, the mirrors are positioned so the light can pass through all three stages. If a double or single mode is chosen as a setup-mode, it is only possible to change the position of the mirrors within the stages being used.

5.4.3 Stage Settings

"Stage Settings" is the last part of a system setup. The Stage Settings panel is at the right side of the "System Settings" window, as shown in Figure 54. For each stage it is possible to choose:

- Which grating in which order shall be used,
- The width of each slit, and
- The offset of the stage (see below).

Gratings and Order

By selecting a grating you also define the dispersion. The higher the groove density of the grating, the higher the dispersion and the lower the CCD spectral coverage. Probable values for groove density of the gratings depend on the settings for the gratings that have been installed and set up in the "Monochromator Settings" window. It is also possible to define the order to be used for each grating.

Example: If you irradiate a grating with a HeNe laser at 632.8 nm, the light beam will exit the stage at 0 nm (order 0), 632.8 nm (order 1), 1265.6 nm (order 2) and higher wavelengths in a distance of 632.8 nm. The reason to use a stage in order 0 is to decrease dispersion to measure a wider range of spectra. By using the second order of a wavelength it is possible to measure a small wavelength with a grating that is usually blazed for wavelengths at a higher spectral area.

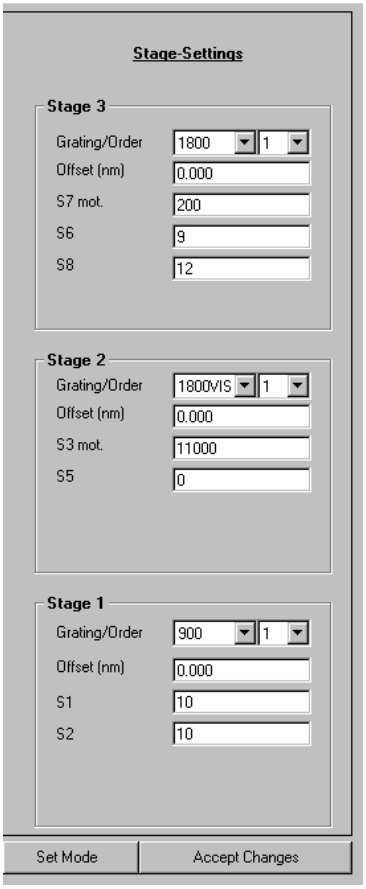


Figure 54. Stage Settings

TIPS:

1. If the gratings of the wrong turret are displayed in the Gratings field, you have to change the turret in the "Monochromator Settings" window.
2. Subtractive mode is only possible if the groove density of the first two stages is the same. If it differs, the dispersion can not be inverted correctly.
3. To illuminate the whole CCD chip, the groove density of the last stage should be twice of the groove density in the first two stages in mode "Triple Subtractive".

5.4.4 Slits

Slit names and status (manual, motorized, or disabled) are determined by the entries made in the "Monochromator Settings" window. The default names of the slits are S1 - 2 in Stage 1, S3 – 6 in Stage 2 and S7 -9 in Stage 3.

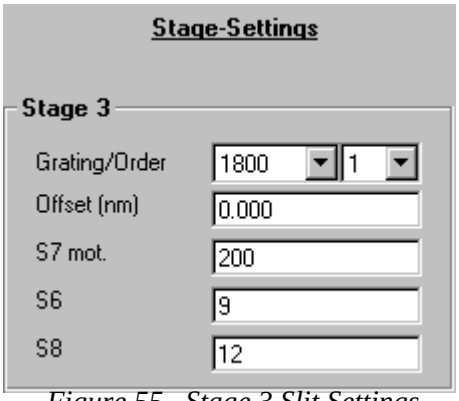


Figure 55. Stage 3 Slit Settings

The active slits are represented in the "System Settings" window by the "Slit" fields (below the "Offsets" field in each stage). The function of the field depends on whether the slit is manual (for example, an entrance slit) or motorized (for example, an intermediate slit):

- If the slit is manual, the field allows you to enter the current slit-width for a manual slit as a comment or reminder of the slit-width it has been set to.
- If the slit is motorized, entering a slit width sends a command to actually change the slit-width. The range of width values for a motorized slit is 10 – 12000 µm.

TIPS:

- To keep stray light at a low level, all slits that are not used in the current setup (for example the intermediate slits, when only one stage is used) should be closed.
- Resolution always depends on the slit-width of the entrance slit. In "Triple Subtractive" mode, the second intermediate slit works as an entrance slit.
- When using a PMT, the intermediate slits should be narrow for stray light rejection but can be opened up to 150 µm.
- For standard applications with a CCD camera we recommend to use the following slit-widths:

Mode	Intermediate Slit 1 [µm]	Intermediate Slit 2 [µm]
Double Additive	12000	0
Double Subtractive	12000	0
Triple Additive	6000	12000
Triple Subtractive	12000	As Entrance

Table 7. Mode vs. Intermediate Slit Width

5.4.5 Offsets

The "Offset (nm)" fields in "Stage-Settings" allow you to enter an offset value to optimize the matching between the stages to the special demands of the current application.

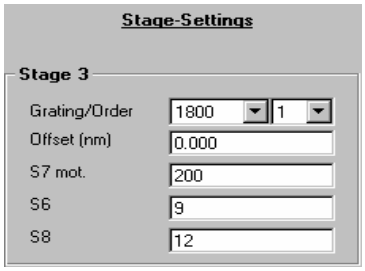


Figure 56. Offset (nm) Setting

CAUTION

The adjusted offset-position is only valid for the current grating and the current wavelength! Note that the values in the offset-table in the "Monochromator Settings" window are set for the whole spectral range of the grating and not for a specific wavelength. Matching stages is explained in *"5.6 Matching the Stages"*, page 79.

5.4.6 Global Settings

Additional settings that are shared by all generated configurations are defined in the "Global Settings" window. Click on the "Global Settings" icon within the Hardware panel to open this window (Figure 57).

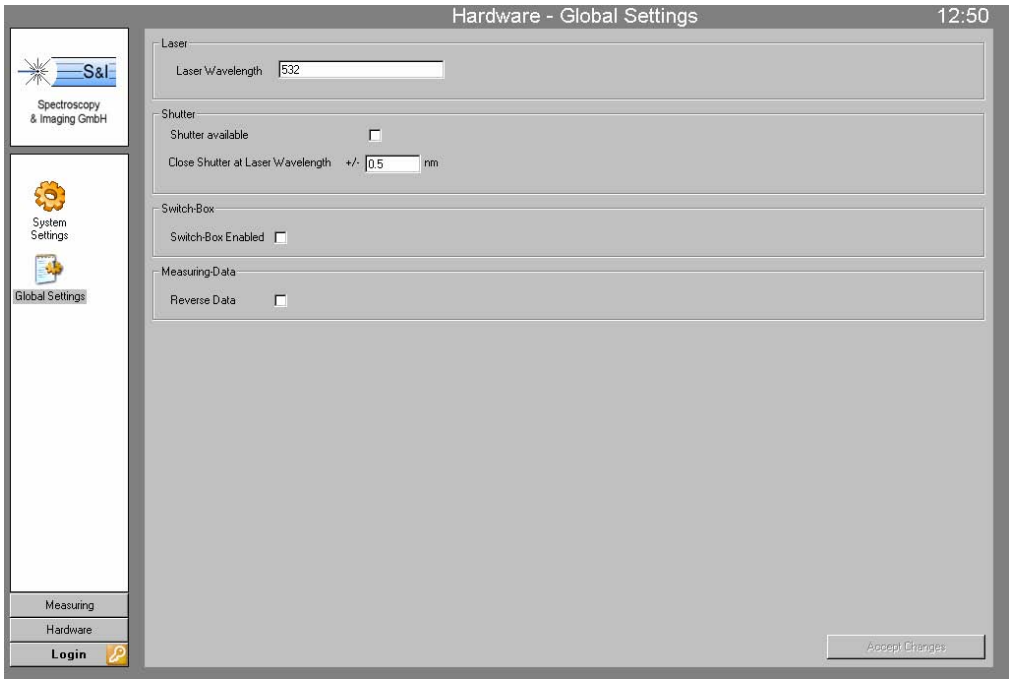


Figure 57. Global Settings window

The global settings that can be entered are:

1. **Shutter protection for PMT in scanning mode against laser-light:** This protection can only be enabled for measuring method "PMT". If a shutter is available, you can enable the protection by selecting "Shutter available". Then you must specify the used laser wavelength in field "Laser Wavelength" and the minimal spectral distance of the central wavelength of the spectrometer from the laser wavelength (field "Close Shutter at Laser Wavelength +/-").

2. **"Switch Box" for additive and subtractive mode**: If there is a "Switch Box" to switch between additive and subtractive mode in the system, it has to be enabled here. In recent systems, the "Switch Box" is obsolete, because the change from Additive to Subtractive mode is done internally in the second stage, with even better performance than the Switch Box provided.
3. **Orientation of measuring data:** Because CCD chips can be mounted in several different orientations it is possible that the information from the signal is transferred inverted from the CCD to the software. Then also received spectra will be shown inverted. To avoid that, the "Reversed Data" checkbox needs to be activated. It is also possible to do that in WinSpec on the Hardware Setup|Display tab page" but do not to use that checkbox in both programs.

5.5 Data Acquisition

To perform an acquisition, click on the "Measuring" button to open the Measuring window (Figure 58):

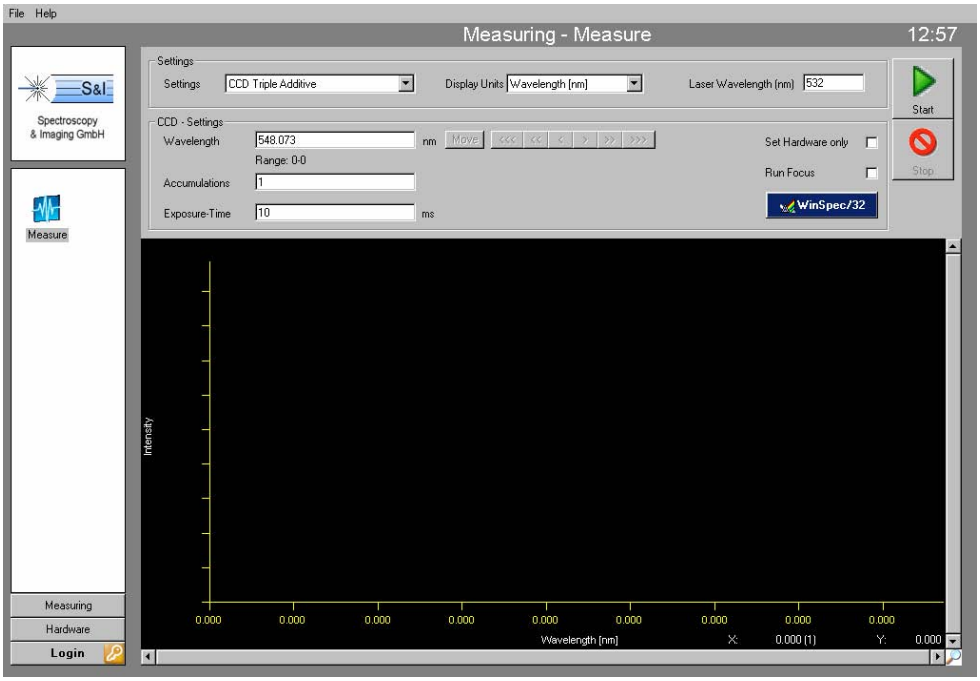


Figure 58. Measuring window

5.5.1 Global Settings and Commands

At first you need to choose one of the configurations that have been generated in "System Settings". The list of the configurations will appear by clicking the arrow at the first combo box in the "Settings" region.

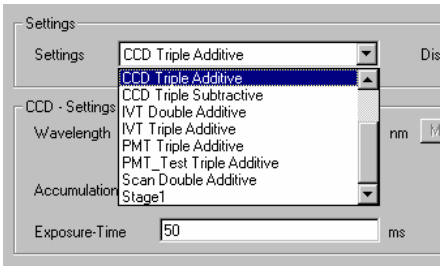


Figure 59. Selection of a Setup

Independent from the chosen configuration it is possible to define the way the units of the spectra are displayed at the bottom of the measuring window. As Figure 60 shows it is possible to choose between:

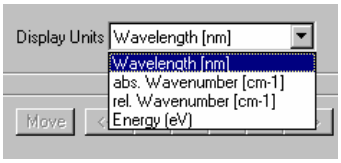


Figure 60. Display Units

- Wavelength,
- Absolute Wavenumber,
- Relative wavenumber and
- Energy

If the selected units are either "Relative Wavenumbers" or "Energy", you also have to enter the used laser wavelength at the third field within "Settings" so the software can perform a correct calculation of the dispersion with reference to the stimulation energy or wavelength.

Figure 61. Start and Stop buttons

To **start** a measurement, click on the "Start" button. While the measurement is in progress, you can interrupt the measurement by clicking on the "Stop" button. The system will finish the actual data point of the measurement and stop. When you click the "Stop Button", the software will ask you if you really want to Stop or to Continue. If you stop a measurement, you will not lose the data that you have already taken.

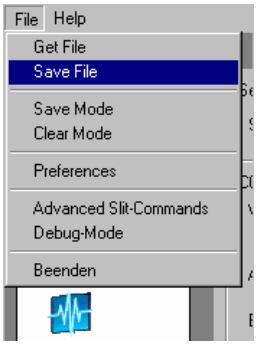


Figure 62. File menu

To **save** an acquired spectrum, click "File" and "Save File" as shown in Figure 62. Measurements with a CCD camera can also be stored through "WinSpec". To **open** a stored spectrum, use "Get File".

Caution: For spectra that are measured with a CCD camera "Get File" is only able to transfer measuring data from WinSpec to the S&I software. Such spectra have to be opened by WinSpec first.

The File menu also allows you to store the measuring settings for each specific setup in "System Settings". To save the settings for a setup, click "Save Mode". "Clear Mode" stores the settings of the last measurement that is done in the current mode.

5.5.2 Data Format and Illustration

A spectrum is always stored as an "SPE" file. This type of file contains a header (with information about the measurement properties) and the data. To view the properties, switch to WinSpec, select the "File" menu, and then select "File Information" as shown in Figure 63.

Then a popup dialog box will appear as Figure 64.

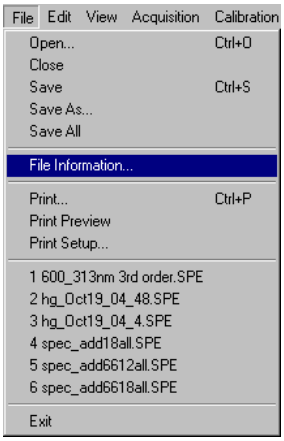


Figure 63. Item "File Information" in WinSpec

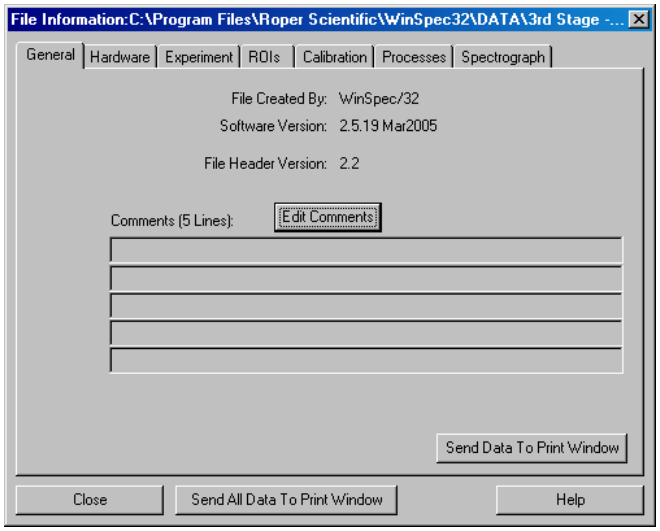


Figure 64. File Information dialog (in WinSpec)

The File Information dialog box has several tab pages. Except for the "General" tab page, all of the tab pages reference the CCD camera settings. These are explained in ***"5.5.4 CCD Detector and WinSpec"***, page 74. The "General" tab page can be used to save information about the spectrometer setup. This can be done manually, by using "Edit Comments" or through the S&I software with the command "File" and "Preferences". Using the button "Preferences" the following popup dialog box will appear:

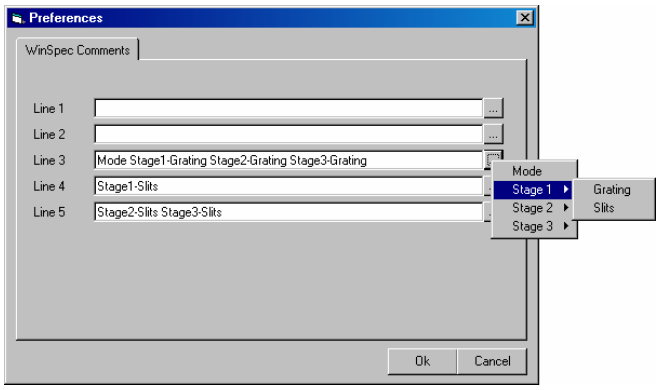


Figure 65. Adding File Information through S&I Software

Through this dialog box it is possible to save the groove density, all slit-widths for each stage, and the name of the setup. All information is stored in the header of the SPE file. Remember to save the file again after adding the header information through "Preferences".

An acquired spectrum can be zoomed by using the magnifying glass at the lower right corner of the Measuring window. You can choose 100 % (zoom-factor 1) up to 800 % (zoom-factor 8) in reference to the y-axis. If you choose "Selection", you can zoom into a defined region. Push the left mouse button to set the start-point and release it to set the end-point of the region you would like to zoom in. It is also possible to use zoom functions in WinSpec. These are explained in the WinSpec software manual. Changes of the zoom-factor never causes any loss of data.

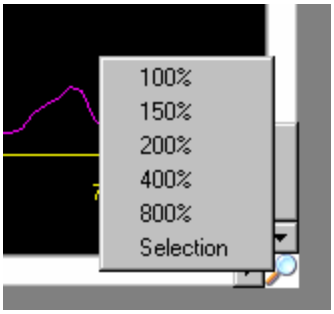


Figure 66. Zoom

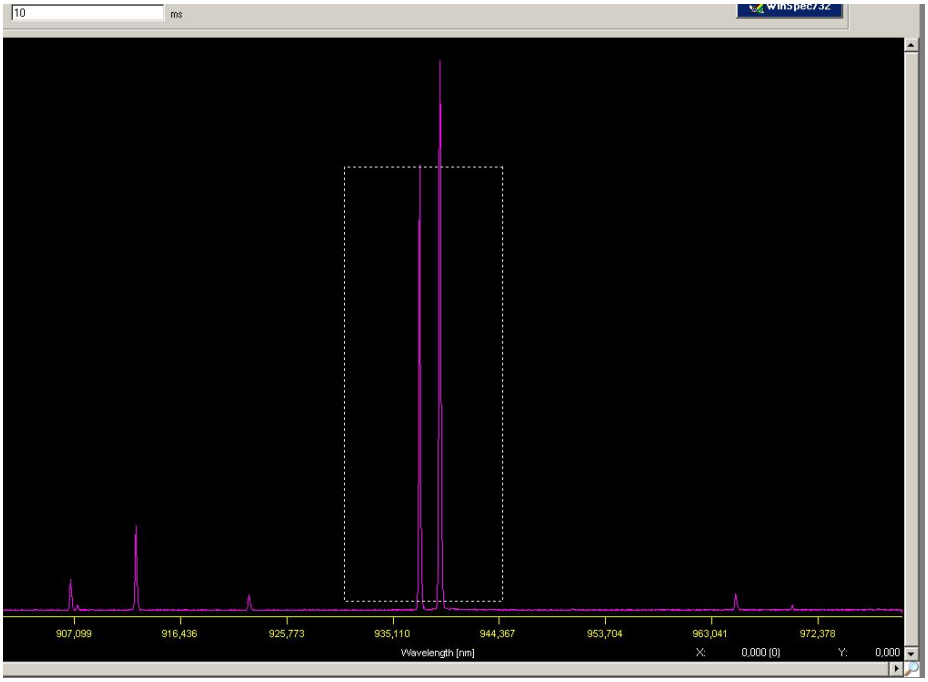


Figure 67. Zoom with "Selection"

5.5.3 Mono-Channel Measurements

For measurements with a photo-multiplier, the software uses different panels for settings.

IVT

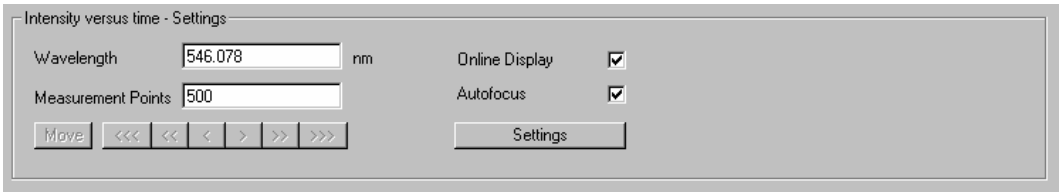


Figure 68. IVT-Mode Measurement Settings

If a configuration with IVT-mode (Intensity Versus Time) is activated, the panel as shown in Figure 68 will appear on the Measuring window. Here it is possible to define the wavelength to which the spectrometer shall move for the measurement. With "Measurement Points", you can choose how often the measurement shall be executed at the defined wavelength. It is also possible to change the wavelength during the measurement by entering a new wavelength value and then using the button "Move" or by using the arrow buttons right of the "Move" button. With the button "Settings" it is possible to enter the advanced settings of the PMT indicator. Each one has its own settings which are explained below within this chapter.

In addition, the "Intensity versus time - Settings" panel includes check boxes for "Online Display" and for "Autofocus". If you select "Online Display", the data will be displayed during the scan. If you select "Autofocus", the data display will always be updated to show the whole intensity range.

PMT

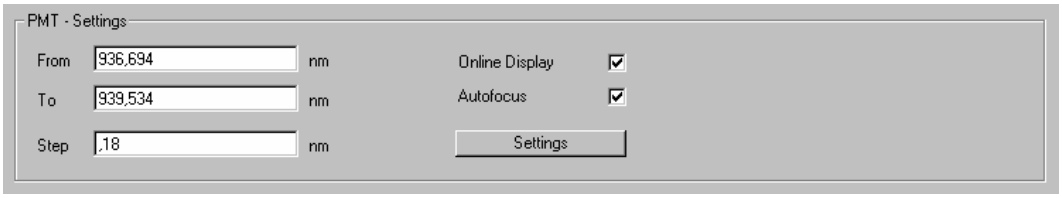


Figure 69. PMT-Mode Measurement Settings

In PMT-Mode, "Online Display", "Autofocus" and "Settings" have the same function as in IVT-Mode. The difference is that the spectrometer does not measure at one fixed wavelength but executes a scan over a defined spectral range. The first wavelength of the scan has to be entered in the "From" field and the last in the "To" field. In the "Step" field, you define the spectral distance between two spectral positions of the spectrometer. The smaller the spectral step size, the higher spectral resolution.

TIPS:

1. If you have a grating with high dispersion, you will need more spectral steps per stepper motor step than if you have a grating with low dispersion.
2. Make sure that the first value of the scan is lower than the second value as the measurement takes much more time when the system is moving backwards during the scan.

Advanced Settings

When you click on the "Settings" button, you access the advanced settings for the PMT's multimeter. Three different indicators are available for this software:

SpectraHub

If the measurement occurs through a SpectraHub, the menu appears on the screen as shown in Figure 70. At the first line of the menu ("Input 1") you select the kind of measuring data the PMT will send to the indicator. A SpectraHub is able to receive data in the form of TTL-Pulses (denoted as "Photon), "Voltage", and "Current".

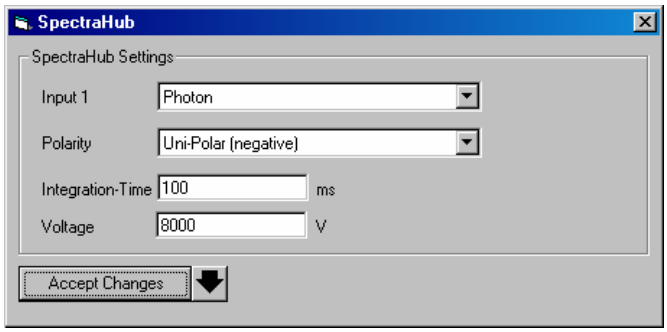


Figure 70. Settings for "SpectraHub"

- **Photon:** If the PMT counts photons in order to send TTL-pulses to the SpectraHub, you can set the period for counting the pulses during each step of the measurement. The SpectraHub accepts values for "Integration-Time" between 5 ms up to 64 s. Here "Polarity" has no function.
- **Current** or **Voltage:** If the PMT measures current or voltage, you must define "Polarity". The choices are "Uni-Polar" (only negative voltage / current) and "Bi-

Polar" (positive and negative voltage / current). In this case "Integration-Time" has no function.

For photomultipliers with integrated high-voltage socket it is possible to software control the PMT cathode's high-voltage. This value has to be entered into the "Voltage" field.

NCL

The settings for the NCL are almost equal to the settings for the SpectraHub. The only difference is that the software needs to know through which channel the PMT is connected to it. This setting can be selected at the "Input Channel" field.

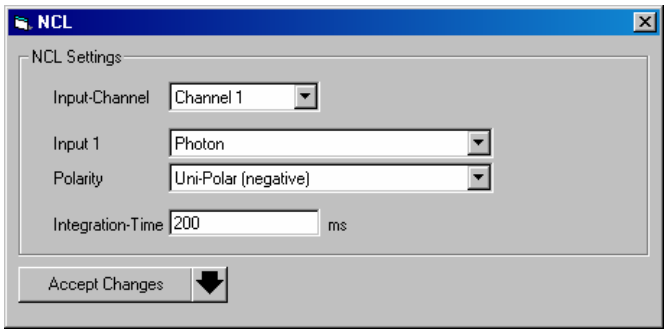


Figure 71. Settings for "NCL"

SR400

Unlike SpectraHub and NCL, the SR400 is only able to measure intensity through photon counting. "Signal" defines which interface is used at the SR400 input channel will be receiving the TTL-pulses from the PMT: "Counter A" (In 1 at the device) and "Counter B" (In 2 at the device). "Input" defines the gate for measuring at the device. If "10 MHz" is used, the internal gate at the device opens and closes 10 million times a second, which means the device is able to count a maximum of 10 million TTL-Pulses from the PMT each second. If "In 1" is used, Counter A is used to define the gate periods. Each time a TTL-pulse occurs at "In 1" the gate opens until "In 2" notes a TTL-pulse from the PMT to store it as a counted photon. After each signal at "In 1" only one signal at "In 2" can be counted.

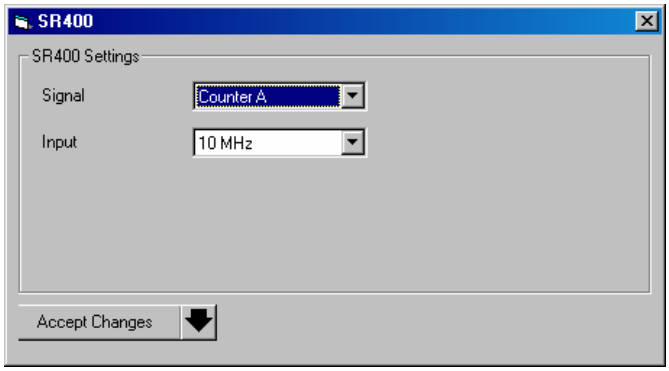


Figure 72. Settings for "SR-400"

All other settings (Integration time etc.) have to be executed at the device itself at this time.

For all three devices the settings need to be stored by using the button "Accept Changes".

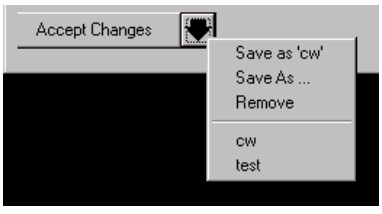


Figure 73. Store Settings for multimeter

To save more than one setting one needs to click the arrow as shown in Figure 73. With "Save As" it is possible to save a setting with an adaptable name. To activate a stored setting click on one of the names under "Remove". With "Remove" it is possible to delete the current setting,

5.5.4 CCD Detector and WinSpec

If "CCD" is chosen as measuring method in the setup, "CCD-Settings" will appear at the top of the panel.

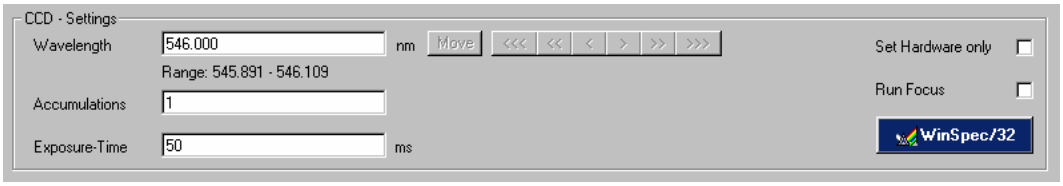


Figure 74. Settings for CCD Measurements

The name of the top field changes depending on the selected "Display Units" (chosen in the "Settings" panel). This is the field where you enter the center wavelength for your measurement. Below this field, you will see the calculated spectral range that will illuminate the CCD (this dispersion is calculated by the software from the focal length, inclusion angle, and detector pixel width entered in the "Monochromator Settings window). When you start the experiment, you will get a spectrum on the CCD whose resolution depends on the properties of your setup in the "System Settings" window.

In the "Accumulations" field, you enter the number of exposures for the measurement of one spectrum. In the "Exposure Time" field you enter the illumination period for each exposure. ***These two values can also be defined through WinSpec***.

To move the system to a new center wavelength only, without taking a spectrum with the CCD, activate the "Set Hardware Only" checkbox. If you activate the "Run Focus" checkbox, clicking on the "Start" button will cause the system to take spectra in "Loop Mode" until you click on the "Stop" button. The "Run Focus" function should be used for alignment of the system or the sample. If "Run Focus" is not activate, the system takes only one spectrum with the given exposure time and the number of accumulations. During the acquisition, the spectra are also displayed in the WinSpec software. To monitor the acquisition, click on the "WinSpec/32" button and you will be in WinSpec.

TIP: If WinSpec is not running, click on the "WinSpec/32" button before clicking on the "Start" button. This will boot the WinSpec program. Then click on the "Start" button to begin acquiring data.

General Settings through WinSpec

Data acquisition with CCD or InGaAs Array detectors is controlled and done through WinSpec. For that reason, the general properties of the detector and the acquisition mode have to be defined there.

Hardware Setup

First of all it is necessary to tell the software which type of detector is being used. Switch to WinSpec and enter the "Hardware Setup" through "Setup" and then "Hardware" to pop up the dialog box shown in Figure 75. The main properties of the detector system ("Controller Type", "Controller Version" and "Camera Type") can be taken from the controller by using the button "Load Defaults From Controller". "Shutter Type" has to be set manually.

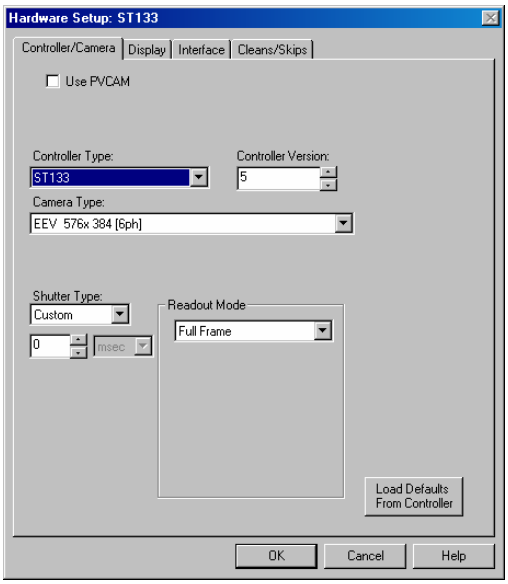


Figure 75. Hardware Setup dialog box in WinSpec

> ***TIP:*** If there are two or more multi-channel detectors mounted to your system, you can switch the detector which will be used for your actual experiment through this dialog box. If you do change the camera type in this dialog box, you should make sure that the correct pixel width value for your detector is entered in the S&I software "Monochromator Settings" window (page 60).

Because CCD chips can be mounted inside of the housing in many different orientations, the orientation of the data display is settable on the "Display" tab page. You can either reverse the orientation here or in the S&I software "Global Settings" window (page 66) but do not to use that checkbox in both programs. In WinSpec, you can also rotate the spectrum 90º counter- clockwise by selecting "Rotate" and flip the data vertically (bottom and top change places) by selecting "Flip".

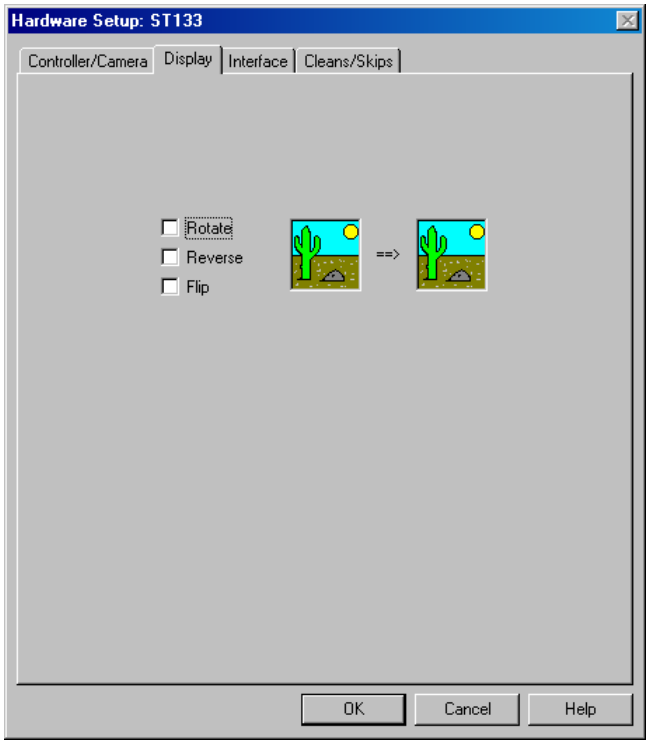


Figure 76. Display Properties of CCD Chip

If the detector uses the TAXI (RSPCI) interface, the next step is to activate the PCI-card. Switch to the "Interface" tab page set the "Type" to "PCI-Timer"

If the detector, is a PIXIS or other detector using the USB2 interface, this tab page is not needed.

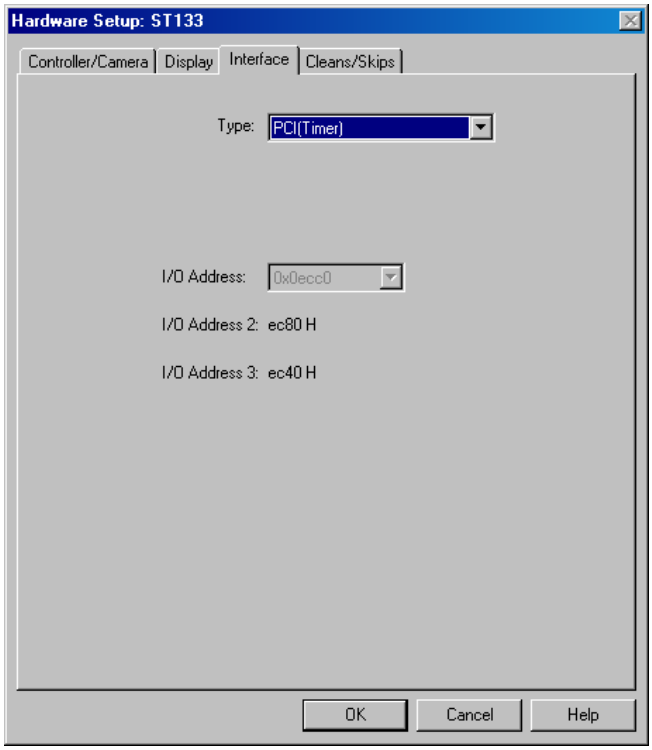


Figure 77. CCD Camera Interface

After setting the right properties of the CCD-system, they have to be stored by using the "OK" button.

Spectrograph Setup

The other general setting that must be done in WinSpec is the definition of the spectrograph. The definition can be done by selecting the "Spectrograph" menu and then selecting "Define". Then the dialog box shown in Figure 78 will appear. Click on the "Install / Remove Spectrograph…" button to pop up the Define Spectrograph dialog box (Figure 79). Here you choose a spectrograph and its corresponding interface. Because the communication with the spectrograph occurs through the S&I software, "Communication Port" has to be put to "DEMO". The kind of the spectrograph is not important.

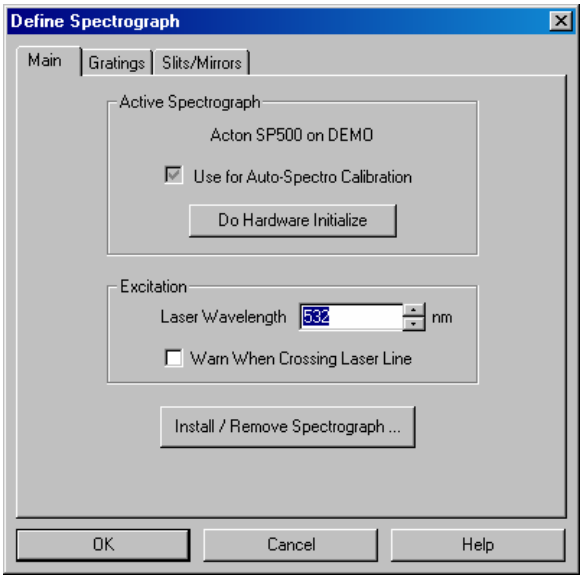


Figure 78. Spectrograph Menu in WinSpec

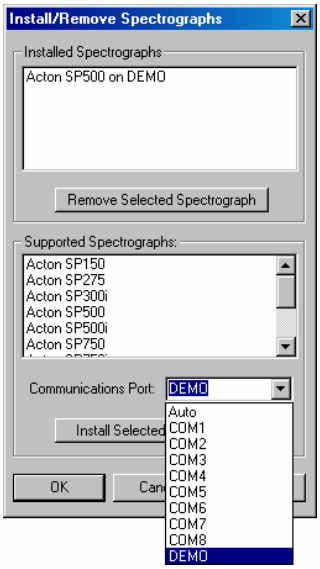


Figure 79. Installation of a Dummy Spectrograph

In situations in which "only one stage" of the system is used (i.e., Spectrograph only), that stage can be controlled completely and only by WinSpec in the CCD mode. In that is case, the "Communication Port" needs to be set to the computer communication port to which that particular stage is connected.

5.5.5 Measurement Parameters in WinSpec

Nearly all parameters for the data acquisition with multi-channel detectors can be set in menu "Experiment Setup" dialog box (menu item "Acquisition", then "Experiment Setup"). **Only "Exposure Time" and "Accumulations" are controlled through the S&I software (beginning of this chapter).**

To understand the use of the "ADC", "Timing", "Process", "Save/Load" and "Data Corrections" tab pages, refer to the WinSpec manual. All parameters in WinSpec need to be set according to your experimental requirements. To take a picture with the detector, choose "Use Full Chip" at "CCD Readout". When measuring spectra, select "Use Region Of Interest".

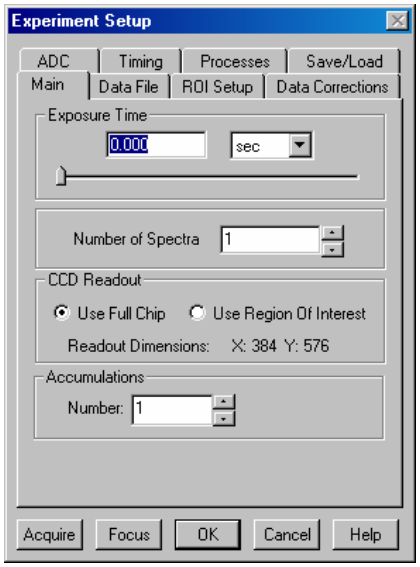


Figure 80. Experiment Setup in WinSpec

The "Data File" parameters are also described in the WinSpec manual. **For data acquisition through the S&I software "Data Type" must be set to "FLOAT"!** All other data types are not supported.

> ***TIP:*** To save time during measurements, you may want to deactivate the checkbox "Confirm before overwriting" (in the "Overwrite / Append" section).

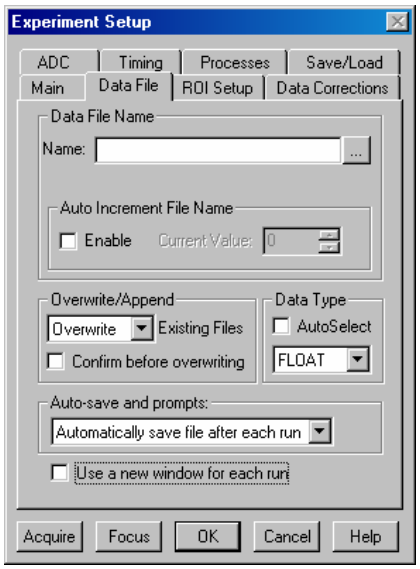


Figure 81. Format of Measurement Data

Setting up an "ROI" (Region Of Interest) can be used to optimize the spectral data that you will acquire.

- For maximum intensity the full height of the CCD may be "binned" (gathered) into one super pixel.
- To minimize the effect of dark charge and keep the background signal as small as possible, you can specify that only the illuminated area of the CCD be read out. CCD systems with less efficient cooling may have a relatively large dark charge, especially with increasing exposure time.
- To read out the whole chip, click on the "Full" button.

Never forget to use button "OK" after setting the parameters.

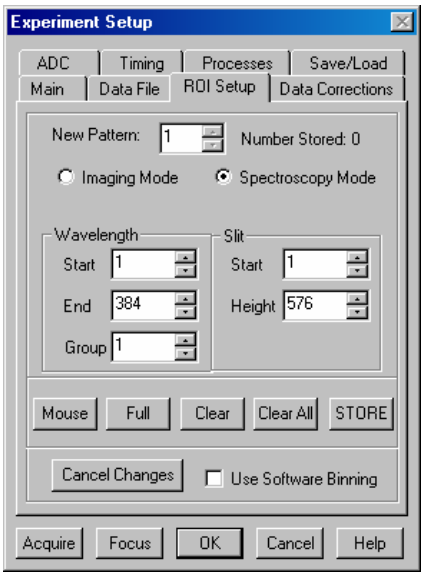


Figure 82. Region Of Interest for CCD Chip

5.6 Matching the Stages

Within the S&I software, there are two different locations that you need to access when matching the different stages: the general "Offset Table" in "Monochromator Settings" and the "Stage Settings" for a specific measurement mode. The matches are stored as "Offsets", which means an additional movement of the turret to the correct position.

5.6.1 Offset Table in the "Monochromator Settings" Window

Before you can access the "Monochromator Settings" window (a Hardware Setup component) to enter or change values, you must log in. This prevents accidental changes to the offset table by users who do not need to do any hardware configuration.

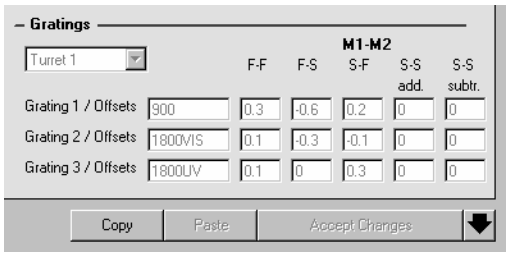


Figure 83. Offset Table in the "Monochromator Settings" window

The offset table keeps matches for each optical path. That means multiple values for each stage. Entering these values in the offset table is necessary because the angle in which the light illuminates the grating differs slightly for the different optical paths. The letters above the table mean:

F-F = Front Entrance – Front Exit

F-S = Front Entrance – Side Exit

S-F = Side Entrance – Front Exit

S-S = Side Entrance – Side Exit

Two things should be considered when entering values into this table:

1. First, the software stores separate offsets for each of the 7 possible modes and separate offsets for each of the three stages. Please take care to select the correct mode and the correct stage when entering the values into the table.
2. Second, the offset table compensates for the offset for the entire spectral range. That means there is only a rough correction for specific wavelengths.

5.6.2 Stage Settings within the "System Settings" window

"Stage Settings" in "System Settings" window are accessible by every user. The offsets in "Stage Settings" are specific values for only one specific configuration and only a specific wavelength range. If you change a grating, the position of one of the diverter mirrors, or change the wavelength, the values are no longer appropriate and you have to enter the new values for the new setup.

Example:

1. The setup has the properties:

   Mode: Triple Subtractive

   Gratings: 1200 g/mm (blazed for visible light) in all stages.
2. Light enters the first stage through the side entrance and reaches the CCD camera at the third stage through the front exit.
3. First find a rough alignment for the spectral range with offset values in "Monochromator Settings". The fields for the values are:

   Mode = Triple Subtractive

   Stage 1: row = 1200 grating; column = S-S (side-side)

   Stage 2: row = 1200 grating; column = sub S-S (side-side subtractive)

   Stage 3: row = 1200 grating; column = S-F (side-front)
4. By using "Advanced slit commands" (explained below) you find the value for the visible light. With a mercury lamp (for example) you can check the offset at 546.07 nm. After that you fill the values into the three described fields in "Monochromator Settings".
5. Next, the setup has to be matched for the laser. In this example a laser with the wavelength 532 nm is used. This matching has to be defined through the offset values within "Stage Settings", without changing any value in "Monochromator Settings".

Matching through "Advanced Slit Commands"

To execute the matching, it is necessary to start a measurement in "Run Focus" mode. This operation is only possible while a running measurement. The locating of the offsets occurs through "Advanced Slit Commands" on the "File" menu (see Figure 84).

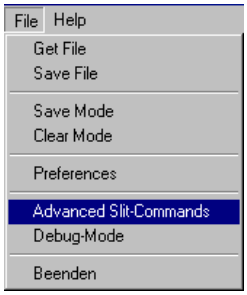


Figure 84. Item "Advanced Slit Commands"

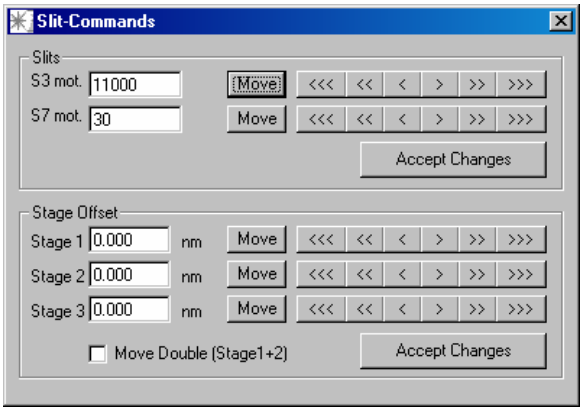


Figure 85. Menu "Advanced Slit Commands"

In this dialog box, you have access to all motorized slits and to all turrets and can move all of them separately. You have two ways to enter or change a slit width or an offset position:

1. Enter absolute values in the input fields and execute the command by clicking on the "Move" button.
2. Use the arrow buttons to the right of the "Move" button. The effect of the buttons on the current value is:

   < / >: Changes the value +/- 10 µm for the slit-width and +/- 0.01 nm for the wavelength

   << / >>: Changes the value +/- 100 µm for the slit-width and +/- 0.1 nm for the wavelength

   <<< / >>>: Changes the value +/- 1000 µm for the slit-width and +/- 1 nm for the wavelength

If "Display Units" is set to "abs. wavenumbers" or "rel. wavenumbers", the region "Stage Offset" will change to relative wavenumbers (unit : cm^{-1}).

Matching should be carried out in the following order:

1. Positioning Stage 1
   a. The entrance slit should be opened to 10-20 µm. All other slits that pertain to the current configuration should be completely opened.
   b. Then, the first intermediate slit should be as narrow as possible to irradiate the second stage.
   c. Next, Stage 1 has to be moved to the position where maximum intensity is displayed at the PMT or the CCD chip.
   d. Step b and Step c should be repeated until only one position of Stage 1 leads to maximum intensity.
2. Positioning Stage 2
   a. The positioning of Stage 2 occurs in the same way as in Stage 1 but with closing the second intermediate slit instead of the first one.

b. The grating in Stage 1 must not be moved while matching Stage 2.

3. Positioning stage 3

   a. If the positioning of Stage 3 occurs with a PMT at the exit slit, the exit slit should be as narrow as possible to irradiate the PMT.

   b. The intermediate slits can be reopened to measuring conditions. When using a CCD you must move Stage 3 until the peak of the wavelength corresponds to the central wavelength that is set in CCD-Settings in the "Measuring" menu.

   c. The gratings in Stage 1 and Stage 2 must not be moved while matching Stage 3.

5.7 Raman Measurements with CCD

The standard procedure for Raman Spectroscopy is to irradiate a sample with a relatively high intensity narrow-banded laser light to observe the interaction between the sample and the stimulation light. The typical unit of measure for this type of spectroscopy is "rel. Wavenumbers". By using this unit, the acquired spectrum is equal for all possible stimulating wavelengths.

In comparison to the intensity of the stimulation light, the Raman signal is very weak. Hence it is of advantage to use a high-sensitivity CCD detector system and to exclude the direct stray light from the measurement. When the system is set to "Triple Additive" mode with a CCD detector, it is nearly impossible to exclude the direct stray light from the spectra as the intermediate slits have to be wide open for that setup.

However, the "Triple Subtractive" mode makes it possible to divide the intensive direct stray light from the weak Raman spectrum very precisely. This is because the interfering stray light, which enters the second stage through the wide opened first intermediate slit, is intercepted at the narrow second intermediate slit (see further explanations in ***"5.4.1 TriVista Configurations"***, page 61). As the second intermediate slit is not completely closed, a small remainder of the stray light is able to enter the third stage. This light appears on rel. wavenumber 0: on the left side in from the laser peak, beneath the boundary of the spectrum that is given by the edges of the first intermediate slit. While observing the intensity of that peak, you can now move the spectrum tentatively as close as possible to the laser line. The resolution of the spectrum in "Triple Subtractive" mode is determined by the groove density of the grating in the third stage and by the width of the second intermediate slit. A high stray light rejection occurs if the bandpass at the entrance of the third stage is narrow which is given by a high groove density in the first two stages. Possible values for smallest wavenumbers are:

Groove Density in first two stages	Wavenumbers
900 g/mm	10-20 cm^{-1}
1800 g/mm	5-10 cm^{-1}

Table 8. Groove Density (Stages 1 and 2) vs. Wavenumbers

Stokes / Anti-Stokes

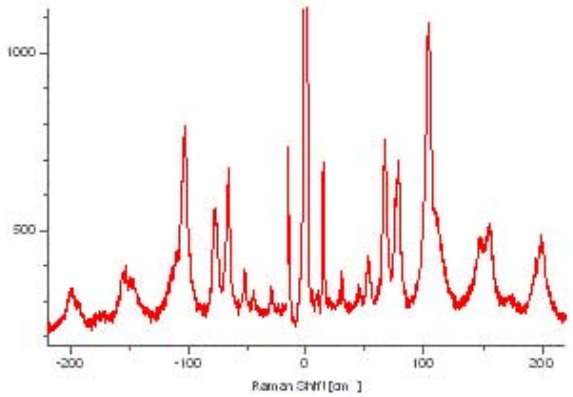


Figure 86. Stokes/Anti-Stokes Spectrum

The laser stop mask (described in ***"4.5 Stokes/Anti-Stokes Laser Stop Mask"***, page 47) can be used to block the center wavelength of a beam or a laser light. If the beam or the laser light is not exactly positioned at the center of the first intermediate slit, you must match the spectrum to the beam:

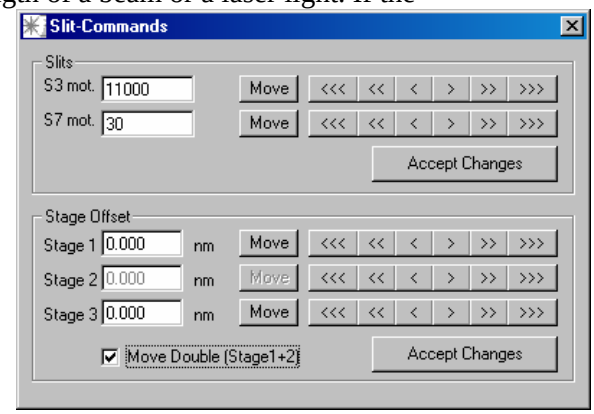


Figure 87. Move First Two Stages Simultaneously

1. In WinSpec, set the Region of Interest so it contains only one pixel for "Binning".
2. In the S&I software, keep the exposure time small to avoid saturation of the CCD-chip
3. Start data acquisition on rel. wavenumber 0 in Focus mode and with Stage Settings as shown in Figure 87.
4. Then slightly move the bar until the laser peak is rejected as good as possible.
5. Fine Adjustment can now be done through "Advanced Slit Commands": Please activate "Move Double" checkbox and move the first two stages until the laser line is completely rejected and positioned at the middle of the beam.

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Chapter 6
Maintenance

6.1 Cleaning the Housing

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

6.2 Optical Surfaces

Optical surfaces may need to be cleaned due to the accumulation of atmospheric dust. Pressurized cans of clean air are available that can be used to blow dust particles from optical surfaces. ***Do NOT touch any optical surface with your fingers or with any kind of material.*** If a grating surface comes in contact with a finger, a finger print will be left on the grating and the grating's performance will be affected. You may be able to remove the finger print using a squirt or two of ***anhydrous*** methanol or ethanol from a squeeze bottle. However, success is not assured and there will be some risk of permanently damaging the grating.

6.3 Alignment

There are no user adjustments inside the spectrograph. Aligning the gratings and mirrors is a factory operation and cannot be performed in the field.

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Chapter 7
Troubleshooting

7.1 TriVista

If you are not seeing the expected spectral information:

1. Check to see if the detector has an internal shutter and verify that the correct shutter is selected in WinSpec.
2. Check the optical path and confirm that intermediate slits are correctly configured
3. Review the Offset Table for the selected mode and stages. You may want to use the Advanced Slit Commands feature to match the stages.
4. Verify that the power supply for each active spectrograph is plugged in and turned on.

7.2 Raman Measurements

If the amount of stray light and resolution is worse than expected, rejection can be enhanced through the alignment of:

- The slit width of the entrance slit and the second intermediate slit,
- The height of the aperture of all involved slits,
- The "Region Of Interest" in WinSpec
- The focal plane of the camera

7.3 SpectraHub

The SpectraHub operates from an external +12 Volt DC supply provided with the SpectraHub at time of shipment. This +12 volts DC is converted to +5VDC digital, +5VDC analog, and +/-15VDC analog voltages internally using board mounted isolated DC to DC converters. The SpectraHub operates using an internal 32 bit microprocessor. Shown below are a list of possible symptoms, what to check and action to take.

Symptom	Check
1. Green power indicator LED does not come on when SpectraHub is switched on.	Make sure power supply is connected to an AC source and the power supply is connected to the SpectraHub.
	If connected properly, check the +12V and +5V at TP12 and TP13 on the SpectraHub pc board.

2. The SpectraSense software cannot find the SpectraHub.	Make sure amber communications light on the rear panel of the SpectraHub flashes as the SpectraHub is switched on.
	Set the computer to terminal emulation mode at 9600 baud and test communications.
3. SpectraSense software cannot find monochromators.	Be sure monochromator is on and fully initialized.
	Connect the computer in terminal emulation mode directly to the monochromator and test communications.

Appendix A

Dispersion Tables

TriVista 555 in Subtractive Mode

Calculated as dispersion of a single 500 mm stage

Wavelength		3600 g/mm		2400 g/mm		1800 g/mm		1200 g/mm		1100 g/mm		900 g/mm		750 g/mm		600 g/mm	
nm	cm^{-1} *	nm/mm	cm^{-1}/mm **	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm
200	50,000	0.48	120.06	0.77	191.56	1.05	261.15	1.61	398.20	1.76	435.30	2.16	533.74	2.60	641.41	3.26	801.86
300	33,333	0.41	46.04	0.72	80.05	1.01	112.02	1.58	174.11	1.73	190.82	2.13	235.16	2.57	283.61	3.24	355.83
400	25,000	0.32	19.74	0.66	41.18	0.96	60.04	1.54	95.78	1.69	105.33	2.10	130.58	2.55	158.11	3.21	199.10
500	20,000	*0.15*	*6.08*	0.58	23.15	0.90	36.05	1.49	59.61	1.65	65.84	2.06	82.23	2.51	100.04	3.18	126.49
600	16,667			0.47	13.16	0.83	23.02	1.44	40.02	1.60	44.44	2.02	56.01	2.48	68.52	3.15	87.05
700	14,286			*0.33*	*6.71*	0.74	15.11	1.39	28.24	1.55	31.57	1.98	40.24	2.44	49.55	3.12	63.29
800	12,500					0.63	9.87	1.32	20.59	1.49	23.23	1.93	30.02	2.39	37.26	3.08	47.89
900	11,111					*0.49*	*6.10*	1.24	15.35	1.42	17.51	1.87	23.02	2.35	28.88	3.03	37.34
1000	10,000							1.16	11.58	1.34	13.41	1.81	18.02	2.29	22.84	2.99	29.81
1100	9,091							1.06	8.76	1.26	10.37	1.74	14.33	2.23	18.39	2.94	24.24
1200	8,333							0.95	6.58	1.16	8.03	1.66	11.51	2.17	15.02	2.89	20.01
1300	7,692							*0.82*	*4.83*	1.05	6.18	1.58	9.31	2.10	12.39	2.83	16.72
1400	7,143									*0.92*	*4.67*	1.48	7.55	2.02	10.31	2.77	14.12
1500	6,667											1.38	6.12	1.94	8.62	2.71	12.02
1600	6,250											1.26	4.94	1.85	7.23	2.64	10.30
1700	5,882											*1.14*	*3.93*	1.76	6.08	2.57	8.87
1800	5,556													1.66	5.10	2.49	7.67
1900	5,263													1.54	4.27	2.41	6.66
2000	5,000													1.41	3.53	2.32	5.79
2100	4,762															2.22	5.04
2200	4,545															2.12	4.38

* - absolute wavenumbers

** - relative wavenumbers

0.15 - dispersion values beyond mechanical scanning range (for reference only)

TriVista 555 in Additive Mode

Calculated as dispersion of a single 1500 mm stage

Wavelength		3*3600 g/mm		3*2400 g/mm		3*1800 g/mm		3*1200 g/mm		3*1100 g/mm		3*900 g/mm		3*750 g/mm		3*600 g/mm	
nm	cm^{-1} *	nm/mm	cm^{-1}/ mm**	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm
200	50,000	0.16	40.08	0.26	64.02	0.35	87.36	0.54	133.44	0.59	145.95	0.72	179.19	0.87	215.65	1.09	270.17
300	33,333	0.14	15.36	0.24	26.73	0.34	37.42	0.53	58.24	0.58	63.85	0.71	78.76	0.86	95.08	1.08	119.46
400	25,000	0.11	6.58	0.22	13.74	0.32	20.04	0.51	32.01	0.56	35.21	0.70	43.68	0.85	52.93	1.07	66.72
500	20,000	*0.051*	*2.03*	0.19	7.72	0.30	12.03	0.50	19.91	0.55	21.99	0.69	27.48	0.84	33.46	1.06	42.34
600	16,667			0.16	4.39	0.28	7.68	0.48	13.36	0.53	14.84	0.67	18.71	0.83	22.90	1.05	29.12
700	14,286			*0.11*	*2.24*	0.25	5.04	0.46	9.42	0.52	10.54	0.66	13.44	0.81	16.56	1.04	21.16
800	12,500					0.21	3.29	0.44	6.87	0.50	7.75	0.64	10.02	0.80	12.44	1.03	16.00
900	11,111					*0.16*	*2.03*	0.41	5.12	0.47	5.84	0.62	7.68	0.78	9.64	1.01	12.48
1000	10,000							0.39	3.86	0.45	4.47	0.60	6.02	0.76	7.62	1.00	9.96
1100	9,091							0.35	2.92	0.42	3.46	0.58	4.78	0.74	6.14	0.98	8.09
1200	8,333							0.32	2.19	0.39	2.68	0.55	3.84	0.72	5.01	0.96	6.68
1300	7,692							*0.27*	*1.61*	0.35	2.06	0.53	3.11	0.70	4.14	0.94	5.58
1400	7,143									*0.31*	*1.56*	0.49	2.52	0.67	3.44	0.92	4.71
1500	6,667											0.46	2.04	0.65	2.88	0.90	4.01
1600	6,250											0.42	1.65	0.62	2.41	0.88	3.44
1700	5,882											*0.38*	*1.31*	0.59	2.03	0.86	2.96
1800	5,556													0.55	1.70	0.83	2.56
1900	5,263													0.51	1.42	0.80	2.22
2000	5,000													0.47	1.18	0.77	1.93
2100	4,762															0.74	1.68
2200	4,545															0.71	1.46

* - absolute wavenumbers

** - relative wavenumbers

0.05 - dispersion values beyond mechanical scanning range (for reference only)

TriVista 557 & 777 in Subtractive Mode

Calculated as dispersion of a single 750 mm stage

Wavelength		3600 g/mm		2400 g/mm		1800 g/mm		1200 g/mm		1100 g/mm		900 g/mm		750 g/mm		600 g/mm	
nm	cm^{-1} *	nm/mm	cm^{-1}/mm **	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm
200	50,000	0.33	81.77	0.52	129.74	0.71	176.47	1.08	268.67	1.18	293.64	1.45	360.01	1.75	432.67	2.19	541.18
300	33,333	0.29	31.74	0.49	54.52	0.69	75.96	1.06	117.65	1.16	128.89	1.44	158.71	1.73	191.32	2.18	240.00
400	25,000	0.22	13.92	0.45	28.26	0.66	40.89	1.04	64.86	1.14	71.28	1.42	88.24	1.72	106.75	2.16	134.33
500	20,000	*0.12*	*4.70*	0.40	16.05	0.62	24.68	1.01	40.48	1.12	44.66	1.40	55.66	1.70	67.62	2.14	85.40
600	16,667			0.33	9.28	0.57	15.87	0.98	27.26	1.09	30.22	1.37	37.98	1.67	46.38	2.13	58.83
700	14,286			*0.24*	*4.92*	0.52	10.51	0.95	19.30	1.06	21.53	1.34	27.34	1.65	33.59	2.10	42.81
800	12,500					0.45	6.96	0.91	14.13	1.02	15.89	1.31	20.44	1.62	25.30	2.08	32.43
900	11,111					*0.36*	*4.41*	0.86	10.58	0.98	12.03	1.28	15.72	1.59	19.62	2.06	25.32
1000	10,000							0.80	8.03	0.9263	9.25	1.24	12.34	1.56	15.57	2.03	20.24
1100	9,091							0.74	6.12	0.871	7.19	1.19	9.84	1.52	12.57	2.00	16.48
1200	8,333							0.67	4.64	0.8082	5.61	1.14	7.93	1.48	10.28	1.97	13.63
1300	7,692							*0.58*	*3.46*	0.7366	4.36	1.09	6.44	1.44	8.51	1.93	11.41
1400	7,143									*0.6538*	*3.33*	1.03	5.26	1.39	7.10	1.89	9.65
1500	6,667											0.97	4.29	1.34	5.95	1.85	8.23
1600	6,250											0.89	3.48	1.29	5.02	1.81	7.06
1700	5,882											*0.81*	*2.80*	1.22	4.23	1.76	6.10
1800	5,556													1.16	3.57	1.72	5.29
1900	5,263													1.09	3.00	1.66	4.60
2000	5,000													1.01	2.51	1.61	4.01
2100	4,762															1.55	3.50
2200	4,545															1.48	3.06

* - absolute wavenumbers
** - relative wavenumbers
0.12 - dispersion values beyond mechanical scanning range (for reference only)

TriVista 557 in Additive Mode

Calculated as dispersion of a single 1750 mm stage with inclusion angle 15.43 degrees

Wavelength		3*3600 g/mm		3*2400 g/mm		3*1800 g/mm		3*1200 g/mm		3*1100 g/mm		3*900 g/mm		3*750 g/mm		3*600 g/mm	
nm	cm^{-1} *	nm/mm	cm^{-1}/mm **	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm	nm/mm	cm^{-1}/mm
200	50,000	0.14	34.68	0.22	55.24	0.30	75.29	0.46	114.91	0.50	125.66	0.62	154.22	0.75	185.58	0.93	232.49
300	33,333	0.12	13.36	0.21	23.12	0.29	32.31	0.45	50.19	0.50	55.02	0.61	67.83	0.74	81.85	0.93	102.82
400	25,000	0.093	5.79	0.19	11.93	0.28	17.34	0.44	27.61	0.49	30.36	0.60	37.64	0.73	45.59	0.92	57.45
500	20,000	*0.047*	*1.86*	0.17	6.73	0.26	10.43	0.43	17.20	0.48	18.99	0.59	23.71	0.72	28.84	0.91	36.47
600	16,667			0.14	3.86	0.24	6.68	0.42	11.56	0.46	12.83	0.58	16.15	0.71	19.76	0.90	25.10
700	14,286			*0.098*	*2.00*	0.22	4.40	0.40	8.16	0.45	9.12	0.57	11.61	0.70	14.29	0.90	18.25
800	12,500					0.19	2.89	0.38	5.96	0.43	6.72	0.56	8.67	0.69	10.75	0.88	13.81
900	11,111					*0.15*	*1.81*	0.36	4.45	0.41	5.07	0.54	6.66	0.68	8.33	0.87	10.77
1000	10,000							0.34	3.37	0.3895	3.89	0.52	5.22	0.66	6.60	0.86	8.60
1100	9,091							0.31	2.56	0.37	3.02	0.50	4.15	0.64	5.32	0.85	7.00
1200	8,333							0.28	1.93	0.34	2.34	0.48	3.34	0.63	4.35	0.83	5.78
1300	7,692							*0.24*	*1.42*	0.31	1.81	0.46	2.71	0.61	3.59	0.82	4.83
1400	7,143									*0.27*	*1.38*	0.43	2.20	0.59	2.99	0.80	4.08
1500	6,667											0.40	1.79	0.56	2.50	0.78	3.48
1600	6,250											0.37	1.45	0.54	2.10	0.76	2.98
1700	5,882											*0.33*	*1.16*	0.51	1.77	0.74	2.57
1800	5,556													0.48	1.49	0.72	2.23
1900	5,263													0.45	1.25	0.70	1.93
2000	5,000													0.42	1.04	0.67	1.68
2100	4,762															0.65	1.47
2200	4,545															0.62	1.28

* - absolute wavenumbers

** - relative wavenumbers

0.047 - dispersion values beyond mechanical scanning range (for reference only)

TriVista 777 in Additive Mode

Calculated as dispersion of a single 2250 mm stage

Wavelength		3*3600 g/mm		3*2400 g/mm		3*1800 g/mm		3*1200 g/mm		3*1100 g/mm		3*900 g/mm		3*750 g/mm		3*600 g/mm	
nm	cm^{-1} *	nm/mm	cm^{-1}/ mm**	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm	nm/mm	cm^{-1}/ mm
200	50,000	0.11	27.29	0.17	43.31	0.24	58.96	0.36	89.89	0.39	98.26	0.48	120.58	0.58	145.05	0.73	181.71
300	33,333	0.10	10.59	0.16	18.19	0.23	25.36	0.35	39.31	0.39	43.08	0.48	53.07	0.58	64.02	0.73	80.38
400	25,000	0.074	4.64	0.15	9.43	0.22	13.64	0.35	21.66	0.38	23.80	0.47	29.48	0.57	35.69	0.72	44.94
500	20,000	*0.039*	*1.57*	0.13	5.35	0.21	8.23	0.34	13.51	0.37	14.91	0.47	18.59	0.57	22.59	0.71	28.55
600	16,667			0.11	3.10	0.19	5.29	0.33	9.10	0.36	10.09	0.46	12.68	0.56	15.49	0.71	19.65
700	14,286			*0.080*	*1.64*	0.17	3.51	0.32	6.44	0.35	7.18	0.45	9.12	0.55	11.21	0.70	14.30
800	12,500					0.15	2.32	0.30	4.71	0.34	5.30	0.44	6.82	0.54	8.44	0.69	10.83
900	11,111					*0.12*	*1.47*	0.29	3.53	0.33	4.01	0.43	5.24	0.53	6.55	0.69	8.45
1000	10,000							0.27	2.68	0.3088	3.09	0.41	4.12	0.52	5.19	0.68	6.76
1100	9,091							0.25	2.04	0.2903	2.40	0.40	3.28	0.51	4.19	0.67	5.50
1200	8,333							0.22	1.55	0.2694	1.87	0.38	2.65	0.49	3.43	0.66	4.55
1300	7,692							*0.19*	*1.15*	0.2455	1.45	0.36	2.15	0.48	2.84	0.64	3.81
1400	7,143									*0.2179*	*1.11*	0.34	1.75	0.46	2.37	0.63	3.22
1500	6,667											0.32	1.43	0.45	1.99	0.62	2.74
1600	6,250											0.30	1.16	0.43	1.67	0.60	2.36
1700	5,882											*0.27*	*0.93*	0.41	1.41	0.59	2.03
1800	5,556													0.39	1.19	0.57	1.76
1900	5,263													0.36	1.00	0.55	1.54
2000	5,000													0.34	0.84	0.54	1.34
2100	4,762															0.52	1.17
2200	4,545															0.49	1.02

* - absolute wavenumbers

** - relative wavenumbers

0.039 - dispersion values beyond mechanical scanning range (for reference only)

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Appendix B

Entrance Slit Drawing

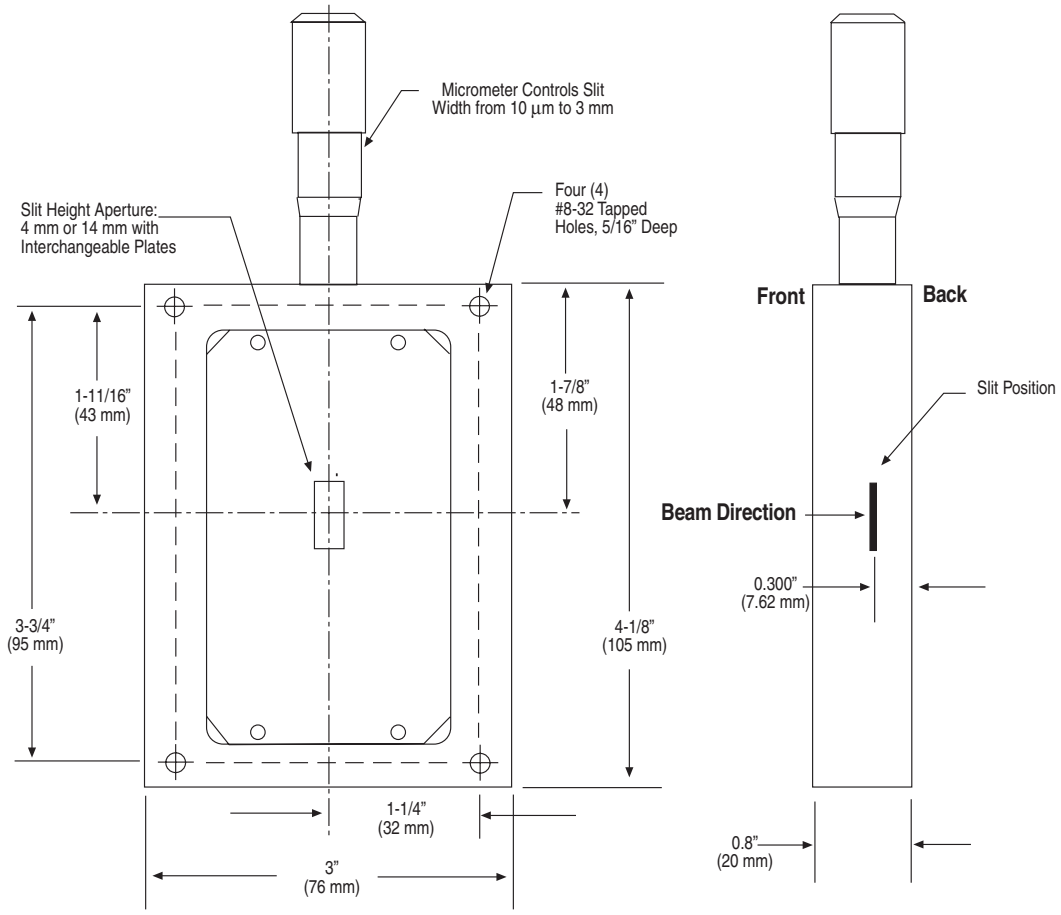

Figure 88. Entrance Slit Assembly Drawing.

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Appendix C
CCD Detector Mounting Instructions

C.1 Mounting a CCD Detector at the CCD Exit Port

The standard mounting flange for CCDs and diode arrays accommodates detectors with two different bolt circles:

1. Three equally spaced #10-32 tapped holes on a 3.60" bolt circle to arm LN- (liquid nitrogen) cooled diode arrays detectors
2. Three equally spaced holes on a 3.88" bolt circle designed to accept #10-32 button head screws and to mount Peltier-cooled diode arrays detectors

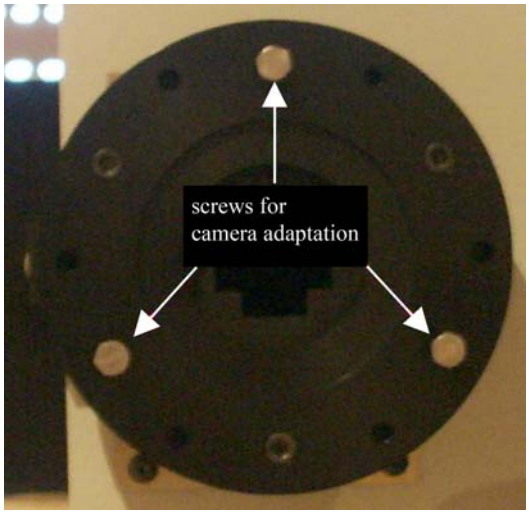


Figure 89. Adapter Screws for Peltier-cooled Diode Arrays

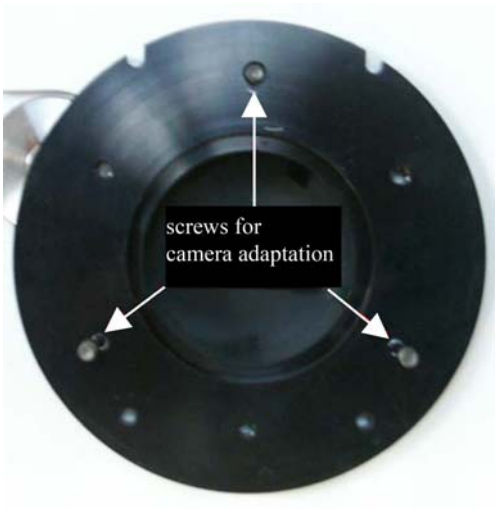


Figure 90. Adapter Screws for LN-cooled Diode Arrays

Before securing the detector to the standard mounting flange adaptation, check whether the spacer that is mounted to the flange (see Figure 91) has to be taken off. This depends on the focal distance (distance from the front mounting surface of the array detector to the actual CCD or diode array element) of the diode array. If the detector focal plane distance falls between 0.67" and 1.00" (17 - 25 mm), then no spacer is required. LN- cooled diode arrays with a shutter never require a spacer. To disconnect the spacer from the flange, use a #10-32 Allen wrench.

Figure 91. Spacer

C.1.1 Mounting Peltier-cooled Diode Array Detectors

To mount a Peltier-cooled diode array, place fastening screws on the exit port. Make sure that the baffle aperture inside is oriented as shown in Figure 92 and Figure 93 in order to match the detector array orientation.

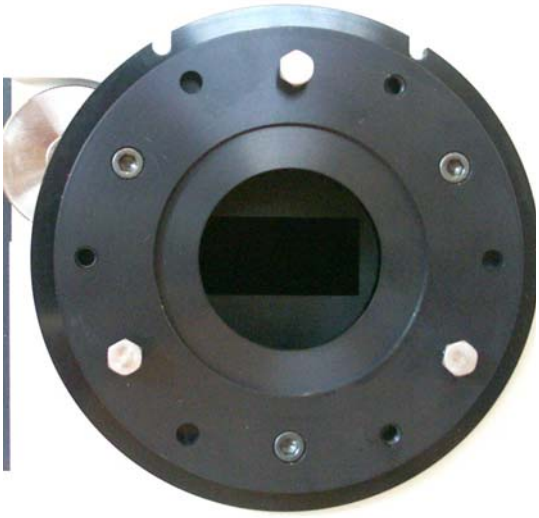


Figure 92. Screws for Peltier-cooled Diode Arrays on 500 mm Spectrograph

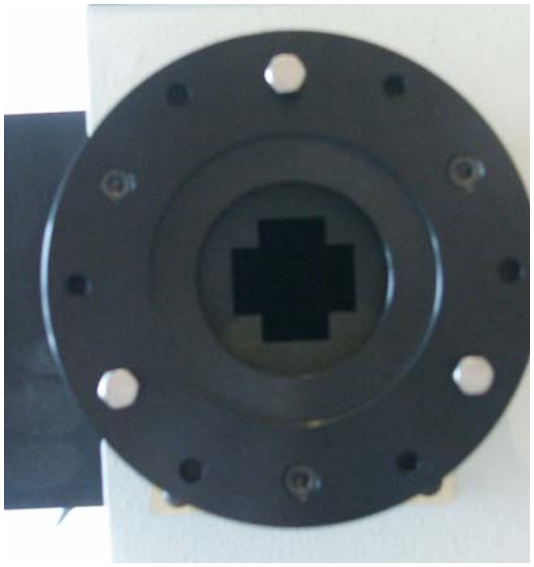


Figure 93. Screws for Peltier-cooled Diode Arrays on 750 mm Spectrograph

Then position the array detector against the mounting flange and match the hole patterns. As final step fasten the array detector mounting flange to the detector. Please take care not to loose the o-ring while positioning.

Figure 94. Mounted Peltier-cooled Diode Array Detector

C.1.2 Mounting LN-cooled Diode Array Detectors

Before mounting a LN-cooled diode array detector, loosen the fixing screw with a 1/8" Allen wrench (see Figure 95) and take off the flange --- gently slide the array detector mounting flange all the way out of the spectrograph housing. Make sure that the sliding tube and o-ring are kept clean.

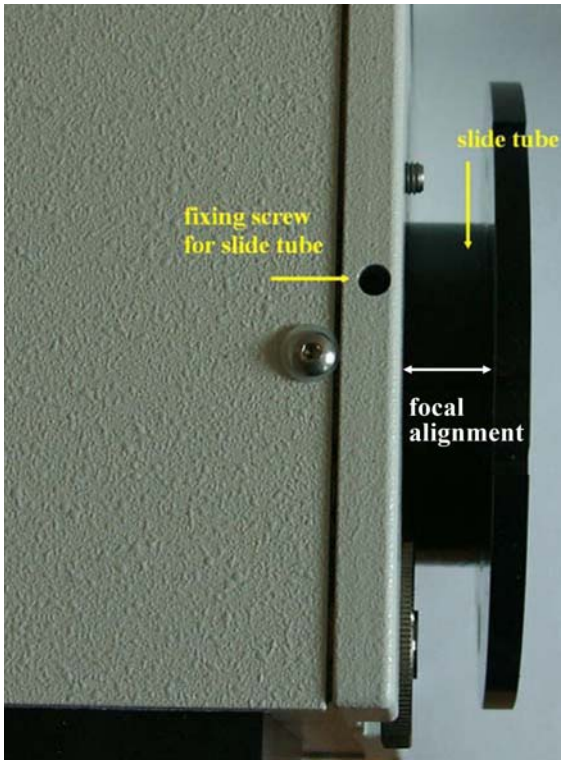


Figure 95. Slide Tube for 500 mm Spectrograph

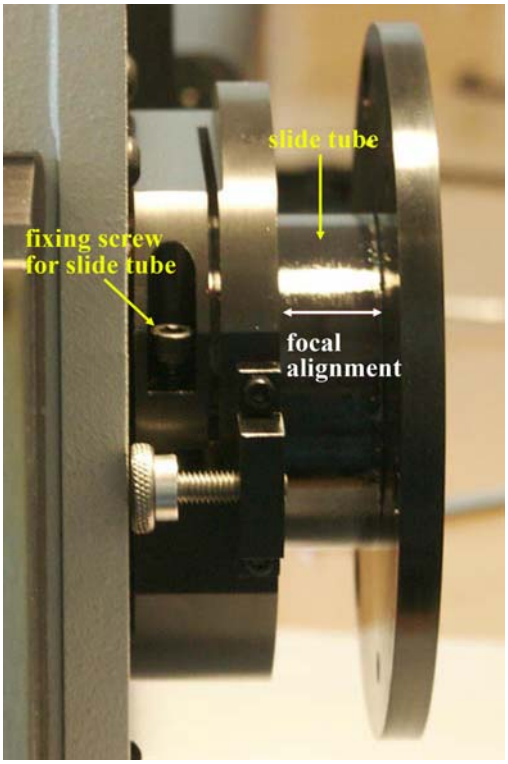


Figure 96. Slide Tube for 750 mm Spectrograph

At this point the procedure differs for detectors with shutter and for detectors without shutter.

With Shutter:

Position the mounting flange against the array detector and match the hole patterns. Then fasten the mounting flange with 3 #10-32 screws. Make sure that the baffle aperture inside is orientated as shown in Figure 97 and Figure 98 in order to match the detector array orientation.

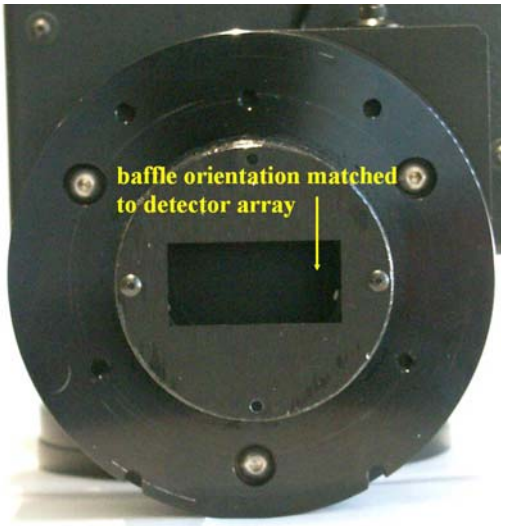


Figure 97. LN-cooled Diode Array Detector to be mounted to a 500 mm Spectrograph CCD-Port

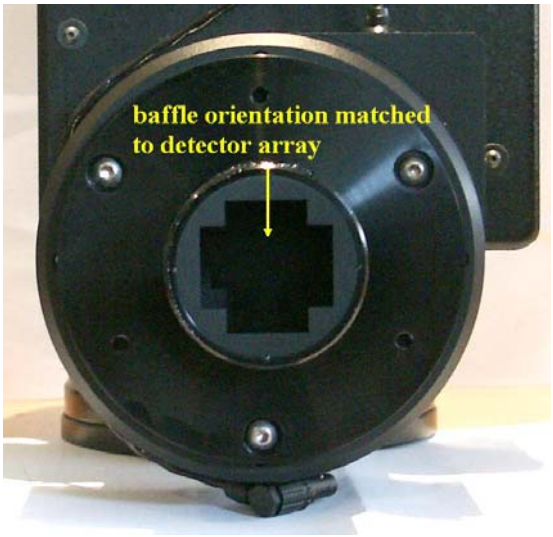


Figure 98. LN-cooled Diode Array Detector to be mounted to a 750 mm Spectrograph CCD-Port

Without Shutter

Take the adapter mount of the diode array and fasten it from backside to the mounting flange of the spectrograph. You need short #10-32 screws with countersunk head to do that. These screws should be delivered with the detector.

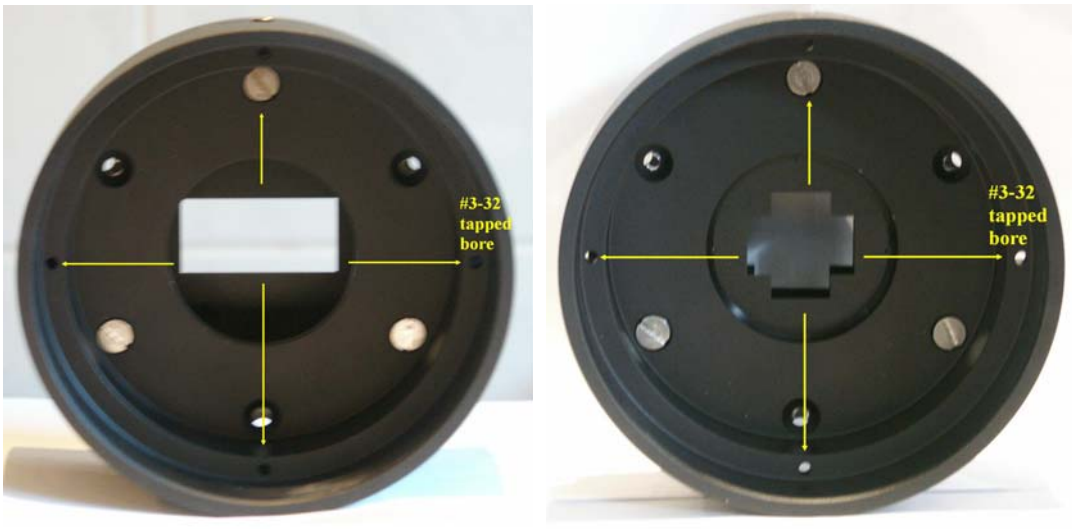


Figure 99. Mounting Spectrograph Flange to CCD-mount without Shutter. Left: with Baffle from 500 mm Spectrograph, right with Baffle from 750 mm Spectrograph

It is very important to connect the two mounts in the correct orientation in order to match the orientation of the detector array: this is only assured when the baffle has the same orientation as the four #3-32 tapped bores (see Figure 99).

Then secure the assembled mount onto the nose of detector with the four #3-32 screws as shown in Figure 100.

Figure 100. Assembled Mount on the Nose of an LN-cooled Diode Array Detector

Then carefully slide the camera together with the mounting flange back into the spectrograph. As final step, fasten the camera with the #1-8 fixing screw.

C.1.3 Focusing and Alignment of Array Detectors

With the array detector mounted to the TriVista, use the following procedure to align and focus the array detector to the system. It is assumed that the array detection system is running with S&I software or WinSpec.

1. Launch a "line" source (e.g. the laser of your measurement system or a mercury lamp with several narrow lines) into the TriVista. Then turn the gratings to (one of) the wavelength(s) of your line source.
2. With the array detector operating, check the image of the light source if running in an imaging mode with a CCD. Otherwise check the line intensity and shape.
3. The array detector mounting flange has a sliding tube, which fits inside the front plate of the spectrograph. As shown in picture Figure 101, loosen the fixing screw of the slide tube and slowly slide the array detector IN or OUT until the sharpest image is achieved or the sharpest line is achieved.

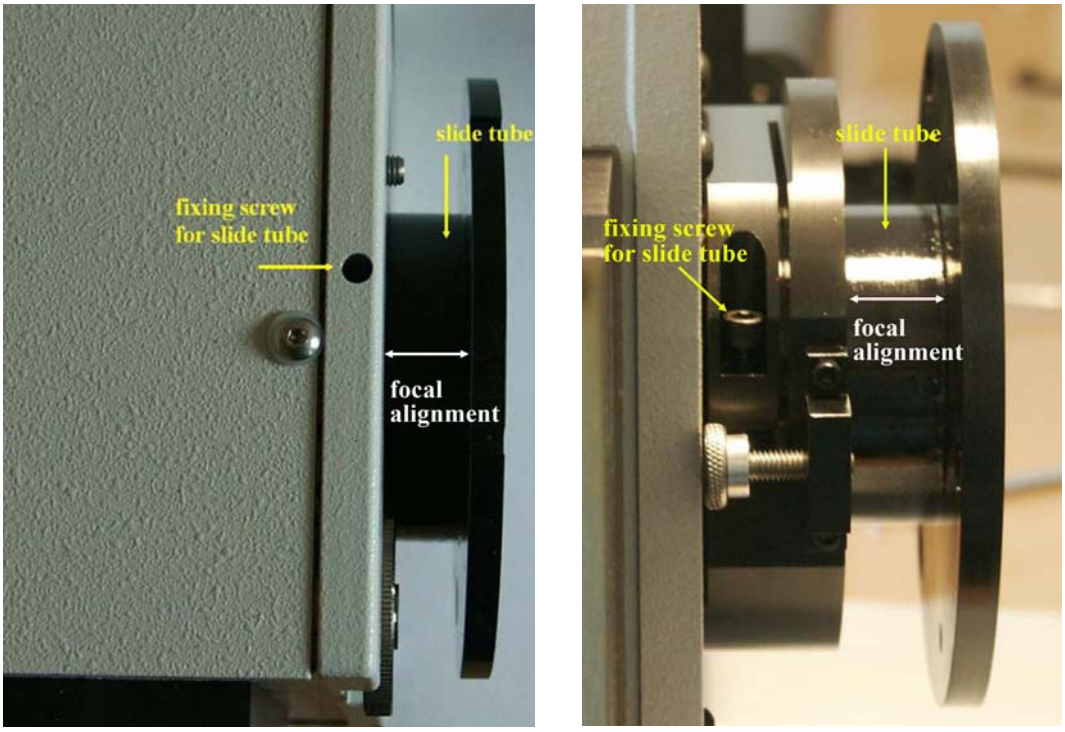


Figure 101. Focal Alignment; left: 500 mm Spectrograph, right: 750 mm Spectrograph

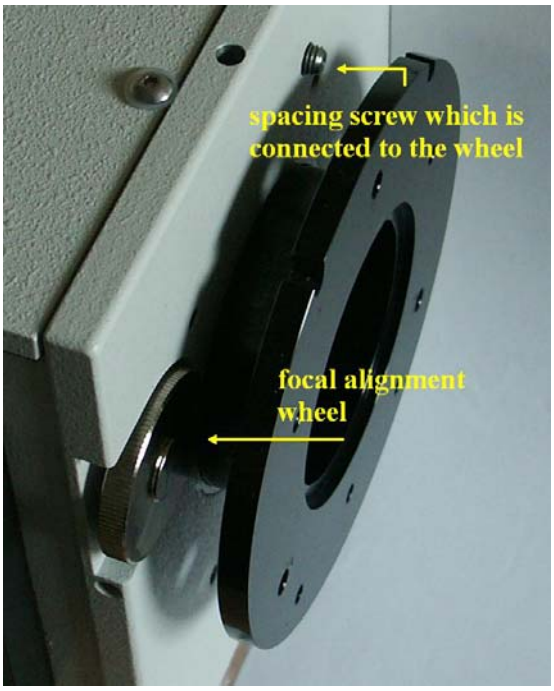


Figure 102. Focus Alignment Wheel (500 mm Spectrograph)

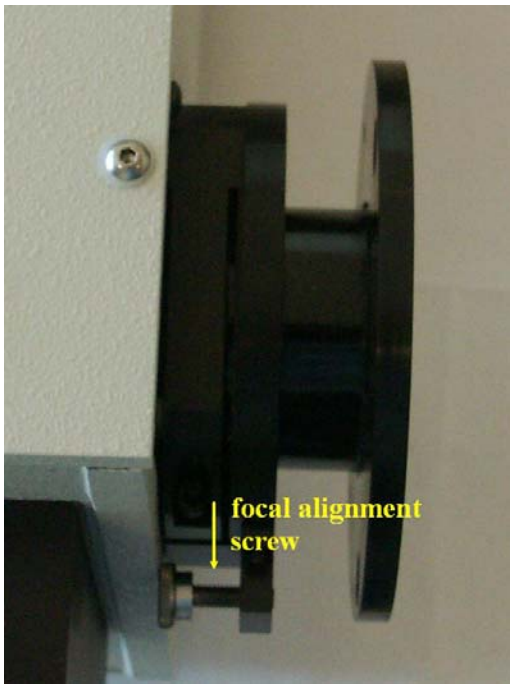


Figure 103. Focus Alignment Screw (750 mm Spectrograph)

1. It is possible to do a fine adjustment of the focal plane by turning the focal alignment screw/wheel. While the wheel/screw is in contact with the flange, it is also possible to rotate the detector without changing the focus position.

2. Rotate the detector until the light source image is vertical on the CCD, or until the best focus is achieved if a diode array is used.
3. Tighten the fixing screw to secure the detector.

Appendix D

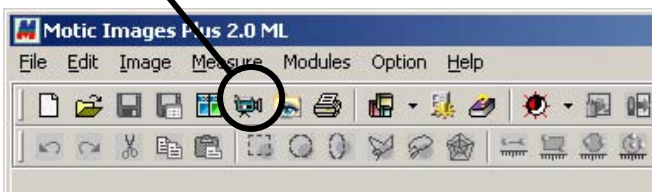
EZ View Alignment tool

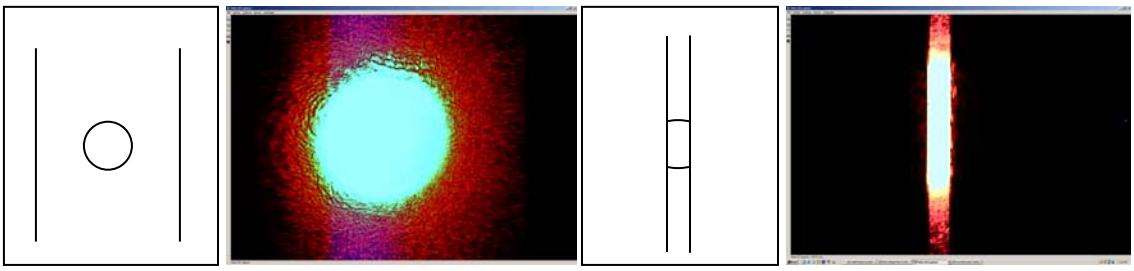
This simple-to-use alignment tool places a high quality video camera on the exit port of the first stage of your triple Spectrometer. This allows you to directly view the entrance slit illumination and focus in real time thus allowing full optimization of the Raman Signal.

EZ View Alignment Instructions:

1. Power up your system and start the TriVista application software.
2. On the Measuring - Measure window, send your spectrometer to zero nanometers by changing the display units to Nanometers, setting CCD Wavelength to 0, and checking the Set Hardware Only box. Click on Start.
3. Click on the Hardware button (lower left), then click on the System Settings icon to open the Hardware - System Settings window. Choose the “Stage 1 only” or “Camera” mode.
4. Set the exit mirror to direct the light out of the front exit port of Stage 1.
5. In the software, click on the Set Mode button.
6. Open the Motic Images Plus 2.0 software.
7. Open the capture window by clicking on the camera icon.

8. Use the image of the slit blades as a reference for focus and adjust the collections optics if necessary. Good focus is determined by the laser focusing optics, sample, and light collection optics. Correctly matched optics can produce a spot as small as 50 µm, but in most cases 150-250 µm is normal. The spot can be larger for some samples, depending on surface conditions.





Use the image of the slit blades to center and focus the image of your sample. The slit blades have been pre-focused.

Slits at 3 mm

With 200 µm slits, the image should look similar to above with good centering in the horizontal and vertical direction

9. Open the entrance slit to 3 mm for spatial optimization and then decrease the slit width while maintaining the intensity. The best resolution is maintained by using the smallest slit setting that will give enough signal to make the measurement. For Subtractive mode operation, remember to match your entrance slit with Slit S7.
10. The Motic Camera software may stay on for as long as necessary. It will not interfere with TriVista operation.
11. To return to normal operation, on the **Hardware - System Settings** window, choose a mode of operation, click “Set Mode” and then click on “Accept Changes”.

Appendix E

Monochromator Wavelength Movement Commands

E.1 Controlling the Spectrograph with Monochromator Control Software

The Monochromator Control Software is normally installed in the directory C:\Program Files\SpectraPro. This directory contains subdirectories Bin and Data. The Bin directory contains the executable code. There will normally be a SpectraPro icon on the desktop which can be used for starting the software. If this icon is not on the desktop go to the SpectraPro Bin directory and start the software. When the Monochromator Control software loads, there is a main screen with selections for both operating the monochromator and various setup functions. Click on the Operation box and a screen will come up which allows for basic control of the monochromator wavelength. All functions of this software are described in the Monochromator Control Software manual supplied on the Monochromator Control Software install CD.

E.2 Control of the 750 mm Monochromator at the Command Level:

Although it requires more programming on the user's part, the monochromator can also be controlled with direct commands through its USB 1.1 port or RS-232 port. The same command set, listed below, is used for both RS232 and USB.

Commands can be sent as single commands or grouped in strings of commands. All commands are single words (contain no spaces) and all commands in a string are separated by at least one space. Parameters, if needed, precede the command and are separated from the command by at least one space (for example, **546.7 GOTO**).

For RS232 operation, the port set-up is 9600 baud, 8 data bits, 1 stop bit and no parity. A convenient tool for trying out this mode of operation is the program HyperTerminal supplied with the Windows operating system. The USB 1.1 port with the driver supplied also shows up as and is treated like a com port – although a very fast one. All commands or strings of commands must be terminated with a carriage return (0D hex). The monochromator responds to a command when the command has been completed by returning the characters OK followed by carriage return and line feed (hex ASCII sequence 20 6F 6B 0D 0A). The default condition is to echo each character that is sent to the monochromator with the RS-232 interface and to not echo the commands when using the USB interface. When sending a command or string of commands, it is important to wait for the monochromator to complete the processing of that command string before sending another command.

E.3 Monochromator Wavelength Movement Commands

Note: In the following list, < and > are the keys normally corresponding to Shift "," and Shift "."

GOTO	Goes to a destination wavelength at maximum motor speed. Accepts destination wavelength in nm as a floating point number with up to 3 digits after the decimal point or whole number wavelength with no decimal point.
<GOTO>	Same as GOTO (For compatibility with software written for previous models.)
NM	Goes to a destination wavelength at constant nm/min rate specified by last NM/MIN command. Accepts destination wavelength in nm as a floating point number with up to 3 digits after the decimal point or whole number wavelength with no decimal point.
<NM>	Same as NM (For compatibility with software written for previous models.)
>NM	Similar to NM except it returns control to user immediately rather than waiting for completion of monochromator wavelength move. Can be used with **?NM** or **MONO-?DONE** below. This command must be terminated with **MONO-STOP** listed below.
	NOTE: Use the **NM** command when communication with the monochromator during the scan is not required.
?NM	Returns present wavelength in nm to 0.01 nm resolution with units nm appended (for example, **?NM 300.00 nm**).
MONO-?DONE	Used with **>NM** command to determine if monochromator has reached the destination. Returns 0 if move is not complete, 1 if move is complete.
MONO-STOP	Stops the monochromator wavelength move after use of the **>NM** command.
NM/MIN	Sets the scan rate in nm/min to 0.01 nm/min resolution with units nm/min
?NM/MIN	Returns present scan rate in nm/min to 0.01 nm/min resolution with units nm/min

E.4 Grating Control Commands

GRATING	Places specified grating in position to the wavelength of the wavelength on the present grating. Up to nine (9) gratings are allowed on three (3) turrets. This command takes a grating number from 1 - 9.

IMPORTANT NOTE: This command assumes that the correct turret is specified by the **TURRET** command. For example, using grating numbers 1, 4 and 7 will place the first grating on the installed turret into that position and call up the parameters for the grating number specified.

?GRATING Returns the number of gratings presently being used numbered 1 - 9.

?GRATINGS Returns the list of installed gratings with position groove density and blaze. The present grating is specified with an arrow.

TURRET Specifies the presently installed turret or the turret to be installed. For example, if installing the second turret, issue the command **2 TURRET** to insure using the correct parameters.

?TURRET Returns the correctly installed turret numbered 1 - 3.

The following command is used for grating installation by ARC part #:

INSTALL Installs new grating parameters into the non-volatile memory of the monochromator. Uses the part # of the grating to specify the parameters. For example, 1-120-500 5 INSTALL places a 1200 g/mm grating blazed at 500 nm into the second grating position on turret #2.

The following commands are used for grating installation by grating parameters:

SELECT-GRATING Specifies the grating number to be installed 1 - 9.

G/MM Specifies groove density of grating to be installed in g/mm. For example 1200 G/MM

BLAZE Specifies the blaze wavelength and units of the grating to be installed with 7 characters of the user's choice. Unlike other commands, this command is issued before the parameters. After the command is issued, the spectrograph responds with " " . Seven characters are then entered (these may be numbers, letters, spaces or special characters).

UNINSTALL Used to remove a grating and its parameters from the spectrograph's non-volatile memory.

E.5 Diverter Control Commands

EXIT-MIRROR Designates the exit diverter mirror to receive the diverter control commands. The 500 mm and 750 mm monochromators will accept this command but it is not required in these monochromators.

ENT-MIRROR Designates the entrance diverter mirror to receive the diverter control commands. This command is for monochromators which can accept two diverter mirrors. 500 mm and 750 mm monochromators will not accept this command.

FRONT	Moves the designated diverter mirror to position the beam to the front port position.
SIDE	Moves the designated diverter mirror to position the beam to the side port position.
?MIRROR	Returns the position of the designated diverter mirror with the responses **"front"** and **"side".**
?MIR	Returns the position of the designated diverter mirror with the responses **0** for front and **1** for side.

E.6 Slit Width Control Commands

FRONT-EXIT-SLIT	Designates front exit slit to receive slit control commands.
	NOTE: The designation remains in effect until changed by another slit designator. This command does not have to be repeated until the designated slit is changed.
SIDE-EXIT-SLIT	Designates side exit slit to receive slit control commands.
FRONT-ENT-SLIT	Designates front entrance slit to receive slit control commands.
SIDE-ENT-SLIT	Designates side entrance slit to receive slit control commands.
MICRONS	Sets the slit width for the designated slit in the range of 10 to 3000 microns to 1 micron resolution.
?MICRONS	Returns the slit width setting in microns to the nearest 1 micron.

E.7 Grating Calibration Commands

INIT-OFFSET	Sets the offset value for the designated grating. Default values are 0 for gratings 1, 4 and 7; 1536000 for gratings 2, 5 and 8; and 3072000 for gratings 3, 6, and 9. The limits on the settings are +/- 2500 for a 1200 g/mm grating. This corresponds to an error of greater than +/- 5 nm for a 1200 g/mm grating. The limits are adjusted for grating groove density (for example, error for a 600 g/mm grating is +/- 5000). The grating density designator used with this command is grating# - 1. For example, enter 3072056. 8 INIT-OFFSET for setting offset on grating #9 - 3rd grating on turret #3. **NOTE:** This command requires a decimal point after the offset value.
INIT-GADJUST	Sets grating adjustment value for the designate d grating. Default values are 10000 for all gratings. The limits on the parameter for this command are +/- 1000 for all gratings. The grating designator used with this command is the grating # - 1. For example, enter 9993 1 INIT-GADJUST for setting gadjust on the second grating of turret #1.

NOTE: This command is to maintain compatibility with previous applications. For new applications, use the INIT-SP750-GADJUST command below.

MONO-EESTATUS Returns setup and grating calibration parameters for all gratings.

RESTORE FACTORY SETTINGS Returns all parameters including grating calibration parameters to the original factory calibrated settings.

NOTE: This command will overwrite any calibration parameters set by the user.

MONO-RESET Initializes the monochromator. Necessary after using INIT-OFFSET, INITGADJUST.

HELLO Same as MONO-RESET. Used to maintain compatibility with existing applications.

MODEL Returns model number of the monochromator (for example, **MODEL SP-2558**)

SERIAL Returns serial number of the monochromator. Format is 7 digits with the first 3 digits being the model # (for example, **SERIAL 27560232**).

E.8 Start-Up Parameters and Their Default Values

DEFAULT VALUES TURRET #1 GRATING #1
WAVELENGTH 0.0 nm
SCAN SPEED 100.0 nm/min

E.9 Setting Alternate Start-Up Parameters

The Grating, Wavelength, and Scan Speed start-up parameter can be changed through the RS232 port or the USB port by using the following commands. These values are stored in non-volatile memory and will be in effect after the next power-up.

INIT-GRATING Selects which of the three gratings on the installed turret the spectrograph will go to after finding 0.0 nm on the first grating of the installed turret (for example, **2 INIT-GRATING** selects the second grating as the default). Accepts values 1 -9.

INIT-WAVELENGTH Sets an initial wavelength for the spectrograph after initialization (for example, **435.84 INIT-WAVELENGTH**). Notice that the two digits after the decimal point are required.

INIT-SRATE Sets an initial scan rate for the spectrograph (for example, **500.00 INIT-SRATE**). Notice that the two digits after the decimal point are required.

E.10 Restoring Factory Settings

The following command is used to return all grating parameters and start-up parameters to the original factory settings. Note that any gratings installed at a later date (after initially receiving the 500 mm spectrograph or 750 mm spectrograph) will be erased from memory using this "restore command".

RESTORE-FACTORY-SETTINGS Returns all parameters, including grating calibration parameters, to the original factory calibrated settings.

NOTE: This command will overwrite any calibration parameters set by the user.

Appendix F
Accessories Listing

F.1 Light Sources

Mercury Light Source (Model MS-416): Compact light source that features high stability and line output useful for wavelength-calibration purposes. There are many lines produced by mercury, including 253.7-nm, 313.1-nm, 365-nm, 435.8-nm, 546.1-nm, 577-nm, and 579-nm wavelengths. This source includes a mercury lamp mounted in a flange that matches the slit body of Acton Research SpectraPro® and similar type spectrometers, plus a power supply.

Deuterium Light Source (Model DS-421): 30-watt light source that provides useful UV continuum starting at ~190 nm and continuing out to ~350 nm. Negligible visible light output helps to minimize stray light.

Tungsten-Halogen Light Sources: Light sources for 350 nm to 2.5 µm.

- **Model TS-425:** 30-watt light source with a DC power supply.
- **Model TS-428:** 250-watt light source that includes variable brightness control, forced-air cooling, and an AC power supply.
- **Model TS-428-DC:** 250-watt light source that features a regulated DC power supply plus variable brightness control.

Xenon Light Source (Model XS-433): 75-watt light source that features broad wavelength output with small source size, permitting more efficient light delivery to a spectrometer. This source provides useful continuum from 190 to 750 nm, with declining output out to 2.7 µm.

Infrared Light Source (Model IS-434): Blackbody source that provides broadband IR output out to approximately 16 µm. It includes a silicon carbide resistor as the IR emitter that is mounted in a housing with a refocusing mirror, cooling fan, and mounting flange. **

Deuterium and Tungsten-Halogen Dual Light Source (Model TDS-429): Combines 30-watt deuterium and tungsten-halogen lamps in the same housing for output useful from 190 nm to 2.5 µm. It includes a manually controlled source-selection mirror (motorized optional), power supplies, and forced-air cooling fan.

** Not available to countries requiring CE certification.

F.2 Fiber Optic Bundles

Single-Leg Fiber Bundles (Models LG-455-020 and LG-456-020): Bundles that contain a single column of 19 fibers, each 200 µm in diameter (~245-µm diameter with cladding), to match a SpectraPro entrance slit. LG-455-020 models are UV-VIS fiberoptic bundles in 1- or 3-m lengths for 190 to 1100 nm. LG-456-020 models are VIS-NIR bundles in 1- or 3-m lengths for 400 to 2200 nm.

Two-Leg Fiber Bundle (Model BFB-455-7): 1-m-long UV-VIS fiberoptic bundle for 190 to 1100 nm. It contains two groups of 200-µm-diameter fibers (~245-µm diameter with cladding), with seven fibers per group and ~1-mm spacing between groups.

Four-Leg Fiber Bundle (Model QFB-455-3): 1-m long UV-VIS fiberoptic bundle for 190 to 1100 nm.It contains four groups of 200-µm-diameter fibers (~245-µm diameter with cladding), with three fibers per group and ~1-mm spacing between groups.

F.3 Fiber Adapters

Fixed-Position Fiber Adapter (Model FC-446-010): Low-cost solution for positioning fiberoptic bundles directly at the entrance (or exit) ports of SpectraPro spectrometers. Holds 10-mm-diameter fiber ferrules.

Adjustable Fiber Adapter (Model FC-466-020): Holds 10-mm-diameter fiber bundles directly at the entrance slit of SpectraPro spectrometers. It includes a spring-loaded slide mechanism for precise horizontal alignment of the fibers to the slit opening. Thumb screws on each side control horizontal adjustments.

Imaging Fiber Adapter (Mmodel FC-446-030): Imaging adapter for fiber bundles designed specifically for our imaging spectrometers. The all-reflective design eliminates chromatic aberrations and the aspheric mirror cancels astigmatism, allowing precise imaging of fibers at the spectrograph entrance slit.

F.4 Single Channel Detectors

PMTs (Side Windows)

Model P1: for use from 190 to 650 nm.

Model P2: for use from 190 to 900 nm.

Model P3: for use from 300 to 1100 nm.

For other models, contact our office.

Integrated Photon Counting Assembly

Model PD-438: PMT housing for direct mounting to SpectraPro slit assemblies.

Model PD-439: PMT housing with integrated light-tight shutter for direct mounting to SpectraPro slit assemblies.

Model PD-471: PMT housing for 1 /8-inch tubes with built in HV supply. Only for SpectraHub.

Model PD-473-1: Includes amplifier-discriminator, HV, and PMT. Works with the Acton Research SpectraHub and Acton Research SpectraSense software

Silicon Detectors

Model SI-440: General-purpose detector with a 10-mm-diameter active area for use from 400 to 1100 nm. Enclosed in housing with the BNC connector. Includes mounting flanges for SpectraPro slit assemblies.

Model SI-440-UV: Detector with a UV-enhanced, 10-mm-diameter active area for use from 200 to 1100 nm operation.

Solid-State Infrared Detectors

Model ID-441: InGaAs Detector with a 3-mm-diameter active area for use from 800 to 1700 nm. Model ID-441-C is thermoelectrically cooled.

Model ID-442: PbS Detector, thermoelectrically cooled. 5 x 5-mm active area, for use from 1100 to 2900 nm.

Model ID-443: InSb Detector, cooled with liquid nitrogen. 4-mm-diameter active area, for use from 1500 to 5000 nm.

Model ID-444: M-C-T Detector, cooled with liquid nitrogen. 4 x 4-mm active area, for use from 2000 to 6000 nm.

F.5 Light-Input Accessories

Raman Notch Filter Chamber (Model NFC-446-040): Efficient and easy method of using cut-off or notch filters with spectrometers. It collects the output of fibers and collimates the beam, which passes through the filter. A second lens focuses the beam on the entrance slit of the spectrometer. It accepts up to 38.1-mm-diameter filters. A micrometer controls the filter angle from 0° to 10° for precise filter tuning.

Nikon® Camera Lens Adapter (Model CM-446-050): Designed specifically for remote light collection and imaging applications. It includes a standard F-mount, which permits a Nikon lens to be mounted on the entrance slit of any Acton Research SpectraPro® spectrometer. The lens focus is at the slit, permitting remote light collection or direct source imaging through the system.

Bilateral Slit Assembly (Model SP-716): Unique, kinematically mountable bilateral slit assembly that includes a micrometer for continuously variable slit-width settings from 10 µm to 3 mm. The slit height is controlled by a baffle plate, allowing standard 4-mm or 14-mm heights. For imaging applications that require a larger area than allowed by the entrance slit of the spectrograph, a customized indexable slit is available.

Motorized Slit Assembly (Model 718): Self-calibrating, 10-µm to 3-mm adjustable bilateral slit. Stepping-motor-controlled adjustments are made in 1-µm increments over the full range. Full control of the slit, including automated bandpass setting, is integrated into Acton Research SpectraSense™ software. Once the slit is set, it maintains its position even with the power turned off. The motorized slit is available for all SpectraPro spectrometers except the SpectraPro 150.

Source-Compensation Accessory (Model SCA-440-UV): Mounts on the exit slit of a monochromator that is used for illumination. It compensates for source fluctuations at a target wavelength, unlike most compensators that look at the total output of a lamp. This selectivity ensures the utmost sensitivity to source variations at any wavelength.

Appendix G
Cable Pinouts and Diagrams

RS232 Connector and Cable

Pin #	Description	
1	open	
2	RD	data from spectrograph to computer
3	TD	data from computer to spectrograph
4	open	
5	ground	
6	open	
7	RTS	
8	CTS	
9	open	

Table 9. RS232 Computer Interface Pin Arrangement

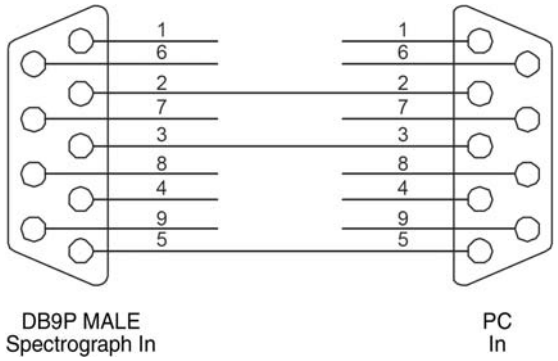


Figure 104. RS232 Cable for connecting TriVista to Computer or terminal.

Power Connector

Pin #	Description
1	+5 V
2	GND
3	GND
4	+24 V

Table 10. Power Input pinout listing.

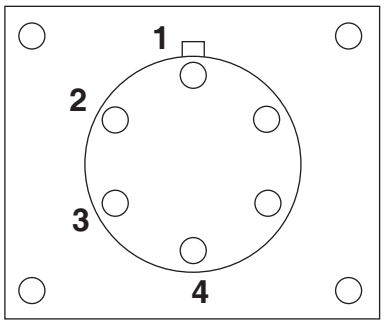


Figure 105. Power Input pinout diagram.

Appendix H

Calibration Lines

MERCURY	184.91 194.17	226.22 237.83 248.20 253.65** 265.20 280.35 289.36 296.73	302.15 312.57* 313.17 334.15 365.02* 365.44 366.33	404.66* 407.78 434.75 435.84*	507.30* (2x253.65) 546.07* 576.96 579.07	625.14 (2x312.57) 626.34 (2x313.17)	730.04 (2x365.02) 760.95 (3x253.65)	
ARGON			394.90	404.44 415.86* 416.42 418.19 419.10 420.07* 425.94 427.22 430.01 433.36		696.54*	706.72 727.29 738.40 750.39 751.46 763.51** 772.38* 794.82	800.62 801.48 810.37 811.53* 826.45 840.82 842.46
NEON			336.99 341.79 344.77 346.66 347.26 352.05* 359.35		533.08 534.11 540.06 585.25** 588.19 594.48 597.55	603.00 607.43 609.62* 614.31* 616.36 621.73 626.65 630.48 633.44 638.30* 640.23* 650.65* 653.29 659.90 667.83* 671.70 692.95	702.41 703.24* 705.91 717.39 724.52 743.89 748.89 753.58 754.41	837.76 849.54 863.46 865.44 878.20 878.38 885.39
	100	200	300	400	500	600	700	800

Table 11. Wavelength Calibration Lines (in nanometers)

** indicates strong line within a wavelength group*
***indicates strongest line for the element*
() indicates 2nd or 3rd order

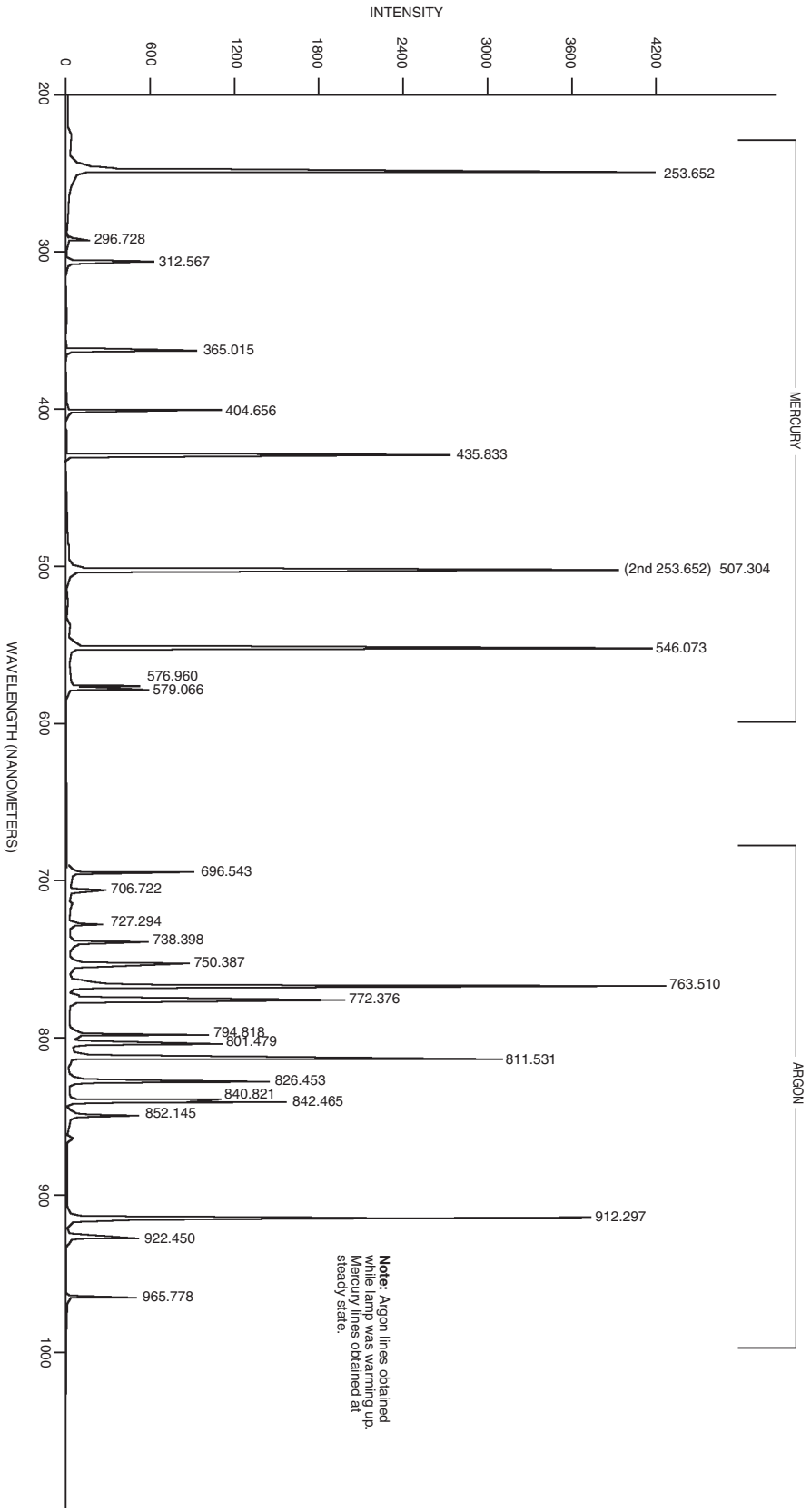


Figure 106. HG-AR Wavelength Calibration Spectrum

Certification and Warranty

Certification

Princeton Instruments/Acton Research Corporation (PI/Acton) certifies that this instrument was thoroughly tested and inspected and found to meet the specifications furnished by PI/Acton when it was shipped from the factory.

Warranty

Princeton Instruments/Acton Research Corporation (PI/Acton) instruments and accessories are warranted for a period of one full year from date of delivery to be free from defects in material and to conform to the specifications furnished by PI/Acton. The corporation's obligation under this warranty is limited to servicing or adjusting an instrument returned to the factory, prepaid, and to repairing or replacing at the factory any part or parts thereof. All purchased items carry the original manufacturers warranty.

Princeton Instruments/Acton Research Corporation shall not be liable for consequential damages resulting from accident, alteration, misuse, improper installation, operation on low or excessive voltages or any use in violation of the operating instructions furnished by PI/Acton.

If any defect appears within the warranty period, the purchaser shall promptly notify PI/Acton. No material will be accepted for repair or replacement without prior authorization from PI/Acton. Upon such authorization and in accordance with instructions of Princeton Instruments/Acton Research Corporation, parts, materials or equipment for which repair or replacement is requested shall be returned to PI/Acton for examination, with shipping charges prepaid by the purchaser. Final determination as to whether a product or part is actually defective rests with Princeton Instruments/Acton Research Corporation.

In such cases where necessary repairs are not covered by this warranty, an estimate of repair charges will be submitted to the purchaser before servicing the equipment.

Princeton Instruments/Acton Research Corporation reserves the right to make changes or improvements upon its products without imposing any obligations upon itself to install the same upon its products previously manufactured.

This warranty is expressly in lieu of all other obligations or liabilities on the part of PI/Acton, and PI/Acton neither assumes, nor authorizes any other person to assume for them, other obligations or liability in connection with the sale of equipment manufactured by Princeton Instruments/Acton Research Corporation.

Equipment Repairs

It is recommended that units requiring service in the United States be returned to the factory. Before instrumentation is returned for service, please consult a service engineer at the factory. In many cases, the problem may be cleared up over the telephone.

If the unit needs to be returned, the service engineer will ask for a detailed explanation of the problems encountered and a purchase order to cover any charges. You will then receive a Returned Materials Authorization (RMA) number. Place this number on the package so the returned equipment can be easily identified when received at the factory. You must also include with the equipment a completed RMA form explaining the symptoms or problems encountered. Without this document, repair turnaround time will be considerably longer.

If the unit is under warranty, the customer is only responsible for the transportation and insurance charges to Princeton Instruments/Acton Research Corporation. PI/Acton is responsible for the return transportation charges. If the unit is out of warranty, the customer is responsible for all transportation charges (including insurance and duty fees, when applicable) as well as all charges incurred to perform the repairs. In this case, the customer can decide the insurance value.

International customers should contact your local manufacturer's representative or distributor for repair information.

Contact Information

Princeton Instruments/Acton have a global support team ready to assist you with whatever query you may have. Our main offices are strategically located around the world to provide a local presence; backed by a dynamic team of dedicated distributors.

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.piacton.com. An up-to-date list of addresses and telephone numbers is posted on the www.piacton.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.

Index

T

W

X

Z

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