

# USERS GUIDE



## SR-303i

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Shamrock SR-303i Base Unit

Firstly thank you for choosing the Andor Shamrock SR-303i. We appreciate you have a choice and are delighted you have selected our equipment to fulfil your requirements.

The Shamrock SR-303i is available in two types:

1. As a pre-aligned detector/spectrometer allowing fast and efficient set-up.
2. As a stand-alone spectrograph, to retrofit existing cameras.

Your SR-303i comes with a range of features including:

- A USB interface giving the user the benefit of “plug-and-play” convenience.
- A unique interchangeable grating turret. This provides flexibility and convenience by giving the user a simple way to change the gratings in the unit.
- An intuitive graphical user interface (dashboard) giving the user complete control over the spectrograph functionality including wavelength control and calibration, grating selection, shutter control slit control and filter selection.
- A range of accessories including optical fibers and inputs, motorised filter wheel, additional grating turrets with pre-installed gratings and camera adaptors.

**1.1 - WORKING WITH THE USERS GUIDE**

This manual is aimed at experienced researchers who will be using the SR-303i to analyse samples spectroscopically. Details are provided on all features and functionality. As far as possible, the descriptions in this **User's Guide** are laid out in sections that mirror the **Windows Interface**. So, whenever you're working with a particular window, you'll find a section in the User's Guide that sets that window in context, reminding you how the window is launched, letting you know what it can do, and telling you what other windows and operations are associated with it.

We hope you find use of our product rewarding. If you have any suggestions as to how our software, hardware or documentation could be improved, please let us know. Contact details of your nearest representative can be obtained on the next page.

**1.2 - DISCLAIMER**

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**1.4 - TRADEMARKS AND PATENT INFORMATION**

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All other marks are property of their owners.

Changes are periodically made to the product and these will be incorporated into new additions of the manual.

## 1.5 - TECHNICAL SUPPORT

If you have any questions regarding the use of this equipment, please contact the representative\* from whom your system was purchased or via one of the following addresses:

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**\*NOTE: THE CONTACT DETAILS FOR YOUR NEAREST REPRESENTATIVE CAN BE FOUND ON OUR WEBSITE.**

## 1.6 - COMPONENTS

The main components & accessories of the Andor Shamrock SR-303i system are shown on **page 12**.

## 1.7 - SPECIFICATIONS

<b>General</b>	Czerny-Turner arrangement with imaging toroidal optics
<b>Focal Length</b>	303mm
<b>Aperture</b>	f/4
<b>Reciprocal Dispersion</b>	2.6nm/mm (nominal)
<b>Wavelength Range</b>	190nm to 10µm (detector dependent)
<b>Wavelength Resolution</b>	0.1nm (<0.2nm with 25µm pixel CCD detector)
<b>Wavelength Reproducibility</b>	± 0.05nm
<b>Wavelength Accuracy</b>	± 0.2nm
<b>Focal Plane Size</b>	28mm wide x 14mm high
<b>Time to switch gratings</b>	<10 secs
<b>Stray Light</b>	$1.5 \times 10^{-4}$ (measured at 20nm from 633nm laser line)
<b>Sizes &amp; Weight</b>	
<b>Length</b>	394mm (15.5")
<b>Width</b>	283mm (11.1")
<b>Height</b>	208mm (7.9")
<b>Optical Axis Heights</b>	127mm (5") with fixed pad feet 143mm (5.6") - 173mm (6.8") with adjustable feet
<b>Weight</b>	20kg (44.1 lb approx)
<b>Slit</b>	
<b>Type</b>	Motorised, 10µm to 2.5mm
<b>Maximum height</b>	14mm (height selectable with interchangeable plates)
<b>Gratings</b>	
<b>Size</b>	68mm x 68mm
<b>Mount Type</b>	Triple grating turret (interchangeable)

**SECTION 2 - INSTALLATION****2.1 - SAFETY PRECAUTIONS**

**THERE ARE NO USER-SERVICEABLE PARTS INSIDE THE SR-303i. A NUMBER OF SCREWS ON THE SR-303i HAVE BEEN MARKED WITH RED PAINT TO PREVENT TAMPERING. IF YOU ADJUST THESE SCREWS YOUR WARRANTY WILL BE VOID.**

**NOTE: The cover should only be opened when absolutely necessary, i.e. to swap out grating turrets or other accessories**

**2.1.1 - Working with Electronics**

The computer equipment that is to be used to operate the SR-303i should be fitted with appropriate surge/EMI/RFI protection on all power lines. Dedicated power lines or line isolation may be required for some extremely noisy sites.

Appropriate static control procedures should be used during the installation of the system. Attention should be given to grounding. All cables should be screwed (finger tight only) into place in order to provide a reliable connection and to prevent accidental disconnection. The power supply to the computer system should be switched off when changing connections between the computer and the SR-303i. The computer manufacturer's safety precautions should be followed when installing the Interface Card into the computer.

The circuits used in the SR-303i & the interface Card are extremely sensitive to static electricity and radiated electromagnetic fields, and therefore they should neither be used nor stored in close proximity to EMI/RFI generators, electrostatic field generators, electromagnetic or radioactive devices, or other similar sources of high energy fields. Some examples of equipment which can cause problems are plasma sources, arc welders, radio frequency generators, X-ray instruments, and pulsed discharge optical sources. Operation of the system close to intense pulsed sources (lasers, xenon strobes, arc lamps, and the like) may compromise performance if shielding is inadequate.

**NOTE: In the event of extreme power or ESD surges, the software may crash. Should this occur, power the SR-303i OFF/ON, then restart the software.**

**2.2 - UNPACKING THE SHAMROCK SR-303i**

**BEFORE** unpacking the SR-303i, allow the shipping box to fully acclimatise to room temperature.

While the SR-303i requires no special placement in a controlled environment it should be noted that it is a precision instrument that will perform best when set up and operated properly.

Please read this manual carefully before using and always handle with the care accorded to any precision instrument.

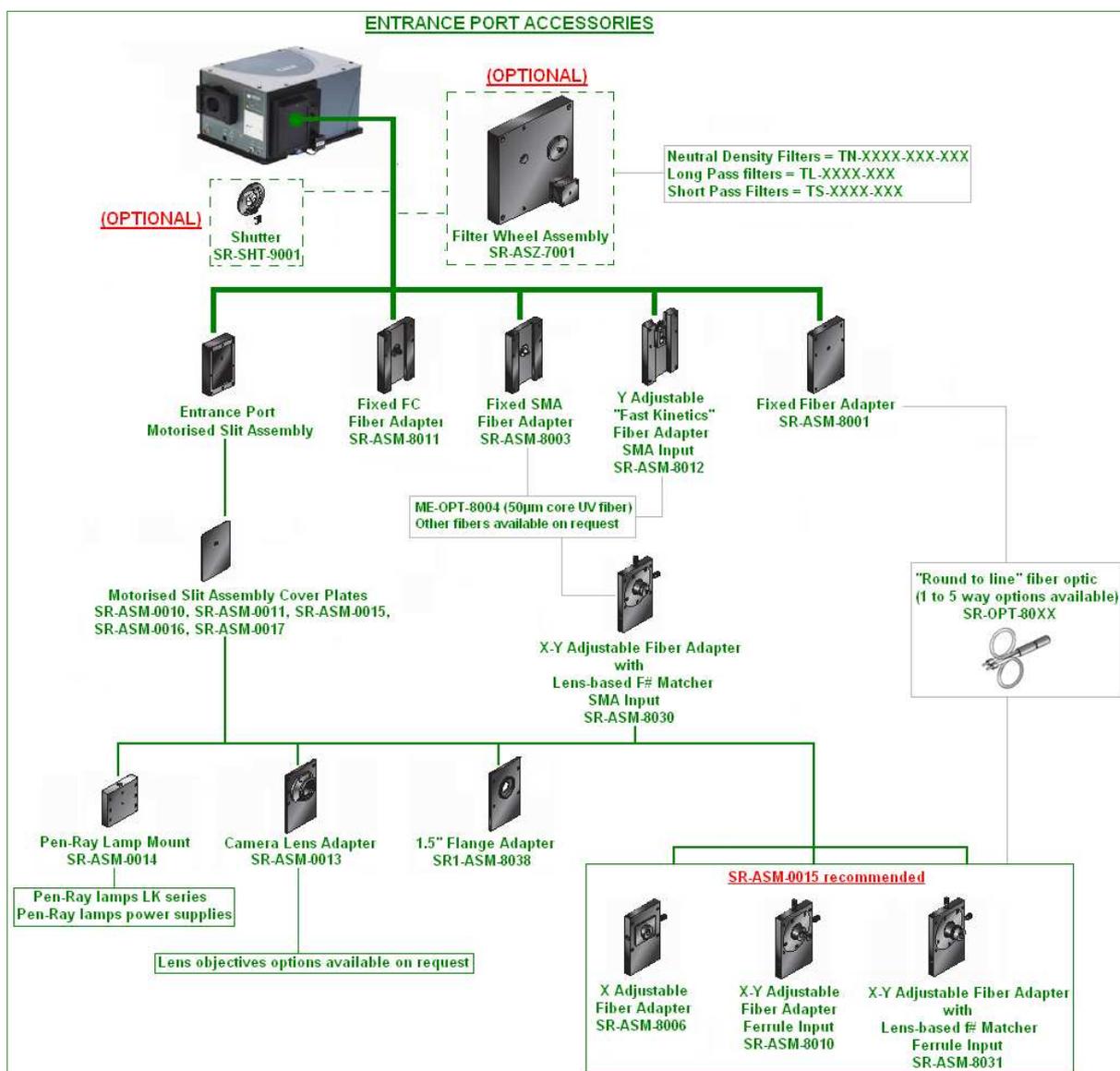
**2.3 - INSTALLING HARDWARE**

Carefully remove the SR-303i from its packaging. The following should be included:

- Shamrock SR-303i base unit
- Universal power supply (with relevant lead and plug - country specific)
- Allen Key set comprising 2mm, 2.5mm, 3mm & 5mm keys
- I<sup>2</sup>C Cable
- USB Cable
- CD containing the SR-303i interface software
- Andor Users guides on CD (Including this manual) and Certificate of Conformance

Depending on the options purchased the following may also be included:

- Andor camera and flange (for connection to the SR-303i)
- Custom flange to connect non-Andor cameras to the SR-303i
- PCI card for connecting the camera to the PC
- PCI or USB 2.0 cable
- Additional PSU (for camera cooling)

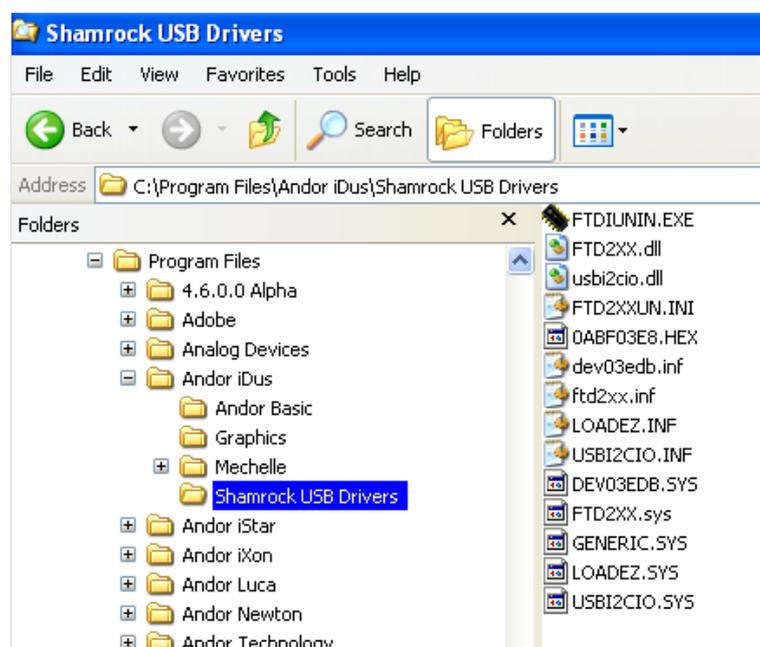


## 2.5- USB INSTALLATION

The SR-303i has a USB interface which allows the system to be used as a standalone device, i.e., independent of an Andor CCD controller card.

To install the USB drivers, firstly connect the USB cable to the computer and to the SR-303i. A **Hardware wizard** will then guide the user through the USB drivers' installation. Several interfaces for this wizard exist, each performing the same function but presenting it in a slightly different way. Two versions of the wizard are shown as examples in the next few pages, i.e. **Windows 2000** and **Windows XP**.

**NOTE: When the Andor Solis software is installed, the drivers for the SR-303i USB should have been placed in the Shamrock USB Drivers folder, e.g.:**



If the drivers are present, copy the **Shamrock USB Drivers** folder from the installation CD-ROM to the **Andor Solis** folder.

1. When the USB cable is connected to a PC running Windows 2000 and the SR303i is then powered on, the following **Found New Hardware Wizard** dialog box should appear:



2. Click **Next>** and the following dialog box should appear:

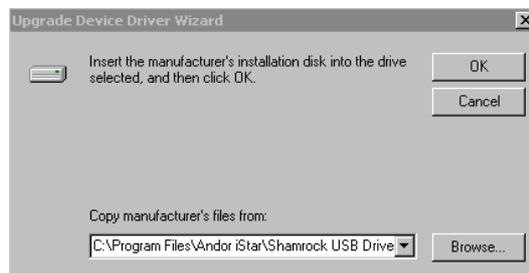


3. Select the **Search for a suitable driver for my device (recommended)** option then click **Next>**.

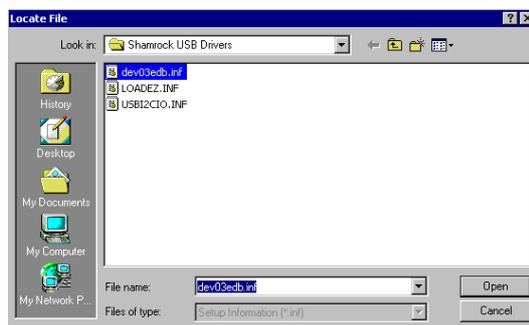
4. The following dialog box should appear:



5. Tick the **Specify a location** option then click **Next>**. The following dialog box should appear:

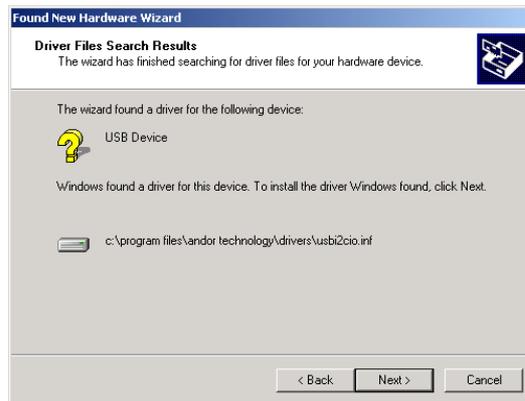


6. Click **Browse...** to go to the correct location for the file **dev03edb.inf**, e.g.:



7. Select the file click **Open**, then **OK**.

8. If the driver is successfully located, the following dialog box should appear:



9. Click **Next>** and the following dialog box should appear:



10. Click **Finish** to complete the driver installation. You can check that the “DeVaSys” USB device is recognised by checking system\hardware\device manager via the Control Panel option of the PC.

## 2.5.2 - Windows XP Hardware Wizard

1. When the USB cable is connected to a PC running Windows XP and the SR303i is powered on, the following **Found New Hardware Wizard** dialog box should appear:



**NOTE:** If this dialog box does not appear, firstly check that the USB cable is securely connected. If that is OK then double-click on the “New unknown USB device” icon, e.g. the icon circled in red below:

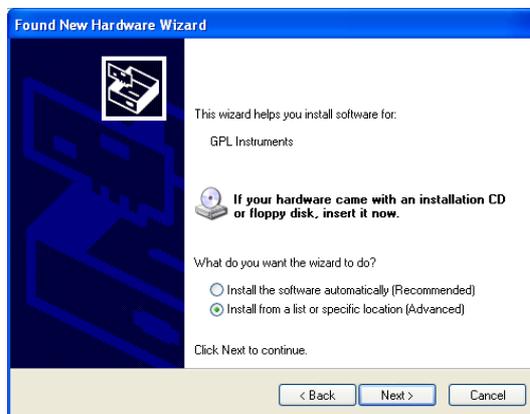


The dialog box should then appear.

- When the dialog box is active, select the **No, not this time** option, e.g.:



- Click **Next>**
- A dialog box similar to the following should appear:



- Select the **Install from a list or specific location (Advanced)** option then click **Next>**. A dialog box similar to the following should appear:



- Select the **Don't search. I will choose the driver to install** option then click **Next>**.

7. The following dialog box should appear:



8. Click on the **Next>** button and the software should begin to install, e.g.:



9. After the software is installed, the following dialog box should appear:



10. Click **Finish**.

The spectrograph software is now ready for use.

**NOTE 1.** If the device is not recognised or the drivers cannot be found despite pointing to the right folder then:

1. The spectrograph must have been powered on before the computer.
2. The USB cable is not properly connected.

**NOTE 2.** If you are installing an SR-303i with a serial number less than SR0045 you should take into account that the USB interface is not “Hot-Plugable”. Before installing the drivers carry out the following actions:

- Switch off the computer and the Shamrock SR-303i.
- Connect the USB cable to the computer then to the Shamrock SR-303i.
- Switch on the Shamrock SR-303i first then switch on the computer.

Also, SR-303i's with a serial number less than **SR0045** have the following two drivers that need to be installed:

- **LOADEZ.INF**
- **USB2CIO.INF**

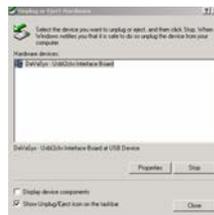
So the driver installation process must be done twice, i.e. once per each driver.

## 2.5.4 - Disconnecting or Reconnecting the USB Interface

The USB can be disconnected or reconnected at any time, provided that the SR-303i software is not running. If you are using a SR-303i with serial number less than SR0045, then its USB connection is **NOT** 'hot-pluggable', and the following steps must be followed to disconnect/reconnect the USB:

Double-click on the USB icon at the bottom-right of the screen.

1. Click on the **DeVaSys - Usb12cio Interface Board** device:



2. Click **Stop**



3. Click **OK** to confirm the device can be safely removed from the system.



4. Click OK again to remove the device.

**NOTE: When the USB interface is used you must carry out the following actions:**

1. **Switch the computer and SR-303i OFF.**
2. **Connect the USB cable.**
3. **Switch ON the SR-303i then switch the computer ON.**

## 2.6 - CONNECTING THE CAMERA TO THE SHAMROCK SR-303i

The camera is connected to the SR-303i using the flange supplied with the product. This process varies depending on whether the user purchased a pre-aligned camera & spectrograph or a “standalone” spectrograph (i.e. supplied without a camera).

### 2.6.1 - Pre-aligned Camera & Spectrograph

When a pre-aligned camera & spectrograph package has been purchased the camera comes pre-fitted with a flange. This flange accurately locates relative to the spectrograph body via precision pins and matching bushings (please see **figure 1** below). These precision pins enable the camera and flange assembly to be repeatedly attached without the need for any additional calibration, or adjustments, to be made.

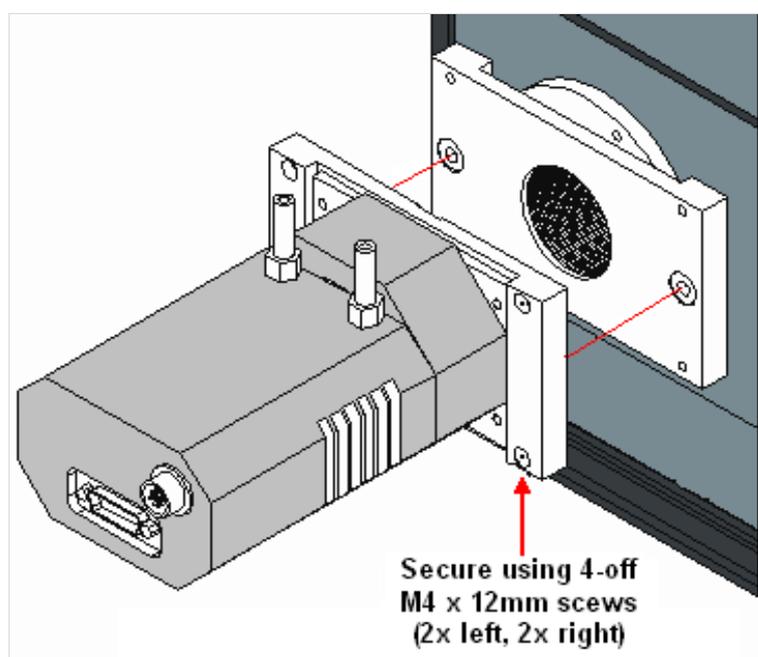


Figure 1: Attaching the pre-aligned detector to the SR-303i

To attach the camera, simply insert the alignment pins into the relevant locators and secure in place using the four M4x123m screws and 3mm Allen key provided. Once connected, no further adjustment is necessary as the unit is aligned and calibrated at the factory.

Where a “standalone” spectrograph (i.e. purchased without, or separately from, an Andor camera) has been purchased the unit is supplied with an appropriate camera flange to allow the camera to be attached to the spectrograph body. The camera must be attached to the flange and the flange attached to the spectrograph body with the screws supplied, e.g.:

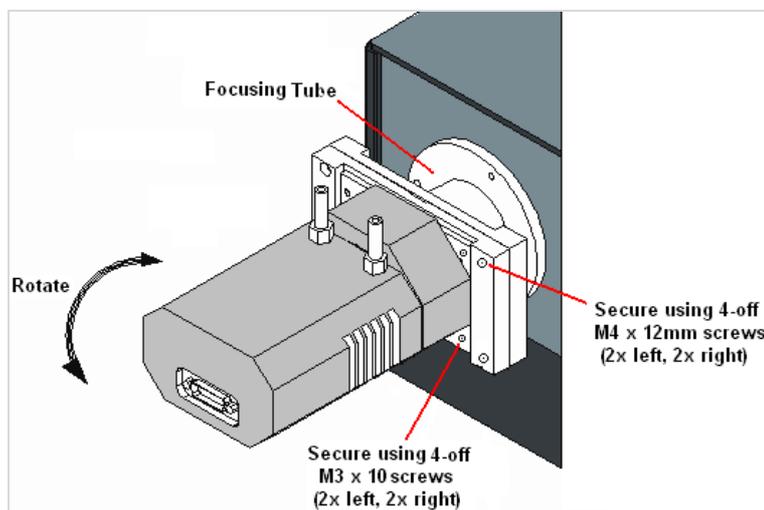


Figure 2: Attaching a camera to the SR-303i

In this instance, the focusing tube is not pre-set before shipping, so the unit must be adjusted to achieve the best possible results with the camera being used. This should be done (after installation has been completed) as follows:

1. Mount the camera onto the SR-303i and start data acquisition.
2. Mount a suitable light source at the entrance slit of the spectrograph (e.g. a Mercury, or Neon discharge lamp).
3. Power the SR-303i on and move the spectrograph to a known spectral line wavelength (e.g. Mercury 435.8nm or the Neon 585.2nm line).
4. Remove the system lid screws, remove the lid and loosen the focusing tube clamp screw using the 5mm Allen key provided. Set the lid squarely back onto the system (do not re-fit the screws).
5. Acquire data using the camera and check the image of the light source, or alternatively, the line intensity and shape. Slowly slide the focusing tube in, or out, until the sharpest image is achieved. It is then necessary to rotate the camera for best alignment.
6. When complete re-tighten the clamping screw, replace the lid and re-attach the lid screws. Please refer to **Offset Adjustment Control** on pages 47 - 48 for details of how to adjust the calibration of the system to the fitted camera.

## 2.7 - ANDOR PCI CARD SYSTEMS

**Figure 3** illustrates the connection details for a standard Andor PCI CCD camera. The PCI Controller Card should be installed as you would other slot-in cards, such as graphic or parallel printer adapter cards. **Please consult the manual supplied with your PC to ensure correct installation of the Controller Card for your particular PC.** Please note that with PCI cards, there are no jumpers for you to set.

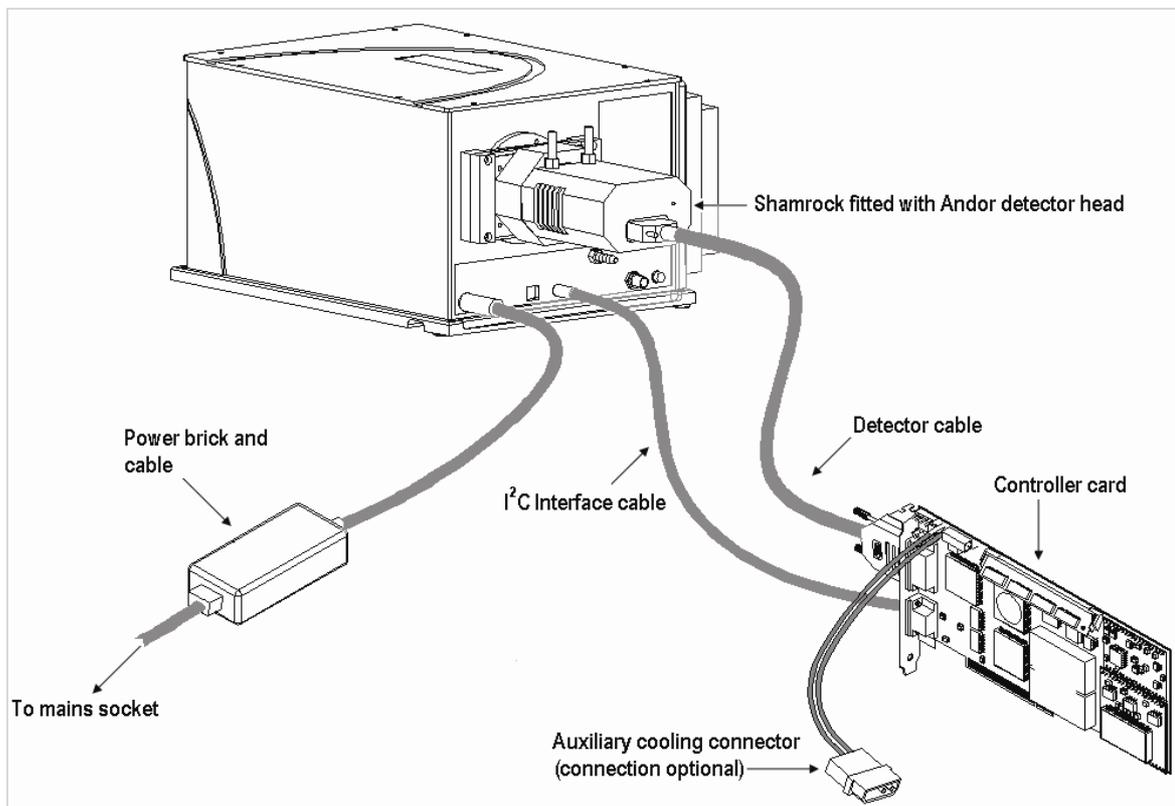


Figure 3: Hardware connections (PCI card CCD systems)

The general procedure for installing the card is as follows (for more detail refer to the specific camera manual):

- Exit the computer's operating system and **switch off** the computer and any peripherals. Fit the supplied anti-static wristband. Remove the cover of the computer.
- While observing appropriate static control procedures, firmly press the connector on the long edge of the card into the chosen expansion slot, so that the card's metal mounting bracket (located at the end of the card and bearing the connectors for the camera and the multiple I/O adapter) is next to the opening on the back panel of the computer.
- Ensure the card's mounting bracket is flush with any other mounting brackets or filler brackets to either side of it. Use the screw removed from the filler bracket earlier to secure the Controller Card in place.
- Replace the cover of the computer and secure it with the mounting screws.

**NOTE:** Some Andor cameras have an I<sup>2</sup>C interface connector fitted. In these cases the I<sup>2</sup>C interface cable illustrated above may be replaced by an optional shorter I<sup>2</sup>C cable that runs from the camera to the SR-303i.

**2.8 - USB INTERFACE DETECTORS**

**Figure 4** shows the electrical connections used when using the Shamrock SR-303i with an Andor iDus USB camera.

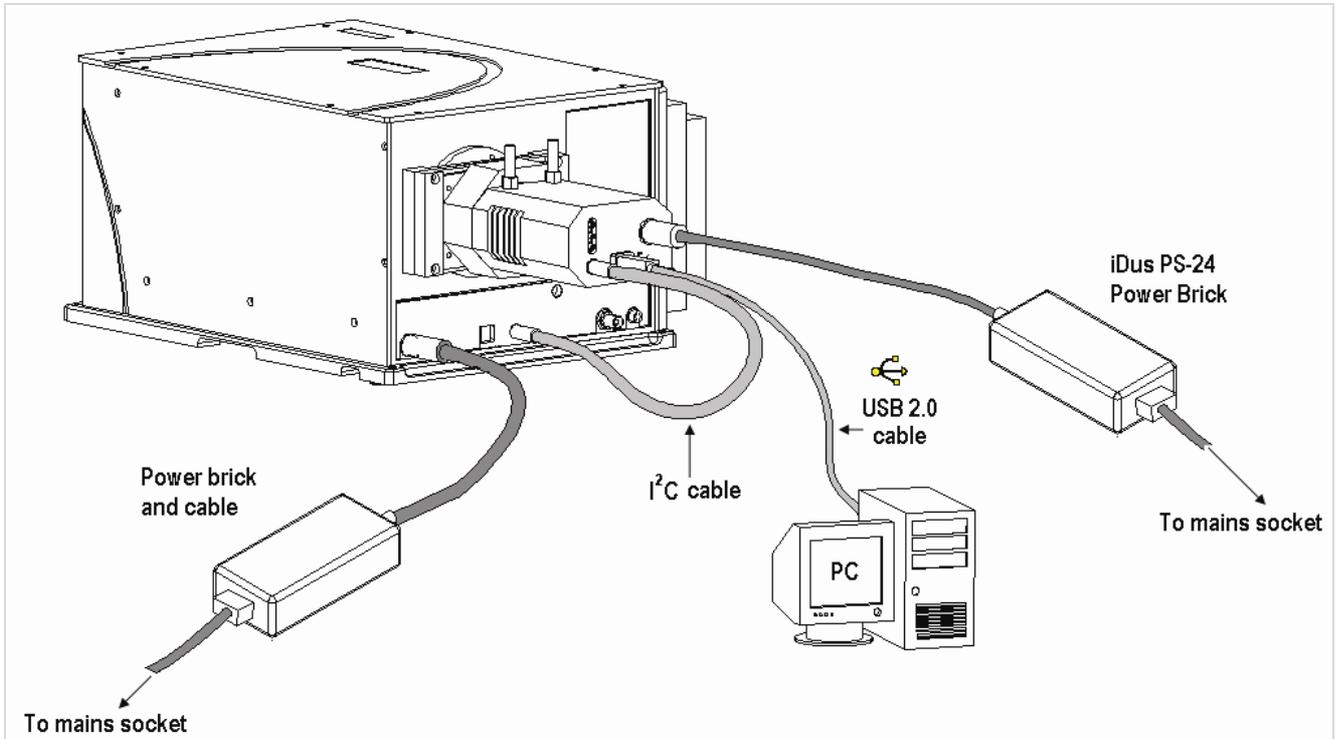


Figure 4: Hardware connections (USB 2.0 CCD systems)

**2.8 - FILTER WHEEL INSTALLATION (PART # SR-ASZ-7001)**

The package containing the filter wheel should have the following items contained within:

- 6-position filter wheel assembly **SR-ASZ-7001** (figure 5 below)
- Filter ring wrench (part number MSC-00176)
- Allen Key (4mm)
- EEPROM updater CD

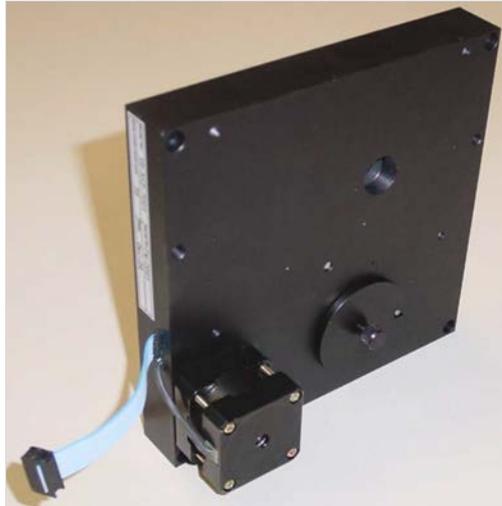


Figure 5: Filter wheel assembly

## 2.8.1 - Installation of the filter wheel onto the spectrograph body

1. Turn off the power to the spectrograph. Carefully tip the spectrograph body onto its side, then remove the PCB cover plate on the underside of the spectrograph and the motorised slit assembly:



2. Remove the 25mm thick spacer block:



3. Attach the filter wheel housing noting the orientation relative to the spectrograph body then re-attach the motorised slit assembly to the filter wheel housing:



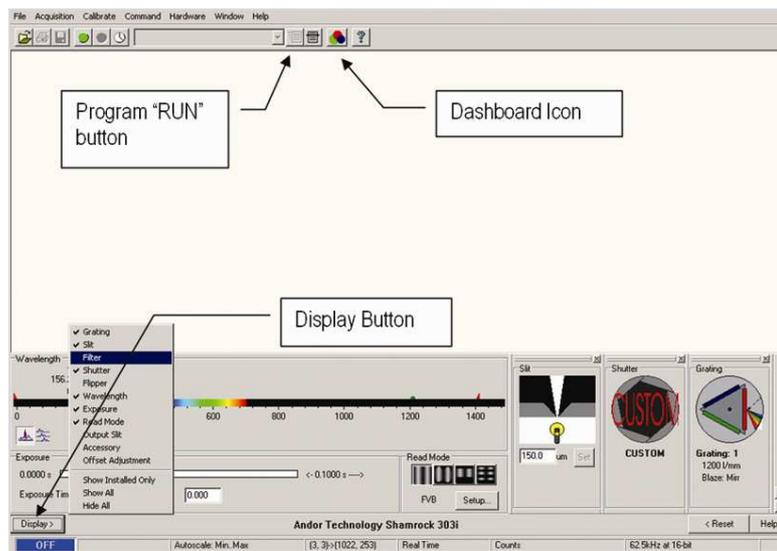
4. Connect the two ribbon cable connectors to the spectrograph PCB (note that the connectors are colour coded):



5. Refit the PCB cover plate

## 2.8.2 - Update of the variables stored in the spectrograph EEPROM

1. Connect the spectrograph and start-up the Andor Solis software
2. Run the EEPROM modifier program saved on the stored CD (**EEPROM SR-xxxx.pgm**, where **xxxx** is the filter wheel serial number). **Note: Some of the numbers are specific to each filter wheel and the label on the CD should match the serial number on the filter wheel label.** This program will update the spectrograph's non-volatile memory with the parameters needed to drive the filter wheel. The **Program 'RUN' button** is located on the main Andor Solis toolbar, e.g.:



Further details on how to run Andor Basic program files can be found in the Andor Solis help facility.

3. When the software is restarted, the system will automatically sense that a filter wheel assembly has been fitted and the filter wheel control graphic will be displayed:



Alternatively, to avoid restarting the software, select the **Filter** option from the display menu and open and close the dashboard control using the icon on the main toolbar.

4. In order to synchronise the filter wheel hardware with the software it will be necessary to perform a reset operation after the Filter Wheel assembly has been fitted. Simply press the  button on the filter wheel control graphic. The filter wheel is now ready for use.

## 2.9 - INSTALLATION OF FILTERS

Filters may be added, removed or replaced in the filter wheel in two ways:

- **Option 1:** by the complete removal of the filter wheel from the filter wheel housing
- **Option 2:** via the filter access hole on the front face of the filter wheel housing

### 2.9.1 - Option 1

Option 1 may be found to be more convenient when a large number of filters are to be added at the same time, or prior to the initial installation of the filter wheel assembly onto the spectrograph body.

1. Remove the filter assembly from the spectrograph in the reverse of the procedure shown on **page 27**. Alternatively, remove the four (M4 x 25mm) cap head screws securing the filter wheel to the spectrograph body and carefully allow the filter wheel and motorised slits to fall forward:



2. The filter wheel has been designed to allow the filter wheel to be removed from the filter wheel assembly housing with the removal of one screw. Unscrew the M5 x 16mm stainless steel Allen bolt from the middle of the filter wheel using a 3mm Allen key and withdraw the wheel from the housing:



3. The filters may now be inserted into the filter wheel. Use the supplied filter ring wrench to first remove and then tighten the 1" filter retaining rings:



4. Remember to take a note of the filter details and the filter number where it has been fitted. These details will be required to update the filter details stored in the spectrographs non-volatile memory (see **page 20**). Re-attach the filter wheel in to the filter housing.

Access to the filters may also be gained via the filter access hole located on the front face of the filter wheel.

1. Remove the magnetic filter wheel access cover by gently pulling it, i.e.:



2. The filter position ID number will now be visible, e.g.:



**NOTE:** The filter position accessible via the access hole has an ID number 2 less than the filter position in the optical path, and the number displayed in the software (e.g. filter position 2) will be accessible via the access hole when filter position 4 has been selected in the software (i.e. 2 → 4).

Similarly, 3 → 5, 4 → 6, 5 → 1, 6 → 2, 1 → 3.

3. Using the software select the filter position needed to bring the required filter position into place.

## 2.9.3 - Initialising the filter wheel

After fitting, or replacing filters, it is good practice to synchronise the filter wheel hardware with the software interface.

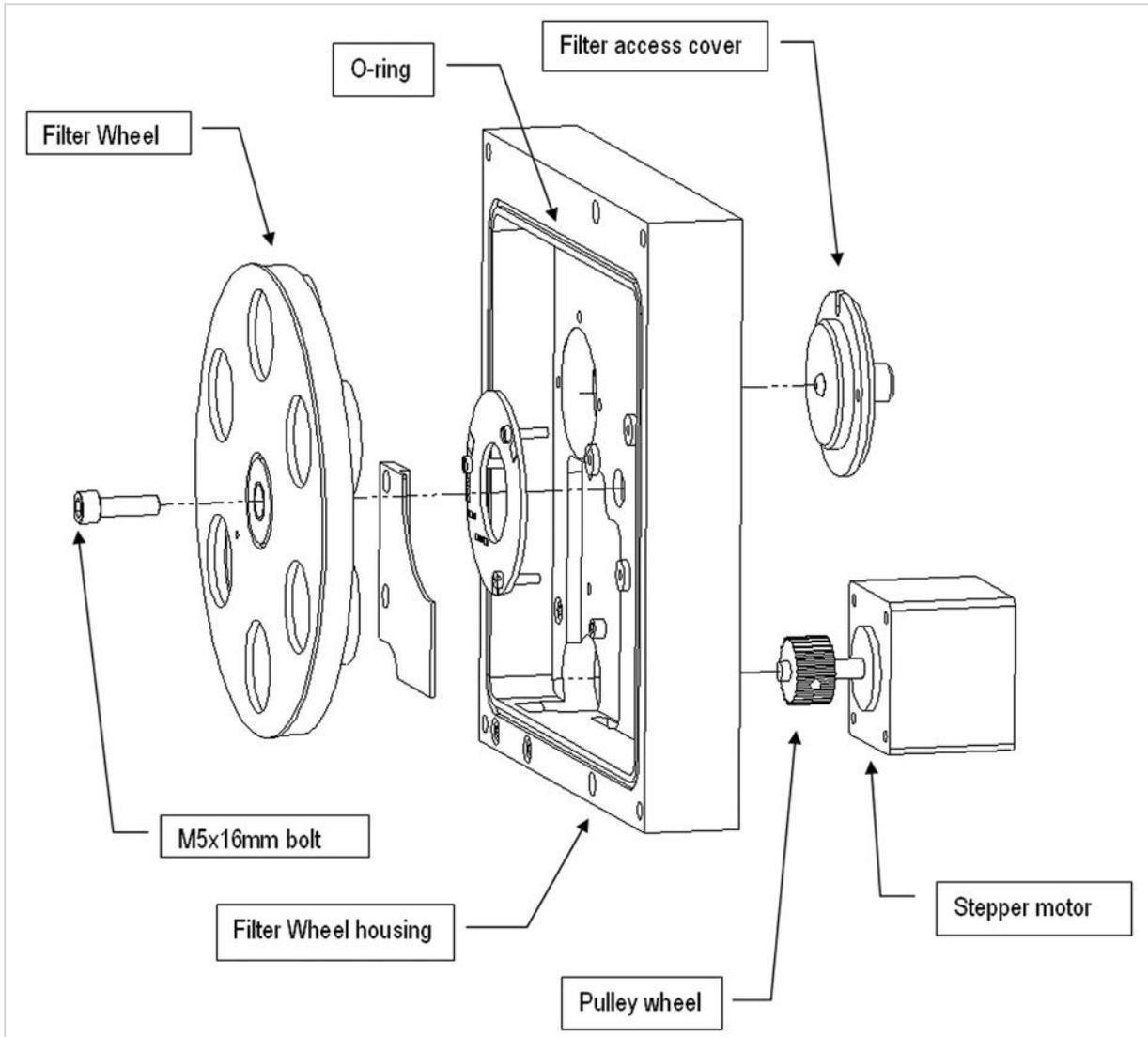
Simply press the  button on the filter wheel control graphic.

**2.9.4 - Filter wheel control and updating the filter details stored in the spectrograph memory**

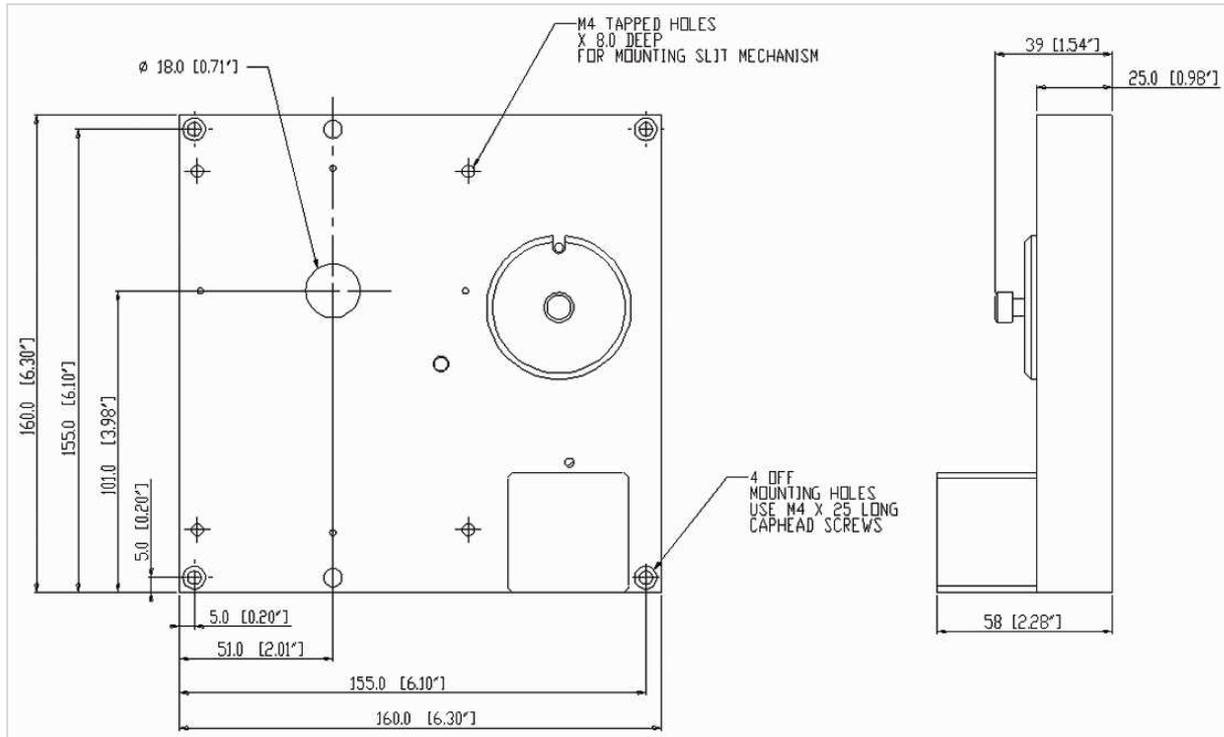
The optional filter wheel accessory is controlled by the Filter Wheel Control. This is described in more detail in on **page 50**.

1. The Filter Wheel Control indicates the currently selected filter and provides details of the filter at the bottom of the control. The filter positions and their details are stored in non-volatile memory (**EEPROM**) in the instrument and should be input by the user after a filter has been fitted. To input (or modify) the details of a particular filter position place the mouse cursor on the required filter position. **Right** click and a filter details input box will appear. Enter the filter details (up to a maximum of 9 characters) and **Left** click when complete.
2. The operation of the filter wheel is very similar to that of the grating turret control. Positioning the cursor over each filter position changes the cursor to a pointing hand and details about the filter are displayed. **NOTE: If the information is not automatically displayed, simply move the cursor out of the filter wheel control box and then back onto the required filter to refresh the information.**
3. To select a filter, simply position the mouse cursor on the required filter and **LEFT** click. The hardware responds by rotating the filter wheel and the filter wheel graphic in the software control rotates to reflect the change. The accessory may be reset by clicking the  button. On completion of a reset the filter wheel defaults to the **Filter 1** position.
4. As the optical path difference will vary with the introduction of the filters into the beam path it may be necessary to re-focus the spectrograph. This is achieved by adjusting the position of the detector. Please refer to **Standalone Spectrograph** on **page 23** for details of adjusting the detector focus.
5. If the filter wheel assembly and/or the motorised slits assembly has been removed from the spectrograph body it may be necessary to adjust the detector offset value stored in the spectrograph memory. Please refer to **Offset Adjustment Control** on **page 47** for further details of this function.

**2.9.5 - Schematic diagram of the filter wheel assembly**



## 2.9.6 - Dimensions & specification of the 6-position filter wheel assembly (part # SR-ASZ-7001)



Specifications	
Filter Size	1"
Maximum number of filters	6
Maximum filter thickness	8mm
Maximum time between filter changes	2 secs

## SECTION 3 - OPERATION

The SR-303i is controlled via the **Dashboard** control (**figure 6 below**). This easy-to-use graphical user interface allows you to control the main hardware components of the SR-303i as well as several acquisition parameters. It is designed to be open during acquisition, allowing continuous adjustment of the available parameters with immediate feedback visible in the acquired data.

The dashboard features large simple controls that graphically represent the associated hardware items. In addition, the controls visually show the state of the hardware, providing an 'at-a-glance' overview of the current setup.

The software is launched by double-clicking the  icon that was created on your desktop when the software was installed. You are firstly presented with the Shamrock SR-303i splash screen, indicating the software is specifically configured to control the SR-303i which in turn, automatically launches the **Dashboard**. The dialog starts up aligned along the bottom of the screen leaving space for an acquisition window to be displayed above it.



Figure 6: Dashboard controls

When the dashboard is launched, it displays only the graphic for the accessories that have been installed (e.g. **Shutter**, **Filter**, **Flipper**, **Grating** and **Output Slit**). Clicking on the **Display** button and selecting **Show All** allows you to select which graphics are displayed. If you display any that are not installed then the graphic indicates that it is only for demonstration purposes only.

The graphics are 'dockable' and may be pulled in and out of the dashboard and arranged as required. Although the dashboard control is primarily used to control the spectrograph hardware there are also some additional real time controls provided that allow several camera-related parameters to be easily changed.

## 3.1 - DETECTOR CONTROLS

The following paragraphs describe the basic camera controls incorporated on the **Dashboard** control. For more detailed descriptions of these parameters and other available adjustments please refer to the supplied camera manual.

### 3.1.1 - Exposure Time Control

The **Exposure Time Control (figure 7)** can be set to any value between the minimum valid exposure time (detector dependent) and 3600 secs. The exposure time can be set in one of two ways by:

1. Using the Exposure Time Edit Box by:
  - Clicking in the Exposure Time Edit Box
  - Deleting the current value
  - Entering the new value
  - Pressing Enter
2. Using the Exposure Time Slider Bar by left clicking on the indicator and dragging it along the bar. As the indicator approaches the end of the slider bar the bar may automatically re-scale itself to new values. Possible scale ranges run from 0 to 0.5, 2.0, 10.0, 100.0, 1000.0 and 3600.0 seconds. As the slider automatically rescales, the arrows at either side of the bar indicate how much the slider bar is able to rescale itself.

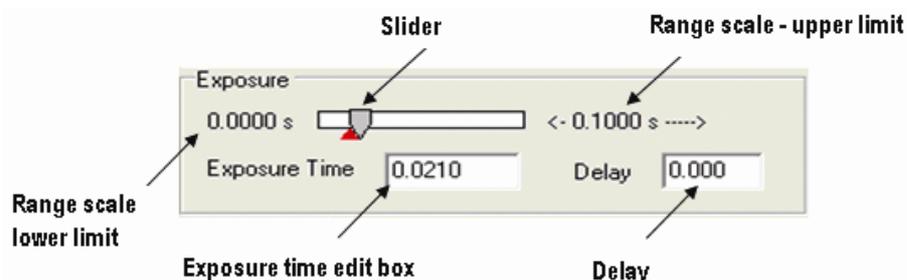


Figure 7: Exposure Time control

A delay may be set by entering a value in the **Delay** edit box. The delay (in seconds) is the time you require between the on-going scans. The system will default to a minimum delay should you attempt to enter too low a value.

**NOTE:** You cannot enter an exposure time of 0, by either method. If this is tried then the system automatically defaults to the minimum exposure time indicated by the red triangle.

The **Read Mode Control** dialog box (**figure 8**) is located to the right of the Exposure control and can be used to change the way in which the information from the CCD in the camera is read. The mode is selected by clicking one of the buttons in the dialog box. Moving the cursor over each button displays a pop-up, indicating the mode selected by clicking on the button. Once a button has been clicked the selected mode is displayed beneath the buttons. There are four modes available (please refer to the camera manual for more details).

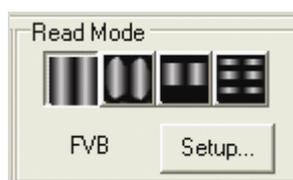


Figure 8: Read Mode control

1. **Full Vertical Binning (FVB):** this allows you to use the CCD as a Linear Image Sensor with the charge from each column of pixels (each column being chip height) being combined, or binned, to give a single value per column
2. **Image Readout:** this is associated with image data display
3. **Single Track:** this differs from FVB in that you can specify the height (in pixels) and vertical position on the CCD of a track from which to bin charge. The aim is to define a horizontal track which corresponds to the position of a spectrum under analysis
4. **Multi-track:** Multi track modes are associated with 2-D data display and allow you to define multiple tracks on the CCD with two options available, i.e. **Standard** & **Custom**. When one option is selected, the parameters for the other option are disabled

Once a mode has been selected, click **Setup...** for more configuration options.

**NOTE: Switching the readout mode automatically changes the way in which the acquired data is displayed. The display mode can also be changed at any time using the speed buttons on the toolbar.**

## 3.2 - SPECTROGRAPH CONTROLS

### 3.2.1 - Reset Menu Options

When the <Reset button on the **Reset Menu (figure 9)** is clicked, you then have several options that allow you to reset the various mechanisms in the system. This may be found to be necessary if a mechanism setting appears to have deviated from the displayed value (e.g. if the stepper motors have been rotated by hand).

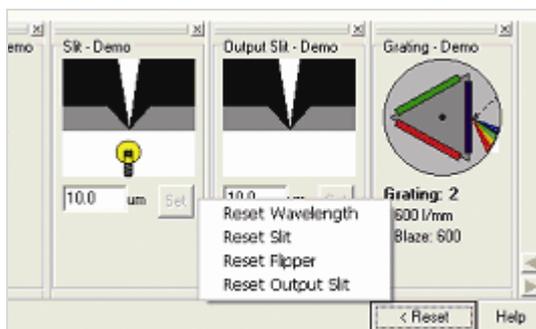


Figure 9: Reset menu options

- **Reset Wavelength** initialises the wavelength drive to a precisely known position. After initialisation the wavelength drive is then set back to the wavelength selected on the dashboard control.
- **Reset Slit & Reset Output Slit** width initialises the motorised slit mechanism. After initialisation the slit width is set to 10µm.
- **Reset Flipper** will set the flipper mirror to the **Port 1** position

## 3.2.2 - Wavelength Drive Control

The wavelength drive hardware not only sets the system to the target wavelength but is also used to control grating selection. The **Wavelength Drive Control (figure 10)** is used for setting the wavelength range for the current grating. The **Grating Control** is concerned with **grating selection** (see pages 44 - 45).

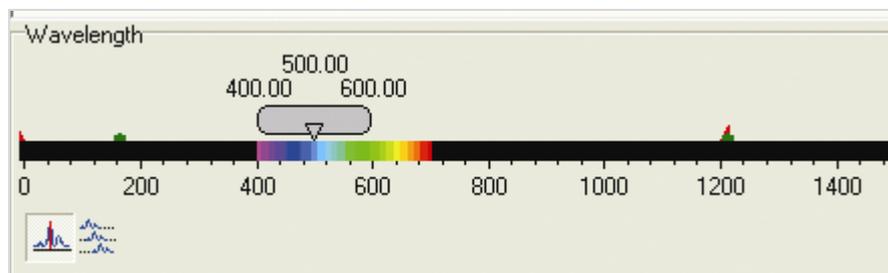


Figure 10: Wavelength Drive Control

The wavelength range that can be measured in a single scan is dependent on the selected grating, the centre wavelength and the width of the CCD detector fitted in the camera. It is calculated by the software and accurately displayed in the visual control section of the dashboard. The slide bar control has three labels floating above it displaying the start, centre and end wavelengths currently in effect. The values displayed correspond to the position and width of the slide bar in relation to the wavelength scale shown.

The start, centre and end wavelengths can be changed in one of two ways:

1. By dragging the wavelength slider with the mouse. This is done by positioning the cursor within the slider (cursor changes to pointing hand), holding down the LEFT mouse button and dragging the slider to the new centre wavelength required. Placing the cursor at either side of the slider allows you to nudge it towards the cursor (use the LEFT mouse button for coarse nudges and the RIGHT mouse button for fine nudges). The size of the nudges can be defined by the user but the defaults are 10nm for course nudges and 1nm for fine nudges.
2. By using the **Wavelength Menu** :



Figure 11: Wavelength menu

This is accessed by positioning the cursor within the slider (cursor changes to pointing hand) and holding down the **Right** mouse button. Selecting an item from the wavelength menu displays a simple dialog that allows you to change the current values.

**NOTE: While the wavelength drive motor is moving the grating, the cursor changes to the hourglass symbol to indicate that the hardware is busy. The cursor reverts to its previous appearance once the movement is complete.**

## 3.2.3 - Step and Glue Function

The **Step and Glue** function allows to user to build up a composite spectrum made up of individual spectra. The user selects the start and wavelength of the scan region and the grating to be used. The software will then control the acquisition of several spectra that cover this spectral region. **Step and Glue** mode is only available with the CCD set in **Single Scan** mode (see **Acquisition, Setup Acquisition** menu).

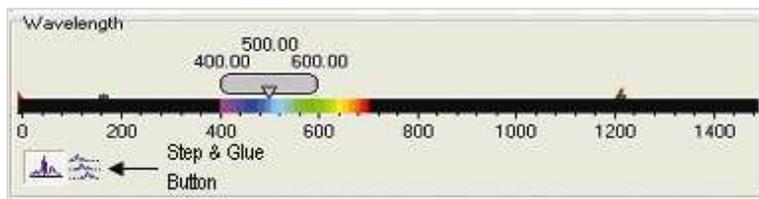


Figure 22: Step & Glue mode selection button

In Step and Glue mode (**figure 13**) the individual scans (datasets) are merged by taking the average of the values in the overlap region from the two input datasets. The points outside the overlap region of the input datasets are used directly. For points falling within the overlap region, the value used is a varying scaled average of the values from each of the datasets. The scale changes linearly between the start and end of the overlap region putting more emphasis on the value from the closest edge of the overlap. To enter the Step and Glue mode click the button on the Wavelength Control (**see figure 12**).

On selection of Step and Glue mode the Wavelength Control will change to the layout shown here:

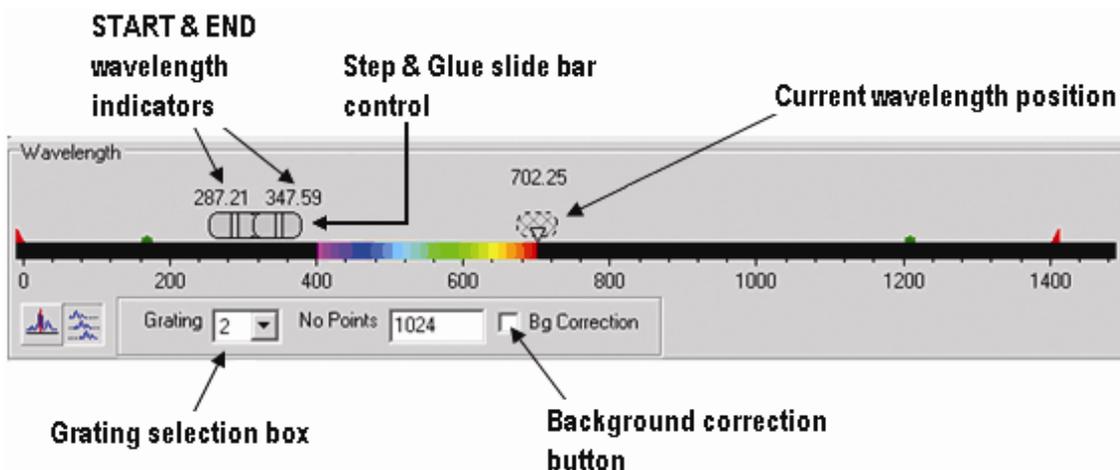


Figure 33: Step & Glue mode selectors

There are now several new graphic features. The hatched slide control bar gives an indication of the current wavelength position and current active grating in the system. The Step and Glue slide bar control will also appear. the slider bar allows the user to enter the start and end wavelengths for the Step and Glue mode and select the grating with which to take the data. The start and end wavelengths can be input in several ways:

1. Left-click and drag the appropriate wavelength indicator
2. Right-click, then manually input the start and end wavelength (see **figure 14 below**)
3. Step and Glue Setup dialog under the menu Acquisition: Setup Acquisition

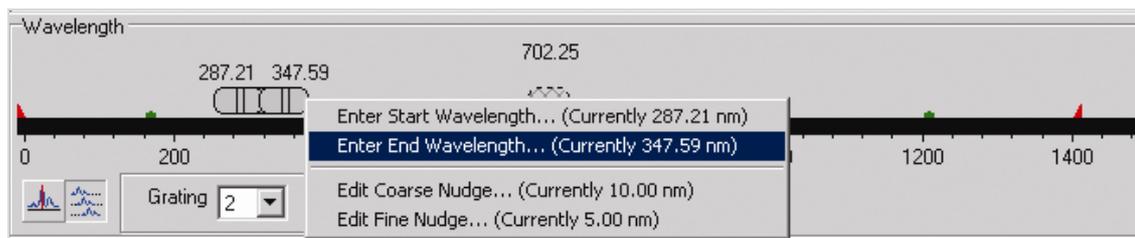


Figure 44: Direct input of Start and End wavelengths

It will be noticed that the Step and Glue slide bar control (**figure 15**), will expand or contract in length to indicate the number of scans that the system must perform to acquire this data (note that the acquire spectra overlap slightly). This allows the Step and Glue algorithm to glue the spectra together.

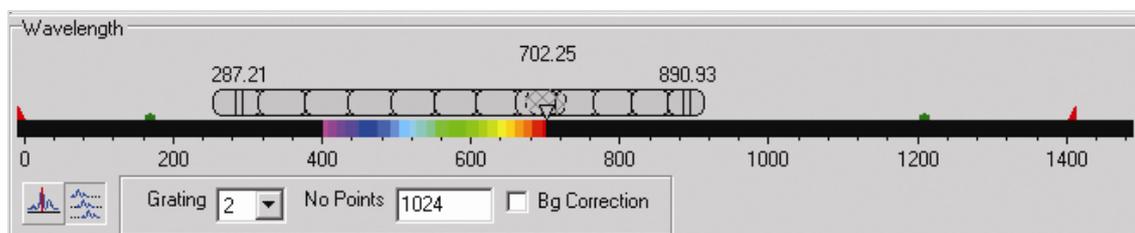


Figure 55: Selecting the Step & Glue scan range

It is also possible to easily change the centre wavelength about which the scan will be performed. This can be achieved by either clicking on any part of the step and glue slide control bar (except the start and end wavelength indicators) and dragging the wavelength bar to the required wavelength region. It can also be modified by 'nudging' the slide control bar. This is achieved by positioning the cursor to either side of the sidebar control then clicking the left or right mouse button. Please refer to **Wavelength Drive Control** on **page 38**.

**NOTE: It is not necessary for the grating control to be set at the required grating. The grating to be used is selected using the Grating Setup dialog box (please see page 44).**

The scan is initiated by clicking the **Take Signal** button  on the main Andor Solis toolbar. If the grating specified in the grating selection box is different from the currently set grating the system will first drive to the selected grating before commencing the scan. If the background (**Bg**) correction box has been ticked an initial background will also be acquired. Progress of the scan is indicated by the movement of the hatched region along the step and glue slide control bar.

**Figure 16** shows the Hg/Ne spectrum acquired with a 1200l/mm grating over the range 300 to 900nm (approx.). It is composed from 13 individual spectra:

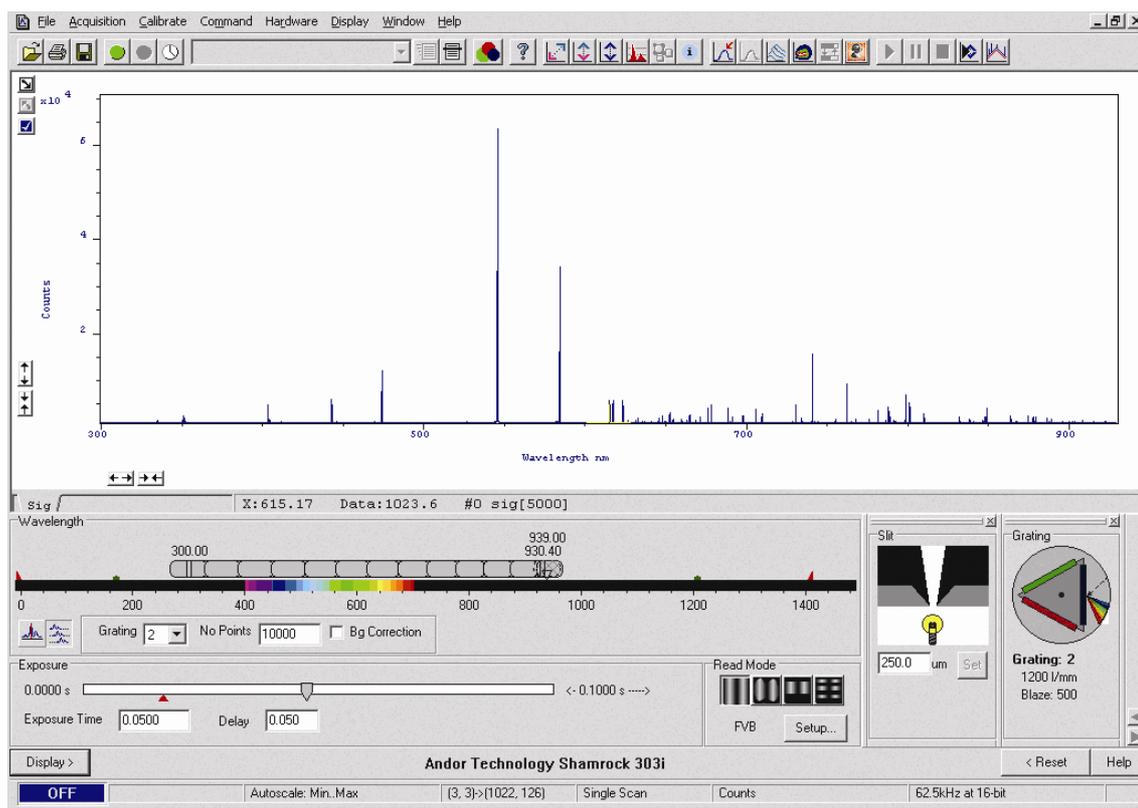


Figure 66: Hg/Ne spectrum

The **Grating Turret Control (Figure 17)** is used to select a new grating by rotating the grating turret to a new position. There are three turret positions available so that a maximum of three gratings can be fitted at any one time. If additional gratings are needed then the turret can be changed to install three new gratings. The values for up to three grating turrets may be stored in the system.

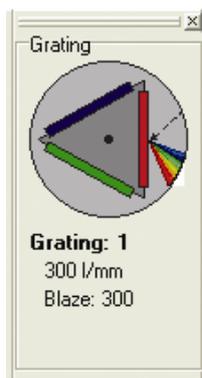


Figure 77: Grating Turret Control

The currently selected grating is always orientated vertically on the right of the display and is also indicated by the arrow and the spectrum graphic. As the cursor is placed over each grating position, the cursor changes to a pointing hand and details about the grating are displayed.

**NOTE 1: If the information is not automatically displayed, Simply move the cursor out of the turret control box and then back onto the grating to refresh the information.**

To change the grating, simply left-click on the grating you want to select. The hardware responds by rotating the grating turret and the turret graphic in the software control rotates to reflect the change.

**NOTE 2: If the wavelength drive is reset then the grating turret automatically resets the grating to position one.**

While the grating is being changed the software indicates that it is busy by displaying the hourglass symbol and the grating information text will read "changing grating..". The maximum time needed to change between gratings is approximately 15 seconds.

**NOTE 3: The text information displayed about each grating is stored in the SR-303i EEPROM. Edit EEPROM dialogs are provided to allow this information to be updated if you change the turret to add new gratings (please see pages 44 - 45 for further details).**

## 3.3 - REMOVING & REPLACING THE GRATING TURRET

1. The SR-303i has a unique replaceable triple grating turret (**figure 18**). This section describes how to replace a previously fitted grating turret and also how to fit a new grating turret. **NOTE: We strongly recommend protective gloves be worn to avoid damage to the gratings.**

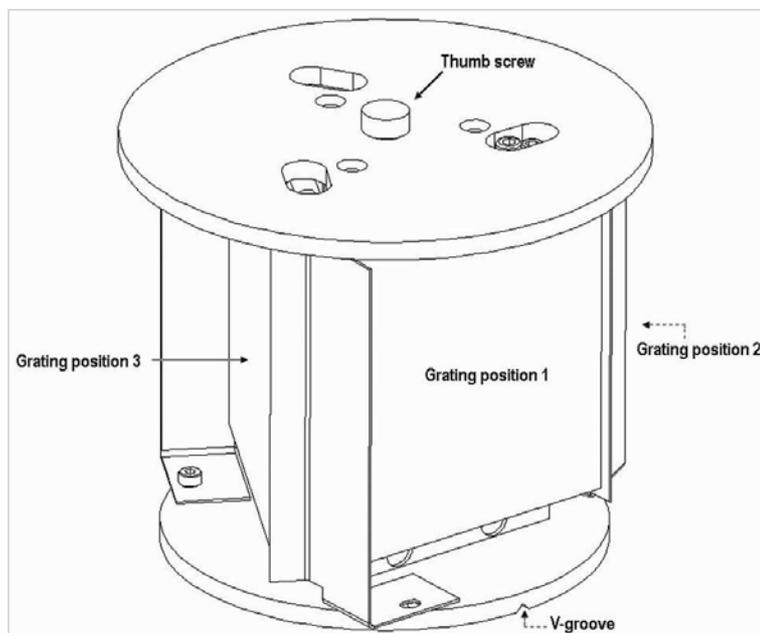


Figure 88: Grating Turret

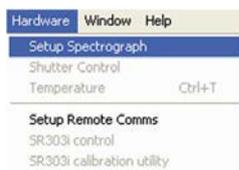
2. Remove the top lid of the spectrograph by unscrewing the eight M4 x 16 countersunk head screws. **CAUTION: GREAT CARE SHOULD BE TAKEN, AS THE DELICATE SURFACES OF THE OPTICS ARE NOW EXPOSED. NEVER TOUCH ANY OF THE OPTICAL SURFACES.**
3. To remove the grating turret loosen the captive thumb screw. Carefully pull the grating turret directly upwards and withdraw from the spectrograph body. Set aside in a safe place. If it is intended to store the turret for any extended length of time place in a dust free, low humidity environment.
4. To replace a previously fitted turret, carefully slide the turret onto the wavelength drive shaft. Rotate the grating turret until the V-groove on the underside of the grating turret locates with the ball plunger on the top surface of the wavelength drive.
5. Finger-tighten the locking screw while maintaining downward pressure on the turret.
6. Replace the spectrograph lid.

Due to the possible rotational angle changes in the physical re-positioning of the grating turret it may be necessary to slightly adjust the centre wavelength calibration of the system. This is achieved by adjusting the detector offset value stored in non-volatile memory (**EEPROM**) on the spectrograph. Please refer to **Offset Adjustment Control** on **page 47** for further details.

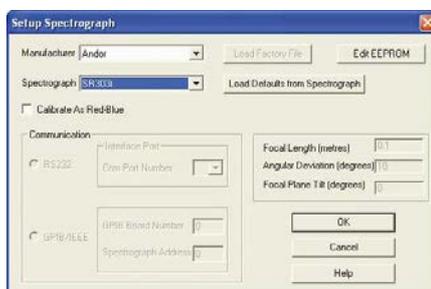
## 3.4 - FITTING A NEW GRATING TURRET

To fit a new turret, follow **steps 1 - 5** for **Removing and replacing the Grating Turret** shown on the previous page. The grating parameters for the new turret must be inputted into the non-volatile memory (**EEPROM**) in the spectrograph.

1. The **Shamrock EEPROM Editor** needs to be open. This is accessed from the **Hardware** menu as shown:



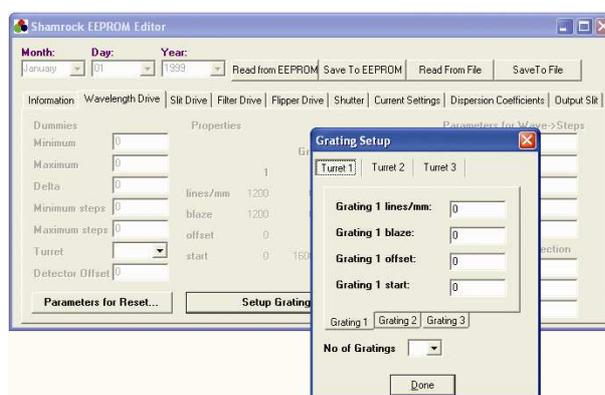
2. The **Setup Spectrograph** dialog box will appear, e.g:



Click the **Edit EEPROM** button and the **Shamrock EEPROM Editor** will appear, e.g.:

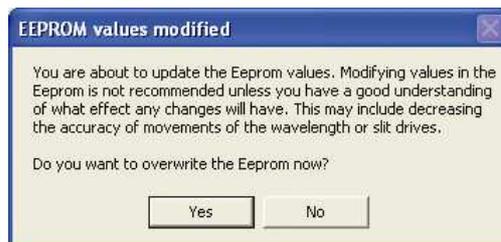


3. Select the **Wavelength** tab and click the **Setup Gratings** button. The **Grating Setup** dialog box will appear, e.g.:



4. First select the turret number that this new turret shall be known by e.g. Turret 2 (T2). Next, input the number of gratings installed on the new grating turret. **Figure 18** on **page 43** illustrates the position order of the three gratings. The Grating 1 position is identified by the V-groove on the base of the turret.
5. The number of lines/mm and blaze details should then be entered into the appropriate dialog box for each grating. These dialog boxes are accessed via the Grating 1,2,3 tabs.

When complete, exit the **Grating Setup**, click the **Save to EEPROM** button and the following message will appear:



6. Click **Yes**. The EEPROM parameters will be overwritten.
7. When complete, exit the Shamrock EEPROM Editor & Setup Spectrograph dialogs.

As there will always be a slight variation in the exact grating angles between turrets it will be necessary to adjust the grating offset values for each of the gratings on the new turret. Please refer to **Offset Adjustment Control** on **page 47** for further details.

**NOTE:** Once these grating offsets have been determined for the new turret, this procedure does not need to be repeated. The relative grating angles on a particular turret will not change unless their adjusting screws have been disturbed. The next time this turret is fitted it should only be necessary to ensure that **TURRET 2** has been selected as the fitted turret. It will still be necessary to adjust the detector offset to allow for the small rotational variations in refitting the turret (see **Offset Adjustment Control** on page 47).

## 3.5 - OFFSET ADJUSTMENT CONTROL

The **Offset Adjustment Control** (figure 19) allows the user to adjust the calibration of the instrument. We shall define two types of offset. A detector offset and a grating offset.

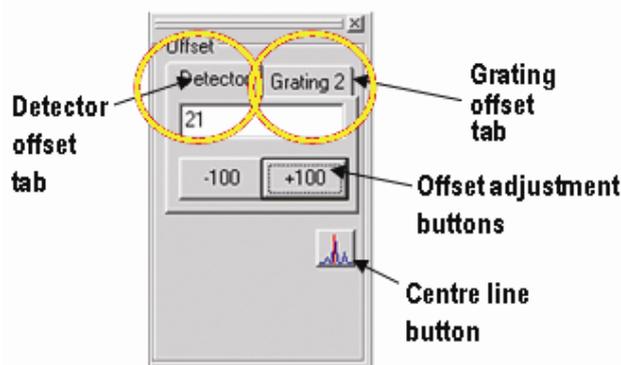


Figure 19: Detector and Grating Offset Adjustment Control

The Detector offset value can be adjusted to correct for any mechanical change that shifts (offsets) the displayed spectrum from the expected calibrated position. For example, if a camera is removed and refitted, or a grating turret is removed and refitted there will most likely be a small mechanical non-repeatability in the exact re-positioning of the component. Any offset introduced will be 'global', i.e. any offset (measured in pixels) will be independent of the grating being used. The grating offset values are also used to correct for any shift between the displayed spectrum from the expected calibrated position. The grating offsets are normally only adjusted when a new grating turret is installed.

For example if a system is calibrated with a particular grating turret (**T1**) and then this turret is swapped out for another one (say **T2**) there may be slight differences between the exact grating angle positions; a grating on **T2** may be angled slightly with respect to a grating at the same position on **T1** and similarly for grating turret positions **2** and **3**. Grating offsets are required for **T2** to compensate for this effect.

**NOTE: The grating offsets are not global in that they are only applied to the respective gratings.**

## 3.5.1 - Offset Adjustment Procedure

Detector or grating offset adjustment is selected via the tabs on the **Offset Adjustment Control**. The following describes the procedure for the detector offset adjustment but the grating offset adjustments are performed in the same manner.

1. If the offset adjustment control is not already displayed press the Display button and select the offset adjustment control. Click the Detector tab on the offset adjustment control.
2. Set a low-pressure mercury (Hg) pen-ray, or Neon (Ne) lamp (or similar) at the entrance slit of the system.
3. Set the entrance slit width to 10microns and input the wavelength of a known and recognisable spectral line into the wavelength control slider. For example the mercury 546.07 or 435.83nm line or the Neon 703.24nm line.
4. Acquire data. The target line should appear close to the centre of the display. Pressing the centre line button on the offset adjustment control will draw a red line on the centre CCD column of the display and serves as a useful aid to offset adjustment (see **figure 20** below).
5. If the spectral line is positioned on the centre line then an adjustment to the detector offset value is not required. If there is a discrepancy between the displayed centre wavelength and the actual wavelength position of the spectral line the offset should be adjusted.
6. Press the appropriate + or - offset adjustment buttons to bring the centre of the spectral line onto the red centre line. The adjustment step size may be selected from a drop down list (right-click either of the keys). It will be found that “zooming” the acquisition display will help the final fine adjustments.
7. When the target spectral line has been centred the procedure is complete. As a rough rule-of-thumb an offset adjustment of approx. 3 units will offset the spectral line by 1 pixel (26 micron wide pixel)

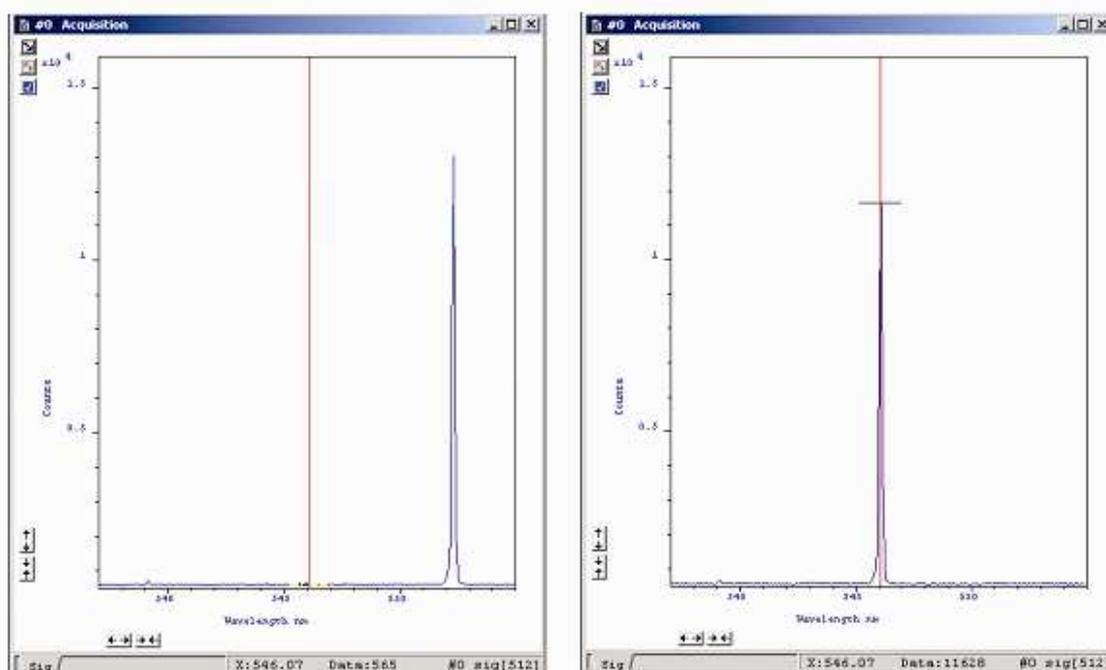


Figure 90: Spectra acquired before (left) & after (right) Detector Offset Adjustment

## 3.6 - SLIT DRIVE CONTROL

The **Slit Drive Control** (figure 21) is used to control the **Motorised Slit Assembly** (see figure 32 on page 57). The slits are used to control the amount of incident light that enters the spectrograph. The width can be varied between 10µm and 2500µm (in steps of 2.5µm). The slit height may be altered by interchanging optional baffle plates (attached to the slit assembly using 5x M2 cross-head screws). The system is supplied with a standard 4mm high x 6mm wide rectangular aperture baffle plate but there are also 8mm and 14mm high options available. A 15mm diameter circular aperture is also available. If additional baffle options are required please contact your nearest Andor representative.

In addition to controlling the level of illumination, the slit width also affects the resolution of the acquired data. There is a trade-off between resolution and throughput. The narrower and shorter the slit the higher the achievable resolution, but at the expense of throughput. As a general rule, it is best if the slit width is set as narrow as possible while still achieving the required throughput. If the signal is too weak the slit width should then be increased.

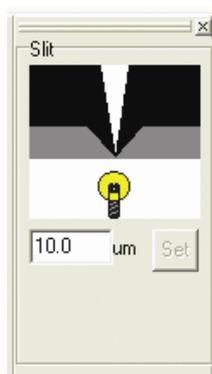


Figure 101: Slit Drive Control

The slit width can be input in a variety of ways:

1. By typing a new value into the slit width edit box and pressing **Enter**
2. By typing a new value into the slit width edit box and clicking the **Set** button
3. Clicking and dragging the edges of the slit in the graphic. Position the cursor over the grey “blade” area of the slit graphic
4. When the cursor changes to a pointing hand, hold down the left mouse button and move the cursor to open, or close, the slit edges. Regardless of which blade you drag, both blades move about the centre of the slit

As you drag the blade the displayed slit width changes to reflect the selected width. The slit drive will drive to the new width value when the mouse button is released.

The minimum and maximum operating values of the motorised slit are 10 and 2500 microns, respectively. If a slit width input is outside of this range the system defaults to the nearest limit value.

The mechanism may be reset via the Reset button and selecting the Reset Slit option. On completion of a ‘reset’ the slit width will default to 10 microns.

3.7 - FILTER WHEEL CONTROL

The optional filter wheel accessory is controlled by the **Filter Wheel Control**:



Figure 112: Filter Wheel Control

The Filter Wheel Control indicates the currently selected filter and provides details of the filter at the bottom of the control. The filter positions and their details are stored in non-volatile memory (**EEPROM**) in the instrument and should be input by the user on first use of the system).

To input, or modify, the details of a particular filter position the mouse cursor on the required filter position. Right-click and a filter details input box will appear. Enter the filter details (up to a maximum of 9 characters) and left-click when complete.

The operation of the filter wheel is very similar to that of the grating turret control. Positioning the cursor over each filter position changes the cursor to a pointing hand and details about the filter are displayed.

**NOTE: If the information is not automatically displayed, simply move the cursor out of the filter wheel control box and then back onto the required filter to refresh the information.**

**To change the filter, simply position the mouse cursor on the required filter and left-click. The hardware responds by rotating the filter wheel and the filter wheel graphic in the software control rotates to reflect the change.**

The accessory may be reset by clicking the  button.

On completion of a reset the filter wheel defaults to the **FILTER 1** position.

**3.8 - SHUTTER CONTROL**

If you have a shutter attached to your system the **Shutter Control** can be used to set the shutter mode of operation:



Figure 123: Shutter Control

There are four modes of operation available:

1. **Always Open:** The shutter will be open before, during, and after any data acquisition.
2. **Always Closed:** This option is selected if you wish to take a series of acquisitions in darkness and do not require the shutter to open between acquisitions. You might, for example, wish to capture a sequence of background values. The shutter remains closed before, during and after any data acquisition.
3. **Fully Automatic (AUTO):** This is the simplest shutter mode as it leaves all shuttering decisions to the system. The software controls the shutter based on the information supplied (e.g. TTL pulse polarity, time to open). In this mode the shutter will open during acquisitions but will automatically close during background acquisitions and during the readout of image acquisitions. **NOTE: This mode is not available with the USB interface.**
4. **Custom:** This mode gives you a greater degree of control over the circumstances in which the shutter opens and closes. This mode is designed to cover any specific behaviour you may require that is not covered by the other three modes. In this mode you must use the shutter dialog to configure the shutter to meet your requirements.

To change the shutter mode, simply place the cursor over the shutter and left-click. This toggles the shutter through the four available options and the change is reflected in the shutter graphic. More detailed descriptions of the various shutter mode control options can be found in the manual supplied with your Andor CCD.

## 3.8.1 - Control of Shutter via External TTL Signal

For flexibility, the shutter in the SR-303i system may also be operated by an external TTL signal. This allows the shutter to be operated by, and synchronised to, other laboratory equipment. The shutter connector is a standard female BNC type and is located as shown in **figure 24**:

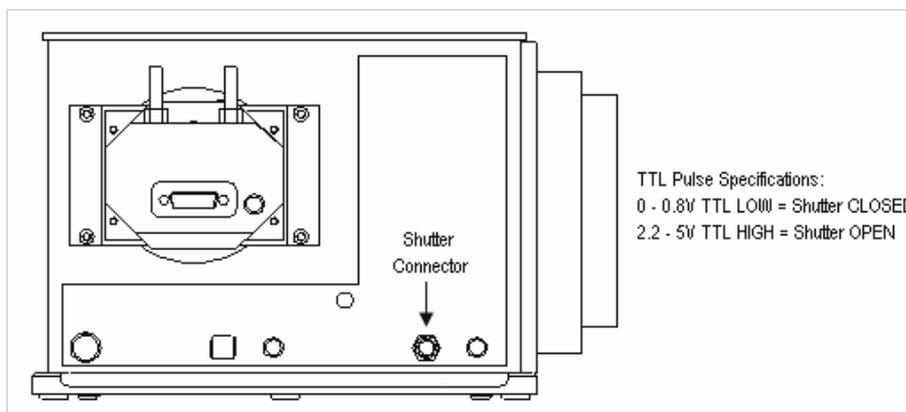


Figure 134: External shutter connector

**NOTE:** For correct shutter operation, via the shutter connector, it is first necessary to ensure that the shutter mode is set to **CLOSED** in the software interface. Similarly, if the shutter control is returned to the software interface it is necessary to either set the external signal to TTL LOW, or disconnect the cable. Failure to do so will mean that the shutter will remain in the open state and will not open and close as desired.

## 3.8.2 - Fitting a Shutter to the Shamrock SR-303i

A shutter can be easily fitted or replaced by the user. Remove the 4 off, M4 x 25mm cap-head screws attaching the 25mm thick spacer block to the body of the spectrograph (**figure 25**). It is not necessary to unplug the slit assembly ribbon cable.

1. Carefully allow the spacer block and slit assembly to fall forward.

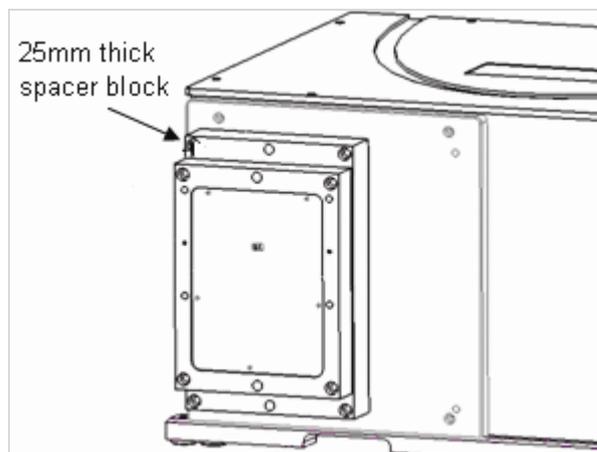


Figure 25: Spacer Block Attachment Screws

2. Attach the shutter to the system using the three M2 x 6mm screws provided (do not over tighten) and attach the 4-way electrical connector to the matching connector on the instrument.
3. Arrange the connector and wires into the recessed pocket taking care not to interfere with the shutter actuator lever (**figure 26**):

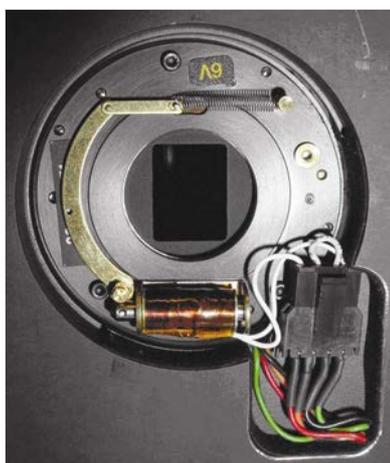


Figure 146: Shutter (shown In-Situ)

4. Replace the spacer block and slit assembly

On re-start, the software will auto-detect that a shutter has been fitted, the shutter control will be displayed and the shutter is now ready for use.

## 3.9 FLIPPER MIRROR CONTROL

The **Flipper Mirror Control** (figure 27) allows you to rapidly select the required exit port. Port 1, or Port 2, is selected by simply clicking on the appropriate port on the Flipper Mirror Control dialog. The selected port is highlighted in yellow and also identified below the graphic. **Figure 28** shows a plan view of the various input and output ports on the Shamrock SR-303i.

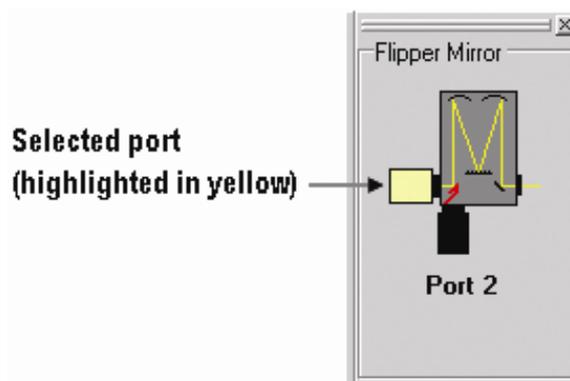


Figure 157: Flipper Mirror Control

**NOTE:** The Dual Exit Port option is not available as an accessory. It must be specified at time of manufacture (SR-303i model # SR-303i-B).

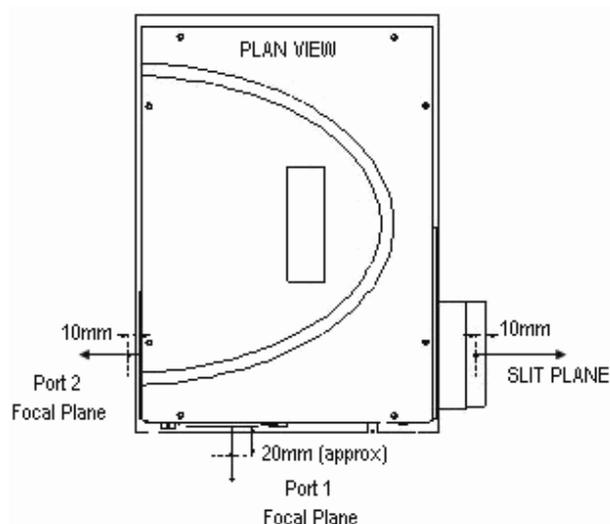


Figure 168: SR-303i Input and Exit Port Arrangement (Model number SR-303i-B)

**3.10 - ACCESSORY PORT CONTROL**

The **Accessory Port Control** (**figure 29**) allows for simple control and communication with other electronic devices via the Shamrock SR-303i software interface. Two TTL compatible outputs are provided and can be controlled via the Accessory Port Control. The accessory connector is located on the side of the spectrograph (see **figure 30** on **page 56**).

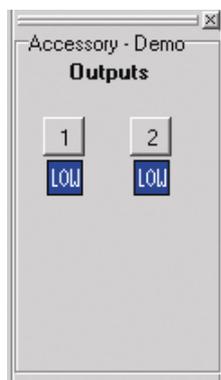
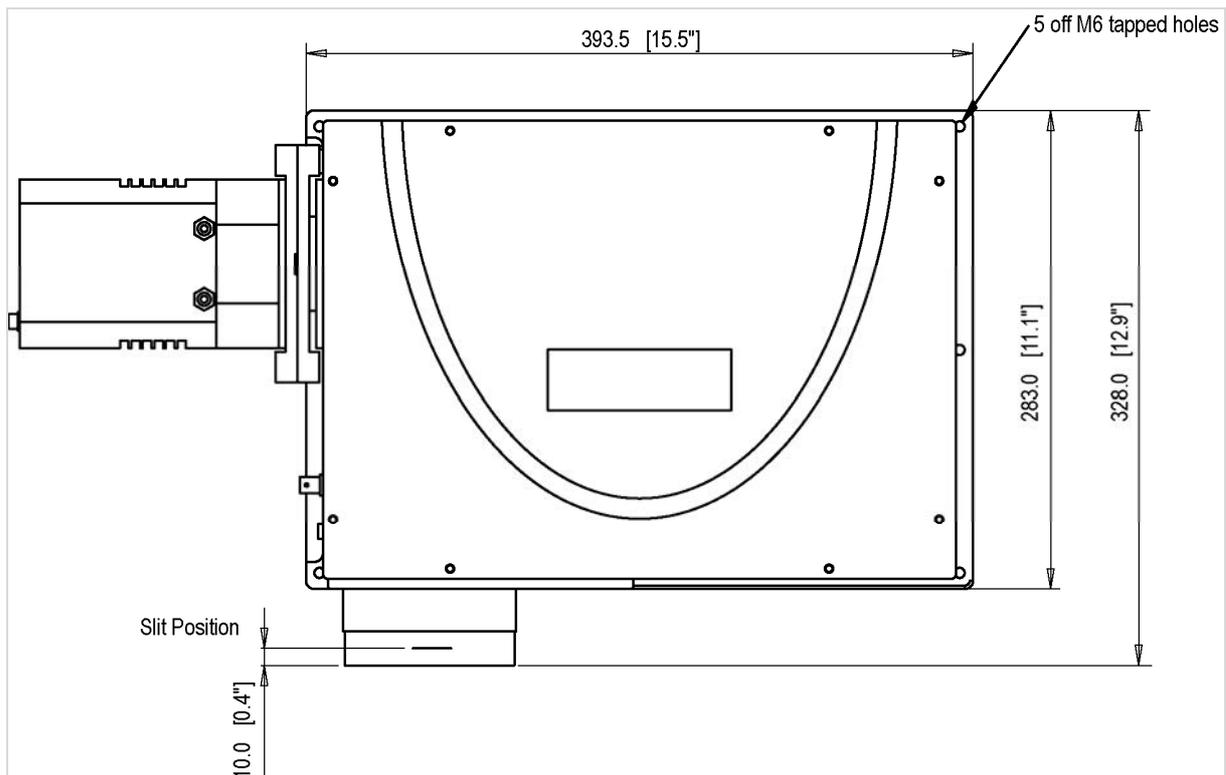
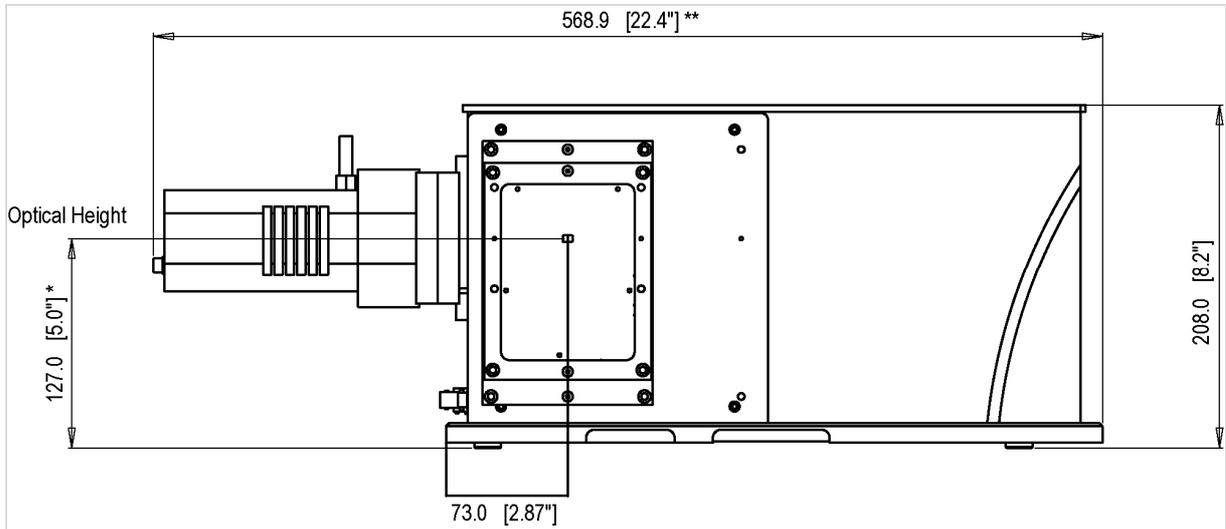


Figure 29: Accessory Port Control

There are also two selectable voltage lines provided. Each line may be individually set to 24V, 12V or 5V via two jumper pins (**Jumper1 & Jumper2**). Please refer to **figure 33** on **page 60** for full details of the 6-way connector pin details and voltage selection jumpers.

**APPENDIX**  
**A1.1 - MECHANICAL DRAWINGS**  
**A1.1.1 - Dimensions**

Note: Dimensions in mm (inches)



**Optical Axis**

127mm [5"] with pad feet

\* The optical path height with standard feet attached as shown. The height with adjustable feet varies between 143mm [5.6"] and 173mm [6.8"]

\*\* The overall length with a standard Andor model attached. The length with an iStar is 622.2mm [24.5"]

**A1.1.2 - Electrical & electronic interface connectors**

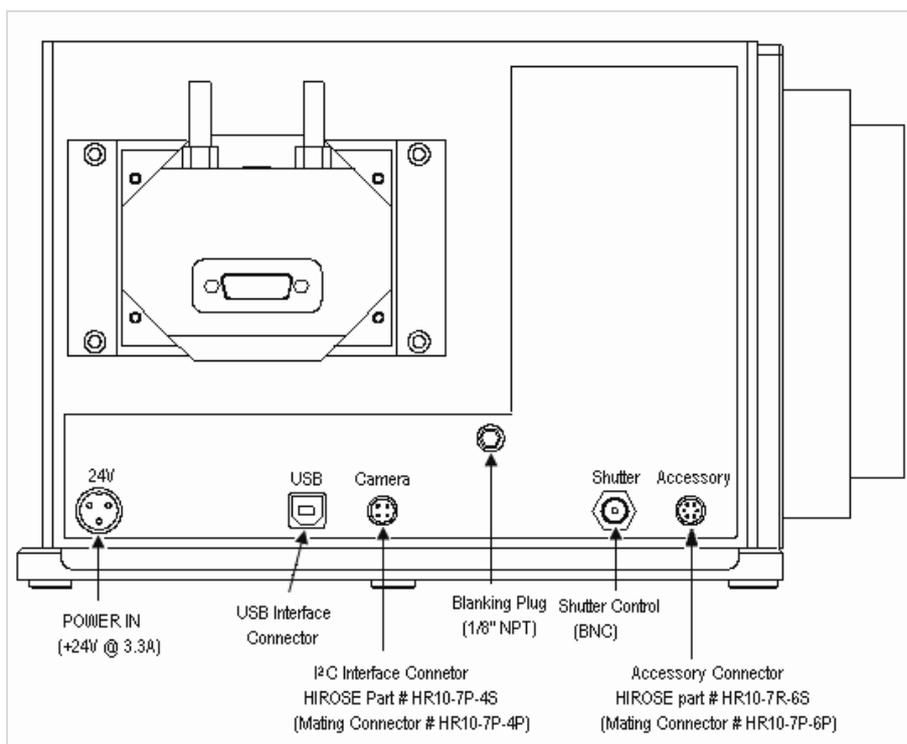
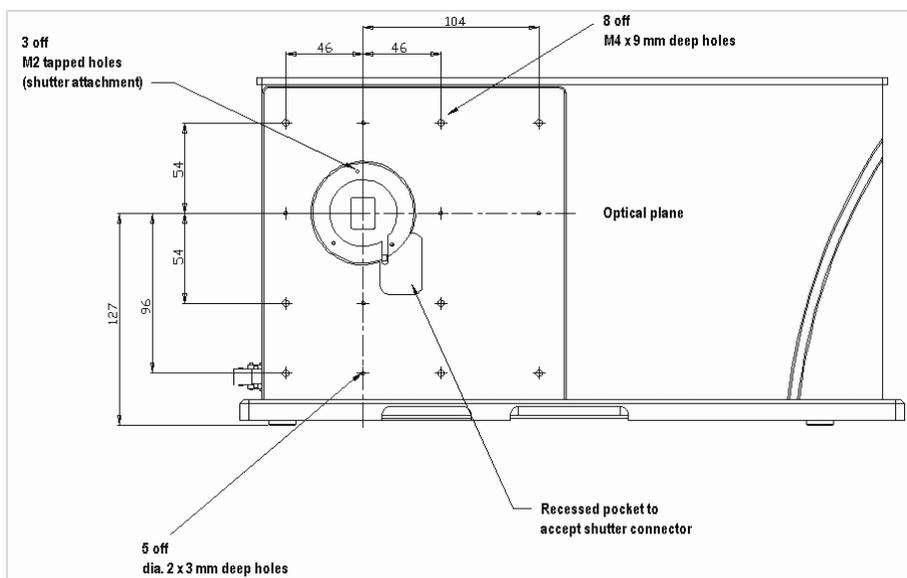


Figure 170: Connectors

**A1.1.3 - Entrance Port mounting details**



**A1.1.4 - Motorised Slit details (Part # SR-ASZ-0103)**

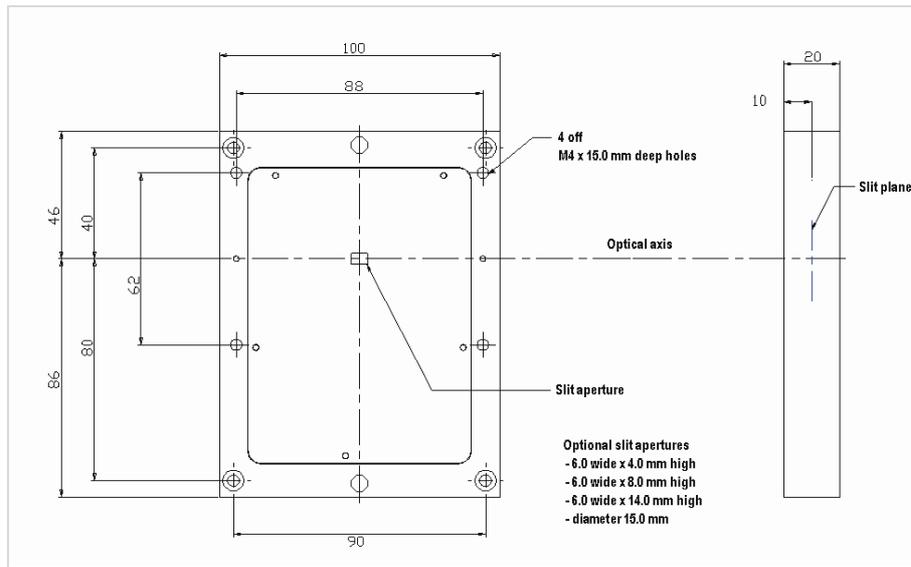
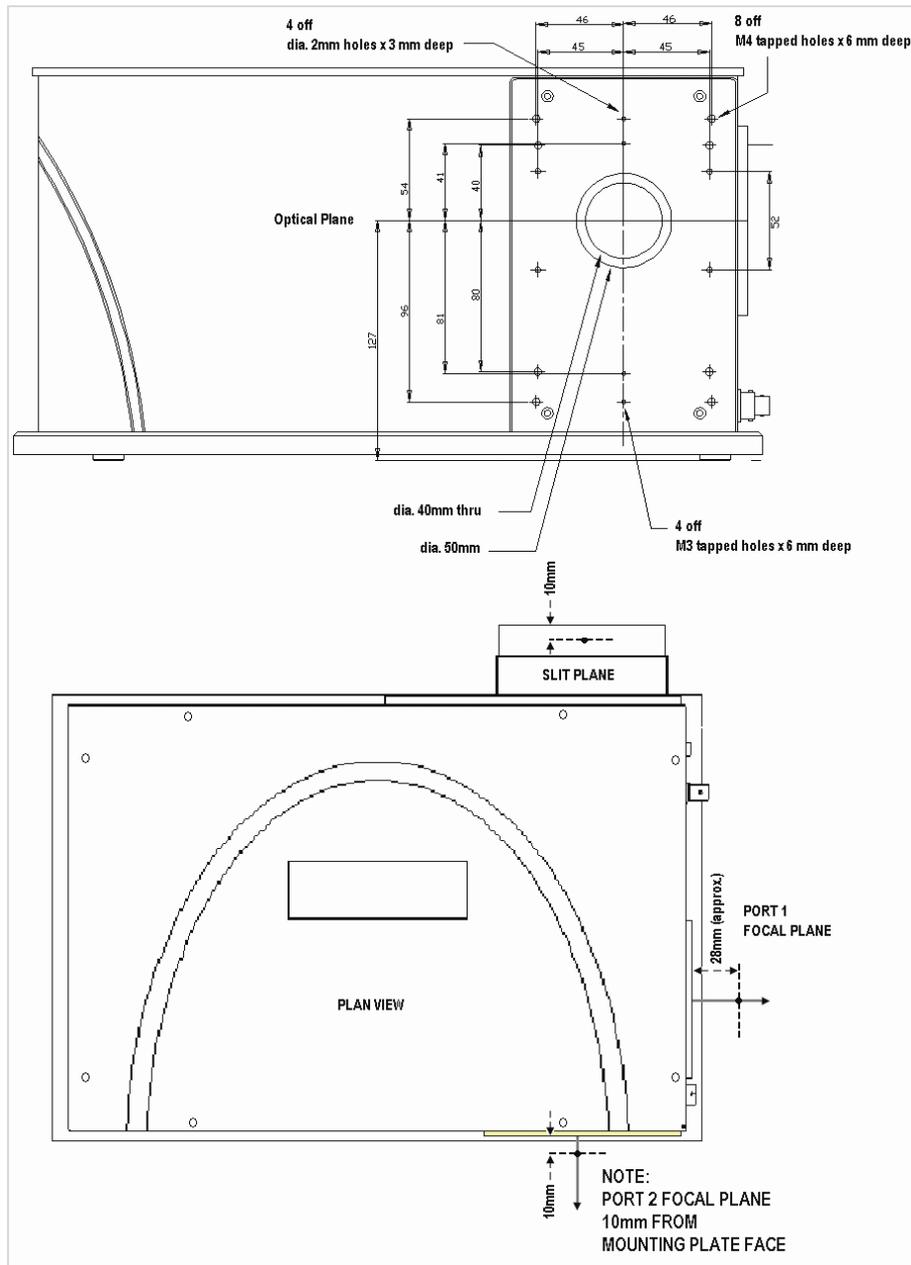


Figure 181: Motorised Slit Assembly

**A1.1.5 - Second Output Port (Port 2) details (Model # SR-303i-B only)**



**A1.1.6- Alignment of optional Imaging Flange Accessory**

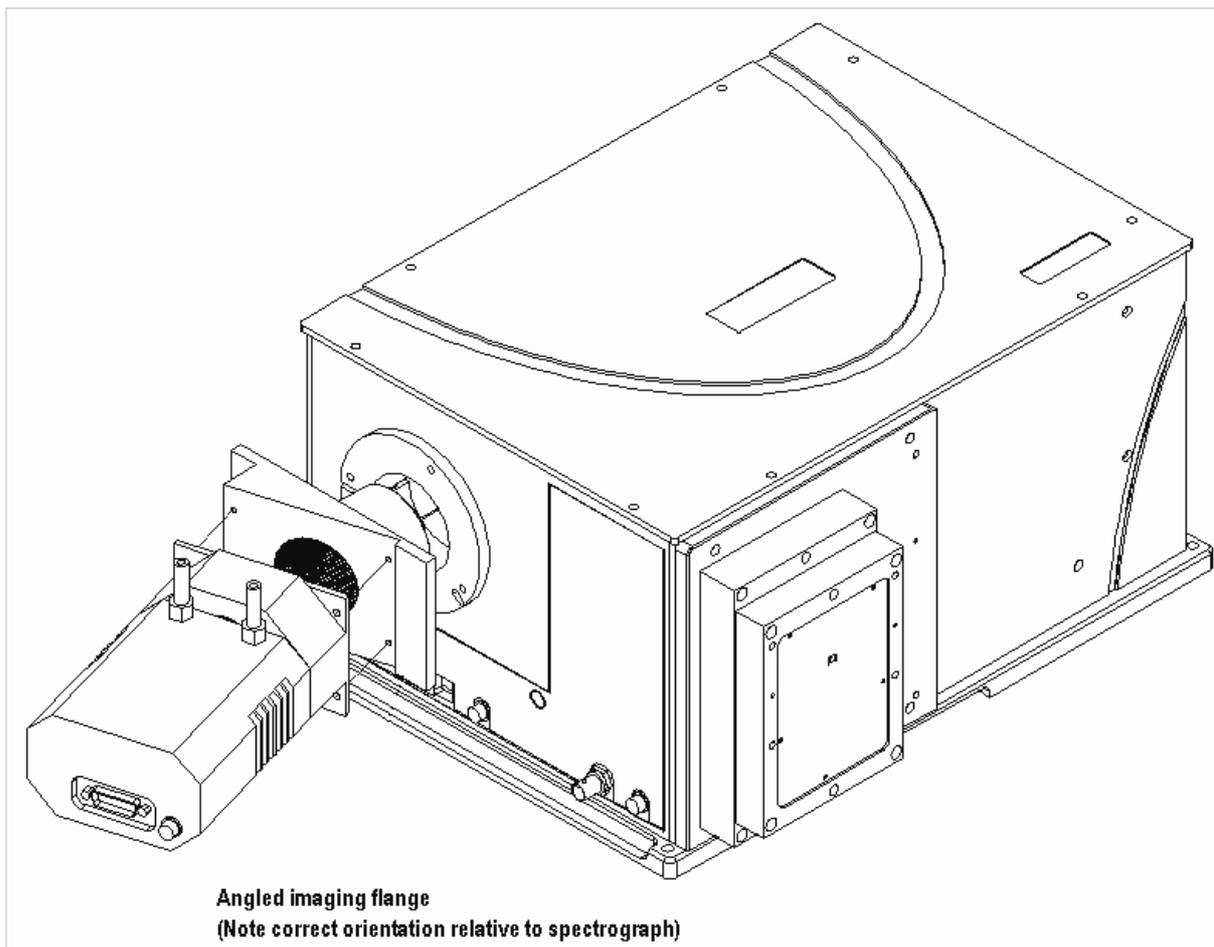
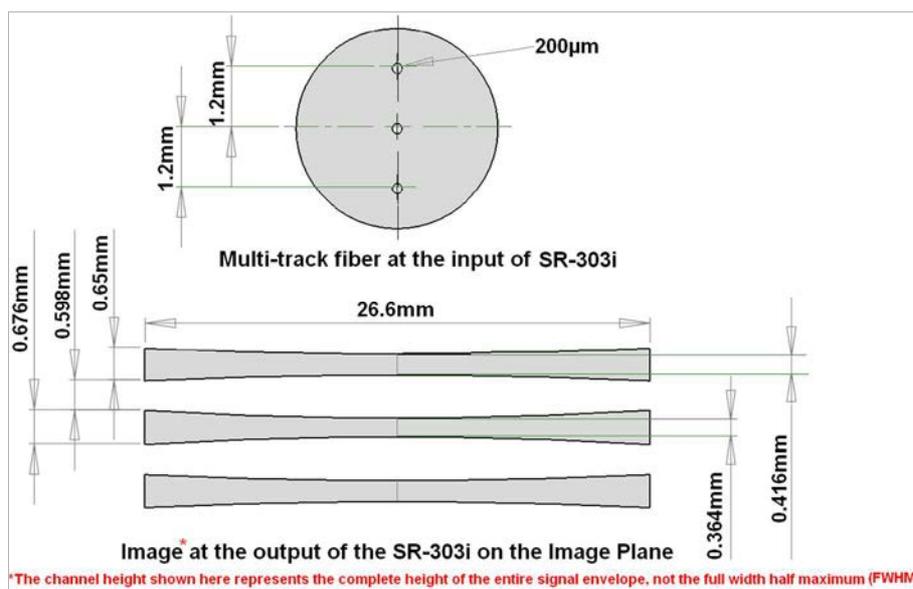


Figure 192



Imaging property of SR-303i at the imaging plane

A1.1.7 - Accessory Connector Pin & Voltage Output Jumper Pin details

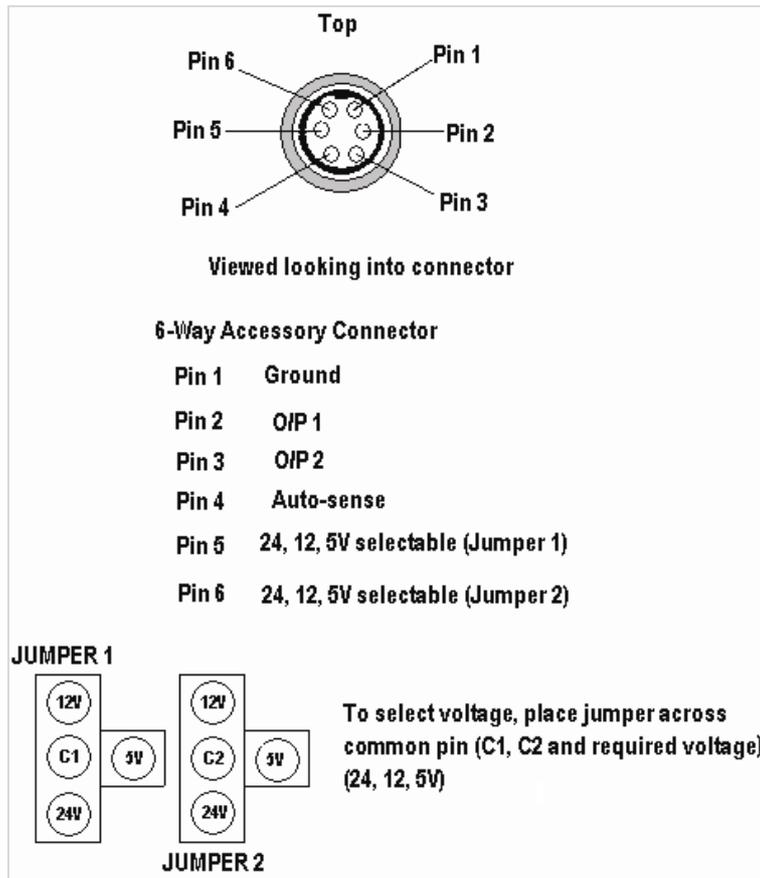


Figure 203: Accessory connector

**IMPORTANT NOTE:** The output voltages are mainly intended for attachment of Andor designed accessories. Other devices should only be connected with caution. Maximum current values are 24V@200mA, 12V@100mA and 5V@100mA. Failure to observe these limits may damage the system.

**A1.2- TERMS & CONDITIONS**

1. In these Conditions:

'BUYER' means the person who accepts a quotation of the Seller for the sale of the Goods or whose order for the Goods is accepted by the Seller.

'GOODS' means the goods (including any instalment of the goods or any parts for them) which the Seller is to supply in accordance with these Conditions.

'SELLER' means Andor Technology plc.

'CONDITIONS' means the standard terms and conditions of sale set out in this document and (unless the context otherwise requires) includes any special terms and conditions agreed in writing between the Buyer and Seller.

'CONTRACT' means the contract for the purchase and sale of the Goods.

'WRITING' includes telex, cable, facsimile transmission and comparable means of communication.

2. Any reference in these Conditions to any provision of a statute shall be construed as a reference to that provision as amended, re-enacted or extended at the relevant time.
3. The headings in these Conditions are for convenience only and shall not affect their interpretation.

**A1.3 - WARRANTIES & LIABILITY**

1. Subject to these Conditions set out below, the Seller warrants that the Goods will correspond with their specification at the time of delivery and will be free from defects in material and workmanship for a period of 12 months from the date of delivery.
2. The above warranty is given by the Seller subject to the following conditions:
  - 2.1 the Seller shall be under no liability in respect of any defect in the Goods arising from any drawing, design or specifications supplied by the Buyer;
  - 2.2 the Seller shall be under no liability in respect of any defect arising from fair wear and tear, wilful damage, negligence, abnormal working conditions, failure to follow the Seller's instructions (whether oral or in writing), misuse or alteration or repair of the Goods without the Seller's approval;
  - 2.3 the Seller shall be under no liability under the above warranty (or other warranty, condition or guarantee) if the total price for the Goods has not been paid by the due date for payment;
  - 2.4 the above warranty does not extend to parts, material or equipment not manufactured by the Seller, in respect of which the Buyer shall only be entitled to the benefit of any such warranty or guarantee as is given by the manufacturer to the Seller.
3. Subject as expressly provided in these conditions, and except where the Goods are sold to a person dealing as a consumer (within the meaning of the Unfair Contract Terms Act 1977), all warranties, conditions or other terms implied by statute or common law are excluded to the fullest extent permitted by law.
4. Any claim by the Buyer which is based on any defect in the quality or condition of the Goods or their failure to correspond with specification shall (whether or not delivery is refused by the Buyer) be notified in Writing to the Seller within 7 days from the date of delivery or (where the defect or failure was not apparent on reasonable inspection) discovery of the defect or failure. If delivery is not refused, and the Buyer does not notify the Seller accordingly, the Buyer shall not be entitled to reject the Goods and the Seller shall have no liability for such defect or failure, and the Buyer shall be bound to pay the price as if the Goods had been delivered in accordance with the Contract. In no event shall the Buyer be entitled to reject the Goods on the basis of any defect or failure which is so slight that it would be unreasonable for him to reject them.
5. Where any valid claim in respect of the Goods which is based on any defect in the quality or condition of the Goods or their failure to meet specification is notified to the Seller in accordance with these Conditions, the Seller shall be entitled to replace the Goods (or the part in question) free of charge or, at the Seller's sole discretion, refund to the Buyer the price of the Goods (or a proportionate part of the price), but the Seller shall have no further liability to the Buyer.

6. Except in respect of death or personal injury caused by the Seller's negligence, the Seller shall not be liable to the Buyer by reason of any representation (unless fraudulent), or any implied warranty, condition or other term, or any duty at common law, or under the express terms of the Contract, for any indirect, special or consequential loss or damage (whether for loss of profit or otherwise), costs, expenses or other claims for compensation whatsoever (whether caused by the negligence of the Seller, its employees or against otherwise) which arise out of or in connection with the supply of the Goods, or their use or resale by the Buyer and the entire liability of the Seller under or in connection with the Contract shall not exceed the price of the goods, except as expressly provided in these Conditions.

7. The Seller shall not be liable to the Buyer or be deemed to be in breach of the Contract by reason of any delay in performing, or any failure to perform, any of the Seller's obligations in relation to the goods, if the delay or failure was due to any cause beyond the Seller's reasonable control. Without prejudice to the generality of the foregoing, the following shall be regarded as causes beyond the Seller's reasonable control:

7.1 Act of God, explosion, flood, tempest, fire or accident;

7.2 war or threat of war, sabotage, insurrection, civil disturbance or requisition;

7.3 acts, restrictions, regulations, bye-laws, prohibitions or measures of any kind on the part of any governmental, parliamentary or local authority;

7.4 import or export regulations or embargoes;

7.5 strikes, lock-outs or other industrial actions or trade disputes (whether involving employees of the Seller or of third party);

7.6 difficulties in obtaining raw materials, labour, fuel, parts or machinery;

7.7 power failure or breakdown in machinery.