SciPV: QE

Software User Manual

Updated for SciPV v1.0.1.2

v1.1.5

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1. Overview

The QE software is a part of the SciPV software offered with the Sciencetech's PTS. This software allows users to measure spectral response (SR), external quantum efficiency (EQE), and internal quantum efficiency (IQE) [with additional hardware]. Other measurement techniques are available as upgrades.

For current-voltage (IV) measurements the IV package is also supplied as part of SciPV software application.

2. Setup and Installation

The software needed to run your PTS is pre-installed on the provided computer, however the instructions below list the procedure taken for installing the PTS software in the case that reinstallation/setup is required.

Please follow the instructions related to your Keithley source meter model. Before starting any installation steps, verify the Keithley version (2400, 2401, 2420, or 2450 that is supplied with your system).

2.1 Keithley 2400 Series (including 2401) Setup

This step should already be completed at Sciencetech, but it is good to verify that the Keithley (and any other accessories to be used with SciPV such as TEC Cell Chuck) is in the correct configuration. If the Keithley being used has not been supplied by Sciencetech, please follow these steps.

1. Turn on the Keithley.
2. Press the MENU button.

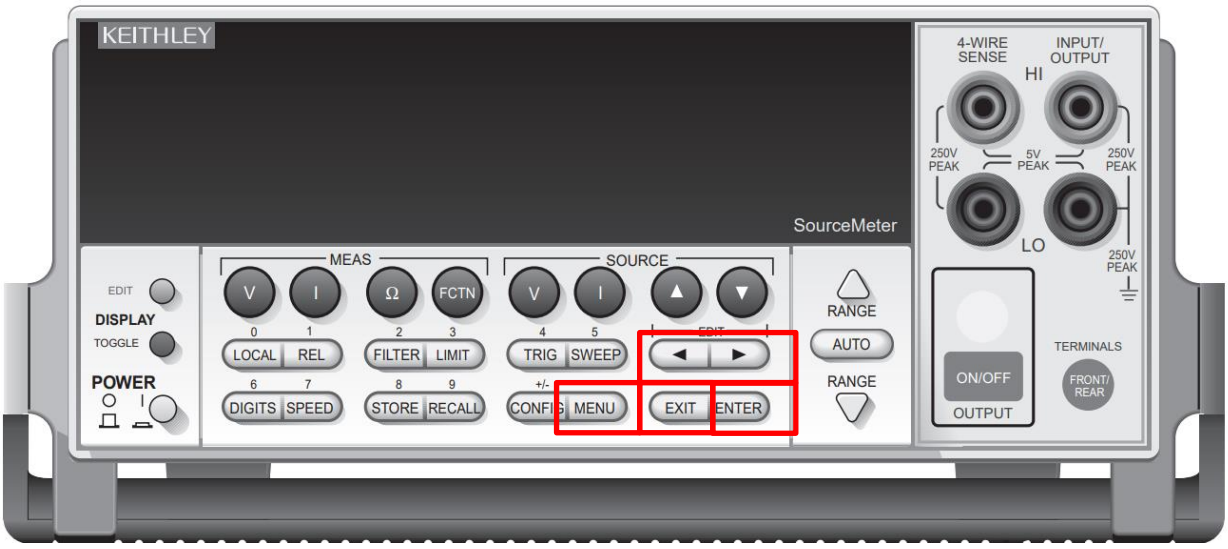


Figure 1: Keithley 24XX front panel.

3. Using the left/right arrows, navigate to COMMUNICATION and press ENTER.
4. Set the Communication field to RS232;press ENTER.
5. Set the baud rate to 19200; press ENTER.
6. Set the Terminator to <CR+LF>; press ENTER.
7. Make sure under FLOW CONTROL, XON/XOFF is selected.
8. Press the EXIT button.

9. Connect the Keithley to the computer with the provided USB to RS232 cable. Connect the RS-232 (DB9) connection on the rear of the Keithley to the computer to be used (if the system was provided by Sciencetech the USB hub will have a label for the Keithley).

2.2 Keithley 2450 Drivers Setup

Keithley 2450's require the following drivers (these drivers will be located on the supplied USB with your system):

1. Install the drivers supplied with your system in the following order:
   A. Install "..\VisaRunTime53\setup.exe"
   B. Install "..\IviSharedComponents64_260.exe"
   C. Install "..\Keithley2450-x64.msi"
2. Connection the Keithley to the computer to be used with the supplied USB cable.

Figure 2: Keithley 2450 back panel.

2.3 Lock-in Amplifier Setup

If the lock-in amplifier is supplied by Sciencetech, it will be configured in the correct state to communicate with SciPV. If you are using your own Stanford 810/830 it will need to be configured in the following manner:

1. Set the communication type to RS232 by pressing the Setup button in the interface section on the front panel of the lock-in and using the rotation dial to switch to RS232.
2. Press the Setup button consecutively, and using the rotation dial, set the following parameters:
    a. Baud Rate: 19200
    b. Parity: None
    c. Address: 8

2.4 Chopper Setup

If the MC2000(B) chopper controller is supplied by Sciencetech, it will be configured in the correct state to communicate with SciPV. If you are using your own MC2000(B) it will need to be configured in the following manner:

1. Install the MC2000(B) software/drivers provided on the USB.
2. Set blade to the correct blade installed in the system. The standard Sciencetech blade is the MC1F2.
3. Enable Auto-Run.

2.5 SciPV Installation

If your system came with a computer supplied by Sciencetech SciPV will come preconfigured and installed on the provided computer. In that case, the Installation steps are only required if a reinstallation is needed.

1. Move the SciPV installation folder to the computer desktop.
2. Install the Drivers (if necessary).
    - Install Prolific Drivers for the Keithley and Stanford Lock-in Amplifier.
        - If your system uses a Keithley 2450, ensure the Keithley 2450 drivers are installed (See Keithley Setup above).
        - If your system uses a Keithley 2400, 2401, or 2420, install the RS232 to USB cable drivers (Prolific_PL2303 – this will be in a separate folder inside the SciPV install master folder).
        - Install the Thorlabs chopper drivers for the MC2000 chopper. See Chopper Setup above.
3. Run setup.exe inside SciPV v1.X.X.X folder (labelled according to the version of SciPV that is supplied). This folder should include the following folders:
        - Assemblies: All complied libraries for your system.
        - Configuration Files: All device configuration files.
        - Device Lists: Contains configuration files specifying known peripherals the system is shipped with. This would include configuration files for known DUTs, reference cells, etc.
        - License: Location of your encrypted Keithley license (if another unlicensed Keithley is connected the program will not work).
        - Modules: All assembly files, AppPersimissions.config and SciPV.config files.

3. QE Software Operation

The QE window will appear as shown below. There may be slight differences in this window appearance depending on the version of the software you have installed. The below highlighted sections of the QE software will be explained in the following text.

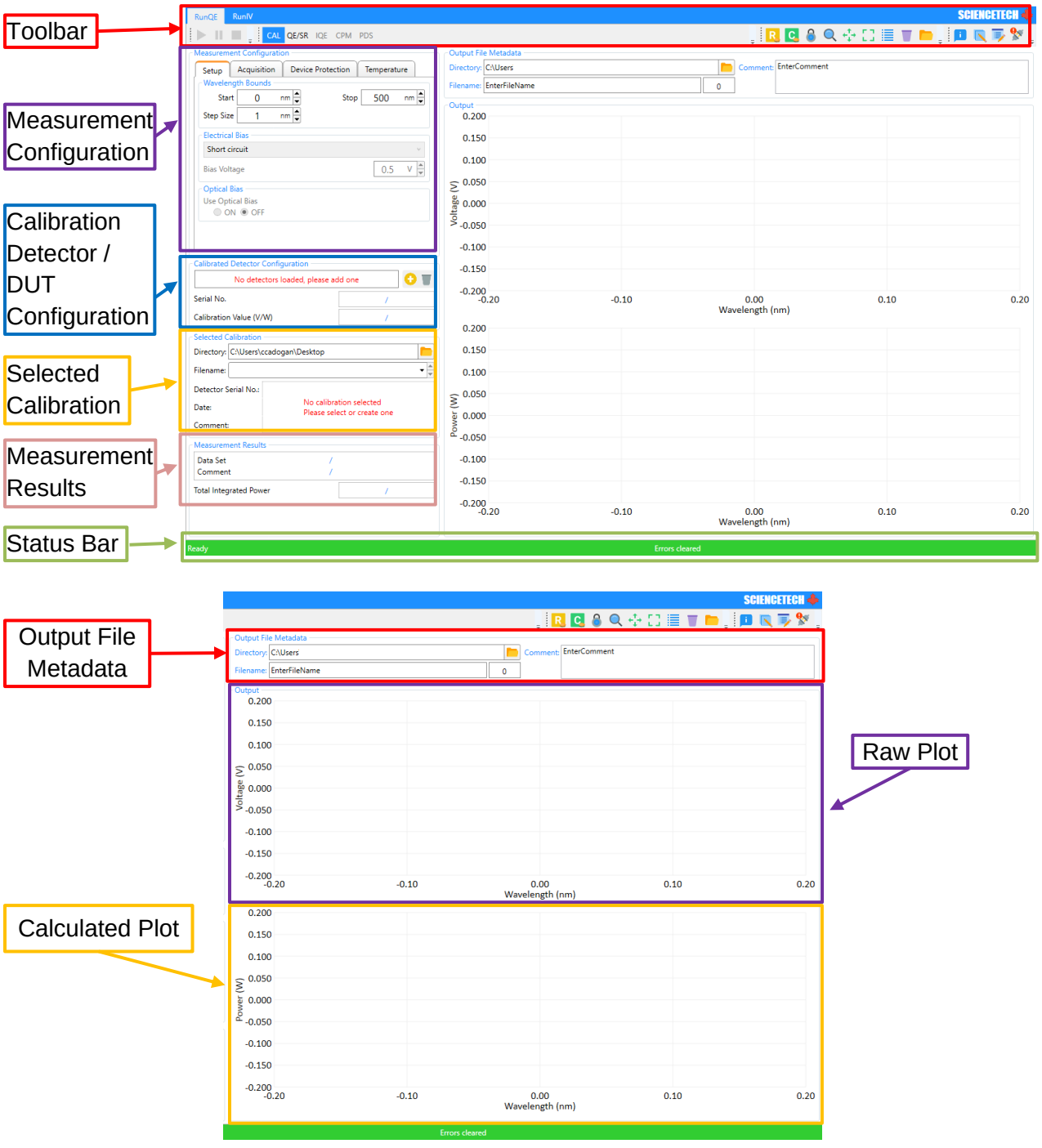
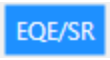


Figure 3: Overview of sections in SciPV: QE software interface.

3.1 Toolbar Buttons

Button	Description
	Start a measurement. Clicking this icon will cause the “Confirm Measurement Setup” window to popup. See Confirm Measurement Setup Window for details.
	Pause/Resume a scan.
	Stop a scan before it is completed. This button will abort the current scan, and the scan cannot be resumed. Instead a new scan would need to be started. Data up to the point the button was pressed is saved.
	**Calibration Scan** Selects calibration scan mode.
	**Quantum Efficiency/Spectral Response (QE/SR) Scan** Selects QE/SR scan mode.
	**Reflectance Scans** Selects reflectance scan mode.
	**Internal Quantum Efficiency (IQE) Calculator** Opens IQE calculation window.
	**Hide/ Display Raw Plots** This will hide/display the raw voltage plots.
	**Hide/ Display Calculated Plots** This will hide/display the calculated plots.
	**Lock Raw and Calculated Plot** Clicking this button will lock raw and calculated plot wavelength axis movements together.
	**Toggle Zoom** Used for zooming in/out on a displayed curve. Simply press on this button and use the scroll wheel of the computer mouse. To disable this feature, press again on this button.
	**Toggle Panning** Used for panning around a displayed curve. Simply press this button and left click on the display area and pan around. To disable this feature, press again on this button.
	**Center Chart** Reset the setting of the display area after using either ‘Toggle Panning’ or ‘Toggle Zooming’.
	**Plot Legend** To hide/show the legend beside the displayed curves. The legend can be used to hide or show specific plots on the chart.
	**Clear Plot Display** To remove displayed curves from the display area. Pressing this button does not delete any of the measured data from your computer directory, but only clears the display area.
	**Open Files** To open previously acquired measurements files for display. These plots will be added to the display screen. This button will only display files that are related to the scan mode that is currently selected. E.g if you have CAL selected and click this button it will only show “.caldat” files to select for display.
	**Configuration File** This will open the directory where the configuration files are stored.
	**Log File** This will open the directory where the log file is stored. This file is useful for debugging and troubleshooting of the software.
	**QE Device Manager** Opens the device manager window. This window shows the connected devices, their COM port number (when applicable), and their connection status. If there is red exclamation mark, this is an indicator that a device(s) is(are) not connected.

3.1.1 QE Device Manager

The device manager shows the connected devices and their COM port number when applicable. This popup window is where you will enter the correct COM port for the various devices needed for SciPV to run. If any of these devices has “Not Connected” below it then the COM port selected is either not the correct COM port for this device or the COM port has not been confirmed, see section 3.1.1.1: Entering A New Device COM for details. It is also possible that the device is not connected to the computer or is not powered on.

When setting up a new PTS, if all devices are connected to the correspondingly labelled USB ports, no COM port number should require updating.

3.1.1.1 Entering A New Device COM Port

To enter a new COM port for a device, first determine the correct port number using Windows Device Manager.

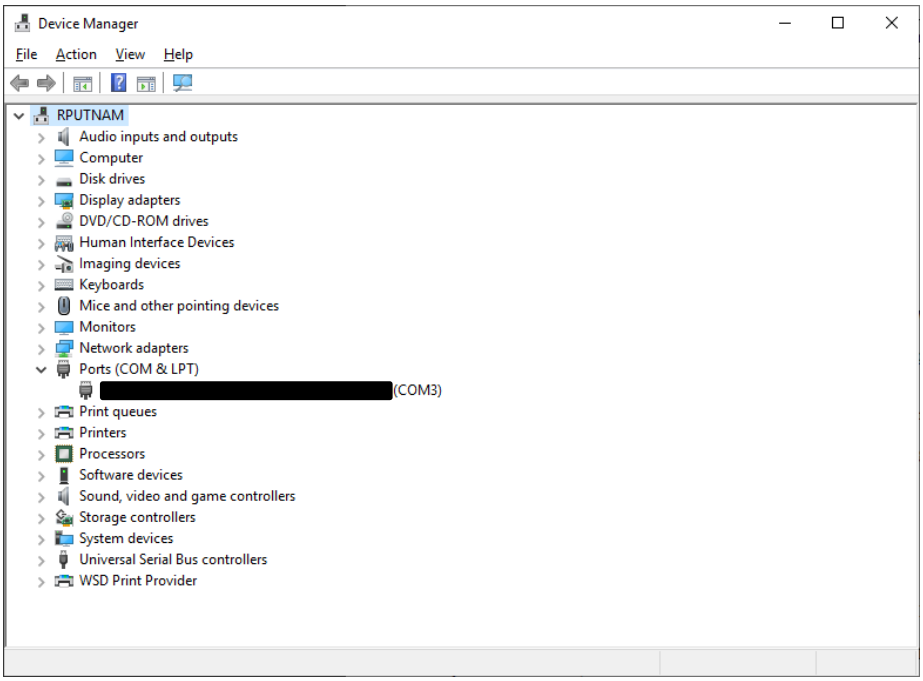


Figure 4: Windows Device Manager.

Once you have determined the correct COM port for your desired device, enter it in the correct *QE Device Manager* location and press the adjacent check mark icon .

Press the refresh icon . If the connection to the device is successful, this area should become greyed out.

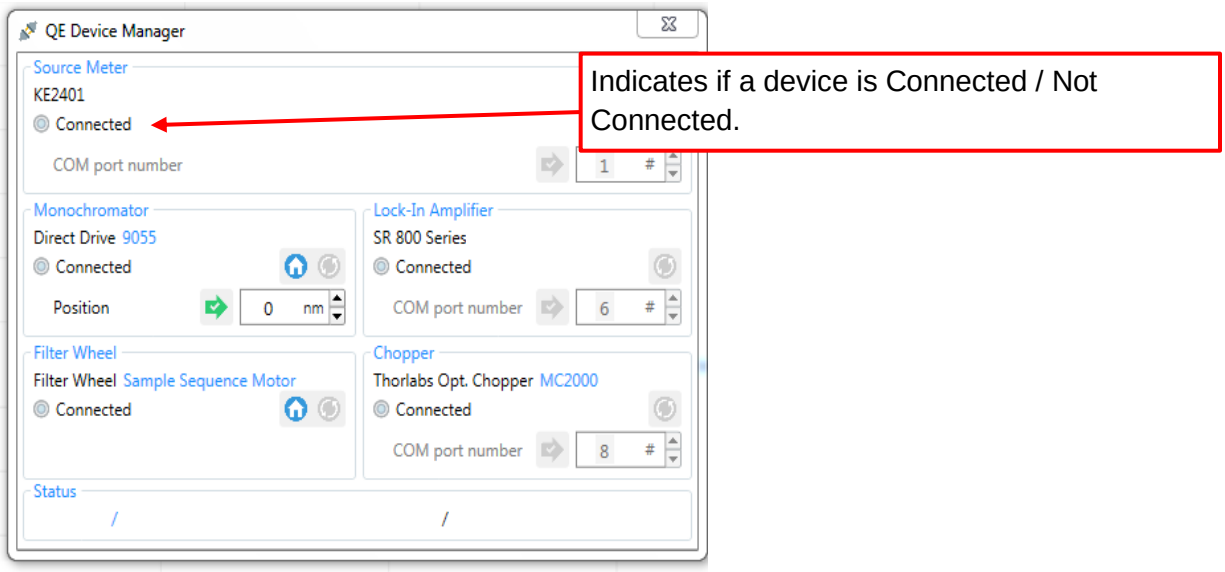


Figure 5: QE Device Manager window.

3.1.1.1 Homing Filter Wheel/ Monochromator

Click the home icon  to move the filter wheel or monochromator to the home position.

- **For the monochromator:** Once the monochromator finishes the homing routine, it moves to the zero position on the first grating of your PTS.
- **For the filter wheel:** Once the filter wheel finishes the homing routine, it moves to the valid filter for the current monochromator wavelength position. Please note that the home icon will not allow you to access any of the filter positions directly.

3.1.2 Confirm Measurement Setup Window

The “Confirm Measurement Setup” window will appear every time you run any type of scan. This window will summarize the settings for the measurement you have selected as well as any measurement instructions related to the measurement you have selected. Please read through this summary to ensure you have selected the correct settings required for your measurement and follow the provided *Measurement Instructions*.

Once you have read through the *Configuration* summary and the *Measurement Instructions*, and are satisfied with the settings entered click on the green check mark arrow.

Below are two examples of the “Confirm Measurement Setup” window for calibration and SR/QE measurements respectively.

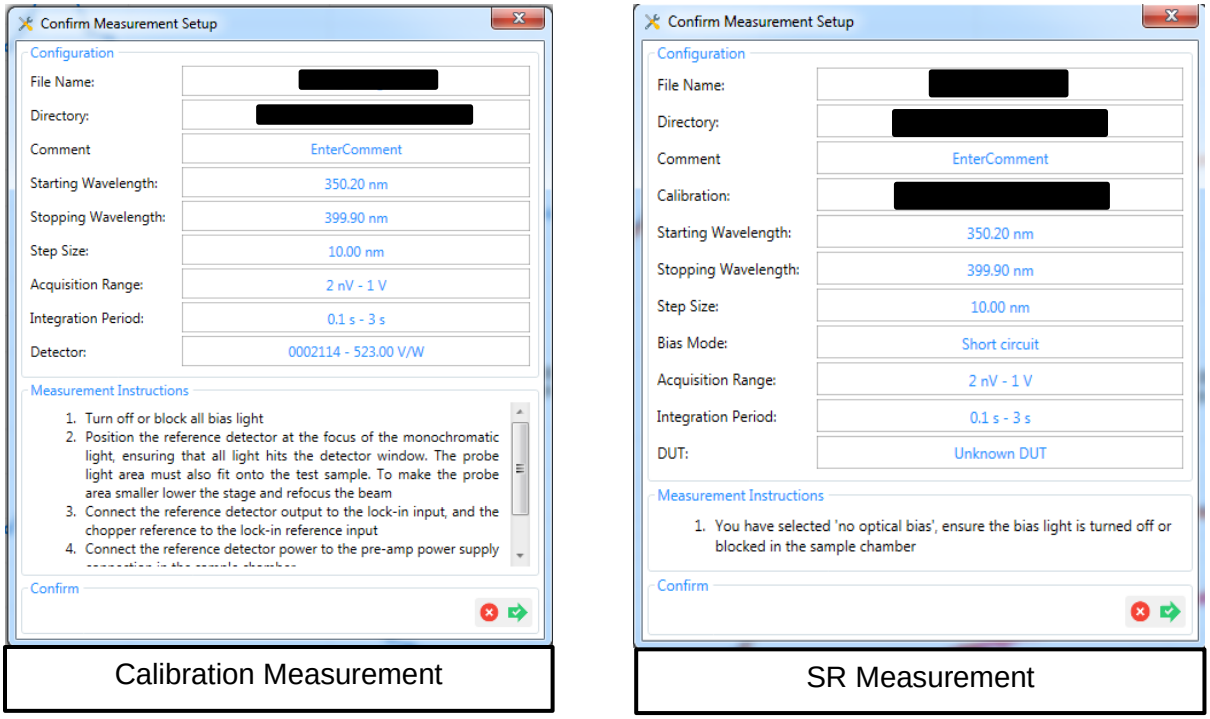


Figure 6: Confirm measurement setup window for (a) calibration measurement and (b) SR measurement.

3.2 Measurement Configuration

WARNING: If the language of your computer is set to a language that uses commas instead of periods to indicate a decimal number, the software will not work. It is recommended to set the computer language to English for SciPV to function properly.

This section will review the features of the measurement configuration section of the QE software which includes: (1) *Setup*, (2) *Acquisition*, (3) *Device Protection,* and (4) *Temperature*.

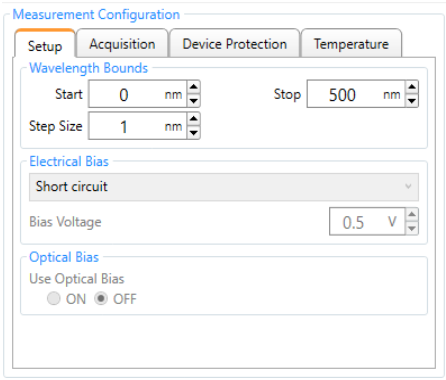


Figure 7: Measurement Configuration - Setup Tab.

3.2.1 Setup

The setup section is where the user will enter the wavelength bounds, step size, electrical and optical bias on the device under test (DUT).

Section	Parameter	Description
Wavelength Bounds	Start	Wavelength (in nm) at which the scan will begin.
	Stop	Wavelength (in nm) at which the scan will end.
	Step Size	Intervals (in nm) between each point of the scan.
Electrical Bias **(greyed out for CAL)**	*Drop-down menu*	Select short circuit, max, or user defined bias voltage value. The default setting is short circuit. See Section 3.2.1.1 for more information.
	Bias Voltage	Select bias voltage value for a user defined voltage. You must first select the user defined in the drop-down menu.
Optical Bias **(greyed out for CAL)**	Use Optical Bias	Select either yes or no depending on your current bias light configuration (using or not using bias light on the DUT). For SR scan “OFF” should be selected, while for QE measurement “ON” should be selected.

3.2.1.1 Electrical Bias

3.2.1.1.1 Short Circuit

Selecting Short Circuit will perform the measurement with zero external voltage measured by the Keithley.

3.2.1.1.2 Max

Selecting Max will perform the measurement with zero internal voltage determined by the maximum signal on the Keithley.

3.2.1.1.3 User Defined Bias

User defined bias allows the user to select a specific bias voltage for the cell during the scan.

3.2.2 Acquisition

The information entered in this section is used for setting the voltage and time constant of the lock-in amplifier as well as the frequency on the chopper.

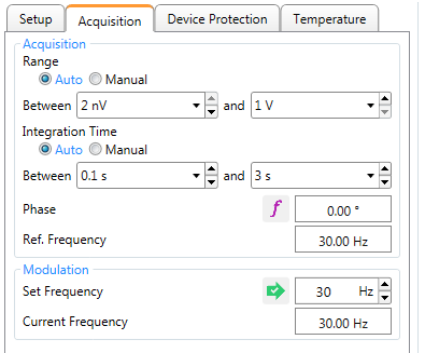


Figure 8: Measurement Configuration - Acquisition tab.

Section	Parameter	Description
Acquisition	Range	Select voltage range used by the Lock-in amplifier. *Select Auto:* Selects voltage range on Lock-in amplifier between the values selected by the user from the drop-down menu. The software will adjust the voltage range on the lock-in amplifier to the ideal range depending on the current signal level. *E.g. if voltage spikes to 50mV but voltage range "Auto" values are between 1µV and 10mV. The system will only adjust the voltage range up to 10mV and down to 1µV.* *Select Manual: Sets voltage range to the selected from drop-down menu. Will not adjust the voltage range if overload occurs on the Lock-in.* *E.g. if voltage spikes to 50mV but voltage range "Manual" value is set to 10mV. The system will not adjust the voltage range.*
	Integration Time	Select time constant on the Lock-in amplifier. See Section 3.2.2.2 for more information.
	Phase	Displays the phase offset. Click the ƒ button to do a manual auto-phase if desired.
	Ref. Frequency	Chopper frequency used as reference frequency on the lock-in amplifier.
Modulation	Set Frequency	Sets the frequency on the chopper. Select the frequency value required and then press the check mark icon to change the chopper frequency setting.
	Current Frequency	Indicates the current frequency of the chopper.

3.2.2.1 Range

It is recommended to always use the full auto range (2nV to 1V) to ensure the lock-in amplifier does not saturate and uses its full dynamic range capabilities.

3.2.2.2 Integration Time

Playing around with the upper limit of the Time Constant can help reduce scan time but can also affect the signal-to-noise ratio of the data. The upper limit required for Integration time is dependent on slit size and DUT signal level. It is also dependant on the chopper frequency. When using a chopping frequency of 30Hz, the minimum time-constant should not be set below 100 ms (3 data points per time-contact, 30Hz results in 3 oscillations per 100 ms).

3.2.3 Device Protection

This section constrains the upper limit of the voltage and current output of the source meter when running an IV sweep which may attempt to source currents and voltages that pose risk of damage to the target cell. This output limits can be used to protect your device under test.

Figure 9: Device protection - device output limits.

3.2.4 Temperature

This section only applies if you are using one of Sciencetech's TEC cell chucks. This option will not be shown in the *QE Device Manager* if you have not purchased a TEC cell chuck.

The "Set Point" section will allow you to set the temperature of the Sciencetech TEC cell chuck to a single set point temperature. After entering the *Set Point* temperature in the Set Point box, press the check mark icon to apply this setting. Make sure that the "Current Temperature" of the cell chuck has reached the "Set Point" before starting the measurement.

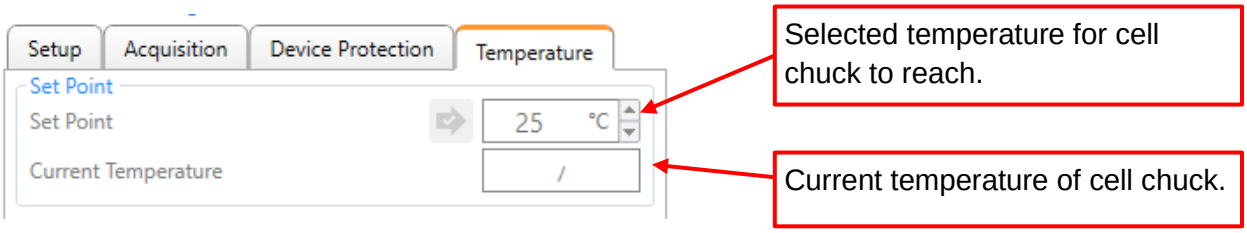


Figure 10: Measurement Configuration – Temperature tab

3.3 Calibration Detector Configuration

This section will only be visible when the CAL button on the toolbar is selected. Otherwise, it will read DUT Configuration, for details on DUT Configuration please see section 3.4.

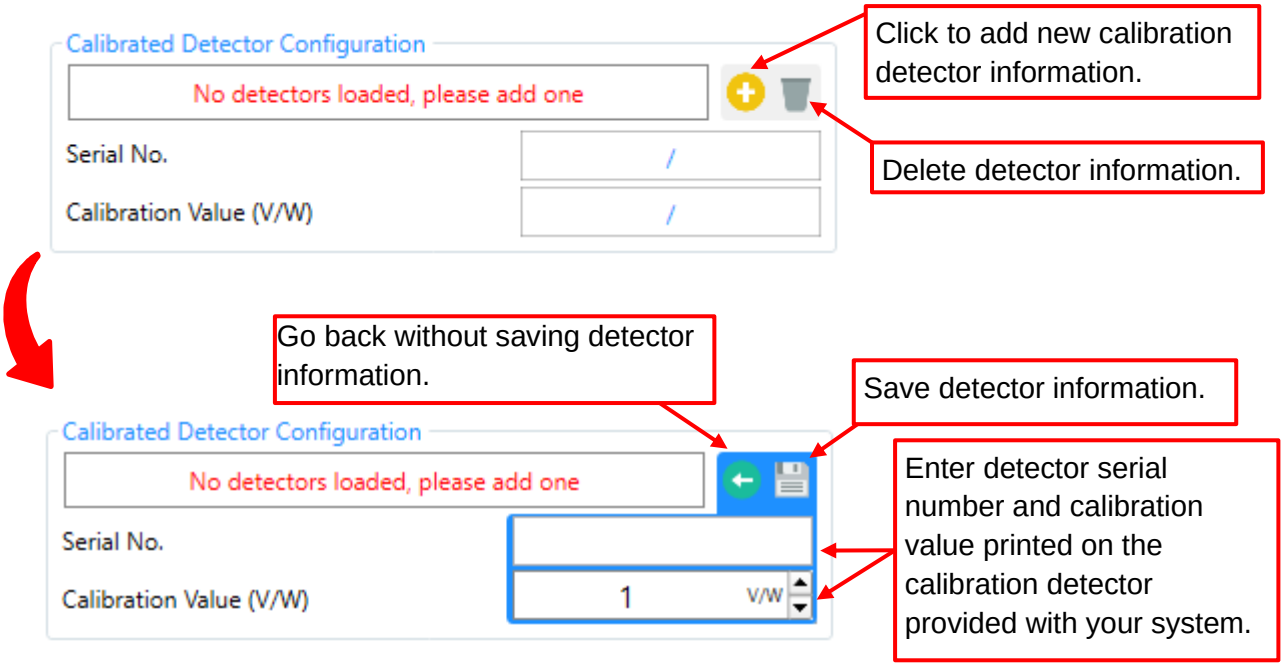


Figure 11 : Calibration Detector Configuration.

When your system is provided by Sciencetech, the detector will be loaded into software already. It is recommended that you do not delete the detector configuration that is provided. With a detector loaded into the software, a drop list will appear where any detector can be selected from a list of detectors. Be sure to verify that the printed value on the detector being used matches the value entered in the software.

If you require a new detector or new calibration, a new detector can be added if needed.

3.4 DUT (Device Under Test) Configuration

This section will not be visible when the CAL button on the toolbar is selected, instead it will read Calibration Detector Configuration, for details on Calibration Configuration please see section 3.3.

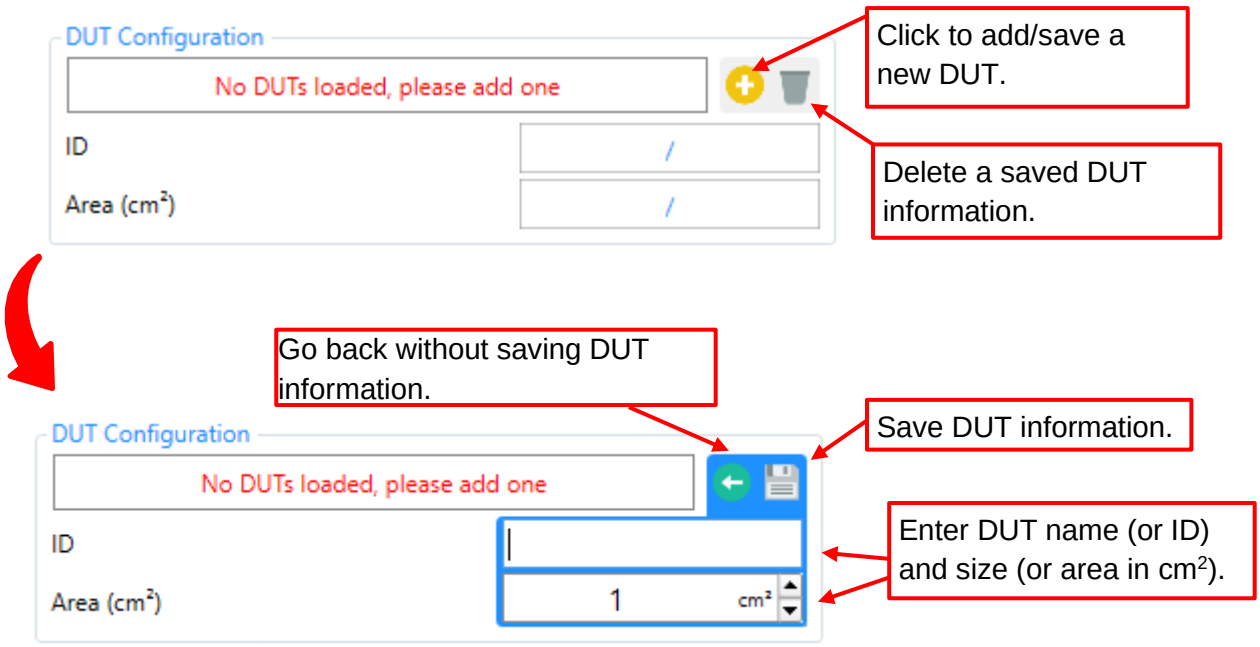


Figure 12 : DUT Configuration.

It is recommended to load all of your DUT's into the software. This information is used for calculations and is stored in the output files so that a scripting function could be used to easily sort data by pulling DUT information out of output files. As multiple DUT's are loaded, a drop-down list can be opened to select the current DUT being used. This also eliminates the need for adding a device name to the filename or comment to sort through files.

3.5 Selected Calibration

This is section allows you to select a previous calibration to be used for your measurement and will indicate which calibration file is currently selected.

When performing a QE/SR measurement, ensure that the correct calibration is selected based on your current measurement setup (typically the most recent calibration file).

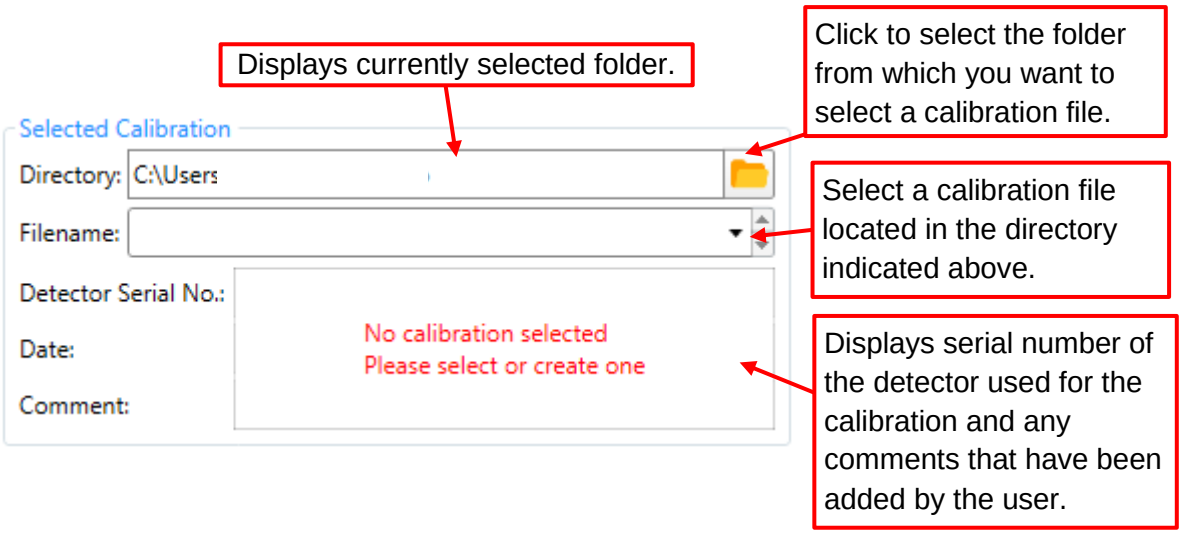


Figure 13: Selected Calibration.

3.6 Measurement Results

Depending on whether you have completed measurements for a calibration or QE/SR measurement, this section will have a slightly different appearance. For details on the *Measurement Results* for a calibration measurement see section 3.6.1: Calibration Mode while for QE/SR measurements see section 3.6.2: QE/ SR Mode.

3.6.1 Calibration Mode

When the CAL button is selected on the toolbar the “Measurement Results” window will appear as shown below.

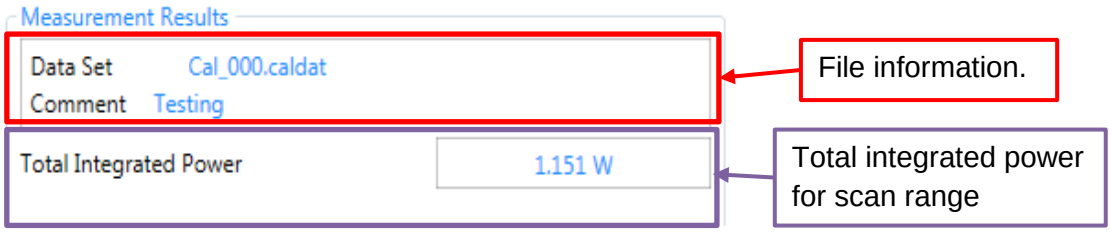


Figure 14 : Measurement Results in Calibration Mode.

3.6.2 QE/ SR Mode

When the QE/SR button is selected on the toolbar the “Measurement Results” window will appear as shown below. This section will show the SR and QE value for your sample.

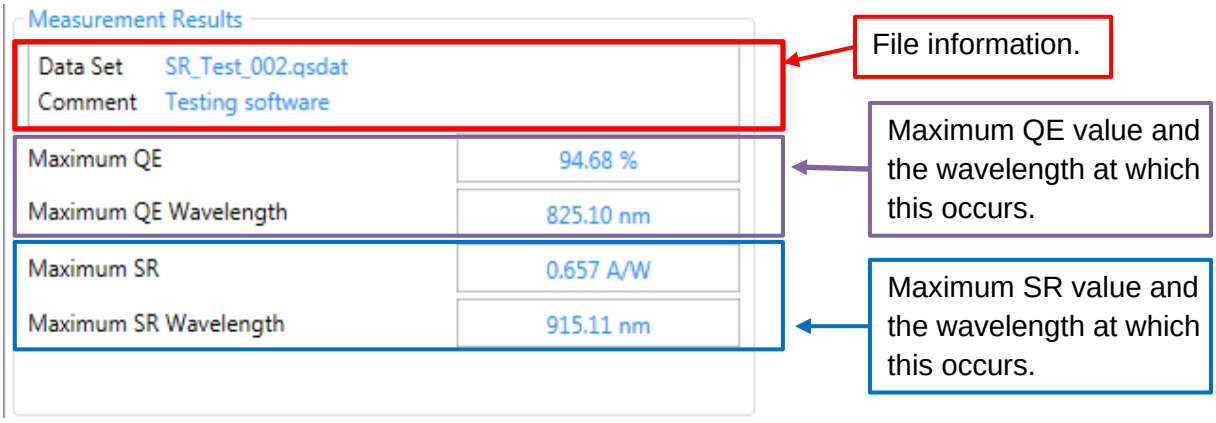


Figure 15 : Measurement Results in QE/SR Mode.

3.7 Status Bar

The status bar is the strip at the bottom of the SciPV application that provides feedback on the current status of the system and any errors that occur.

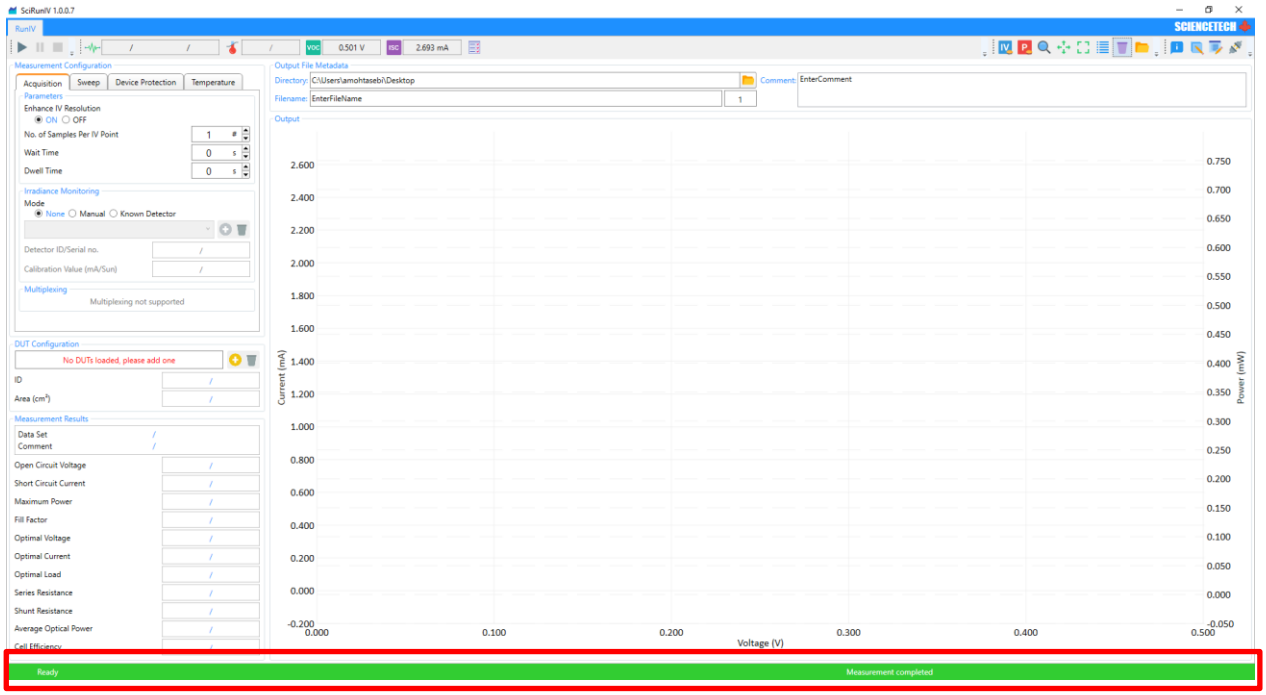


Figure 16 : Status Bar

The status bar will be one of three colours, GREEN, BLUE, or ORANGE.

3.7.1 Green Status Bar

If the status bar is green, the system is ready to be used and has completed any actions successfully. The status bar will display “Ready” on the left.

3.7.2 Blue Status Bar

If the status bar is blue, the system is currently performing an action, such as a scan. The status bar will display a string of the action that is currently being completed near the middle. The status bar will display “Working” on the left.

3.7.3 Orange Status Bar

If the status bar is orange, an error has occurred. The orange bar overrides all other colours. If the system is ready (green), or working (blue), the status bar will remain orange if an error has occurred. To view the error(s) that have occurred, click the error log button.

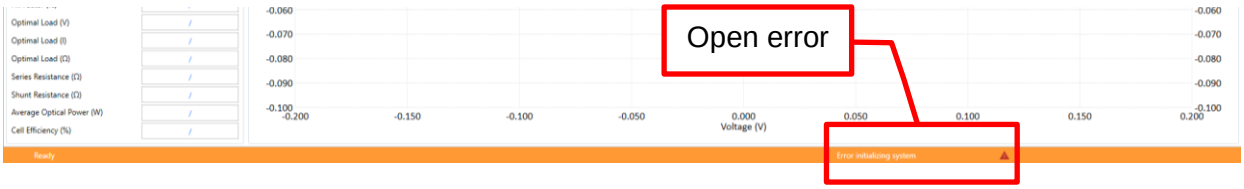


Figure 17 : Status Bar with error notification.

Once the error log is open, the errors can be viewed. Please see the troubleshooting section of this user manual for various errors explanations and solutions. To clear an error, press click the trash can. To clear all errors, click the broom. The status bar will not change from orange until all errors are cleared manually.

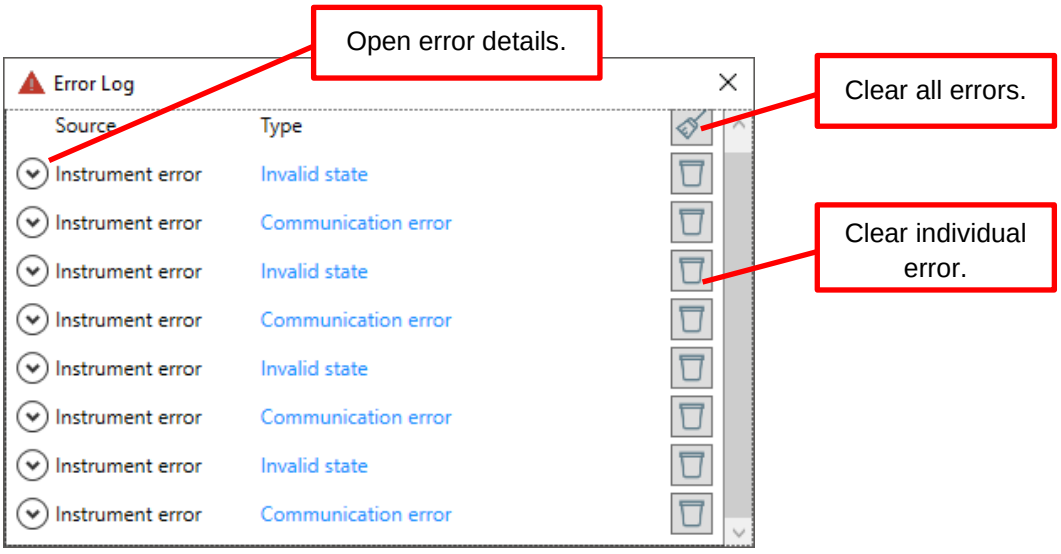


Figure 18 : Error Log window.

3.8 Output File Metadata

This section allows the user to specify the location where output data files are saved, the saved file name, and file comments (optional). Output files automatically index themselves, which means that if a target directory already contains a file with the target file name then the output will be saved with an indexed suffix which is specified by the number to the right of the file name. For example, the first file in a given directory will be saved as *file_000,* and the next will be saved with the name *file_001*. When the application detects that an invalid target file name or directory has been specified the field will become colored red.

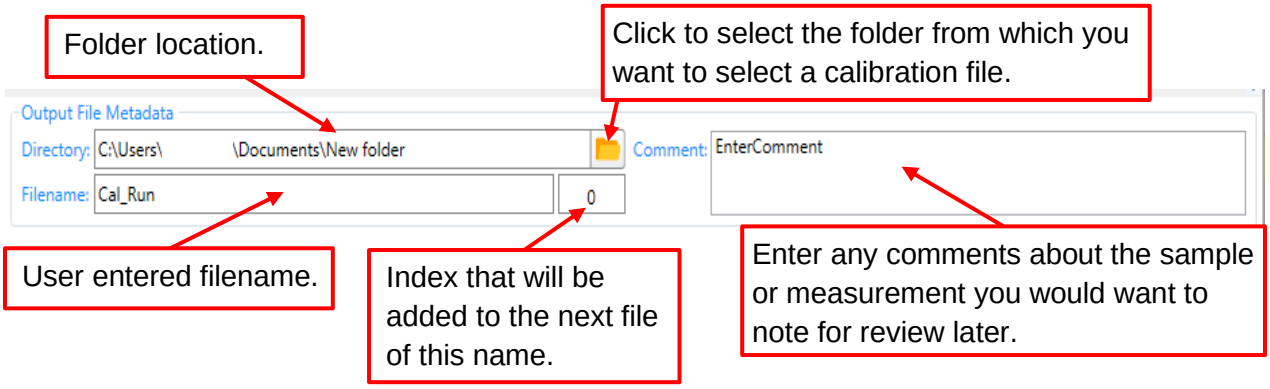


Figure 19 : Output File Metadata.

3.8.1 Output File Format

All output files are formatted for easy import into various analysis tools such as excel and MATLAB. The output files are TSV delimited and support drag-and-drop directly into both MATLAB, Excel, and other analysis tools.

3.8.1.1 Calibration Files

For calibration measurements, the output data file(s) will be generated with the extension "**caldat"*. The file headers in the calibration file will be as shown below.

```
START HEADER:    CALHeader
FileName:        "CalRun_000.caldat"
Date:            [redacted]
Comment:         "EnterComment"
DetectorID:      [redacted]
DetectorHash:    [redacted]
CalibrationValue:[redacted]
SoftwareVersion:         "1.0.0.7"
StartWavelength:         "300"
StopWavelength: "1100"
StepSize:        "10"
END HEADER

START DATA:      [d6p-1] [d6p0] [d6p0]
Wavelength(λ)    Voltage(V)      Power(W)
```

Figure 20 : Calibration output file headers format.

3.8.1.1 QE/SR Files

For QE/SR measurements, the output data file(s) will be generated with the extension "**.qsdat"*. The file headers in the QE/SR file will be as shown below.

```
START HEADER:   QESRHeader
FileName:       "SR_000.qsdat"
Date:           [redacted]
Comment:        "EnterComment"
DUTID:  "Unknown DUT"
DUTHash:        "-1"
BiasCondition:  "SHORT_CIRCUIT"
CalibrationFile:        "CalRun_000.caldat"
SoftwareVersion:        "1.0.0.7"
StartWavelength:        "301"
StopWavelength: "1100"
StepSize:       "10"
END HEADER

START DATA:     [d6p-1] [d6p0] [d2p0] [d6p0]
Wavelength(λ)   Voltage(V)      QE(%)   SR(A/W)
```

Figure 21 : QE/SR output file headers format.

3.9 User-Interface Note

If a parameter is invalid, a file is not selected, or there is an error on a file name the area of issue will have a red-border indicating the field with an issue. Red text is displayed in red border location indicating the issue with invalid parameters, name, file, or etc. This feature is useful to quickly identifying any issues with a given measurement setup. Shown below is an example where a calibration file was not selected before a QE or SR measurement was attempted. This resulted in the Selected Calibration box turning red.

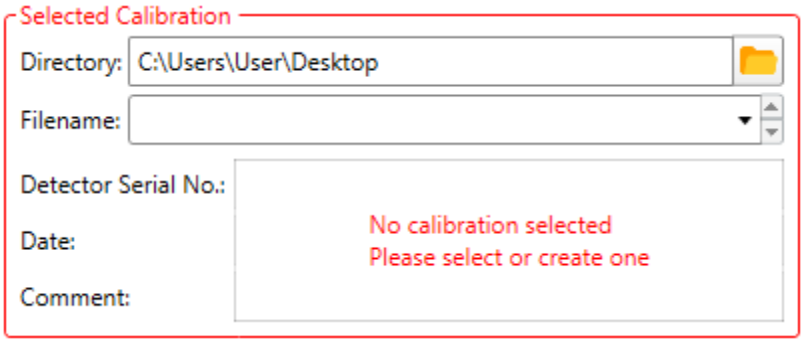


Figure 22 : Example of an invalid parameter message.

4. Configuration Files

The configuration files installed with your system are all needed for the SciPV software to function properly. A back-up of these files can be found on the USB supplied with your system. These configuration files should not be adjusted by the user and may be requested by Sciencetech engineers for troubleshooting purposes. If your system is upgraded after purchase then new configuration files may need to be installed for the upgrade to function properly. These files include:

- Device Configuration Files
- Module Configuration Files
- Application Configuration Files
- System Settings Configuration File

To locate the configuration files for your system, you can use the configuration file button located on the toolbar. All settings that may require adjustment can be adjusted through the SciPV graphical user interface.

5. Setting Monochromator Wavelength

The instructions in this section are to be used for setting the wavelength of the monochromatic light of the PTS. Please ensure you have read through the hardware and software manual for the PTS before attempting this. For instructions on performing measurements please see section: *Performing Measurements*.

Before opening the software, you should follow the start-up protocol for the PTS outlined in the user manual. If SciPV is opened before following start-up protocol this will cause many errors as the program will be unable to find the various devices it needs to communicate with.

1. Follow the start-up protocol found in the Hardware User Manual. If you have a custom system you should also review the custom manual for your system before proceeding.
2. Now that your system is properly started, double click on the SciPV icon on the desktop then select the QE tab.
3. Select the device manager icon. In the device manager popup window in the monochromator section press the home monochromator button. Once the homing process has completed, enter the value of the wavelength you would like the monochromator to move to.

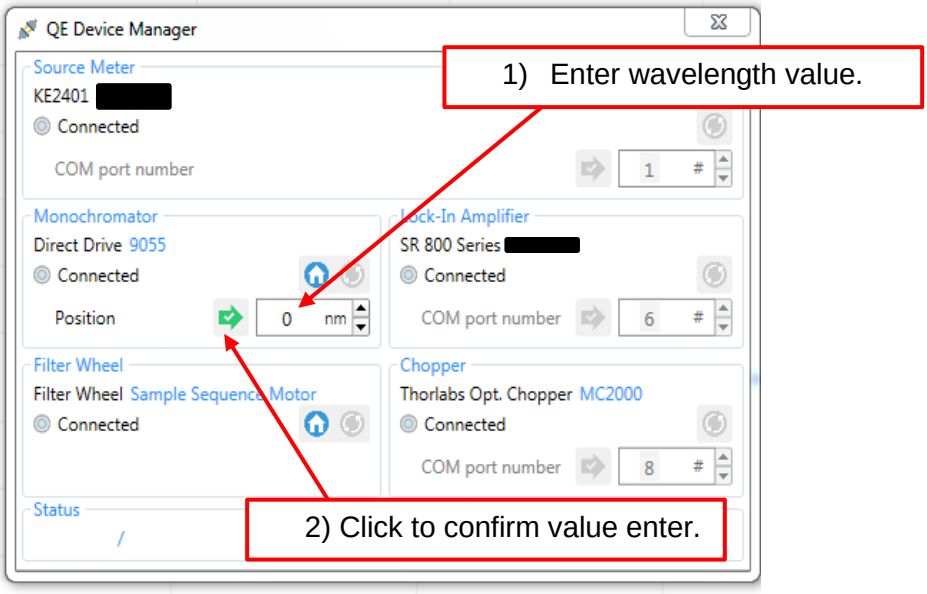


Figure 23 : QE Device Manager - entering wavelength value.

4. Click the submit icon in order to have the monochromator move to the desired wavelength.

6. Performing Measurements

6.1 Performing CAL (Calibration) Measurements

1. First, follow the start-up protocol (see PTS Setup User Manual or Custom User Manual where applicable).
2. Then select the SciPV icon on the computer's desktop. This software comes pre-installed on the computer that is provided with the PTS. If this is the first time you are using your PTS, home the monochromator.
3. If you have a customized PTS you should first review the *CAL Measurement Protocol* section in your custom user manual before proceeding with any CAL measurement. If you have already reviewed the instructions in your custom manual or have a standard PTS then you can proceed to the next steps.
4. Connect the reference detector to the BNC and DB9 connections in the sample chamber.
5. Set the monochromatic light to 0 nm. This will make easier for you to focus the light on to the detector. For details on changing the monochromatic light wavelength value please refer to section 3.9: Setting Monochromator Wavelength.
6. Place your reference detector under the monochromatic light and focus the light on to the detector such that the light underfills the detector. You may need to raise or lower the sample stage in order to focus the light on to the detector. If your system is customized, please refer to your custom manual under the CAL Measurement Protocol (Hardware Section).

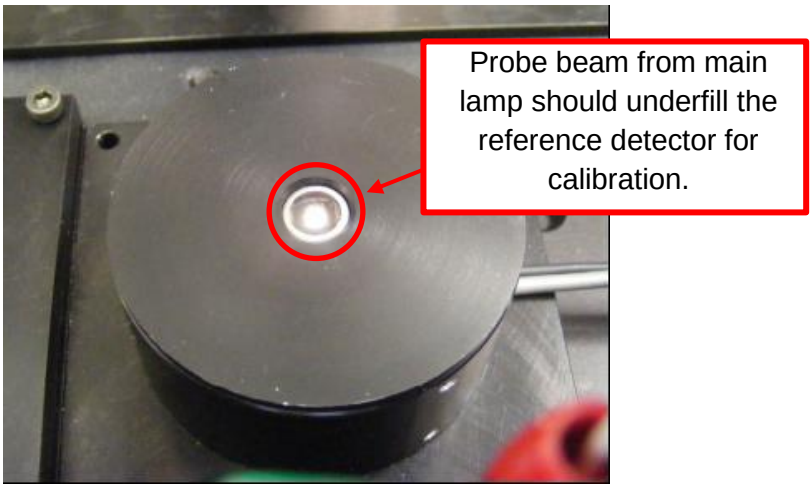


Figure 24 : Probe beam focused on reference detector.

7. Once you have determined the focusing height (the height at which the monochromatic light is properly focused on to the detector) you should do one of the following to prevent overloading the lock-in amplifier:
    a. Move the detector to the left or the right where the light is focused on to the detector window. You can then put the reference detector back in place when you are ready to take a measurement.

b. Cover the detector to prevent overloading. You can remove the cover once you are ready to take a measurement.
c. Change the monochromatic wavelength to 100 nm or any wavelength were the light output is low. If you select this option then you will not need to conduct any further action when you have to start your measurement.

8. Enter the “Start and “Stop” wavelengths and “Step Size” you would like to use. Remember that this wavelength range should be equal to or larger than the range you will use for subsequent scans. **It is very important that your calibration settings are the same as those for your later scans. This includes monochromator output slit width and lamp power settings.**
9. Next go to the *Acquisition* tab in the *Measurements Configuration* section and select the *Range* and *Integration Time*. You can either select *Auto* or *Manual* depending on your needs.
    a. For samples with low signal, you should use a higher maximum integration time while for samples with a stronger signal you can use a shorter maximum integration time.
10. Next you will need to enter the *Serial No.* and *Calibration Value* [this information is printed on the side of the detector] in the *Calibrated Detector Configuration* of the reference detector if the detector is not already loaded into the software. Ensure the detector being used is the selected detector.
11. Next select where you would like the file to be saved by going to the *Output File Metadata* section and click on the folder icon to select the folder location.
12. In the popup window titled *Browse For Folder,* select the folder where you would like to save your measurement files and click OK. This folder location should now be in the *Directory* of the *Output File Metadata.*
13. After you have completed entering measurement settings and file information, press the start button on the toolbar.
14. If you have moved or covered the reference detector to prevent the monochromatic light from overloading the lock-in amplifier, you should now put it back in place or uncover the reference detector. If you have changed the wavelength from 0 nm to prevent overloading the lock-in amplifier then no action is required at this step.
15. The *Confirm Measurement Setup* Window will then popup. After reading through the information in this window and you are satisfied with the information entered for your measurement, press the check mark icon.
16. The status bar will change to blue indicating that the measurement has begun.
17. When the measurement is complete the status bar will turn green.

6.1.1 CAL Measurement Sequence

The measurement sequence for a CAL measurement will be as follows:

1. The software will first do a rapid scan to determine the maximum signal expected during the measurement, and then do an auto-phase at this wavelength.
2. Then at each point in the scan, as specified by the wavelength range and step size values entered, the program will perform the following steps:
    a. If Auto Range and/or Auto Integration are selected then the software will select a value for the voltage range and/or integration time that satisfies a preprogrammed threshold and is within the minimum and maximum values selected in the *Acquisition* tab.
    b. The software will measure the voltage and calculate the power at this wavelength point.
    c. The wavelength, voltage and power values will be stored in the CAL output file.

6.1.2 Completed CAL Measurement

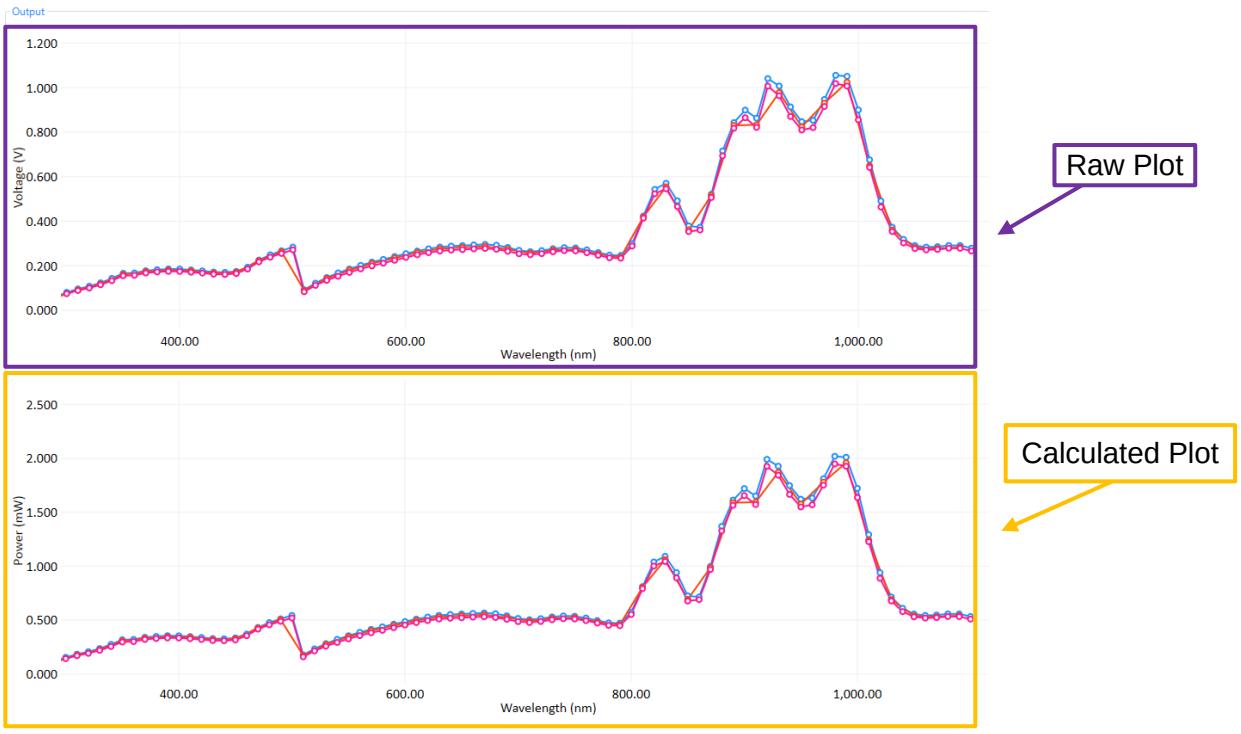


Figure 25 : Completed CAL measurement.

6.2 Performing QE/SR Measurements

1. To perform a SR or QE scan, you must either perform a calibration scan or select one. [Please remember that SR/QE scans should be taken under the same conditions as your calibration and the wavelength range should be within that used for the calibration scan. A new calibration should be taken every time the system is turned on].
2. If you have a customized PTS you should first review the *SR and QE Measurement Protocol* sections in your custom user manual before proceeding with any SR or QE measurement. If you have already reviewed the instructions in your custom manual or have a standard PTS then you can proceed to the next steps.
3. Connect your sample to the banana connections in the sample chamber. If you are using a Sciencetech cell chuck please refer to the cell chuck user manual for connecting to your sample.
    a. If your PTS is customized please refer to the custom manual provided with your system, in addition to any cell chuck manual provided.
4. Set the monochromatic light to 0 nm. This will make it easier for you to focus the light onto your sample. For details on changing the monochromatic light wavelength value please refer to *Setting Monochromator Wavelength.*
5. Then in the *QE* section of the SciPV software press the *QE/SR* button.
6. Then enter the “Start” and “Stop” wavelengths and “Step Size” you would like to use. Remember that this wavelength range should be equal to or less than the range of the calibration measurement being used. It is very important that your QE/SR settings are the same as those for your calibration scans. This includes monochromator output slit width and lamp power settings.
7. Then enter the *Electrical Bias* and *Optical Bias* of your sample.
    a. **For SR measurements**: the bias light should be blocked using the shutter/turn off and the *Optical Bias* set to OFF.
    b. **For QE measurements:** the bias light should be on the sample and the *Optical Bias* set to ON.

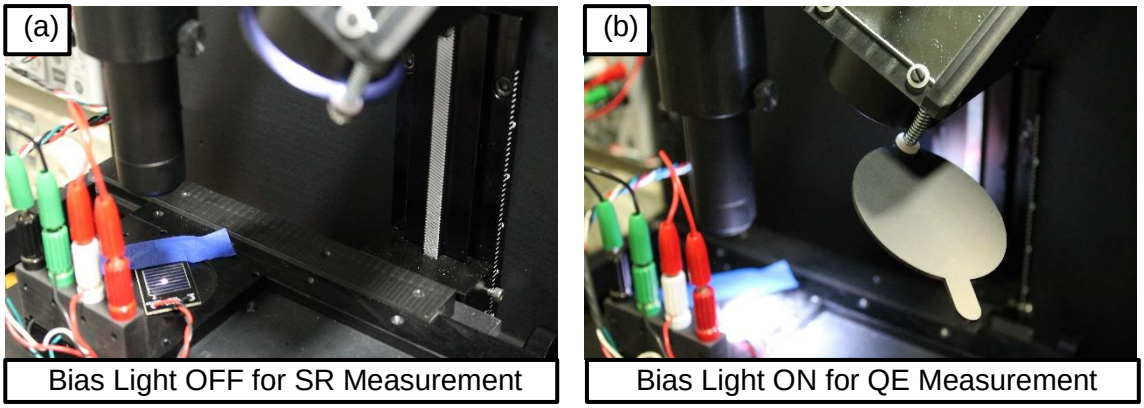


Figure 26: (a) Bias light ON for SR and (b) bias light OFF for QE.

8. Next go to the *Acquisition* tab in the *Measurements Configuration* section and select the Range and Integration Time needed for your measurements. It is recommended

to always use the full auto Range (2nV to 1V) to ensure the lock-in amplifier does not saturate and uses its full dynamic range capabilities. The upper limit required for integration time is dependent on slit size and DUT signal level. It is also dependant on the chopper frequency. When using a chopping frequency of 30Hz, the minimum time-constant should not be set below 100 ms.

9. Then you can enter DUT Configuration information. If you do not enter anything in this section then the software will just have this as “Unknown” in the output file generated.
10. Then select the calibration file in the *Selected Calibration* section for the current system configuration.
11. Next select where you would like the file to be saved by going to the *Output File Metadata* section and click on the folder icon to select the folder location.
12. In the popup window “*Browse For Folder”,* select the folder where you would like to save your measurement files and click OK. This file location should now be in the *Directory* of the *Output File Metadata.*
13. After you have completed entering the measurement settings and file information, press the start button on the toolbar.
14. The Confirm Measurement Setup Window will then popup. After reading through the information in this window and satisfied with information entered for your measurement press the check mark icon.
15. The status bar will change to blue indicating that the measurements has begun.
16. When the measurement is complete the status bar will turn green. The software will display the results in the *Measurement Results* and the plot window for the *Calculated Plot* will is display both the SR and QE plots.

6.2.1 QE/SR Measurement Sequence

The measurement sequence for a QE measurement will be as follows:

1. The software will either auto-phase at 0 nm or if there is saturation on the lock-in at 0 nm or it will do a rapid scan to determine the maximum wavelength and auto-phase at this value.
2. Then at each point in the scan, as specified by the wavelength range and step size values entered, the program will perform the following steps:
    a. If Auto Range and/or Auto Integration are selected then the software will select a value for the voltage range and/or integration time that satisfies a preprogrammed threshold and is with in the minimum and maximum values selected in the *Acquisition* tab.
    b. Then the software will measure the current and calculate QE and SR at this wavelength point.
    c. Then the wavelength value, voltage, QE and SR values will be stored in the CAL output file.

6.2.2 Completed QE/SR Measurement

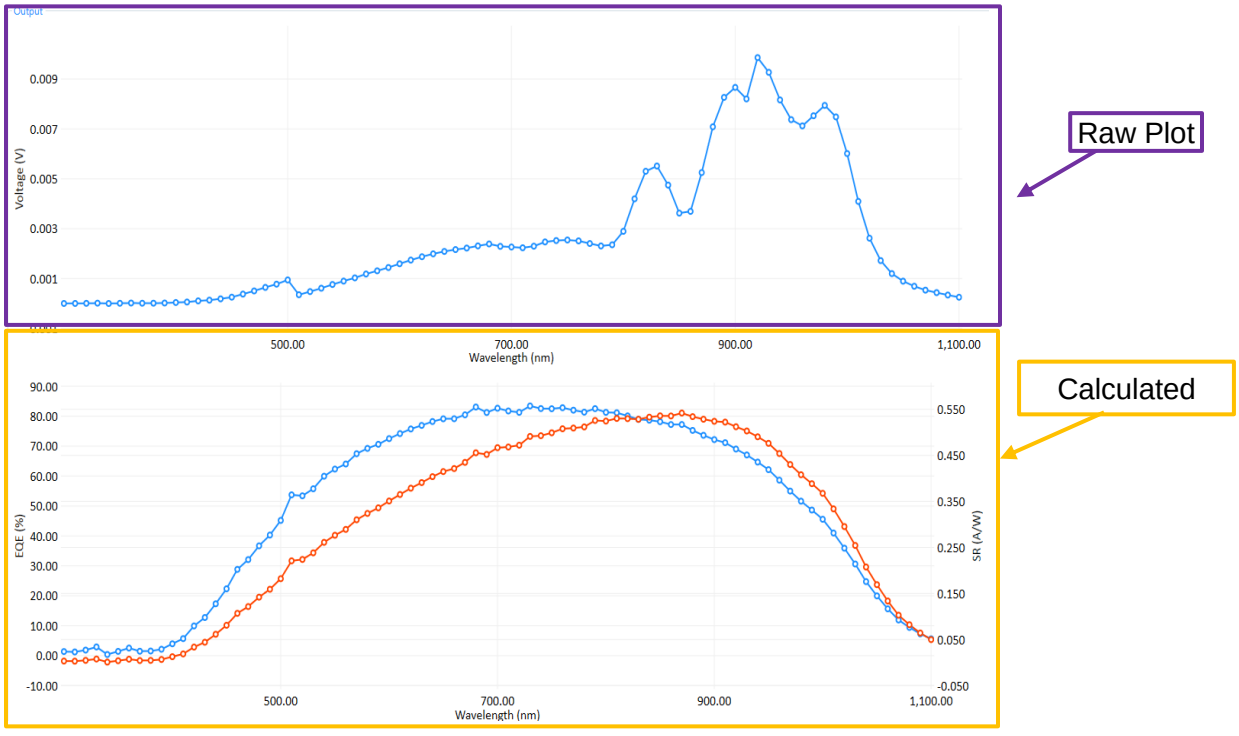


Figure 27 : Completed QE/SR measurement.

6.3 Performing IV Measurements

Before attempting to conduct an IV measurement you should read the SciPV: IV Software User Manual and the PTS Setup User Manual. If you have a custom PTS you should also read through the custom manual for your system before attempting a measurement.

For IV measurements you can either use the bias lamp output in the vertical orientation with the sample at the working distance specified in your system's QC report or you can use it on an angle at the focal point of the monochromatic light. If you have a custom PTS then please refer to the IV Measurements Protocol outlined in your custom manual.

1. If you have a customized PTS you should first review the *IV Measurement Protocol* sections in your custom user manual before proceeding with IV measurement. If you have already reviewed the instructions in your custom manual or have a standard PTS then you can proceed to the next steps.
2. To access the IV section of the SciPV software you will need to click on the IV tab. Please note that the device manager will only show the devices related to taking an IV measurement, for instance you will not have access to change the monochromatic light source wavelength if you are in the IV tab.
    a. If you need to change, for example, the monochromatic wavelength you will need to click back on the QE tab, then select the device manager icon and change the wavelength value on the monochromator. For help with setting monochromatic light source wavelength please review the section: *Setting Monochromatic Wavelength.*
3. For using the bias light vertically skip to the next step. If using the bias light on an angle, see Figure 26: (a) Bias light ON for SR and (b) bias light OFF for QE:
    a. Set the monochromatic light to 0 nm. This will make easier for you to focus the light on to the detector. For details on changing the monochromatic light wavelength value please refer to *Setting Monochromator Wavelength.*
    b. Then position your sample such that it is centered around the monochromatic light beam spot.
    c. Then rotate the bias lamp so that it is centered on the sample.
4. If using the bias light vertically:
    a. Position the bias lamp beam turner to point straight down.
    b. Then position your sample such that it is at the center of bias light.
    c. Then adjust the height of your sample until it as the specified working distance for your system.
5. Connect your sample to the banana connections in the sample chamber. If you are using a Sciencetech cell chuck please refer to the cell chuck user manual for connecting to your sample.
    a. If your PTS is customized please refer to the custom manual provided with your system.
6. For IV measurements, the monochromatic light should illuminate the sample. You can either turn off the monochromatic light if it will not be used again, or if you do need to use the monochromatic light after your IV measurement you can set the

monochromator wavelength to 100nm. For help with setting monochromatic light source wavelength please review the section: *Setting Monochromatic Wavelength*.

The following steps are a brief explanation for how to setup and start the IV measurement in software. It is recommended to use the SciPV: IV user manual for more in-depth information.

7. Select Irradiance monitoring type, None, Manual, or Known Detector (Acquisition Tab).
   a. If Manual, enter the manually measured irradiance value at the target plane
   b. If Known Detector, ensure the correct detector is loaded with correct calibration value.
8. Select DUT configuration.
   a. If your DUT does not exist, create the new DUT.
9. Select No. of Sample Per IV Point (Acquisition Tab).
10. Enable User Reference Cell, Enhance IV Resolution, and Multiplexing as desired (if applicable – Acquisition Tab).
11. Set Cell Area (if applicable – Main Window).
12. Set Sweep Mode and configure User Defined sweep if selected (Sweep Configuration Tab).
13. Set No. of IV Points (Sweep Configuration Tab).
14. Set Sweep Direction (Sweep Configuration Tab).
15. Select output folder, enter Filename, and Comment.

6.3.1 Completed IV Measurement

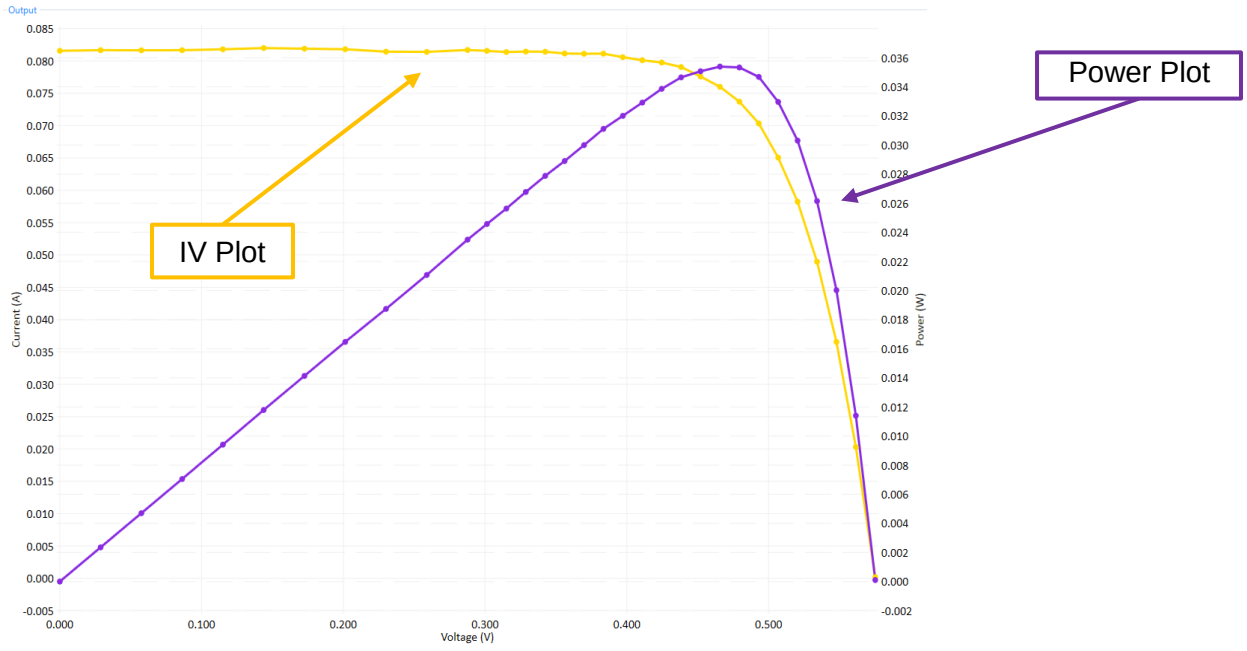


Figure 28 Completed IV measurement.

6.4 Performing IQE Measurements

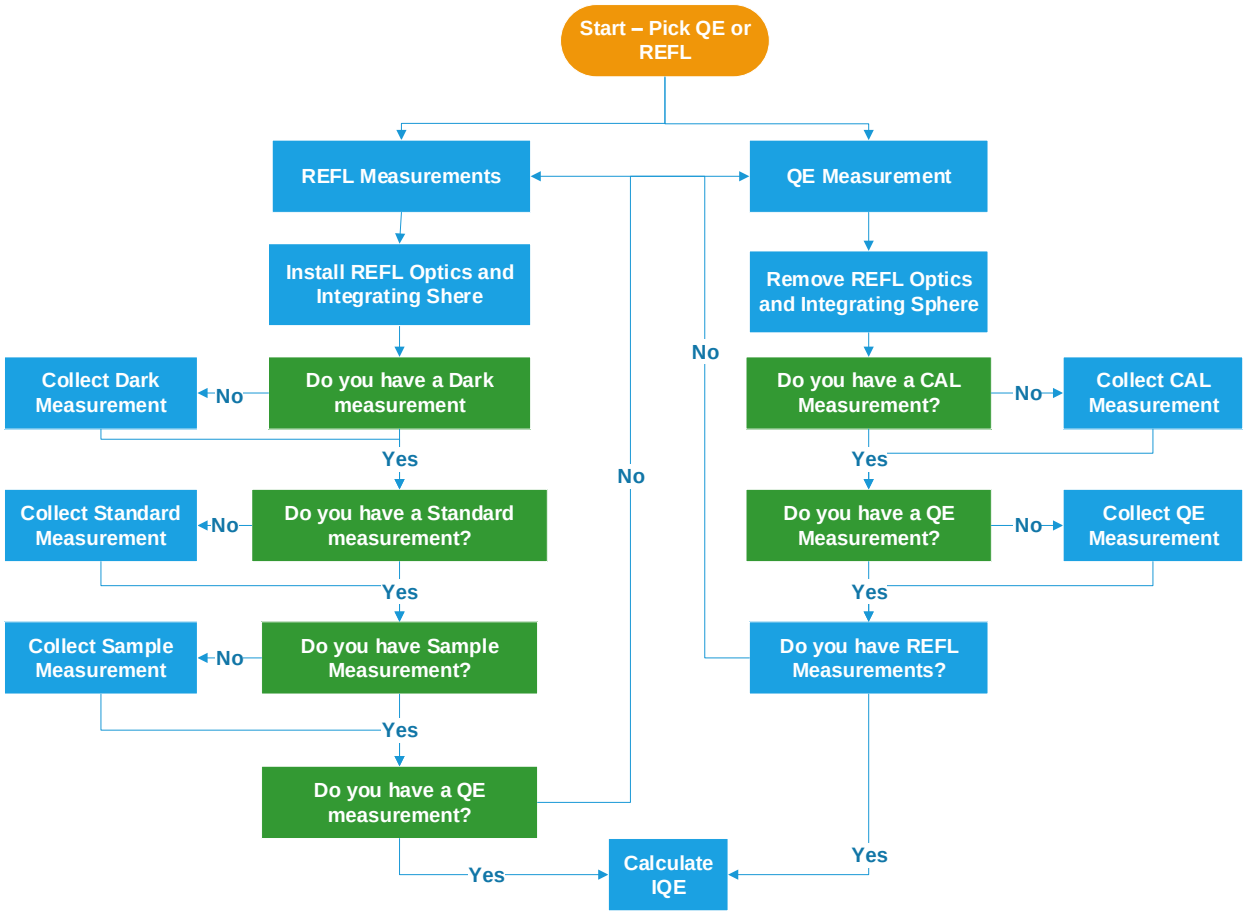
IQE measurements require the IQE add-on to Sciencetech's PTS. If you have not purchased this add-on and would like to perform IQE measurements please contact Sciencetech.

In order to calculate the internal quantum efficiency of a sample using Sciencetech's reflectance method (IQE-IS-R), multiple measurements are required. To obtain an IQE measurement you will need to conduct a reflectance measurement which includes a dark measurement, reflectance standard measurement, reflectance sample measurement in addition to external quantum efficiency (sometimes labelled as QE) measurement. All these measurements are required in order to calculate the IQE of a sample.

It is suggested that a dark measurement be completed before other reflectance measurements and that all scan parameters are the same for all measurements (reflectance, dark, and EQE), i.e. start, stop, and step wavelength.

All measurements MUST be completed with the exact same scan parameters, monochromatic light power supply setting, and slit width.

6.4.1 IQE Measurement Flowchart



6.4.2 IQE Measurement Set Up

If you have a customized PTS you should first review the *IQE Measurement Set Up Protocol* sections in your custom user manual then proceeding with IQE related measurements. Only if your custom manual indicates that you should follow the instructions in this section (section 6.4.2) should you follow the instructions listed in this section.

Only after following the instructions in your custom manual or the instructions listed in this section should you proceed to the IQE related measurements.

1. To perform a dark measurement, the standard PTS setup needs to be removed from the PTS measurement table, and the reflectance setup installed. Simply slide the standard sample tray out, and the reflectance tray in.

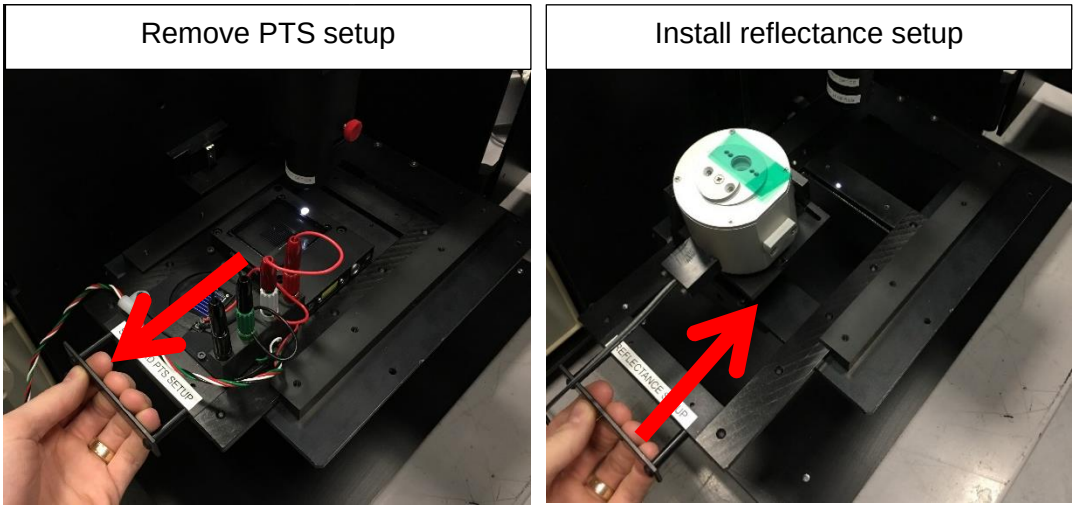


Figure 29: Remove standard PTS tray and install reflectance tray.

2. Attach the IQE optic to the standard PTS output optics on the monochromatic light output by threading onto the standard optics.

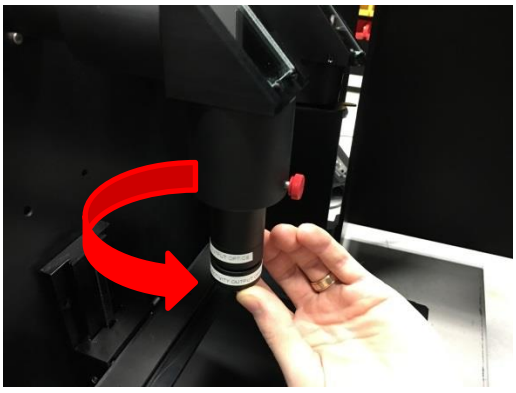


Figure 30: Attach reflectance optics.

3. With the reflectance setup installed, the integrating sphere will now need to be aligned to the monochromatic light output. Carefully remove the *Alignment Port* plug and roughly align the integrating sphere opening above the monochromatic light output. Ensure there is no sample in place and only the black integrating sphere sample tray is attached to the integrating sphere. Look through the opening of the open alignment port and center the monochromatic light on the sample port. **Take extra caution to ensure there is no sample in place, looking through this port with a sample in place could cause eye damage.**

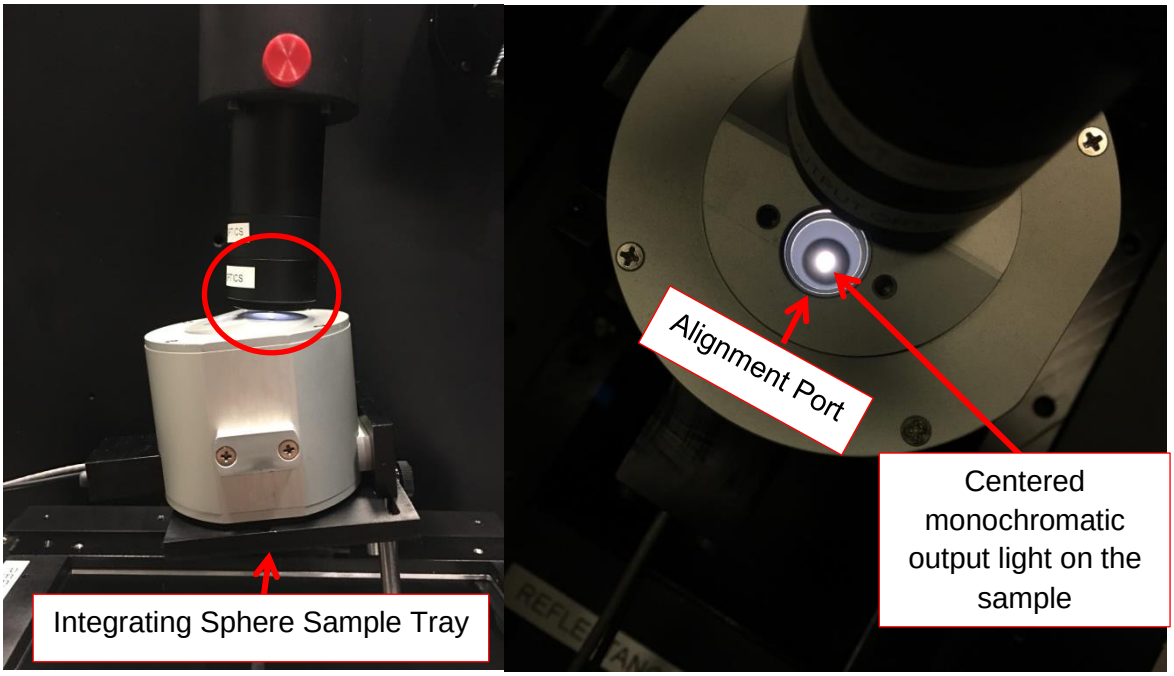


Figure 31: Align integrating sphere.

4. Once the monochromatic light is centered on the sample port, make sure that the beam spot is properly centered. The reflection of the monochromatic light off the mirror should be close to centered on the alignment port. If not, the tilt of the monochromatic light output with respect to the integrating sphere must be adjusted.

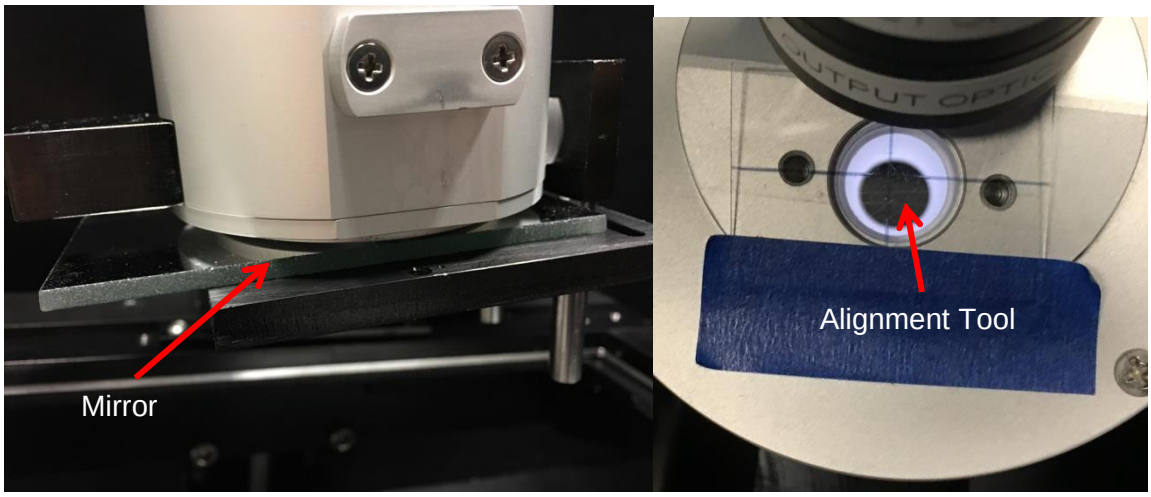


Figure 32: Align monochromatic output light.

5. The alignment of the integrating sphere will be setup at Sciencetech, and only adjustment of the monochromatic output tube will be required. Loosen the red thumbscrew on the top of the monochromatic light output and make small rotational adjustments to best center the monochromatic light reflection on the alignment tool.

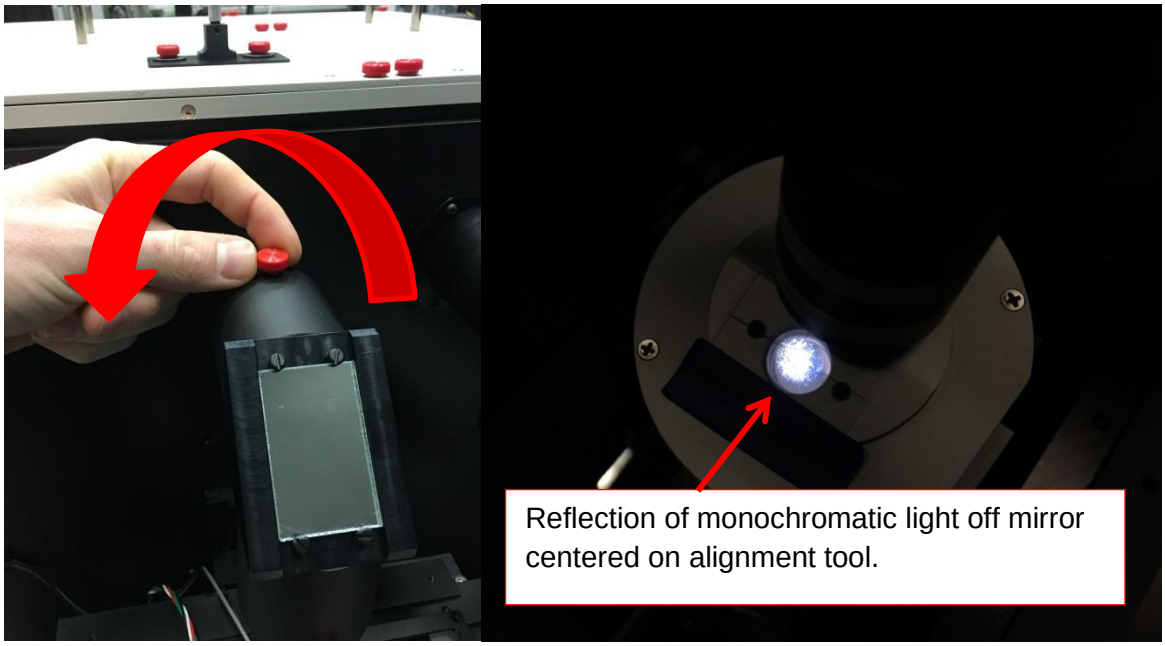


Figure 33: Align monochromatic output light 2.

6. Once complete, re-tighten the red thumbscrew and replace the alignment port plug (replacing the alignment port plug may require moving the entire PTS stage lower to insert the port plug. Simply raise the stage back up again once the port plug is in place.

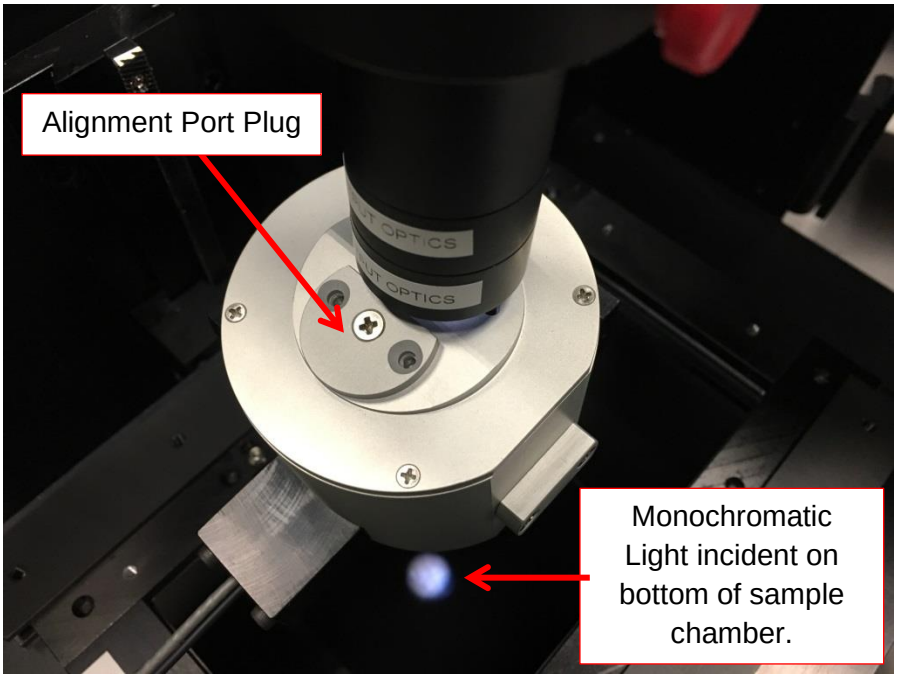


Figure 34: Add port plug and remove sample tray for dark measurement.

7. The integrating sphere is now setup and aligned. To perform a dark measurement, remove the integrating sphere sample tray completely and allow the monochromatic light to hit the bottom of the PTS sample chamber (see previous picture). Ensure there are no foreign objects that the monochromatic light is incident upon that may cause reflections.
8. Then install and secure the IQE integration sphere attachment. Connect the power connections for the integrating sphere detector to the pre-amp and the BNC signal connections on the back wall of the sample chamber.

6.4.3 REFL Dark Measurement

A dark measurement is performed with the light source ON but with no sample or sample tray in place, see Figure 34. This measurement is used to account for the background signal level that is measured by the detector inside the integrating sphere that is NOT reflected by the sample. The dark measurement is the signal level measured with zero reflectance (no sample).

A dark measurement is required to calculate the reflectance. Without a proper dark measurement, the background signal level will not be properly accounted for and will attribute to offsets in the total reflectance measured.

1. First follow the instructions in section 6.4.2: IQE Measurement Set Up.
2. Now that the integrating sphere is now setup and aligned. To perform a dark measurement, remove the integrating sphere sample tray completely and allow the monochromatic light to hit the bottom of the PTS sample chamber (see Figure 34). Ensure there are no foreign objects that the monochromatic light is incident upon that may cause reflections.
3. Then on the SciPV software click QE tab. Then click the REFL button.
4. Next select the desired wavelength and step size for your measurement.
5. In the “Measurement Type” session select *Dark* from the drop-down menu.

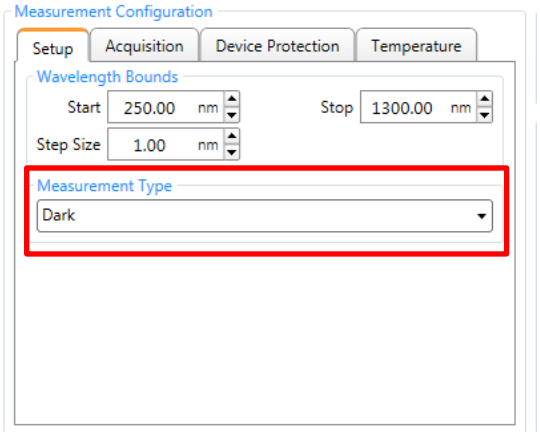


Figure 35: Selecting measurement type for REFL tab in SciPV:QE.

6. In the *“Output File Metadata”* session enter the desired folder location and file name along with any comments you wish to add to the output file.
7. Then go to the *“Acquisition”* tab in the *“Measurement Configuration”* session and select the range and integration time you would like to use for the measurement.
8. Then close the sample chamber doors and press the start button. This will cause the *“Confirm Measurement setup”* window to pop up. Review the measurement parameters and click the check mark icon if the parameters are as you require.
9. After clicking the check mark icon, the measurement will begin. When completed the status bar will read *“Measurement Complete”*.

6.4.4 REFL Standard Measurement

1. If you have just completed a dark measurement, the integrating sphere should be already setup and the only setup that is required is attaching the sample tray and placing the standard on the sample tray. If you have a customized PTS you should first review the *REFL Standard Measurement Protocol* sections in your custom user manual before proceeding.
2. Attach the integrating sphere sample tray to the integrating sphere by loosening the thumbscrew on the side of the sample tray and slide the tray along the two metal rods attached to the side of the integrating sphere. Place the reflectance standard on the sample tray (ensure that it is centered with the sample port) and slide the sample tray upwards until the standard is as close as possible to the sample port opening on the integrating sphere. Ensure the monochromatic light is incident on the standard when the standard is placed centered on the sample tray. **DO NOT look through this alignment port with a sample in place as this could cause eye damage.** If you have a customized PTS you should first review the *REFL Standard Measurement Protocol* sections in your custom user manual before proceeding.

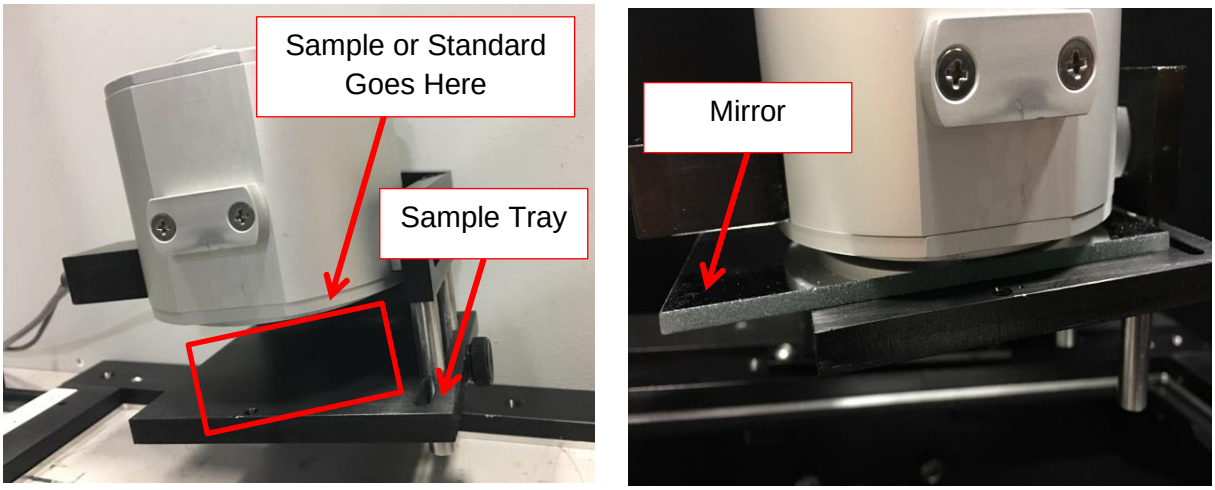


Figure 36 : (a) IQE sample and standard location. (b) Integrating sphere with mirror standard in place.

9. Ensure the integrating sphere detector is connected to the pre-amp and the BNC signal connections on the back wall of the sample chamber.
10. Then on the SciPV software click QE tab. Then click the REFL button.
11. Next select the desired wavelength and step size for your measurement.
12. In the “Measurement Type” session select *Standard* from the drop-down menu, see Figure 35 .
13. In the Output File Metadata” session enter the desired folder location and file name along with any comments you wish to add to the output file.
14. Then go to the “Acquisition” tab in the “Measurement Configuration” session and select the range and integration time you would like to use for the measurement.
15. Then close the sample chamber doors and press the start button. This will cause the “Confirm Measurement setup” window to pop up. Review the entered parameters and click the check mark icon if the parameters are as you require.
16. After clicking the check mark icon, the measurement will begin. When completed the status bar will read “Measurement Complete”.

6.4.5 REFL Sample Measurement

1. If you have just completed a standard measurement, the integrating sphere should be already setup and the only setup that is required is attaching the sample tray and placing the sample on the sample tray. If you have a customized PTS you should first review the *REFL Sample Measurement Protocol* sections in your custom user manual before proceeding.
2. Attach the integrating sphere sample tray to the integrating sphere by loosening the thumbscrew and sliding the tray onto the two metal rods attached to the side of the integrating sphere. Place the sample centered on the sample tray and slide the tray upwards until the sample is as close as possible to the sample port opening on the integrating sphere. Ensure the monochromatic light is incident on the sample when the sample is placed centered on the sample tray. If you have a customized PTS you should first review the *REFL Sample Measurement Protocol* sections in your custom user manual before proceeding.
3. Ensure the integrating sphere detector is connected to the pre-amp and the BNC signal connections on the back wall of the sample chamber.
4. Then on the SciPV software click QE tab. Then click the REFL button.
5. Next select the desired wavelength and step size for your measurement.
6. In the “Measurement Type” session select *Sample* from the drop-down menu, see Figure 35.
7. In the Output File Metadata” session enter the desired folder location and file name along with any comments you wish to add to the output file.
8. Then go to the “Acquisition” tab in the “Measurement Configuration” session and select the range and integration time you would like to use for the measurement.
9. Then close the sample chamber doors and press the start button. This will cause the “Confirm Measurement setup” window to pop up. Review the entered parameters and click the check mark icon if the parameters are as you require.
10. After clicking the check mark icon, the measurement will begin. When completed the status bar will read “Measurement Complete”.

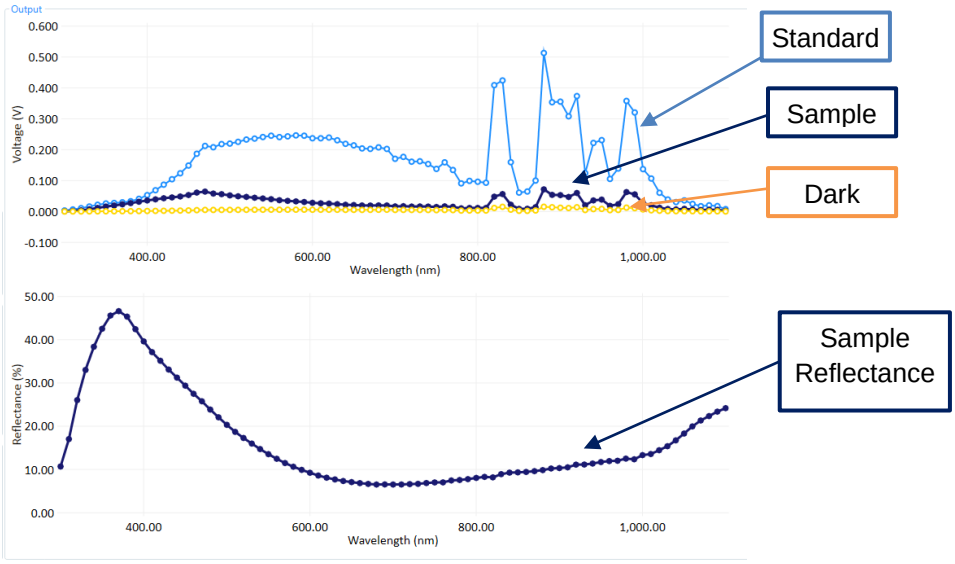


Figure 37: Completed sample reflectance measurement

6.4.6 IQE Calculation

1. To perform an internal quantum efficiency (IQE) calculation the external quantum efficiency of the sample and reflectance spectrum are required. First, complete both measurements with your PTS. It is advised to keep scan parameters constant between the EQE (see sections 6.1 and 6.2) and reflectance measurements (see sections 6.4.1 to 6.4.5) for the best possible results.
2. To perform an IQE calculation, click on the IQE button on the right-hand side of the tool bar.

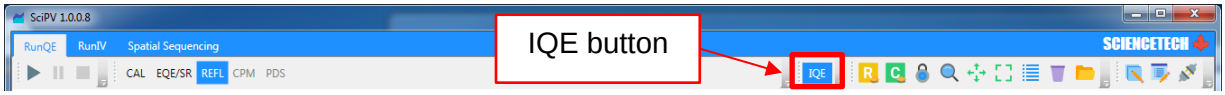


Figure 38: IQE Calculation icon

3. After pressing the IQE button, the IQE Calculator window will pop-up.

Figure 39 : IQE Calculator window

4. To select the EQE measurement you would like to use for the IQE calculation, click on the folder icon in the *"EQE File"* section, see Figure 39. Then select the EQE file that you wish to use for the IQE calculation, see Figure 40.

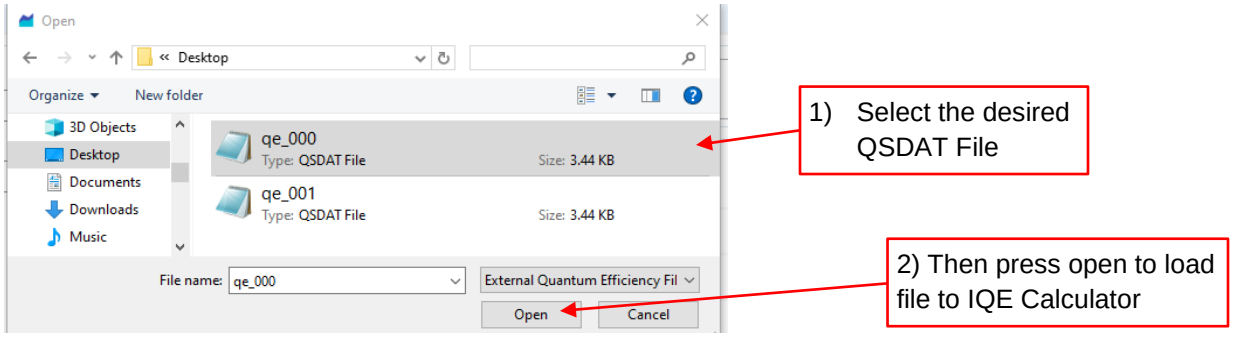


Figure 40: Selecting EQE or Sample Reflectance File for IQE calculator

5. To select the sample reflectance measurement you would like to use for the IQE calculation, click on the folder icon in the *"Sample Reflectance File"* section, see Figure 39. Then select the sample reflectance file that you wish to use for the IQE calculation, see Figure 40.
6. To calculate the IQE using the EQE and sample reflectance files you have selected click on the calculator icon on the top left-hand corner of the *IQE Calculator* window. The IQE curve will then be plotted in magenta in the plot display region of the *IQE Calculator* window.

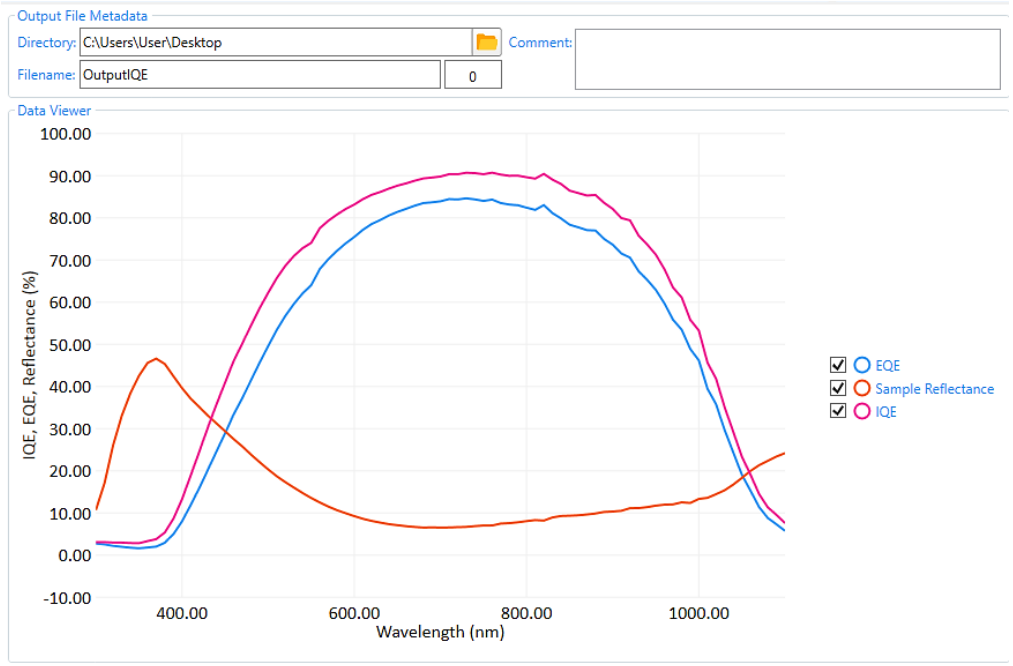


Figure 41: Completed IQE calculation

7. To save the data plotted in IQE Calculator window, first enter the output file metadata. Then click on the save button on the top left-hand corner of the window.

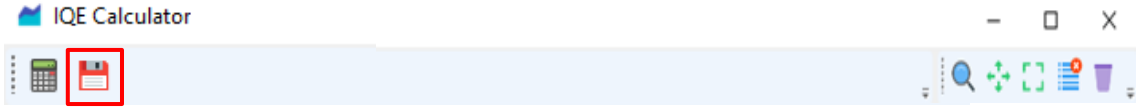


Figure 42: IQE Calculator tool bar

7. Troubleshooting

7.1 Error initializing System

This error is most likely due to the hardware not being powered on, not connected to the computer, invalid drivers, or an incorrect COM port.

Ensure all hardware is powered on and connected to the computer. Review section 2 to ensure all drivers are installed for your systems hardware. Also ensure that the correct COM ports are entered in the *QE Device Manager*. The COM ports can be determined using Windows Device Manager.

7.2 Communication Lost to Hardware

7.2.1 Chopper, Lock-in Amplifier and/or Keithley

1. If there is difficulty connecting to the chopper, lock-in and/or Keithley device through the SciPV software check the Device Manager on the computer and verify that the COM port entered in the software corresponds to the correct device. . If you are getting errors on the computers device manager and the computer is failing to connect to the device(s), restart the computer and check the device manager again. If the problem still persists proceed to step 2.
2. If you are certain the COM port entered is correct, try restarting the hardware. You can do this by turn off the sensitive equipment switch and waiting a about 5 to 10 sec before turning it back on. Because you have turn off sensitive equipment the SciPV software will ask you to close it. Please do so and then restart the SciPV software.
3. If you have already done steps 1 and 2 and you are still unable to connect to the device(s). Restart both the hardware and the computer and unplug and re-connect the USB connection(s) for the troubled device. Then restart the SciPV software.

7.2.2 Filter Wheel and/or Monochromator

1. If the filter wheel and/or monochromator do not automatically connect in the software, first try to press the refresh icon for the device that is not connected.
2. If after pressing the refresh button the device still does not connect then restart the sensitive equipment by turning off and on the sensitive equipment switch and unplug and re-connect the USB connection(s) for the troubled device. If you have a customized PTS which does not have a filter wheel and/or monochromator connected to a sensitive equipment switch then you will need to refer to the custom manual provided with your system for restart these pieces of hardware.

7.3 Cell Connections

It is important to make sure that all electrical connections to the cell are made well. If you obtain IV/SR/QE curves that seem strange it is a good idea to check all the electrical connections. If poor electrical connections exist, you can usually troubleshoot this by checking for connectivity with a multimeter. If there is a large resistance (>1Ω) between two points in a circuit that are electrically connected, then there is likely a bad contact between those points.

Observe the following points as well to help fix bad connections.

7.3.1 Tighten Connections

Where connections are made with screws be sure to tighten the screws fully.

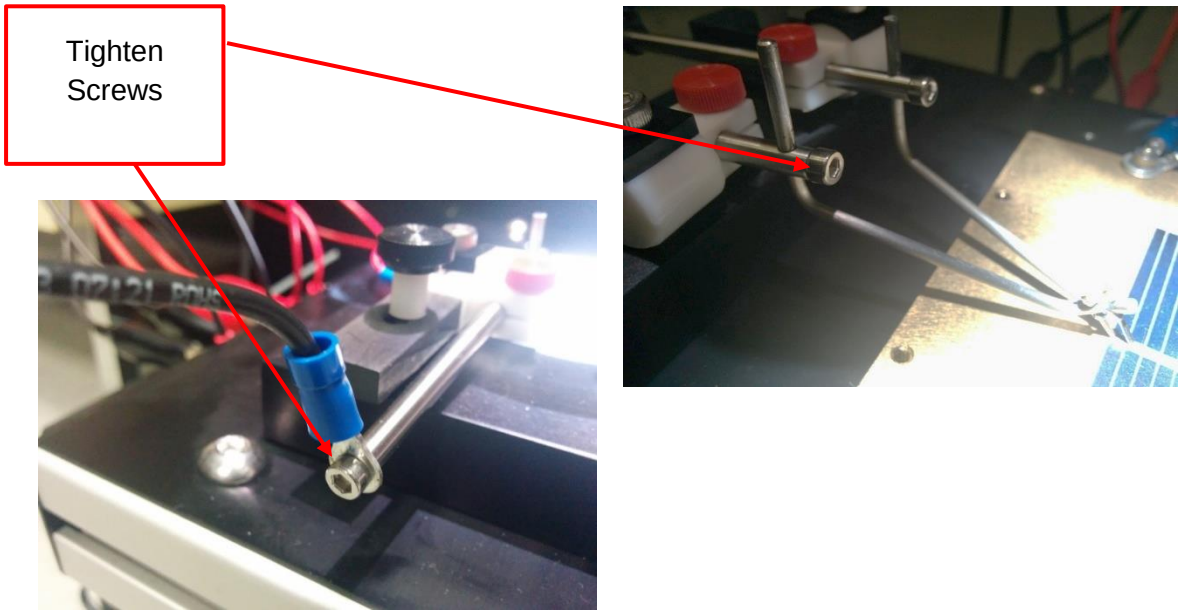


Figure 43: Ensure tight connections troubleshooting.

7.3.2 Probe Tip Placement

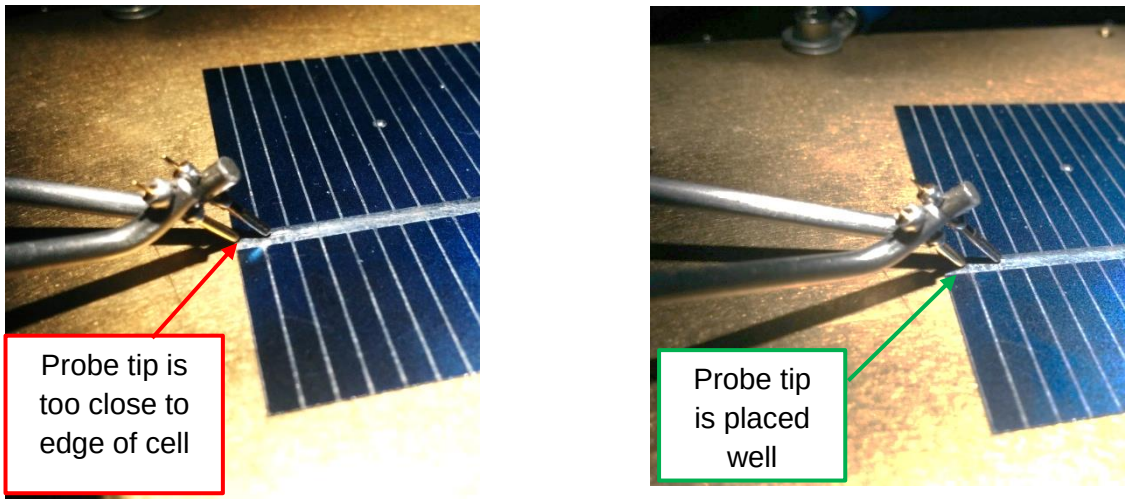


Figure 44: Well-placed probes troubleshooting.

7.3.3 Clean and Re-Seat Contacts

For contacts at binding posts it is possible that something can get stuck in the binding post and create a bad contact. It is a good idea to re-seat the contacts. For forked cables it is a good idea to clean the forks with alcohol on occasion.

Figure 45: Clean electrical connections troubleshooting.

7.4 Noisy or Irregular IV, SR or QE Plots

Poor sample connections (intermittent or high resistance) may explain poor results. Soldered or welded wires are by far the best and most reliable way to make connections, but silver paste (conductive epoxy) is acceptable. Pressure contacts MUST have the largest area possible to distribute applied force. Flat contacts with a low resistance and malleable surface material are best to prevent cracking a fragile sample or penetrating the contact area.

For example, if a force of only 1 gram is applied to a ball probe tip having a diameter as large as 1 millimeter, the pressure applied would be about 32kg per cm^2 andthe pad could deform to a depth of 1 micron. and much more if the ball is smaller or the surface is too hard to deform appreciably. To check contact resistance, do an IV plot with bias light illumination.

7.5 Noisy QE Plots

Noisy QE plots are usually due to fluctuations in the bias light being high compared to the monochromatic light signal, but the quality of the data in the calibration run will limit the ultimate measurement quality achievable during the QE scan. The best way to reduce the bias light noise contribution is to apply a mask to the sample that will limit the area illuminated by the bias light to not much more than that illuminated by the probe light.

Then, make sure that the signal to noise ratio of the calibration run is as high as possible. Although power settings and slit widths must match for calibration and QE scans, it is reasonable to use a longer Time Constant (3x) for calibration than QE scans. **Never use a very short Time Constant for calibration.**

There are several ways to improve the displayed signal to noise ratio and the most important and effective of these is to increase the amount of monochromatic light reaching the sample. Set monochromatic source to maximum, improve coupling of the source to monochromator, increase the step size to allow an increase in the input and output slit widths, adjust each slit width (they may be different) to set the resolution to 2x the step size (sample interval).

It is the slit width that determines the resolution. It may be acceptable to increase slit widths (i.e. reduce the resolution) even further than the optimum as set by step size above while maintaining the small step size to provide over-sampling. Remember to maintain matching slit widths and step sizes for the calibration and Q.E. scans.

An increase of a factor of 3 in the amount of monochromatic light striking the sample will reduce the noise by a factor of three. An increase in Time Constant by a factor of 10 will also reduce the noise in the data display by a factor of three but will increase run times by a factor of ten. Use AUTO Time Constant for a dynamically changing trade-off between run time and displayed (recorded) noise.

Finally, a reduction in the amount of white bias light by a factor of 3 can also reduce the noise in the processed data by a factor of three if the calibration run is noise free. An effective way to reduce the noise contribution of the bias light with samples having area much larger than the monochromatic probe light is to mask the illuminated area until it is slightly smaller than the minimum monochromatic probe illumination area. The mask will limit the bias light area to the minimum necessary and thus maximize the signal to noise ratio. The default bias light footprint is large enough to allow I-V testing at one sun with samples up to 5cm in diameter.

If minimum size masking is used it will be necessary to run a new reference scan with the mask in place over the reference detector to account for the reduction in input test power due to the smaller area. A mask can be made by cutting out the desired spot size from thick black paper. As

the larger aperture (approximately 6.5mm dia.) is greater than the reference detector diameter of 5mm, no extra reference scan will be required. The smaller mask is about 3.5mm in diameter and a new reference scan WILL be required in this case.

7.6 QE Greater than Expected

QE calculations that produce higher values than expected (100%) are usually due to taking insufficient care to ensure that ALL of the monochromatic light is collected by the calibration detector during the calibration run. Just filling the window is NOT good enough, it must be UNDERFILLED. If this means reducing the height of output slit and reducing power available to strike the sample, then this MUST be done and the power increased by other means.

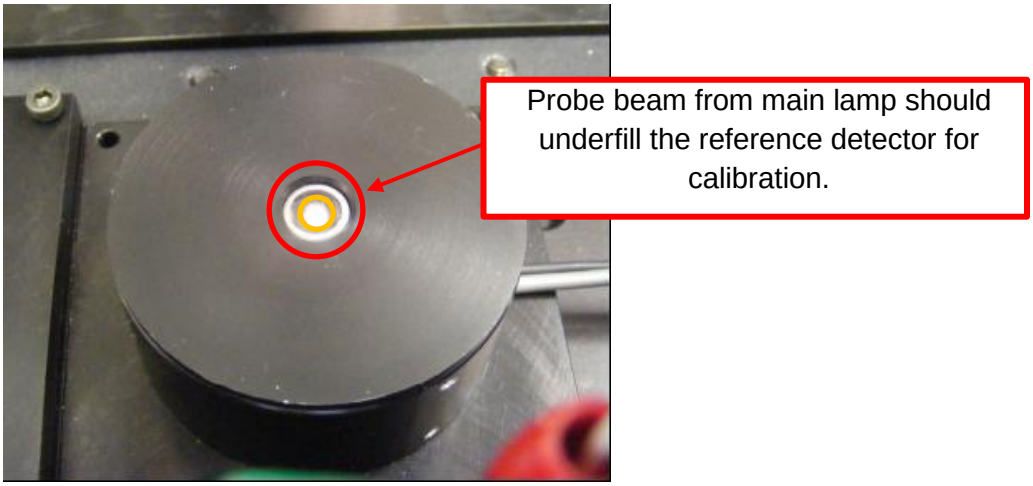


Figure 46: Monochromatic light focus on reference detector.

QE values can also be greater than expected if the small amounts of light present in rings around the probe spot but not measured in the calibration scan are allowed to fall on the test sample. This will usually result in much higher than expected photocurrent. Carefully examine the probe spot on a dark mask which allows the main spot to pass through a hole. If you can see ANY light on the opaque part of the mask, use a mask with a 5mm maximum aperture to prevent unmeasured power from reaching the sample.

7.7 QE Lower than Expected

As all of the monochromatic light must be collected by the reference detector during the calibration run, so must ALL of the monochromatic light be collected by the sample. It must be UNDERFILLED. This may require raising the test cell towards the monochromatic light source and lowering the reference detector to keep it at the focus. The calibration run should not be attempted until all required conditions can be met.

Small reductions in QE may be caused when more of the monochromatic light is reflected from the sample than expected. This can be caused by transparent cover plates and increased by unnecessarily oblique angles of incidence of the monochromatic light.

7.8 IQE higher or lower than expected

To be added.

7.9 Decimals numbers

When entering decimals into the SciPV software, these values should be only entered using a period. The software will not function properly if commas are included in a number value entered by the user.

8. Important Notice

All electrical instruments may be dangerous if not handled in accordance with proper instructions and common precautions. Sciencetech Inc. will not be responsible for any damage caused by such units if instructions herein are not followed and repairs are not attended to or performed by company-trained or licensed personnel. All instruments should be operated with proper grounds on power line and should not be opened or handled as to electrical or electrically operated components without being switched off and disconnected from power receptacle.

Sciencetech Inc. reserves the right to make adjustments or improvements in its product without notice and without obligation to subsequent purchasers and without being required to make corresponding changes or improvements in products theretofore manufactured and sold.

We have done our very best in the manufacture and packing of this material. The transportation carrier is now responsible for delivering it to you in its original good condition, since all purchases are FOB London.

If the shipment is NOT delivered in good order and in accordance with quantity shown on Bill of Lading or Packing Slip, have the shortage or damage noted by the Carrier on both the delivery receipt and the freight bill, or by special form provided by United Parcel or the Post Office.

The Interstate Commerce Commission has ruled that Transportation Companies will not honor any losses or shortage claims unless exceptions are noted on the freight bill at the time of delivery. It is the buyer's responsibility to make a complete inspection immediately upon receipt of purchased goods.

If you accept shipment from the Transportation Carrier short of what is enumerated on the Bill of Lading – or in damaged condition – without having proper notation made by the Carrier, you do so at your own risk.

If bundles or crates are in apparent good order, but on opening contents are found to be damaged, call Carrier for adjuster to view same and have the Transportation Company/United Parcel/Post Office mark the freight bill or packing slip relative to such concealed damage. Make your claim at once for the Transportation Company/United Parcel/Post Office has a limited time for presentation of claims.

We are willing to assist you in every possible manner in collecting claims for loss or damage on this shipment, but this willingness on our part does not make us responsible for filing or collecting claims or replacing materials. Claims for Loss or Damage on shipment may not be deducted from out invoice, nor pay of the invoice withheld awaiting adjustment of such claims, as we cannot guarantee safe delivery.

Important: Do not return goods without written authority.

Contact factory for return material authorization.

Returned goods will not be accepted by us from the Transportation Company/United Parcel/Post Office unless written authorization has been issued by Sciencetech Inc.

Return of special or non-stock items cannot be authorized. Credit for goods returned - under authorization - will depend on the value to us based on our selling price, less a fair charge to cover the expense of shipping - re-handling - transportation - refinishing, etc, providing material is received in good condition - transportation charges prepaid - credit rendered to be used against future purchases.

All equipment manufactured by Sciencetech Inc. has been subjected to extensive performance and quality control testing. In order to constantly improve our product, we ask your assistance. Upon installation of our equipment, please fill out the attached card and return to us.

By completing the card and returning it to Sciencetech, you will register your instrument in warranty and enable us to provide you with the best possible service.

9. Warranty and Assistance

All Sciencetech products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. Products sold or resold, but not manufactured by Sciencetech, carry the warranty, if any of the original manufacturer. We will repair or replace products that prove to be defective during the warranty period or employ our best efforts to effect repair or replacement of equipment sold, but not manufactured, by Sciencetech. No other warranty is expressed or implied.

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