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Simply Brighter

Mightex Spectrometer Software User Manual

Version : 1.0.3

Sept. 28, 2009

Relevant Products

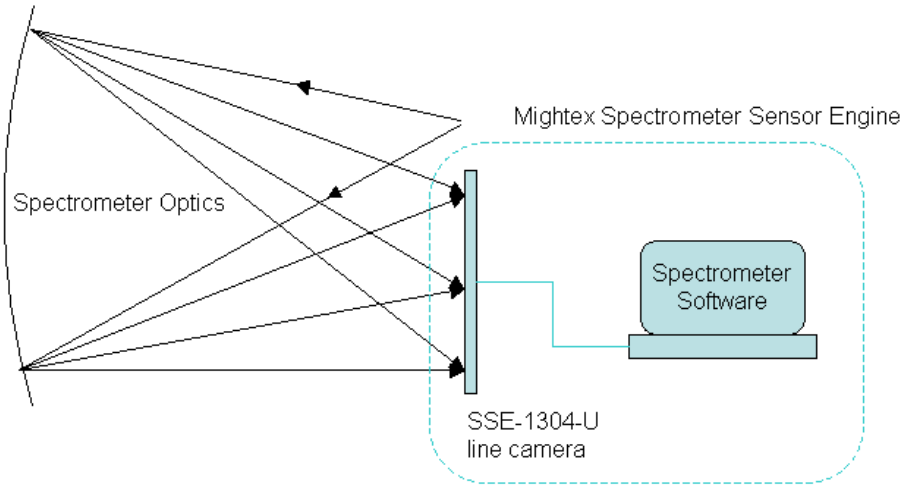
Part Numbers
SSE-1304-U

Revision	Date	Author	Description
1.0.0	May 18, 2008	JT Zheng	Initial Revision
1.0.1	Apr. 24, 2009	JT Zheng	SSE Description
1.0.2	Aug. 4, 2009	JT Zheng	Din8 pin definition
1.0.3	Sept. 28, 2009	JT Zheng	Adding RRC and ETC features

Table Of Content

About Mightex Spectrometer Sensor Engine

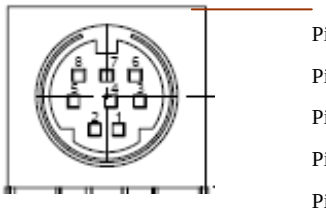
Mightex Spectrometer contains an Optical System and a Spectrometer Sensor Engine (SSE), the Spectrometer Sensor Engine (SSE) consists of two components:
1) Mightex CCD Line Camera (SSE-1304-U), and
2) Mightex Spectrometer Software.



The spectrometer software provides a powerful set of spectrometer functions such as wavelength calibration, dark/bright references, spectrum display, and file management…etc. This is the same software used for another product "Mightex Spectrometer Sensor Engine" (refer to the figure above), Mightex SSE is a spectrometer engine and user might have his own optics. For SSE users, They might set up optics (spectrograph) and place the line camera at the focal plane of the spectrograph. And they can use this software for all spectrometer functionalities, This releases users from the burden of programming spectrometer functions so that they are able to build their spectrometers much more efficiently and cost- effectively.

Connector Definition

Mightex spectrometer has two connectors, one is the standard USB 2.0 Type B connector, and the another one is a 8 pin Din connector as following: (It's the receptacle on the spectrometer)



Pin1 : GPIO1
Pin2 : GPIO2
Pin3 : GPIO3
Pin4: GPIO4
Pin5 : TRIG+
Pin6: TRIG-
Pin7: GND
Pin8: GND

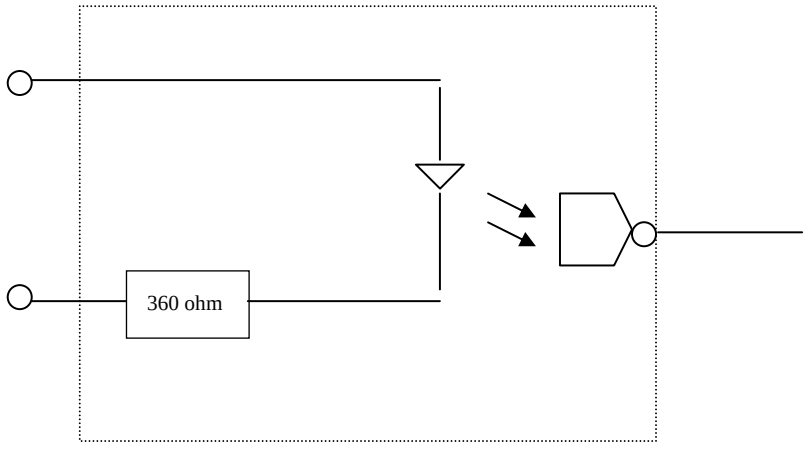
Mightex provides a Din8 cable which mates with the Din8 receptacle of the spectrometer, the Din8 cable has the following wire definition:

Pin	Signal	Wire Color
Pin1	GPIO1	BLACK
Pin2	GPIO2	DEEP BROWN
Pin3	GPIO3	RED
Pin4	GPIO4	LIGHT BROWN
Pin5	TRIG+	YELLOW
Pin6	TRIG-	GREEN
Pin7	GND	BLUE
Pin8	GND	PURPLE

Caution: *For user wants to use those pins, user must be very careful not to shorten two different signals . Doing so may damage the camera, in worst case, even the PC itself.*

Note:

1). TRIG+ and TRIG- ----- External trigger signals are mainly used while the device is set in **TRIGGER** mode. Internally, the controller has the following opto-coupler based design for each trigger input:



The diode is expected to be working under :

Iforward = 6mA – 20mA

Vforward = ~1.2V

As we have a 360ohm resister built in, we expect 3.3 – 10.0V source with 6mA minimum current source capability to be the trigger input. For the device, it's falling edge assertion, so a "H" → "L" edge will be a valid trigger signal. It's recommended to be a positive pulse with its width more than 20us.

2). GPIO: 4 GPIO pins are provided, each GPIO pin provides LVTTL level and 8mA source/sink current while it's configured as output, it can also be configured as Input pin.

Software Installation

Minimum Operating System/Hardware requirements:

Processor: Pentium III,900M or above

Operating System: Windows 2000/XP/Vista

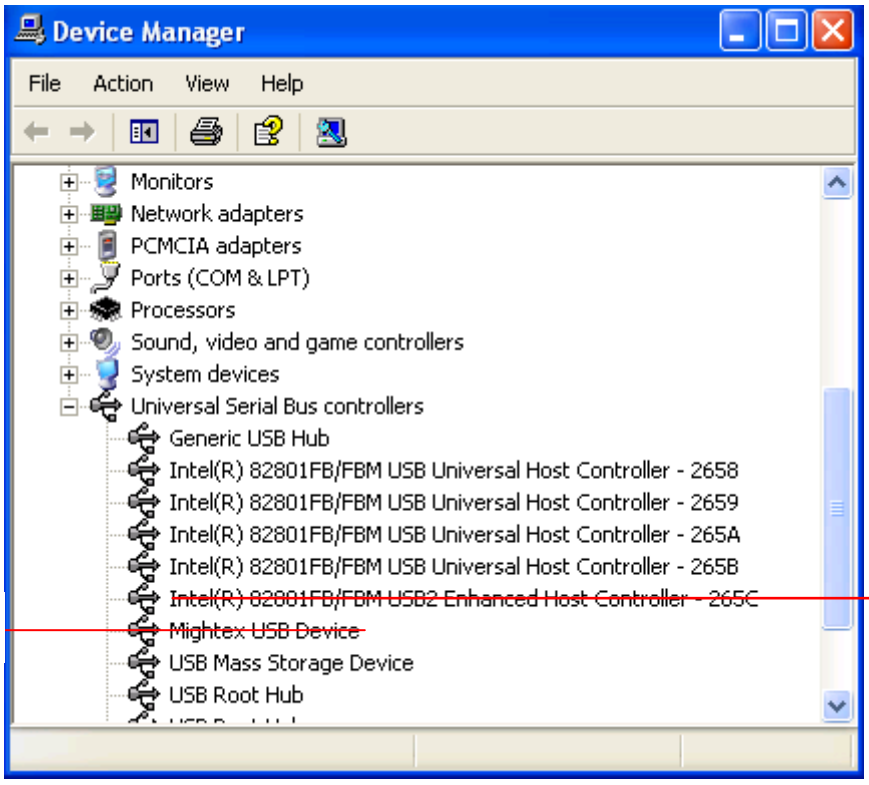
RAM: 256M or greater

USB 2.0 Host Controller: required.

Spectrometer USB Driver Installation:

**. The following installation procedure is based on XP, for 2000 or Vista, the GUI might be slightly different.*

Mightex Spectrometer is based on Mightex CCD Line Camera, it uses high speed USB2.0 port (480M) for data collection, USB 2.0 Enhanced Host controller MUST be present on host PC, user may check this by going to "Control Panel | System | Hardware | Device Manager | Universal Serial Bus Controllers", the "USB Enhanced Host Controller" or "USB2 Enhanced Host Controller" should be present as following:

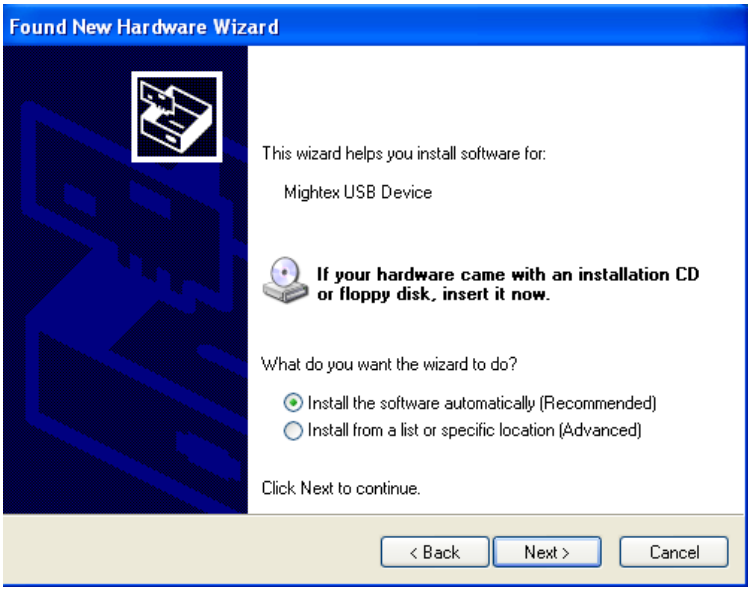


Windows Device Manager

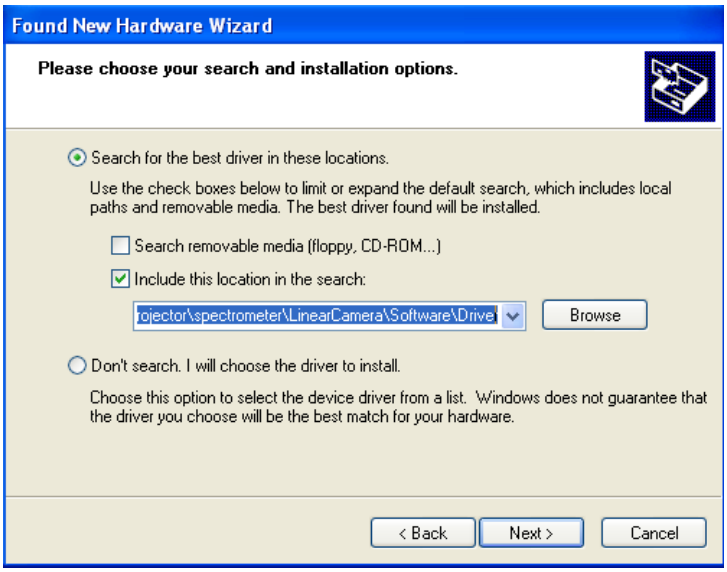
On a PC with USB Enhanced Host Controller (USB2.0 hardware), user can plug the camera into one of its available USB2.0 port, for the first time, Windows will prompt with "Found New Hardware" as following:

And immediately, windows will show the “Found New Hardware Wizard”:

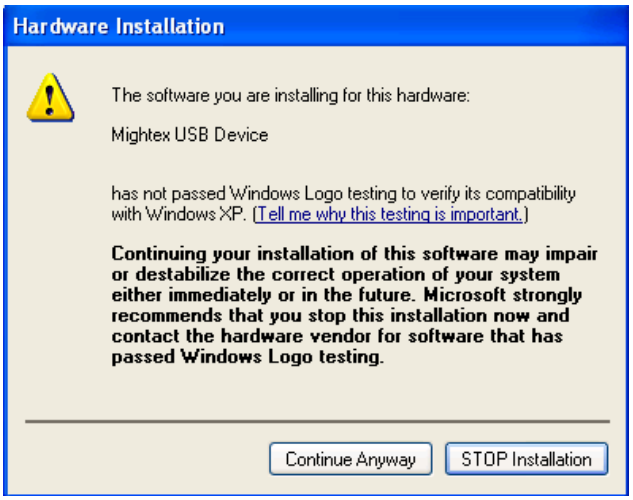
User should choose the “No, not this time” (because we know the location of the INF and driver file, don’t bother Windows to search for it), and click [Next], the wizard goes:



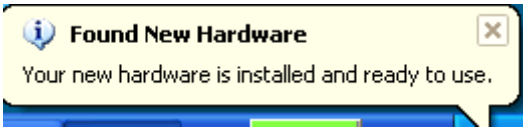
Choose “Install from a list or specific location (Advanced)” (as we know the location of the driver) and click [Next] button, and it goes:



User may use [Browse] button to specify the location (in this case, it's in the \driver sub-directory of the installation CD) and click [Next]. Windows will show the following dialog:

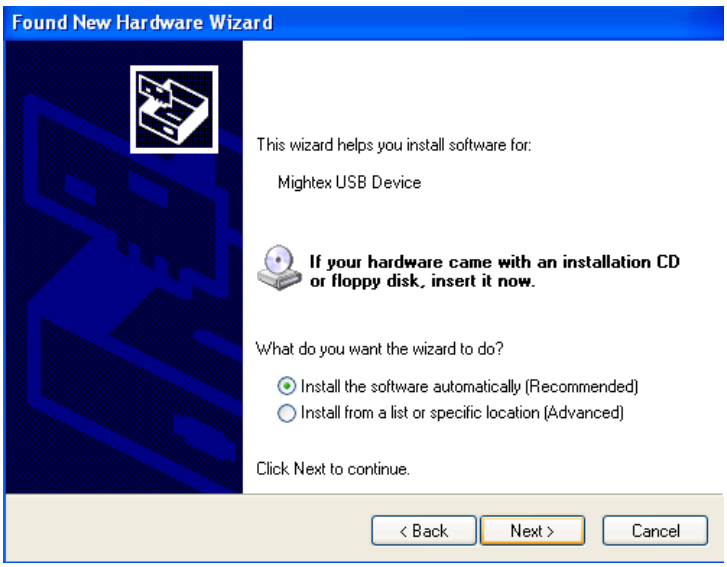


Please click the [Continue Anyway] button to continue the installation, and finish the installation automatically. You will see windows show:



After it's properly installed, user will see the "Mightex USB Device" in the windows device manager (please refer to previous page for this).

If user change the device to another USB port on PC after installation, PC may prompt again with the same new hardware wizard, please following the same sequence but, as we had already installed the driver, this time you should go with "install the software automatically (recommended)" as following:



Click [Next] to finish the wizard as the first time installation.

Note for any USB2.0 Port, the above installation sequence will only occur once, after successful installation, windows will automatically recognize the device and load proper driver for all following uses.

Application Installation

User can simply copy all the files under the \Application sub-directory of the CD into a target directory of your local disk, and run the “Mightex_SSE.exe” file

CD ROM File Organiztions:

In CD ROM, it has the following sub-directory:

\Drivers

It has two files “MtCCDUsb.inf” and “MtUsb.sys” which is used for driver installation.

\Application

It has EXE file and related DLL files, and two pre-defined sub-directories as following:

\Appdata : it has five pre-defined files and one pre-defined sub-directory.

Para.ini : Main Parameter file for SSE.

Pixelmode.ini : Parameter file for SSE

WavelengthSets.ini : Pre-defined wavelength sets.

CalibrationFile1.cal : Example of calibration file.

ImportFile1.mtp : Example of import file.

\ModuleNo_SerialNo : This is a sub-directory which includes RRC and ETC calibration files, those files are generated in factory when the device is calibrated.

\Data : This is an empty sub-dir, user might put spectrum data files under it, for example, user can use it as “Time line” save/load path.

Getting Started

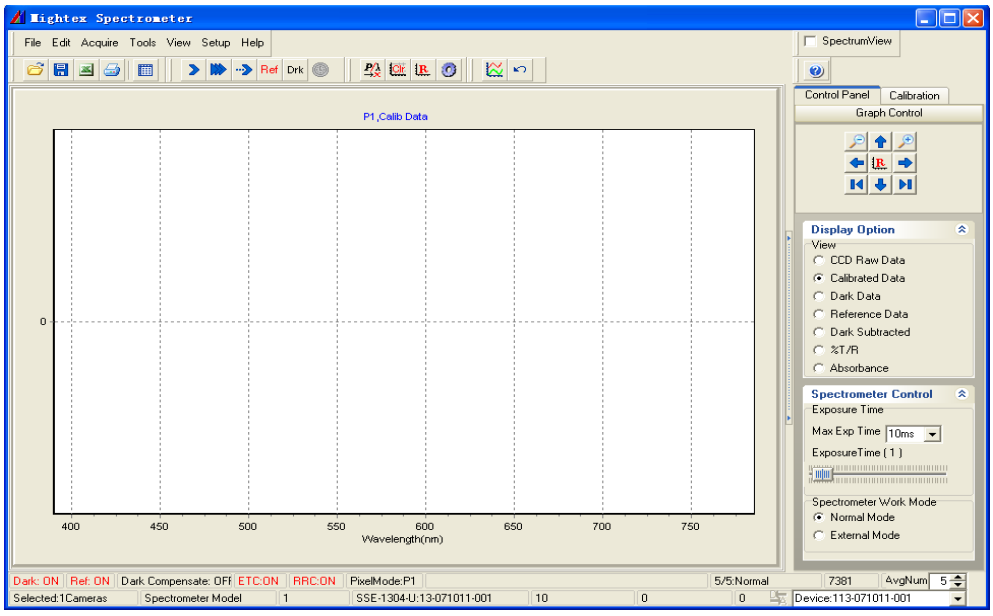
Connect the Spectrometer to the USB 2.0 port of your computer, if the spectrometer driver has been successfully installed, the found-new-hardware information will be shown on the desktop for the first time plug in.

Start the Application

Start the application by running “Mightex_SSE.exe”.

A device selection form with the module no. and serial no. of Spectrometer connected to the computer will be shown. The device is selected by default.

User should always click the OK Button and the main window shows up.



Note: *. If the setup is not calibrated, a warning message might show up, it’s recommended that user should do wavelength calibration prior to other wavelength related operations (refer to “Wavelength Calibration” paragraph for the details). And there’re three ways to have the device calibrated:

1>.Follow the steps in “Wavelength Calibration” to do the calibration manually, user must have a standard light source (with known peaks of certain wavelengths).

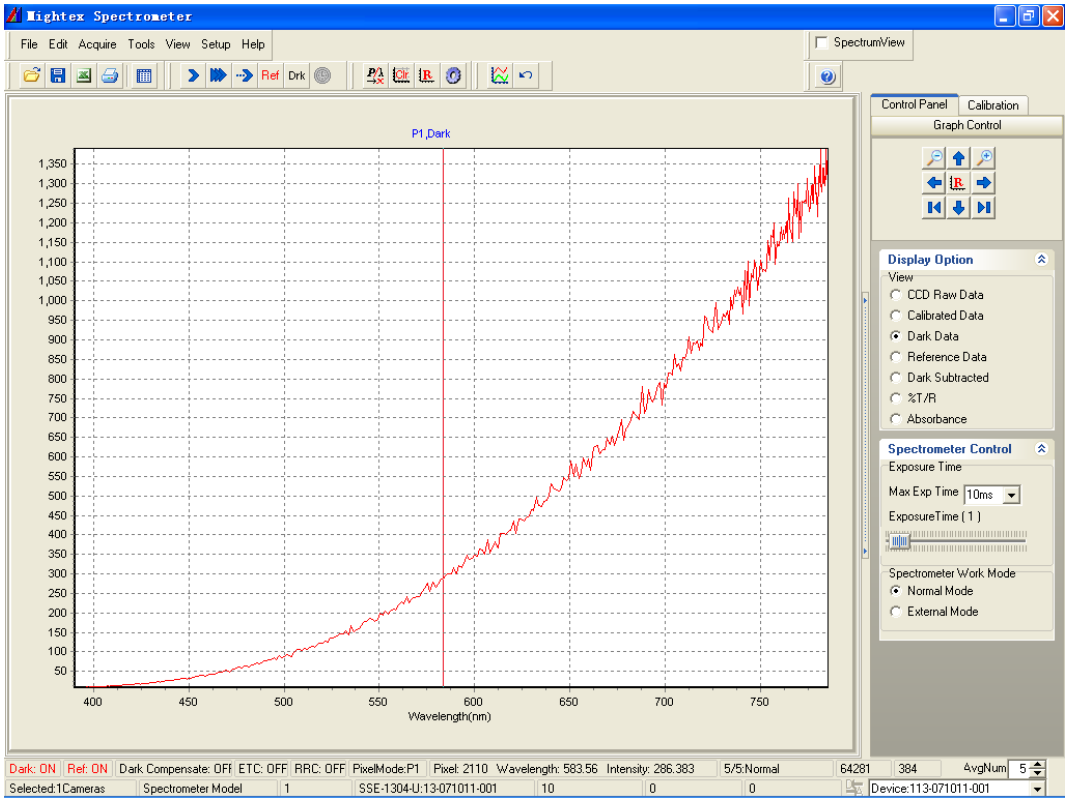
2>.User might import a parameter file (*.mtp) which contains calibration coefficients, please refer to “Import Parameter File” (the CD ROM contains one example mtp file).

3>.User might input a calibration file (*.cal, the CD ROM contains one general calibration file “CalibrationFile1.cal”), So user must have the calibration file (for this particular device) first, a calibration file is generated via the method <1> above.

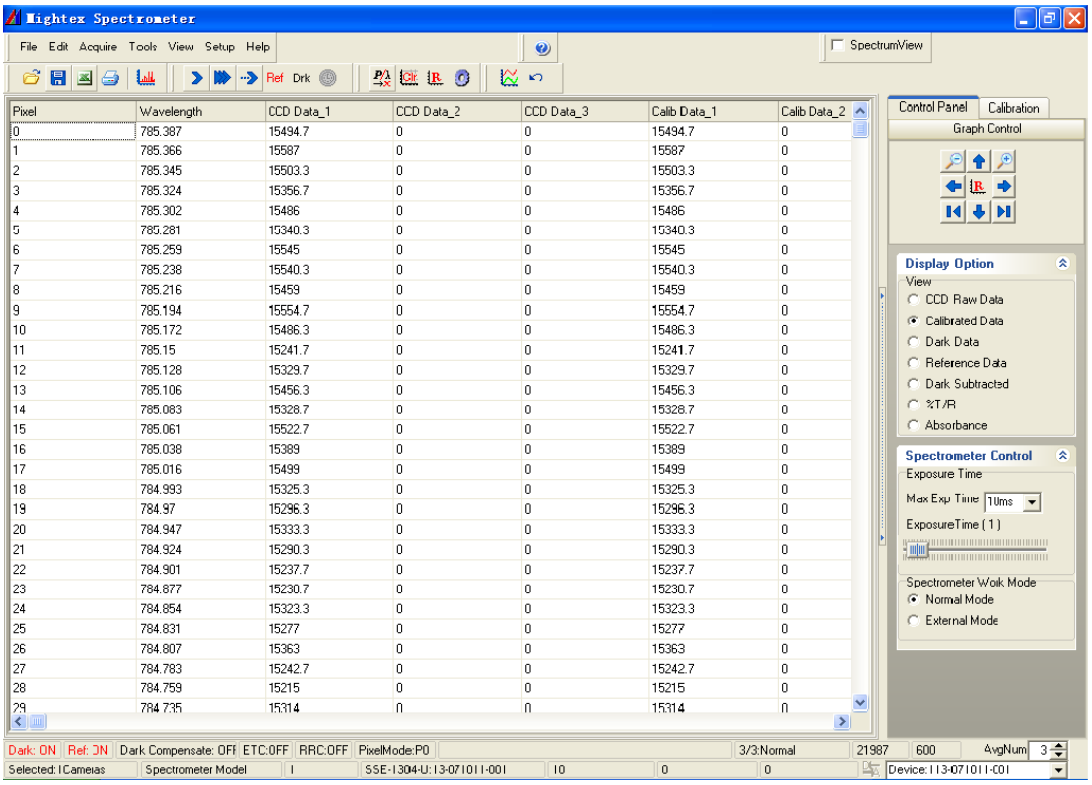
**. If there’s no hardware connected to the PC, user can still run the software, but all device related features are disabled.

Scan Spectrum Data

Click ‘Acquire One Spectrum’ speed button  , the software will ask the spectrometer to acquire spectrum **ONCE** (One spectrum might include multiple frames, actual frames depend on the frame average number settings) and shown on the graph.



By default, it’s in “Chart” mode, user can also view the spectrum in “Table” mode, Clicking the ‘View Data’ speed button  , the application shows the spectrum in Table mode (shown in next page).



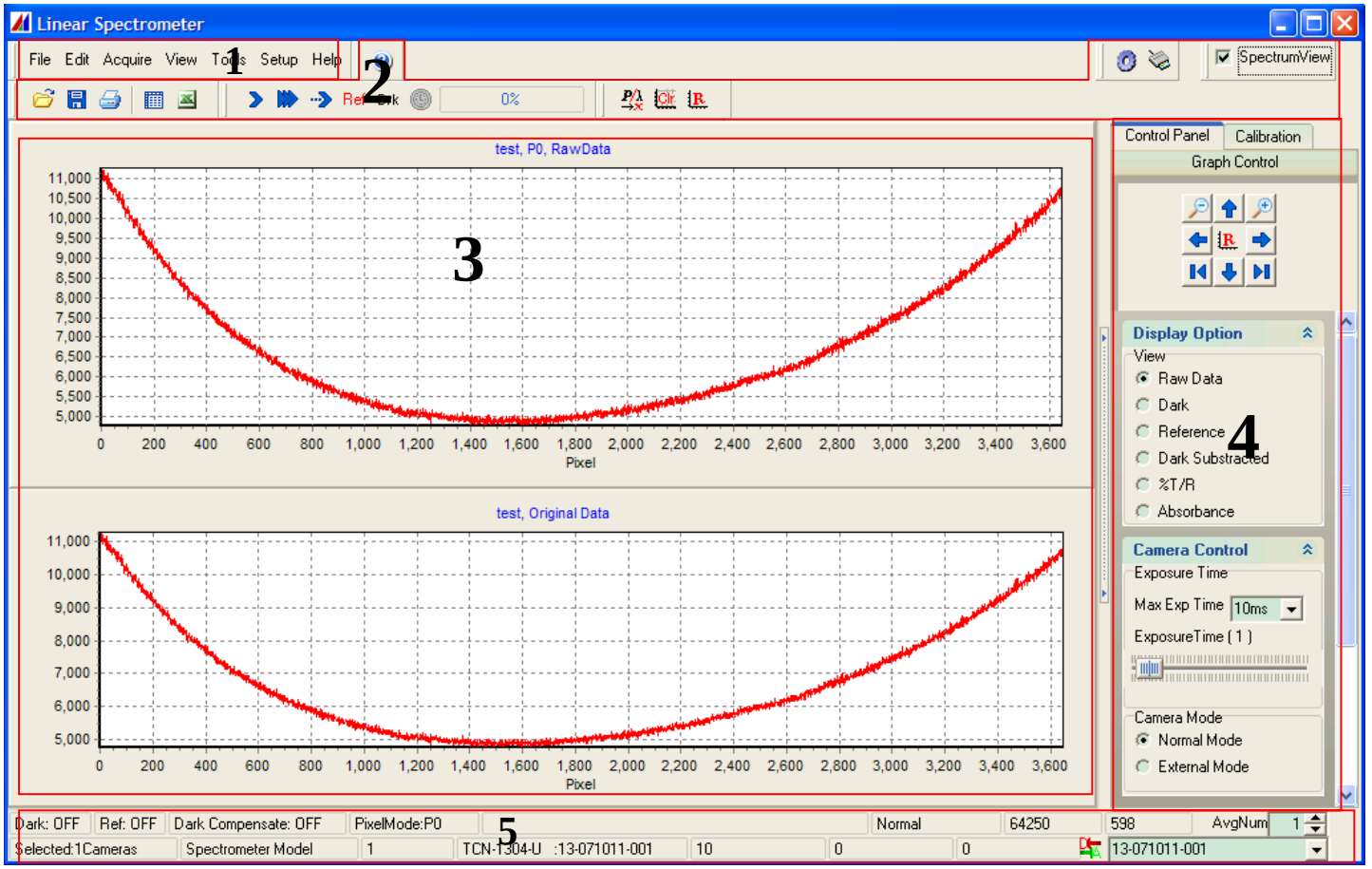
While the data is shown in Table mode, the button becomes  , clicking it will show the spectrum data in Chart mode agin.

Save Data.

By Click the 'Save' speed button  , user can specify a directory to save the scanned spectrum data to a user specified file (*.TXT file). The saved spectrum file can be loaded back later. (The format of the spectrum data file is described in details later).

Software Main User Interface

The main window of the application has been divided into Five Parts.



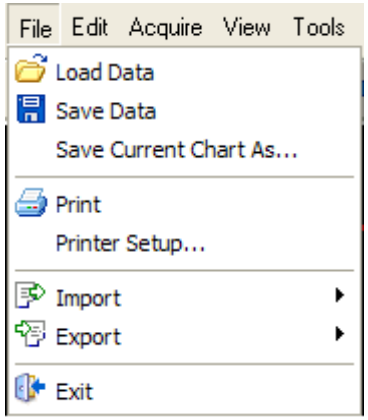
1 Main Menu
2 Toolbar
3 Working area
4 Control Area
5 Status Bar

1). Main Menu

There are totally seven main menu items at the top level.

File

The File Menu contains general menus related to the spectrum loading, saving, printing, importing/exporting operations.



Load Data: Load the saved spectrum data(text file) from disk.

Save Data: Save current spectrum data to file (text file)*

Save Current Chart As: save chart according to selection (picture file, txt data file).

Print: Print current spectrum as graphic.

Printer Setup: Opens windows printer setup dialog.

Import: Importing Spectrometer's parameter file**.

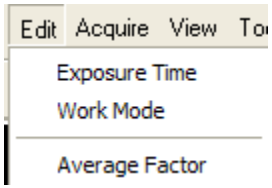
Export: Exporting current data to an delimiter based text file.

Exit: Exit the application.

*. *The spectrum data includes all the data such as current spectrum data, dark data, reference data…etc. (refer to the details of spectrum data file)*

**. *For details, please refer to "The importing parameter".*

Edit

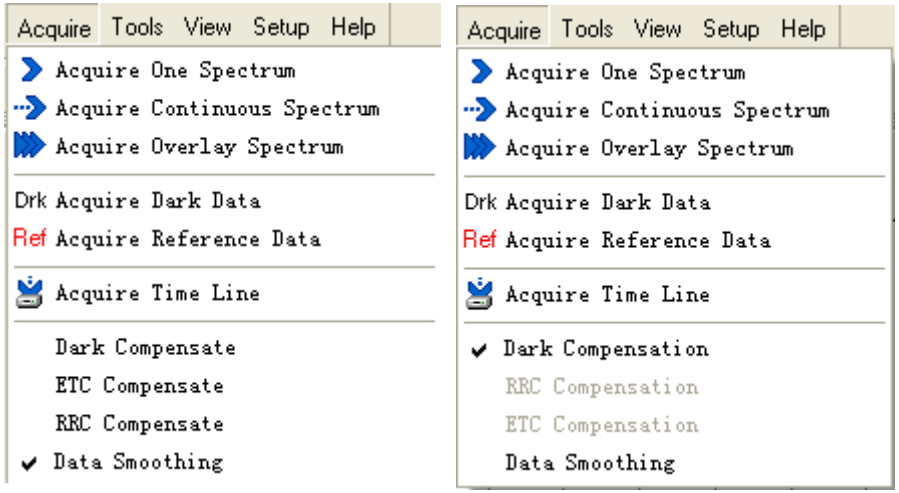


Exposure Time: Change the integrating time of spectrometer.

Work Mode: This is the low level hardware control of the spectrometer, which is described in detail later.

Average Factor: Edit the average frame count of each spectrum.

Acquire



Acquire One Spectrum: Scan One spectrum.

Acquire Continuous Spectrum: Scan spectrum continuously

Acquire Overlay Spectrum: Scan Multiple spectrums (totally 3 spectrum can be shown on the main chart).*

Acquire Dark Data: Scan the spectrum once and saved as dark data.

Acquire Reference Data: Scan the spectrum once and saved as reference data.

TimeLine: Opens an additional form for timeline spectrum scan functions.

Dark Compensate: Enable automatically dark compensation.

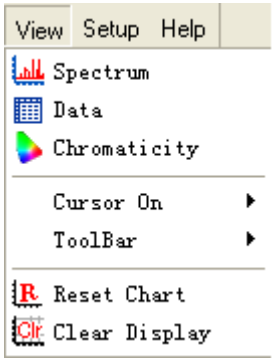
ETC Compensate: Enable ETC Compensation. (This button will be disabled if ETC file does not exist).

RRC Compensate: Enable RRC Compensation. (This button will be disabled if RRC file does not exist).

Data Smoothing: Enable spectrum “smooth” data processing after scanning.

*. *For getting overlay spectrums, user should click this menu item (or its quick button) repeatedly*.

View



Spectrum: View the current spectrum in chart.

Data: View the current spectrum data in table.

Chromaticity: View the Chromaticity coordinates and related information of the current scanned spectrum.

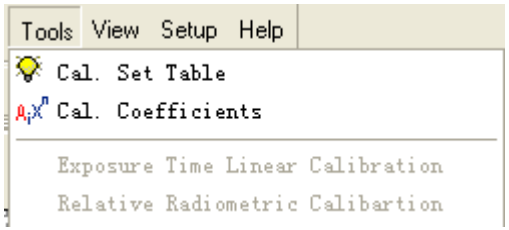
Cursor On: Cursor Enable/Disable when viewing multiple spectrums in the main chart.

Tool Bar: Control the visibility of tool bars.

Reset Chart: Reset the chart x and y axis in its standard format.

Clear Display: Clear Chart.

Tools



Cal.Set Table: Open wavelength set definition form.

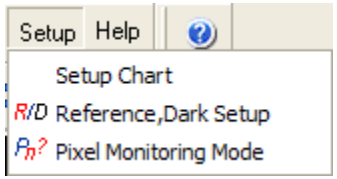
Cal. Coefficients: Open wavelength and pixel calibration coefficient form, which allows user to view the calibration coefficients. Note, it's **NOT** recommended for user to adjust those parameters manually)

Exposure Time Linear Calibration: Invoke the ETC calibration form.

Relative Radiometric Calibration: Invoke the RRC calibration form.

(Note: these two calibrations should be carried out by factory.)

Setup

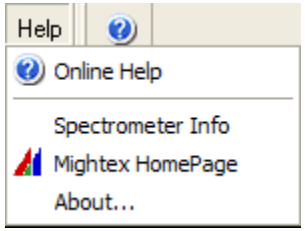


Setup Chart: Opens Chart editing form, which allows user to edit chart settings including coordinates, color, … etc.

Reference, Dark Setup: Opens reference spectrum and dark spectrum setup form.

Pixel Monitoring Mode: Opens the pixel mode editing form which allows user to set to different pixel mode.

Help



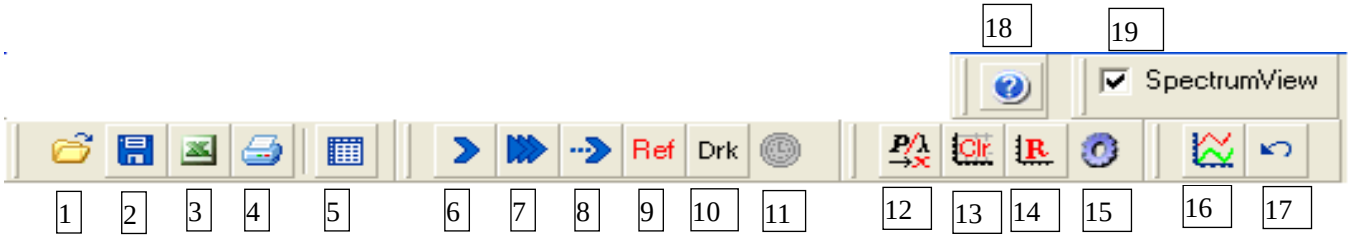
Online Help: Opens the help file.

Spectrometer Info: Opens a form showing the device information of the current selected spectrometer.

Mightex Homepage: Visit the Mightex Homepage at: www.mightex.com

About: Opens the about dialog.

2). Toolbar



The quick buttons on tool bar can be divided into **SIX** groups according to their functions: (Each group is on its own Tool Bar)

- ***Standard group***: including the speed buttons 1,2,3,4 and 5
- ***Spectrum operation group***: including the speed buttons 6,7,8,9,10 and 11
- ***Chart control group***: including the speed buttons 12,13, and 14,15
- ***Curve smoothing operation group:*** including the speed buttons 16,and 17
- ***Help group***: including the speed button 18
- ***Bottom chart control group***: including the speed button 19

  The visibility of the above first 5 groups can be controlled by the 'View' -> Tool Bar' button on the main menu.

The quick buttons of each group are listed as following:

1: Open File Button

2: Save Data to Filerst

3: Export Data to Excel File

4: Print Current Chart

5: Change Viewing Type Selection, used to change viewing type of working area between chart mode and table mode

6: Grab One spectrum

7: Grab overlay spectrums

8: Grab continuous spectrum

9: Grab Ref spectrum data

10: Grab Dark data

Buttons 6 to 10 are only functional with the pixel monitoring mode P0,P1,P2,P3.

Button 9,10 grab one spectrum and save it into Ref/Dark array, in addition, it also save the array into Ref/Dark files specified in "Reference, Dark Setup" dialog box. (later described in Reference Data & Dark Data Setup)

11: Monitor Pixels by Time

Buttons 11 is only functional with the pixel monitoring mode P4, P5, P6 and P7.

12: Change X axis Unit

Buttons 12 is for switch the X-Axis unit between Pixel and wavelength, it's only functional with the pixel monitoring mode P0, P1, P2 and P3, and when wavelength calibration is done.

13: Clear Chart

14: Reset Chart X and Y scale to it standard setting

15: Invoke Upper Chart and Bottom Chart Setup Form

16: Apply Curve Smooth

17: Undo Smooth

18: Help Menu

19: Muti-Spectrum view, when checked, an additional chart is shown below the main chart.

3). Working Area

The working area can be in either “Chart” or “Table” mode as following:

Chart mode: it have two charts, the upper one is the main chart, and the bottom is the additional chart, which can be chosen to show or hide by checking or unchecking the ‘Spectrum View’ check box on the toolbar, the default state of the bottom chart is “Hiding”, so user usually only see the main chart in the working area.

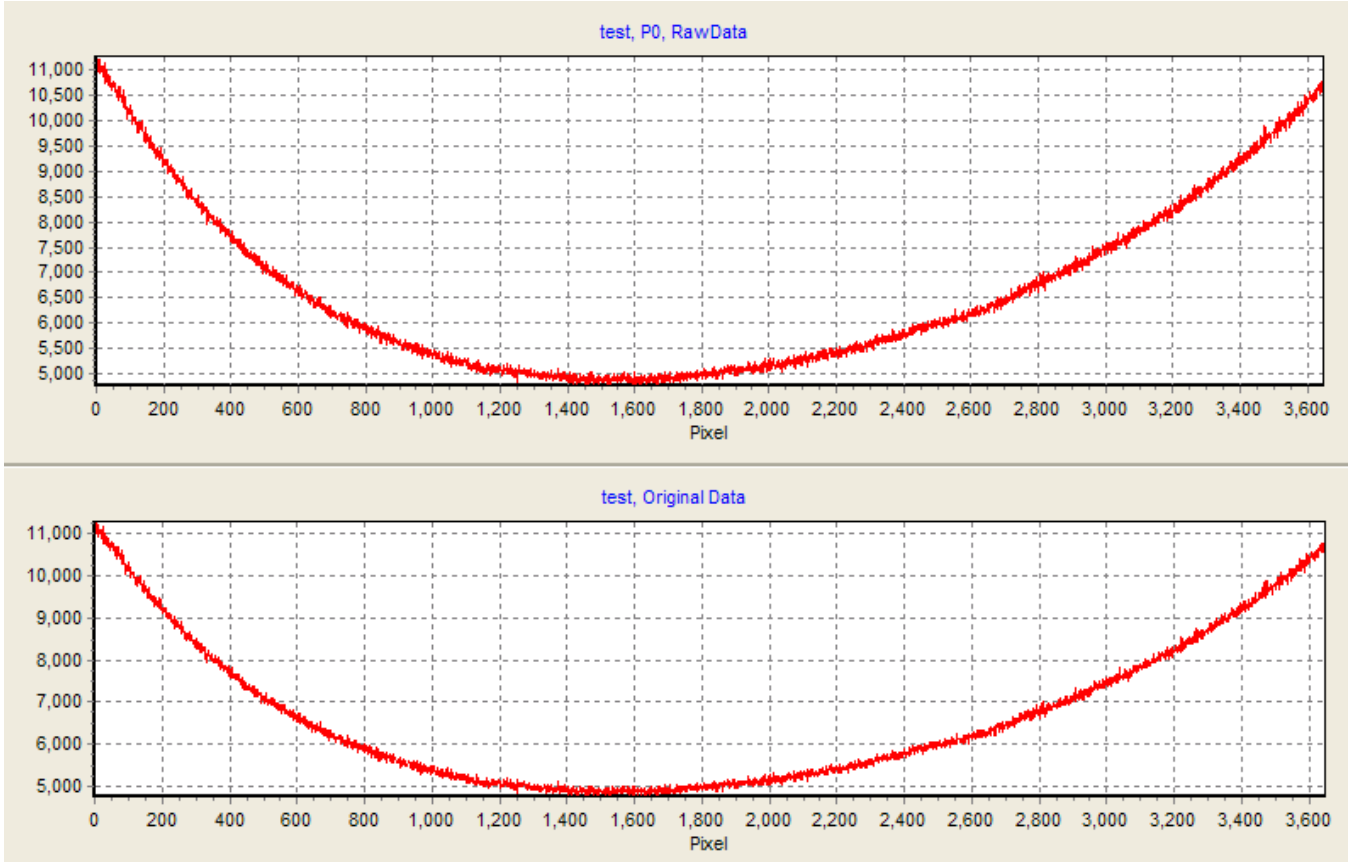


Table mode:

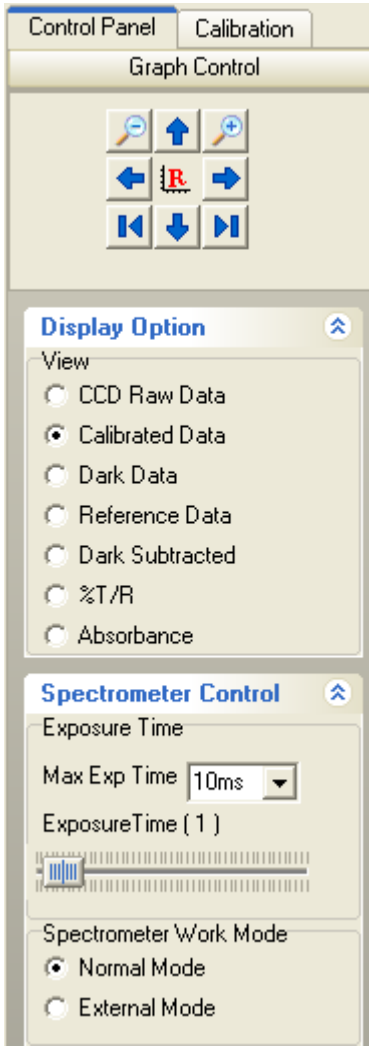
In this mode, the spectrum data is shown in a table as following:

Pixel	Wavelength	Raw Data_1	Raw Data_2	Raw Data_3	Dark Substracted_1	Dark SubStrac
0	830.003	11205	0	0	0	0
1	829.881	11152	0	0	0	0
2	829.759	11282	0	0	0	0
3	829.638	11226	0	0	0	0
4	829.516	10993	0	0	0	0
5	829.394	11015	0	0	0	0
6	829.273	11095	0	0	0	0
7	829.151	11112	0	0	0	0
8	829.03	11026	0	0	0	0
9	828.908	11121	0	0	0	0
10	828.786	11019	0	0	0	0
11	828.665	11216	0	0	0	0
12	828.543	10930	0	0	0	0
13	828.422	11016	0	0	0	0
14	828.3	10989	0	0	0	0
15	828.178	11077	0	0	0	0
16	828.057	10989	0	0	0	0
17	827.935	11085	0	0	0	0
18	827.814	10887	0	0	0	0
19	827.692	11051	0	0	0	0
20	827.571	11073	0	0	0	0
21	827.449	11057	0	0	0	0
22	827.328	10954	0	0	0	0
23	827.206	10895	0	0	0	0
24	827.085	11143	0	0	0	0

4). Control Area

The control Area contains two tabs: “Control Panel” and “Calibration”:

Control Panel Tab



This Tab contains three control groups: **Graph Control**, **Display Option Control** and **Spectrometer Control**.

Graph Control contains nine speed buttons for controlling the chart viewing.

: Zoom out the Graph; : Zoom In the Graph;

: Move graph Up ; : Move graph down; : Move the graph Left; : Move graph right;

: Shrink the graph to the left; : Expand the graph. : Reset the chart to its standard format..

Display Option Control contains controls of the data to be displayed on the chart.

CCD ***Raw Data***: Display the acquired RAW spectrum directly

Calibrated Data: Display the spectrum after ETC and RRC if these options are enabled, otherwise it is the same as CCD Raw Data;.

Dark: Display the current grabbed/loaded dark spectrum, if no dark spectrum has been loaded or grabbed, dark data will be 0;

Ref: Display the current grabbed/loaded reference spectrum

Dark Subtracted: Display the spectrum which has subtracted the dark data from the current spectral data.

%T/R: Display the spectrum ratio which is defined as (Raw data – Dark Data)/Reference Data;

Absorbance: Display the spectrum of absorbance which is defined as: Log_{10}(Reference Data/(Raw Data-Dark Data))

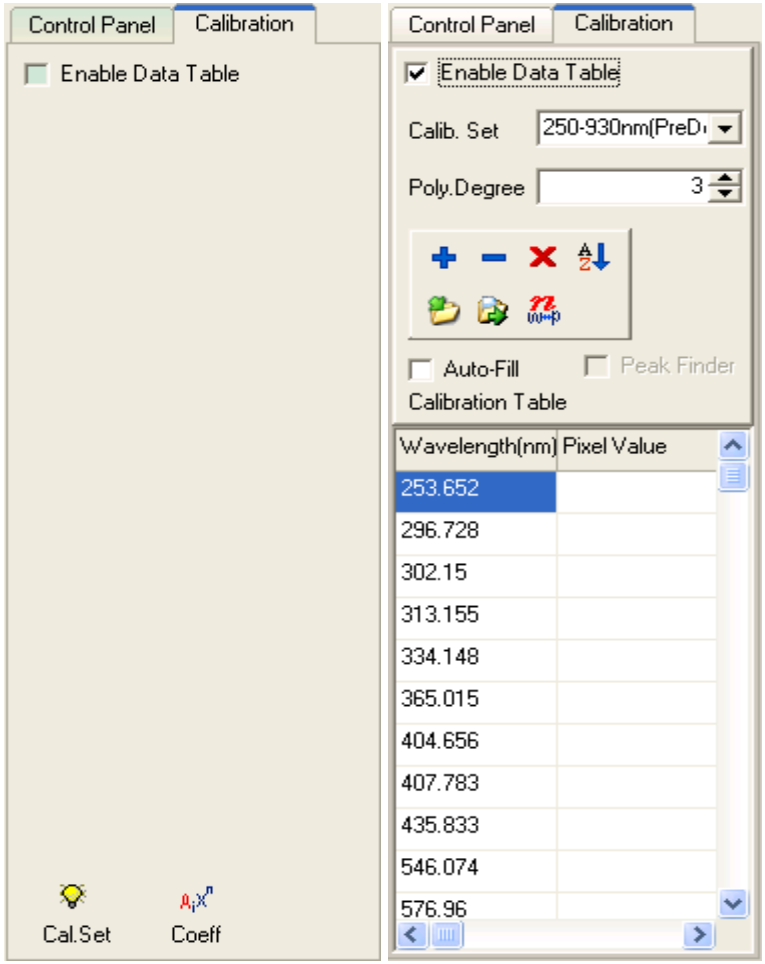
Spectrometer Control Controls the spectrometer’s exposure time and Work mode.

Exposure Time**:** This is the integrating time for each scan.

Spectrometer Work Mode: In Normal Mode, the spectrometer does the scanning whenever the software acquires the frame data. While in External mode, the spectrometer won’t do scanning until there’s an external trigger assertion, note that there must be an external hardware trigger signal input via the Din8 connector while it works in this mode. In most cases, the spectrometer should be in Normal mode only (**even with the external Trigger/pace features in “Time Line” function, user should keep the spectrometer in “Normal” mode**).

Calibration Tab

When user enters the calibration tab, the “Enable Data Table” checkbox is not checked (shown in the left side), there’re only two buttons on it. User might check the ‘Enable Data Table’ check box to enable the wavelength calibration functions (shown in the right side).



Enable Data Table : When checked, the full calibration table is visible.

Cal.Set : Open the form of wavelength set management.

Coeff : Open the form of calibration coefficients management.

Calib. Set 250-930nm(PreD : You can select the predefined wavelength set, the wavelengths in the selected set will be shown in the Calibration Table below.

Poly.Degree 3 : The polynomial degree of the fitting curve. It’s fixed to 3.

: Insert a row above; : Delete current selected row;

: Clear the ‘Pixel Value’ column of the selected row.

: sort the current calibration table by wavelength..

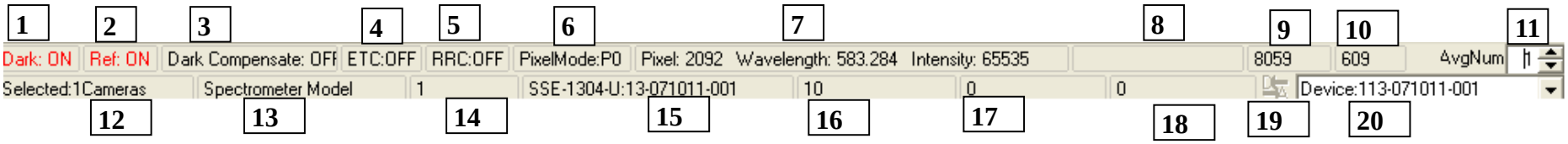
: save wavelength-pixel data to a calibration file. : load wavelength-pixel data from a calibration file.

: calculate the coefficients using least square method.

Auto-Fill : When checked, a cursor will show on the main chart which is used to help locating the position of the spectrum peak. When user single clicks the cursor, the corresponding pixel value is filled in the current row automatically. Note that user should uncheck it while doing other normal chart operations, only enable it while user wants to fill the peak pixel value

Auto-Fill Peak Finder : When the check box ‘Auto-Fill’ is checked, the check box ‘Peak Finder’ will be enabled. User might check it to activate the peak finder tool. When it’s activated, user just needs to place the cursor near the spectrum peak, the application will find the peak and automatically fill the pixel value in the table.

5). Status Bar



1: Dark Data Status: 'Dark:ON' means dark data has been loaded; 'Dark: OFF' means dark data has not been loaded.

2: Reference Data Status: ON/OFF status means reference data is loaded or is NOT loaded.

3: Auto Dark Compensate Status, refer to Auto Dark Compensate description later.

4: ETC Compensation Status.

5: RRC Compensation Status.

6: Show current Pixel mode, refer to Pixel Mode description later.

7: Current Cursor Information

8: Scan Spectrum saturation status. 'Normal' or 'Over Saturated', if it's 'Over Saturated', user must reduce the exposure time.

9: Current Spectrum Frame's Time Stamp (For technical services only) .

10: Black Pixel value, when Auto Dark Compensation is enabled, this value will be subtracted from the spectrum data. (For technical services only)

11: the average frames of each spectrum.

12: Currenttly Selected Spectrometer No.

13: The model type of current working Spectrometer

14: The working set no. of current working Spectrometer

15: The model no and serial no of current working spectrometer

16: Exposure Time

17: Trigger Event

18: Trigger Status

19: System Button, to reselect spectrometer

20: Lists of Selected Spectrometers.[1]

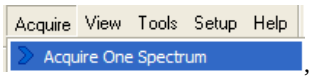
Note: the items in GRAY is reserved for factory use only

Software Operations

Acquire Spectrum

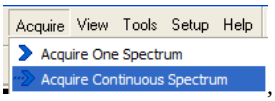
Before acquire the spectrum, user should the device is connected to the computer properly.

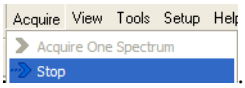
Acquire One Spectrum

By clicking the 'Acquire One Spectrum' speed button  on the toolbar or clicking the 'Acquire|Acquire One Spectrum' on the main menu 

, the Spectrometer will scan the spectrum **ONCE** and transmit the data to application.

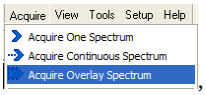
Acquire Spectrum Continuously

By Clicking the 'Acquire Spectrum Continuously' speed button  on the toolbar or clicking the 'Acquire|Acquire Continue Spectrum' on the main menu 

, the spectrometer will scan the spectrum and transmit the data to application continuously. The 'Acquire Spectrum Continuously' speed button will change to 'Stop' button  and the 'Acquire|Acquire Continue Spectrum' will also change to 'Acqure|Stop' 

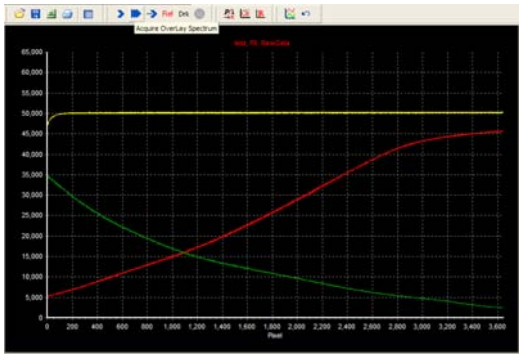
. By clicking one of them, the spectrum will stop scanning/transmitting data. And the speed button/menu item will change back.

Acquire Overlay Spectrum

When clicking the 'Acquire Overlay Spectrum' speed button  or 'Acquire|Acquire Overly Specturm' 

, multiple spectrum (up to 3) can be drawn on the same chart.

Clicking the speed button or menu item once, the first spectrum will be acquired and shown on the main chart. When clicking the button twice and third times, the second and third spectrum will be acquired and shown on the main chart. After three spectrums has been shown on the spectrum, when user clicks the 'Acquire Overlay spectrum' again, the chart will be automatically reset and the acquired spectrum will be the first spectrum again and shown on chart, the form looks like the following: (Note that the overlay spectrums are in different colors)



Acquire Dark Data

User might want to subtract the background ("dark data") from each spectrum scanning, for doing that, user should have "dark data" by doing a dark data acquiring first:

1) Make sure the spectrometer is connected to PC properly.
2) Run the application
3) Turn off the lamp or (light source), click the Drk button on the toolbar or the 'Acquire|Acquire Dark Data' on the main menu.

The spectrometer will acquire a spectrum and this spectrum will be saved into software's internal dark data array , at the same time, the spectrum is saved to the specified dark file (the file is specified in "Reference, Dark Setup" dialog box, it's described in Reference Data & Dark Data Setup) and the default dark file (dark.txt) simultaneously.

The Dark Status on the status bar will be in RED and shown as 'Dark: On' (which means the dark data array is already available). And the display option will be automatically shifted to 'Dark' which show you the dark data just acquired.

Note:

1， After acquiring dark data, you should manually change the Display option to raw or other selection if you want to display raw data or dark-subtracted data. Also note that acquiring dark data only make the dark data available (user also might load it from a pre-saved file to make the dark data available), user has to select the "dark-subtracted data" from Display Option for it to be subtracted from raw data.

2，For most accurate measurements a new dark spectrum should be taken whenever exposure time is changed.

Acquire Reference Data

In some applications, user might want to set display option is set to '%T/R' or 'Absorbance', a reference spectrum is needed. Acquiring reference spectrum data is similar to acquiring one spectrum. Reference spectrum data can be acquired by clicking the 'Acquire Reference' speed button Ref on the toolbar or the 'Acquire|Acquire Reference Data' on the main menu.

Similar to the "Acquire Dark Data" above, the reference data array will also be saved to specified reference file and default reference file.

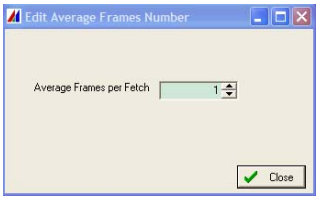
After reference spectrum data has been acquired, the display option will be automatically set to 'Reference', and the reference data status on the status panel will be shown 'Ref: ON' in red.

Note: you should manually change the Display Option to raw or other selection if you want to display raw data or other data.

Edit Spectrum Average

For each spectrum acquiring, user might want to get average spectrum data from multiple frames. For doing that, user might set the average number more than 1, for example, if user sets the average number to 2, the spectrometer will actually acquire 2 frames and get the average of these two samples to be one spectrum. The averaging number can be edited in two ways:

- By AvgNum 1 in the right corner of the status bar.



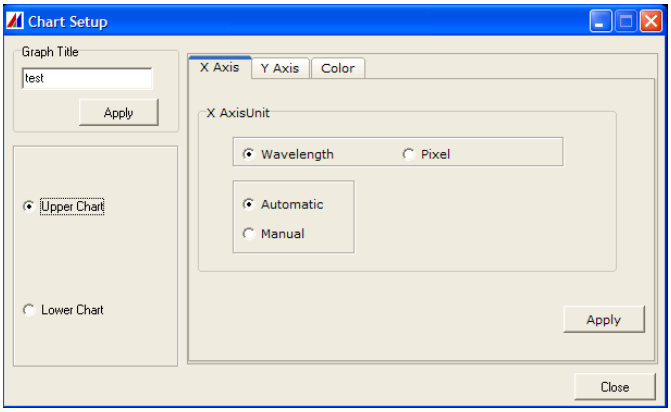
- A dialog box 'Edit Average Frames Number' is shown as right by the 'Edit|Average Factor' menu item. User can set average number on it.

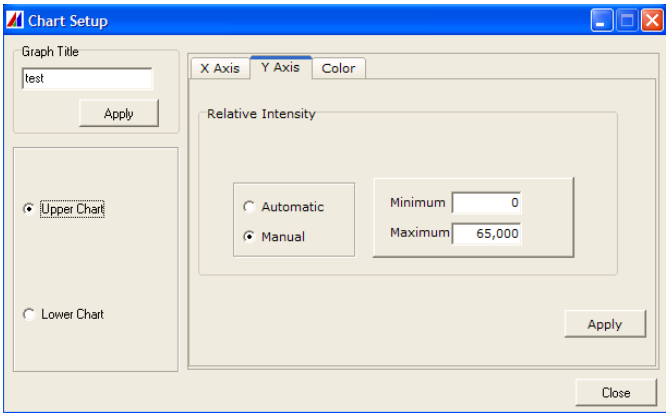
Customizing Chart

User can customize the main and bottom chart on 'Chart Area' in the 'Work Area' via the 'Chart Setup' form which will show up by clicking the 'Setup|Setup Chart' menu item.

User can edit graph title in the 'Graph Title' group, which will take effect for both charts.

The left side radio group allows you to choose the chart you want to edit.



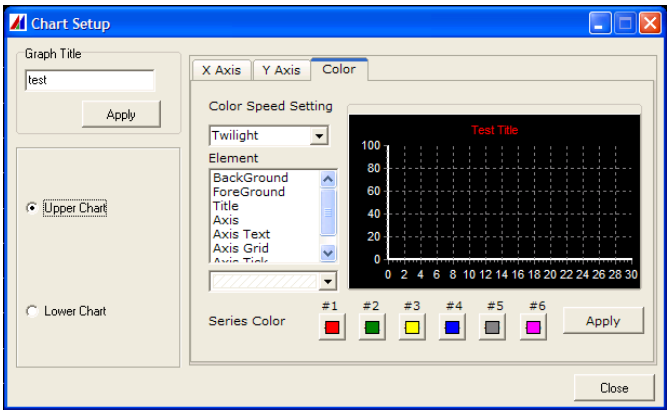


For each chart, user can edit its abscissa, ordinate, and the color of each element.

Abscissa: the unit of the x-axis can either be the wavelength or pixel. For each of them, user can choose to let the application define the minimum and maximum of the x-axis(automatic) or edit them manually. By choosing automatic, the application will define the minimum and the maximum according to the spectrum data. By choosing manual, an edit panel will be shown to allow you to edit the minimum and maximum value of the x-axis.

Important: Abscissa Edit mode will only be available when the Pixel monitoring mode is at P0, at other pixel monitoring mode, the abscissa will not be allowed to be edit. (refer to the details of Pixel Monitoring mode later)

In this application, this software only implements the relative intensity. So the unit of the Y-axis is fixed.

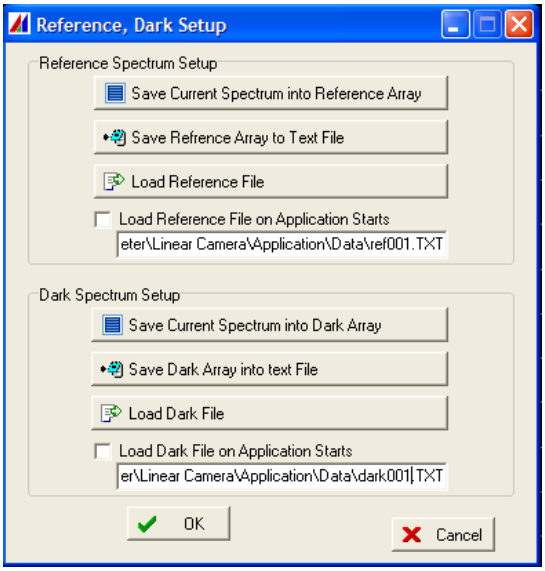


Color: In this tab, user can edit the color of the chart element, including background color, foreground color, chart title color, axis color, axis text color, axis grid color, axis tick color and the series color.

For the upper chart, there're six series which are used for overlay spectrums and P4/P5 mode, user can set the color for each series.

Reference Data & Dark Data Setup

User might save the current scanning spectrum data as dark or reference data, and later on, user might load the pre-saved dark or reference data file back, user can do all those operations by clicking the 'Setup|Reference,Dark Setup' menu item, which shows the 'Reference, Dark' Setup dialog box as following:



'**Save Current Spectrum into Reference Array**': after user gets the spectrum data, user might set the current spectrum (the first spectrum if it's overlay spectrum acquiring) as the current reference data by clicking this button.

'**Save Reference Array to Text File**': Clicking this button will pop up a 'save as' dialog, which allows user to save the current reference data to a reference file.

'**Load Reference File**': Clicking this button shows an 'open' dialog, which allows you to load a pre-saved reference file as current reference data, and the file name is shown in the edit box below.

The 'Load Reference File on Application Starts' checkbox allows user to choose whether or not to load the reference file automatically when user starts the application.
The bottom edit box lists the current reference file. When the check box is checked, the application will load the file specified here. If this box is empty, the application will load the default file if it's available (As while user does a reference data scanning, the software also save the reference data to a default file).

The '**Dark Spectrum Setup**' part has the same functions as the '**Reference Spectrum Setup**' part.

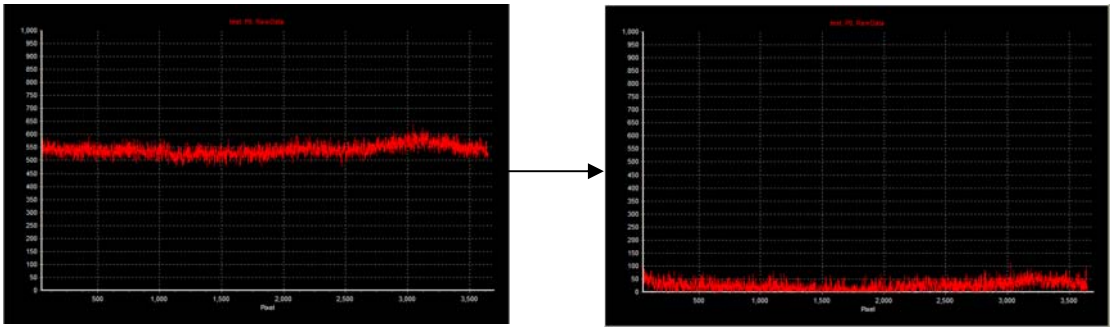
IMPORTANT: When software starts, it will load dark and reference spectrum according to the settings user set in this dialog box. If the "Load Reference File On Application Starts" (or "Load Dark File On Application Starts') is not checked or if they're checked but the specified files are invalid, software will try to load the default files which are under the 'appdata' (".\appdata\ModuleNo_SerialNo\ref.txt" and ".\appdata\\ModuleNo_SerialNo\dark.txt files"). If those files doesn't exist or are invalid (e.g. for the first time running of the application), software won't load the files.

Dark Compensation

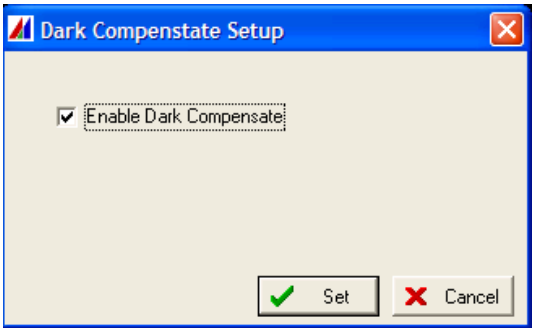
As the CCD sensor has electronic noises even in the total dark environment, the scanned data are usually not zero. These readings can be called “electronic dark data”, These data are almost equal in the whole pixel range if the spectrometer is not over saturated.

By dark compensate, the electronic dark data can be subtracted from all spectrum data.

The spectrums scanned in the dark field with and without dark compensate show in the following, left spectrum is without dark compensation and right one is with dark compensated.



Dark compensation can be enabled by clicking ‘Acquire|Dark Compensate’ menu item, the ‘Dark Compensate Setup’ form is shown which allows you to enable or disable the automatic dark compensation.

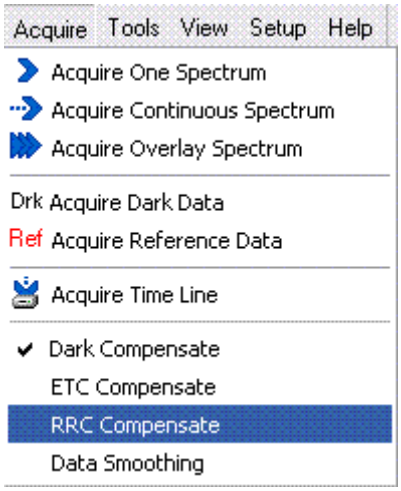


Note: *While ‘Dark Compensation’ is enabled, it’s a “Global” setting for all scannings, for example, if it’s enabled while grabbing dark or reference spectrum, the dark or reference spectrum data are also subtracted by the “electronic dark data”. This also implies that in most applications, user should set this setting (enable or disable) prior to all other operations such as getting dark/reference data, and getting the normal spectrum data, changing this setting usually needs user to re-scanning the dark/reference data.*

RRC (Relative Radiometric Calibration) Compensation

If the RRC calibration was done with a highly stable calibration source,, the calibration file ("RRC.cal") is under the \App_data\ModuleNo_SerialNo sub-directory, for user to enable the RRC compensation, user can do:

1. Select RRC Compensation in the Acquire menu of the spectrometer main window.



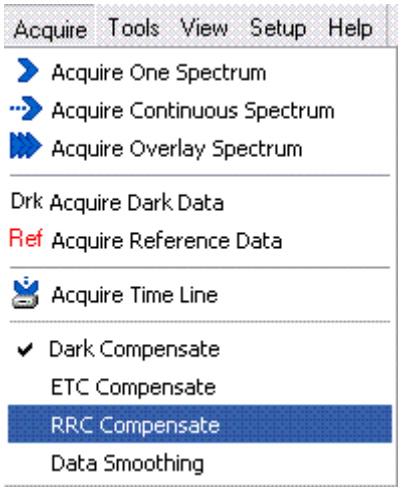
2. Select *Calibrated Data* option on the left panel under Display Option. Calibrated spectrum will now be displayed.

For details of RRC, please refer to the "RRC Compensation Details" below.

ETC (Exposure Time Calibration) Compensation

If the ETC calibration was done with a highly stable calibration source, the calibration file ("ETC.cal") is under the \App_data\ModuleNo_SerialNo sub-directory, for user to enable the ETC compensation, user can do:

1. Select ETC Compensation in the *Acquire* menu of the spectrometer main window.



2. Select *Calibrated Data* option on the left panel under Display Option. Calibrated spectrum will now be displayed.

Note: When user enables "RRC Compensation", "ETC Compensation" is enabled automatically, However, when user disables "RRC Compensation", "ETC Compensation" will NOT be disabled, user has to explicitly disable it if needed.

Important: When RRC Compensation or ETC Compensation (Or both of them) are enabled, the spectrum data from the spectrometer will be corrected with the RRC or ETC calibration data, when user chooses "Calibrated Data" in Display Option, the corrected spectrum will be displayed. User might select "CCD Raw Data" to display the raw spectrum which is read from the spectrometer.

When RRC/ETC is OFF, "CCD Raw Data" is essentially the same as "Calibrated Data".

If user uses "Dark Subtracted" or "%T/R"…etc., user should get Dark or Reference spectrum first, please note that after user change the RRC or ETC options, user should get Dark and Reference spectrum under the current compensation options.

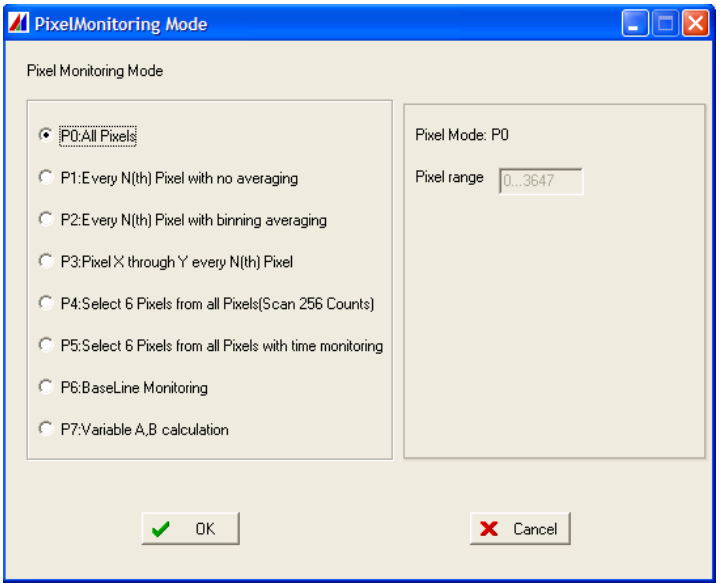
Pixel Monitoring Mode

Introduction.

Although the software acquires frame data from all pixels, but the application provides user options to view those data in different formats. There are totally 8 pixel monitoring modes user can choose.

You can click the 'Setup|Pixel Monitoring Mode' menu item, and the 'pixel monitoring mode' form will show up as following:

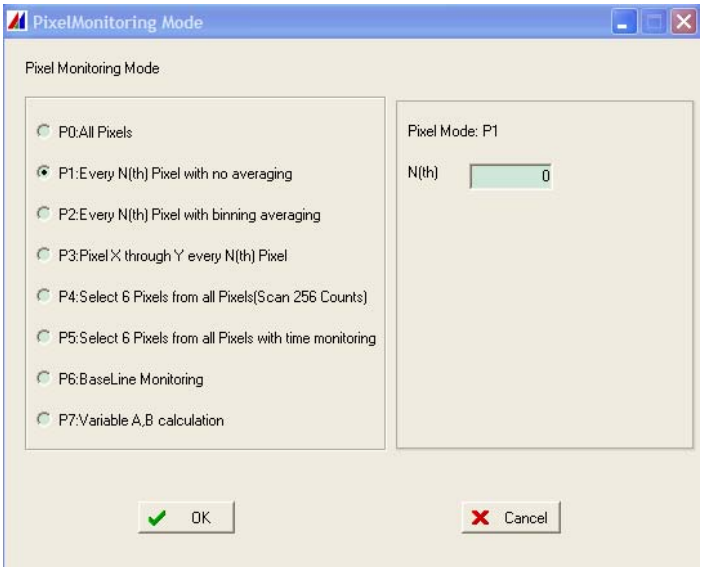
Pixel Monitoring Mode: P0



It this mode, the application will show all the pixel data on the chart, and user might choose the unit of x-axis as pixel or wavelength (if the device is calibrated).

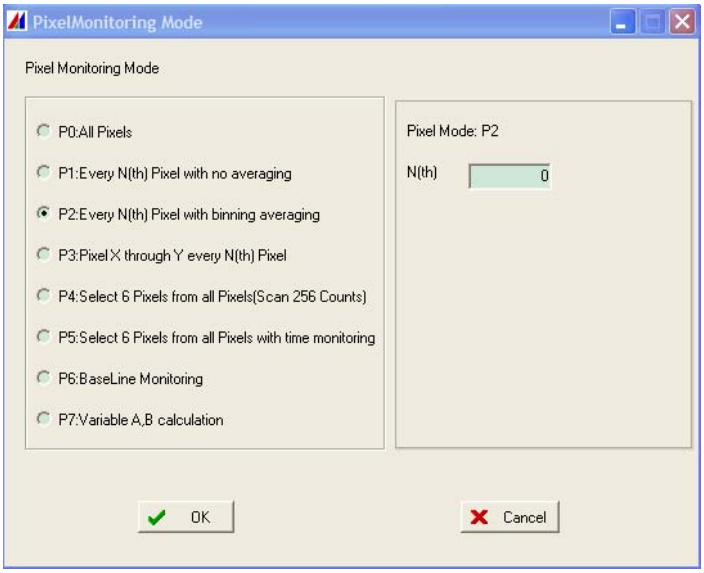
The Pixel range on the right side always shows the maximum pixel range of the spectrometer.

Pixel Monitoring Mode P1:



In this mode, the application will show the pixel data every N(th) pixel.

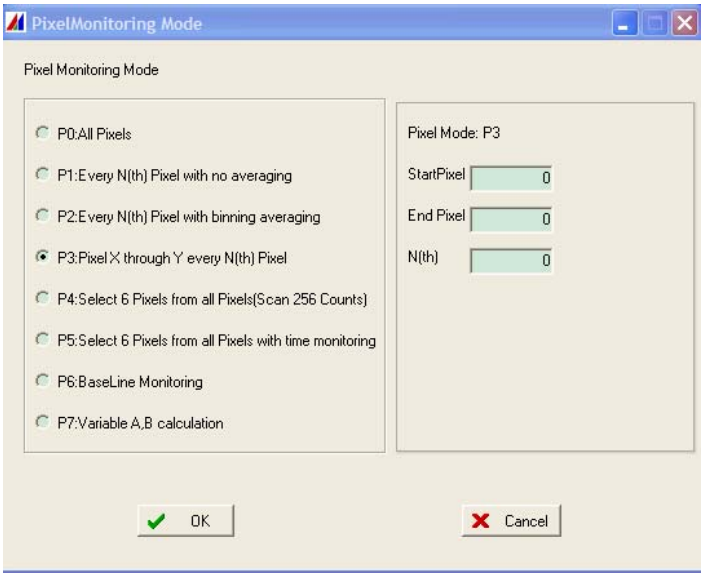
Pixel Monitoring Mode P2:



In this mode, the application will show pixel data every N(th) pixel, the N(th) pixel value is the arithmetic averaging value between from N(th) to N+N-1(th). That is:

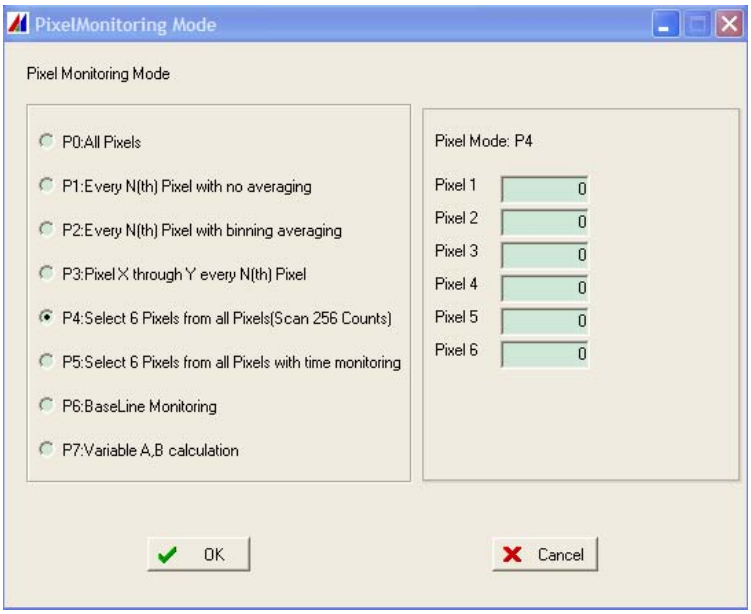
N(th) := [(N)th+(N+1)th+(N+2)th+(N+3)th+…+(N+N-1)th] / N

Pixel Monitoring Mode P3:



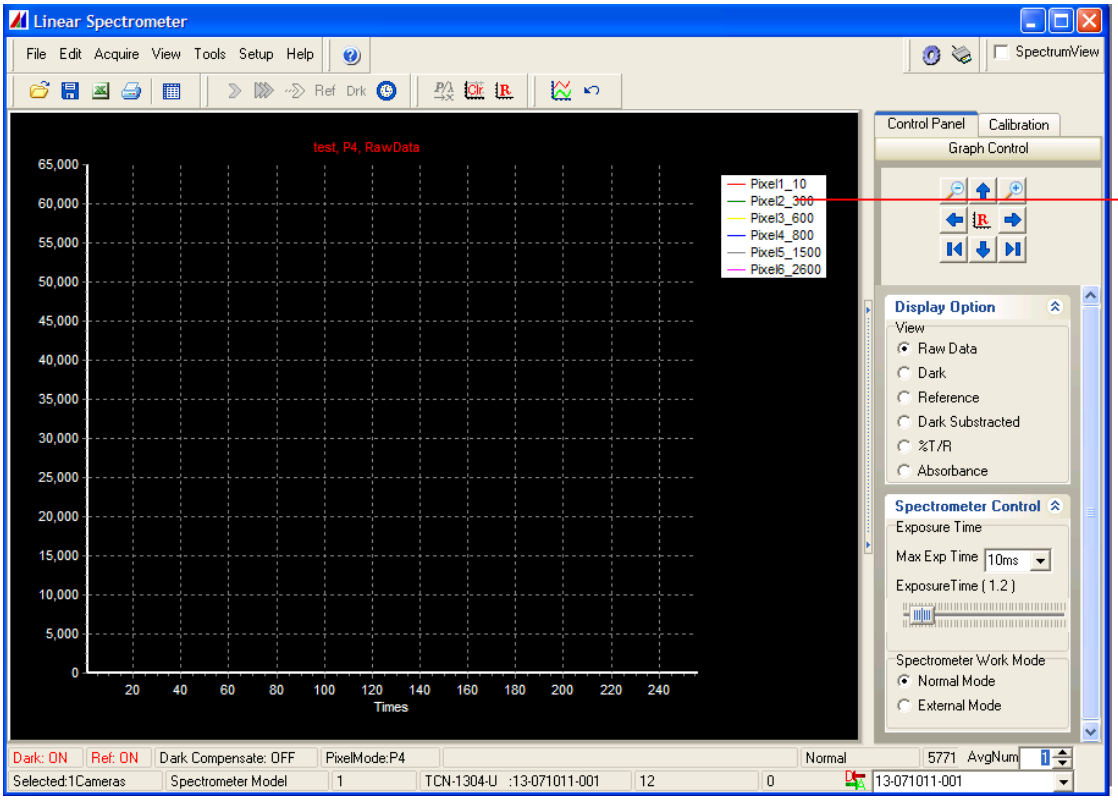
In this mode, the application allows you to view a section of pixel range by editing the start pixel number and end pixel number. Also, by editing the N(th) edit box, you can choose to view the pixel data every N(th) in the range defined by Start Pixel and End Pixel.

Pixel Monitoring Mode P4:



In this mode, the application allows you to choose specific 6 pixels to view their data in 256 scans.

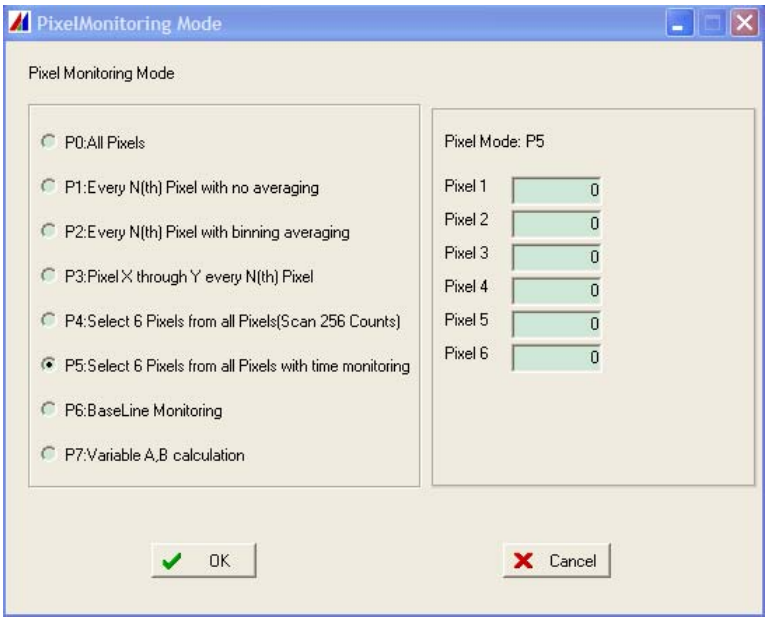
After you clicking 'OK' Button to accept the selection, the control goes back to main application and the UI will be changed to the following graph:



The 'Monitor Pixels by Time' button  is available in this pixel mode (and for the following P5, P6 and P7 mode), the other acquire action buttons are disabled. The main chart title has been change to show the current pixel mode (e.g. P4), and the legend of the main chart depicts the selected 6 pixels differentiated by the series color. At the top of the status bar, the pixel mode status also show the selected pixel mode. By clicking the 'Acquire time

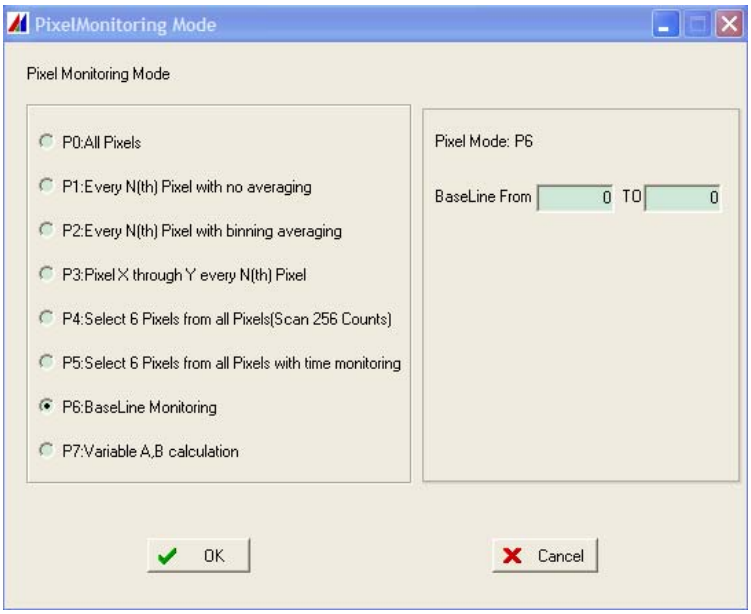
Line' button, the application will scan these selected 6 pixels for 256 times.

Pixel Monitoring Mode P5:



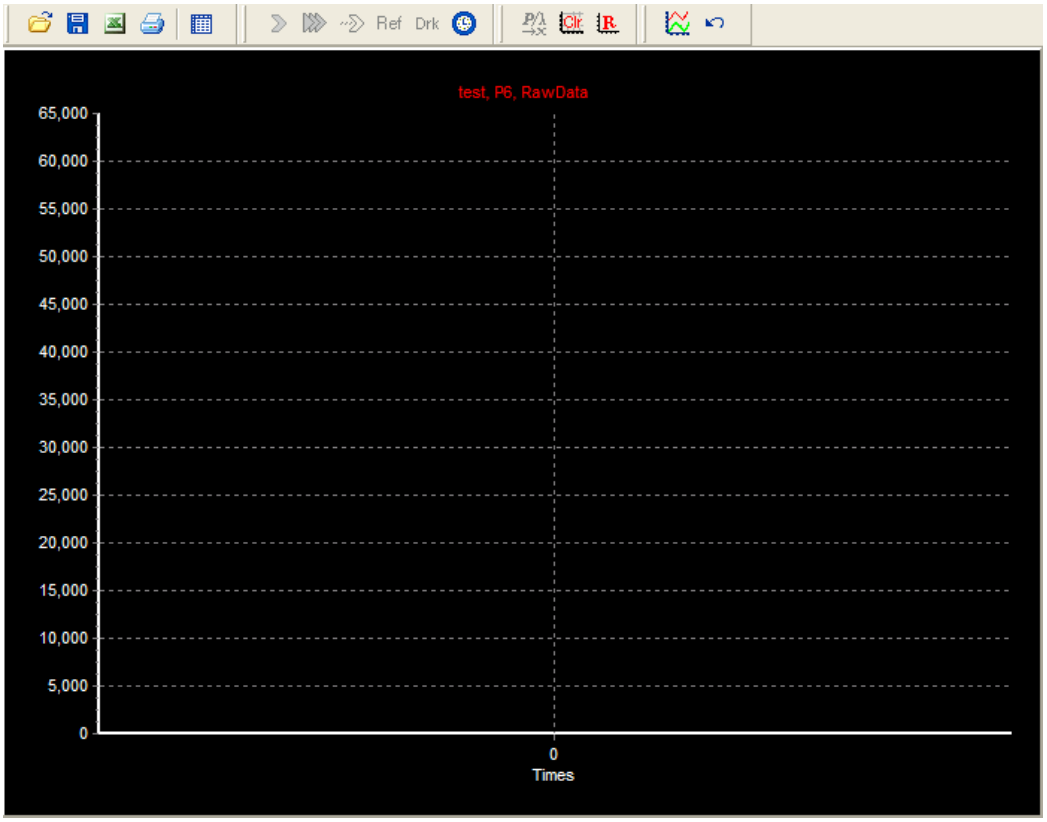
This pixel monitoring mode is similar to P4 mode, except that its scanning process is continuous until user stops it. (Note: the software will stop it if the scanning count goes to very huge, otherwise there might be issues due to limited PC resources).

Pixel Monitoring Mode P6:



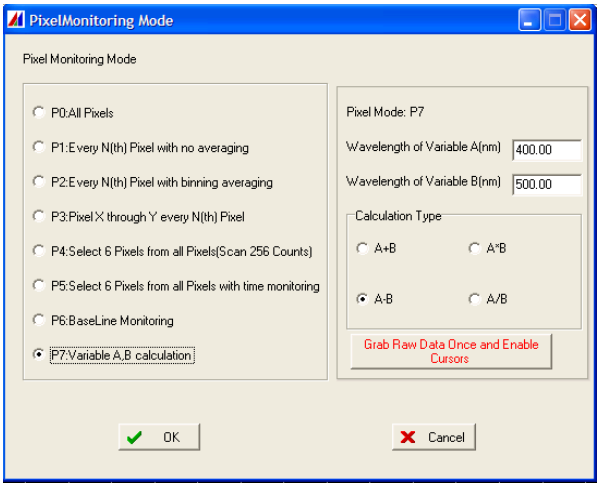
In this pixel monitoring mode, the application allows user to specify a range of the pixel number and will calculate the arithmetic average value of these pixel data. The result will show in the main chart as function of time. The scanning is continuous until user stops it.

Click 'OK' Button to accept the selection and settings. The control will go back to main application and the UI will be changed to the following:



The 'Monitor Pixels by Time' button  is enabled and other acquiring buttons are disabled. By clicking this button, the application will continue to show the specified pixel average until user stops it.

Pixel Monitoring Mode P7:



In this mode, the application allows you to choose two wavelengths at which the scanning data are calculated in the form of the selected calculation type. The result will be monitored continuously until user stops it.

In the two wavelengths edit box, you can manually input the wavelengths.

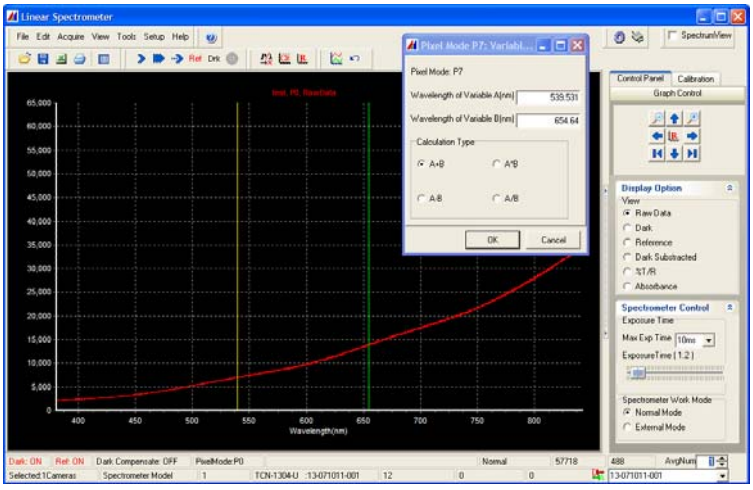
Calculation type allows you to choose the calculation method of these two wavelengths' data.

For the two wavelengths, you can manually input them in the edit boxes as shown above (400.00 and 500.00) or use the application to position the wavelength.

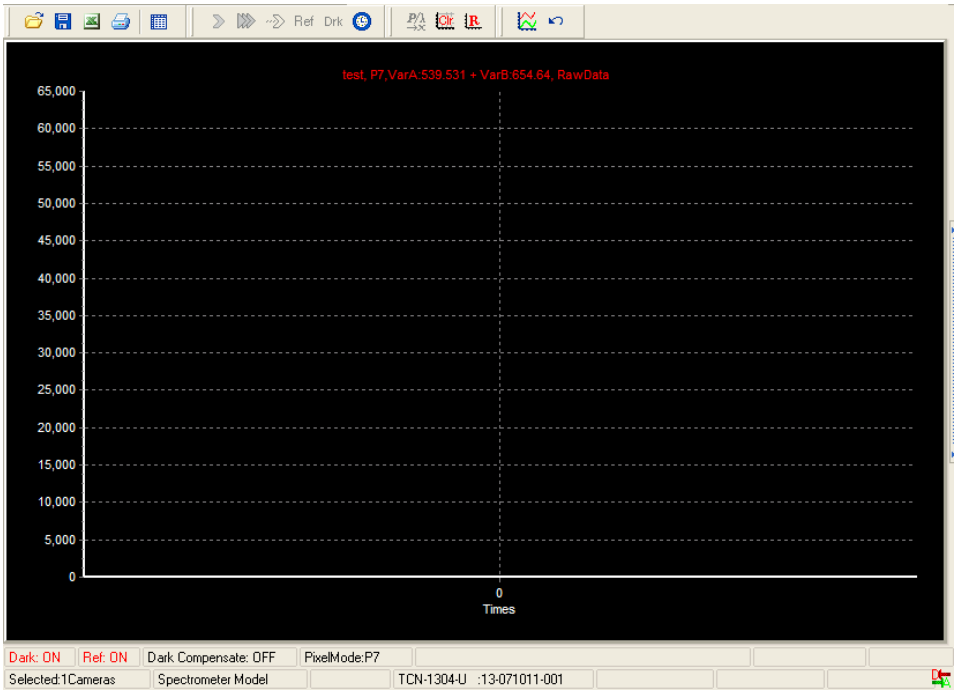
By clicking the button 

, the application will open a form called 'Pixel Mode P7: Variable AB', at the meantime, two cursor lines are visible on the main chart, the unit of abscissa of main chart will be automatically set to wavelengths, and the position of the these two cursors will be directed shown on the two edit boxes 'Pixel Mode P7: Variable AB'.

User can fetch one spectrum raw data by clicking the 'Grab One Spectrum…' button. And you can drag the two cursor lines to set the wavelengths. After two wavelengths have been set, choosing the calculation type, and click the 'OK' button to close the form 'Pixel Mode P7'.



After user have chosen pixel mode P7, selected the two wavelengths and calculation type, the main chart will looks like:



The ‘Monitor Pixels by Time’ button  is enabled and the other acquire buttons are disabled. The Pixel mode status on the status bar will be changed to ‘Pixel Mode:P7’.

The chart title will show the two wavelengths and the calculation type. The unit of X-axis of the main chart will be changed to ‘Times’.

By clicking the ‘Monitor Pixels by Time’ button  , user can monitor the variable calculated by the two wavelengths continuously until user stops it.

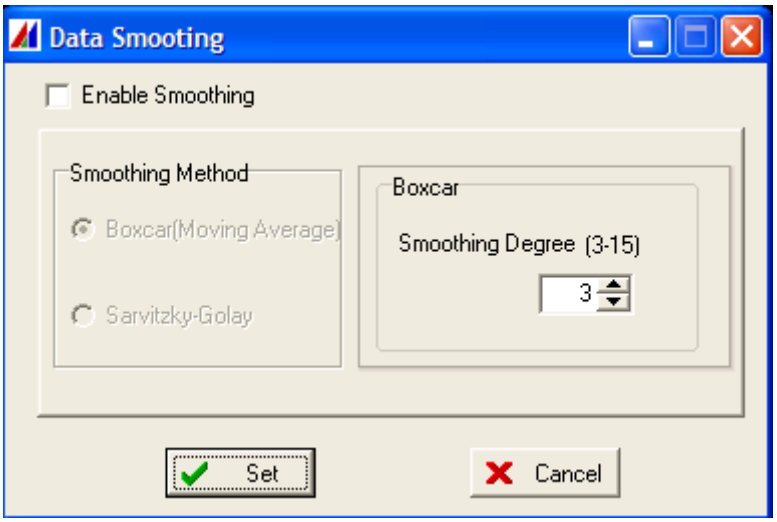
Note: As Pixel Mode 7 is based on wavelengths, user can only select this mode after the wavelength calibration is done.

Smoothing

Smoothing function can be used for spectrum data processing. (For P0, P1, P2 and P3 Pixel modes only)

For using smooth function, user has to enable it by Check the 'Data Smoothing' checkbox on the 'Data Smoothing' dialog box, which is show up by clicking the 'Acqure|Data smoothing' menu item, additionally, user must make the 'Curve smooth' toolbar visible via the tool bar visibility control. (Under the 'View|Tool bar' menu item)

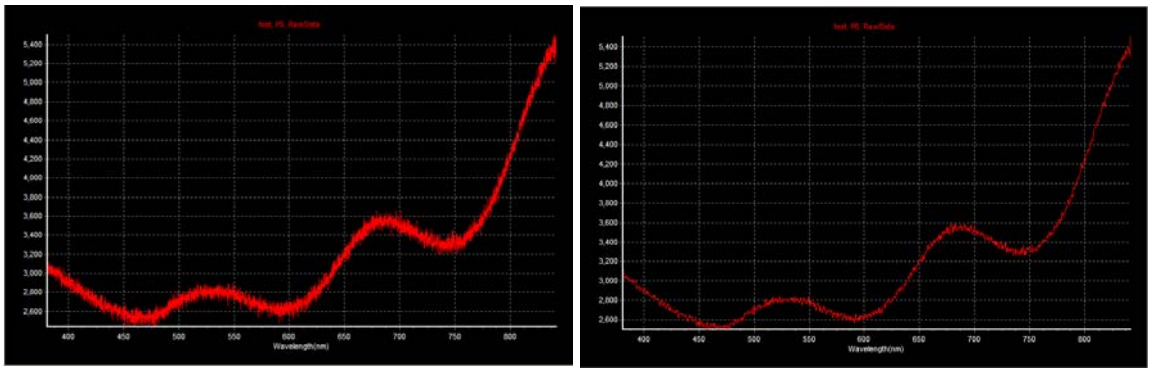
After user checks the 'Data Smoothing', a 'Data Smoothing' Form will be visible.



By enable the 'Enable Smoothing' Check box, user can choose the smoothing type between 'Box Car' method or 'Savitzky-Golay' method, in the right panel, user can edit the parameter of the selected smoothing method.

After user clicks 'Set' button, the 'Smooth Panel' on the toolbar is visible as  .

By clicking the 'Apply Smoothing' button  , user can smooth the current spectrum using the selected method. And user can use the 'Undo smooth' button  to recover the spectrum data.



The upper left spectrum is the raw data, the right spectrum is the data has been smoothed using the Savitzky-Golay method.

Time Line:

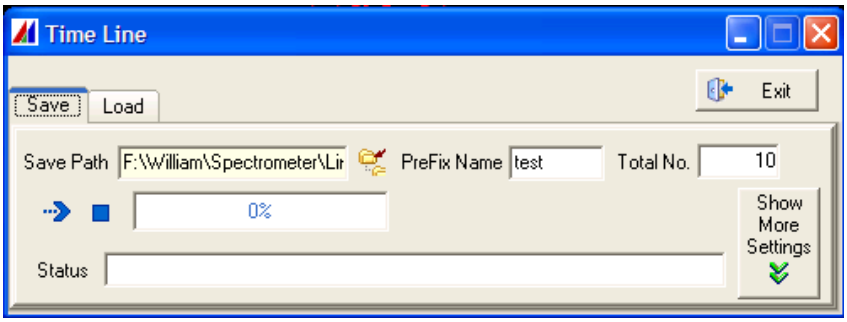
Notes: Acquire timeline can only be available at the pixel monitoring mode ***P0.***

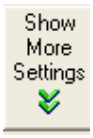
Application allows user to continuously grab the spectrums in predefined moments and save them into disk.

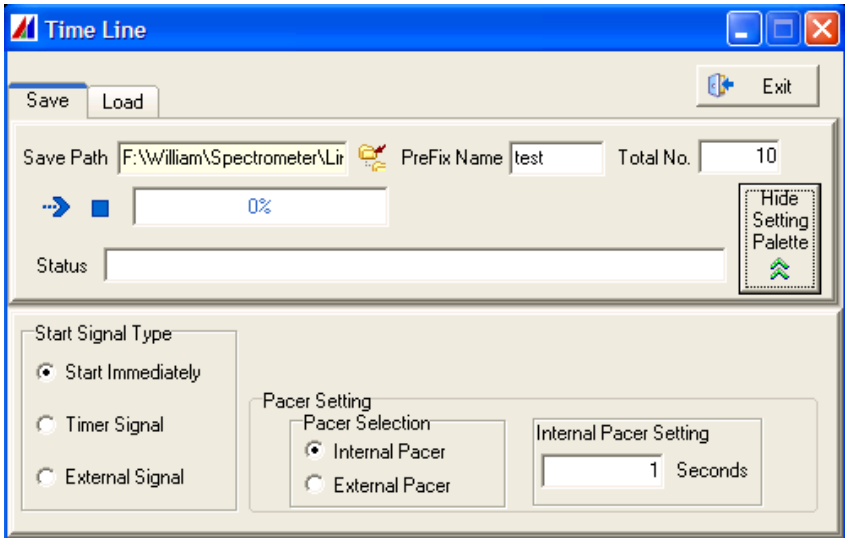
In the pixel monitoring mode P0, the 'Acquire|Acquire Time Line' menu item is enabled. When user clicks it, a 'Acquire Time Line' dialog box is shown as following.

The form has two tabs, one is for the settings of saving data and the other is for the settings of loading data.

Save Data:



The button  reveals additional settings that will be shown when user clicks it.



Save Path: By clicking the button  , user can choose a directory in which the grabbed spectrum data are stored.

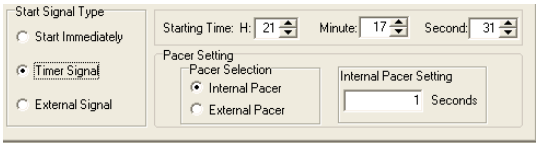
Prefix name: in this edit box, user can choose the prefix of the saved file name. Provided the name is 'test', then the saved file name for the n_{th} fetching data is test_n.txt under the saved path.

Total No: total number of the fetch spectrum.

At the bottom panel, user can choose the start signal type and pacer type which are described later.

After all settings have been set, click the button  , the spectrometer will start to fetch the Total No

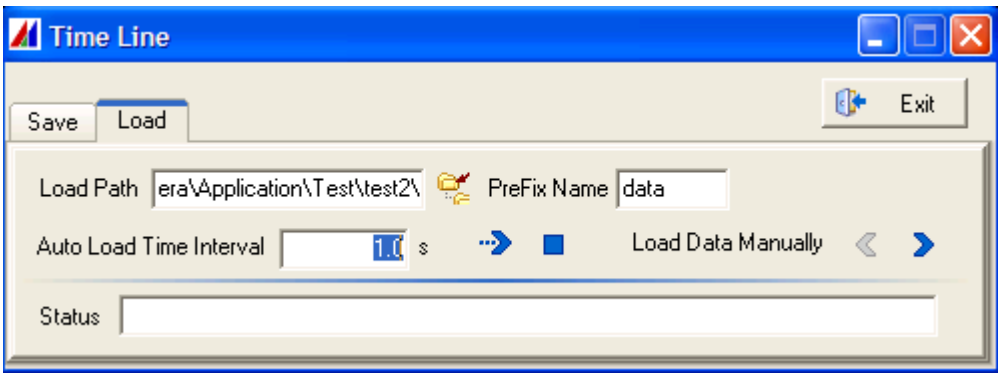
spectrums with the selected start signal and pacer. The status of the fetching will be shown on the Status edit box.

Start Signal	Pacer Type	Description
Start Immediately	Internal Pacer	The spectrum will be grabbed immediately when you click the Start button, and the sequential grabbings are controlled by the internal pacer. The internal pacer interval can be edited in the box 'Internal pacer setting'.
Start Immediately	External Pacer	The spectrum will be fetched immediately when user clicks the start button, but the actual spectrum grabbing can only be triggered by the external trigger signal.
Time Signal	Internal Pacer	After choose the time signal as the start signal, the start time panel will be visible in the right.  The spectrum will be grabbed when the timer reaches the time user sets after you click start button. And the following grabbing will be controlled by the internal pacer.
Time Signal	External Pacer	Similar to the above one, the grabbing is started at the time setting by user, but actual grabbing can only be triggered by the external trigger signal.
External Signal	Internal Pacer	At this setting, the spectrum will be grabbed when the one external signal has been detected after you click start button. The sequential grabbing are controlled by the internal pacer, the external signal is ignored for all the sequential fetches.
External Signal	External Pacer	The first spectrum grabbing will be initiated when an external signal has been detected after you click start button, the sequential grabbing also controlled by the external pacer. (Actually, it's the same as the Start Immediately/External Pacer)

*. For internal pacer, user can set the pacer, however, if the pacer is smaller than the one spectrum time (e.g. if user set exposure time to 100ms and average frame number to 4, the minimum spectrum time is 400ms), the software will use the minimum frame time instead internally.

IMPORTANT: For all time line features, including the 'External Signal' starting and 'External Pacer', user should set the camera mode to 'NORMAL', it's **NOT** necessary to set mode to 'EXTERNAL'. And user should set the Frame average number to 1, as the device only generates one frame upon each trigger.

Loading Data:



Load Path: select the directory from which the spectrum data will be loaded.

Prefix Name: Edit the prefix of the loaded file.

Auto Load Time Interval: edit the timer interval to load the files.

: Load the data continuously according to the timer.

: Stop loading the time

: Load the file manually.

Note that while 'Auto Load Time Interval' is set, and user clicks , the files will be loaded one by one in the setting time interval, user might observe the spectrum in the main chart, and the loading progress is shown on the Status bar.

Wavelength Calibration

Before doing the wavelength calibration, make sure:

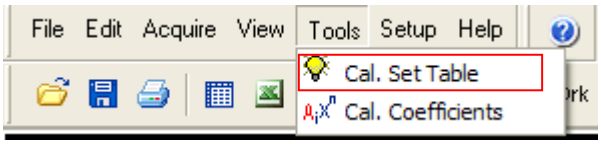
- Connect the spectrometer you want to calibrate to computer and start the application.
- Have a lamp or light source with peaks on known wavelengths and those peaks should properly cover the spectrometer wavelength range.
- Connect the light source or lamp to the spectrometer.

Setup Wavelength Table

Before starting to do wavelength calibration, user might want to define a wavelength set which contains multiple wavelength points, and user can give it a set name, which can be used later on wavelength calibration. The 'Calibration Setting' box is for this operation.

There are two ways to show 'Calibration Setting' box:

- Click 'Tools|Cal. Set Table' menu item;

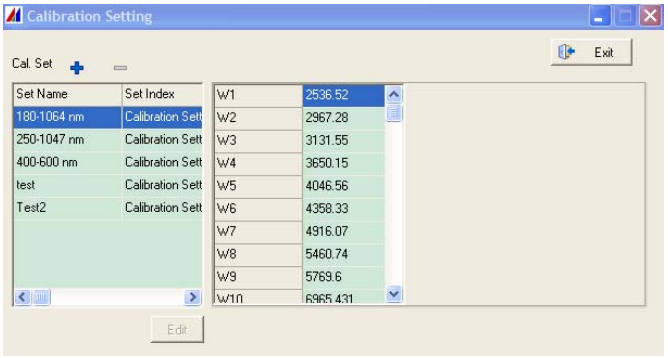


or

- In 'Calibration' Tab, uncheck the box 'Enable Data Table'. At the bottom of this Tab, Click

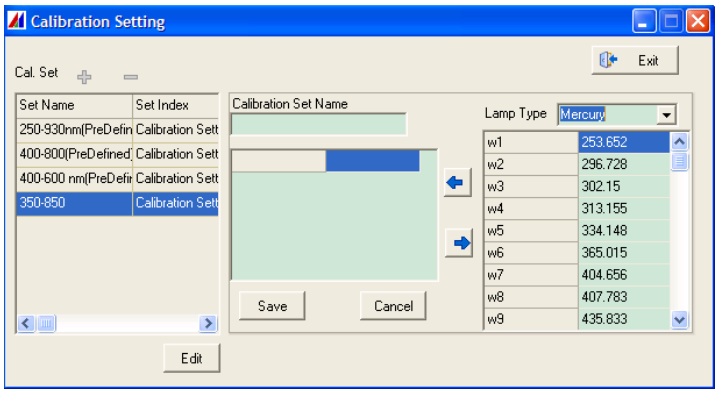
Button.

The 'Calibration Setting" box is as following:



The Left side table lists the existing Wavelength sets, the table in the middle shows the wavelengths of the selected wavelength Set. By Clicking Plus sign button, you can create a new wavelength set. By Clicking the Minus Sign Button, you can delete the current selected wavelength Set. Note that the first 3 wavelength sets are predefined which editing is NOT allowed, the following sets are customer defined, so while user selects those customer defined sets, the [Edit] button is enabled to allow user to edit the wavelengths in this set.

After Clicking Plus Sign Button (or the [Edit] button on a customer defined set), the 'Calibration Setting' Form will change to the following:

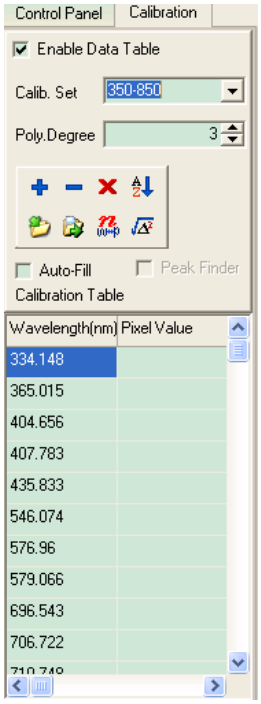


User can input the name of this new wavelength set in the edit box below 'Calibration Set Name'.

You can choose the lamp type from the pull-down list box, there're two predefined lamps, the table below lists the characteristic wavelengths of the selected lamp you have chosen. By double clicking a certain wavelength, or clicking the  button after choosing a certain wavelength, this wavelength is added to the wavelength set. For a certain wavelength in the set, user might use the  button to remove it from the set. (Note, user might also manually edit the wavelength value)

After proper adding of the wavelengths, click 'Save' Button to save your settings, the new added wavelength set is added to the existing set table on the left.

Wavelength Calibration



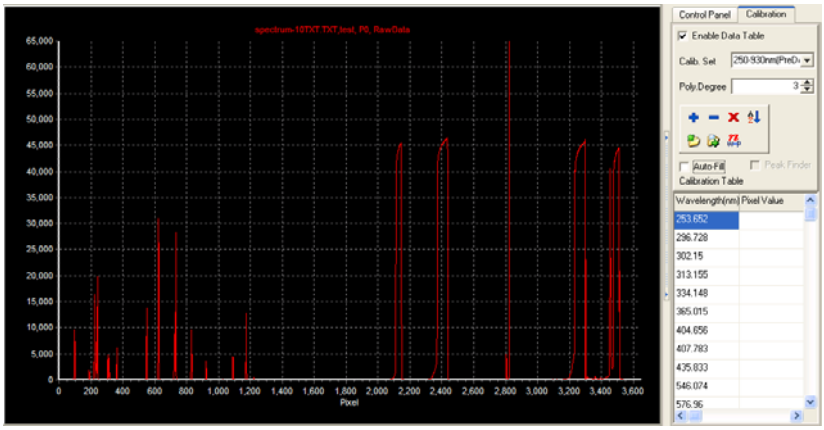
Note: The wavelength calibration here adopts the polynomial equation to express the relationship between 'pixel number' and 'Wavelength' in the form of (the max poly degree is 3):

Wavelength(nm)= A0*Pixel+A1*Pixel^1+A2*Pixel^2+A3*Pixel^3.

After the pixel no. and related wavelength has been defined, the application using least square error method to find the best coefficients.

1) Acquire a 'Raw Data' spectrum when light source is ON
   - Run the Application.
   - Must set to P0 mode
   - Change the unit of the abscissa of the chart to Pixel.
   - Select 'Raw Data' in the "Display Option" on the "Control Panel".
   - Click "Acquire One" Button to scan one spectrum.

2) Select 'Calibration' Tab in the 'control area', and check the 'Enable Data Table' checkbox. The 'calibration' Tab will show the content as the right. The pull-down list in the right side of 'Calib. Set' lists the predefined wavelength sets described above. Choose a Calib. Set, and select Polynomial degree (default is 3, which means totally four coefficients will be calculated, currently, the degree is fixed to 3). As the light source is turned on, so we will get the following chart:



3) Activate the cursor on spectrum by checking the ‘Auto Fill’ check box.

4) Place the cursor on one spectrum peak which is corresponding to the wavelength selected in the right calibration table. Clicking the cursor, the relative pixel value will be added to the corresponding pixel value cell. Usually, user should do:

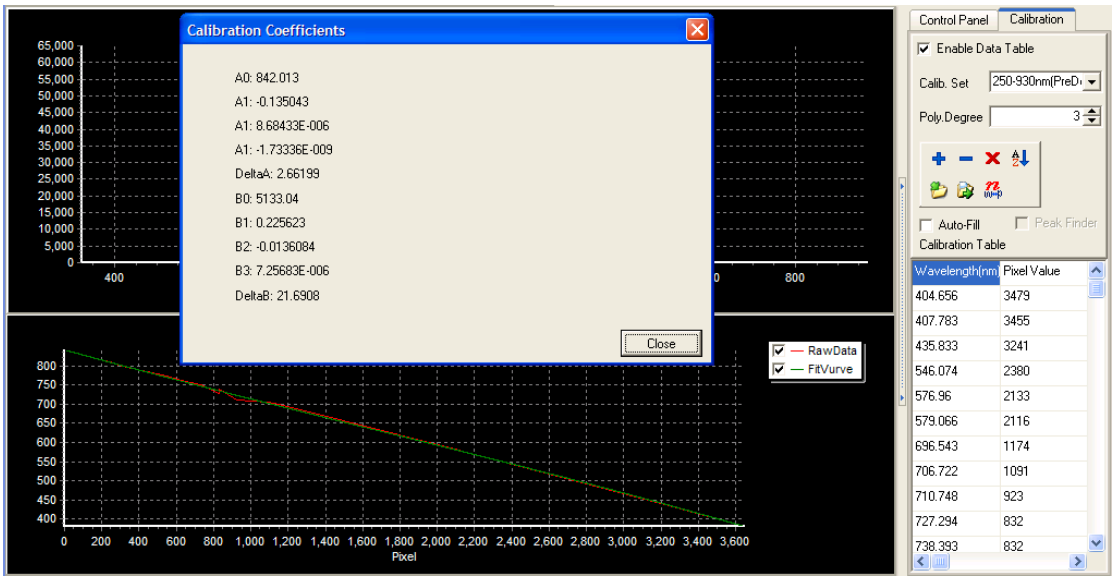
   a) Select a wavelength on the table

   b) Enable the ‘Auto Fill’ checkbox

   c) Moving the cursor to the peak which is corresponding to the wavelength selected in step (a) and click. The pixel value will be filled automatically on the space beside the wavelength in the table.

   Note: If we want the software to find the exact pixel value of the peak, you might check the ‘Peak Find’ checkbox and move the cursor near the peak and click, the software will find the peak for you and auto-fill the table. ‘Peak Find’ check box is an One-Shot function, you have to check it for each peak.

5) After you have finished filling the calibration table. You can click the calc. curve fitting button  , the software will calculate and try to find best coefficients. If you enable the bottom chart (by check the spectrum view check box on the tool bar), the original wavelength-pixel graph and the fitted wavelength-pixel graph will show on the bottom chart. And an additional message box will show the calculated coefficients and also the errors as following:



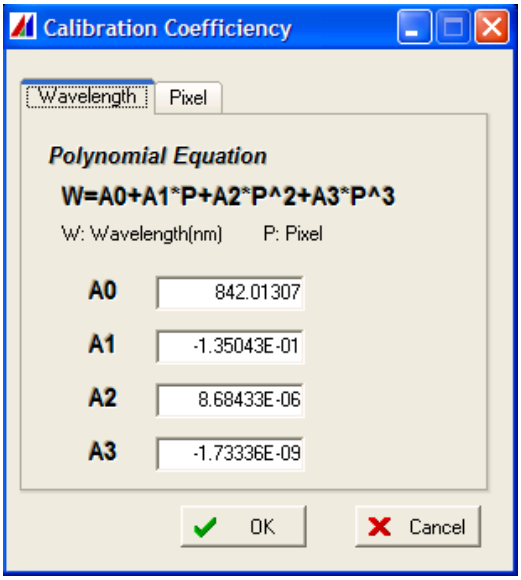
Note: *while user shows the fitting curve on bottom chart, its bottom axis will be forced to be in 'Pixel' unit, if It was in 'Wavelength' unit previously, user might have to use the*  *button to let the bottom chart to show spectrum in wavelength mode correctly.*

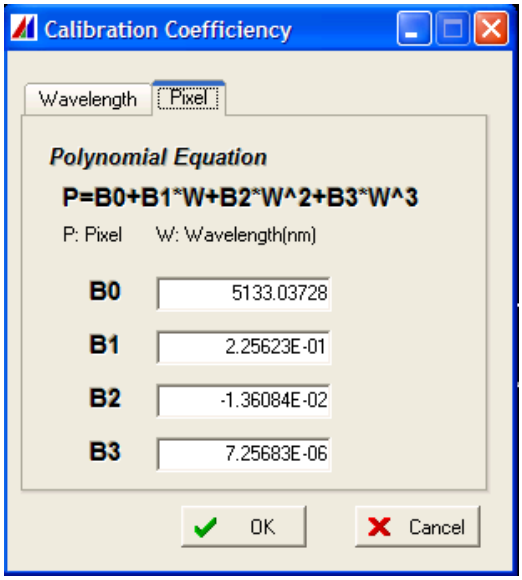
6) User should save the calibration coefficients by click the  button, this will let software to store those parameters in a specified file. And later on, user might manually load calibration parameters back by clicking  button.

Note: *Usually user does NOT need to load it manually, as after wavelength calibration, the software will store the calibration coefficients in "para.ini" file and automatically load them back while the software is started.*

Manually input Wavelength Calibration Coefficients

After the curve fitting, the fitted coefficients are automatically saved to the spectrometer's parameter file. If user wants to manually fine tune the coefficients user might open the calibration coefficients form by





clicking the "Tools|cal. Coefficients" menu item.

In this form, user can view the two fitted functions coefficients: from pixel to wavelength and from wavelength to pixel. User might fine tune the coefficients by manually input new coefficient, and after changes are made, user has to restart the application for them to be effective.

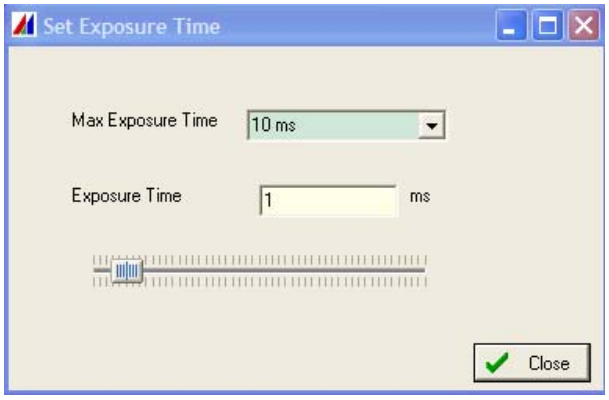
Note: This feature is mainly for technical services only.

Spectrometer Control

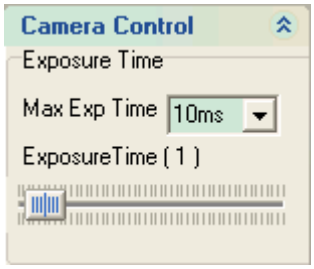
Change Exposure Time

There are two ways to change the integrating time of the current spectrometer.

- Through the additional form 'Set Exposure Time' by clicking the 'Edit|Exposure Time' menu item, the form is as following:



- By sliding the tracking bar in the 'spectrometer control' group on the 'control panel' tab.



These two methods are identical. The 'Max Exposure time' combo box allows you to choose the maximum exposure time of the tracking bar. User might drag the slide bar or edit the exposure time (on the 'Set Exposure Time' dialog box only). The new exposure time will be effective immediately.

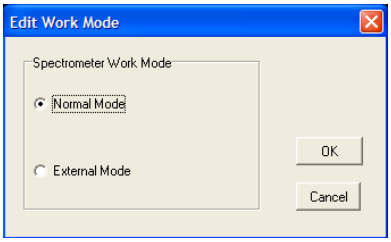
Change Working Mode

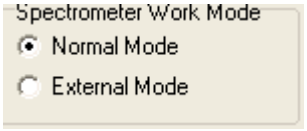
The spectrometer has two working modes:

- Normal Mode (also called Continue mode), in this mode, the spectrometer is grabbing spectrum data continuously.
- External Mode, in this mode, the spectrometer grabs spectrum data while there's an external trigger signal.

There are also two methods to change the work mode of the spectrometer,

- The 'Edit Work Mode' dialog box which is shown by the clicking 'Edit|Work Mode' menu item. The form is as the one on the right side.
- By the 'Spectrometer Work mode' radio group in the 'Spectrometer control' on the 'Control Panel'.



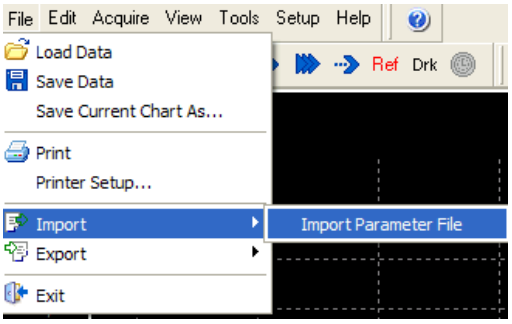


Note: In almost all applications, user use Normal mode.

Import parameter File

A new spectrometer might come with an import parameter file, which contains wavelength calibration coefficients information of this device, user might simply import the file into the software.

Parameter file import can be done by the 'File|Import|Import Parameter File' menu item.



After clicking this menu item, an open dialog is open. Choosing proper parameter file and click 'OK' button, the parameter file will be loaded automatically. The main purpose of importing a parameter file is for getting calibration coefficients, after loading the parameter file, application must be restarted to apply the new parameter file, and the coefficients will be active. So this is an alternative way to have the device calibrated.

Parameter file is a *.mtp file with the following format:

[SpectrumPara]
Type=
ModuleNo=
SerialNo=
Minimum Exposure Time=
PixelNum=
A0=
A1=
A2=
A3=
B0=
B1=
B2=
B3=
[EndOfParaFile]

Saving Data

The spectrum data can be saved to disk by either clicking the  on the tool bar or clicking the 'File|Save Data' menu item. A file save dialog is open, choose the directory and input the file name, the data will be automatically saved to this directory.

The saved data has the following format, the words in the parenthesis mark are notes that is not saved in the file.

2008-03-25 21:49:02	(Data and time when the file is saved)
TCN-1304-U	(the spectrometer module no)
13-071011-001	(the spectrometer series no)
100	(the minimum spectrum meter's exposure time)
0	(the minimum spectrum meter's pixel no.)
3648	(the spectrum meter's pixel amount)
1200	(the exposure time of the current data)
842.013	(the pixel to wavelength calibration coefficients A0)
-0.135	(the pixel to wavelength calibration coefficients A1)
0.000	(the pixel to wavelength calibration coefficients A2)
-0.000	(the pixel to wavelength calibration coefficients A3)
5133.037	(the wavelength to pixel calibration coefficients B0)
0.226	(the wavelength to pixel calibration coefficients B1)
-0.014	(the wavelength to pixel calibration coefficients B2)
0.000	(the wavelength to pixel calibration coefficients B3)

(The followings are the saved data format.)

PixelNo Wavelength Raw_1 Raw_2 Raw_3 DarkSub_1 DarkSub_2 DarkSub_3 %T/R_1 %T/R_2 %T/R_3 Ref Dark Absorbance_1 Absorbance_2 Absorbance_3

0 842.013 5396.00 5297.00 5396.00 4889.00 4790.00 4889.00 0.74 0.73 0.74 6579.00 507.00 0.13 0.14 0.13

Loading Data

The saved spectrum data can be loaded by either clicking the  button on the tool bar or 'File|Load Data' menu item. After clicking, an open dialog will be shown, choose the directory where you stored the data and select one file, click 'Open' button, the saved data will be automatically loaded and that the spectrum data will be shown on the main chart.

The application title will be changed to the file name of the loaded file.

Note: *We can see from the above "Saving Data", the serial no. of the device is saved in the file as device information, while loading the file, if the device information of the file is NOT matched with the current device, the software will still load the file but it will be in "No Device" mode. (As if user run the software without device connected), in this mode, most of the device related features are disabled.*

RRC (Relative Radiometric Calibration) Compensation Details

There are two types of applications of spectrometers. One is for relative measurements such as spectral transmission, reflection and absorption where a standard sample with known spectral property is used as a reference. The other type of application is to measure various radiometric quantities such as spectral radiant existence of a source or spectral irradiance on an object. One example is spectral radiant intensity characterization of a LED source. For this type of measurements it is essential that any spectral dependence of spectrometer response being calibrated out.

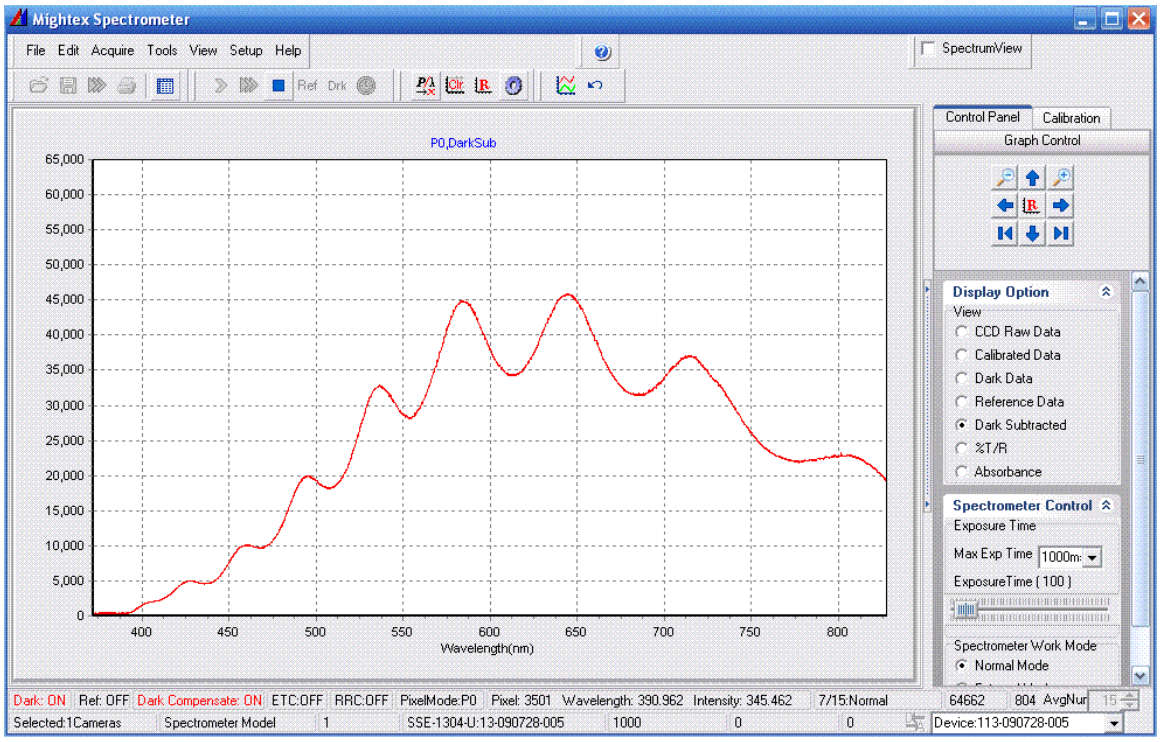
Many factors contribute to spectral response of a spectrometer. Quantum efficiency of the sensor, optical interference of thin films on the sensor, diffraction grating efficiency, mirror reflectance, transmission of order sorting filters, optical aberration and vignetting if any, all have spectral dependence and in some cases fairly strong spectral dependence. Other components outside of the spectrometers such as optical fiber/light guide, collecting optics and windows may also introduce additional spectral dependence to the measurement system.

In order to perform a radiometric calibration one must have a radiometric calibration source with known output spectrum. The calibration source is coupled into the spectrometer through various means such as an optical fiber. It must be noted that the radiometric calibration is for the entire system immediately after the calibration source, not just for the spectrometer. For this reason any change of the coupling optics outside of the spectrometer after calibration can alter the spectral response of the system and thus invalidate the radiometric calibration.

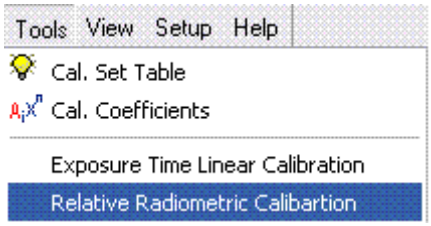
Mightex choose to support a relative radiometric calibration(RRC) in its spectrometer software instead of an absolute radiometric calibration. After RRC spectral response of the system is calibrated out. However the spectrometer readout is still in pixel values rather than radiometric quantities. At this point only a single calibration factor is needed to relate the pixel value to a radiometric quantity of interest. This single calibration factor, applicable to the entire wavelength range, is left to the user to determine. The RRC approach provides maximum flexibility to the user to handle different applications. For example in one application a pixel value of 10,000 may correspond to a spectral radiance of $3W/m^2$ sr nm, in another application the same pixel value may correspond to a spectral irradiance of $5W/m^2$ nm.

*RRC Calibration Procedure(***A radiometric calibration source is required***)*

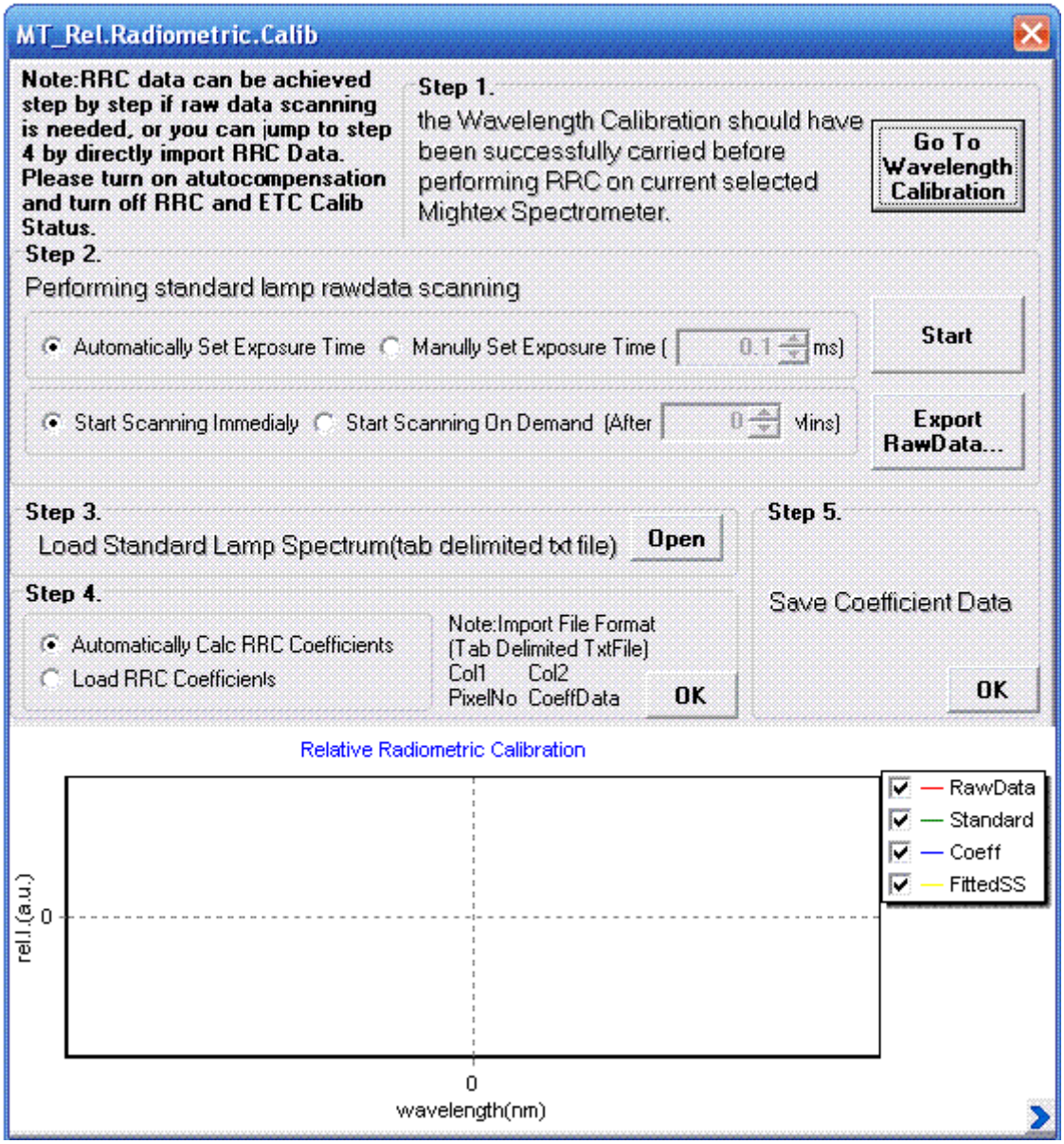
1. Wavelength calibration must be performed before RRC.
2. Connect the radiometric calibration source with known spectrum to the spectrometer.
3. Turn on radiometric calibration source if not already and let it warm up to stabilize. Acquire spectrum and adjust exposure time so that the maximum pixel value is above 40,000. Make sure no pixel value is saturated.



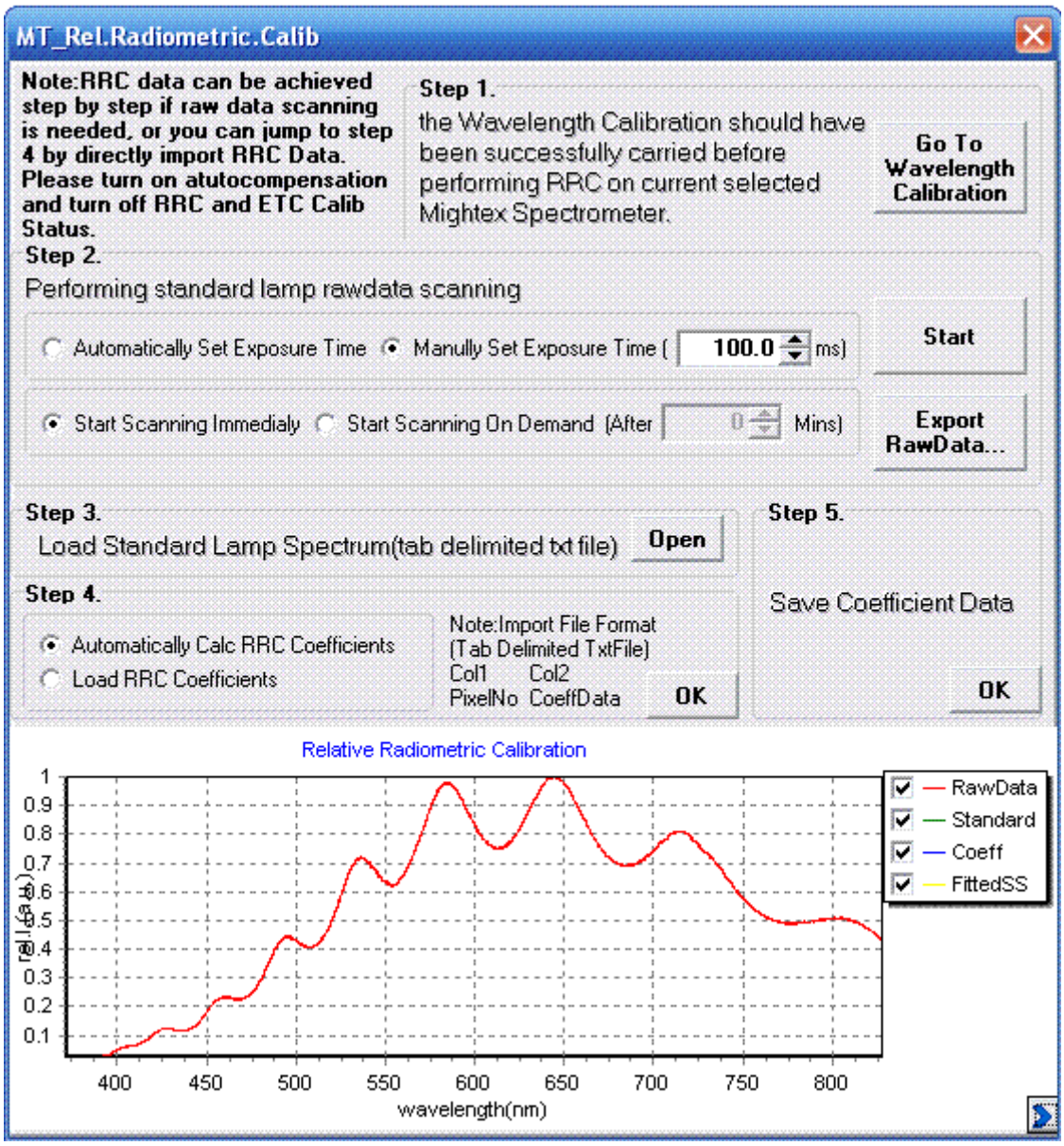
4. Invoke RRC from the Tools menu.



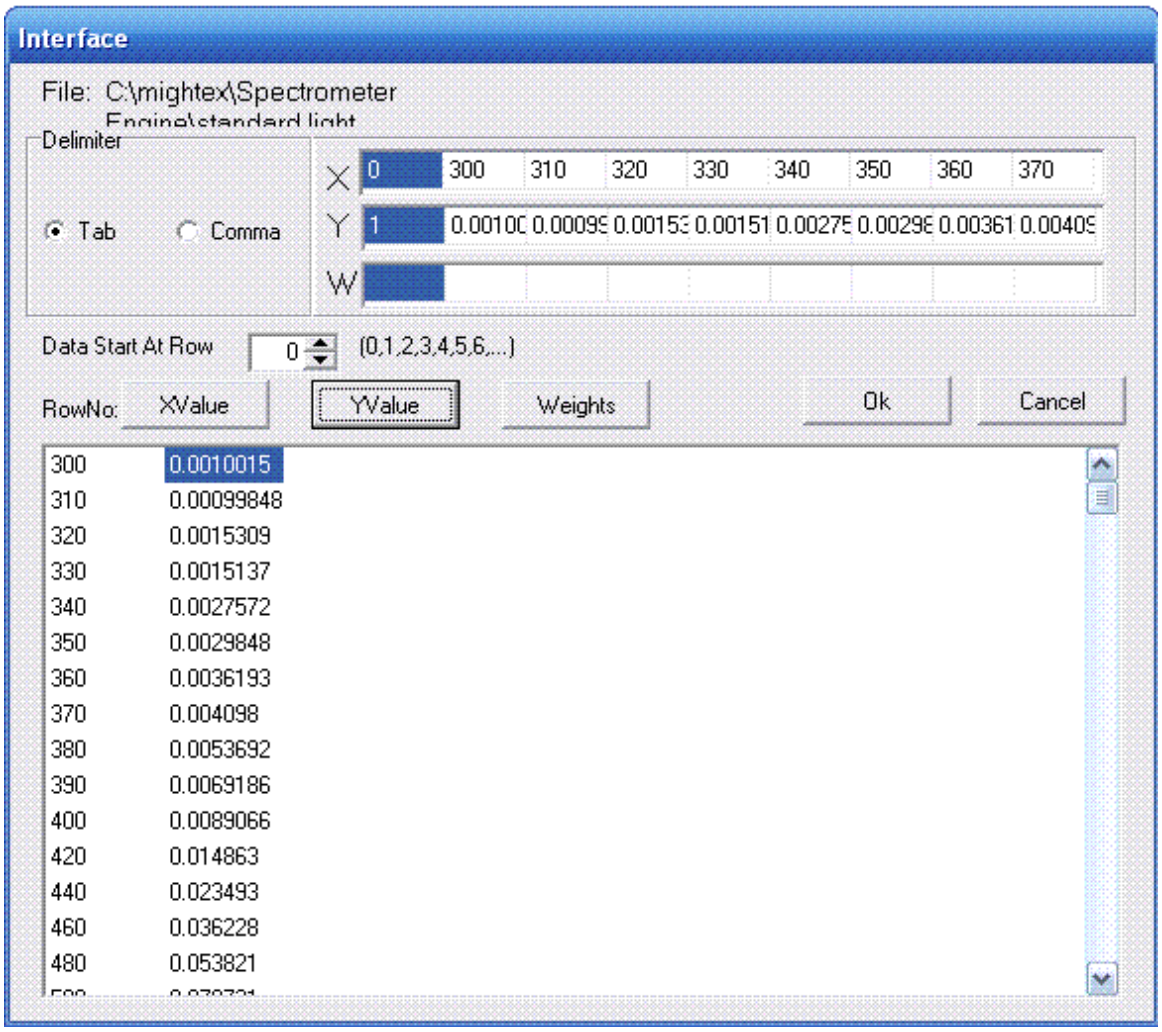
5. RRC User Interface



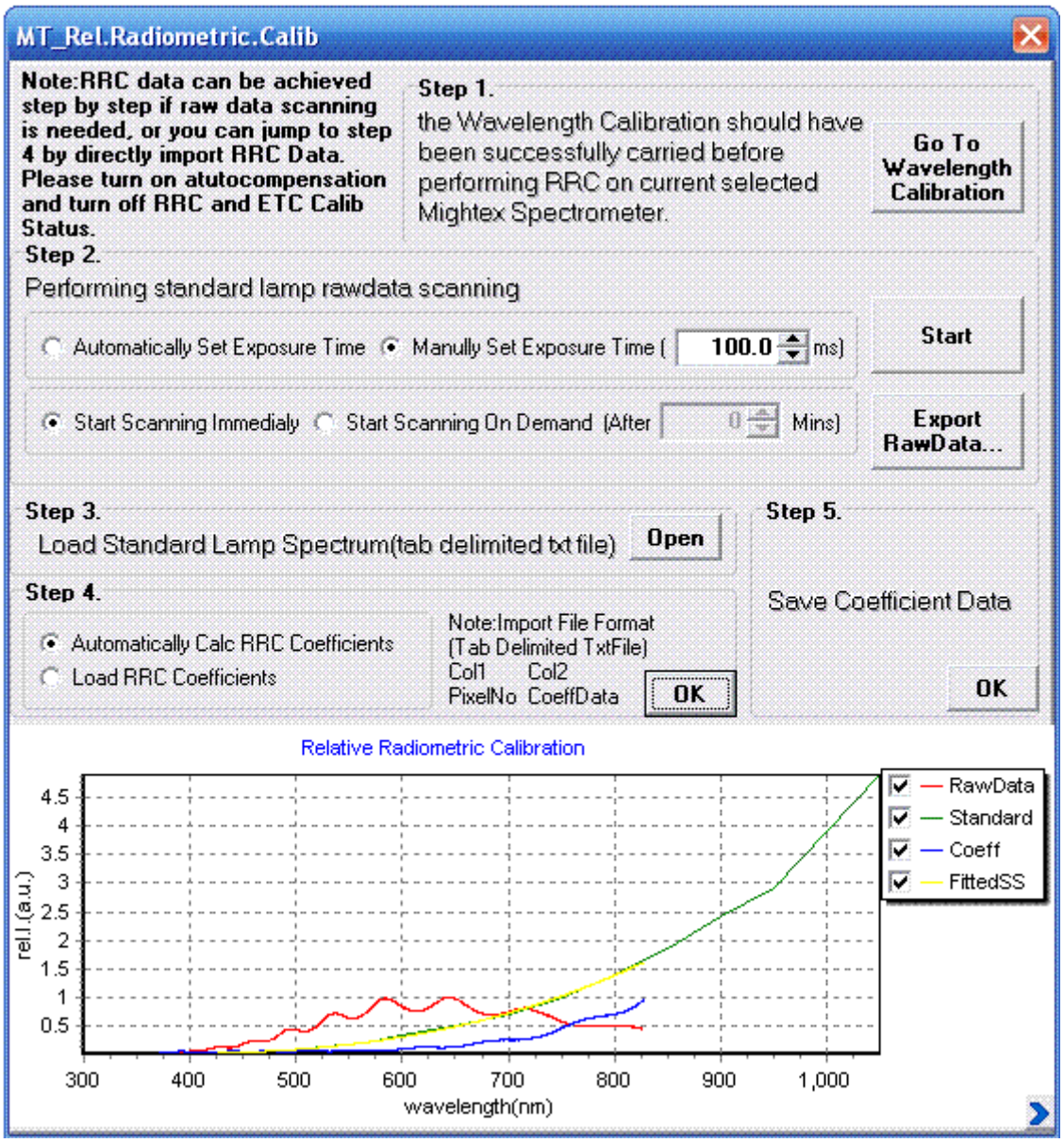
6. Set proper exposure time. Exposure time found in Step 3 can be manually entered. User may also select the *Automatically Set Exposure Time* option to let the software choose a proper exposure time.
7. Click Start button to grab raw data. Raw data is normalized and shown in the window at the bottom. Tabulated data can be seen by click the arrow at the lower right corner of the RRC window. Data may also be exported to a text file.



8. Click the *Open* button to import the spectrum of the radiometric calibration source. The spectrum should be in a text file with wavelength in one column and spectrum in the other column. Wavelength unit should be nanometer.



9. Select the proper delimiter according to file format. Data start row equals number of rows occupied by non-data text. Click the first wavelength data and then click the *XValue* button to import wavelength. Click the first spectrum data and then click the *YValue* button to import the spectrum data. If weights are assigned to wavelengths import the weights. Click *OK* button to finish. The imported calibration spectrum will be shown in the RRC data window.
10. In the RRC interface select *Automatically Calc RRC Coefficients* and click the *OK* button. Calibration coefficients is calculated and shown in the data window. Also shown is the spectrum after calibration, which should be very close to the imported spectrum of the radiometric calibration source.

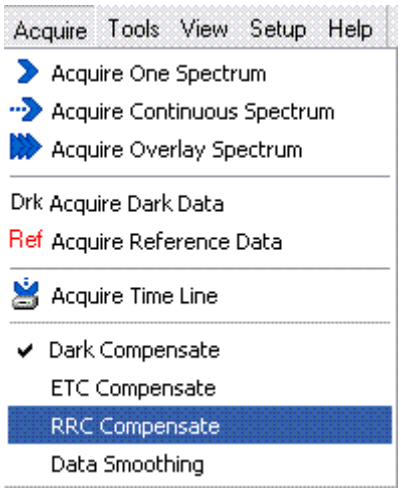


11. Save the calibration coefficients by clicking the *OK* button. This completes the relative radiometric calibration process.

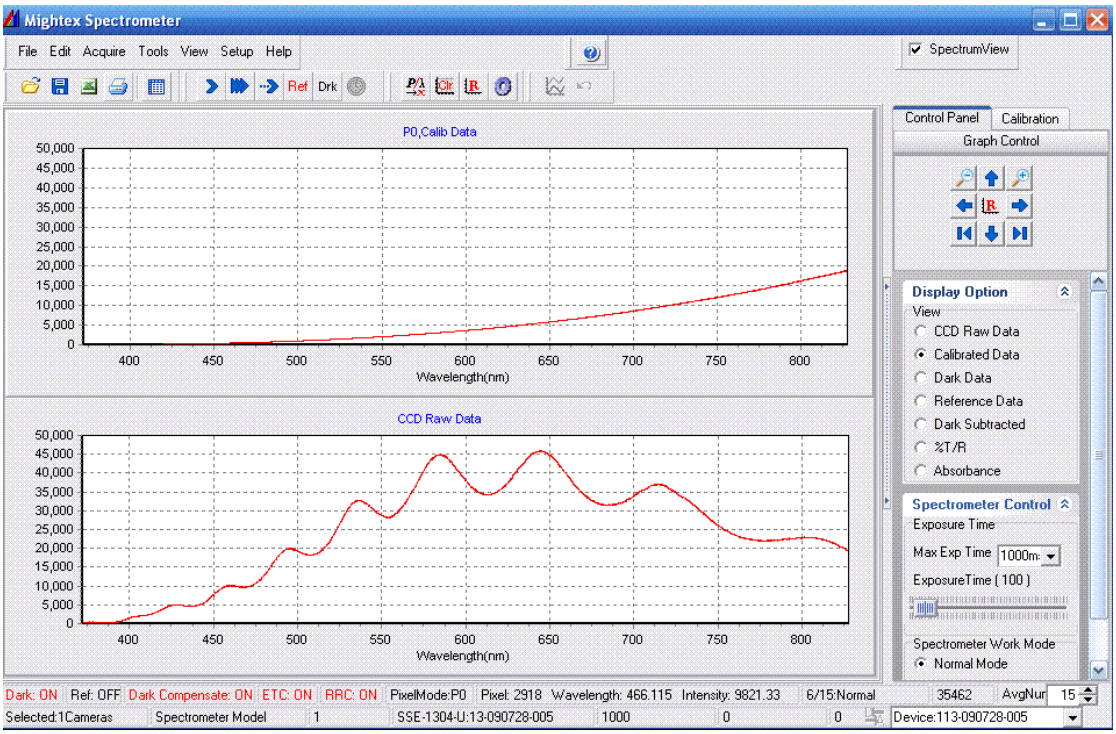
Note: The calibration file should be under the \app_data\ModuleNo_SerialNo sub-directory.

Applying Relative Radiometric Calibration

3. Select RRC Compensation in the Acquire menu of the spectrometer main window.



4. Select *Calibrated Data* option on the left panel under Display Option. Calibrated spectrum will now be displayed.



A sample of raw spectrum and calibrated spectrum with both RRC and ETC ON.

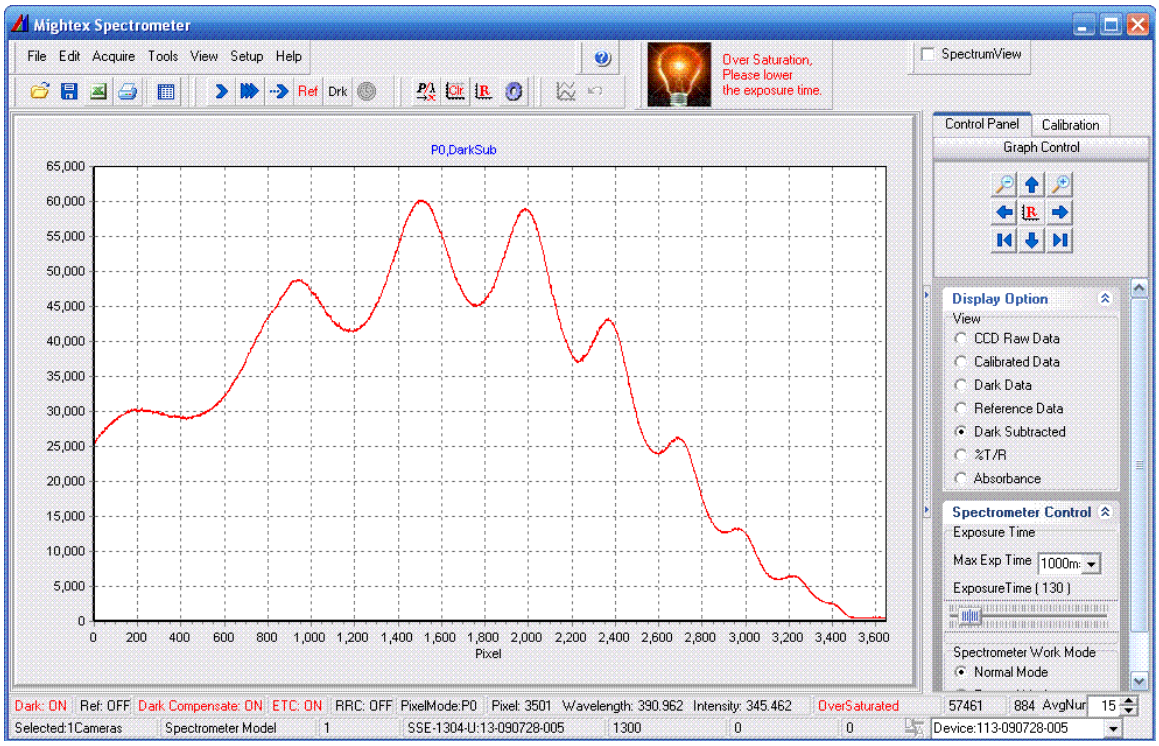
ETC (Exposure Time Calibratin) Compensation Details

Linear response of a spectrometer is often required for quantitative studies. Linear response is also critical when compare two spectra measured with different exposure times. Response of a CCD pixel is not strictly linear with incident optical power or exposure time. Therefore a linearity calibration is necessary when strictly linear response is required.

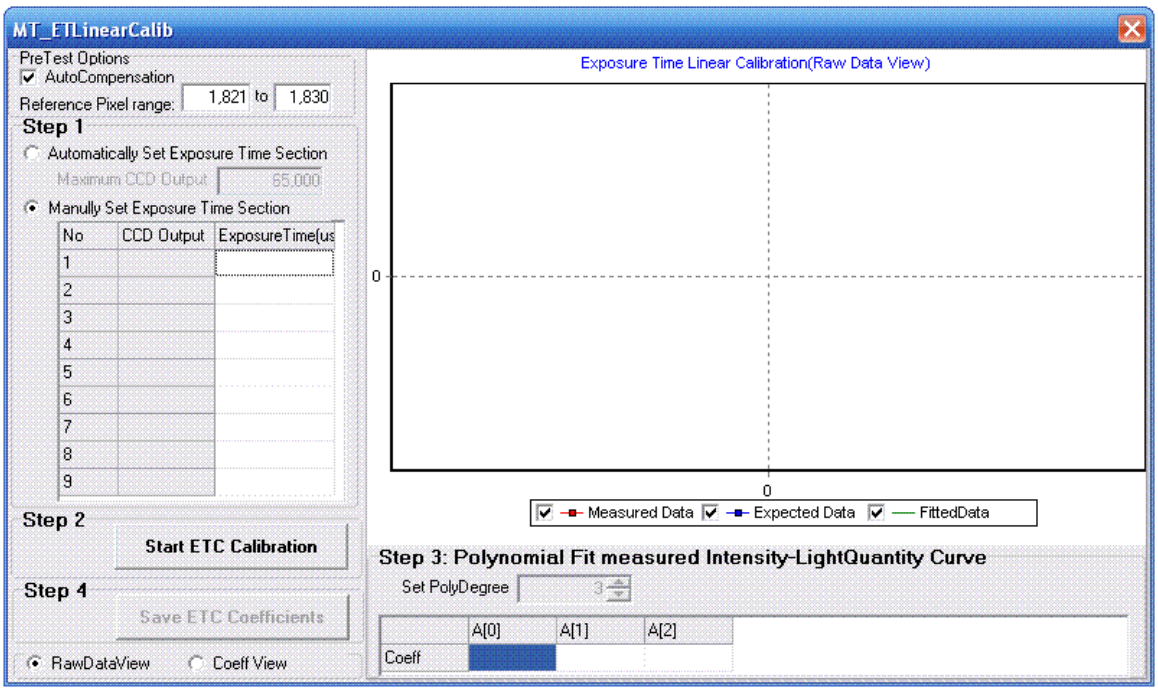
Linearity calibration may be performed with a series of linearly increasing optical powers or a series of linearly increasing exposure times. Exposure time calibration(ETC) is much easier to implement. All is required is a highly stable light source set at a constant output level.

ETC Calibration Procedure(**A highly stable source is required**)

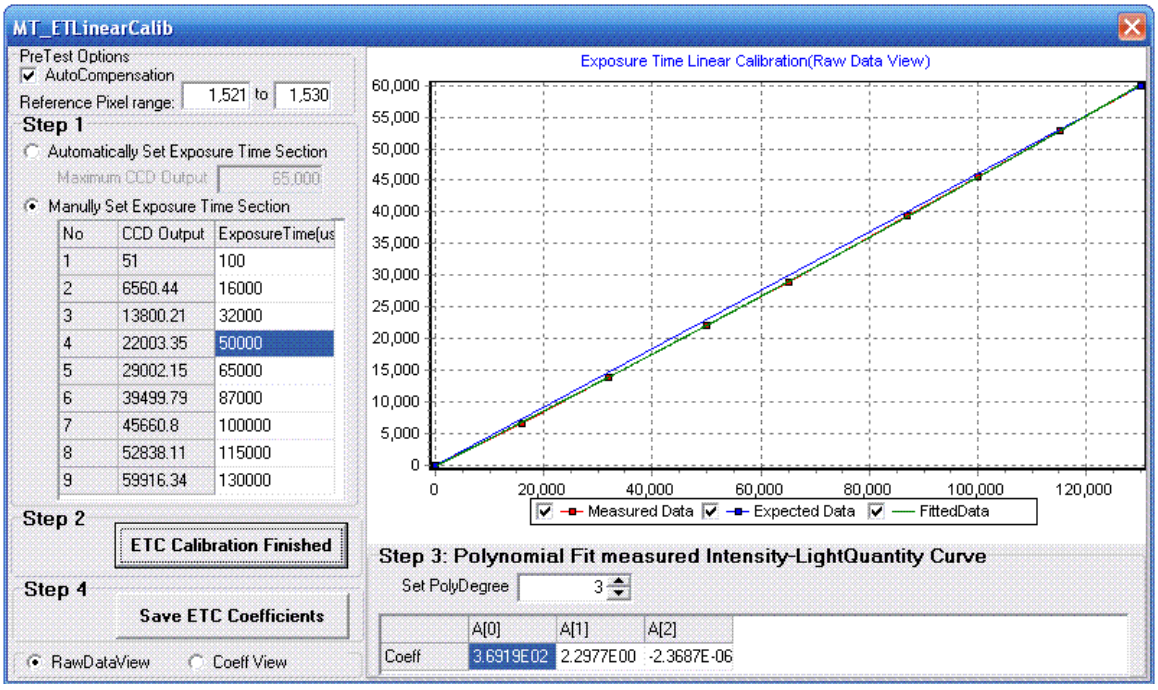
1. Turn on the light source and let it warm up to stabilize.
2. Acquire spectrum and adjust exposure time so that the maximum pixel value is above around 60,000. Make sure no pixel value is saturated. Record exposure time and pixel number of the peak.



3. Invoke Exposure Time Linearity Calibration from the Tools menu.



4. Use pixels near the peak found in Step 2 for *Reference Pixel Range*. Select *Manual Set Exposure Time* option. Enter 100us which is the minimum exposure time supported by the spectrometer into the first exposure time. Enter the exposure time found in Step 2 into the last exposure time. The exposure times in between should be approximately uniformly distributed. Click *Start ETC Calibration* button to start the calibration process.

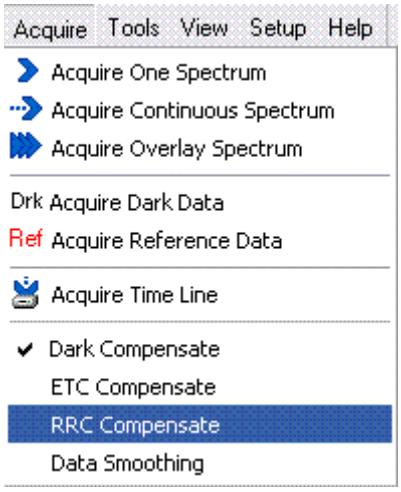


5. Set *Polynomial Degrees* for curve fitting. Usually three is sufficient.
6. Click *Save ETC Coefficients* to save the calibration coefficients. This completes the ETC calibration process.

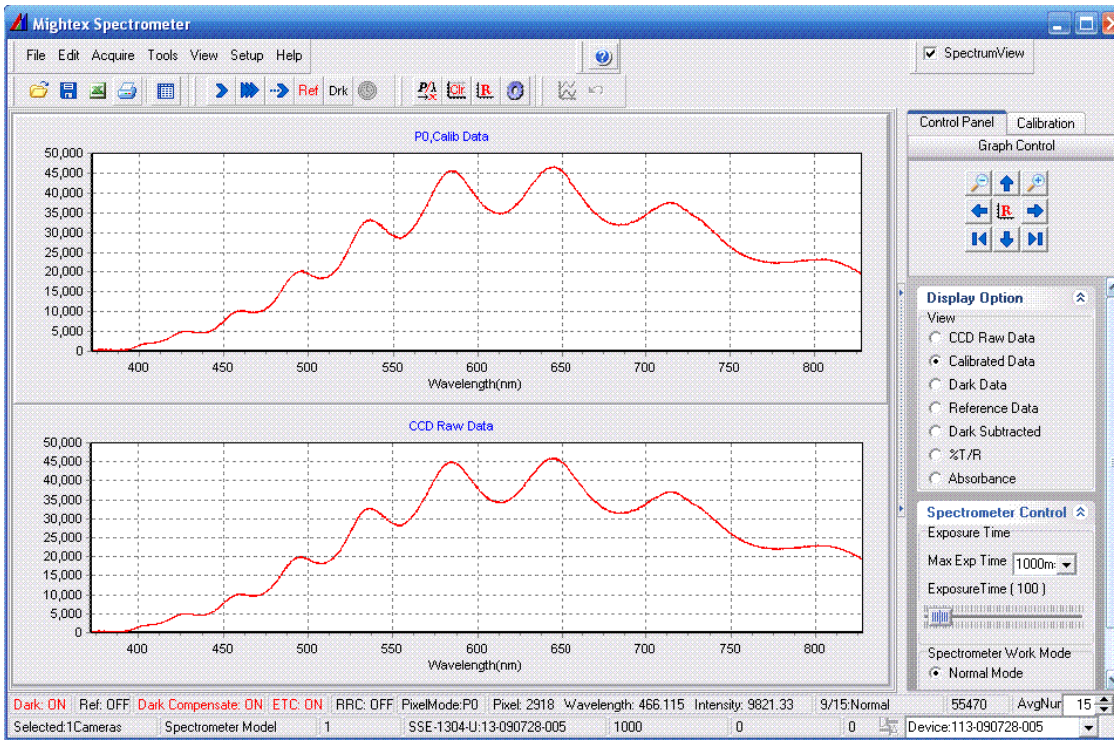
Note: The calibration file should be under the \app_data\ModuleNo_SerialNo sub-directory.

Applying Exposure Time Calibration

3. Select ETC Compensation in the *Acquire* menu of the spectrometer main window.



4. Select *Calibrated Data* option on the left panel under Display Option. Calibrated spectrum will now be displayed.



A sample of raw spectrum and calibrated spectrum with ETC ON only.