Simply Brighter

Mightex Spectrometer
Software User Manual

Version 2.3

Sep 2020

Relevant Products

Part Numbers
SSE-1304-U

Revision History

| 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
2.1.1	Jun.10, 2013	William	GUI functions updated
2.1.2	Feb.17, 2017	William	Modify Trig Signal Description
2.2.1	Aug.08,2018	William	Modify reference data definition.
2.2.2	Oct.11,2018	William	Add new smooth module
2.3	Sep. 2020	William	Modify the black field handling algorithm

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Table of Content

1 About Mightex Spectrometer Sensor Engine

Mightex Spectrometer contains an Optical System and a Spectrometer Sensor Engine (SSE), the SSE consists of two components:
1) Mightex CCD Line Camera (SSE-1304-U)
2) Mightex Spectrometer Software.
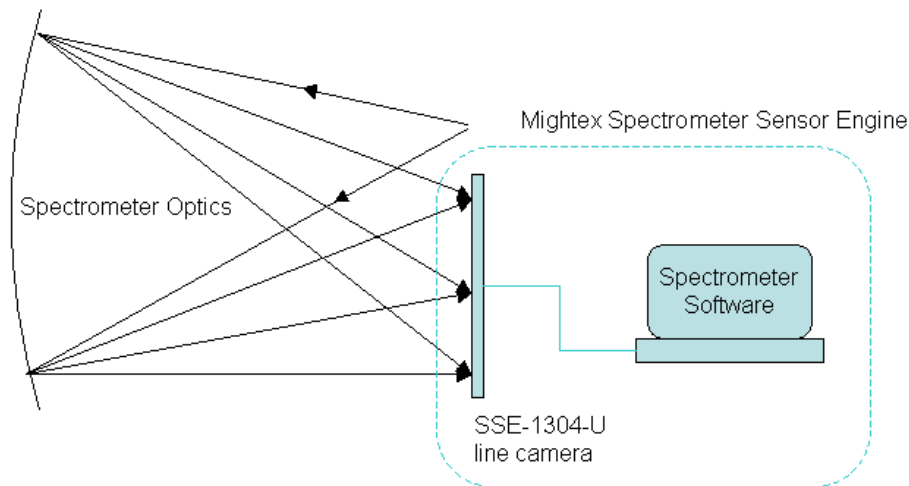
The spectrometer software provides a powerful set of spectrometer functions such as wavelength calibration, dark/bright references, spectrum display, and file management. This is the same software used for another product "Mightex Spectrometer Sensor Engine" (Mightex SSE, refer to the figure above). Mightex SSE is a spectrometer engine and users might have their own optics. SSE users might set up optics, such as a spectrograph, and place the line camera at the focal plane of the spectrograph. This software can be used for all spectrometer functionalities which release users from the burden of programming spectrometer functions, enabling them to build their spectrometers much more efficiently and cost-effectively.

2 Connector Definitions

Mightex spectrometer has two connectors: one is the standard USB 2.0 Type B connector and one 8 pin Din connector as seen below: (It's the receptacle on the spectrometer)
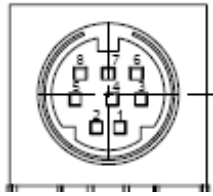
Pin1：GPIO1

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 users who want 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:
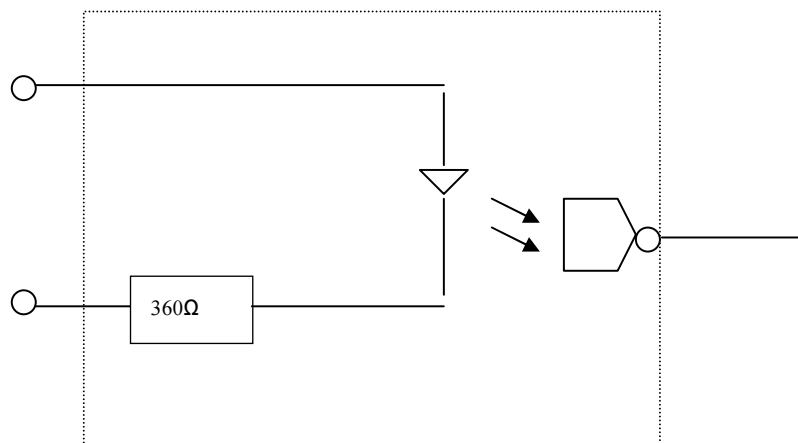
The diode is expected to be working under :

$I_{forward}$ = 6mA – 20mA

$V_{forward}$ = ~1.2V

As we have a 360Ω resister built in, we expect a 3.3 – 10.0V source with 6mA minimum current source capability to be the trigger input. This device has a rising edge assertion, so an "L" → "H" edge will be a valid trigger signal. However, it is recommended to be a positive pulse with its width more than 20μs.

2). GPIO: 4 GPIO pins are provided. Each GPIO pin provides LVTTL level and 8mA source/sink current while it is configured as an output. It can also be configured as an input pin.

3 Software Installations

Minimum Operating System/Hardware requirements:

Processor: Pentium III,900M or above

Operating System: Windows 2000/XP/Vista/7/10

RAM: 256M or greater

USB 2.0 Host Controller required.

1)   **Spectrometer USB Driver Installation**:

 . The following installation procedure is based on windows 7. For 2000, Vista, XP or 10, the GUI might be slightly different.

The Mightex Spectrometer is based on the Mightex CCD Line Camera, which uses a high speed USB2.0 port (480M) for data collection. A USB 2.0 Enhanced Host controller MUST be present on the host PC. To check this, go 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
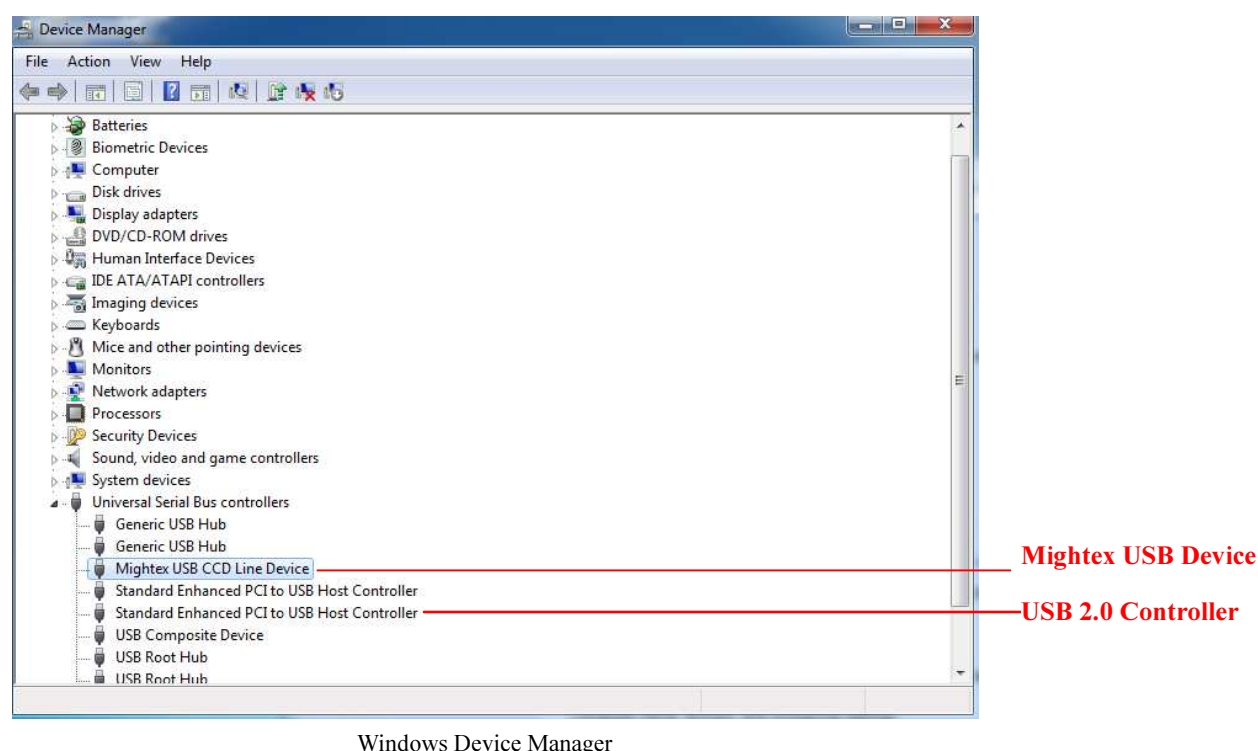
On a PC with USB 2.0 installed, the camera can be plugged into one of its available USB2.0 ports. On the initial plug-in, Windows will prompt the "Found New Hardware" dialog as below:
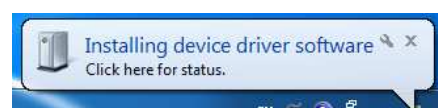
Generally, Windows will do all the installation (of the device driver) automatically, however, in some cases,

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Windows might not be able to install a proper driver and it might show:

In such case, user has to install the driver manually in the following steps,

a) User should go to the "Device Manager" with "Control Panel | System | Device Manager", when the line camera is being plugged (in this example, the line camera is TCN-1304-U).

In the "Device Manger", User can see the device "USB-TCD1304-1" is marked with a yellow exclamation which means the device driver is not correctly installed.
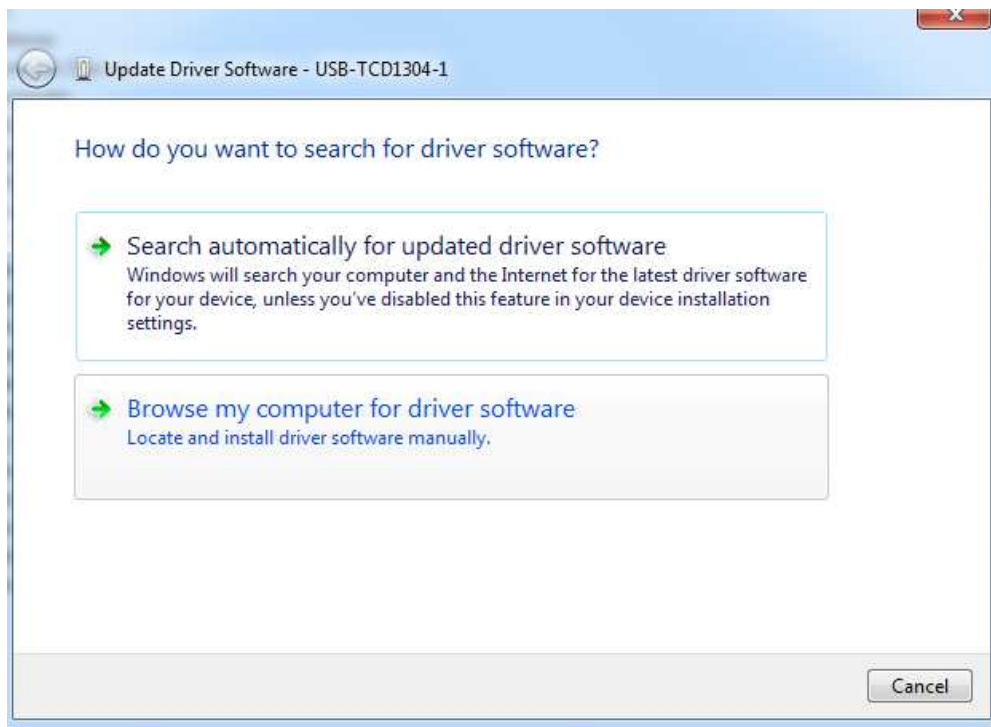
b) User can right click the "USB-TCD1304-1" device and click the "Update Driver Software…" in its popup menu.
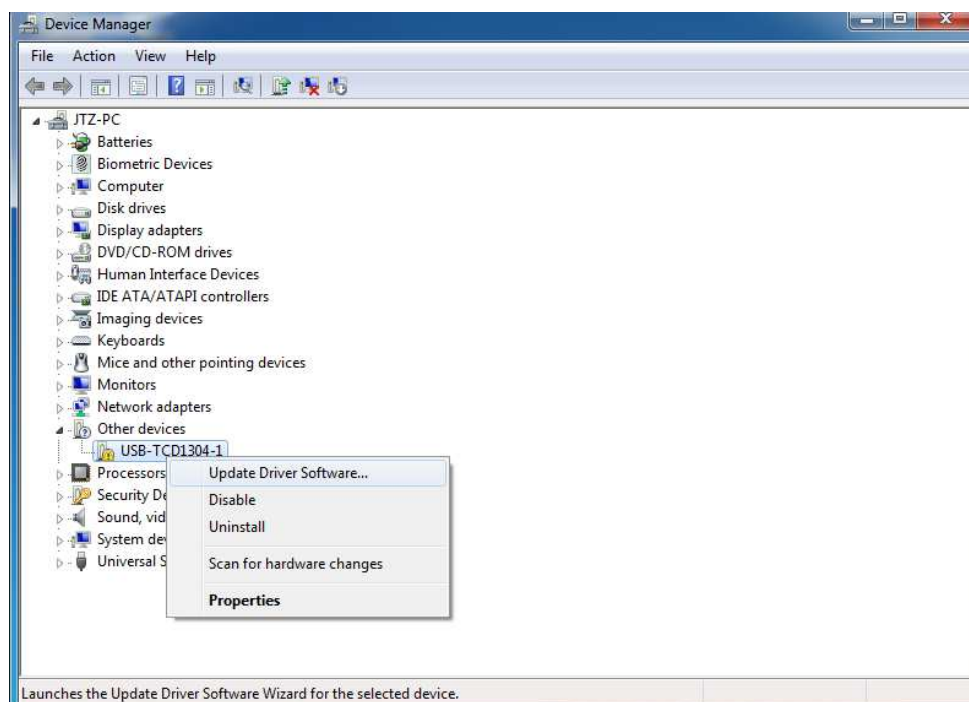
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c)   When click it, it shows the following windows and user should choose the "Browse my computer for driver software".

d)   When clicking on the "Browse my computer for driver software", windows will show
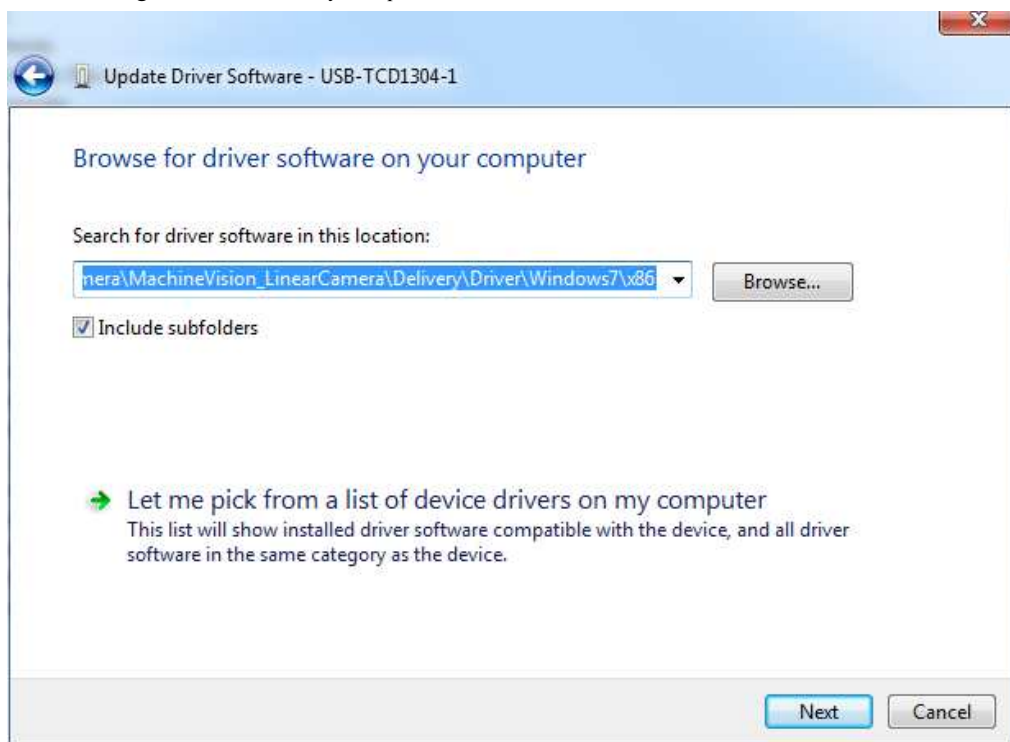
User should click the "Browse…" button and go to the path (sub-dir) in which the proper driver is stored, note that the drivers (for different windows versions) are stored in the CD-ROM\drivers\ sub-dir, e.g. for Windows 7,

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Windows 8.x, and Windows 10, the drivers are under CD-ROM\driver\Windows7, for 32bit windows version, user should use the driver under \x86 sub-dir, for 64bit windows, user should use the driver under \x64 sub-dir.

After browsing to the correct path (e.g. \driver\Windows7\x86 for 32bit Windows7, 8.x or 10), user can click "Next" button and Windows will show
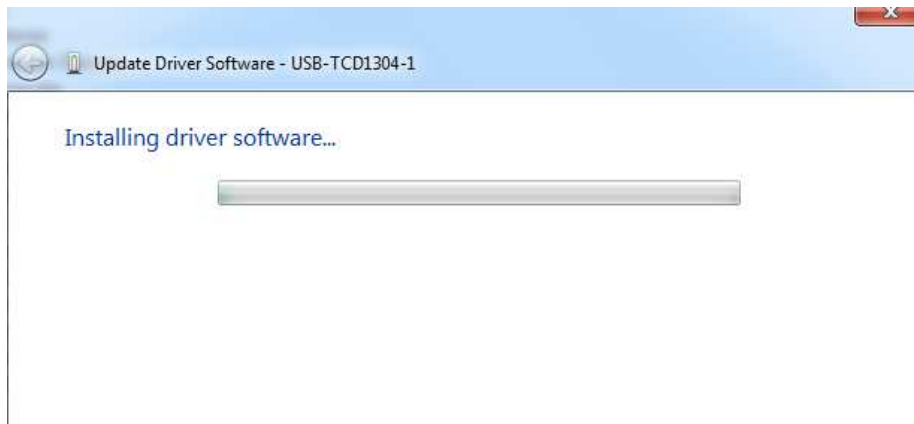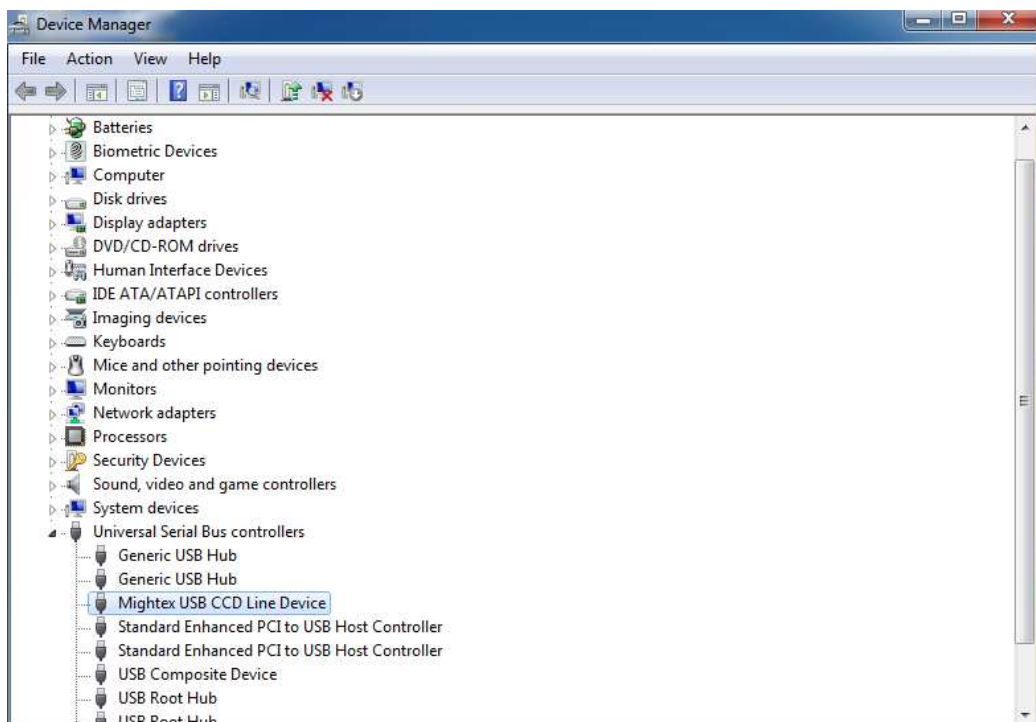

This might take some time and when it's done, the following window may show up:

User should click the [Install] button then the following windows will show

e) After installation is finished, user can check the "Device Manager" again and it will show as following:

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2) CD ROM File Organizations:

The CD-ROM has the following sub-directories:

\Drivers

It contains 3 sub-directories for different Windows versions, each containing .INF and .SYS files for driver installation.

\Application

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

\Appdata: contains 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.

\ModuleNo_SerialNo : This is a sub-directory storing an .XML based calibration file, which is generated in factory when the device is calibrated.

\Data: This is an empty sub-directory. It can be used to store spectrum data files or a "Time Line" save/load path.

\Documents

It contains two PDF files: Mightex Spectrometer User Manual.pdf (this manual) and Mightex SSE SDK guide.pdf.

3) Application Installation

Copy all the files under the \Application sub-directory of the CD into a target directory of the PC's local disk, and run the "Mightex_SSE.exe" file.

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4 Getting Started

Connect the Spectrometer to the USB 2.0 port of the PC. 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.

1) Start the Application

Start the application by running "Mightex_SSE_App.exe", the main window will open.

Note: If the setup is not calibrated, a warning message might appear or some functions are disabled. It is recommended that wavelength calibration be performed prior to other wavelength related operations (refer to "Wavelength Calibration" paragraph for details). There are several ways to have the device calibrated:

1> Follow the steps in "Wavelength Calibration" to do the calibration manually, using a standard light source (with known peaks of certain wavelengths).

2> Import a calibration file, *.CAL. If the calibration file for this particular device is not present on startup, a calibration file should be generated manually using the results acquired via the method <1> above (please refer to the example CalibrationFile1.cal on the CD ROM for the format of the calibration file).

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

2) Scan Spectrum Data

Click 'Acquire One Spectrum' button ▶, the spectrometer will acquire a spectrum **ONCE.** Note that one spectrum might be the averaged result of multiple frames, and actual frame number depends on the frame average number setting. See Figure 4.1 for a sample spectrum.
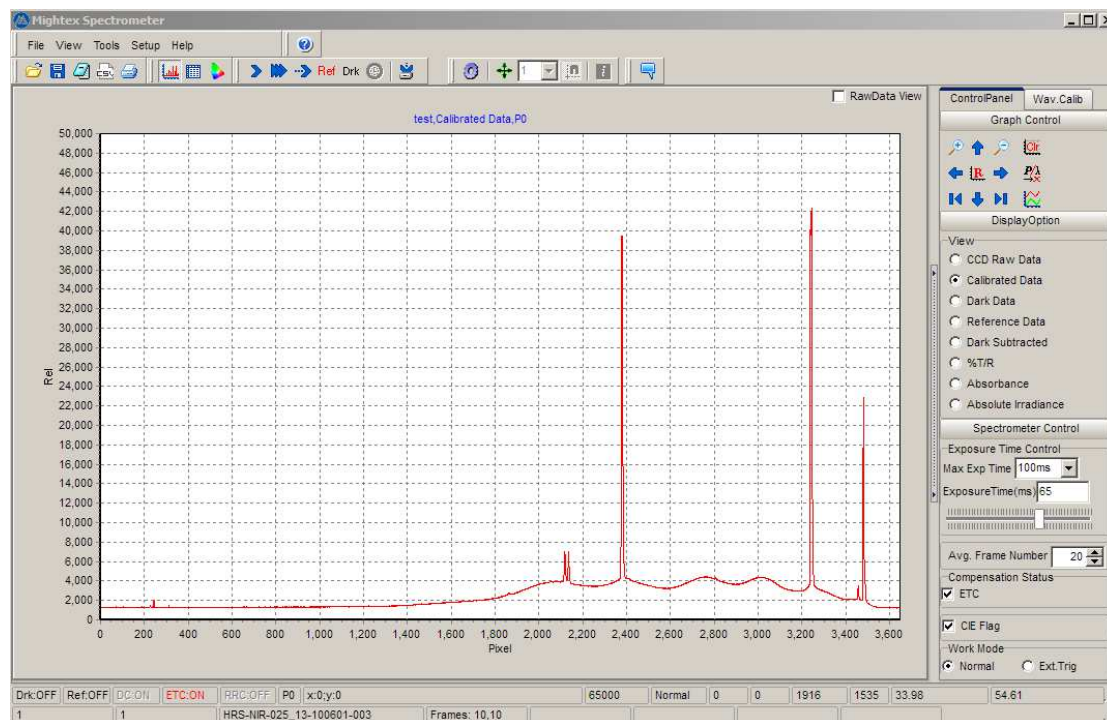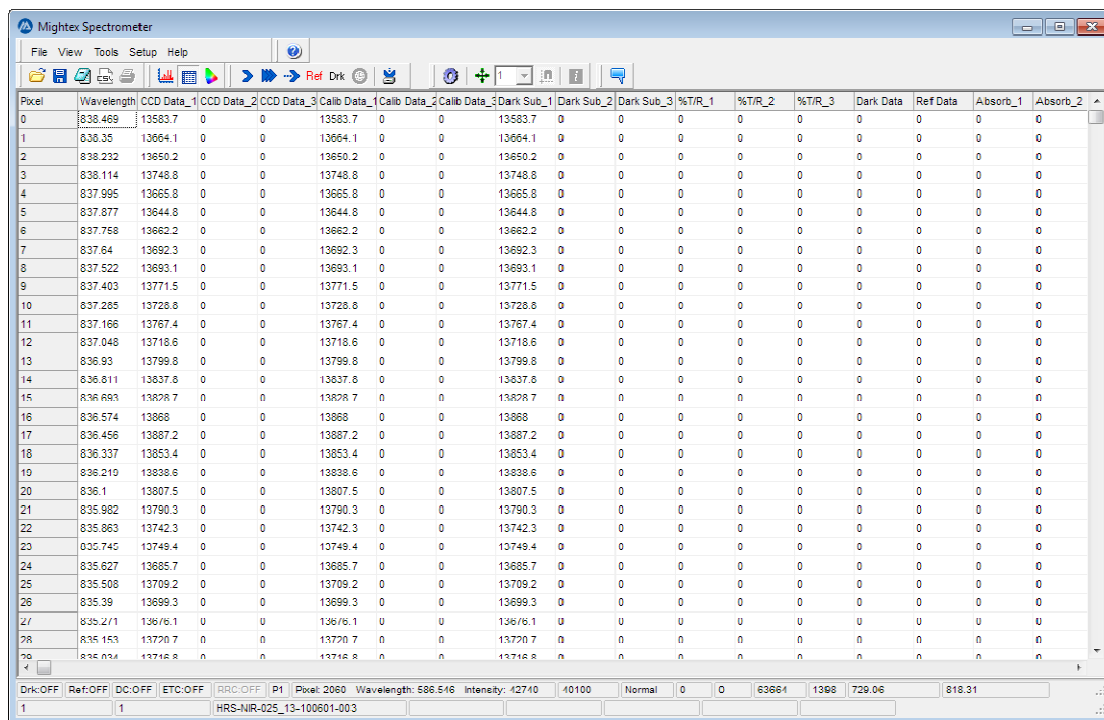

Figure 4.1

The display is in "Graph" mode by default. To view the spectrum in "Table" mode, click the button located on the tool bar. The application will display the spectrum in Table mode, Figure 4.2.

Figure 4.2 Table Mode

3) Save Data.

Clicking the 'Save' button saves the scanned spectrum data to a specified directory as a Mightex spectrum data file (*.mtd file). The saved spectrum file can be loaded back later. (The format of the spectrum data file is described in details later).

5 Software Main User Interface

The main window of the application is divided into five parts, see Figure 5.1
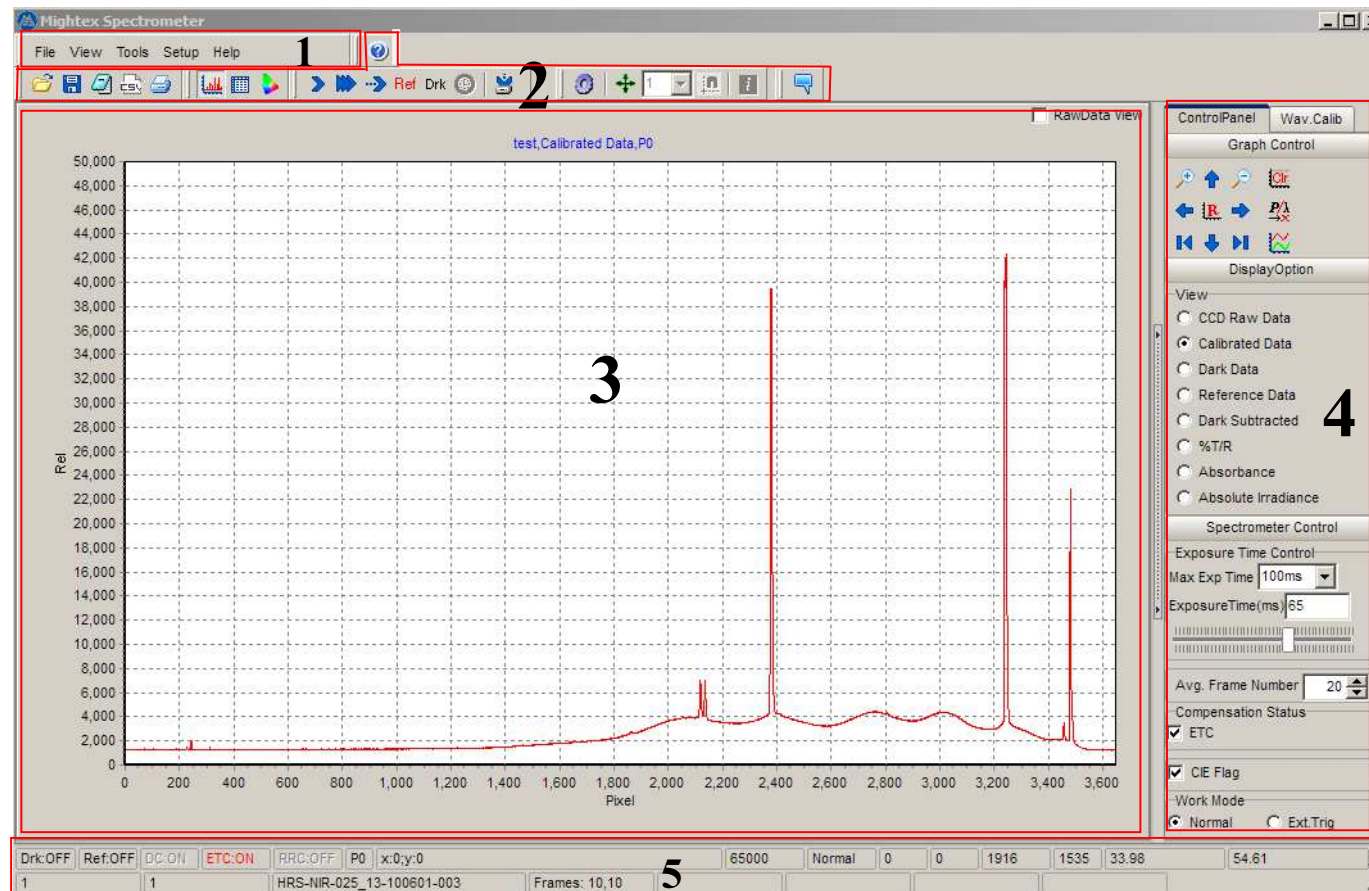
1 Main Menu
2 Toolbar
3 Working area
4 Control Area
5 Status Bar

Figure 5.1

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5.1. Main Menu

File   View   Tools   Setup   Help

There are a total five main menu items at the top level.

File

The File menu contains general options related to the spectrum loading, saving, printing, importing/exporting operations.
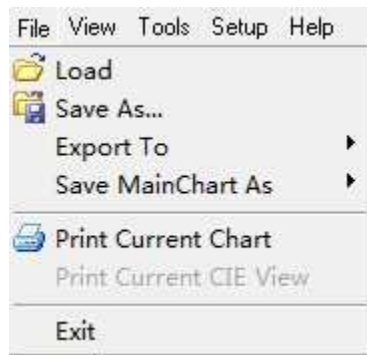
'Load': Load the saved spectrum data (*.mtd) file.

'Save As': Save current spectrum data to file (CSV, TXT or MTD).

'Export To': Export Current spectrum data to a SPC file ('See Appendix SPC file format').

'Save Main Chart As': Save main chart (graph view mode) to a file (which could be a picture file or txt data file).

'Print Current Chart': Generate a print report based on current chart.

'Print Current CIE View': Open Chromaticity print preview form and print chromaticity view.

 (Note: Only available in Chromaticity View Mode)

'Exit': Exit the application.

View
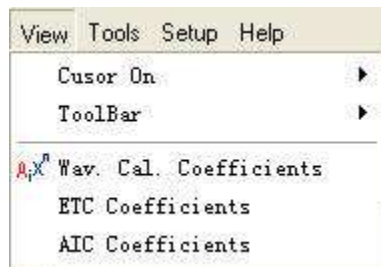
'Cursor On': Enable/Disable Cursor in the main chart, and cursor information.

'Toolbar': Control which icons appear in the tool bar.

'Wav. Cal. Coefficients': Open wavelength and pixel calibration coefficient window.

'ETC Coefficients': View ETC Calibration Coefficients (Only available when ETC cal. Coefficients exists).

'AIC Coefficients': View absolute irradiance calibration coefficients (Only available when AIC cal. Coefficients exists).

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Tools
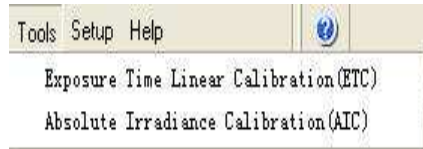
Exposure Time Linear Calibration (ETC): Invoke the ETC calibration form.

Absolute Irradiance Calibration (AIC): Invoke the AIC calibration form.

Setup
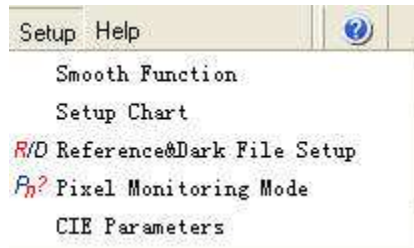
Smooth Function: Opens the smoothing function and parameters setup form.

Setup Chart: Open Chart editing form, used to edit chart settings such as coordinates, color… etc.

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

Pixel Monitoring Mode: Opens the pixel editing mode form, allowing the selection of several different pixel editing options.

CIE Parameters: Opens the CIE chromaticity parameters setup form.

Help
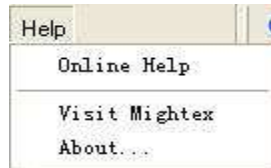
Online Help: Opens the help file (this file).

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

About: Opens the about dialog.

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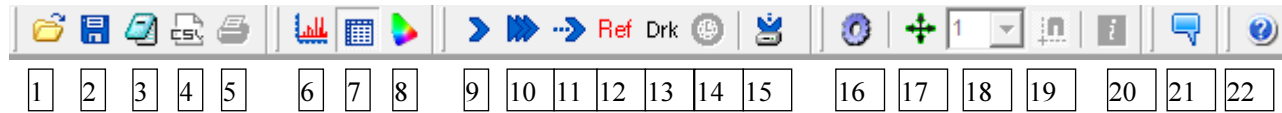
5.2. Toolbar

The quick buttons on the tool bar can be divided into **SIX** groups according to their functions

Standard group: include the quick buttons 1, 2, 3, 4 and 5.

Data Viewing Group: include the quick buttons 6, 7 and 8.

Spectrum Operation Group: include the quick buttons 9, 10, 11, 12, 13, 14 and 15.

Chart Control Group: include the quick button 16, 17, 18 and 19.

Commenting Group: include the quick button 20.

Help Group: include the quick button 21.

The visibility of the above first 6 groups can be controlled by the 'View' -> Tool Bar' button on the Main Menu.

The functions of the speed buttons of each group are listed as following:

1: Open File.

2: Save Data to a *.mtd File.

3: Export Data to a TXT File

4: Export Data to a CSV file.

5: Print Data.

6: Switch to Graph Mode: View obtained spectrum in graph mode.

7: Switch to Table Mode: View obtained spectrum in table mode.

8: Switch to Chromaticity Mode: View CIE parameters of obtained spectrum.

9: Acquire one spectrum

10: Acquire overlay spectrum

11: Acquire continuous spectrum

12: Acquire Ref spectrum data

13: Acquire Dark data

14: Acquire Spectrum for Pixel Mode P4, P5, P6 and P7.

15: Acquire TimeLine data.

Buttons 9 to 13 are only functional with the pixel monitoring mode set to P0, P1, P2, P3.

Button 12 and 13 obtain one spectrum and save it into Ref/Dark array, respectively.

Button 14 is only functional when the pixel mode is set to P4, P5, P6 or P7.

Button 15 is not functional when the pixel mode is set to P4.

16: Open Chart Setup Form

17: Main chart cursor enable/disable control.

18: Main chart cursor target series selection.

19: Main chart cursor behavior control, snap to point or not.

20: Show main chart cursor information in cursor position.

21: Commenting Tool, click to open a box used for personal comments.

22: Help Menu, click to show user guide.

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5.3. Working Area

The working area can be in either "Graph Mode", "Table mode" or "Chromaticity mode," described below:

1) **Graph Mode**:

This mode can have two charts, as seen in Figure 5.2. The upper chart is the main chart which displays the spectrum data according to the display option. The bottom chart, which can be set to visible or invisible by checking or unchecking the 'RawData View' check box on the top right corner on the working area, only shows the CCD raw data. The default state of the bottom chart is invisible.
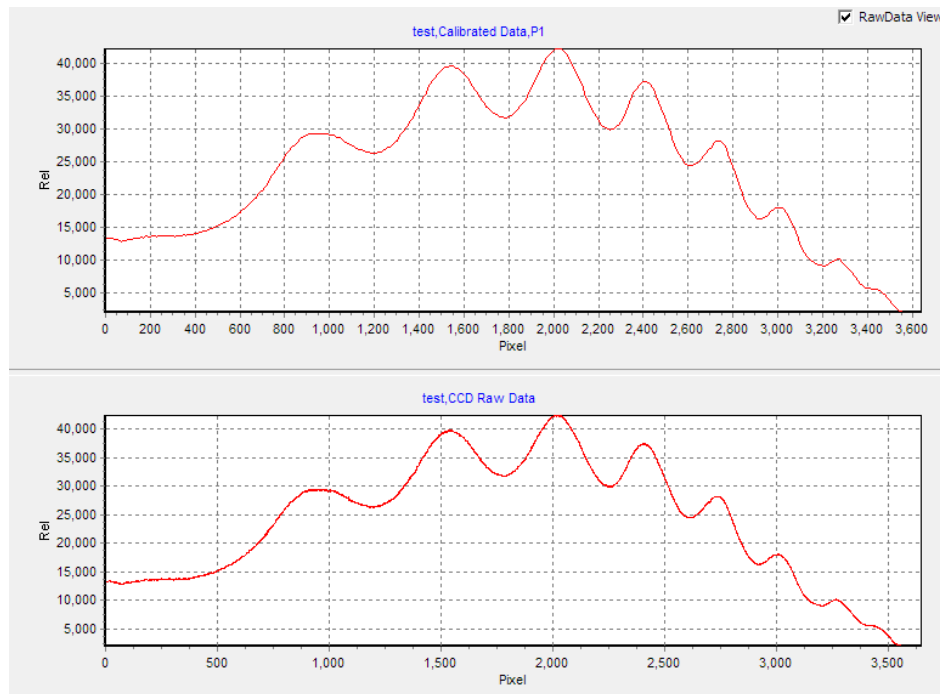

Figure 5.2

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2) Table Mode:

In this mode, the spectrum detailed data are shown in a table as Figure 5.3.

Pixel	Wavelength	CCD Data_1	CCD Data_2	CCD Data_3	Calib Data_1	Calib Data_2	Calib Data_3	Dark Sub_1	Dark Sub_2	Dark Sub_3	%T/R_1	%T/R_2	%T/R_3	Dark
0	838.469	13164.7	0	0	13164.7	0	0	13164.7	0	0	0	0	0	0
1	838.35	13270.5	0	0	13270.5	0	0	13270.5	0	0	0	0	0	0
2	838.232	13381.5	0	0	13381.5	0	0	13381.5	0	0	0	0	0	0
3	838.114	13361	0	0	13361	0	0	13361	0	0	0	0	0	0
4	837.995	13272.9	0	0	13272.9	0	0	13272.9	0	0	0	0	0	0
5	837.877	13259.3	0	0	13259.3	0	0	13259.3	0	0	0	0	0	0
6	837.758	13216.7	0	0	13216.7	0	0	13216.7	0	0	0	0	0	0
7	837.64	13290.9	0	0	13290.9	0	0	13290.9	0	0	0	0	0	0
8	837.522	13327	0	0	13327	0	0	13327	0	0	0	0	0	0
9	837.403	13362.4	0	0	13362.4	0	0	13362.4	0	0	0	0	0	0
10	837.285	13352.1	0	0	13352.1	0	0	13352.1	0	0	0	0	0	0
11	837.166	13340.5	0	0	13340.5	0	0	13340.5	0	0	0	0	0	0
12	837.048	13320.6	0	0	13320.6	0	0	13320.6	0	0	0	0	0	0
13	836.93	13366.4	0	0	13366.4	0	0	13366.4	0	0	0	0	0	0
14	836.811	13388.6	0	0	13388.6	0	0	13388.6	0	0	0	0	0	0
15	836.693	13447.9	0	0	13447.9	0	0	13447.9	0	0	0	0	0	0
16	836.574	13459.5	0	0	13459.5	0	0	13459.5	0	0	0	0	0	0
17	836.456	13444.4	0	0	13444.4	0	0	13444.4	0	0	0	0	0	0
18	836.337	13403.4	0	0	13403.4	0	0	13403.4	0	0	0	0	0	0
19	836.219	13404.8	0	0	13404.8	0	0	13404.8	0	0	0	0	0	0
20	836.1	13418.1	0	0	13418.1	0	0	13418.1	0	0	0	0	0	0
21	835.982	13343.5	0	0	13343.5	0	0	13343.5	0	0	0	0	0	0
22	835.863	13270.5	0	0	13270.5	0	0	13270.5	0	0	0	0	0	0
23	835.745	13286.6	0	0	13286.6	0	0	13286.6	0	0	0	0	0	0
24	835.627	13362.9	0	0	13362.9	0	0	13362.9	0	0	0	0	0	0
25	835.508	13365.3	0	0	13365.3	0	0	13365.3	0	0	0	0	0	0
26	835.39	13297	0	0	13297	0	0	13297	0	0	0	0	0	0
27	835.271	13340.2	0	0	13340.2	0	0	13340.2	0	0	0	0	0	0

Figure 5.3 Table Mode
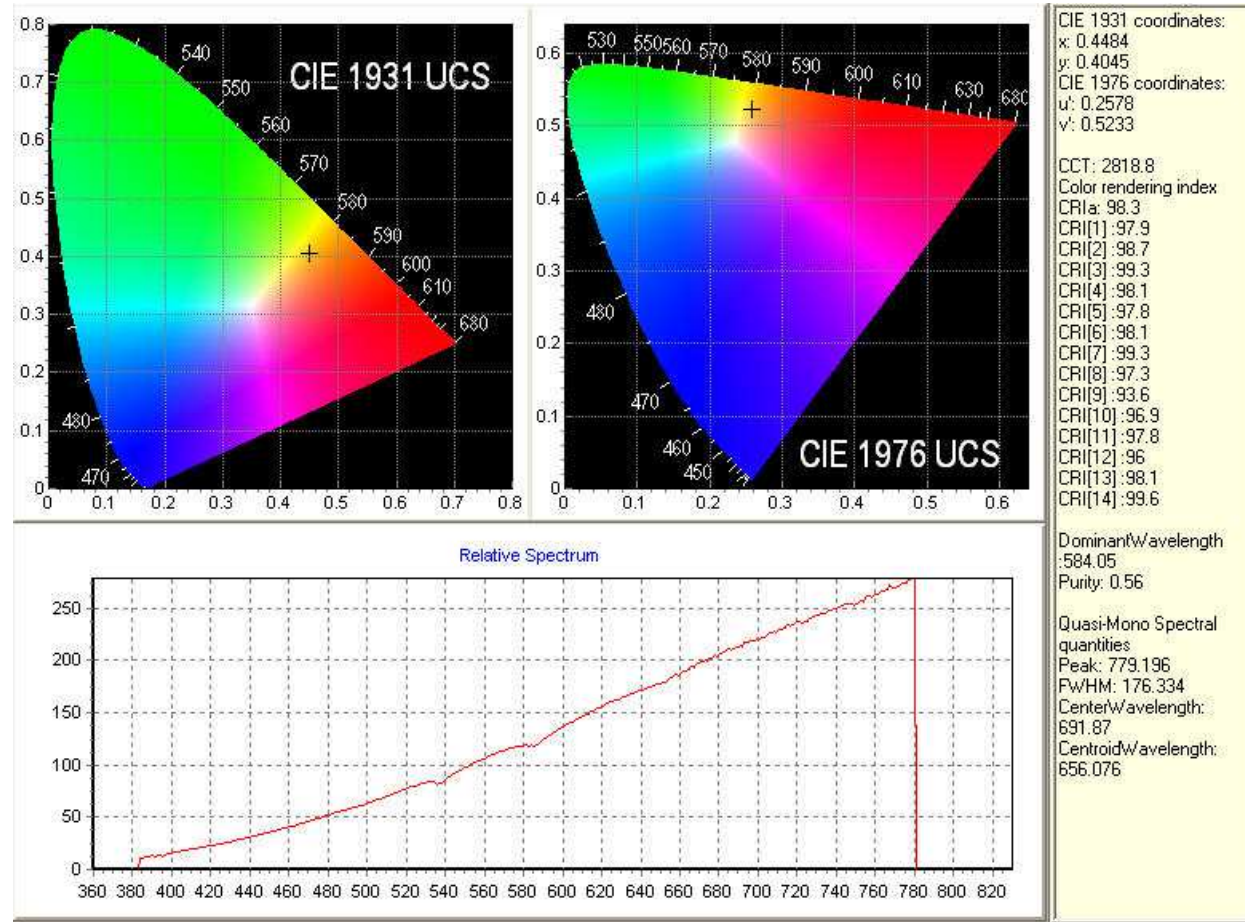
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3)   Chromaticity Mode

Figure 5.4

Clicking the speed button will switch to the chromaticity mode, see Figure 5.4. In this mode, the calculated CIE colorimetric coordinates (1931x, y and 1976u', v') of the current acquired spectrum will be plotted on the 1931UCS chart and 1976UCS chart according to the selected display option. The CIE colorimetric parameters calculated are different in different display options.

If *'Dark Subtracted'* is selected, the two colorimetric coordinates will be calculated and shown on the text pad.

If '*%T/R*' is selected, the two colorimetric coordinates along with CIE 1976Lab coordinates will be calculated and shown on the text pad.

If *'Absolute irradiance'* option is visible and selected, in addition to the two colorimetric coordinates, the CCT (correlated color temperature) and CRIs (14 color rendering index together with CRIa) defined by CIE will also be shown on the text pad.

The normalized spectrum (wavelength range 360 to 830) will be shown on the bottom chart for all options.

Notes: 1) The Chromaticity Mode will be available if current connected spectrometer is wavelength calibrated.

2) For the CIE parameters to be calculated, check the [CIE Flag] box of the [Spectrometer Control] group on the [Control panel] before clicking the Acquire One Spectrum data.

3) The CIE parameters will only be calculated in 'Acquire One Spectrum'. Clicking other acquiring actions, e.g. 'Acquire Overlay', 'Acquire Continuous', 'Acquire Dark' or 'Acquire Ref' will not calculate the CIE parameters.

4) The CIE parameters will be calculated in Pixel Mode P0, P1, P2 and P3 but not in P4, P5, P6 and P7. Even in P1, P2 and P3, the original spectrum is adopted for calculation just as in P0 mode.

5) The colorimetric coordinates is confined to 4 valid digits and CCT is confined to one digit.

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5.4. Control Area

The control Area contains two tabs: "Control Panel" and "Wavelength Calibration". The control Area will only be visible in Graph mode and Chromaticity Mode.
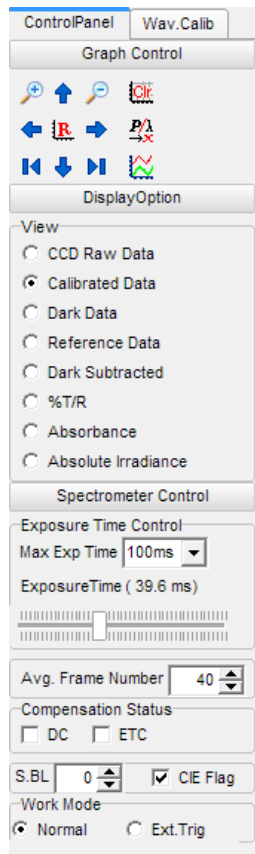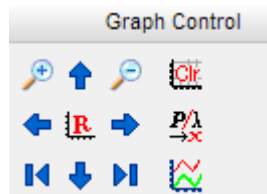

Figure 5.5 Control Area

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1) Control Panel Tab

This Tab, figure5.5, contains three control groups: **Graph Control**, **Display Option** and **Spectrometer Control**.

■ **Graph Control** contains 13 quick 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;

 : Expand the graph to the left;

: Expand the graph to the right.

 : Reset the chart to its standard format.

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: Clear Chart, clear all chart contents.

: Change the unit of x-axis between pixel and wavelength (This button will be enabled if wavelength calibration is available).

: Bring up the smooth module on current display choice.

Note: When switched to [Chromaticity Mode], the graph control will be invisible.

■ **Display Option** 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 if ETC is enabled, otherwise it is the same as CCD Raw Data.
Dark:	Display the current obtained/loaded dark spectrum, if no dark spectrum has been obtained or taken, dark data will be 0;
Ref:	Display the current obtained/loaded reference spectrum.
Dark Subtracted:	Display the spectrum which has subtracted the Dark Data from the current Calibrated Data.
%T/R:	Display the spectrum ratio which is defined as *(**Dark Subtracted**/**Reference Data**)*;
Absorbance:	Display the spectrum of absorbance which is defined as: $\mathbf{Log_{10}}$(**Reference Data**/***Dark Subtracted***);
Absolute Irradiance:	Display the spectrum of test light in absolute irradiance units (Only available when absolute irradiance calibration coefficients exists), See <u>appendix 4 AIC</u> for details.

Note: 1) In [Chromaticity Mode], there are no CIE parameters calculated for [CCD Raw Data], [Calibrated Data], [Dark], [Ref] and [Absorbance].

2).When no wavelength calibration information was found for the device that is connected, the [Absolute Irradiance] will be disabled.

■ **Spectrometer Control:** Contains Controls of the working parameters of spectrometer, e.g., exposure time, Average frame number, and compensation flags, etc.

Exposure Time: This is the integration time for each frame, the minimum exposure time and the exposure time step is 100μs, which means the set exposure time is a multiple of 100μs.

Avg. Frame Number: Set the frame number for each acquiring action.

Compensation Status: Set the auto dark status and ETC status of the grabbed frame.

CIE Flag: Set the CIE flag to enable or disable calculation of the CIE parameters.

Work Mode: Switch spectrometer working mode between Normal Mode and External Trigger 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, the spectrometer should be kept in "Normal" mode**).

Note: Setting new spectrometer control parameters will affect next grabbed frame, and have no effect on the current or previous frames.

2) Wavelength Calibration Tab

*Important Notice: To get into this tab, the **Pixel Mode** has to be set to **P0** and **X-axis unit** has to be in **pixels**.*

When wavelength calibration is needed, the wavelength calibration tab can be used to perform the calibration. When the "Enable Data Table" checkbox is not checked (shown in the left side), there are only two buttons on it (Cal. Set and Coeff). Checking the 'Enable Data Table' check box will enable the wavelength calibration functions (shown on the right side). See appendix 1 wavelength calibration for details.
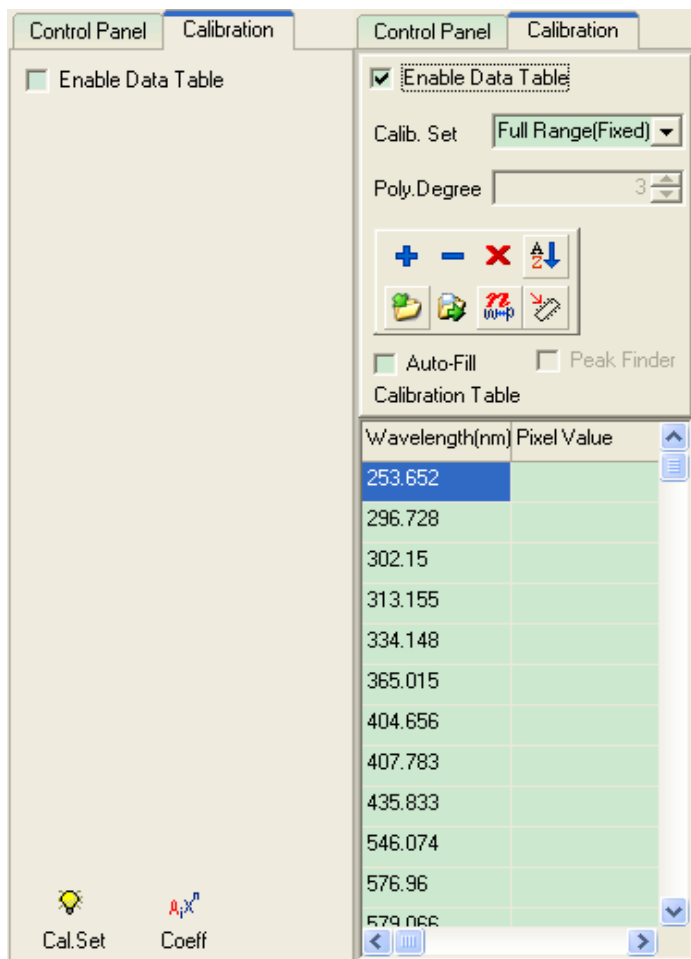
☑ Enable Data Table : When checked, the full calibration table is visible.

Cal.Set : Opens the wavelength set management window.

Coeff : Opens a new window to view or edit the calibrated wavelength-pixel coefficients.

Calib. Set 250-930nm(PreD ▼) : Selecting the predefined wavelength Sets and 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 is fixed to 3.

The 8 buttons on the next panel are used to control the behavior of the following calibration table.

+ : Insert a row.   : Save wavelength-pixel data to a calibration file.

− : Delete current selected row;   : Load a previously saved wavelength-pixel data.

✗ : Clear the 'Pixel Value' column.   : Calculate the coefficients using least square method.

↓ : Sort the table by wavelength in ascending order.   : Save coefficients.

☐ Auto-Fill : When checked, a cursor will show on the main chart which is used to help locate the position of the spectrum peak. When user right clicks the cursor, the corresponding pixel value is filled in the current row automatically.

☑ Auto-Fill ☐ Peak Finder : When the check box 'Auto-Fill' is checked, the check box 'Peak Finder' will be enabled. Check this to activate the peak finder tool. When it is activated, the cursor only needs to be placed near the spectrum peak and the application will find the peak and fill the pixel value in the table automatically.

Control Panel	Calibration		Control Panel	Calibration
☐ Enable Data Table			☑ Enable Data Table	

Calib. Set	Full Range(Fixed) ▼
Poly.Degree	3

Wavelength(nm)	Pixel Value
253.652	
296.728	
302.15	
313.155	
334.148	
365.015	
404.656	
407.783	
435.833	
546.074	
576.96	
579.066	

☐ Auto-Fill   ☐ Peak Finder

Cal.Set   Coeff

5.5. Status Bar

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

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

3: Auto Dark Compensation Status, obsolete.

4: ETC Compensation Status: refer to Appendix 2 ETC

5: RRC Compensation Status, obsolete.

6: Current Pixel mode, refer to Pixel Mode description.

7: Current Cursor Information: displays cursor information such as pixel index, wavelength value and y value of the main chart when cursor is enabled.

8: Exposure Time of current frame, in µs.

9: Saturation status of current frame. 'Normal' or 'Over Saturated'. If it is 'Over Saturated', reduce the exposure time.

10: Triggering status of current frame.

11: The total triggering count of current frame.

12: The time stamp of current frame.

13: The factory debugging information.

14: If AIC file of current spectrometer exists and CIE Flag is on, this area shows the total irradiance.

15: If AIC file of current spectrometer exists and CIE Flag is on, this area shows the total Illuminance.

16: The total count of currently connected supported Mightex spectrometers.

17: The index of current working spectrometer.

18: The module information of current working spectrometer.

19: The grabbing information.

Note: The grey items are only for factory usage.

6 Software Operations

6.1 Acquire Spectrum

Note: Before acquiring the spectrum, be sure to connect the Mightex spectrometer to the computer properly.

Acquire One Spectrum

By clicking the 'Acquire One Spectrum' quick button ❯ on the toolbar, the Spectrometer will scan the spectrum **ONCE** and transmit the data to the application.

Acquire Spectrum Continuously

By clicking the 'Acquire continuous spectrum' quick button ⇢ on the toolbar, the spectrometer will scan the frame and transmit the data to the application continuously. The icon of the speed button will change to 'Stop' ■. Clicking again, the spectrometer will stop scanning/transmitting data.

Acquire Overlay Spectrum

When clicking the 'Acquire Overlay Spectrum' quick button ⏩, multiple spectrums (up to 3) can be saved to the main chart.

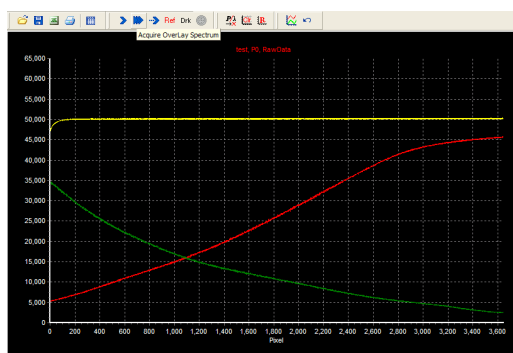

Figure 6.1. Multiple spectrums obtained with the 'Acquire Overlay Spectrum' button

6.2 Acquire Dark Data

Subtracting dark data is a way to eliminate ambient light from the spectrometer readings. To acquire dark data:
Make sure the spectrometer is connected to the PC properly.
Run the application.

Turn off the lamp or (light source) and click the Drk button on the toolbar.

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 name is specified in the "Reference, Dark Setup" dialog box, which is described in Reference Data & Dark Data Setup.
The Dark Status on the status bar will be in RED and shown as 'Drk: On', which indicates that the dark data array is already available, and the display option will be automatically shifted to 'Dark', which shows the dark data just acquired.
Note: Dark status can be set by either using the 'Acquire Dark Data' button, or by loading a pre-saved dark file. Acquiring dark data will only make the dark data available to the following acquiring actions, which means that

acquiring dark data will overwrite the current spectrum data.

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

After acquiring the dark data, the display option will switch to 'Dark' automatically, and should be manually changed in the display option if wanting to view other plots.

6.3 Acquire Reference Data

Some applications may require the display option to be set to '%T/R' or 'Absorbance'. In this case, a reference spectrum is needed, which can be acquired by clicking the 'Acquire Reference' quick button Ref on the toolbar. Similar to the "Acquire Dark Data" above, the reference data array will also be saved to specified 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.

6.4 Edit Frame Average Number

The acquired spectrum data might be averaged from multiple frames if the average frame number is greater than 1. E.g., if the average number is set to 2, the spectrometer will actually acquire 2 frames and get the average from these two frames then send it back to application. The average frame number can be edited through the Spectrometer Control section of the Control Panel tab.
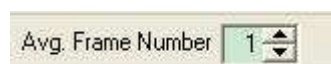
Note: When ETC flag is turn on, the application will spend much of CPU time on the ETC calculation which may slow down the application and GUI response will also be delayed.

6.5 Customizing Chart

The appearance of main chart or bottom chart can be customized through **'Main Menu | Setup | Setup Chart'** or the [Setup Chart] quick button on the toolbar, which will open a new window to edit the charts, Figure 6.2.

Graph Title:

Edit the title of the graphs in the 'Graph Title' group, which will take effect for both charts.

Charts:

Choose which chart to customize by selecting either Upper Chart or Lower Chart.

Note: 'Main menu | Setup | Setup Chart', means to open the Setup chart menu item of the Setup menu on the main menu area.
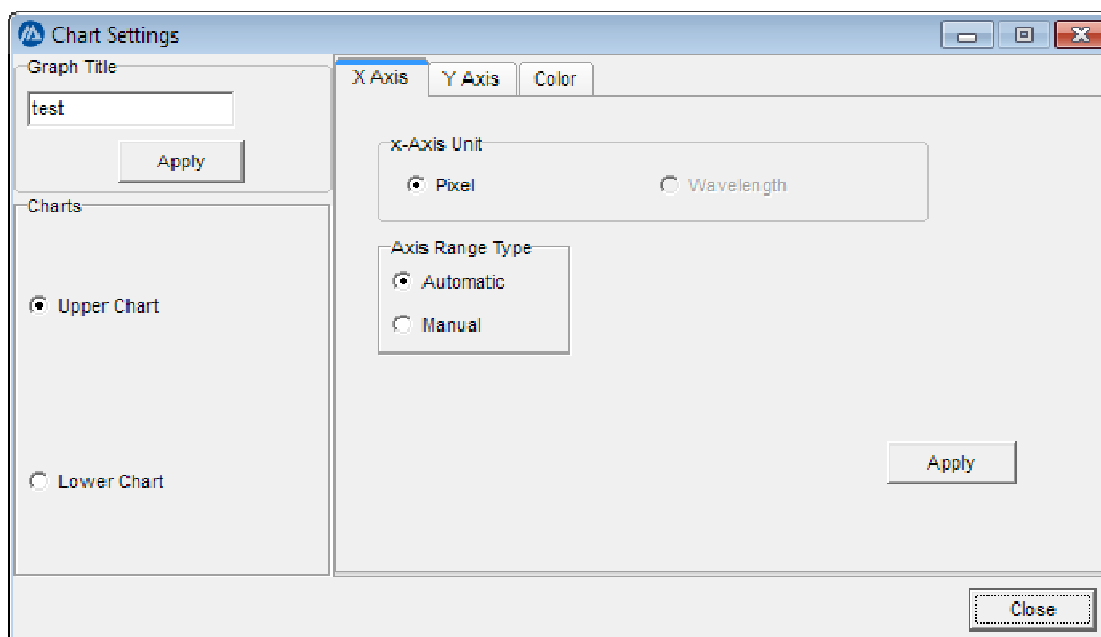
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Figure 6.2

For each chart, the parameters of X-Axis, Y-Axis, and the color of chart elements can be edited.

X-Axis Tab: the unit of the X-Axis can either be the wavelengths (λ, in nm) or pixels. For both units, the application can be used to define the minimum and maximum of the X-Axis automatically or 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 minimum and maximum values to be inputted manually.
Important: X-Axis Edit mode will only be available when the Pixel monitoring mode is set to P0, at other pixel monitoring modes, the X-Axis may not be edited. (Refer to the details of Pixel Monitoring mode later)

Y-Axis Tab: The units of the Y-Axis are automatically controlled by the application. The minimum and maximum can be controlled either automatically or manually.

Color Tab: Use this option to edit the color of several chart elements, including background color, foreground color, chart title color, axis color, axis text color, axis grid color, axis tick color and the series color.

6.6 Reference Data & Dark Data Setup

The reference and dark data can be acquired through the quick button on the tool bar. To manage the reference and dark data, the application provides a handy tool to save or load the reference and dark data which can be opened through the Main Menu 'Setup | Reference&Dark File Setup', Figure 6.3.

Save Current Spectrum into Reference Array': By clicking this button, the current Calibrated Data (the first spectrum obtained if GrabOverlay is clicked) will be set as the Reference Array.

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

Load Reference File': This button allows a pre-saved reference file to be loaded as the current reference data. The file path is shown in the edit box below the button. When the 'Load Reference File on Application Starts' box is checked, it will load the selected reference file automatically when starting the application.

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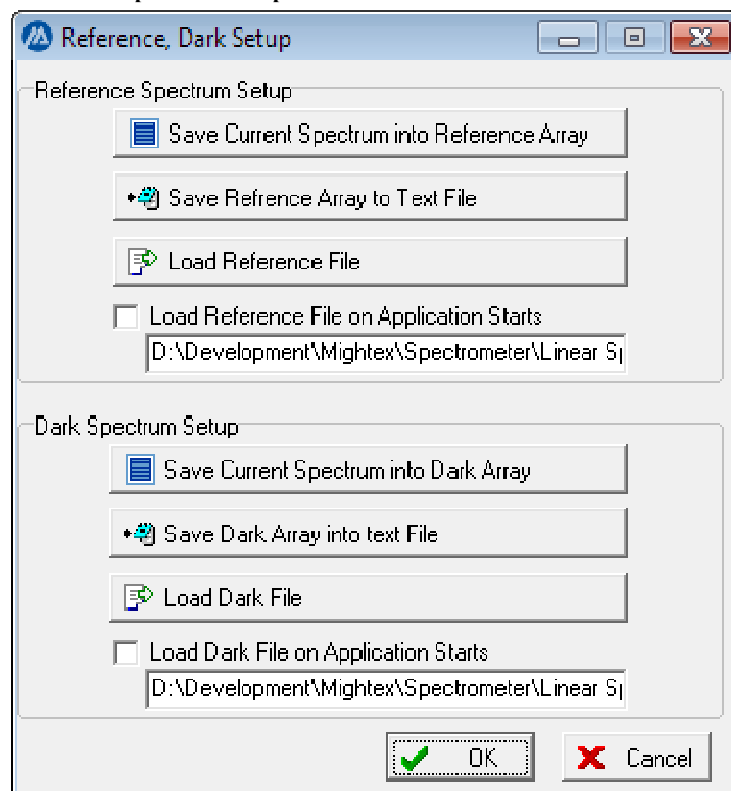

Figure 6.3 Reference and Dark setup Dialog

IMPORTANT: When the software starts, it will load the dark and reference spectrums according to the settings 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 are checked but the specified files are invalid, the software will not load the files.

6.7 ETC (Exposure Time Linear Calibration) Compensation

ETC compensation status can be controlled by the ETC check box in the spectrometer control group in the control panel ☑ ETC .

After ETC is turned on, the compensated frame data can be seen by choosing the [Calibrated Data] option in display option.

Important: *When ETC Compensation is enabled, the spectrum display from the spectrometer will be corrected with the ETC calibration data if "Calibrated Data" is selected in Display Options. Selecting "CCD Raw Data" will display the raw spectrum without the ETC calibration. When ETC is OFF, "CCD Raw Data" is essentially the same as "Calibrated Data". If using "Dark Subtracted" or "%T/R"…etc., obtain the Dark or Reference spectrum first. Please note that after ETC options have been modified, Dark and Reference spectrums should be obtained*

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again under the current compensation status.

For details of ETC, please refer to the "Appendix 2 ETC Compensation Details"

6.8 Pixel Monitoring Mode

Introduction

Although the software acquires frame data from all pixels, the application provides the options to view those data in different formats. There are a total of 8 pixel monitoring modes from which to choose.

Click the main menu 'Setup|Pixel Monitoring Mode' to open the 'Pixel Monitoring Mode' form, Figure 6.4:

1) Pixel Monitoring Mode: P0
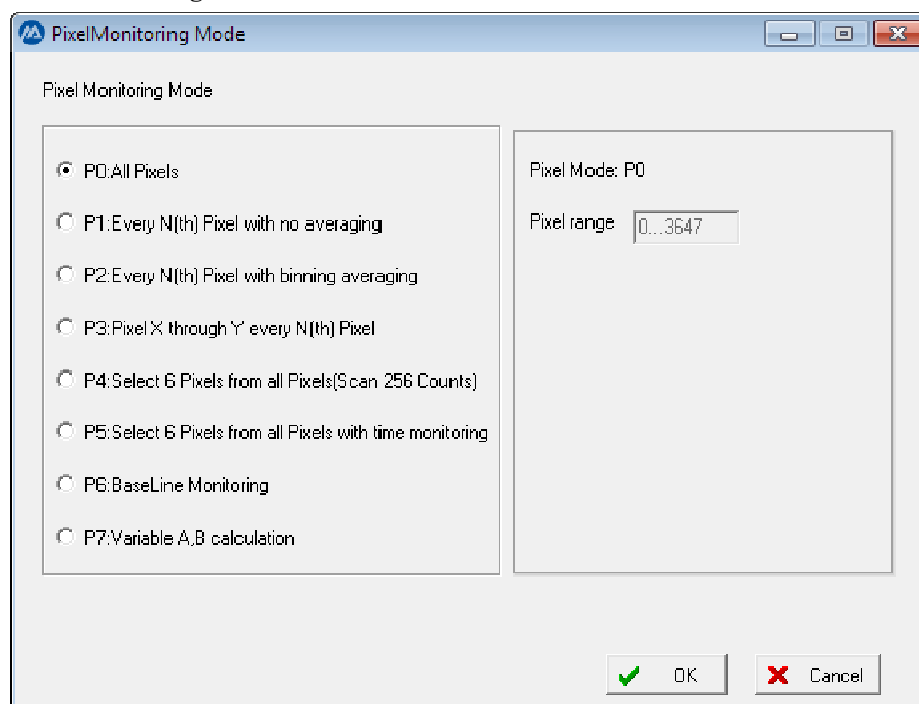
Figure 6.5 Pixel Monitoring Moe P0

In this mode, the application will show all the pixel data on the chart, and the unit of x-axis can be defined as pixel or wavelength (if the spectrometer is wavelength calibrated).

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

2) Pixel Monitoring Mode P1:

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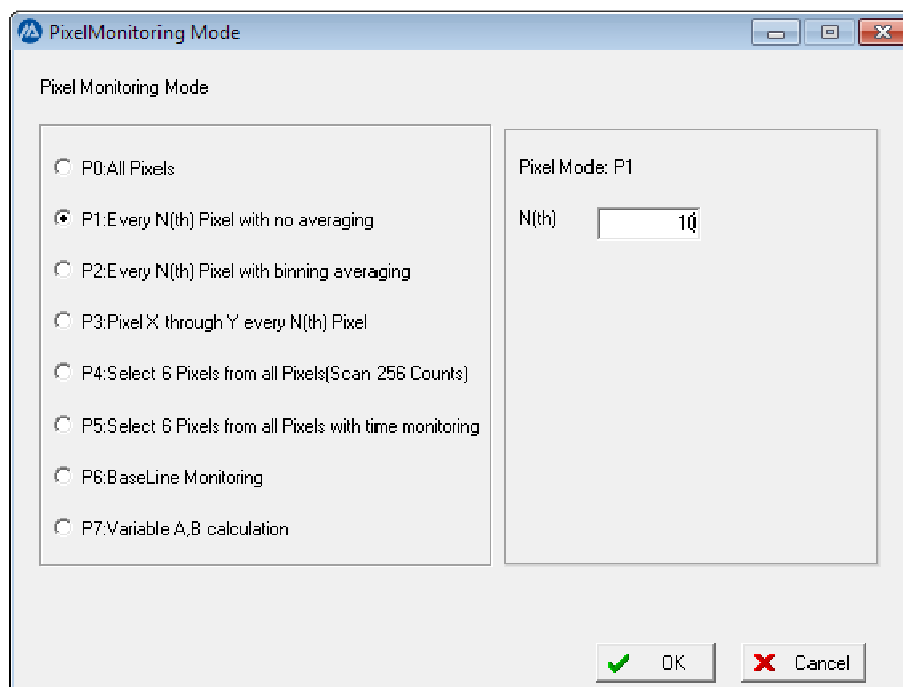
Figure 6.6 Pixel Monitoring Mode P1

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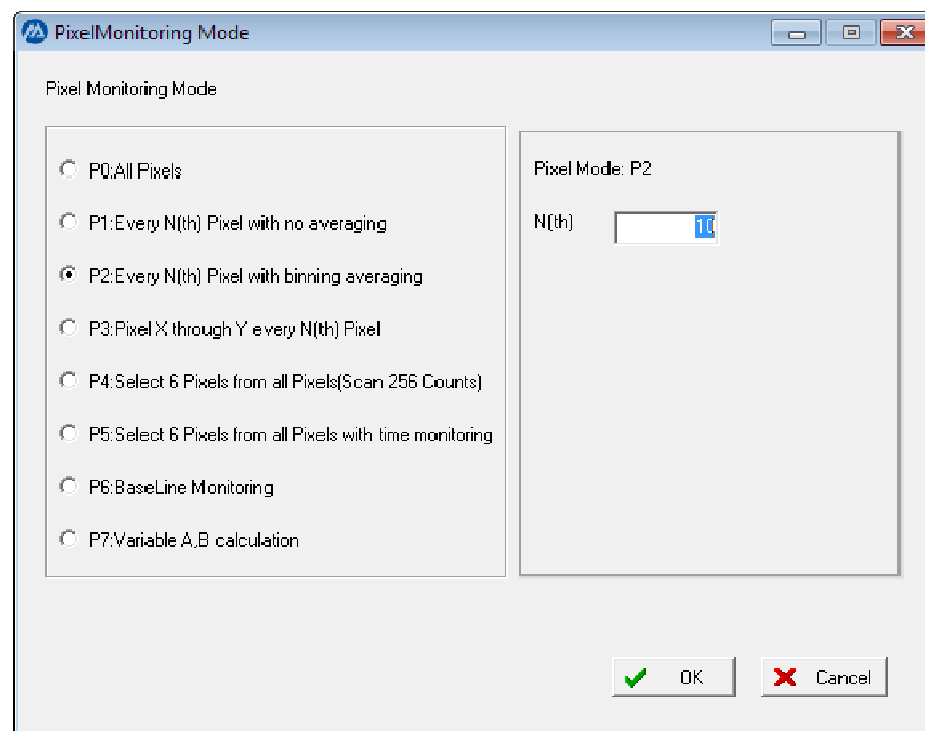

3)   Pixel Monitoring Mode P2:

Figure 6.7 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 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

4)   Pixel Monitoring Mode P3:

Figure 6.8 Pixel Monitoring Mode P3

In this mode, the application can display a section of pixels by editing the Start Pixel number and End Pixel number. Also, editing the N(th) box will display every N(th) pixel in the range defined by Start Pixel and End Pixel.

5)   Pixel Monitoring Mode P4:

Figure 6.9 Pixel Monitoring Moe P4

In this mode, the application can select 6 specific pixels to view from the data in 256 scans.

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After clicking the 'OK' Button, the control goes back to the main application and the UI will be changed to the following graph:
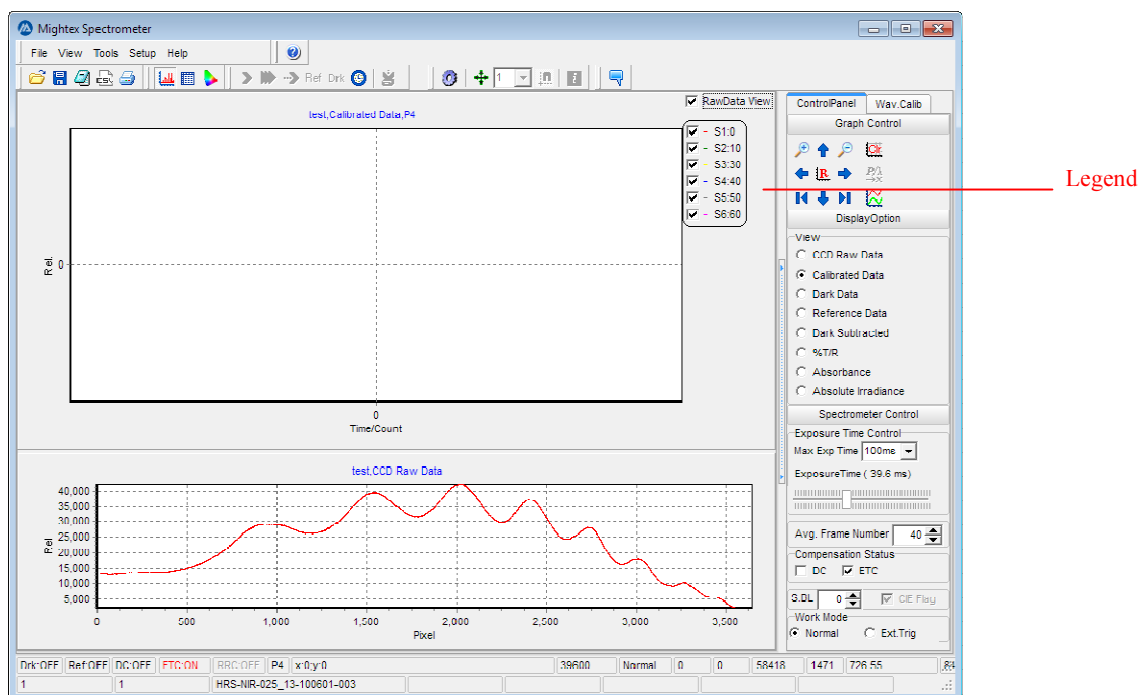
Figure 6.10 GUI for Pixel Monitoring P4T7

The 'Pixel Mode 4T7 Grabbing' button [icon] is enabled in this pixel mode (and for the following P5, P6 and P7 modes). The other acquiring action buttons are disabled. The main chart title has been changed to show the current pixel mode (e.g. P5), 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 shows the selected pixel mode. By clicking the 'Pixel Mode 4T7 Grabbing' button, the application will scan these selected 6 pixels 256 times.

6) Pixel Monitoring Mode P5:
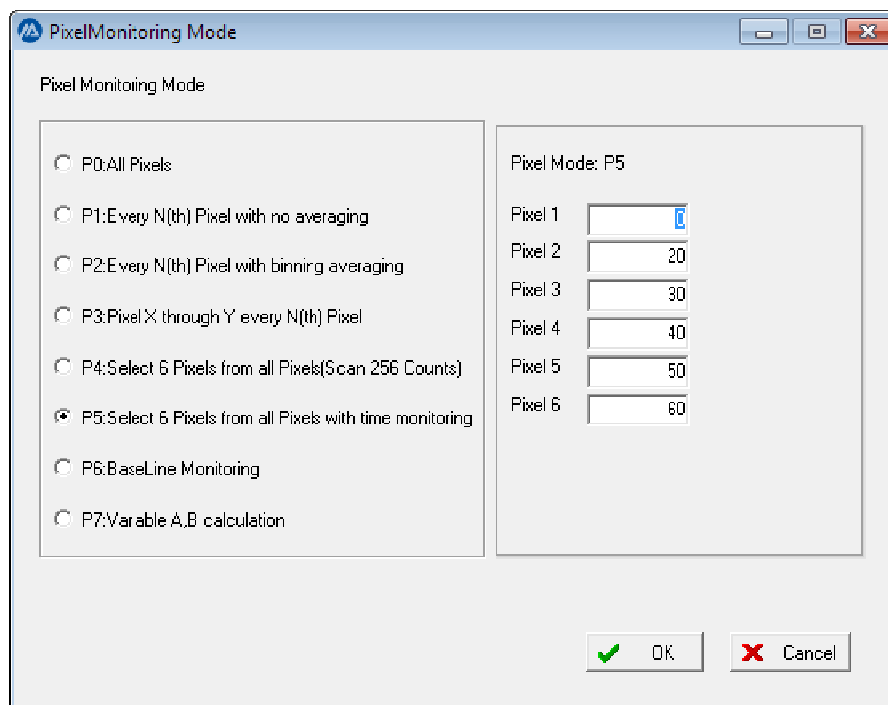
Figure 6.11 Pixel Monitoring Mode P5

This pixel monitoring mode is similar to P4 mode, except that its scanning process is continuous until a command is given to stop it. (Note: the software will stop it if the scanning count becomes very large, otherwise there might be issues due to limited PC resources).
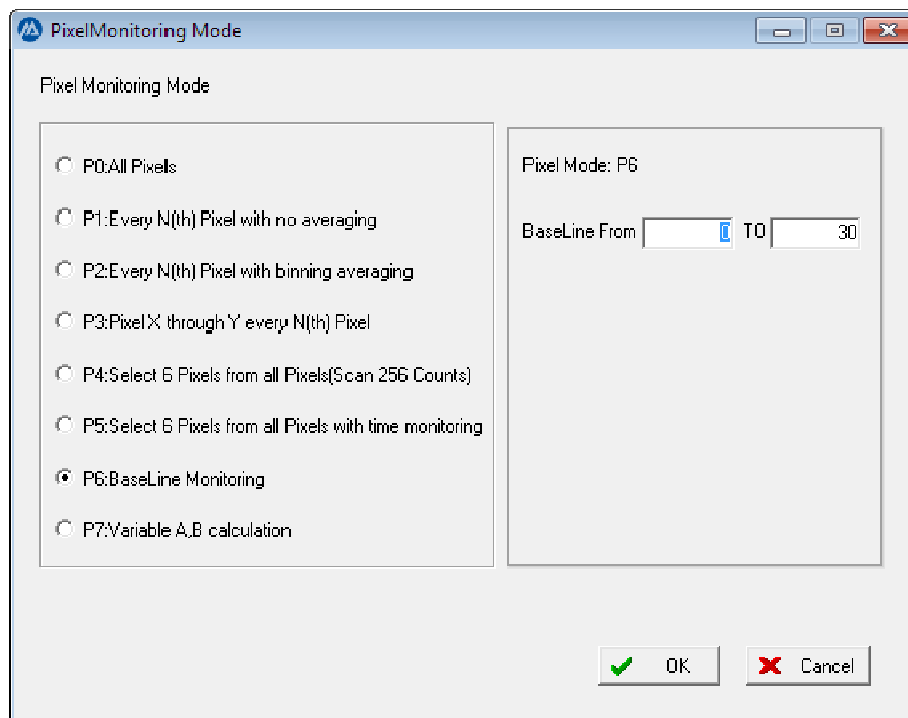
7)   Pixel Monitoring Mode P6:

Figure 6.12 Pixel Monitoring Mode P6

In this pixel monitoring mode, a range of the pixel number can be specified and the application will calculate the arithmetic average value of these pixel data. The result will show in the main chart as function of time. The

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scanning is continuous until commanded to stop.

Click the 'OK' Button to accept the selection and settings. The control will go back to the main application and the UI will look like the UI of P4.

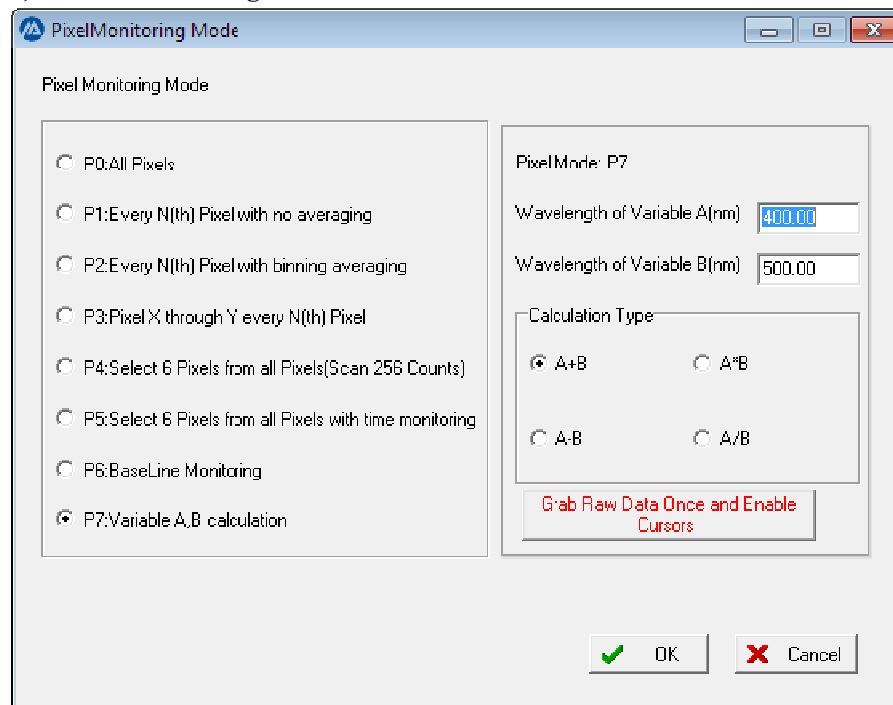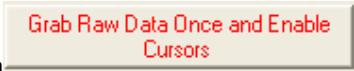**8) Pixel Monitoring Mode P7:**

Figure 6.13 Pixel Monitoring Mode P7

In this mode, the application will ask for the two wavelengths at which the scanning data are calculated in the form of the selected calculation type. The two wavelengths can be input manually in the edit boxes as shown above (400.00 and 500.00) or input using the application to position the wavelength. The result will be monitored continuously until manually stopped. The desired calculation method can be chosen for the two wavelengths' data.

By clicking the button [Grab Raw Data Once and Enable Cursors], the application will open a form called 'Pixel Mode P7: Variable AB'. At the same time, two cursor lines are visible on the main chart, the unit of abscissa on the main chart will automatically be set to wavelengths, and the position of the these two cursors will be directly shown on the two edit boxes 'Pixel Mode P7: Variable AB'.

Obtain one spectrum raw data by clicking the 'Acquire One Frame' button then manually drag the two cursor lines to set the wavelengths. After two wavelengths have been set, choose the calculation type, and click the 'OK' button to close the form 'Pixel Mode P7'.
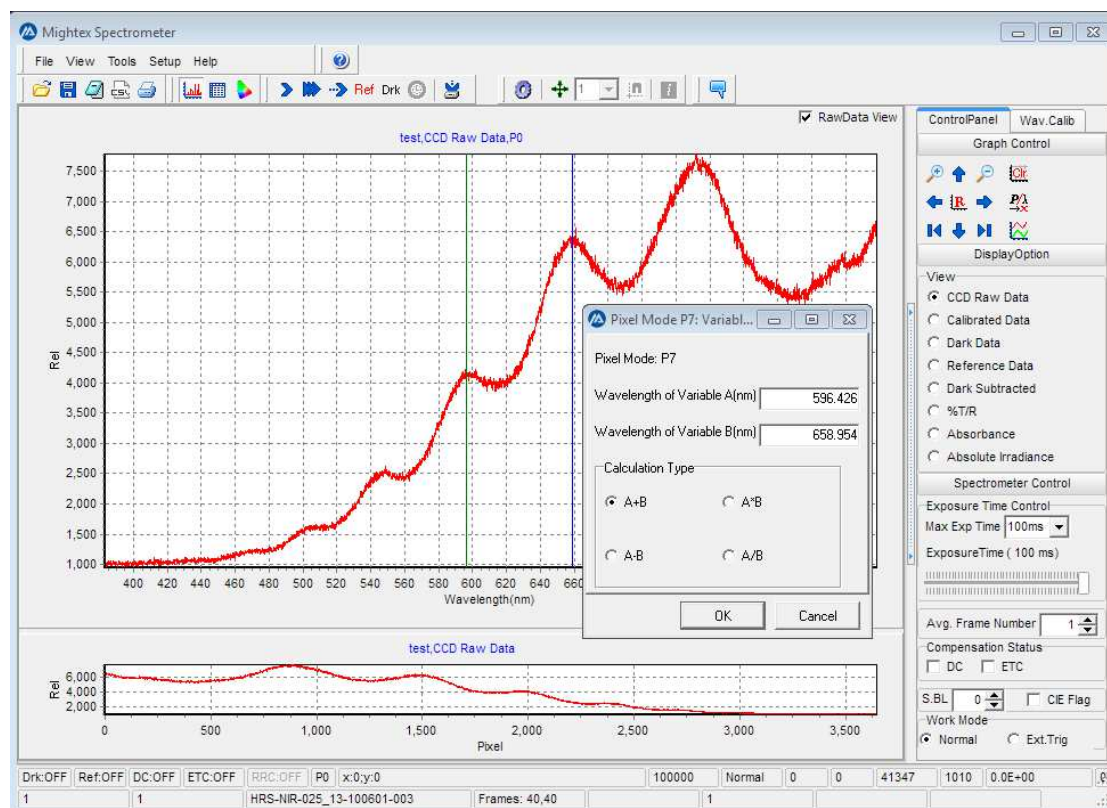
Figure 6.14 GUI for manually selecting wavelengths of P7

After pixel mode P7 has been chosen, select the two wavelengths and calculation type The main chart's title will include the two wavelengths value and the calculation type. The application looks similar to pixel mode P4.

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

6.9 Smoothing

The smoothing function can be used for spectrum data processing (For Pixel modes P0 only). The data smoothing method can be selected from the main menu 'Setup | Smooth Function'.
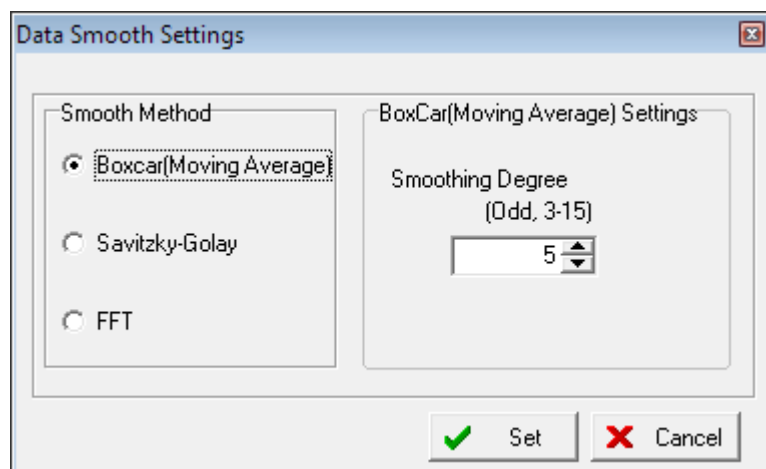
Figure 6.15 Smoothing Function Dialog

The smoothing method can be 'Box Car' method, 'Savitzky-Golay' method, FFT method. The parameter of the

selected function can be edited in the right panel. After selecting the smoothing method and proper parameters, click the 'Set' button to accept the settings.

Clicking the 'Open Smooth Module' button [icon] on the Graph control in the Control Panel will open a smooth module which takes current display option data as source and displayed as the blue series, see figure 6.16. The previous selected smooth method is displayed in the right control panel. Click the speed button [icon] on the right panel will apply the smooth with selected smooth setting. The smoothing history is recorded in the grid. The speed button [icon] is used for reverse the latest smooth data back to previous one.
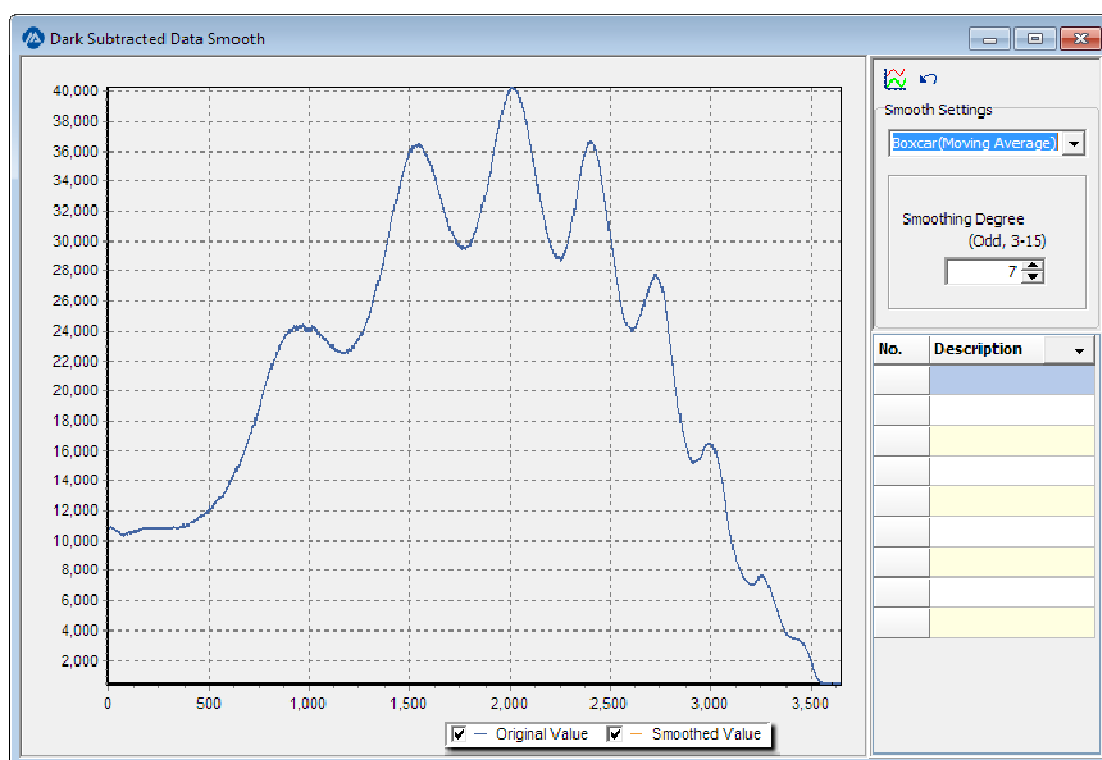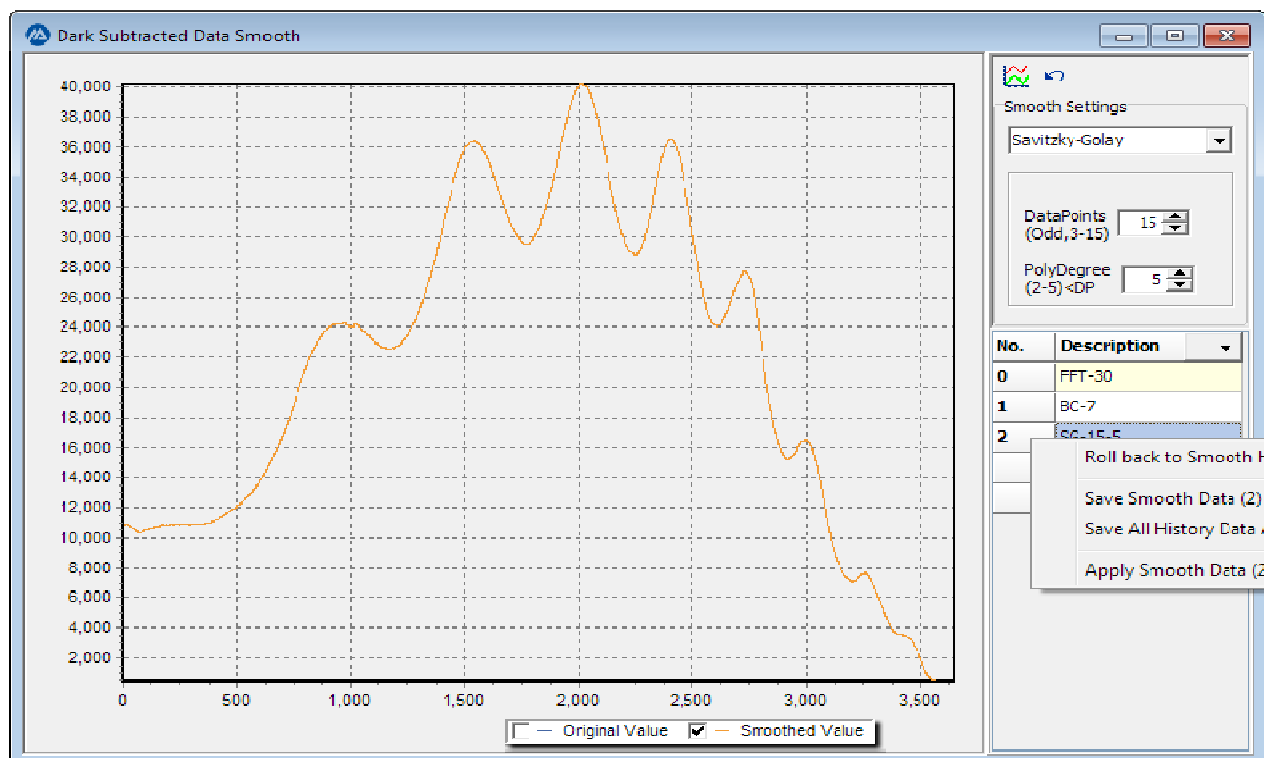

Figure 6.16 Smoothing Module

Figure 6.17 Smoothing example

Figure6.17 is an example of smoothing dark subtracted data, which is first smoothed using FFT with level 30, then again smoothed with box-car with car size 7 and finally with Savitzky-Golay method. Right click the smoothing history data will bring up a popup-menu which allows user to roll back smoothed data to a previous point, to save smooth data to a file or apply smooth data to source.

6.10 Time Line:

*Notes: Acquire timeline is only be available in the pixel monitoring modes **P0 to P3.***

The application can continuously grab spectrums in predefined moments and save them onto the disk.

In the pixel monitoring modes P0, P1, P2, and P3, the 'Time Line Function' quick button on the toolbar is enabled. When clicked, an '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.
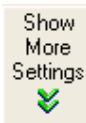
1) **Save Data:**
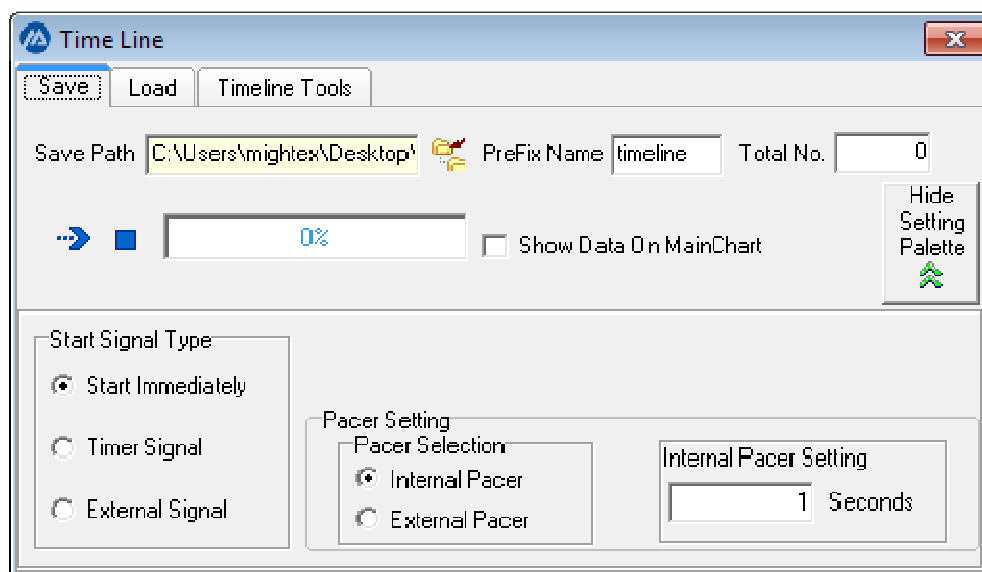
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The button [Show More Settings] reveals additional settings when clicked.
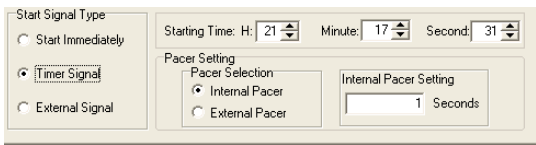

Figure 6.18 Time Line saving dialog

Save Path: Click the button [icon] and choose a directory in which the grabbed spectrum data are stored.

Prefix Name: Choose the prefix of the saved file name. If the name is 'test', for example, then the saved file name for the n_{th} collection of data is test_n.txt under the saved path.

Total No: Total number of the collected spectrum.

At the bottom panel, there is an option to choose the start signal type and pacer type, which are described later.

After all settings have been set, click the button [icon]. The spectrometer will start to collect the Total No spectrums with the selected start signal and pacer. The status of the collecting will be shown on the Status edit box.

Start Signal	Pacer Type	Description
Start Immediately	Internal Pacer	The spectrum will be grabbed immediately when clicking the Start button [icon], and the sequential collections 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 grabbed immediately when cling the start button [icon], but the actual spectrum collecting can only be triggered by the external trigger signal.
Time Signal	Internal Pacer	After choosing 'Time Signal' as the start signal, the start time panel will be visible on the right. The spectrum will be grabbed when the timer reaches

		the time specified after clicking the start button ➤. And the following collections will be controlled by the internal pacer.
Time Signal	External Pacer	Similar to the previous case, the collecting is started at the designated time setting, 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 an external signal has been detected after clicking the start button ➤. The sequential collecting are controlled by the internal pacer. The external signal is ignored for all the sequential collections.
External Signal	External Pacer	The first spectrum grabbing will be initiated when an external signal has been detected after clicking the start button ➤. The sequential grabbing is also controlled by an external pacer.

*. For internal pacer, if the pacer is smaller than one spectrum time (e.g. if exposure time is set 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 is **NOT** necessary to set mode to 'EXTERNAL'. Also, the Frame average number should be set to 1, as the device only generates one frame upon each trigger.
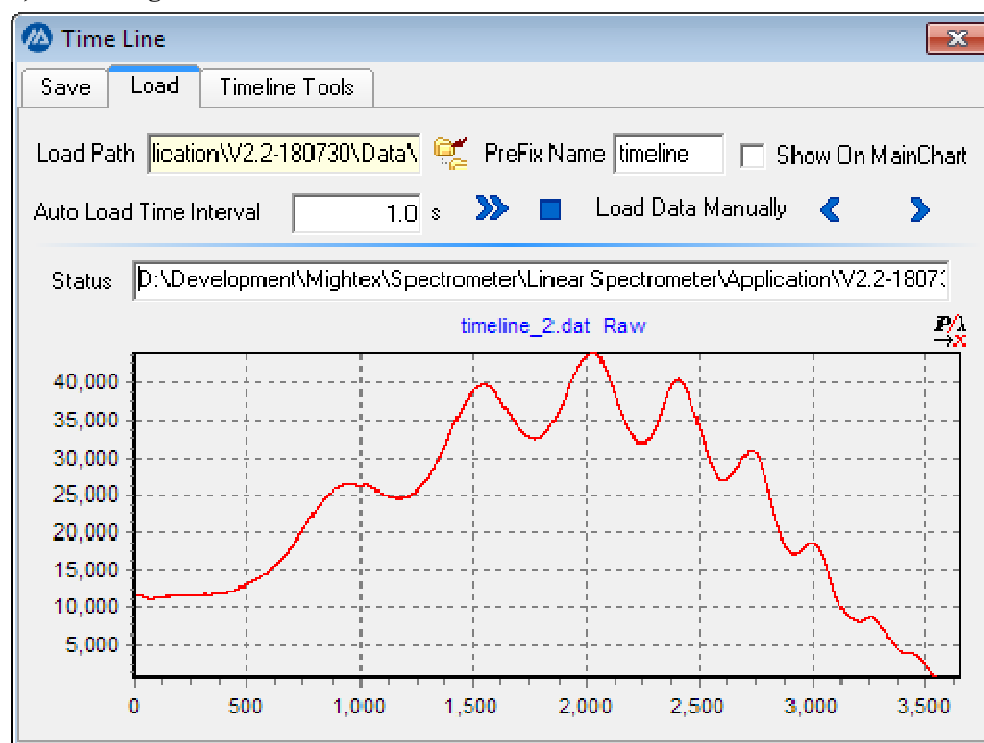
2) **Loading Data:**

Figure 6.19 TimeLine Loading dialog

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

Prefix Name: Edit the prefix of the loaded file.

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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: a) *To view the loaded spectrum, the main chart bottom axis unit has to be set to pixel.*

    b) *While 'Auto Load Time Interval' is set, clicking the* *button will load files one by one in the setting time interval. The spectrum can be observed in the main chart, and the loading progress is shown on the Status bar.*

3) Timeline tools
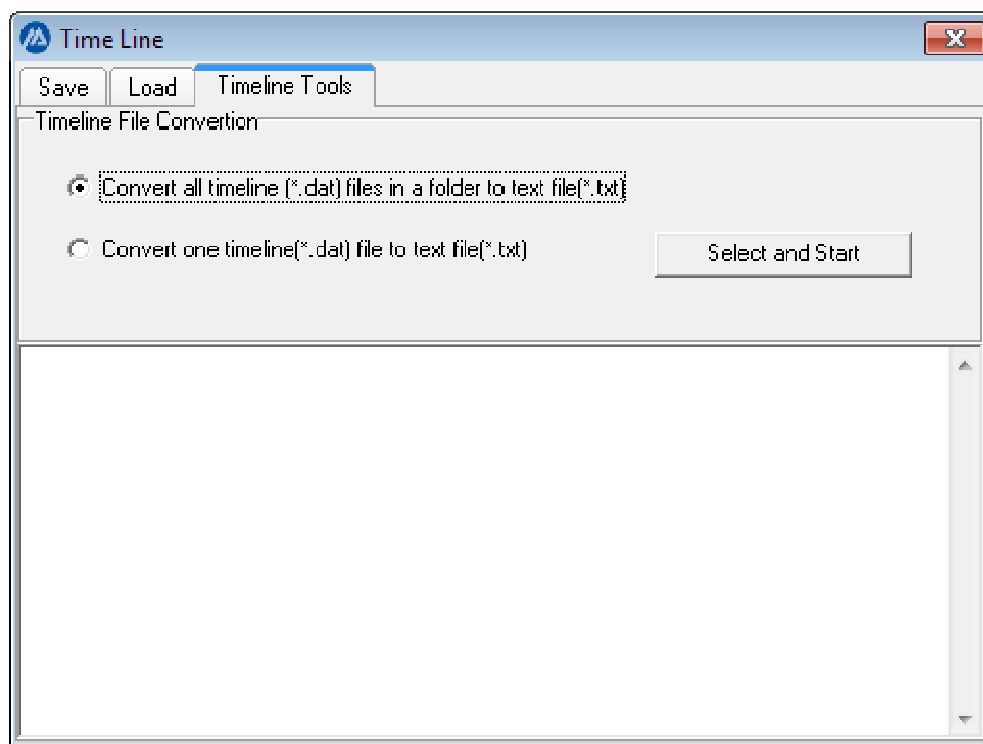
The timeline function saves all recorded data in binary files (*.dat). For convenient data analysis, a tool is provided to convert the saved binary timeline data file to text file, which can convert a single binary file or all binary file within a folder.

6.11 Spectrometer Control

1) Exposure Time

The 'Max Exposure time' combo box opens a drop down menu to choose the maximum exposure time of the tracking bar. After dragging the sliding bar to a new location, the new exposure time will be effective in the next acquiring action.

2)   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.

The working mode of the spectrometer can be controlled via the Work Mode section in the Spectrometer Control group in the control panel. The default working mode of the spectrometer is normal mode.
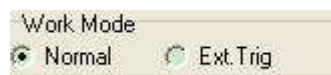
Note: In almost all applications, Normal mode should be used

6.12 Commenting

The application allows for comments after acquiring a frame. The comments will be saved together with frame data.

Simply clicking the 'Comment' quick button on the toolbar will open a comment window.

6.13 Saving and Loading Data

1)   Saving Data

The spectrum data can be saved to disk by either clicking the on the tool bar or clicking the 'File | Save As…' menu item. After the file save dialog is opened, 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 marks are notes that are not saved in the file).

@mightex_spectrum_save 2 2 0	(File Header and data file version)
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 spectrometer's exposure time)
0	(the spectrometer's work mode, 0 for normal mode 1 for Ext. Trig.)
3648	(the spectrometer's pixel amount)
1200	(the exposure time)
8.38295738431254E+0002	(the pixel to wavelength calibration coefficients A0)
-1.18050277757737E-0001	(the pixel to wavelength calibration coefficients A1)
-2.28504849803754E-0006	(the pixel to wavelength calibration coefficients A2)
1.22108982484139E-0010	(the pixel to wavelength calibration coefficients A3)
6.58942631406947E+0003	(the wavelength to pixel calibration coefficients B0)
-7.74318084552069E+0000	(the wavelength to pixel calibration coefficients B1)

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4.40312073483289E-0004	(the wavelength to pixel calibration coefficients B2)
-6.91953090953480E-0007	(the wavelength to pixel calibration coefficients B3)
0	(the unit of absolute intensity)
2	(the average frame number)
0	(the dark compensation status)
0	(the ETC flag)

PixelNo   Wavelength   CCD_1   CCD_2   CCD_3   Calib_1   Calib_2   Calib_3   DarkSub_1
DarkSub_2   DarkSub_3   %T/R_1   %T/R_2   %T/R_3   Ref   Dark   Absorb_1 Absorb_2   Absorb_3
        AbsIrrad_1   AbsIrrad_2   AbsIrrad_3

0   8.38295738431254E+0002   1.15000000000000E+0001   0.00000000000000E+0000
0.00000000000000E+0000   1.71994247225183E+0001   0.00000000000000E+0000
0.00000000000000E+0000   1.71984247225183E+0001   0.00000000000000E+0000
0.00000000000000E+0000   2.29587835035620E-0003   0.00000000000000E+0000
0.00000000000000E+0000   7.49100000000000E+0003   1.00000000000000E-0003
2.63905106926053E+0000   0.00000000000000E+0000   0.00000000000000E+0000
1.00000000000000E-0003   0.00000000000000E+0000   0.00000000000000E+0000

CIE Parameters

0

0

    3.83297018443503E+0002

    8.38295738431254E+0002

    3.83297018443503E+0002

    8.38295738431254E+0002

3.83297018443503E+0002

    8.38295738431254E+0002

User Comments

2) Loading Data

The saved spectrum data can be loaded by either clicking the ⬚ button on the tool bar or 'File | Load' menu item. After clicking, an open dialog will be shown, choose the directory where the data is stored and select one file, then click 'Open' button. The saved data will be automatically loaded and the spectrum data will be shown on a standalone widow like the following figure.

Following the window title, there are two lines showing the file name, spectrometer information, date and time when saved.

The saved data can also be viewed in three modes: graph mode, table mode and chromaticity mode which can be selected using the tab controls at the bottom.

The right panel has two quick buttons which allow for the selection of the x-axis units and viewing the comments saved. Additionally, there is a 'Viewer' section which can be used to change the type of data displayed on the main window.
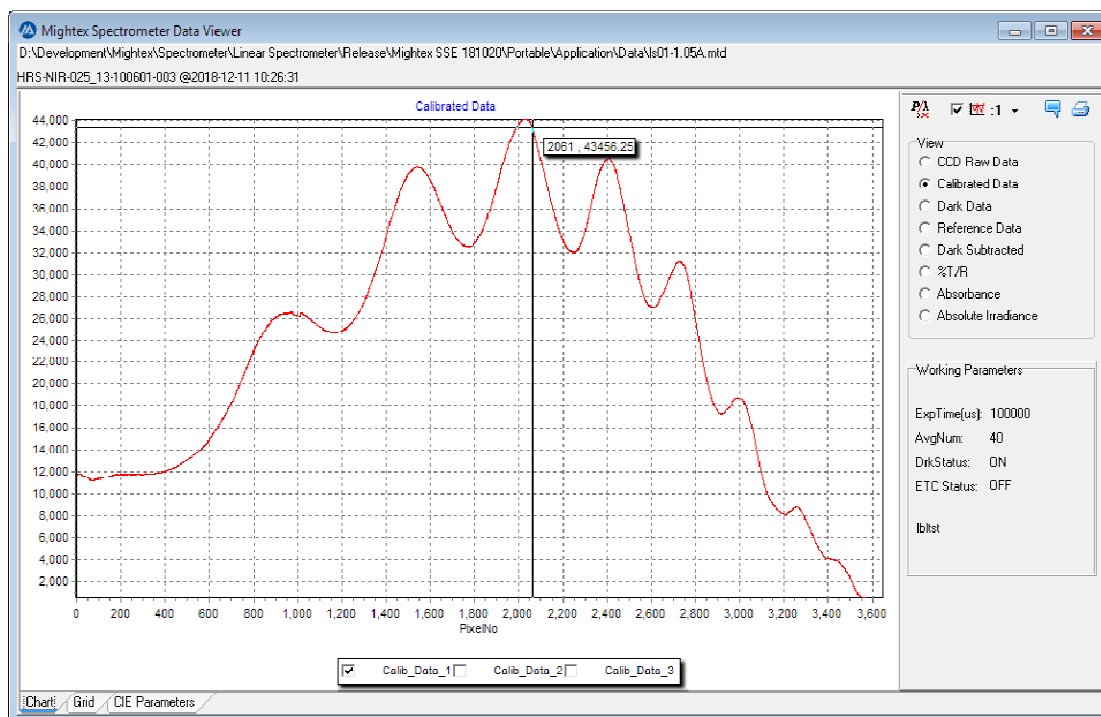
Figure 6.19 View data GUI

6.14 Exporting data to SPC file

The Acquired Spectrum and calculated CIE parameters can be exported to an SPC file by clicking main menu [File]|[Export To][SPC File], figure 6.20

Figure 6.20 export to spc file

Note:

1) please refer to https://ftirsearch.com/features/converters/SPCFileFormat.htm for the general definition of thermal scientific SPC File format.

2) Please refer to the Appendix, Mightex SSE SPC File format for sse related SPC file format.

6.15 Printing and Exporting Report

The acquired spectrum and calculated CIE parameters can be printed export using print functions provided.

1) Graph mode printing and exporting

When in graph mode, clicking the quick button or [Print Current Chart] on the [File] menu, application will

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generate a report based on current display option and printing dialog see figure 6.21 and figure 6.22.
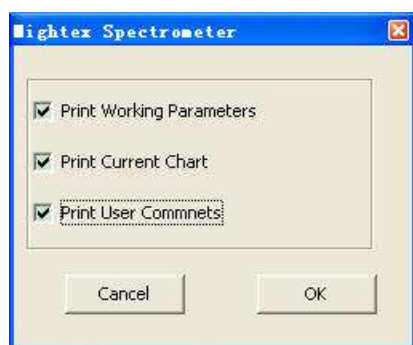
Figure 6.21 Graph printing dialog
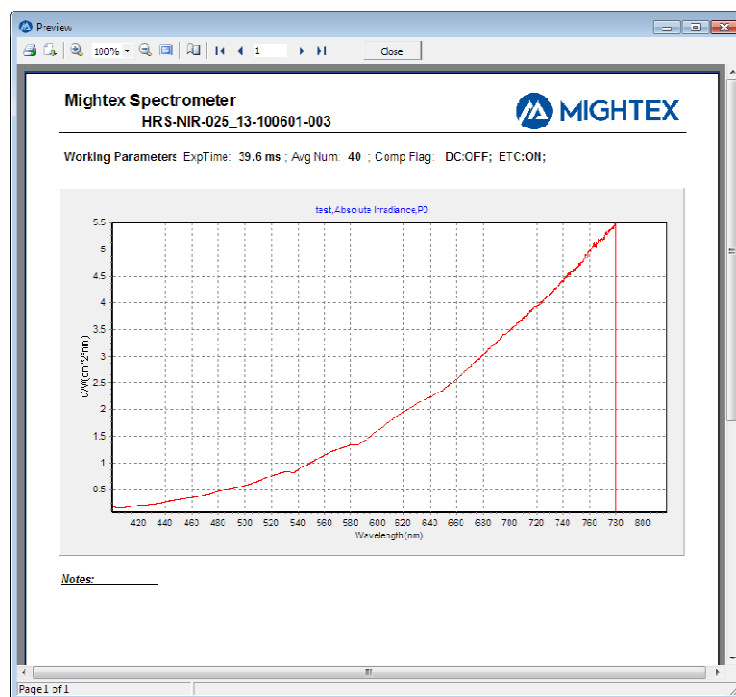
Figure 6.22 Graph mode printing preview

2) Chromaticity mode printing and exporting.

When in Chromaticity mode, clicking the quick button or [Print Current CIE View] on the [File] menu will generating a chromaticity report, see figure 6.23 and figure 6.24.

Figure 6.23 Chromaticity Print dialog

HRS-NIR-025_13-100601-003
Mightex Spectrometer Absolute Irradiance Data

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Working Parameters ExpTime: **39.6 ms** ; Avg Num: **40** ; Comp Flag: **DC:OFF; ETC:ON;**

CIE 1931 Colorimetery Coordinates(x , y): (0.4808 , 0.4041)
CIE 1976 Colorimetery Coordinates(u', v'): (0.2792 , 0.528)

CCT :2384.1

Color Rendering Index:
CRIa : 97.1	CRI5 : 96.6	CRI10 : 93.0
CRI1 : 96.9	CRI6 : 95.4	CRI11 : 96.7
CRI2 : 97.1	CRI7 : 98.5	CRI12 : 89.9
CRI3 : 96.5	CRI8 : 97.9	CRI13 : 96.6
CRI4 : 97.6	CRI9 : 92.6	CRI14 : 97.9

Dominant Wavelenglength and Excitation Purity: DW: 587.151nm, EP: 0.656

Absolute Parameters: Wavelength Range(400 , 838.46)
Absolute Irradiance : 739.99(uW/(cm^2*nm))
Illuminance : 862.12(lx)

Mono-Spectral Quantities: Wavelength Range (400,838.46)
Peak : 780.095 nm ;FWHM : 112.429 nm;Center Wavelength : 723.88 nm ;Centroid Wavelength : 677.17 nm;
Notes:

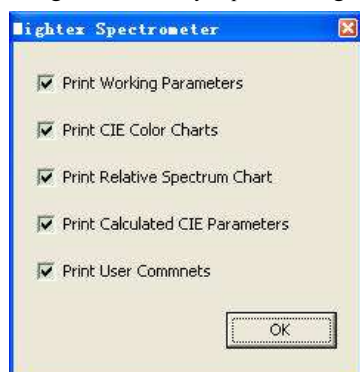2018-10-23-15:42:37   p1

Figure 6.24 Chromaticity Print preview

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3) Print and export the report

The generated reports can be printed by clicking the print button on the top left corner of Preview Dialog which will invoke the system's print dialog to choose the printer and setup page.

By clicking the export button next to the print button, the report can be exported to BMP, JPEG or PDF file.

Appendix 1 Wavelength Calibration

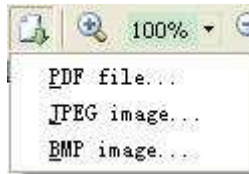Before doing the wavelength calibration, make sure:

Connect the spectrometer desired to be calibrated to the computer and start the application.
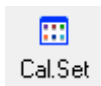
Have a lamp or light source with peaks of known wavelengths whose peaks properly cover the spectrometer wavelength range.

Connect the light source or lamp to the spectrometer.

1)   Setup Wavelength Table

Before starting to do wavelength calibration, it is suggested to define a wavelength set which contains multiple wavelength points. This set can be given a name which can be used later on for another wavelength calibration. The 'Calibration Setting' box is used for this operation.

To open the 'Calibration Setting' box, go to 'Wav. Calib' Tab, uncheck the box 'Enable Data Table', and at the bottom of this tab click the [Cal.Set] button.

The 'Calibration Setting' box is as follows:
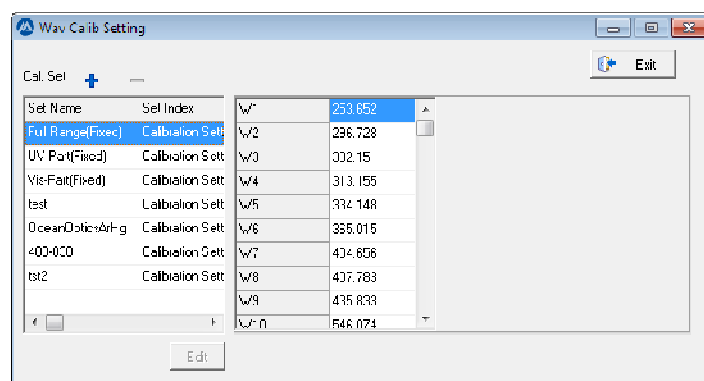
The left side table lists the existing Wavelength sets. The table in the middle shows the wavelengths of the selected wavelength set. By clicking [+] button, a new wavelength set is created. Clicking the [-] button deletes the current selected wavelength set. Note that the first 3 wavelength sets are predefined, for which editing is NOT allowed. The following sets are customer defined, so when those customer defined sets are selected, the [Edit] button is enabled to allow the user to edit the wavelengths in this set.

After clicking the [+] button (or the [Edit] button on a customer defined set), the 'Calibration Setting' Form will change to the following:
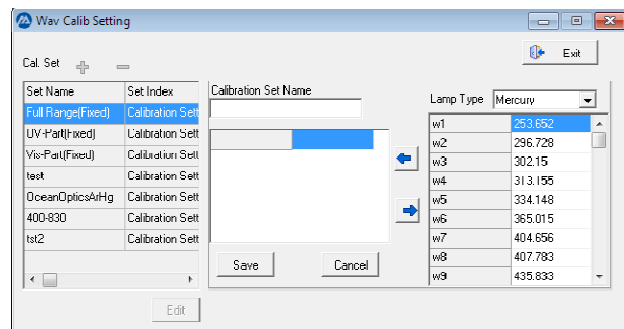
This new wavelength set can be named in the edit box below 'Calibration Set Name'.

A lamp type can be chosen from the pull-down list box. There are two predefined lamps, and the table below lists the characteristic wavelengths of the selected lamp 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, use the [▶] button to remove it from the set. (Note, wavelength values can also be manually edited.)

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

2)   Wavelength Calibration

Note: The wavelength calibration adopts the polynomial equation to express the relationship between 'pixel number' and 'Wavelength' in the form of:

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

After the pixel numbers and related wavelengths have been defined, the application will use the least square error method to find the best coefficients.

a)   Acquire a 'Raw Data' spectrum when light source is ON

Run the Application, set to P0 mode.

Change the units of the X-axis to Pixel.

Select 'CCD Raw Data' in the "Display Option" on the "Control Panel".

Click "Acquire One Frame" Button to scan one spectrum.

b)   Select 'Calibration' Tab in the 'Control Area', and check the 'Enable Data Table' checkbox. The 'Calibration' tab will show content as seen on the right. The drop-down box for 'Calib. Set' lists the predefined wavelength sets described above. Choose a Calib. Set, and select a Polynomial degree (currently fixed to 3).   Here is an example spectrum:
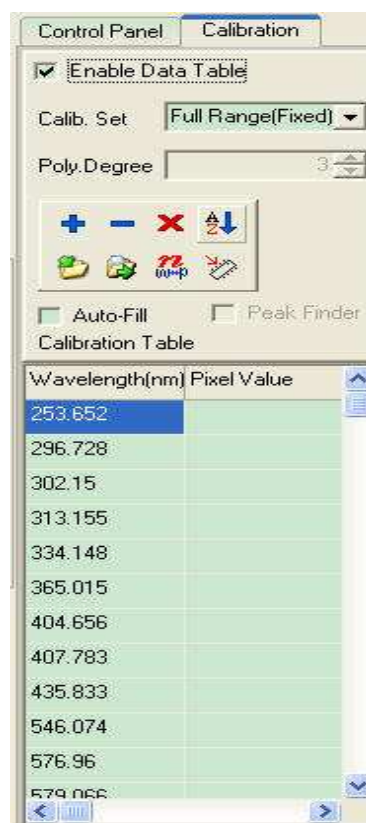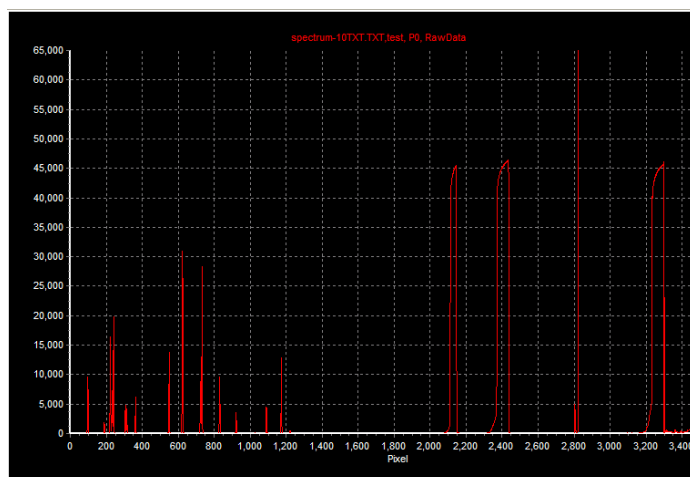
Activate the cursor on the spectrum by checking the 'Auto Fill' check box.

Place the cursor on one spectrum peak which is corresponding to the known wavelength selected in the calibration table. Right clicking on a peak will send the relative pixel value to the corresponding pixel value cell. These steps can be repeated for all wavelengths in a set.

a.   Select a wavelength on the table

b.   Enable the 'Auto Fill' checkbox.

c.   Move 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.

The software is also able to find the exact pixel value of the peak. By checking the 'Peak Find' checkbox, moving the cursor near the peak and right clicking, the software will find the peak automatically and auto-fill the table.

When finished filling the calibration table, the wavelength-pixel pair data can be saved in a standalone file by clicking the 'Save calibration table data' button [icon]. It will save the calibration table in a text file with the extension *.cal. Use the 'Load calibration table data' button [icon] to load the previously saved calibration table files, which can be used to re-calibrate the spectrometer without using a standard lamp in case the standard file data is lost.

By click the 'Calc. Curve Fitting' button [icon], the software will calculate and try to find the best coefficients. If the bottom chart is enabled (checking 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. An additional message box will show the calculated coefficients and the errors as following:
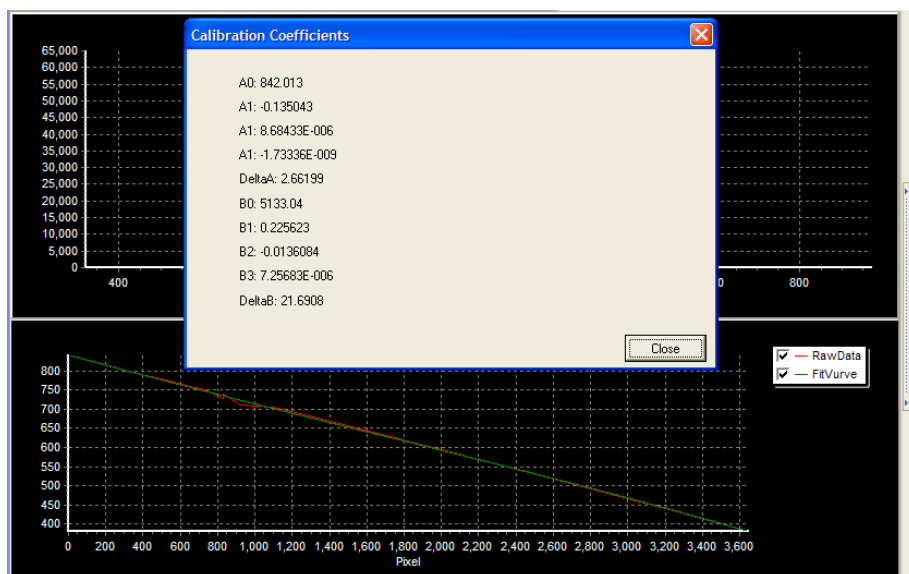
Note: *While the fitting curve is displayed on the bottom chart, its x-axis will be forced to be in 'Pixel' units. If it was in 'Wavelength' units previously, use the* *button to let the bottom chart display the spectrum in wavelength mode correctly.*

Save the calibration coefficients by clicking the button, which will store those parameters in the calibration file to the device's specific folder. If the spectrometer is equipped with e2prom, this will also save the calibration coefficients to the e2prom.

3)   Manually input Wavelength Calibration Coefficients
After the curve fitting, the fitted coefficients are automatically saved to the spectrometer's parameter file. It is possible to manually fine tune the coefficients in the 'Calibration Coefficients' form by clicking the "View | Wav. Cal. Coefficients" menu item.

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This form displays the two fitted functions' coefficients: from pixel to wavelength and from wavelength to pixel. The coefficients can be manually adjusted by clicking any coefficients that needs modification, and an edit box with 'tick' and 'cross' buttons will pop up allowing current coefficients to be changed. In order to apply the changes, restart the application. *This feature is mainly for technical services*.

Appendix 2 ETC (Exposure Time linear Calibration) Compensation Details

The linear response of a spectrometer is often required for quantitative studies. Linear response is also critical when comparing two spectra measured with different exposure times. The response of a CCD pixel is not strictly linear with incident optical power or exposure time. Therefore, a linearity calibration is necessary when a 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 that 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 not saturated. Make sure no pixel value is saturated. Record the exposure time and pixel number of the peak.
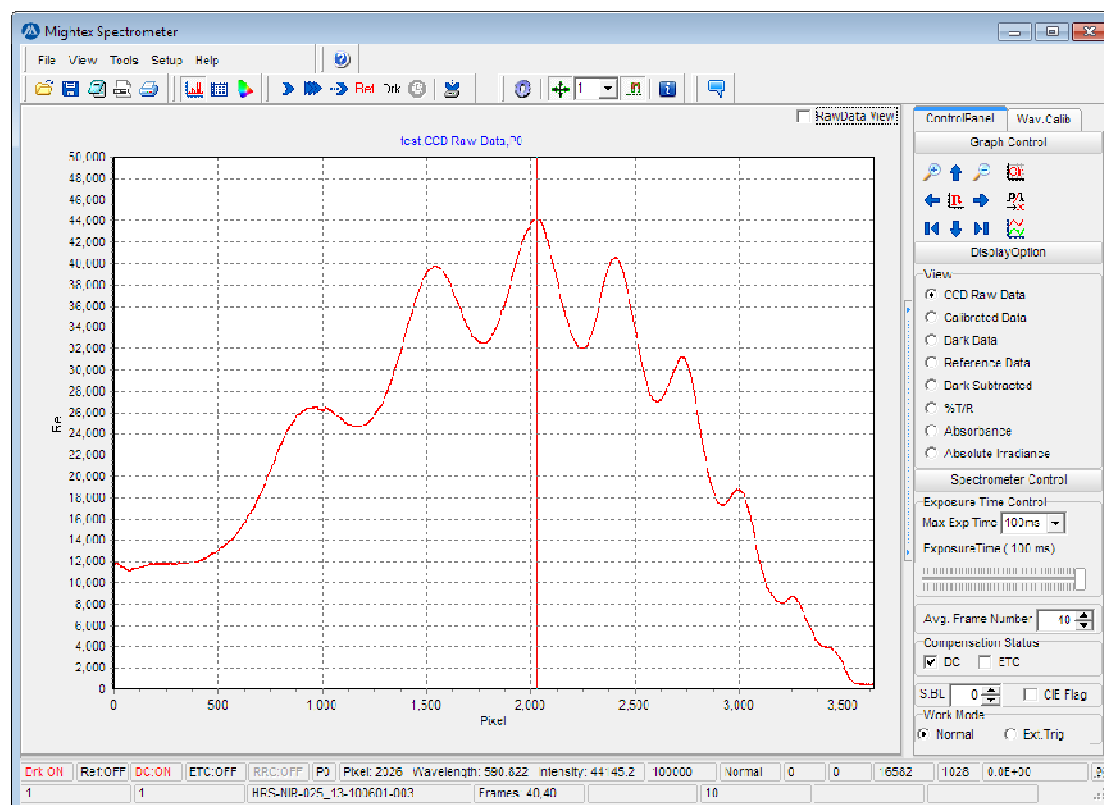
Invoke Exposure Time Linearity Calibration from the Tools menu.

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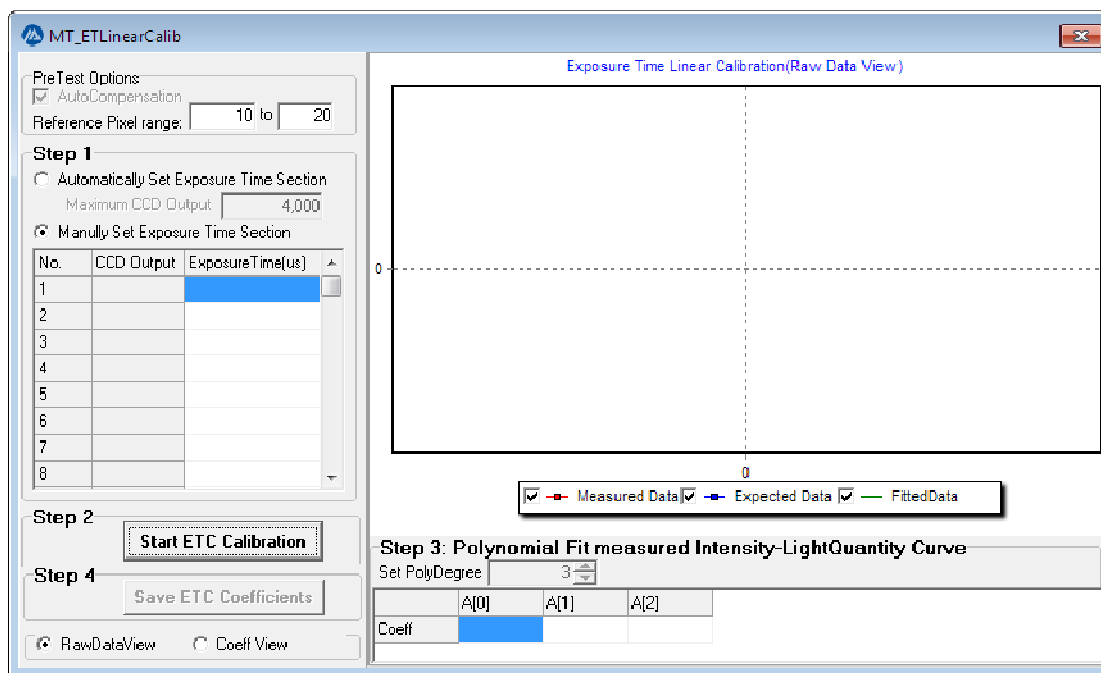
3) Use pixels near the peak found in step 2 for *Reference Pixel Range*. Select the *Manual Set Exposure Time* option. Enter 100µs, which is the minimum exposure time supported by the spectrometer, into the first exposure time.   Enter the exposure time recorded in step 2 into the last exposure time. The exposure times in between should approximately be uniformly distributed.   Click [*Start ETC Calibration]* button to start the calibration process.
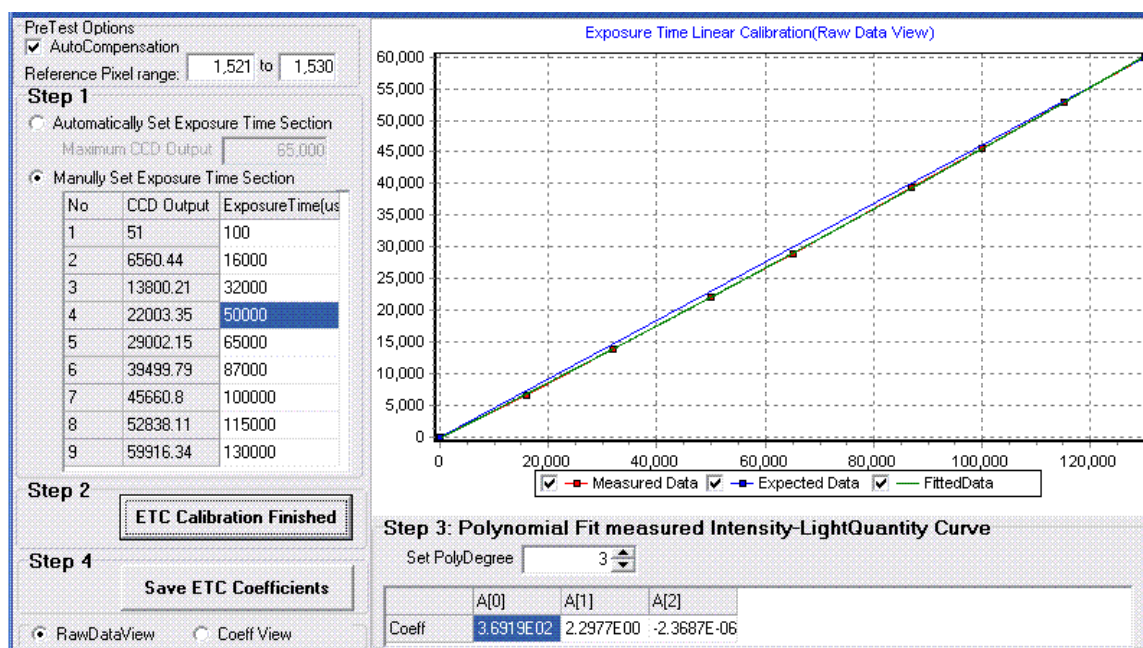
4) Set *Polynomial Degrees* for curve fitting. Usually three is sufficient.
Click *Save ETC Coefficients* to save the calibration coefficients.   This completes the ETC calibration process.

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

Applying Exposure Time Calibration

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Check ETC Compensation in the Compensation status group in the Spectrometer Control in the control panel.

☑ ETC

Acquire one frame, and then select the 'Calibrated Data' option on the right panel under Display Option. The Calibrated spectrum will now be displayed.
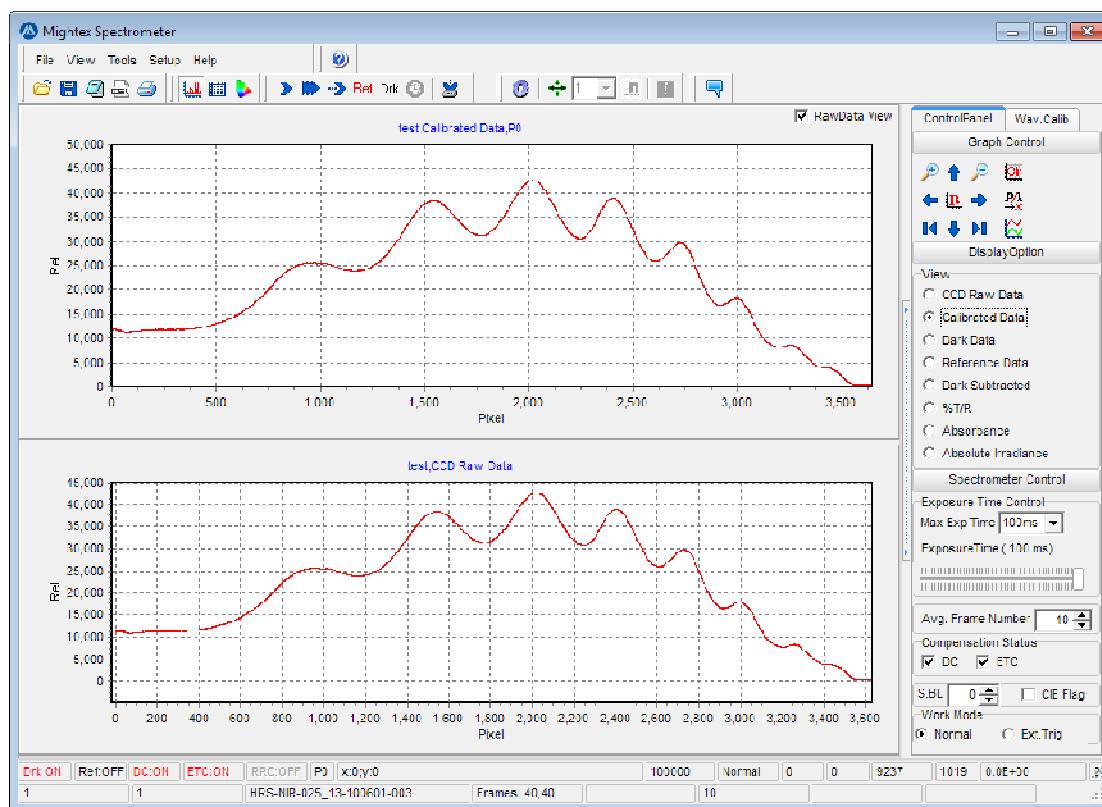
A sample of Raw Spectrum and Calibrated Spectrum, with ETC ON.

Appendix 3 AIC (Absolute Irradiance Calibration)

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 is calibrated out.

Many factors contribute to the 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 spectrometer, 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 a 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 spectrometer software supports absolute irradiance calibration (AIC). After AIC, the spectral response of the system is calibrated out, and when the absolute irradiance option is chosen, the software will display spectral irradiance data in unit of $\mu W/cm^2 nm$. Additionally, integrated irradiance ($\mu W/cm^2$) and illuminance (lux) are also displayed in real time. The wavelength range of integration may be specified. Furthermore, colorimetric parameters such as color coordinates, color temperature, and color rendering index are also computed based on the measured spectral irradiance.

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

Wavelength calibration and exposure time linearity calibration (ETC) must be performed before AIC. ETC should be enabled.

1) Connect the radiometric calibration source with a known spectrum to the spectrometer.
2) Turn on the radiometric calibration source and let it warm up to stabilize. Acquire a spectrum and adjust the exposure time so that the maximum pixel value is above 40,000. Make sure no pixel value is saturated. Write down the exposure time for later use.
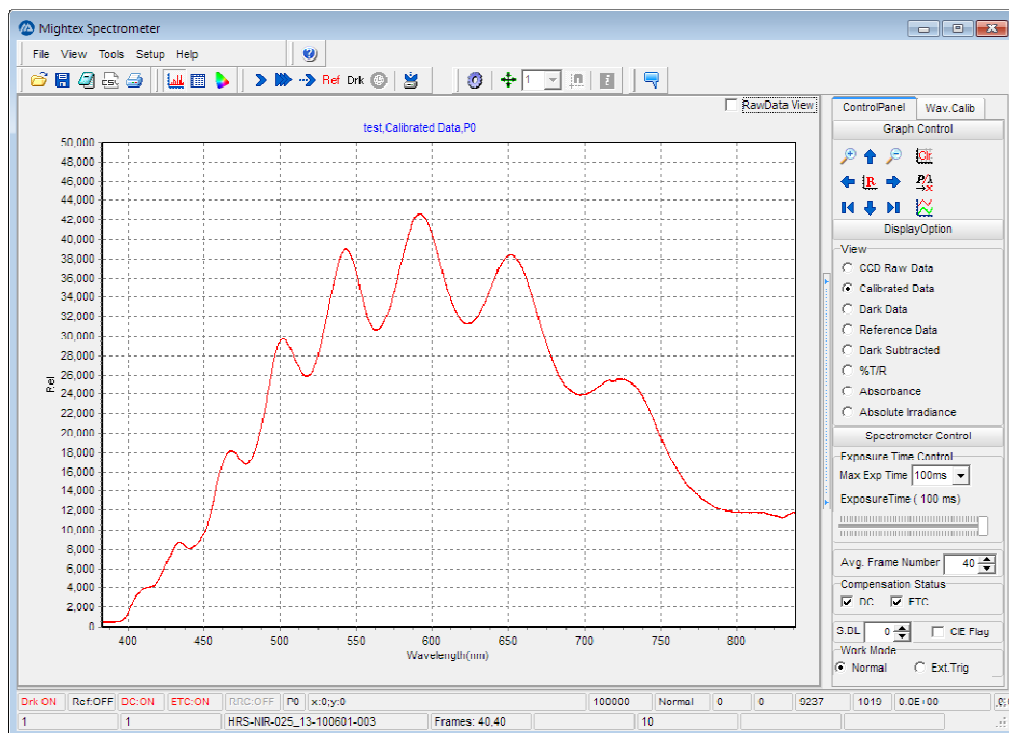
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Invoke AIC from the Tools menu.
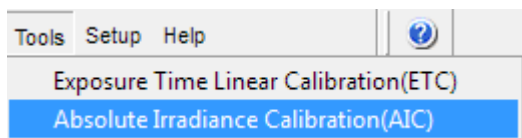
AIC User Interface

3) In most cases only one light source will be used for calibration. In these situations select *Standalone light source*. The following steps show the case where two separate light sources are used, each covering a segment of the wavelength range.

4) Select *Combined light source*. Enter joint wavelength. This is the wavelength where the two light source spectra meet. Click *OK*. In Step 2 select irradiance unit according to the data file of the light sources. Click *OK*.

5) Click *Load* in Step 3 to load the irradiance data file for the first calibration light source. Data should be in a text file with wavelength in one column and irradiance in the other column. Wavelength unit should be nanometers.
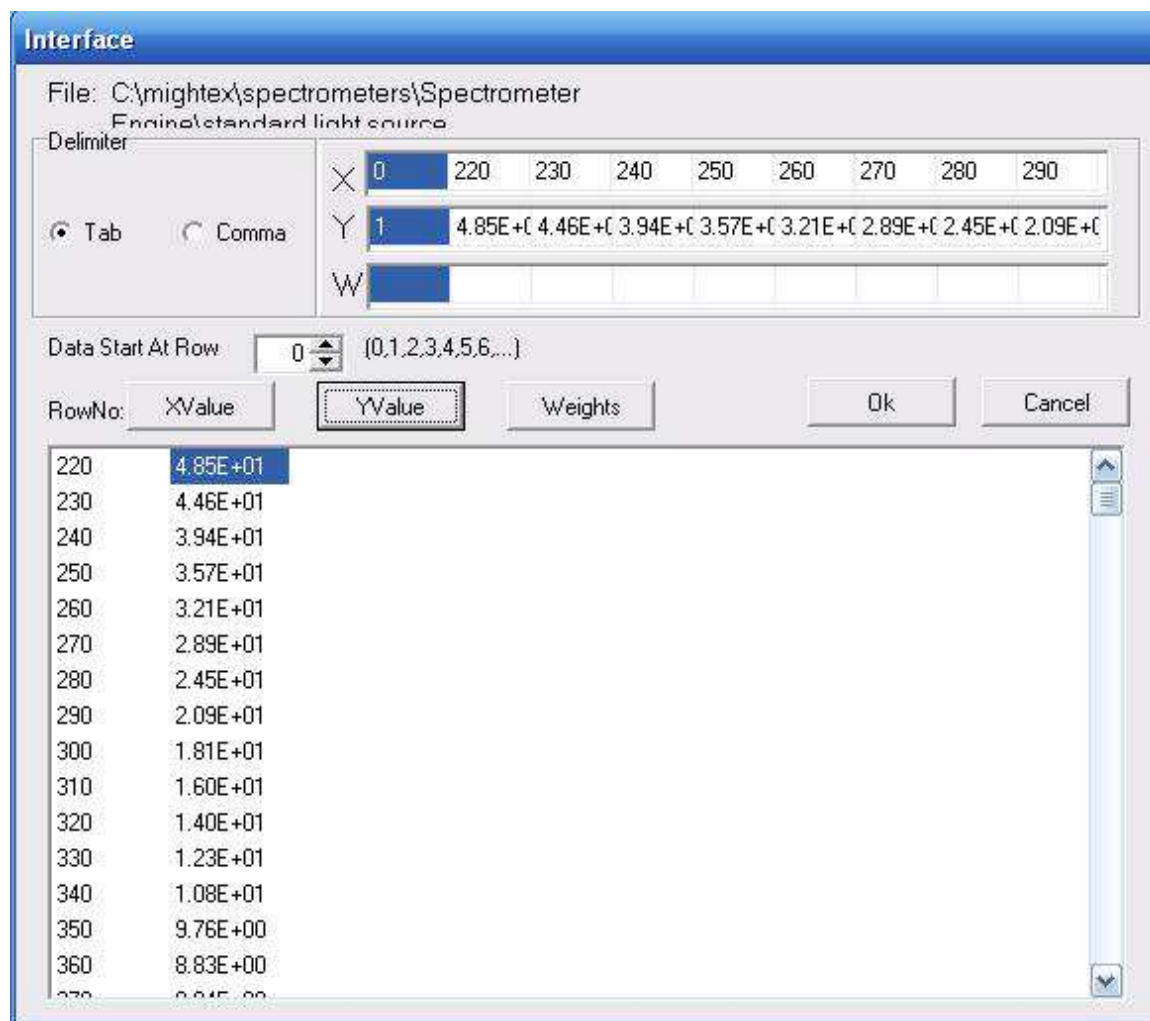
6) Select the proper delimiter according to file format. Data start row equals the number of rows occupied by non-data text. Click the first wavelength data and then click the *XValue* button to import wavelength. Click the first spectrum data and then click the *YValue* button to import the spectrum data. If weights are assigned to wavelengths, import the weights. Click *OK* button to finish. The imported calibration spectrum will be shown in the data window as well as in the chart.

7) In Step 3 in the AIC window, increase the terms of polynomial to at least 8, and then click [Polyfit] to generate a polynomial fit of the irradiance data.

8) Enter the proper exposure time in Step 4. Click [Start] in Step 5 to acquire a raw spectrum.
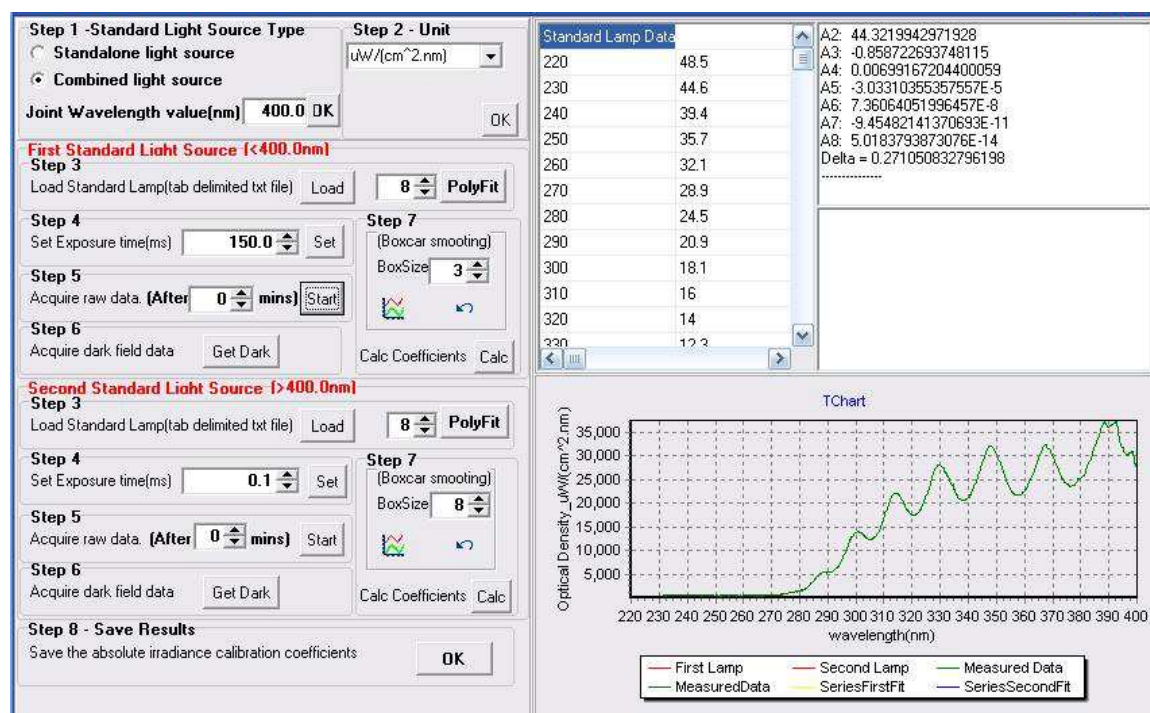
Disconnect the fiber or Cosine corrector from the light source, and cover the fiber or Cosine corrector with a black cloth. Then click [*Get Dark]* in Step 6 to acquire a dark spectrum.   Step 7 can be used to smooth the data. Please click the smooth function only once. Click *Calc* button to calculate the calibration coefficients. The chart should show that the calibrated measurements closely match the imported irradiance data of the light source.
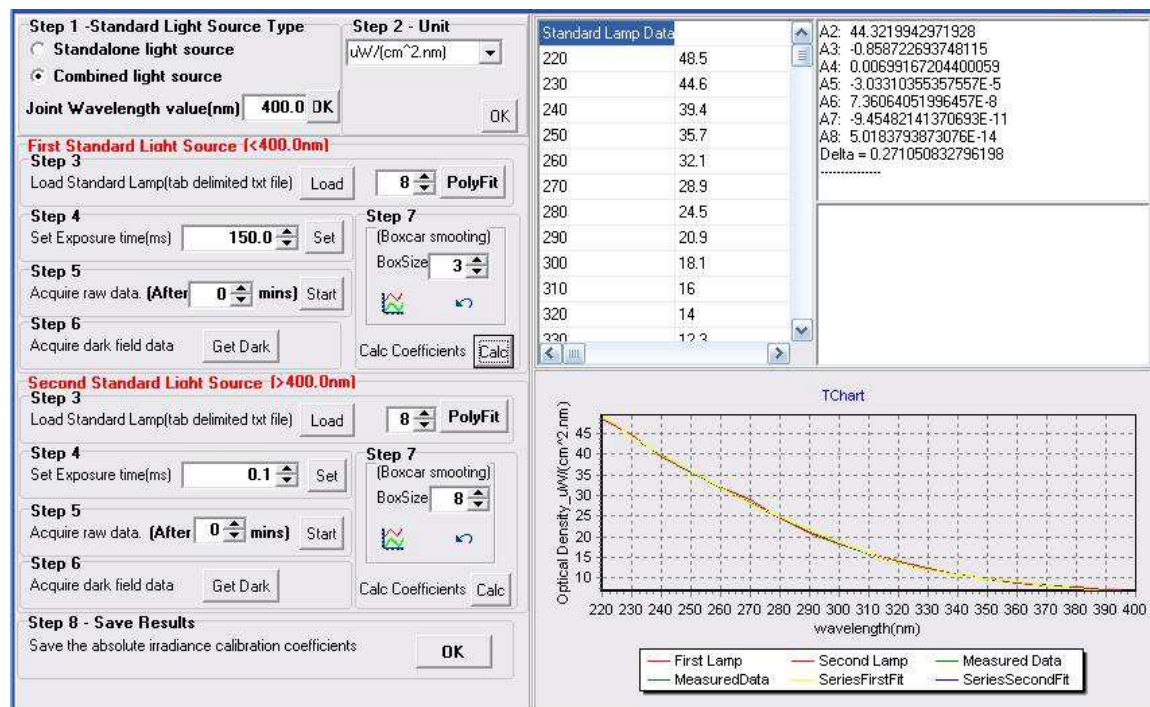
Connect the fiber or Cosine corrector to the second light source. Repeat above steps for the second light source. Note that the proper exposure time is generally different from that for the first light source.
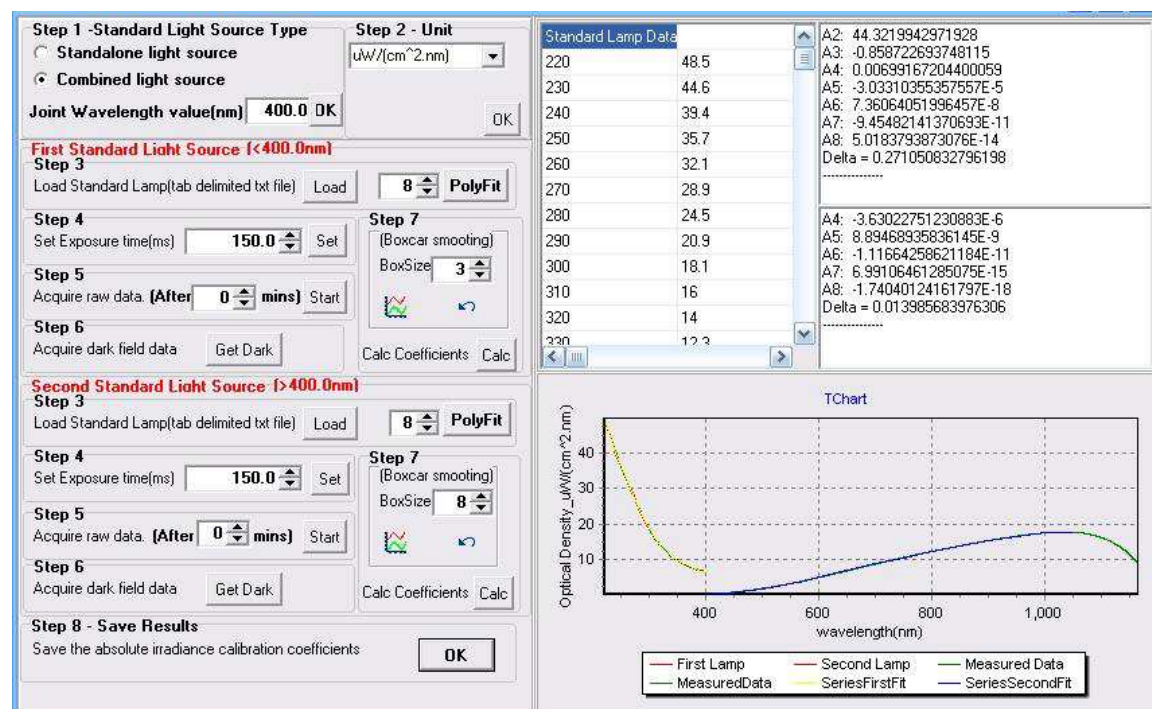
Save the calibration coefficients by clicking the [*OK*] button in Step 8. This completes the absolute irradiance calibration process.

Appendix 4 Mightex SSE SPC File Format

1. The file structure of the Mightex SSE SPC file format

```
[ S P C H D R                                    ]
[ 0   S U B H D R                                ]
[ 0   S U B F I l e - W a v e l e n g t h   D a t a   V a l u e        ]
[ 1   S u b H D R                                ]
[ 1   S U B F i l e     C C D _ 1                 ]
[ 2   S U B H D R                                ]
[ 2   S U B F i l e     C C D _ 2                 ]
[ 3   S U B H D R                                ]
[ 3   S U B F i l e     C C D _ 3                 ]
[ 4   S U B H D R                                ]
[ 4   S U B F i l e     C a l i b _ 1             ]
[ 5   S u b H d r                                ]
[ 5   S U B F i l e     C a l i b _ 2             ]
[ 6   S u b H d r                                ]
[ 6   S U B F i l e     C a l i b _ 3             ]
[ 7   S u b H d r                                ]
[ 7   S U B F i l e     D a r k S u b _ 1         ]
[ 8   S u b H d r                                ]
[ 8   S U B F i l e     D a r k S u b _ 2         ]
[ 9   S u b H d r                                ]
[ 9   S U B F i l e     D a r k S u b _ 3         ]
[ 1 0   S u b H d r                              ]
[ 1 0   S U B F i l e     % T / R _ 1             ]
[ 1 1   S u b H d r                              ]
[ 1 1   S U B F i l e     % T / R _ 2             ]
[ 1 2   S u b H d r                              ]
[ 1 2   S U B F i l e     % T / R _ 3             ]
[ 1 3   S u b H d r                              ]
[ 1 3   S U B F i l e     R e f   D a t a         ]
[ 1 4   S u b H d r                              ]
[ 1 4   S U B F i l e     D a r k   D a t a       ]
[ 1 5   S u b h d r                              ]
[ 1 5   S U B F i l e     A b s o r b a n c e _ 1 ]
[ 1 6   S u b H d r                              ]
[ 1 6   S U B F i l e     A b s o r b a n c e _ 2 ]
[ 1 7   S u b H d r                              ]
[ 1 7   S U B F i l e     A b s o r b a n c e _ 3 ]
[ 1 8   S u b H d r                              ]
[ 1 8   S U B F i l e     A b s o l u t e   I r r a d i a n c e   1 ]
```

```
[ 1 9   S u b H d r                                        ]
[ 1 9   S U B F i l e   A b s o l u t e   I r r a d i a n c e   2 ]
[ 2 0   S u b H d r                                        ]
[ 2 0   S U B F i l e   A b s o l u t e   I r r a d i a n c e   3 ]
[ L O G S T C                                              ]
[ L o g D a t a                                            ]
[ L o g T e x t  -  U s e r   C o m m e n t s              ]
```

2. SPCHDR definition and typical Value
typedef struct
{
```
    BYTE    ftflgs;     //0x04
    BYTE    fversn;     //0x4B
    BYTE    fexper;     //0
    char    fexp;       //0x80
    DWORD   fnpts;      //Max CCD Points
    double  ffirst;     //0
    double  flast;      //MAXCCDPoints-1
    DWORD   fnsub;      //21
    BYTE    fxtype;     //22
    BYTE    fytype;     //0
    BYTE    fztype;     //0
    BYTE    fpost;      //0
    DWORD   fdate;
    char    fres[9];
    char    fsource[9]; //'MTSSESPC'
    WORD    fpeakpt;
    float   fspare[8];
    char    fcmnt[130];/*fcmnt[0..15]   holds the module No, space padded.
                        fcmnt[16..31] holds the serial No. space padded.
                        fcmnt[32.37] holds the mightex spc file version, current is 02.01.00
                        fcmnt[38..129] must be zero */
    char    fcatxt[30];     //0
    DWORD   flogoff;    //the offset of Log Sect
    DWORD   fmods;      //0
    BYTE    fprocs;     //0
    BYTE    flevel;     //0
    WORD    fsampin;    //0
    float   ffactor;        //0
    char    fmethod[48];   //0
    float   fzinc;          //0
    DWORD   fwplanes;   //0
    float   fwinc;          //0
    BYTE    fwtype;         //0
    char    freserv[187]; /* Reserved (must be set to zero) */
} tSPCHDR;
```

3. SUBHDR and subfile

typedef struct
{
```
    BYTE    subflgs;    //0
    char    subexp;     //0x80
    WORD    subindx;
    Float   subtime;
    float   subnext;
    float   subnois;        /*Used as the unit of corresponding subfile, value see fxtype, fytype.*/
    DWORD subnpts;      //0
    DWORD subscan;      //0
    float   subwlevel;  //0
    char    subresv[4];     /* Reserved area (must be set to zero) */
} tSUBHDR;
```

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Note: There are a total of 21 sub-files (see file structure) so the sub-index has a value from 0 to 20. "subnois" is used as the unit of the corresponding sub-file. A Sub-file with sub-index 0 stores the wavelength value, the value of "subnois" is 3 which is defined in fxtype as namometers. Other sub-files with sub-index from 1 to 20 sets the "subnois" from the value defined for fytype. E.g, sub-file 10 stores the %T/R value, the value of "subnois" is 11 which is defined in fytype as percent.

4. Log Block

We put working parameters and calculated CIE parameters (if Calc CIE Flag is turned ON) into the log binary block and put the user comments into the log text block if there are any user comments.

Thus when calc CIE flag is turned on, the Log binary block is divided into two section: working parameters section and CIE parameters section. Otherwise the log binary block stores only working parameters.

1) Working parameters section.
```
typedef
{
    byte    WorkMode     ;
    byte    AutoDarkFlag ;
    byte    ETCFlag       ;
    byte    RRCFlag       ;
    byte    Reserved[4]   ;
    Int     ExposureTime;
    Int     AvgFrameCnt ;
    Double A[4]          ;
    Double B[4]          ;
    Int     Reserved[31];
    Int     CIEInfo ; //0 if CalcCIEFlag is OFF or Byte size of CIE Binary Block
} tSSEWorkPara;
```

CIE parameters Section

```
typedef
{
    Byte CIEStandardObserver; //31 for 2 degree or 64 for 10degree
    Byte Reserv[7];

    int drksubx ;                //(int)10000* 0.xxxx)
    int drksuby ;                //(int)10000* 0.yyyy
    int drksubu';                // (int)10000* 0.uuuu
    int drksubv';                // (int)10000* 0.vvvv

    int CIEStandardLightSource;  //
    int tvrx;                    //(int)10000* 0.xxxx
    int tvry;                    //(int)10000* 0.yyyy
    int tvru';                   //(int)10000* 0.uuuu
    int tvrv';                   //(int)10000* 0.vvvv
    int TvRL;                    //(int)10 * L*
    int TvRa;                    //(int)1000 * a*
    int TvRb;                    //(int)1000 * b*
    int StandardIllux;
    int StandardIlluy;
    double TvrStartWav;
    double TvREndWav;

    int AbsIntenx;               //(int)10000* 0.xxxx
    int AbsInteny;               //(int)10000* 0.yyyy
    int AbsIntenu';              //(int)10000* 0.uuuu
    int AbsIntenv';              //(int)10000* 0.vvvv
    int CCT;
    int CRIa;                    //(int)10 * CRIa
    int CRI[14];                 //(int)10 *CRI[1..14]
    int Irradiance;
    int Illuminance;   ;
    int Reserved[31]; ;
    int Purity;                  // (int)1000 * purity
```

```
    double DominantW;
    double AbsMeasStartWav;
    double AbsMeasEndWav;


    double MonoSpectralStartWav;
    double MonoSpectralEndWav;
    double PeakWavelength;
    double FWHMWav;
    double CenterWav;
    double CentroidWav;
    Int Reserved[100];
}
```