Instruction Manual

Hydrogen Spectra

Balmer Series Apparatus

Model: HO-ED-S-03B

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Product Features

HOLMARC's 'Hydrogen Spectra-Balmer Series Apparatus' is specially designed for the determination of wavelengths of Balmer series from hydrogen emission spectra and to find the Rydberg constant. This apparatus comprises of high performance CCD Spectrometer, Mercury lamp with power supply and Hydrogen Spectrum Discharge Tube coupled with a High Voltage Transformer. Spectrometer utilizes Constant Deviation Pellin Broca Prism for spectral dispersion and is compatible with USB 2.0 interface. The better sensitivity of the CCD makes this spectrometer suitable for applications with lower light signals as well. The software developed for this instrument has facilities for capturing single or continuous spectra, custom wavelength calibration, dark subtraction and intensity comparison, simultaneous display of overlay multiple spectra, exporting data to Microsoft excel, automatically timed spectrum saving etc.

Mercury lamp is used as the standard element to find the unknown wavelengths of hydrogen. Later using the hydrogen spectrum and the energy level quantum number; Rydberg constant can be determined. High Voltage Transformer is supplied with Hydrogen Spectrum Discharge Tube. The discharging action is controlled by a variable knob and can be adjusted to get optimum performance of Hydrogen.

Getting Started

a. Safety Instructions

1. The hydrogen discharge lamp is powered by high voltage and the tube gets hot. DO NOT touch the tube anywhere especially near the ends where the electrical contacts are made.
2. It is best that students work in low light and dust free atmosphere.

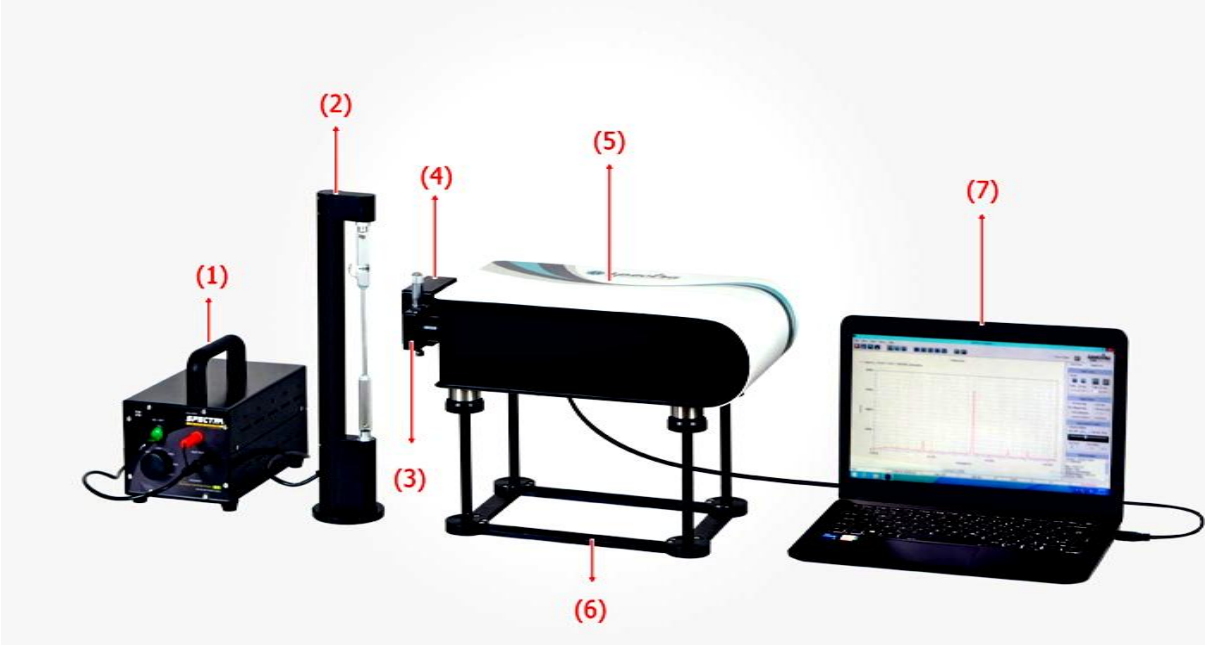
b. Components Included

Please check if the following items are present while the instrument package is delivered.

1. Prism Spectrometer with CCD - 1 No
2. Mercury Discharge Tube with lamp house - 1 No

3. Hydrogen Discharge Tube with lamp house - 1 No
4. High Voltage Power Supply - 1 No
5. Software CD/Pendrive - 1 No
6. AC Power Cord - 1 No
7. USB Cable for CCD - 1 No

c. Parts Listing



1. High Voltage Power Supply
2. Mercury/Hydrogen Discharge Tube with Lamp House
3. Adjustable Slit
4. CCD
5. Constant Deviation Spectrometer
6. Stand for Spectrometer
7. Laptop (Not in the scope of the supply)

Fundamentals

1. To calibrate the prism spectrometer using mercury lines, using Hartmann equations.
2. To determine the wavelengths of Balmer series in the visible region from hydrogen emission spectrum.
3. To determine the Rydberg constant.

Theory:-

Hydrogen atoms in a discharge lamp emit a series of lines in the visible part of the spectrum. This series is called the Balmer Series after the Swiss teacher Johann Balmer (1825-1898) who, in 1885, found by trial and error a formula to describe the wavelengths of these lines. This formula is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$$

where n are integers, 3, 4, 5, … up to infinity and R is a constant now called the Rydberg constant.

Then in 1889, Johannes Robert Rydberg found several series of spectra that would fit a more general relationship, similar to Balmer's empirical formula. This general relationship is known as the Rydberg formula and is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] \quad n_i > n_f$$

where n_i and n_f are integers, 1, 2, 3, 4, 5, … up to infinity, with $n_i > n_f$. For the hydrogen atom, n_i = 2 corresponds to the Balmer series. In the SI system of units, $R = 1.097 \times 10^7\ m^{-1}$.

Balmer Series – Spectral Lines:-

Name of Line	n_f	n_i	Symbol	Wavelength (nm)
Balmer Alpha	2	3	H_α	656.28
Balmer Beta	2	4	H_β	486.13
Balmer Gamma	2	5	H_γ	434.05
Balmer Delta	2	6	H_δ	410.17

Calibrating Spectrometer with low pressure Hg & calculating Hartmann's constants

Every element emits a characteristic spectrum of its own. To find the wavelength of light emitted usually the spectrum of a standard source is measured and compared. The unknown wavelength is determined by using Hartmann equations. The wavelength of the prominent lines in any spectrum of is studied by using the Hartmann's formula,

$$\lambda (d) = \lambda_0 + C / (d - d_0)$$

where λ_0, C and d_0 are Hartmann's constants that must be evaluated experimentally. This is done by substituting the distances d of three known lines (in the mercury spectrum) from an arbitrary point and their wavelengths λ in the above equation and solving the three equations. If we could find three lines with scale readings d_1, d_2 and d_3 corresponding to known wavelengths λ_1, λ_2 and λ_3 respectively, then we can find Hartmann's constants using the following relations:

$$\mathbf{A = (\lambda_2 - \lambda_1) / (\lambda_3 - \lambda_1)}$$

$$\mathbf{B = (d_2 - d_1) / (d_3 - d_1)}$$

$$\mathbf{\lambda_0 = \{(A \times \lambda_3) - (B \times \lambda_2)\} / (A - B)}$$

$$\mathbf{d_0 = \{(B \times d_3) - (A \times d_2)\} / (B - A)}$$

$$\mathbf{C = \{(\lambda_2 - \lambda_1) \times (d_0 - d_1) \times (d_0 - d_2)\} / (d_2 - d_1)}$$

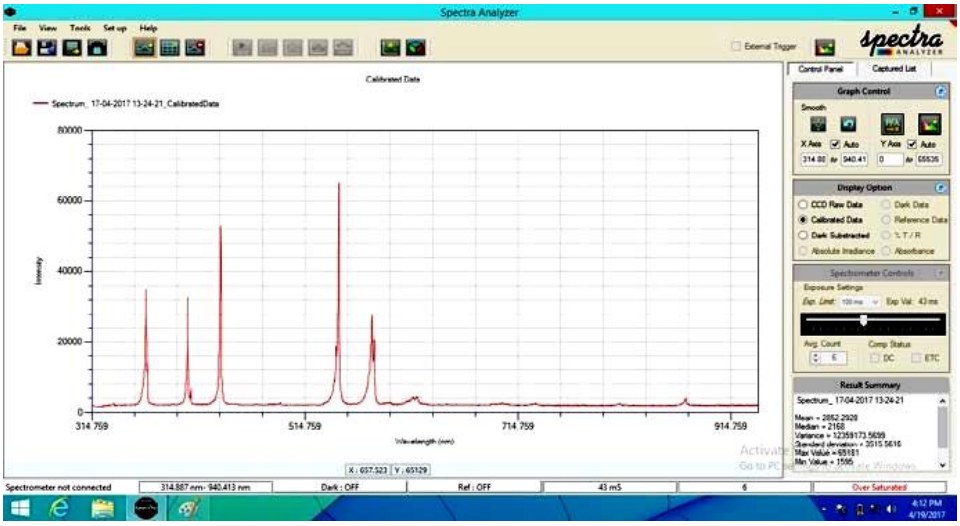
The wavelength of the prominent lines in any spectrum of is studied by using the Hartmann's formula,

$$\mathbf{\lambda (d) = \lambda_0 + C / (d - d_0)}$$

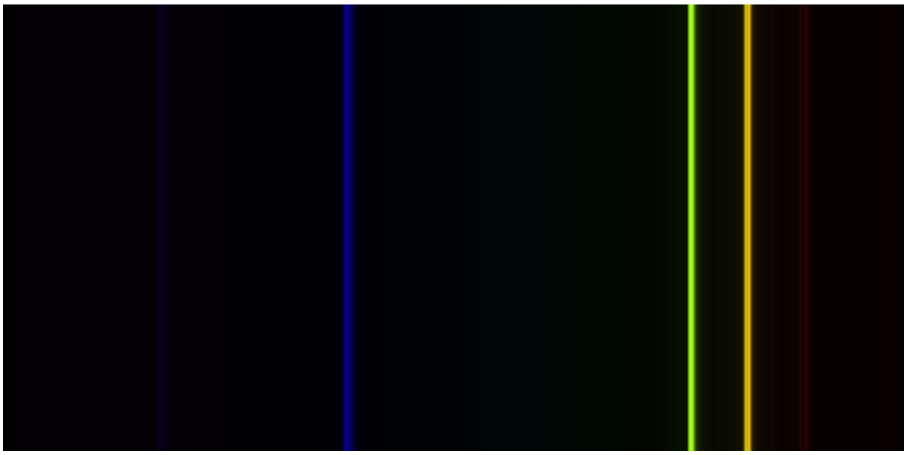
Procedure of the Experiment

1. Place the constant deviation spectrometer on the stand and keep it on a rigid table.
2. Connect the spectrometer to the computer via USB cable.
3. Now click on the icon 'HOLMARC spectra analyzer 'from desktop to open the software.
4. On the screen you will find a window for logging into the software. Login as 'user'.
5. Switch on the mercury lamp and place it in front of the slit of the spectrometer.

6. To observe the discrete spectrum of mercury click on the run icon, to start live spectrum view. (Adjust the slit width using the micrometer screw provided to get precise sharp spectral lines.).
7. You will see a live plot with pixel values on X - axis and Y -axis shows intensity. Once you obtain the sharp good resolved spectral lines, click the stop button and then click on the 'Acquire single spectrum icon 'to capture the current spectrum.
8. Find the pixel values of the peaks obtained by zooming the graph. To zoom right click on the graph and drag a rectangle around the point whose values need to be measured.
9. Using the values obtained and the known wavelengths find the Hartmann's constant. Take any three known wavelengths and find the Hartmann's constant.



Colour of spectral lines	Known Wavelength (nm)	CorrespondingPixel values (X - axis)
Violet	$\lambda_1 = 404.656$	$d_1 =$
Blue	$\lambda_2 = 435.833$	$d_2 =$
Green	$\lambda_3 = 546.096$	$d_3 =$
Yellow	$\lambda_4 = 579.066$	$d_4 =$



Wavelength of Hydrogen Spectrum – Balmer Series

1. To find the wavelength of emission spectra of certain materials replace the mercury source with Hydrogen discharge tube and its power supply.
2. To observe the discrete spectrum of Hydrogen click on the run icon, to start live spectrum view. (Adjust the slit width using the micrometer screw provided to get precise sharp spectral lines.).
3. Once you obtain the sharp good resolved spectral lines, click the stop button and then click on the 'Acquire single spectrum icon 'to capture the current spectrum.
4. Find the pixel values of the peaks obtained by zooming the graph.
5. Using the pixel values in the given below equation we can obtain the corresponding wavelengths.

$$\lambda\,(d) = \lambda_0 + C\,/\,(d - d_0)$$

Distance of line from reference point, *d* (pixel values)	Calculated wavelength $\lambda = \lambda_0 + [\,C\,/\,(d_0 - d)\,]$ *nm*

Determination of Rydberg Constant

We have the Balmer series formulae

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$$

where n are integers, 3, 4, 5 … up to infinity and R is a constant now called the Rydberg constant. So we have the Rydberg constant given by,

$$\mathbf{R = 1/\lambda\,(1/2^2 - 1/n^2)}$$

Wavelength (nm)	n	n^2	$\mathbf{R = 1/\lambda\,(1/2^2 - 1/n^2)}$

Average Rydberg constant, R = ---------- m^{-1}

Components Included with Specifications

1. Constant Deviation Spectrometer

Prism type	:	Pellin Broca Prism
Design	:	Constant Deviation 120F
Spectrometer Input	:	Micrometer controlled slit (1Rev: 0.25m, 1Div: 0.005 mm)
Spectrometer output	:	CCD Electronic output through USB connected to a PC
Wavelength Range	:	400 - 800 nm
Wavelength Accuracy	:	+ / - 2 nm

2. CCD Camera

CCD detector	:	Sensitive linear array 0-3647 pixels
Pixel size	:	800 x 200 micron
A/D Resolution	:	16 Bits
Exposure Time	:	0.1 - 6500 ms
Frame rate	:	138 scan / second
Compatibility	:	Any windows platform OS
Interface	:	USB 2.0

3. **Discharge Source with Power Supply**

Discharge Tubes	:	Mercury & Hydrogen
Power Supply	:	0-4000 V (Variable)

Technical Support

- Before you call the HOLMARC Technical Support staff, kindly gather the following information:
- Title and model number (usually listed on the label) Approximate age of apparatus
- Detailed description of the problem/sequence of events Have the manual in hand to discuss your 4query

Feedback

If you have any comments regarding our product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, kindly inform us. HOLMARC appreciates any customer feedback. Your inputs help us evaluate and improve our product.

Appendix I

Spectra Analyzer Software

Holmarc Spectra Analyzer application can be downloaded from the Holmarc website site, or retrieved from the CD/Pendrive that you received with your Spectrometer.

Minimum Operating System/Hardware requirements:

- Processor: Pentium Dual Core or above @2GHz or above.
- Operating System: XP /7/8/8.1/10/11
- RAM: 2 GB or greater.
- USB 2.0 Host Controller required.

1) Spectrometer Camera Driver Installation:

The Holmarc Spectrometer is based on the Holmarc 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. Install the camera driver from the folder Camera Driver depend on the operating system.

Steps:-

- Connect spectrometer to the computer.
- Open the Control Panel.
- Click Device Manager.
- Under Other devices, right-click on the 'Camera' and choose update driver software.
- Choose Browse my computer for driver software.
- Navigate to depending operating system folder form Camera driver folder and click Ok. Then click Next
- When the pop-up screen appears, choose Install this driver software anyway.
- When the driver installation is successful, successful screen will shown.

Windows 8/8.1/10 imposes strict limitations on driver signing. Because of this, unsigned drivers require extra steps for installation.

- Click Windows icon & Type "change advanced startup options". Press Enter.
- In Windows 8, Click General. Under Advanced Startup, click Restart Now.

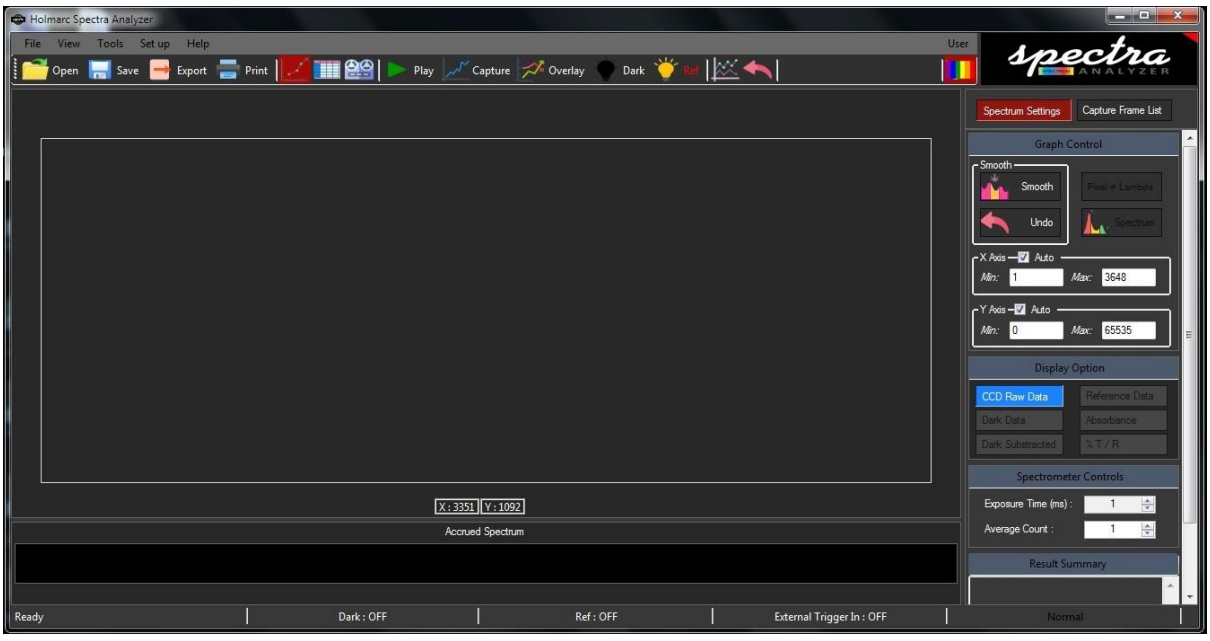
- In Windows 8.1 & 10, Click 'Restart Now' button from 'Update & Recovery -> Recovery -> Advanced Startup.'
- After restarting, click Troubleshoot.
- Click Advanced Options.
- Click Windows Startup Settings.
- Click Restart.
- After restarting computer a second time, choose Disable driver signature enforcement from the list by typing the number 7 on your keyboard.
- After restarting, install the Camera driver normally; however, Windows will display a warning message. When the warning appears, click Install this driver software anyway.

2) Application Installation

- Install .Net frameworks from the folder Runtimes depend on the operating system if required.
- Run Spectrometer application Setup from the folder Software.

3) Start the Application

- Start the application by running "Spectra Analyzer", the main window will open.



- Note: If the setup is not calibrated, a warning message may appear. 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, *.WCAL from CDROM/Pendrive. If the calibration file for this particular device is not present in CDROM, a calibration file should be generated manually using the results acquired via the wavelength calibration method.

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

a) Scan Spectrum Data

- Click ‘Acquire Single 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
- The display is in “Graph” mode by default. To view the spectrum in “Grid View” mode, click the button ( ) located on the tool bar. The application will display the spectrum in Table mode, Figure shows below.

Appendix II

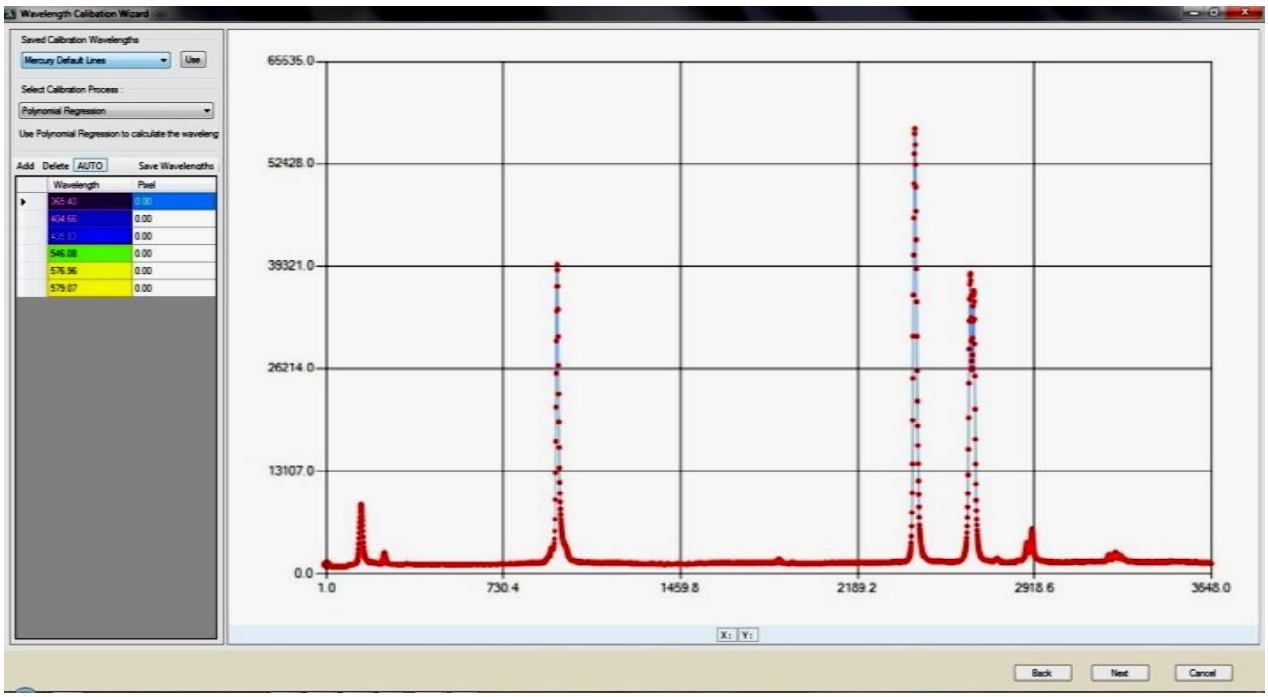
Wavelength Calibration

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 known wavelengths whose peaks properly cover the spectrometer wavelength range. Connect the light source or lamp to the spectrometer.

Steps:-

1. Open the 'Spectra Analyzer' software and Login as administrator using the user name & password.
   User name: Administrator Password: Admin123*
2. Click RUN button. Please check x axis in pixel mode (P/λ→x).
3. You can see discrete spectrum lines. Make it clear & sharp with good intensity by adjusting the exposure time. Also adjust the slit width of spectrometer to get narrow bandwidth/sharp line spectrum.
4. After obtaining a good spectrum, click Stop (STOP) button. Click ( ) Acquire Single button to capture the current spectrum.
5. Select Wavelength Calibration from the menu and click **Tools → Wavelength Calibration**
6. In the calibration wizard, click 'Next'.



7. Use saved wavelengths to automatically enter the wavelengths to data table. (Combo box contains default mercury lines, current calibration wavelengths if wavelength exists and user saved wavelengths).
8. The table in the left bottom shows the wavelengths of the selected wavelength set. By clicking 'ADD' button, a new wavelength set is created. Clicking the DELETE button deletes the current selected wavelength set. Note that the first 3 wavelength sets are predefined for Hartman regression and 4 wavelengths for Polynomial regression. By clicking save wavelengths, to save current wavelength sets.
9. Right click near the peak of the spectrum. Click Zoom. Then click and drag creating a rectangle, which includes the first peak, and release the mouse button. The first peak will be zoomed in.
10. Right click again and click Select to show a cross cursor.
11. Place the cursor on spectrum peak ball which is corresponding to the known wavelength selected in the calibration table. Clicking on a peak ball will send the relative pixel value to the corresponding pixel value cell. These steps can be repeated for all wavelengths in a set.
12. Select a wavelength on the table
13. Check 'Auto' button for automatically enters pixel value to corresponding pixel value cell. Otherwise manually enter relative pixel value corresponding pixel value cell
14. Move the cursor to the peak which is corresponding to the wavelength selected and click. The pixel value will be filled automatically on the space beside the wavelength in the table.
15. Click next, and then the coefficients are shown in the table. Click Save to save the calibrated wavelength to user selected location.