

SP1 & SP2 Spectrometers

Operating Manual



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Introduction

The SP1 and SP2 are both grating-based spectrometers that have linear CCD outputs and fiber optic inputs. The SP1 works in the range of 400 to 800nm and the SP2 works from 500 to 1000nm. The optical design is a very compact Czerny-Turner grating spectrometer using an SMA connectorized fiber input. The systems come fully calibrated from the factory, and can easily be recalibrated on site using a standard emission source (i.e. He, Hg, H, Ar, etc.). The spectrometer connects directly to a computer using a standard parallel port connection. Integrated routines allow averaging, smoothing, peak finding, as well as saving and recalling data sets.

The initial setup of the SP1 and SP2 is simple to complete in less than 15 min. The remainder of this manual is devoted to the setup procedure and features of the spectrometer units. A troubleshooting section and detailed specifications of the various components are provided to further assist.

Installation

Parts List

The SP1 and SP2 come with the following parts: Interface Box, Spectrometer Head, Power Cord, Parallel Port Cable, Interface Cable, 50 μ m Core Fiber Optic Patch Cable and software. The parts are labeled on the diagram below.



Connections

Connect the spectrometer to the computer as follows:

Connect the interface cable (DB9) between the spectrometer head and the front face of the interface box.

Connect the parallel port cable between the rear panel of the interface box and the parallel port on the computer.

Power-up the computer.

Power-up the interface box.

Connect the fiber optic patch cable and feed in the light that is to be analyzed.

Parallel Port Requirements

In order to achieve very fast data transfer between the spectrometer and the computer the parallel port needs to have bi-directional capabilities. The BIOS settings of the computer require the on-board parallel port to be set in EPP mode and the protocol must be version 1.9. On older BIOS versions the protocol version is 1.7, which will not work for this system. Some ECP modes can emulate an EPP mode, but they must be version 1.9.

Checking and Setting the EPP Mode

When turning the computer on, immediately go into the computer's BIOS setup mode. Generally the parallel port attributes may be found under peripherals. Use your BIOS keyboard function to scroll through the port options. SPP, EPP, EPP/ECP and ECP options may be present (standard parallel port, enhanced parallel port, extended capabilities port). Change the setting to EPP. The BIOS should prompt you as to what protocol version is available. If you do not have version 1.9,

you more than likely have an older PC that does not have the capabilities. ECP does emulate the EPP mode but it must be version 1.9. Once the EPP mode version 1.9 has been set, save and exit the BIOS menu. Your computer will now start with the necessary port mode to run the spectrometer.

Extra Port or No EPP Version 1.9 Mode

If the computer you are working with requires the on-board parallel port for printing or external drive functions or does not support EPP version 1.9 then you need to obtain an extra I/O peripheral card for your PC. We have tested the Warp Nine ISA parallel port card. This ISA card is EPP/ECP and emulates the EPP with the correct protocol. If a card is needed, follow standard installation procedures of the manufacturer. The card must have the correct address, either 378h or 278h. Make sure the peripheral or the spectrometer has the same address setting. The ISA card is generally set by jumpers on the card while the on-board port on the computers motherboard is set in the BIOS by software.

At this point the spectrometer should be completely connected to the computer system and ready to run. Go on to the next chapter for an explanation of the spectrometer software.

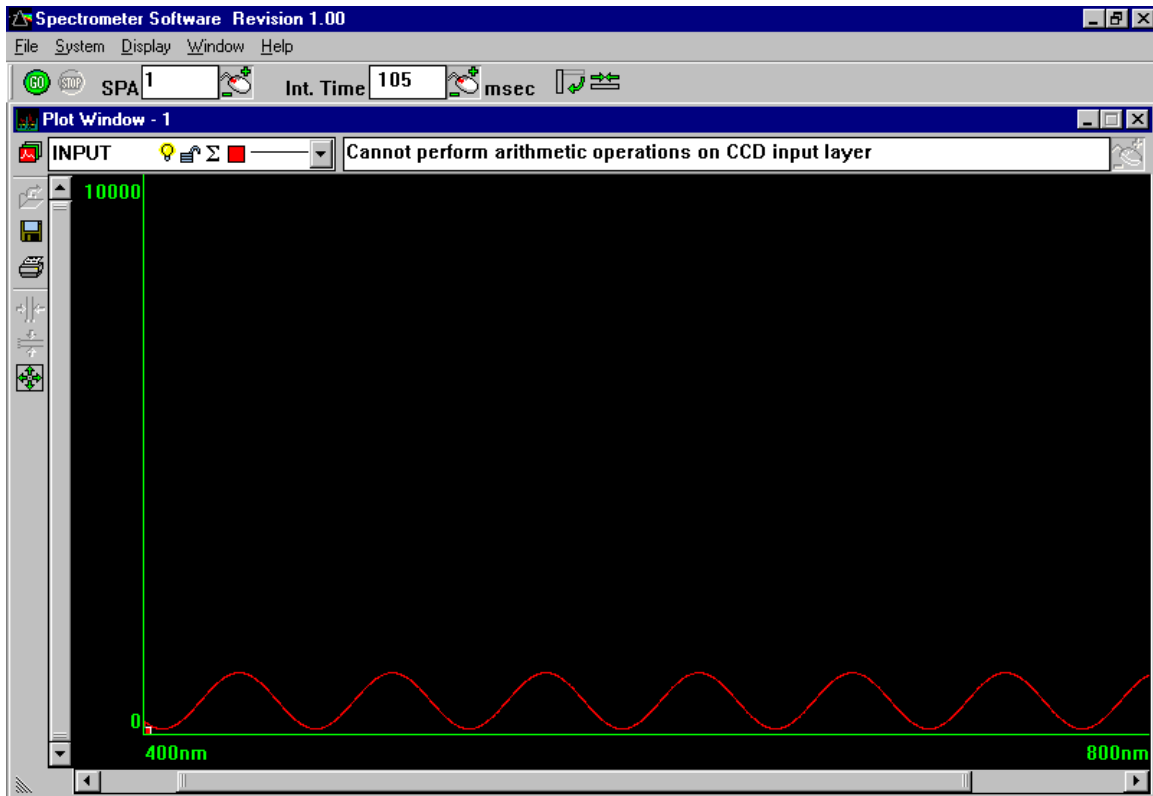
Installing Software

From either the CD-ROM or the 3.5" disk, run the setup program and follow the prompts. On the CD-ROM version of the software, a PDF edition of the manual is included.

Software

Quick Start

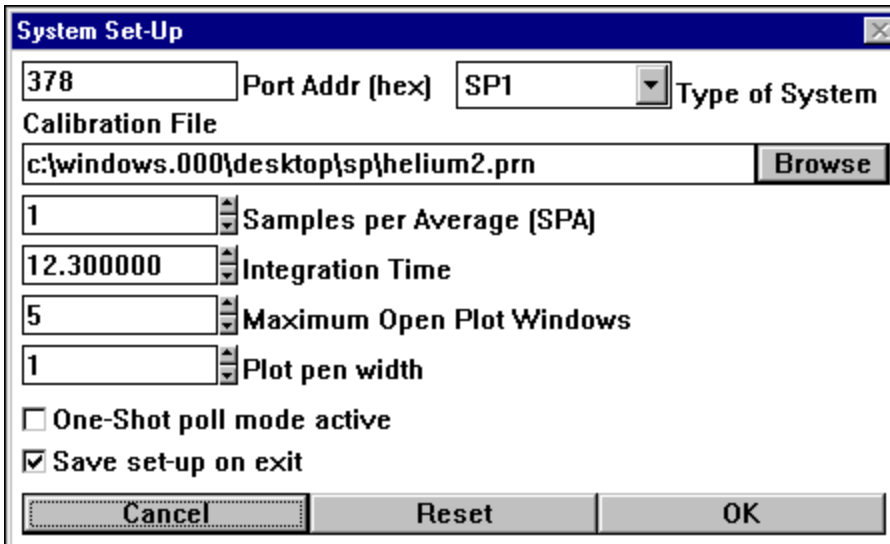
Assuming that all of the installation instructions have been followed, it is now time to run the spectrometer software. Double click on the spectrometer icon that has been placed on your desktop, or go to the **Start Menu -> Thorlabs Spectrometer -> Spectra**. The screen that appears is as follows:



The spectrometer program is ready to take data. The buttons that control the global features of the spectrometer are discussed later.

First Time Start

If this is the first time starting the spectrometer there are a couple of settings that must be checked. Left-click on **System->Set-Up** on the menu bar. The following menu will appear:



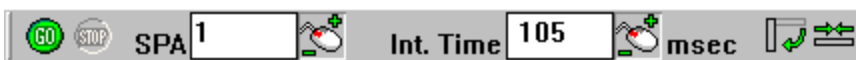
The **Type of System** must be set to SP1 or SP2 depending on the spectrometer head you have, and the **Calibration File** should be set to the default calibration labeled def-cal.prn in the spectrometer directory.

The default setting of the **Maximum Open Plot Windows** is five, which seems to work well on most systems. Each plot window consumes memory; so on systems without much RAM, this number should be lowered.

The **Port Addr (hex)** should be the parallel port address in hex notation.

One-Shot poll mode active should not be checked unless the spectrometer will be used for single shot data. **SPA** and **Integration Time** are arbitrarily set since they can be controlled actively in the main window.

The Main Toolbar



Below are descriptions of each of the buttons:



The **GO** button starts polling of the spectrometer.



The **STOP** button stops polling of the spectrometer.



SPA stands for samples per average. When the **SPA** is set at one, there is no averaging occurring. Any number greater than one represents the number of samples averaged together for the data displayed.

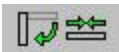


Int. Time is the integration time. This represents how sensitive the CCD is to incoming light. CCD pixels act like light buckets, gathering photons. The integration time display represents how many milliseconds the bucket is open. For very bright sources, low integration times are required, whereas for weak sources, longer integration times should be used. As in the light bucket analogy, CCD pixels can be overfilled. This is called saturation and will cause the output to be misleading.

TOOLBAR TIP



The mouse with +/- symbols can be used to quickly change the value of the quantity associated with it. Move the pointer over the icon and press the left button. While holding the button down, moving the mouse up increases the value, and moving the mouse down decreases the value.





Toolbar Settings are manipulated by this pair of buttons. The button on the left controls the orientation of the tool bar and the button on the right controls its length.

Getting Your First Spectrum

With an understanding of the main toolbar, it is easy to bring up your first spectrum. With light being fed into the spectrometer head through the SMA connectorized fiber and SPA set to one, click on the go icon. If there is no signal, increase the integration time until a signal starts to appear. Once a signal is attained, there are ways to zoom in on it. This is explained in the next section on scroll bars.

Scroll Bars

Scroll bars are used to scale the graphical output in the plot window. The image to the right shows a portion of the vertical scroll bar. The vertical scroll bar controls the relative amplitude of the peaks of the spectrum that is being viewed. Move the cursor around the bar. The cursor symbol will change from  to  when the cursor is in a position to change the vertical scale. While in that position hold down the left button and move the cursor up and down noting the change in the scale. Changes in the vertical scroll bar affect the amplitude and changes in the horizontal scroll bar affect the wavelength range.



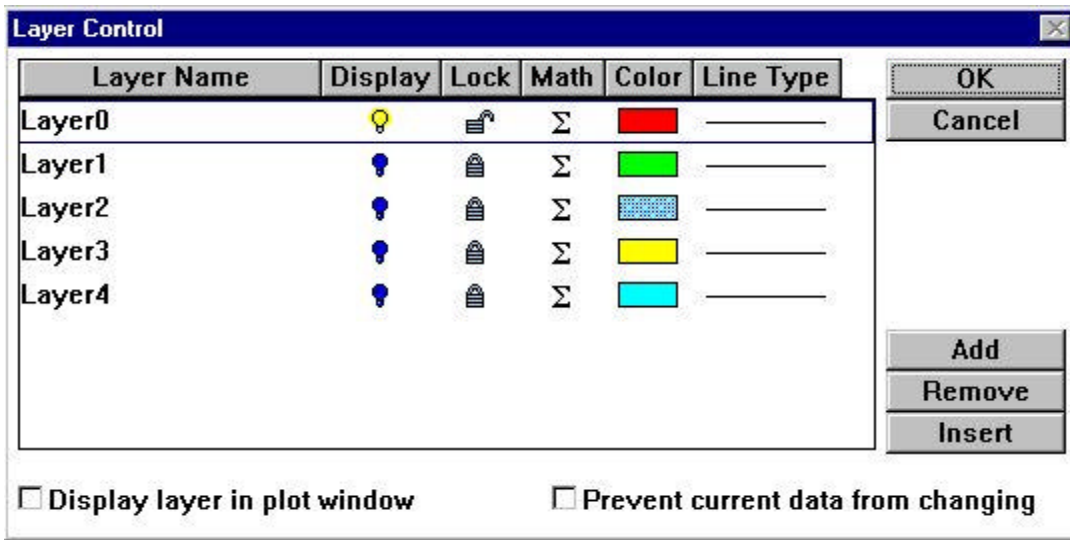
Layers

One of the unique features of the software for the SP1 and SP2 is the ability to see the raw data while performing mathematical function on various other layers. At the top of the plot window, a button bar appears as below:



Layer Control

The **Detailed Layers Adjustment** icon is used to access the layer control menu. It allows for general control of all layers. Additional layers and controls on existing layers may be specified here. The following sample menu is displayed:



This menu allows for the user to add and remove layers as well as control the display features of each layer.

The bulb represents whether or not the layer is displayed in the plot window. represents that the layer is on and represents that it is off

The lock specifies whether the layer may be changed. is unchangeable and may be changed.

Σ This function allows access to another layer of menu that controls the math functions acting on the data. Any layer, with the exception of Layer0, may be made up of existing layers in combination.


The **Add** button adds a new layer to the end of the list of layers. The **Insert** button inserts a layer above the selected layer. The **Remove** button removes the selected layer (CCD input layer cannot be removed).

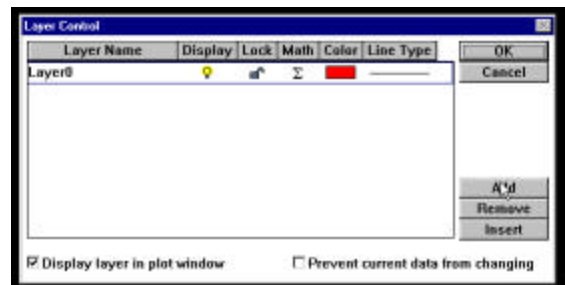
Later sections of the manual go into more detail with the mathematics, but it is worthwhile to mention here that +, -, * and / are all acceptable functions. For example, Layer3 might equal Layer2*Layer0/Layer1+Layer1. The math submenu appears as follows:



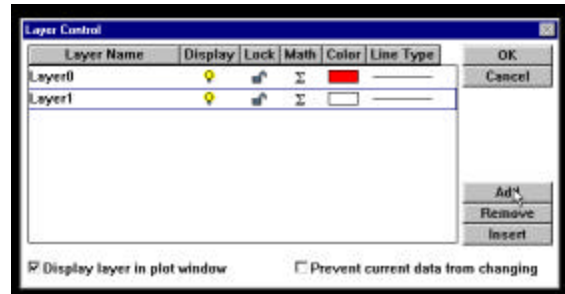
Layer Changing Example

As a simple example, here are the steps so the input spectra is doubled:

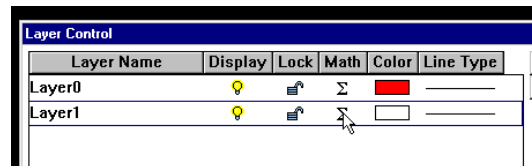
Step 1: Click on the  icon in order to bring up the layer control menu. In the example, there were no previous layers, so only Layer0 appeared. If there are other layers, it is simple to highlight them and remove them. The screen that comes up looks as follows:



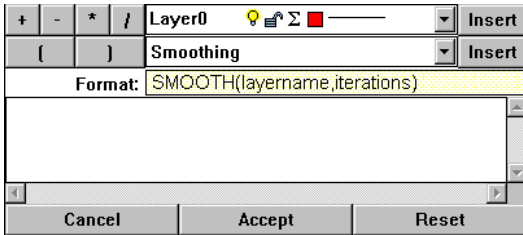
Step 2: Click on the **Add** button as in the picture and Layer1 will appear that can now be used to display the math function.



Step 3: Click on the math symbol as in the illustration. This will bring up the math menu for Layer1

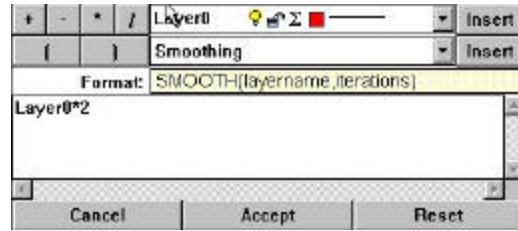


Step 4 The math menu should come up appearing as follows:



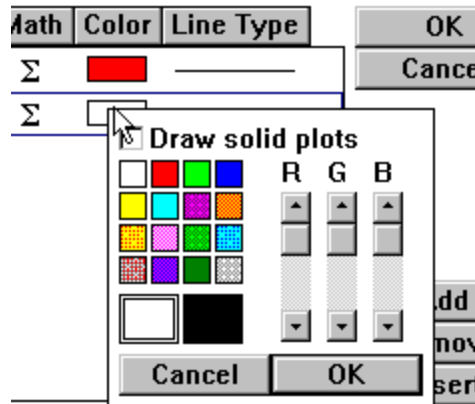
Layer1 will be Layer0*2. First select layer for calculation, then click **Insert**. Next, select the * button. Finally, type in the number 2.

The end result should appear as follows:

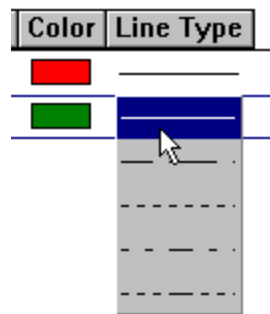


Then click on accept to continue.

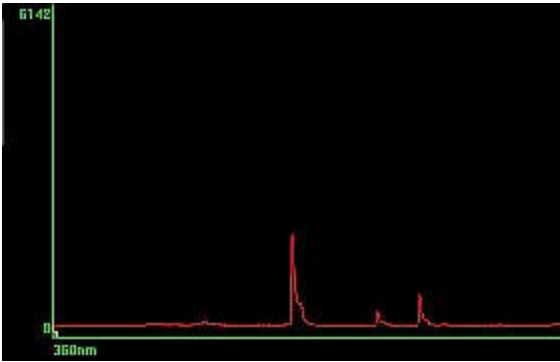
Step 5: This will bring us back to the layer control menu. Click on the color for Layer1 to bring up the color menu. This allows the choice of color for the display. To change the color, click on the color square, or use the RGB (red, green, blue) sliders to make a new color.



Step 6: To change the line type that Layer1 will display in, click on the line for Layer1 as shown to the right. This will allow a number of different choices.

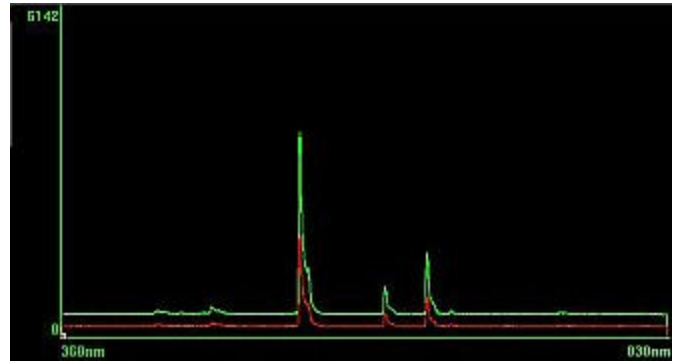




The following page will show the results of the above actions on a helium spectrum.



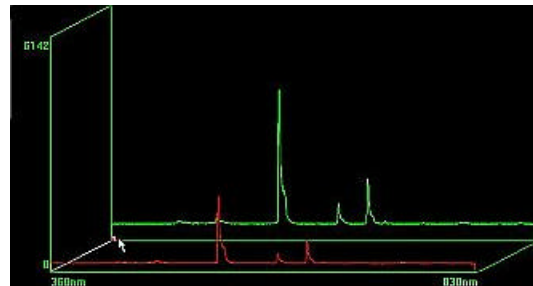
In the diagram, Layer0 is turned on and shows a helium spectrum.

In this diagram, Layer1 is green and turned on. The arithmetic used to derive Layer1 is $2 * \text{Layer0}$



To better see the two separate layers the plot window can be shifted into 3D mode. To do this, move the cursor to the origin where there is a small red dot. When the cursor is over the small red dot, it will change from  to . At this point, hold down the left mouse button and move the cursor towards the center of the plot window. This will cause the plot to fold out in 3d.

The resulting effect should look like this image. More about 3d views will be discussed later in the manual.




Current Layer



The layer that is displayed at the top of the plot window is considered to be the current layer. Whatever functions are called act upon this layer. If snap cursors, vertical cursors, or horizontal cursors are displayed, they show up on this layer. The area to the right of the layer name and attributes shows the mathematical function that is operating on the layer. At the far right is a mouse control that allows for interactively controlling the values within the math function. This is used as follows:

Highlight the numeric part of the mathematical expression that will be altered.



Move the mouse over the  button.

While holding down the right mouse button, move the mouse forward to increase the value, and backward to decrease the value.

Note: When decreasing values in this manner, it is very easy to decrease the value to zero. This can cause errors such as division by zero that will stop the polling of the spectrometer.

Averaging & Smoothing

There are a couple of ways to deal with averaging and smoothing in the SP1 and SP2.

Averaging



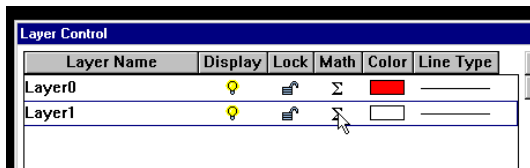
The averaging routine uses the **SPA** (Samples Per Average) function. This function is accessible through the main toolbar. Averaging works on Layer0 as a rolling average and the number in the **SPA** function represents the number of complete data sets averaged. When a source is noisy or fluctuating, the **SPA** function can act to provide a stable output.

Smoothing

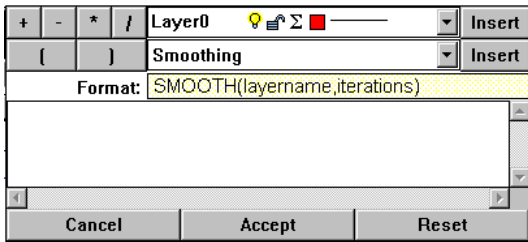
Smoothing uses a mathematical algorithm to attempt to remove noise. Unlike the averaging function, smoothing is done on an existing layer and presented in another layer (i.e. Layer1 can display Layer0 smoothed). Layer0 can never display another layer smoothed because it always represents the raw data.

Smoothing Example

Choose the layer that will display the smoothed output and click on the math icon Σ .



This will bring up the math menu. In this case the math menu for Layer1 is being shown.



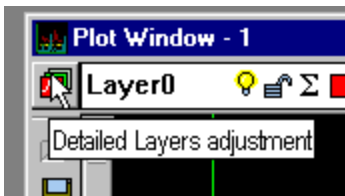
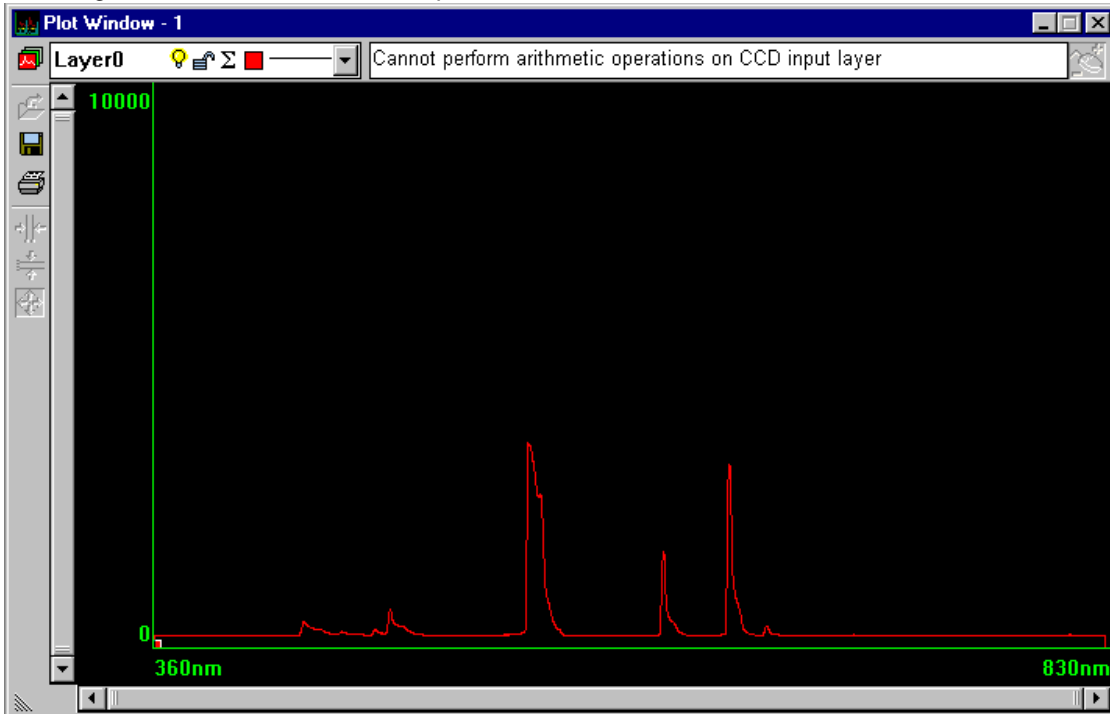
The next step could be typed in or the **Insert** buttons may be used. In the text box, it must read **SMOOTH(Layer0,5)**. The syntax of the smoothing function is **SMOOTH(layername,iterations)**. The above example will show Layer1 to be Layer0 smoothed with 5 iterations. The exact number of iterations to use on a data set is usually determined with trial and error.

Peak Finder

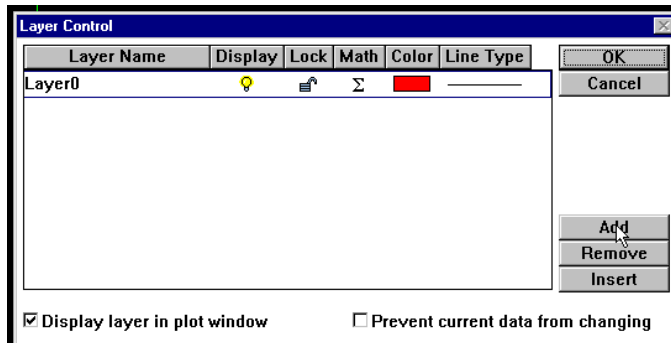
The SP1 and SP2 have a function that is specifically designed to find peaks within a given spectra. The peak finding function looks for local maxima and represents them as a plot similar to a delta function with the relative intensity of the maxima. This is a very convenient way to compare emission line spectra. A simple example of using the peak finder follows:

Helium Spectrum Example

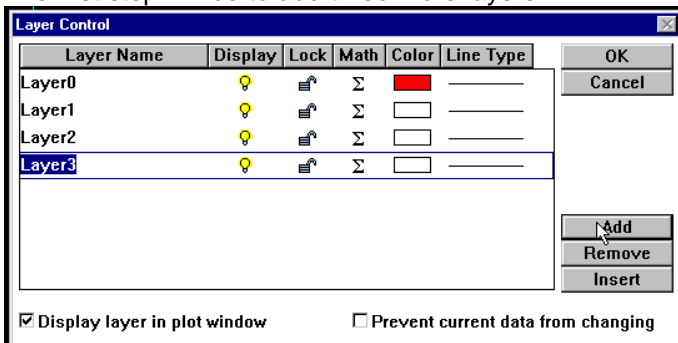
The diagram below shows the raw input of a helium source.



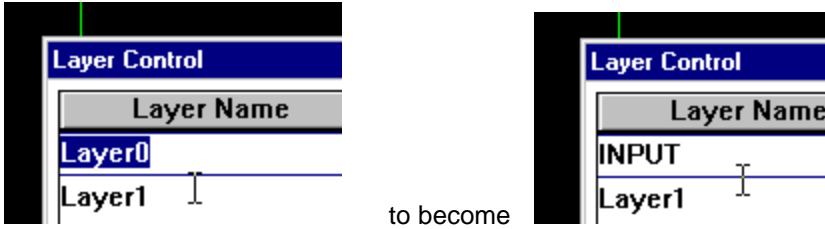
In order to bring out the peaks, extra layers will be added. Clicking on the layer icon brings up the layer menu.



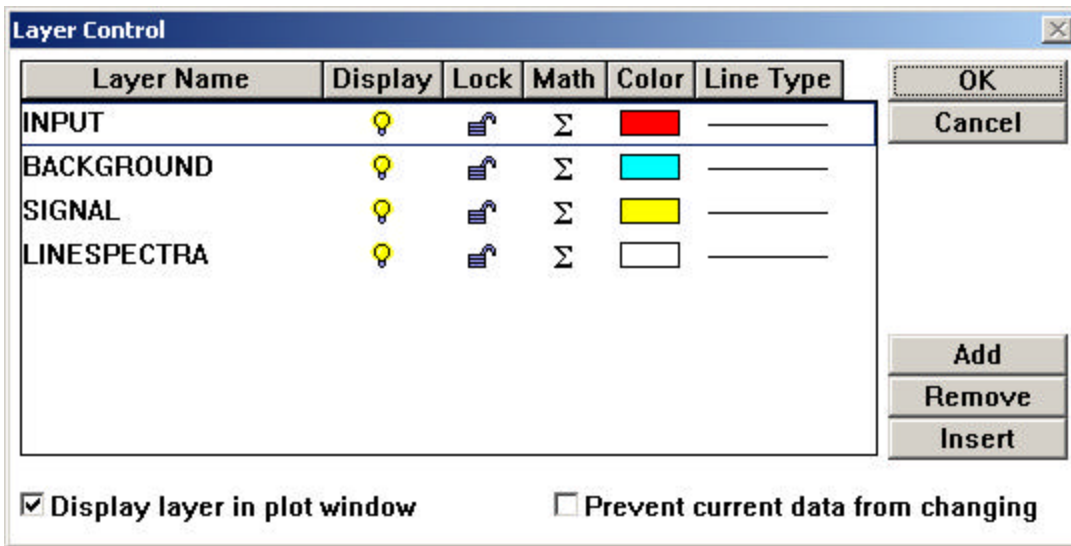
The first step will be to add three more layers:



For convenience, it is simple to change the layer names at this point. Highlight the name to be changed and type in the replacement to change the name.



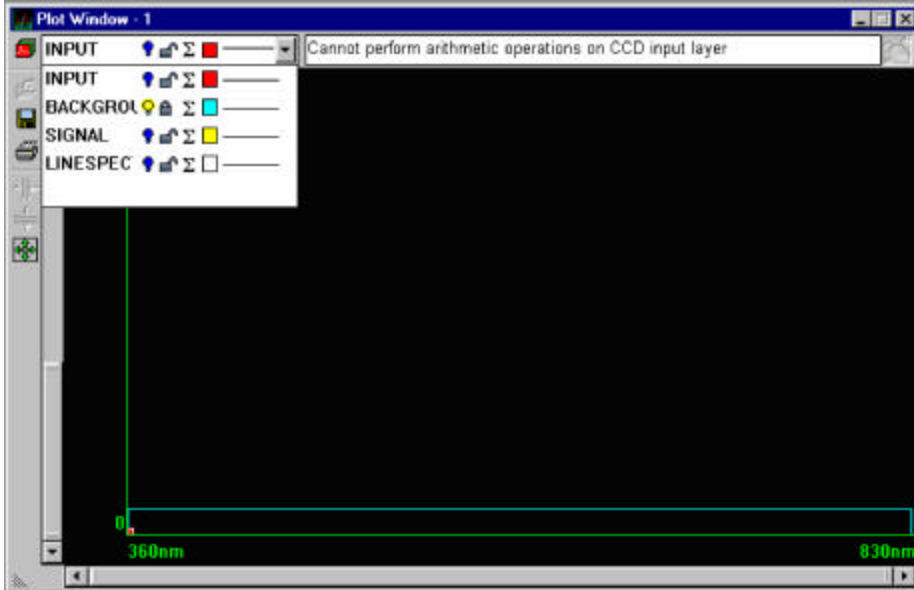
All the layers are changed as shown in the following image. This is also a good time to change the color of each layer, as shown:



Note: Layer names may not contain spaces.
All of the layer definitions are explained below.

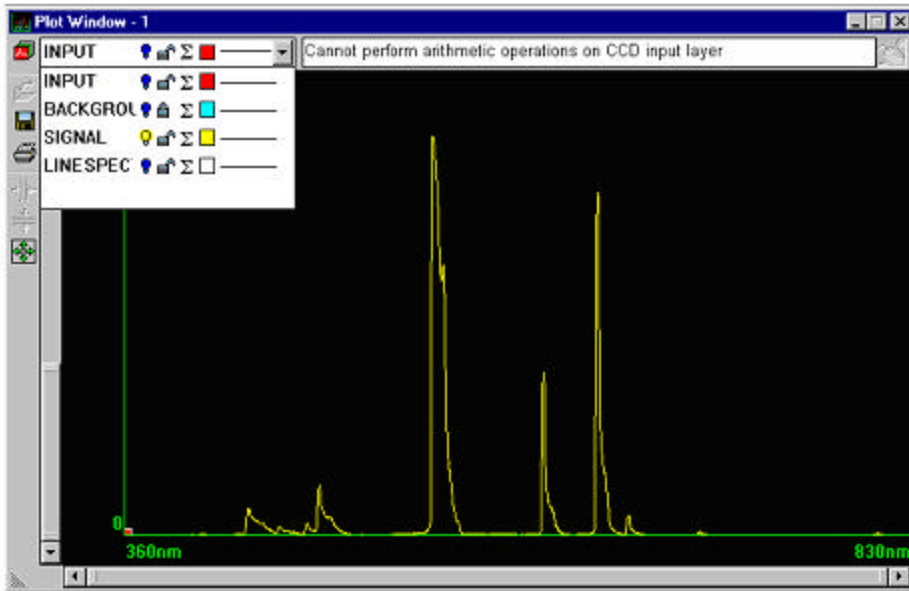
BACKGROUND

The layer called **BACKGROUND** will be a sample with the helium source turned off. To define this layer, the math menu is brought up and the definition of the layer should be entered as **INPUT**. To capture the background noise, physically block the source. Use the lock symbol to ensure that the signal does not change when the source is allowed to enter the spectrometer again. The symbol of the lock must be closed for the layer to remain frozen in its state. If the lock is open, clicking on it with the mouse will close it. With only the **BACKGROUND** layer turned on, the display should be as follows on the next page (regardless of the source being off or on):



SIGNAL

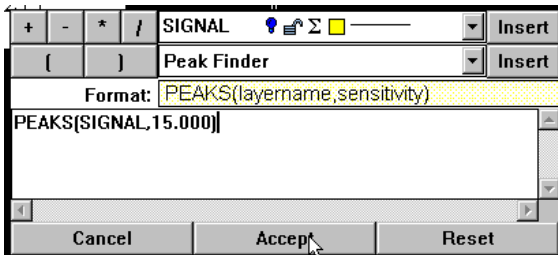
The layer named **SIGNAL** is to be defined as **INPUT-BACKGROUND**. To define this layer, click on the math icon Σ for the **SIGNAL** layer and enter the formula. When the **SIGNAL** layer is displayed alone, it appears as follows:



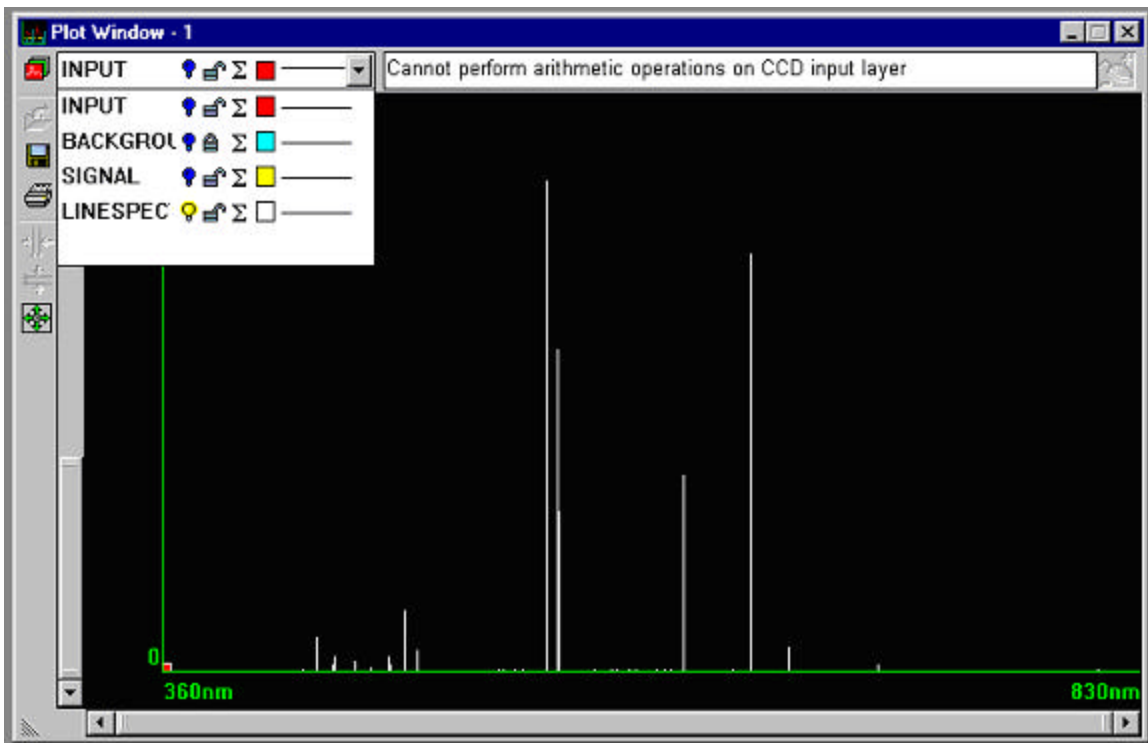
The **SIGNAL** is really just the **INPUT** layer with the offset subtracted out.

LINESPECTRA

The final layer is the **LINESPECTRA** layer. Using the math icon Σ , select **Peak Finder** from the function drop down menu, or enter **PEAKS(layername,sensitivity)** in the text box. Enter **SIGNAL** for the layername and 15.000 for the sensitivity, as shown:



When the **LINESPECTRA** layer is displayed alone, it appears as follows:



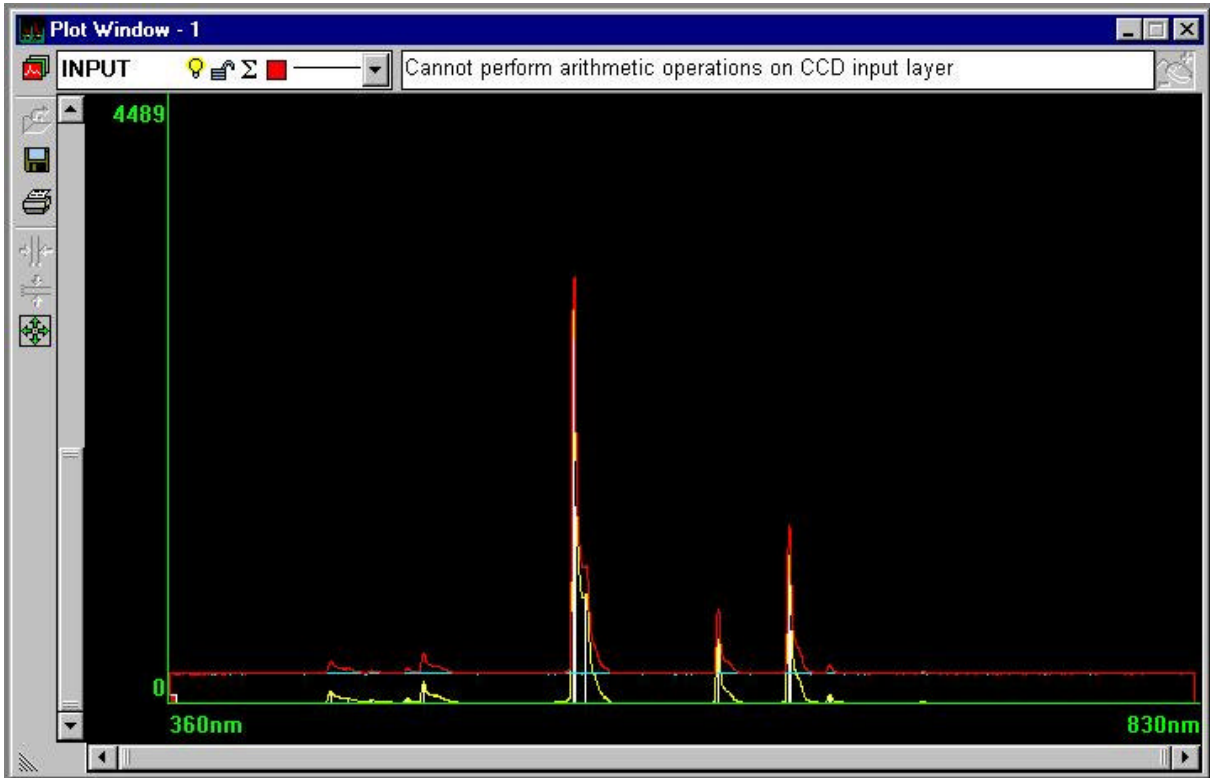
Mathematical Functions



The mathematical functions that can be performed by the SP1 and SP2 allow the user open-ended capabilities. In the previous section, the example used subtraction to take out the background, or dark noise, from the signal. Complex functions may be entered and executed on any given layer except the input layer. Squaring a layer can be achieved by multiplying the layer by itself, which can act to intensify the spectral information. Information from locked layers can be mathematically compared to active layers. The symbols, $+ - * /$, as well as levels of parentheses, can be used.

NOTE: When using predefined functions like **PEAKS()**, **SMOOTH()**, etc., the syntax does not allow the use of mathematical functions. This can easily be worked around. By using the predefined function on a layer, a math function can be performed on a newly created layer.

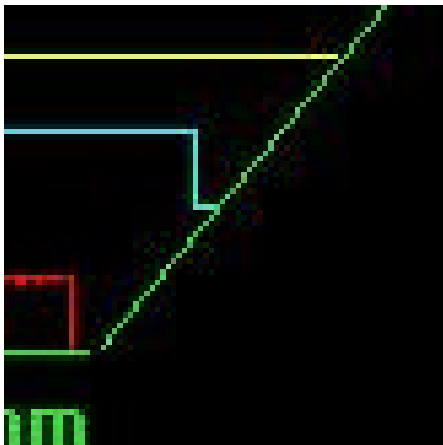
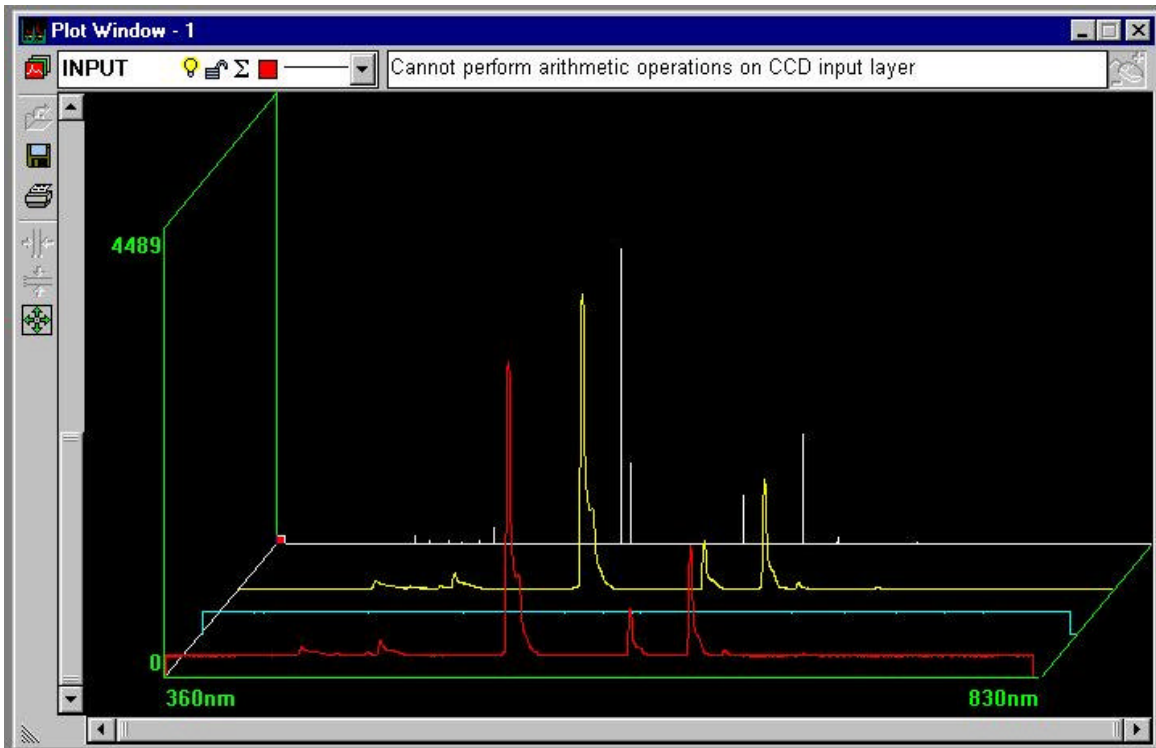
3d View

When working with multiple layers, it is often convenient to be able to see all of them separately. In the example of the Peak Finder function, there were a total of four layers being displayed. One way to see the layers would be to turn all of them off except the one of interest. However, other important information may be overlooked. Displaying all the layers simultaneously can be confusing as can be seen below:



To better see the two separate layers, the plot window can be shifted into 3D mode. To do this, move the cursor to the origin where there is a small red square. When the cursor is over the small red square, it will change from  to . At this point, hold down the left mouse button and move the cursor towards the center of the plot window. This will cause the plot to fold out in 3d.

The screen now appears as on the top of the next page:



In the example, it was important that the background noise was filtered out. In the 3D view, the offsets are clearly shown, as can be seen in this close-up view of the right edge of the plot window. As expected, the offsets are displayed in the **INPUT** and **BACKGROUND** layers, but not in the **SIGNAL** layer.

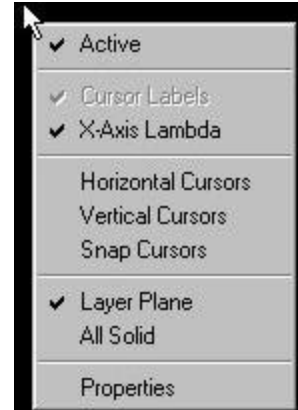
Cursors


A number of different cursor and display features can be accessed through right clicking of the mouse. In the plot window, click the right mouse button. This image should appear. Each of the options will now be explained:


Active – determines whether the window is running or not. This is particularly useful when there are multiple plot windows being displayed.


Cursor Labels – mark the cursor with labels such as x1 or x2 so the cursor may easily be identified.


X-Axis Lambda – switches between measurement of wavelength in nanometers and pixel number. When it is checked, the measure is in nanometers.




Horizontal Cursors – draws a pair of horizontal cursors that may be moved from up and down to define a region of interest. When the mouse is moved over a horizontal cursor line the arrow will change to . While the mouse is in this state, holding down the left mouse button will allow the horizontal cursor line to be dragged. A readout is given that gives the location of y1, y2, and the difference between y1 and y2. The readout may be dragged to anywhere on the plot window, by holding down the left mouse button while the mouse pointer is over it.

With Horizontal Cursors displayed, clicking on the Zoom to current horizontal cursors button  (on the toolbar on the left side) will zoom to the area between the Horizontal Cursors.

Vertical Cursors – draws a pair of vertical cursors that may be moved from side to side to define a region of interest. When the mouse is moved over the vertical cursor line the arrow will change to . While the mouse is in this state, holding down the left mouse button will allow the vertical cursor line to be dragged. A readout is given that gives the location of x1, x2, and the difference between x1 and x2. The readout may be dragged to anywhere on the plot window, by holding down the left mouse button while the mouse pointer is over it.

With Vertical Cursors displayed, clicking on the Zoom to current vertical cursors button  (on the toolbar on the left side) will zoom to the area between the Vertical Cursors.

Snap Cursors – provides a movable vertical cursor and draws a horizontal cursor corresponding to the data point that the vertical cursor crosses. This is a way to zero in on local maxima and minima. Click and hold the left mouse button while  is on a vertical cursor to change its location.

Layer Plane – boxes the current layer. In the 2D view this has no effect, but in the 3D view it helps in distinguishing which layer is current and being operated on.

All Solid – makes the graphical output opaque for each layer. It helps in visualization when doing a monochromatic printout of the 3D view. In the 2D view, it acts to partially block viewing the layers behind Layer0.

Properties – allows the altering of all of the functions on one menu.

Calibration

Calibration of the spectrometer system is done at the factory. A routine is included to re-calibrate the spectrometer. The calibration steps are as follows:

Go to **System->Calibrate** from the menu bar. A spreadsheet appears to perform the calibration.

If you are ready to make a new calibration, click on the **Clear** button in this window. This will make all of the wavelength values zero.

In the plot window, right click to bring up plot menu options. Make sure that **X-Axis Lambda** is unchecked and **Snap Cursor** is checked.

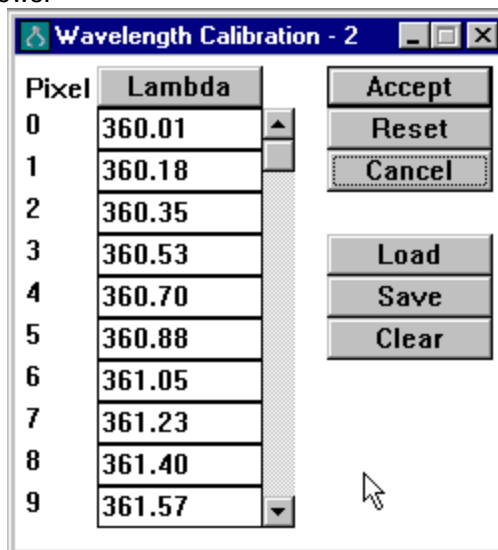
With a known spectral line source such as Hg-Ar, He, H, etc., move the vertical snap cursor to one of the known emission lines until the horizontal part of the snap cursor is maximized. Note the **x1** pixel value.

Go back to the wavelength calibration window and record the known wavelength for that pixel number.

Repeat this for as many wavelengths as possible. The more known wavelengths, the more precisely the spectrometer will be calibrated.

Once all the known wavelengths are in the spreadsheet, click on the **Wavelength** heading of the column. This will cause an internal function to calculate the other pixel wavelengths.

Save this calibration by pressing the **Save** button and naming the calibration.



Storing and Retrieving Data

One of the more useful features of the spectrometer is the ability to store and retrieve data. Storing the active layer is done by hitting the **SAVE** button. The save window is displayed asking in which directory to save the data. The spectral files are saved with the extension **.spe** in the chosen directory. The data in the **.spe** file is saved in a text format so it may be imported into other programs for analysis. To view the data, open **Windows Notepad** and then open the saved **.spe** file inside of it.

To retrieve a saved spectrum, first select an open layer by using the layer pull-down menu. Then use the **LOAD** button to load a saved layer.

Troubleshooting

Parallel Port Operations and Configurations

Data transfer is accomplished using the ECP/EPP Mode ver 1.9. The system uses the ECP protocol and transfers EPP mode. This parallel port configuration allows the μ controller and PLD's in the interface to transfer of data at such fast data rate.

Computer BIOS.

On newer PC's in the boot BIOS, the parallel port should be set to: ECP+EPP ver1.9 default address: 378h. If neither ECP/EPP or EPP mode ver 1.9 is available then the PC is limited and the interface and cannot transfer at the desired data rate. To overcome the limitations we recommend for older PC an external parallel card that supports ECP is used.

In the NT and Win2000 operating system

The parallel port device driver TVICPORT.SYS must be located in winnt\system32\drivers **With Win2000 you must have administrative rights for that PC in order for the system run.** When the spectra program is initially executed and the error "System unable to contact external hardware" is displayed first, then there is a communication error from incorrect port settings or port control.

In the Win95 and Win98 operating system

The parallel port device driver TVICPORT.VDX must be located in \windows\system folder. When the spectra program is initially executed and the error "System unable to contact external hardware" is displayed first, then there is a communication error from incorrect port settings or port control.

SP and LC1 Connections

The parallel cable must be secured, the serial cable must be secured. **Make sure the AC power switch is set to your AC line voltage 115 or 230 VAC.**

Run the LC1 or SP spectra program

In set-up, the parallel port address must be the same as the BIOS, default 378h When running the LC1, ambient light will saturate the CCD. Set the integration time to 0.001. Set the Samples Per Average SPA to 1. You should observe a deflection in intensity if you block light from the CCD. If the LC1 camera is to be used with ambient light variation then ND filters must be used to limit the brightest values.

Run the SP1 or SP2 Spectra program

In set-up the parallel port address must be the same as the BIOS, default 378h When running the SP Spectra set the integration time to about 10mSec and the SPA to 1, ambient light coming through the SMA connector will show a deflection the Y axis. You should be able see a change by covering up the SMA connector.

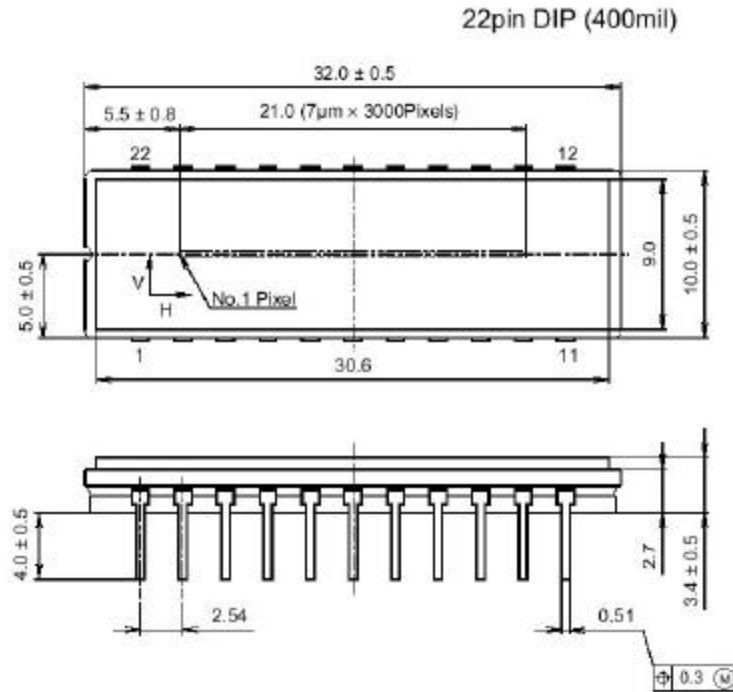
When I turn on the horizontal or vertical cursors, they are not displayed on the screen.

This is most likely caused by the fact that the active (or selected) layer is not turned on. In the upper left hand corner of the plot window, the current layer is displayed along with icons that represent various properties of it. If the light bulb icon is turned off, then the layer will not be displayed, and cursors associated with that layer will also not be visible.

Specifications

CCD Specifications

ILX526A - 3000-pixel CCD Linear Image Sensor (B/W)



PACKAGE STRUCTURE

PACKAGE MATERIAL	Cer-DIP
LEAD TREATMENT	TIN PLATING
LEAD MATERIAL	42 ALLOY
PACKAGE WEIGHT	3.0g

Description

The ILX526A is a rectangular reduction type CCD linear image sensor designed for bar code POS hand scanner and optical measuring equipment use. A built-in timing generator and clock-drivers ensure single 5V power supply for easy use. 22 pin DIP (Cer-DIP)

Features

Number of effective pixels: 3000 pixels
 Single 5V power supply
 Built-in timing generator and clock-drivers
 Electrical shutter function

Pixel size: $7\mu\text{m} \times 200\mu\text{m}$ ($7\mu\text{m}$ pitch)
 High sensitivity: $300\text{V}/(\text{lx} \cdot \text{s})$
 Built-in sample-and-hold circuit
 Clock frequency: 100kHz (Min), 1MHz (Max)

Software Specifications

The software for the SP1 and SP2 needs the following minimum computer requirements:

Pentium-Based PC with 64MB RAM

Hard-drive, CD-ROM or 3.5" Disk

EPP Parallel Port

Optical Specifications

The spectrometer has a 600 line/mm reflective grating in a Czerny-Turner configuration to minimize aberrations. A 50 μ m core SMA connectorized fiber optic patch cable is included for light input. The internal optical design is optimized for a 0.22 NA or less input from the fiber.