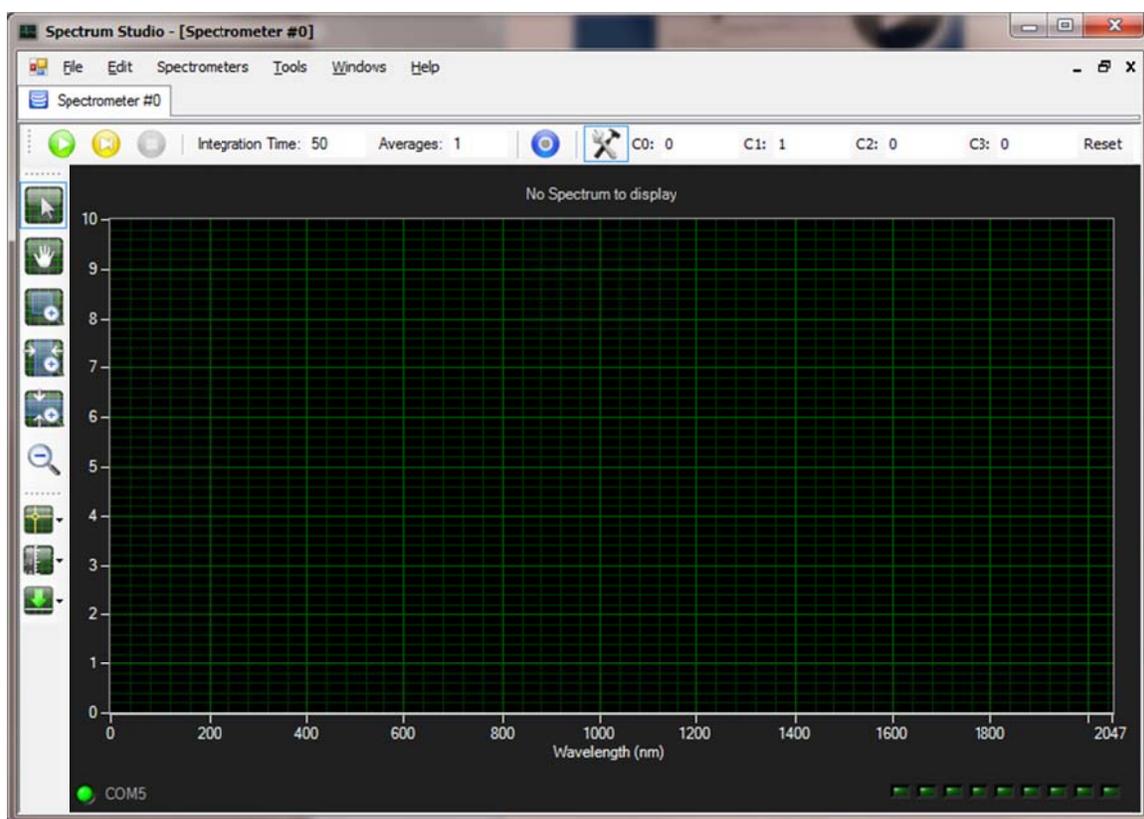


Spectrometer Alignment and Calibration

Electronic version available at <http://www.science-surplus.com/products/spectrometers/spectrometer-resources>

Install the Software

Before beginning the alignment procedure, install SpectrumStudio™ on your computer using the provided installation CD. After the installation has completed, power the spectrometer using the provided 5V adapter and connect the spectrometer to the computer using the provided serial cable. You can also use a USB to serial adapter, assuming you have installed the proper driver (provided by the manufacturer of the adapter). After the spectrometer is powered and connected, open SpectrumStudio™. If everything is connected properly, you should see a screen similar to the following:



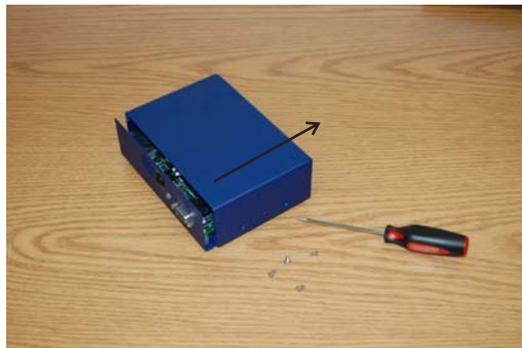
If the spectrometer was not detected, ensure that it is correctly powered (the red LED on the back should be on) and connected to a properly functioning serial port, and then press Ctrl+D to redetect the spectrometer. Once the spectrometer is detected, press the “Spectrometer Settings” button (the hammer and wrench icon) to display the calibration coefficients. Verify that your coefficients are set to $C0=0$, $C1=1$, $C2=0$, and $C3=0$. If the coefficients need to be changed, simply place the cursor in the box, type the new value, and press enter. After the coefficients are set, press the yellow “Scan Once” button and verify that the spectrometer returns a spectrum. Once this setup is complete, disconnect the spectrometer from the serial cable in preparation for alignment and unplug the power adapter.

Spectrometer Alignment

The alignment procedure falls into four basic tasks: open the spectrometer, roughly align the internal optics, set the angle and position of the focusing mirror, and optimize the position of the collimating mirror. The last two tasks are typically iterated to achieve the best overall spectral resolution and lineshape symmetry. Aligning the spectrometer for good resolution at a single wavelength can usually be accomplished quickly. Optimizing the spectrum over the entire spectral range is much more challenging, but with patience and care you can perform this operation successfully. We suggest you read the entire document before actually performing the steps, so you understand the big picture.

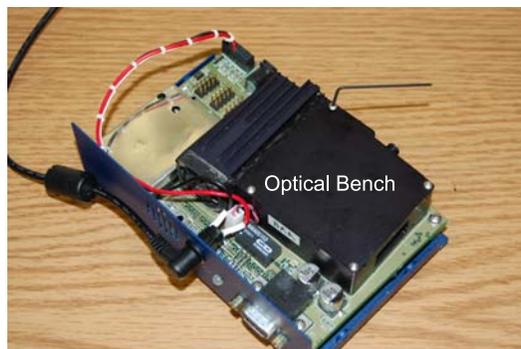
Open the spectrometer

1. The spectrometer's enclosure is made of two parts. You only need to remove the top portion of the enclosure to perform the alignment. Using a small Phillips head screwdriver, remove the four screws found on the sides of the enclosure. Then slide the top portion of the enclosure in the direction of the optical input until it comes off. Place the enclosure top and its screws in a safe place so they are not lost.

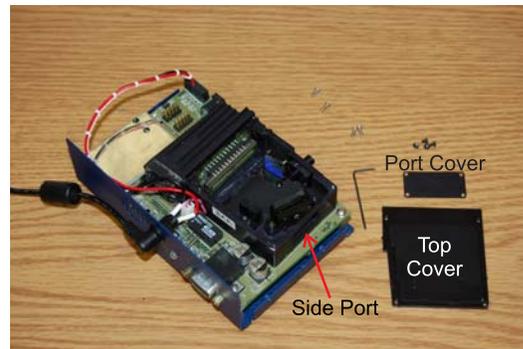


WARNING: the spectrometer electronics are sensitive to electrostatic shock (esd). Standard grounding precautions should be taken each time before touching the spectrometer internals to avoid permanently damaging this unit.

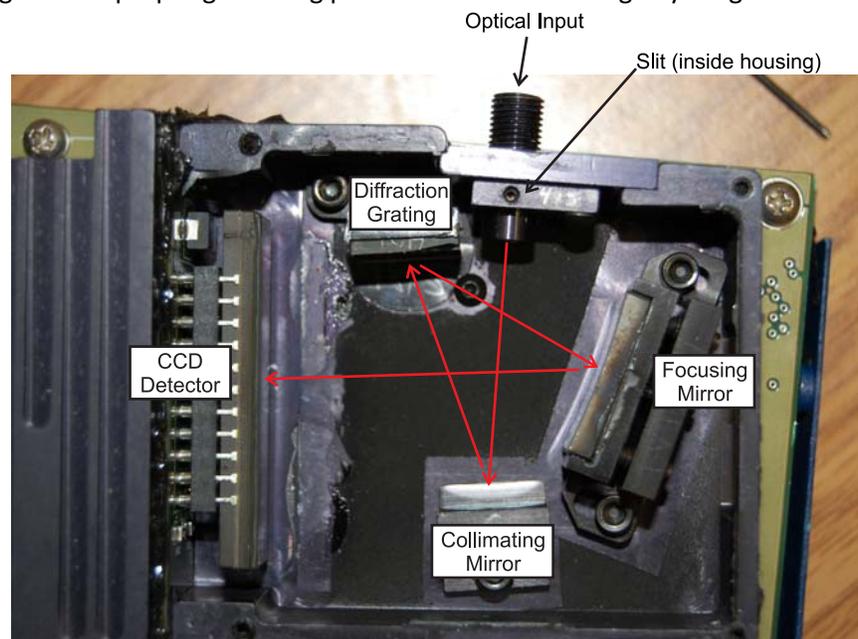
2. The large black box attached to the green circuit board is the optical bench for the spectrometer.



You need to remove the top cover of the optical bench to gain access to the spectrometer optics. Locate the four black or silver screws on the top cover of the optical bench and remove them using a 0.050" hex key (such as item 7122A13 or 5503A13 on mcmaster.com). The top cover should lift off with little effort. You also need to remove the side port cover of the optical bench. Locate the four screws that hold on the port cover and remove them. The spectrometer should now appear similar to this:



Before beginning the alignment, take some time to understand the path of light in the spectrometer, but **do not touch the optical surfaces (the silvered parts of the mirrors and the ruled part of the grating)**. **Acids from your fingers can ruin the surfaces.** Also, recall that the electronics can be damaged by static electric discharge so use proper grounding practices before touching anything.



Light enters the spectrometer from a fiber attached to the optical input and then passing the spectrometer's entrance slit. The first mirror it encounters collimates the light and directs it to the diffraction grating. The diffraction grating separates the light by wavelength, and directs the separated

light towards the larger focusing mirror. The focusing mirror focuses each wavelength of light at a different horizontal position on the linear CCD detector. This linear intensity pattern is read by the electronics of the spectrometer and passed back to the computer.

Roughly align the internal optics

Your next task is to make sure the internal optics are approximately aligned. You'll fine-tune the alignment later.

3. Attach the provided orange fiber optic to the optical input of the spectrometer.
4. In a darkened environment, shine a bright light source (such as a laser pointer or bright white LED) into the unattached end of the fiber. You should be able to see light entering the spectrometer if you place a small white piece of paper just after the slit. (Note: In principle you can align the spectrometer by shining light directly into the spectrometer without the fiber. However, you will typically get better results using the optical fiber.)
5. Using a 3/32" hex key (such as item 5497A25 from mcmaster.com) loosen the screw holding the collimating mirror in place. Adjust the left-right rotation of the collimating mirror so that the light from the mirror strikes the grating on the side closest to the entrance slit. Then lightly re-tighten the screw for the collimating mirror. Depending on your spectral requirements, the optimal alignment may put only part of the incident light onto the diffraction grating.

NOTE: The diffraction grating may have small optical defects, such as a small chip on the edge or corner or what looks like faint lines on the grating or specks of dust. Our experience suggests that these small defects do not significantly affect the spectrometer performance. Diffraction gratings cannot be cleaned. We strongly recommend against touching the grating with anything – no solvent, no fingers, no tissues. A gentle air stream may be used to remove dust.

6. Loosen the two screws holding the diffraction grating in place. Rotate the grating (left-right) to put your incident light onto the focusing mirror. Exercise extreme caution when adjusting the grating. The grating surface is easily damaged.

Set the angle and position of the focusing mirror

Adjust the focusing mirror. The focusing mirror has several adjustments. Its mount is attached to the optical bench by two screws. Small adjustments to the tip and tilt of the mirror can be made using the four set screws located on the back of the mount. You can gain access to these four screws by through the side port behind the focusing mirror.

7. Using the 3/32" hex key, loosen the screws holding the focusing mirror mount to the optical bench. Rotate the mirror (left-right) until your incident light falls onto the CCD detector. Typically, better alignments can be achieved when this mirror mount is rotated as far clockwise as possible. Lightly tighten the screws holding the mirror mount in place.

WARNING: In the next step you will adjust the tip-tilt adjusters on the focusing mirror. These adjusters comprise an over-constrained mechanical system. The mirror is mounted on a thin aluminum plate. The plate has a screw attached to the middle. This screw passes through a stiff little spring and connects to the mirror mount with a small nut. The four set screws on the back of the mount then push against this thin aluminum plate. Tip-tilt adjustments should be made by first loosening one of the set screws, and then tightening the corresponding screw on the other edge of the mount. If these set screws are overtightened, the focusing mirror may break. Caution should be exercised to avoid this undesirable outcome.

8. Adjust the four set screws on the back of the focusing mirror mount to make sure that the light falls on the sensitive area of the CCD detector. This light-sensitive area is the thin gray line running horizontally across the CCD detector. If this is not obvious, you may wish to consult the Sony ILX-511 datasheet (for example, <http://www.datasheetcatalog.org/datasheet/sony/a6800099.pdf>). The last page of the datasheet shows the specified area.

Optimize the position of the collimating mirror

The final task is to optimize the alignment of the collimating mirror. This should be carried out in a dark room with a suitable light source fiber-coupled into the spectrometer. We use a Hg-Ar spectrum lamp, although a low-pressure germicidal Hg lamp (without any phosphor) may also work. For optimizing on only a single wavelength, a laser pointer at that wavelength is adequate. The CCD detector is very sensitive to low light levels, requiring the ambient light to be very low. It may be helpful to partially cover the spectrometer with a dark cloth during this procedure. Before carrying out this step, the spectrometer should be connected to the computer, the software should be running, and the spectrometer should be in "Scan Continuous" mode (the green "play" button) so that the spectrometer is continuously reading the spectrum of the input light. You will want to make sure that the tip-tilt adjustments on the focusing mirror are made to optimize the light signal falling on the CCD array, resulting on a large signal plotted by the software.

9. Loosen the screw holding the collimating mirror in place.
10. SLOWLY move the mirror forward and backward, looking for the position that produces the best spectrum, according to your requirements. (Usually, you would optimize line width to get the best resolution.)
11. If you rotate the collimating mirror, the spectrum will shift left or right. Ideally, you should not rotate the collimating mirror in this step, as this can introduce asymmetries in the spectral lines.
12. After the desired collimating mirror position is obtained, the spectrometer's spectral coverage can be adjusted by rotating the diffraction grating.

We typically find that iterating the positions of the collimating and focusing mirrors is required to obtain symmetric spectral lines over a broad spectral range. With care, 1 nm resolution can be achieved using

the 1800 l/mm grating. When you are satisfied with your alignment, tighten the collimating mirror mount, the grating mount, and the focusing mirror mount. Make final adjustments to the tip-tilt of the collimating mirror to maximize the signal on the CCD detector. Replace the two optical bench covers. Replace the blue enclosure top.

Some comments on the optics

Ideally, the two mirrors in the spectrometer are used to place an image of the entrance slit on the plane defined by the CCD detector. When these mirrors are not optimally aligned, the image plane is curved. You will see this in your alignment when, for example, the spectral lines at the low-numbered pixels are nice and sharp and the spectral lines on the other end are broad (or perhaps vice versa). The curvature of this focal plane depends very sensitively on the positions of the two mirrors.

When we align spectrometers, we first choose a position for the focusing mirror (the big one) then we very slowly adjust the position of the collimating mirror. If the spectrum is sub-optimal, we re-position the focusing mirror and then very slowly adjust the position of the collimating mirror. We have been successful making these adjustments by hand and have successfully trained a number of others to make these adjustments. However in our own work, we use a micrometer-driven translation stage for the collimating mirror adjustments. We also typically cannot use all 2047 pixels. On our wide-range spectrometers, optimal alignment uses only pixels from about 250 or 300 up to 2047. Including the first few hundred pixels requires mirror alignments that give asymmetric spectral lines.

Good luck, have fun, and be patient.

Calibrating the spectrometer's wavelength scale

We calibrate the wavelength scale by measuring the spectrum of a Hg-Ar lamp. Exact wavelengths can be found online, for example at the NIST atomic spectra database website (<http://www.nist.gov/pml/data/asd.cfm>). We find the prominent peaks in the spectrum, and write down the pixel number at which the peak occurs in a file. Using a program like OpenOffice or Microsoft Excel (or any number of other programs like Scilab, Octave, Mathematica, Matlab, or an online program like <http://www.shodor.org/chemviz/tools/regressionjava/index.html> etc.) we fit the wavelength vs. pixel number to a third-order polynomial. This generates the coefficients you need to calibrate the wavelength scale. When you enter these coefficients into SpectrumStudio(c), be sure to use the correct formula. The coefficient C0 is the constant offset term, the coefficient C1 is the linear term, etc.