Laser-Induced Spectroscopy
LIBS2000+

Installation and Operation Manual

Document Number 161-00000-000-02-0406

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Important Safety Notices

WARNING

The LIBS System uses a Class IV laser. Exposure to the laser can cause eye and skin damage. Although the LIBS System incorporates numerous safety features, due care is required when using a laser to prevent injury.

1. Use safety goggles at all times when operating the laser as a standalone unit.
2. Only permit trained personnel to operate the laser.
3. Read all the instructions that accompanied your laser.

Table of Contents

About This Manual

Document Purpose and Intended Audience

This document provides the user of the LIBS 2000+ for setting up, calibrating and performing experiments with their system.

What's New In This Document

This version of the *Laser-Induced Spectroscopy LIBS2000+ Installation and Operation Manual* updates the safety instructions.

Document Summary

Chapter	Description
Chapter 1: *Introduction*	Contains descriptive information about the LIBS2000+ system. It also provides laser requirements and shipment components.
Chapter 2: *Installing the LIBS System*	Provides installation and configuration instructions.
Chapter 3: *Operation*	Contains instructions for operating the LIBS2000+ System.
Chapter 4: *Troubleshooting*	Contains recommended steps to isolate and correct common problems.
Appendix A: *Specifications*	Provides product specification data.
Appendix B: *User Interface*	Contains a quick reference guide to the OOILIBS user interface features.

Product-Related Documentation

You can access documentation for Ocean Optics products by visiting our website at **http://www.oceanoptics.com**. Select *Technical → Operating Instructions*, then choose the appropriate document from the available drop-down lists. Or, use the **Search by Model Number** field at the bottom of the web page. You can also access operating instructions for Ocean Optics products from the *Software and Technical Resources* CD that ships with the product. Engineering-level documentation is located on our website at *Technical → Engineering Docs.*

Other Ocean Optics documentation related to your LIBS system includes the following:

- *HR2000 and HR2000CG-UV-NIR High-Resolution Fiber Optic Spectrometers Installation and Operation Manual* located at **http://www.oceanoptics.com/technical/hr2000.pdf**.
- *LIBS Imaging Module Installation and Operation Instructions* located at **http://www.oceanoptics.com/technical/LIBS Install.pdf**
- *OOIBase32Spectrometer Operating Software* located at **http://www.oceanoptics.com/technical/ooibase32.pdf**
- *Correcting Device Driver Issues* located at **http://www.oceanoptics.com/technical/engineering/correctingdevicedriverissues.pdf**

Upgrades

Occasionally, you may find that you need Ocean Optics to make a change or an upgrade to your system. To facilitate these changes, you must first contact Customer Support and obtain a Return Merchandise Authorization (RMA) number. Please contact Ocean Optics for specific instructions when returning a product.

Chapter 1

Introduction

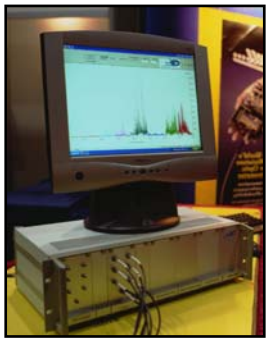
Product Overview

The Ocean Optics LIBS2000+ Laser-induced Breakdown Spectrometer is a detection system that permits real-time, qualitative measurements of trace elements. This broadband, high-resolution instrument allows for spectral analysis from 200-980 nm, with resolution of ~0.1 nm (FWHM). Sensitivity has been reported to parts-per-billion and picogram levels.

The LIBS2000+ comes in a standard 3U rack case with handles for extra convenience. The LIBS2000+ operates with any 32-bit, USB-compatible Windows PC. We provide OOILIBS Application Software with spectral-saving and data-logging capabilities for operating the LIBS2000+ and for firing the laser. Correlation Software, developed with the University of Florida, provides instant material identification when using the LIBS2000+ and a spectral library consisting of 2500 atomic emission lines from the NIST (National Institute of Standards and Technology) tables for elemental identification.

The LIBS Imaging Module is available for use with the LIBS system to enable you to precisely adjust the laser to focus on the exact spot on the sample that you wish to analyze. The LIBS Imaging Module also comes with PixeLINK™ software for the camera to capture high quality images on your PC.

How the LIBS2000+ Works



A high-intensity, 10 nanosecond-wide laser pulse beam is focused on the sample area. When the laser is fired, the high temperature of the laser ablates the surface of the sample and creates plasma. As the plasma decays or cools, excited atoms in the plasma emit light of characteristic wavelengths distinct to the elements present. All elements have emission spectra in the 200-980 nm region. The detection system uses seven of our HR2000 High-resolution Miniature Fiber Optic Spectrometers, each with a 2048-element linear CCD array. All spectrometers are triggered to acquire and read out data simultaneously. The detectors in the broadband (200-980 nm) LIBS2000+ collect the signal; software included with the system displays and identifies the emission spectrum.

Advantages of Broadband LIBS Techniques

Many LIBS systems have a small spectral range. The LIBS2000+ is the first to provide broadband spectral analysis. Because the system is noninvasive, you can perform real-time measurements *in situ*, in hostile industrial, chemical and biochemical environments with little or no sample preparation.

LIBS Emission ID

The reason we at Ocean Optics have designed a broadband high-resolution spectrometer is to be able to both see and resolve all the lines from all the elements. Our resolution is ~0.1 nm, less than this in the UV-blue and a bit higher in the red-IR. Because the LIBS-generated lines are stark broadened to about 0.2 nm or so in the UV and about 0.3 nm in the IR, the system can resolve everything that is possible to observe.

The laser-induced plasma begins life as very hot 15,000 K plasma emitting a large bremsstrahlung continuum. Depending on the sample matrix, most emission analysis is performed for a few microseconds for this to decay so as to not mask the line structure. During this time, the higher order transitions decay away, leaving mostly I and II atomic emissions. These are the ones that are idenified.

Also entering into the emissions from the elements in the interrogated plasma are the collision dynamics of the plasma. Rate equations can be used to analyze the target, but emission signatures, sample-standards and correlation techniques are preferred to identify materials with the OOILIBS Software.

Elemental analysis and identification are very important in understanding content, and in some cases are used for quantitative analysis. To perform analysis and identification, you must use an element catalog to help determine when a particular element is present.

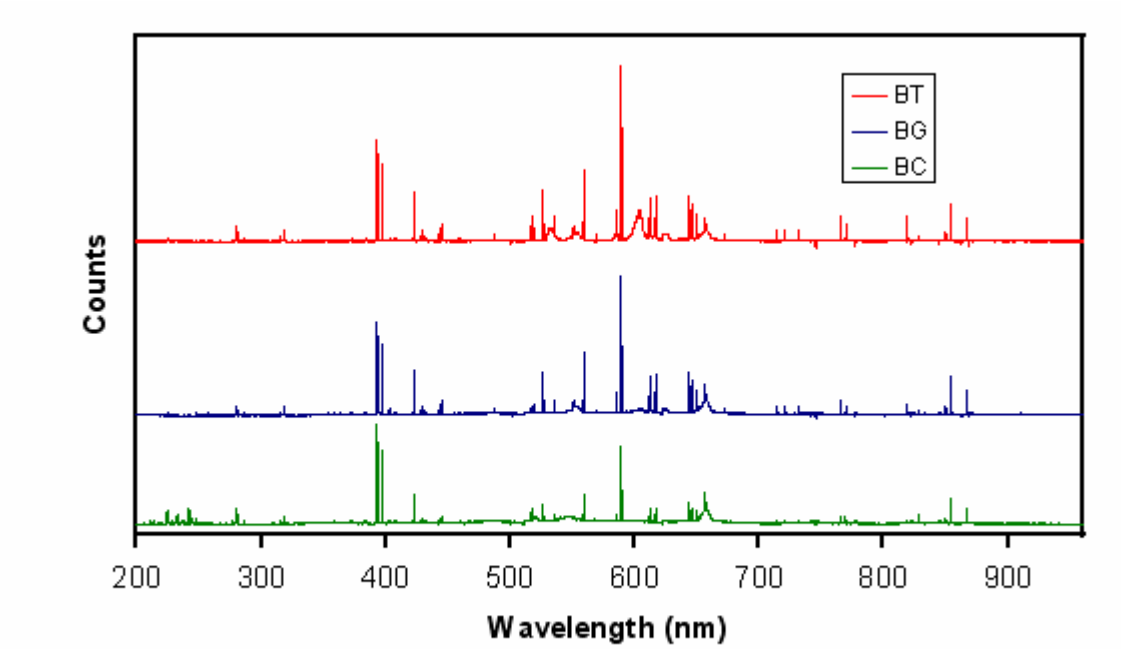
Currently we use a catalog that was derived from the MIT wavelength tables. It consists of the persistent lines of the elements from spark spectra and is the closest to a complete catalog of the brightest lines around the temperature of the decayed plasma. As part of an international standards committee project, Ocean Optics is in the process of compiling a persistent line emission set for LIBS, using the LIBS plasma. This will take some time and will be integrated into our base table as time goes on. These studies are to be done in an Argon gas environment.

How can we be sure that the identified elements are actually present? OOILIBS software contains two rating mechanisms:

- The first rating mechanism indicates how many lines of those in our persistent line set are present. Thus, if 5 of 7 possible have been identified, you can be fairly certain that that element is present. If one of 7 is present, could it be something else? Perhaps a line that is not in our catalog from another species?
- For the second analysis technique, the emission lines have an appearance value based on experimental observation. It could be that this single line is the brightest of those from this element and the others are weak. So, we rate the element using a formula based on these appearance levels. If only the weakest line of the 7 appears, it is ranked very low and indicates that this is from one of the unknowns. If it is the strongest line, it will be rated high, allowing you to be certain that it was present. If you have the highest 5 of the 7 in the table, the rating will be extremely high.

OOILIBS software allows you to call any number of spectral libraries you wish to use. Our present library has greater than 2000 lines available. There are no overlaps, but as we advance to more sophisticated libraries, there certainly will be. The full NIST catalog has so many lines (>100,000) that everything would be identified many times over, even though the probability of appearance may be small to zero. That is why we have not included it.

Refer to **http://physics.nist.gov/PhysRefData/contents-atomic.html** to print lists and observe the latest work. For a list of the persistent lines of spark spectra, consult one of the CRC manuals (*Handbook of Chemistry and Physics*). Even the old publications are quite accurate.



* These preliminary spectra are courtesy of the U.S. Army Research Laboratory and the U.S. Army Soldier and Biological Chemical Command.

LIBS2000+ Spectra of Anthrax SurrogatesBC (Bacillus Cereus), BG (Bacillus Globigii), BT (Bacillus Thuringiensis)

Applications

The LIBS technique is useful in areas such as:

- Environmental monitoring (soil contamination, particulates)
- Materials analysis (metals, plastics)
- Forensics and biomedical studies (teeth, bones, glass)
- Military and safety applications (explosive particles, chemical and biological warfare agents)
- Art restoration/conservation (pigments, precious/ancient metals)

Laser Requirements for LIBS2000+

You can supply your own Q-switched laser (from our certified list), or you can purchase one through Ocean Optics. We recommend the ULTRA CFR Nd:YAG laser from Big Sky Laser Technologies (www.bigskylaser.com/compactseries.html). The ULTRA CFR was used when testing prototypes of the LIBS2000+. The rugged and field-portable ULTRA CFR delivers Q-switched pulses at 1.06 µm, with variable repetition rates from 1 to 20 Hz. At 1.06 µm, the laser has a pulse stability of ±3%.

Shipment Components

Ocean Optics' LIBS functionality can be purchased as a complete system, including the spectrometers and related fibers, laser, LIBS Imaging Module, and OOILIBS software. The system is also completely customizable. The modular nature of the LIBS2000+ system allows you to purchase just the spectrometer. Users can then provide their own fixtures and/or Q-switched laser. You can specify the number of spectrometers (1–7), as well as their gratings, lenses, slits and filters. Contact an Ocean Optics Application Scientist for more information on customizing your LIBS System.

Standard LIBS System

A standard-channel LIBS System ships with the following components:

- Seven (7) **HR2000 Spectrometers** in a rack enclosure
- One (1) **+ 5 VDC Power Supply** – For the spectrometer rack assembly
- Four (4) **BNC cables**
- One (1) **heptafurcated fiber** (seven-to-one furcation)
- One (1) **fiber bundle**
- One **USB interface cable**
- **Packing List** – The packing list is inside a plastic bag attached to the outside of the shipment box (the invoice arrives separately). It lists all items in the order, including customized components in the spectrometer (such as the grating, detector collection lens, and slit). The packing list also includes the shipping and billing addresses, as well as any items on back order.
- **OOILIBS CD** – This disc contains the OOILIBS software that not only controls the spectrometer and the laser, but also provides for extensive data analysis. It also contend OOIBase32 software, which is required to use OOILIBS software.
- **Software and Technical Resources CD** -- This disc contains software, operating instructions, and product information for all Ocean Optics products. You need Adobe Acrobat Reader version 6.0 or higher to view these files (version 7.0 is included on the CD).

  With the exception of OOIBase32 Spectrometer Operating Software, all Ocean Optics software requires a password during the installation process. You can locate passwords for the other software applications on the back of your CD package.

- **Laser Safety Manual**

Other Required Equipment

- **LIBS Sample Chamber** (LIBS-SC) and 12-VDC power supply – Permits a clear view of the sample ablation. Includes a manual x-y-z stage. The inside lens and spectrometer probe mounting hardware are reconfigurable with additional components readily available. The sample chamber also includes a blower and evacuation system to feed in alternate gasses (such as argon) and a laser safety cutoff switch.

- **Laser** (LIBS-LASER) – You can supply your own laser or purchase one through Ocean Optics. We recommend the ULTRA CFR Nd:YAG laser from Big Sky Laser Technologies (**www.bigskylaser.com/compactseries.html**). Laser requirements include a low-divergence laser beam (a tight focus is required to achieve a spark), an active electro-optic Q-switch, and external triggering and synchronization for the laser flashlamp and Q-switch through the OOILIBS Software.
- **Personal computer** – With Windows 98/Me/2000/XP operating system

Additional Recommended Equipment

- **LIBS Imaging Module** – Consists of a PixeLINK™ Megapixel FireWire Camera, either black and white (LIBS-IM) or color (LIBS-IM-SC), in a box mounted in between the LIBS laser and the LIBS Sample Chamber. This product is designed to enable you to precisely adjust the laser to focus on the exact spot on the sample that you wish to analyze. The imaging module also comes with PixeLINK software for the camera to capture high quality images on your PC and a 12 VDC power supply.
- **Argon Gas Tank and Cable** – Supplies argon gas to the LIBS Sample Chamber to prevent Pennington-type reactions from occurring
- **Safety goggles** – Although the LIBS Sample Chamber is constructed of special safety glass to protect you from the laser, it is recommended that you purchase safety goggles to use whenever you are working with a Class III or above laser.

Chapter 2

Installing the LIBS System

Overview

In general, installing the LIBS2000+ involves the following steps:

► ***Procedure***

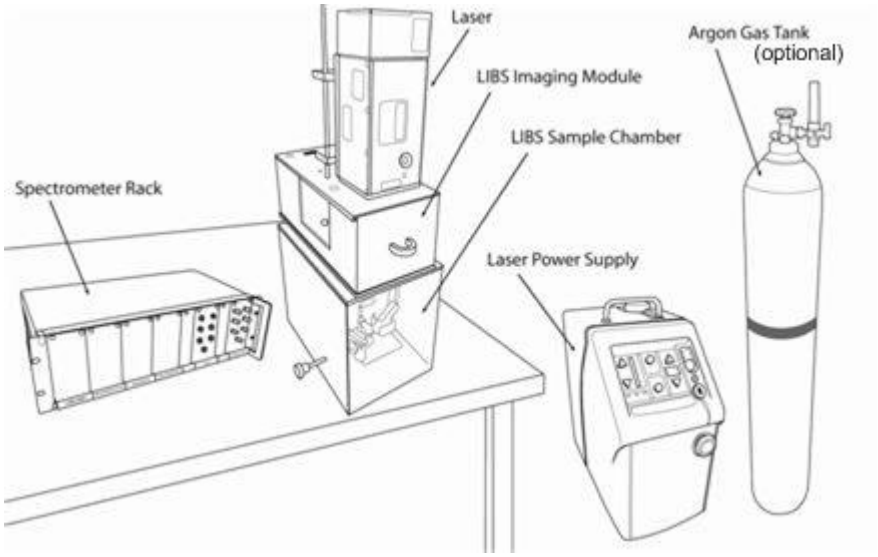
1. Unpack and set up the LIBS2000+ components. See *Hardware Set-up*.
2. Install the OOILIBS software on the PC you intend to use with your LIBS 2000+ System, and then restart the PC. See *Software Installation*.
3. Connect the cables to the appropriate connectors on the LIBS2000+ equipment (see *Hardware Cabling*).
4. Test that the LIBS 2000+ System is operational (see *System Start-up*).

Note

Consult the instructions provided with the LIBS Imaging Module and the laser being used for complete installation and operation instructions for those products. General guidelines are provided in this manual, but may not cover all the information that you need to install and operate these components of your LIBS System.

Hardware Set-up

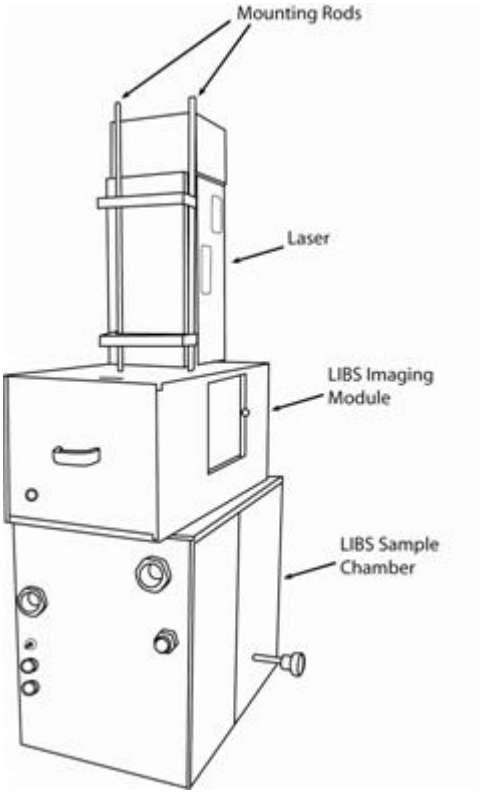
Set up your LIBS2000+ System in the configuration shown in the following figure. Do NOT connect any of the cables until you have installed the OOILIBS Software.



LIBS2000+ Hardware Set-up

► *Procedure*

1. Remove the LIBS2000+ components and laser from their packaging.
2. Place the sample chamber and the rack of spectrometers on a clean, flat surface.
3. If you have purchased the LIBS Imaging Module, place it on top of the sample chamber.
4. Mount the laser head on top of the LIBS Imaging Module (if purchased), or directly on top of the sample chamber if you do not have an imaging module. A mounting bracket is attached to the laser head with steel rods to facilitate mounting and laser alignment into the sample chamber.
5. Insert rods from the laser through the imaging module and into the sample chamber for firm support. The laser rests flush on top of the imaging module (or sample chamber, if you do not have an imaging module).



Mounting the Laser (Rear View)

6. Fill the laser power supply with distilled water (only).
7. Go on to *Software Installation*.

Software Installation

OOIBase32 Software Installation

OOIBase32 Spectrometer Operating Software must be installed for you to use OOILIBS software. OOIBase32 is located both on your OOILIBS CD and on the Software and Technical Resources CD. You can install it from either CD. This software is also available from our Ocean Optics website at **http://www.oceanoptics.com/technical/softwaredownloads.asp**. You can also install it from the web.

For further OOIBase32 installation instructions, see the OOIBase32 Spectrometer Operating Software Installation and Operation Manual on either the OOILIBS CD or the Software and Technical Resources CD.

OOILIBS Software

OOILIBS Software was designed specifically for the LIBS2000+ System. It records and stores data for export to Microsoft Excel and similar programs using the standard Microsoft commands such as File Save, File Print, etc.

Caution

You MUST install the OOILIBS software application prior to connecting the LIBS System hardware to the PC. The OOILIBS software installation installs the drivers required for HR2000 spectrometer installation. If you do not install OOILIBS first, the system will not properly recognize the spectrometers.

If you have already connected the spectrometers to the PC prior to installing OOIBase32, consult *Chapter 4: Troubleshooting* for information on correcting a corrupt HR2000 installation.

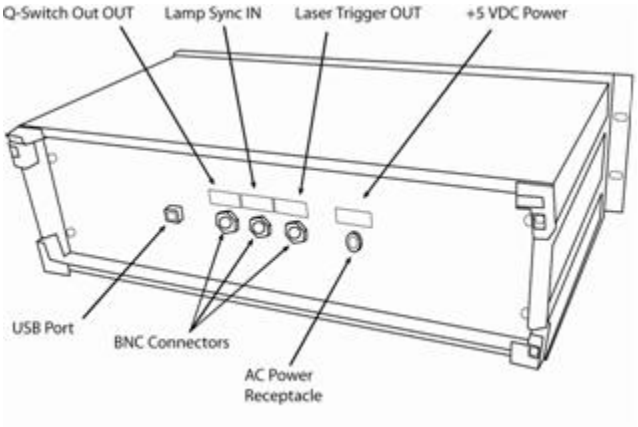
► *Procedure*

1. Insert the *Software and Technical Resources* CD that you received with your LIBS2000+ System and download the OOILIBS software that you purchased to your PC. The password for this software is on the back of the CD jacket.
2. Follow the prompts in the Installation Wizard to install the software.

Hardware Cabling

► *Procedure*

1. Plug the external +5 VDC power supply into the spectrometer rack.



Rear Panel of Spectrometer Rack

2. Plug the USB cable into the USB port on the rear of the spectrometer rack, then into the PC's USB port.

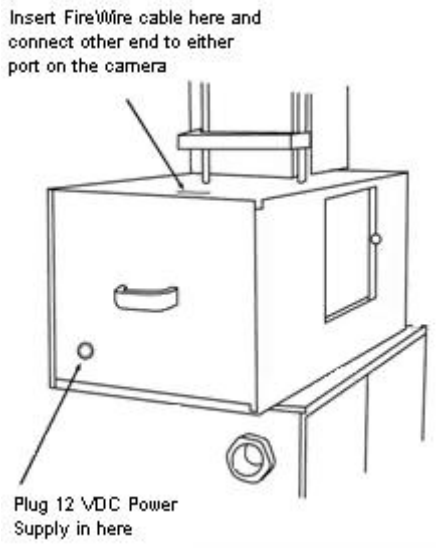
3. Connect the heptafurcated fiber from the rear of the Sample Chamber to the seven spectrometer channel SMA connectors on the front of the spectrometer rack. The computer's operating system will recognize the new hardware and load the appropriate drivers for each of the seven spectrometers in the LIBS system.
4. Start the OOILIBS software and configure your spectrometers (see *System Start-up*).
5. Attach the laser cables from the laser to the laser power supply. See your laser's documentation for specific instructions.
6. Using the supplied BNC cables, attach them to the connectors on the back of the laser power supply, then connect them to the Laser Trigger OUT, Lamp Sync IN, and Q-Switch OUT to the BNC connectors on the rear panel of the spectrometer rack.

Caution

Beware of lasers that use negative logic and/or high voltage outputs. Lamp Sync signals as high as 33 volts have been observed in testing, and the electronics in the LIBS2000+ may not survive pulse voltages of this intensity. The spectrometer electronics are designed to drive the 50ohm loads associated with BNC connectors, and all signals are 5V TTL.

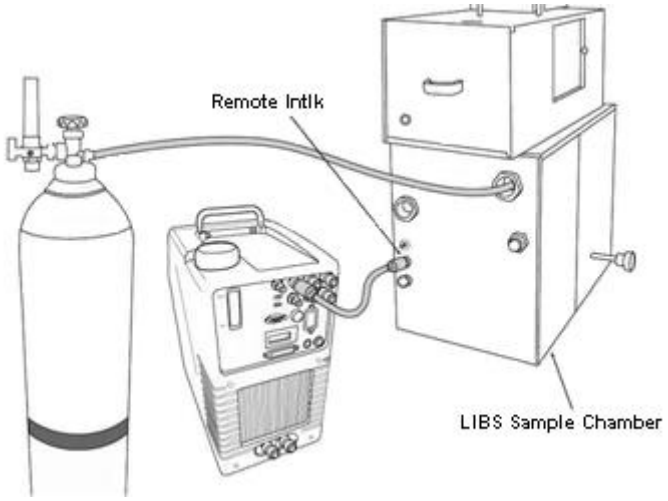
Laser Connection	Spectrometer Connection	Function
External Trigger (IN)	Laser Trigger OUT	This cable is connected to the external trigger connection of the laser. It initiates a laser fire.
Flash Lamp Fire (OUT)	Lamp Sync IN	This cable is connected to the lasers' strobe synchronization output. It tells the spectrometer the exact time the strobe is firing. If such a line is not available, connect this to the ***Laser Trigger*** **OUT** cable using a BNC tee.
External Q-switch (IN)	Q-Switch OUT	This cable connects to the external Q-switch of the laser. It fires the Q-switch under software control. Most lasers have a switch that must be set to allow this to happen. If only an external trigger input is available, you do not need to use this line, but you will have no control over the Q-switch event.

7. If you are using the LIBS Imaging Module, plug in its 12 VDC power supply and connect the firewire cable from the camera to the PC. Then install the PixeLink software from the *LIBS and PixeLink Software* CD that comes with the imaging module. See the *LIBS Imaging Module Installation and Operation Instructions* that came with your LIBS Imaging Module. Refer to *Product-Related Documentation* to get another copy of these instructions.



Rear Panel of LIBS Imaging Module

8. Connect the 12 VDC power supply to the LIBS Sample Chamber.
9. Connect one end of the BNC cable to the LIBS Sample Chamber. Remove the cap from the Remote Interlock (**Remote Intlk**) connector on the back of the laser power supply and attach the other end of the BNC cable.



Connecting the LIBS Sample Chamber to the Laser Power Supply and Argon Gas

10. Install the fiber optic assembly in the Sample Chamber and roughly align.
11. Ensure that the switches on the rear of the laser power supply are set for external triggering.
12. If you intend to use argon gas in your set-up, connect the argon gas tank to the LIBS Sample Chamber.

System Start-up

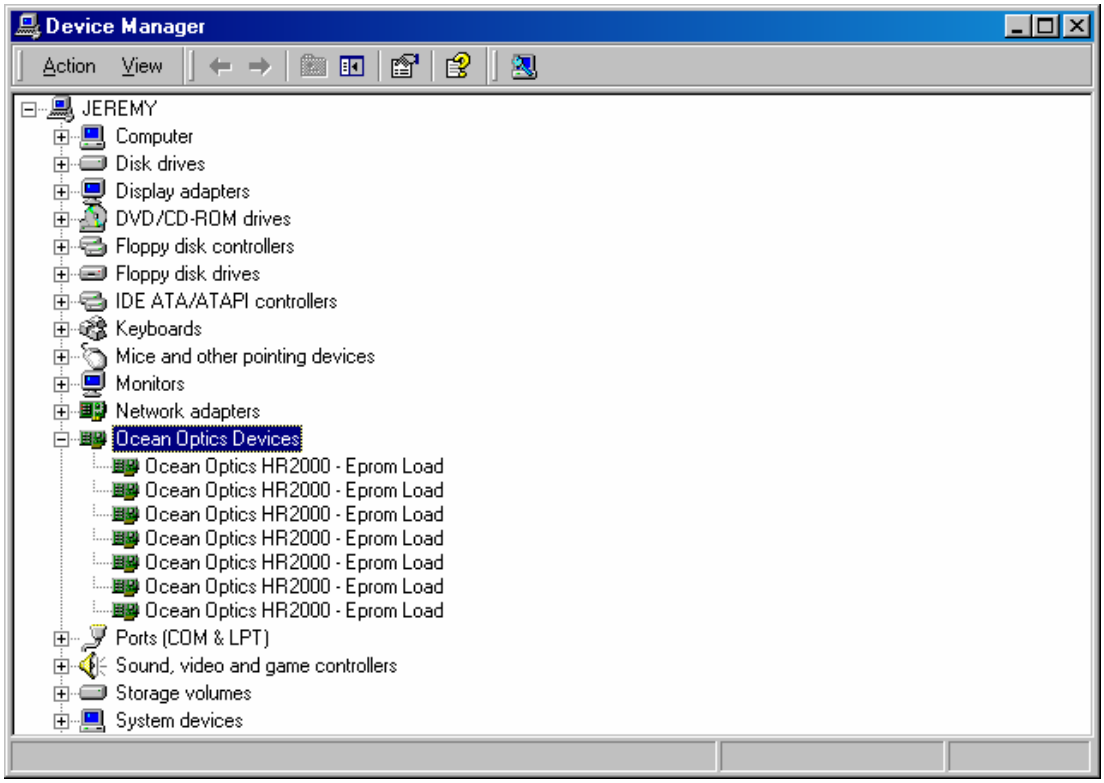
When you first use this LIBS2000+ Spectrometer on this computer, you must assign spectrometers to channels and load the element library.

Assigning Spectrometers

► ***Procedure***

1. Start the OOILIBS program. You may receive an error message the first time you start the software. This is normal. Continue to Step 2.
2. Confirm that the spectrometers have installed properly. To do this,
   a. Navigate to **Control Panel | System** (or right-click on **My Computer** and select **Properties**):

      For Windows 2000/XP: Click the **Hardware** tab, then click the **Device Manager** button. For Other Windows Versions: Click the **Device Manager** tab. The **System Properties** screen appears.

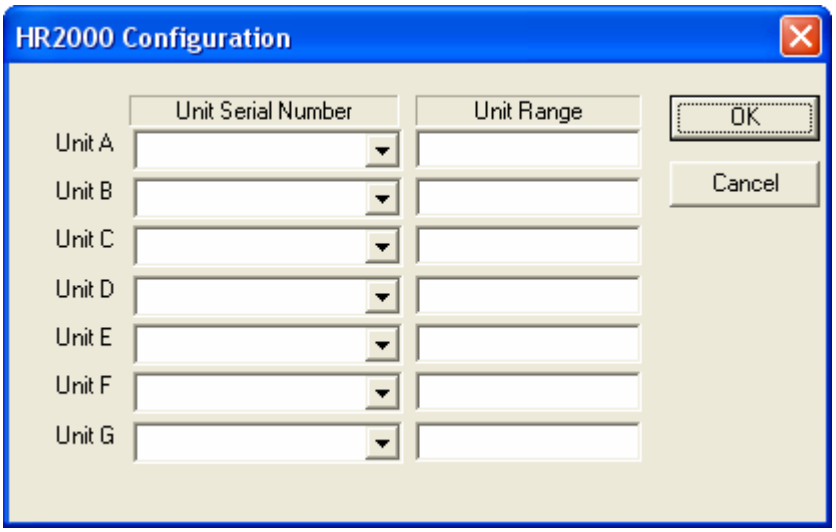


   b. Click on the **Ocean Optics Devices** node. If this node is absent, expand the USB Devices node. Seven HR2000 Spectrometer entries should be visible. This indicates that the LIBS2000+ spectrometers have been properly installed.

Note

If there are any yellow or red symbols next to each spectrometer entry, then you must reinstall OOILIBS, reboot the system, and then reconnect the spectrometer.

3. In the OOILIBS program, select **Tools | Select Spectrometer Modules**. The **HR2000 Configuration** screen appears. Of the 8 possible spectrometer assignments, only 7 are active.



4. Click on the arrow for the first box (Unit A) to see a selection of 7 serial numbers.
5. Double-click on the lowest number and assign it to the first space. This is important in that it tells the software which serial number correlates to the lowest wavelength spectrometer. The range box should display the range of the spectrometer (this feature is not fully implemented).

Note

If you mistakenly assign an incorrect serial number, click on the text in the Unit Serial Number column for that serial number. Highlight the text and delete it. Then, reassign the correct serial number.

6. Proceed to assign serial numbers (in order of ascending serial numbers) to Units B-G.
7. Click the **OK** button when you have assigned all serial numbers.
8. You have now configured the **Select Spectrometer Modules** screen.
9. Exit OOILIBS software.
10. Restart OOILIBS software. The range at the bottom of the screen should be about 200–980 nm. If this is not the case, or if you receive another error message, refer to Chapter 4: *Troubleshooting*. Otherwise, you are ready to take data.

Loading the Element Library

The element library enables you to identify the elements present in a sample by comparing the emission lines detected in the sample to elements in a standard catalog.

► *Procedure*

To load the Element ID Library,

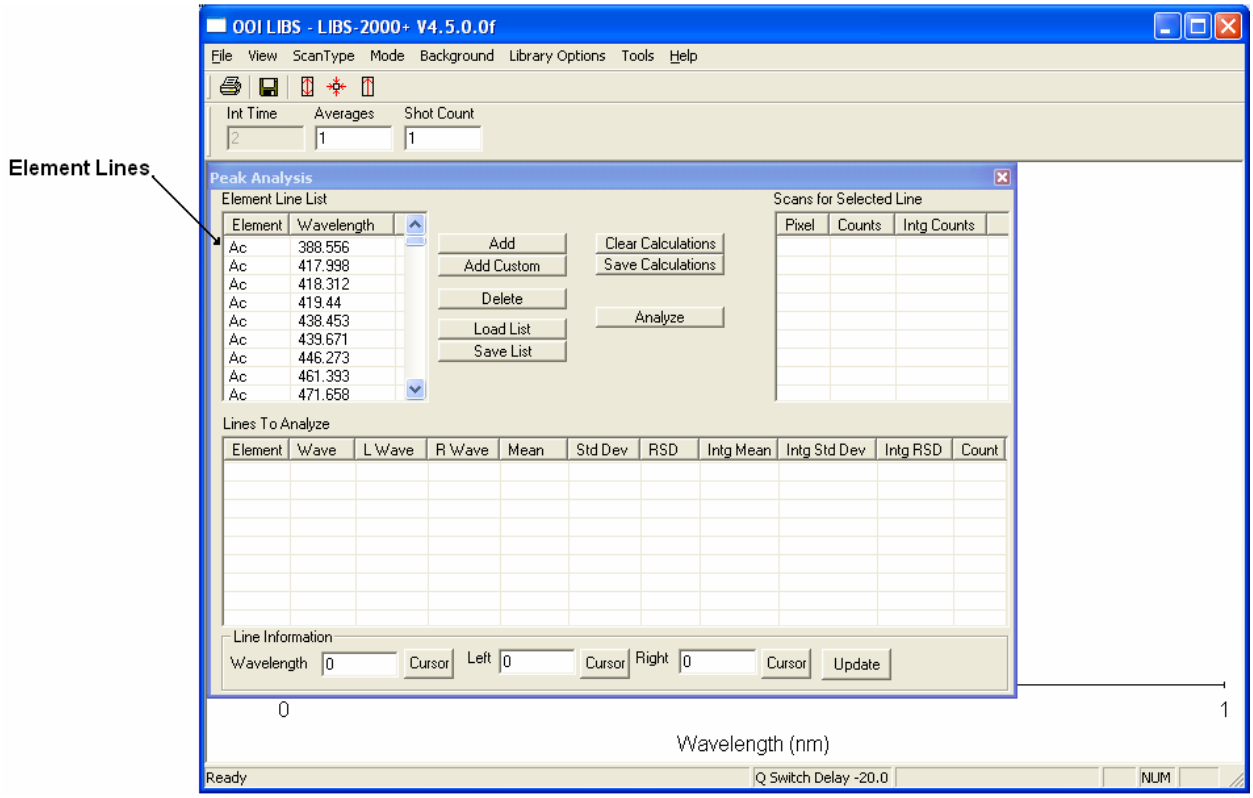
1. Select **Library Options | Element ID | Load Library** from the OOILIBS software menu.
2. Browse to the element catalog that you want to load. By default, the OOILIBS installation places the catalog in **Program Files | Ocean Optics | OOILIBS**, unless you changed its location.
3. Select the file (*.spe) and click **Open** to load the file. It is recommended that you select the OOISpeciesB.spe file since it contains more element lines than the OOISpecies.spe file.

You can check that the library has loaded successfully on the **Peak Analysis** screen.

► *Procedure*

To check that the Element ID Library has loaded successfully,

1. Select **Mode | Peak Analysis** from the menu. The **Peak Analysis** screen appears.



2. Verify that data from the Element ID Library appears in the Element Line List.

Chapter 3

Operation

Overview

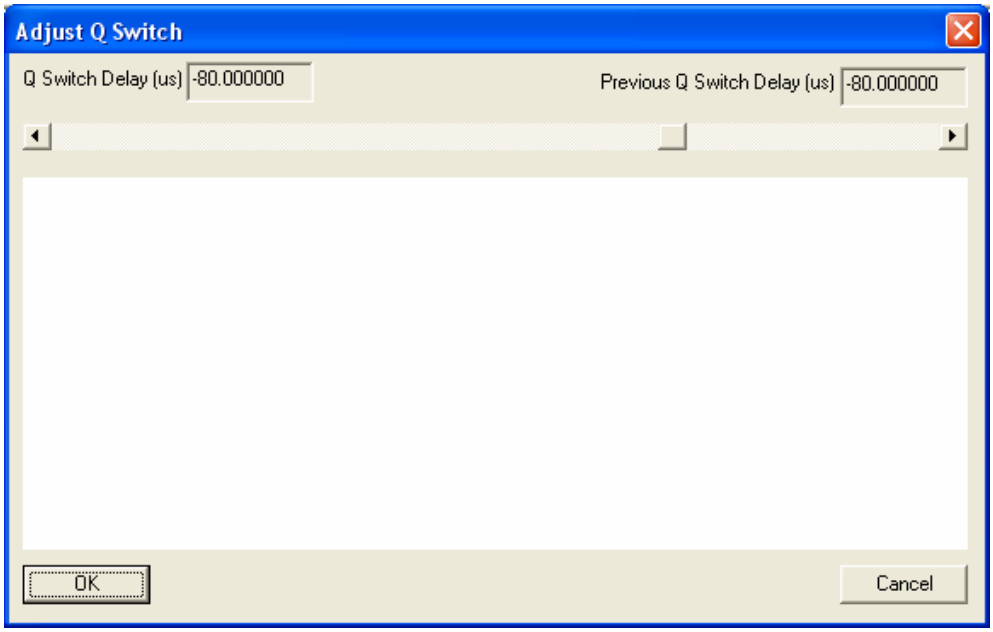
Laser-Induced Breakdown Spectroscopy (LIBS) is based on the interaction of a laser with a sample to produce an optical emission spectrum specific to that sample. A pulsed laser focused onto a solid, liquid, or gas sample vaporizes a small portion of that sample for analysis. The super-heated, ablated material is transformed into a plasma. Plasma is a form of matter in which the original chemical bonds of the substance are broken apart and the resulting atoms are converted into a mixture of neutral atoms, ions, and electrons. The atoms and ions within the expanding plasma release some of their energy by emitting light, which produces a characteristic emission spectrum in the UV, VIS, and NIR spectral range.

Configuration

Set Q-Switch Delay

The Q-Switch window allows you to set the position of the firing of the laser with respect to the opening of the electronic aperture. If you do not hear the laser firing, it is most likely due to an improper setting of the Q-Switch:

Value	Meaning
Negative (–)	Q-Switch is being fired before aperture has opened
Positive (+)	Q-Switch is being fired after aperture has opened



► ***Procedure***

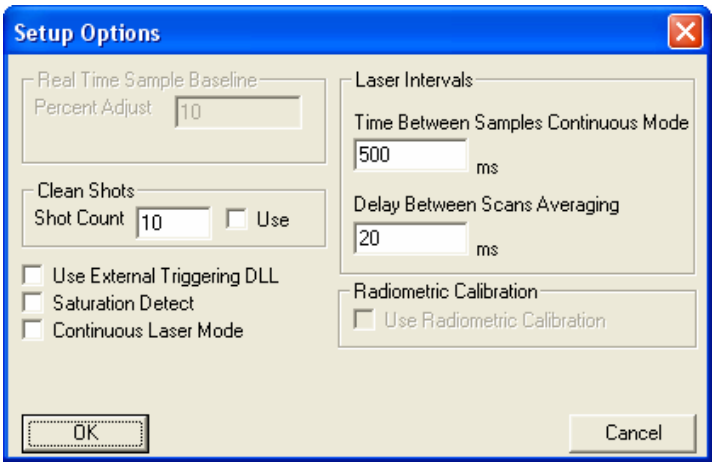
1. Move the slider to the desired time to set the Q-switch delay.

   After moving the slider, OOILIBS will take a shot and display the spectrum. The current time is set in the Q Switch Delay box, and the original (previous) time is shown in the Previous Q Switch Delay box.

2. Click the **OK** button to save the new time, or click the **Cancel** button to cancel any changes.

Setup Options

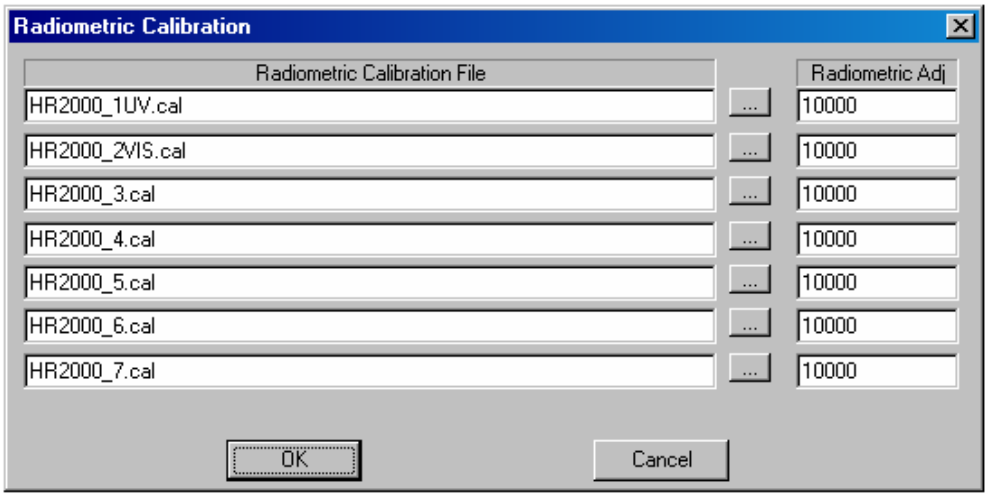
Use this screen to configure the setup options for your LIBS system.



Option	Description
Percent Adjust	Multiplier for the Real Time Background options. OOILIBS calculates the background and multiplies it by this variable before subtracting.
Clean Shots	• Number of clean shots to take when you click the **Clean** button, or • Number of clean shots to take before each scan if you enable the **Use** button.
Use External Triggering DLL	Uses the External Triggering DLL. OOILIBS makes calls before and after scans to this DLL file. You can replace this file with custom code.
Saturation Detect	Displays a message if the spectrum is saturated.
Continuous Laser Mode	Instructs the software to use the Continuous Laser mode. Only use this mode with laser systems that must continuously fire the flash lamp.
Time Between Samples Continuous Mode	Delay that occurs after a scan (in Continuous mode) and prior to the next scan.
Delay Between Scans Averaging	Delay between scans on any type of scan (averaging, shot count, etc.).
Use Radiometric Calibration	Enables the radiometric calibration files

Set up Radiometric Information

Use this screen to assign calibration files to each channel.



To use the **Radiometric Calibration** screen, select the calibration files for each channel using the browse button located between the two columns.

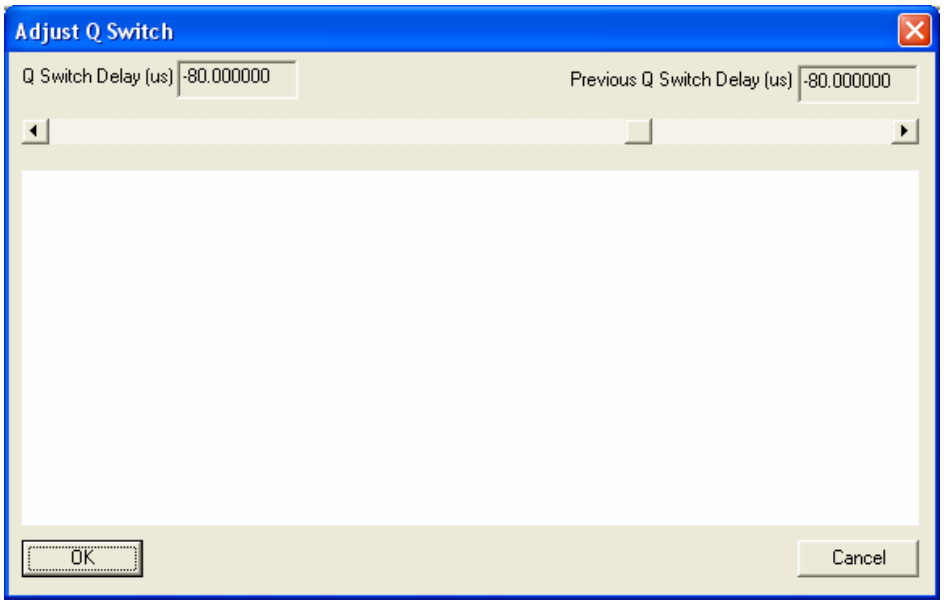
The first radiometric calibration file is for Spectrometer Unit A, the second file is for Spectrometer Unit B, etc. You can also apply a channel-specific Radiometric Adjustment to scale the calibrated data.

Initial Testing

Once you have set up your LIBS2000+ system and configured it, you are ready to perform initial testing with a sample.

► *Procedure*

1. Check that the switches on the rear of the laser power supply are set for external triggering.
2. Turn the laser power supply on, making sure that the prf (laser repetition rate) is set to 0, the Q-Switch is on, and the power bar is adjusted to 5 bars.
3. Push the Run button on the laser power supply. The flash lamp capacitor should charge and remain idle while waiting for an external trigger.
4. Open the door of the Sample Chamber and make sure that the laser power supply automatically shuts down.
5. Close the Sample Chamber door and push the Run button again to recharge the flash lamp capacitors.
6. Insert a standard LIBS sample into the Sample Chamber.
7. In OOILIBS, select **Scan Type | Single Shot** from the menu bar.
8. In OOILIBS, click the **Scan** button. The laser should fire in the Sample Chamber.
9. In the Sample Chamber, align the fiber optic assembly relative to the sample plasma to optimize sensitivity of the LIBS measurement.
10. In OOILIBS, select **Tools | Set Q Switch Delay** from the menu bar. This opens the **Adjust Q Switch** window, displaying the signal based on the Q-switch delay. You can be sure that this is functioning properly by observing the change in continuum and emission strength as a function of delay settings, both positive and negative.



11. In OOILIBS, select **Scan Type | Continuous** from the menu bar.
12. Change the power settings on the laser power supply and verify that the power adjusts accordingly. You should hear a "pop" of the laser in the Sample Chamber, indicating a change in power.
13. Click the 

button in OOILIBS to test the LED targeting sources.

Using OOILIBS Software Modes

The mode windows (**Mode** menu selection) or analysis windows provide multiple ways of analyzing LIBS data. When you select a mode from the Mode menu, the control window for that mode opens. You can then analyze your data.

You can have multiple windows open at once, but only the current mode will automatically update after each scan. You will need to manually configure the other windows to update with each new scan.

Pixel Correlation Mode

Option	Description
Correlation Results	Displays the library entries and their correlation coefficient, comparing each to the current sample in memory.
View Sample	Displays the selected library entry in the graph window.
Correlate	Correlates the sample in memory against the current library.
Linear/Rank	Two different methods of correlation.

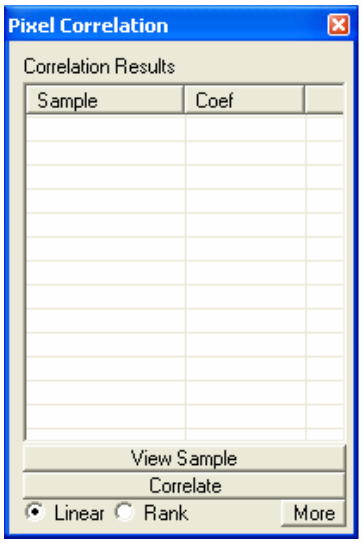
Option	Description
More/Less	Changes the size of the window. Allows you to shrink the window to allow better viewing when not adding new samples.
Add Sample	Adds a new sample to the current library. Click the Scan button to take a scan. After the scan is complete, you will be asked to enter a name for the sample. Once you enter a name, the sample is added to the library. Remember to save the library (**Library Options | Correlation | Linear Correlation | Save Library**).
Delete Sample	Deletes the selected sample from the library. After deleting a sample, the changes to the library are not saved. Save the changes (**Library Options | Correlation | Linear Correlation | Save Library**).
Start Range	Specifies the beginning boundary used in the correlation.
End Range	Specifies the end boundary used in the correlation.

Pixel Correlation Procedure

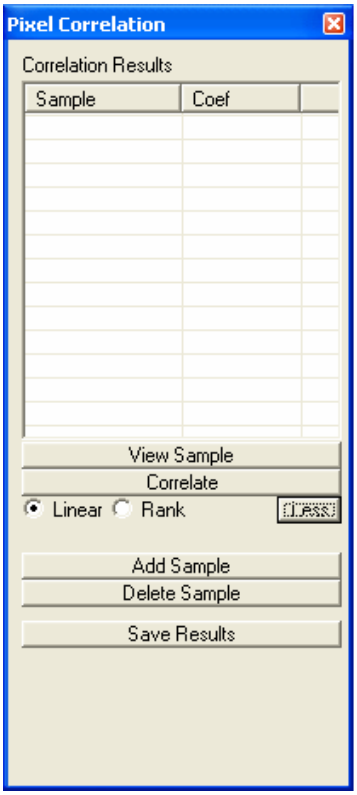
► *Procedure*

Follow the steps below to use the Pixel Correlation Mode:

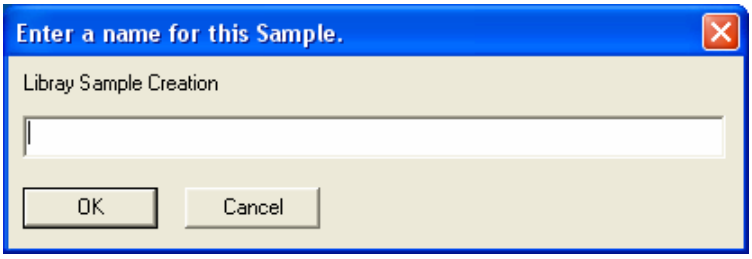
1. Select **Mode | Pix Correlation** from the menu.



2. Click the **More** button.



3. Click the **Add Sample** button. The **Scan** button now changes to a **Sample** button.
4. Set the number of averages you want to use, then click the **Save Sample** button.
5. Enter a library name for the saved sample.



6. Click the **Correlate** button. You should get a 1.
7. Click the **Scan** button. You should get a number very close to 1.
8. Save the new library using the Correlation menu.

Element ID Mode

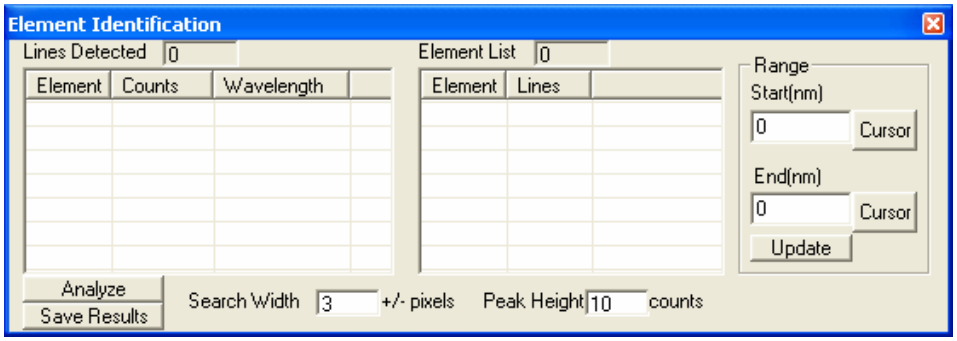
Option	Description
Lines Detected	Displays the number of Elemental Lines detected, and lists them in a table below. You can click on any column header to sort the data by that column. Double click on any line to zoom in on that line.
Analyze	Analyzes the current sample in memory and displays the results.
Save Results	Writes an ASCII file containing a list of the lines and elements.
Element List	Displays the number of elements detected and displays a table of them below. The element name, number of lines found, and the element probability are listed.
Search Width	Specifies the range of pixels surrounding the wavelength to examine when detecting a peak.
Peak Height	Specifies the minimum height of a peak to qualify for inclusion on the list.
Range	Sets the elemental analysis range. You can click the cursor buttons to use current cursor positions.

Elemental ID Procedure

► *Procedure*

Follow the instruction below to use the Elemental ID Mode:

1. Select **Mode | Element ID** from the menu to open the **Element Identification** window.



2. Click the **Scan** button.

   You should now have a list of lines detected in the left window of the **Element Identification** window. If you do not obtain this data, increase the search width or decrease the peak height.

Peak Analysis Mode

Option	Description
Elements List	Displays a list of all elements in the Elemental Library.
Scans for Selected Line	Displays the individual scan data for the selected lines in the Lines to Analyze window.
Add	Adds the selected elements from the Elements List to the Lines to Analyze list.
Add Custom	Adds a blank element to the Lines to Analyze list. You must set the wavelength after adding a custom type.
Delete	Removes the selected line from the Lines to Analyze list.
Save List	Saves the list of lines to an ASCII file, allowing you to load it later.
Load List	Loads the saved list of lines.
Lines to Analyze	Displays the list of lines for analysis including the Element Name, Wavelength, and several other values (see table below)
Clear Calculations	Clear the calculations.
Save Calculation	Save the calculations to an ASCII file.

Lines to Analyze Options

Option	Description
L Wave/R Wave	Left and right side of the peak used to subtract background. The system draws a line from the left and right points, then subtracts that value from the peak.
Mean	Mean/average intensity of all count scans taken.
Std Dev	Standard deviation of all count scans taken.
RSD	Residual standard deviation of all count scans taken.
Intg	Integrated values, calculated by adding the intensities from the L Wave to the R Wave. All Intg calculations are based on this value.

Option	Description
Intg Mean	Integrated mean/average of all count scans taken.
Intg Std Dev	Integrated standard deviation of all count scans taken.
Intg RSD	Integrated residual standard deviation of all count scans taken.
Count	Number of scans taken for each line. This value is used in the calculations described above.

Lines Information

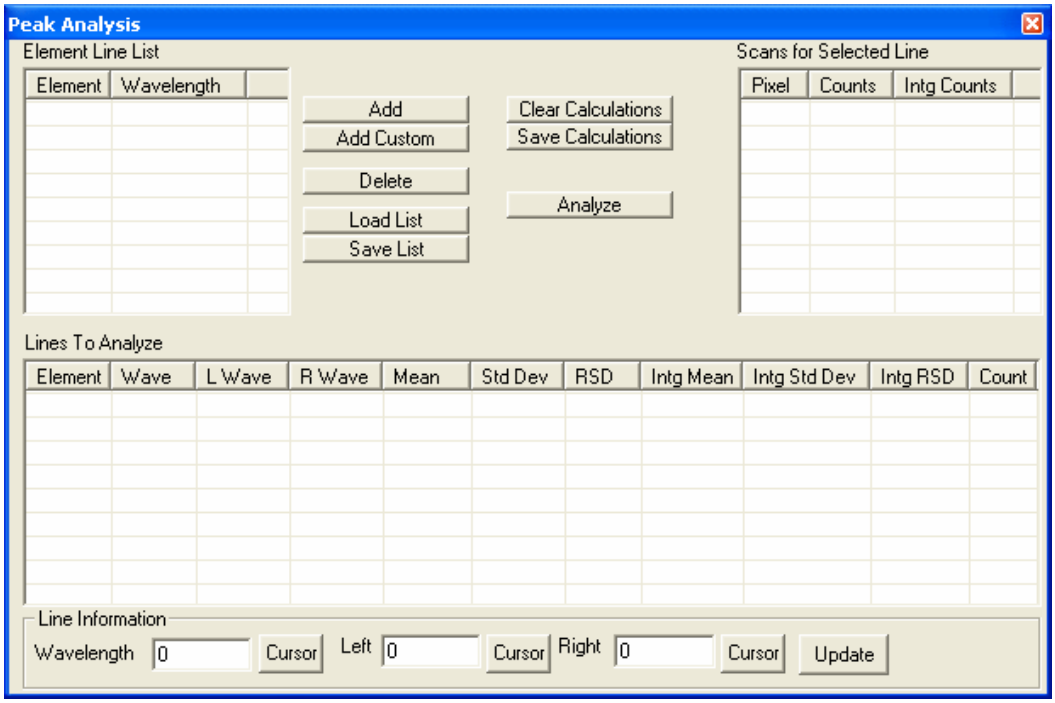
Option	Description
Wavelength	Wavelength assigned to the currently selected line. You can change this value, and set the custom value for a custom line. Place the graph cursor at the desired position and click the cursor button to set this value.
Left	Left wavelength, or L Wave. Place the graph cursor at the desired position and click the cursor button to set this value.
Right	Right wavelength, or R Wave. Place the graph cursor at the desired position and click the cursor button to set this value.
Update	Save the information to the currently selected line. No changes will be made until you click the update button.

Peak Analysis Procedure

► *Procedure*

Follow the instruction below to use the Peak Analysis Mode:

1. Select **Mode | Peak Analysis** from the menu. The **Peak Analysis** screen appears.



2. Select a line from the element list, then click the **Add** button. Repeat this step until you have loaded all the desired lines.
3. Modify any properties, the L Wave, the R Wave, or set the Wavelength value for custom waves.
4. Click the **Update** button to save the changes.
5. Click the Scan button repeatedly.

   You should begin to see data appear in the **Lines to Analyze** section.

Performing Correlation in OOILIBS

Follow the instructions in the sections below to perform a correlation in OOILIBS:

- *Accessing the Correlation Window*
- *Adding Samples to the Correlation Library*
- *Saving the Correlation Library*

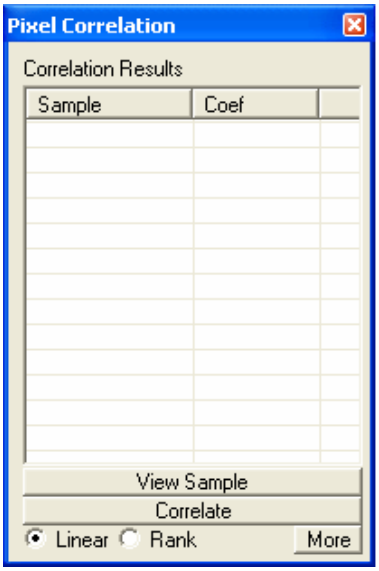
Accessing the Correlation Window

► *Procedure*

1. Start the OOILIBS software.
2. Obtain a few samples to make sure that the system is working correctly.

3. Then select **Pix Correlation** from the Mode menu available from the OOILIBS menu bar.

   The main **Pixel Correlation** window appears:

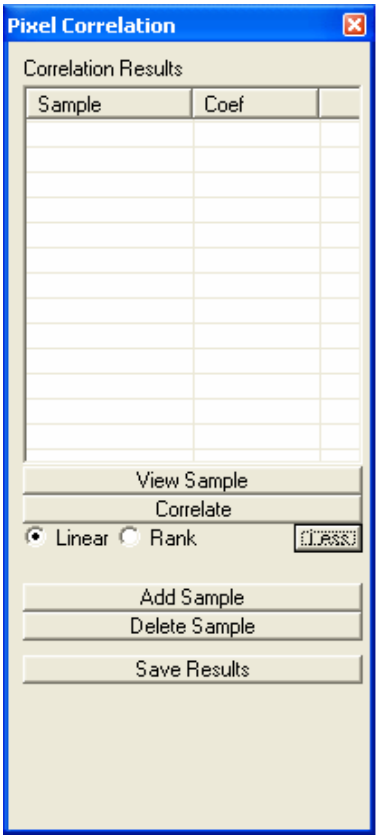


From this point, you can add a sample to the correlation library.

Adding Samples to the Correlation Library

► *Procedure*

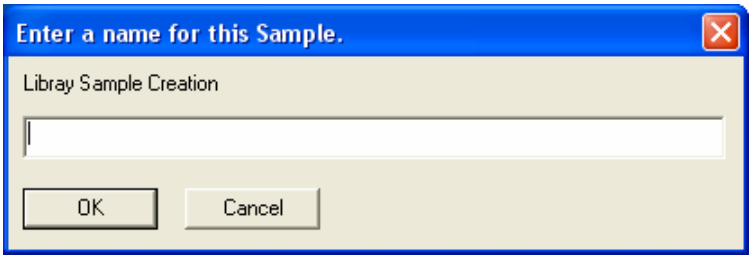
1. Click the **More** button to expand the **Pixel Correlation** window. Notice that the library is currently empty (indicated by the empty correlation results list).



You can now add samples to the library.

2. Click the Add Sample button. The Scan button changes to a **Save Samp** button.

3. Set the number of scans to average and click the **Save Samp** button. A dialog box opens.
4. Enter the name of the sample in the dialog box and click the **OK** button. You are then prompted to enter a name for the sample.



Assign a name that is indicative of the sample it will be representing. If you do not want to name the sample, click the **Cancel** button to abort the sampling process.

The new sample then appears in the list in the **Correlation Results** window. Click the **Scan** button to update the list with the results of the scan of your sample. You should now have a correlation coefficient very close to 1, depending on the properties of the material.

5. Repeat this process for as many samples as you would like to compare against.
6. Click the **Less** button to minimize the extra information. You only need to expand this option when you are adding new samples.

Saving the Correlation Library

► ***Procedure***

1. Open the **Library Options** Menu.
2. Select **Correlation | Linear Correlation | Save Library**.
3. Enter the name of the library to save and click the **Save** button.

   Upon startup, the software automatically loads the last library in use. If you now load the saved library, then exit and restart the program, your saved library will automatically load upon startup.

   In Pixel Correlation mode, each time you take a scan, the system will automatically correlate it. If you are in a different mode, you must manually click the **Correlate** button. The system then correlates the library against the current spectrum in memory.

Correlation Tips

The following tips will help you perform a correlation with OOILIBS:

- On occasion, you may only want to look at a specific range. You can do this by manually defining a Correlation Range. Place the cursor at the starting wavelength and click the **Cursor** button. This populates the starting wavelength. Then, repeat for the ending wavelength. After you enter the range, click the **Update** button to save them. To use the full range, set both the starting and ending wavelengths back to 0.
- There are two methods of correlation: Linear and Rank. Rank is more powerful, but you should experiment with Linear to see how your results differ. Switch between modes by toggling the button between Linear and Rank.
- You may receive better results by taking multiple single shots, then loading the shots into their library rather than averaging a single sample into the library. For instance, if you are sampling stone, you would add a sample called Stone 1. Then, you would move the stone to a different spot and take another sample, saving it as Stone 2, etc. This way, you have several samples of the same material. A scan that identifies any of these materials will return a match for stone.

Chapter 4

Troubleshooting

Overview

The following sections contain information on troubleshooting issues you may encounter when using the LIBS 2000+ system. If the suggested solutions do not correct the situation, contact Ocean Optics Technical Support.

HR2000 Connected to PC Prior to OOILIBS Installation

If you connected your Ocean Optics USB device(s) to the computer prior to installing your Ocean Optics software application, you may encounter installation issues that you must correct before your Ocean Optics device will operate properly.

Follow the applicable steps below to remove the incorrectly installed device, device driver, and installation files.

Note

If these procedures do not correct your device driver problem, you must obtain the *Correcting Device Driver Issues* document from the Ocean Optics website: **http://www.oceanoptics.com/technical/engineering/correctingdevicedriverissues.pdf**.

Remove the Unknown Device from Windows Device Manager

► ***Procedure***

1. Open Windows Device Manager. Consult the Windows operating instructions for your computer for directions, if needed.
2. Locate the **Other Devices** option and expand the **Other Devices** selection by clicking on the "+" sign to the immediate left.

Note

Improperly installed USB devices can also appear under the Universal Serial Bus Controller option. Be sure to check this location if you cannot locate the unknown device.

3. Locate the unknown device (marked with a large question mark). Right-click on the **Unknown Device** listing and select the **Uninstall** or **Remove** option.
4. Click the **OK** button to continue. A warning box appears confirming the removal of the Unknown Device. Click the **OK** button to confirm the device removal.
5. Disconnect the HR2000 Spectrometer(s) from your computer.
6. Perform the steps in the following *Remove Improperly Installed Files* section.

Remove Improperly Installed Files

► ***Procedure***

1. Open Windows Explorer.
2. Navigate to the **Windows | INF** directory.

Note

If the INF directory is not visible, you must disable the Hide System Files and Folders and Hide File Extensions for Known File Types options in Windows Folder Options. Access Windows Folder Options from Windows Explorer, under the **Tools | Folder Options** menu selection.

3. Delete the **OOI_USB.INF** in the INF directory. If your computer is running either the Windows 2000 or XP operating system, you must also delete the **OOI_USB.PNF** file in the INF directory.
4. Navigate to the **Windows | System32 | Drivers** directory.
5. Delete the **EZUSB.SYS** file.
6. Reinstall your Ocean Optics application and reboot the system when prompted.
7. Plug in the USB device.

The system is now able to locate and install the correct drivers for the USB device.

Laser Troubleshooting

Problem

The laser will not start.

Probable Cause

On water-cooled lasers, bubbles may have developed in the cooling system. This will prevent water from traveling to the laser head and result in a nonfunctional laser.

Solution

► ***Procedure***

1. Tilt the power supply of the laser 30 degrees right or left.
2. Allow the power supply to remain in that position until the bubbles clear.
3. Try to start the laser again.

Spectrometer Troubleshooting

Continuous Beeping from System

Problem

The system is continuously beeping.

Probable Cause

The PC cannot communicate with the USB devices.

Solution

► ***Procedure***

1. Remove the USB devices from the PC,
2. Remove all installed Ocean Optics USB drivers, and
3. Restart the system.
4. Ensure that OOILIBS is installed, then reconnect the LIBS2000+ Spectrometer to the PC.

System Prompts for ezusb.sys or an .inf File

Problem

During installation, the system is requesting a file named ezusb.sys or an .INF file.

Probable Cause

The system cannot locate the USB drivers or .INF files.

Solution

Navigate to the appropriate directory for each file.

For the ezusb.sys file:

- Windows 98/ME - C:\windows\system32\drivers
- Windows 2K/XP - Directory may be winnt instead of windows. All other information the same.

For the .INF file:

- Windows 98/ME - C:\windows\inf **or** C:\windows\inf\other
- Windows 2K/XP - Directory may be winnt instead of windows. All other information the same.

Verifying Device Setup

Problem

How do I verify that the devices have been setup correctly?

Solution

► *Procedure*

Follow the steps below to verify device installation:

1. Navigate to **Start | Settings | Control Panel**.
2. Double-click on the **System** icon.
3. Select the **Device Manager** tab (Windows 98/ME), or click the **Device Manager** button (Windows 2K/XP). A list of installed devices appears.
4. Expand the USB Devices tree. The Ocean Optics HR2000 should be listed several times, depending on the number of units in your system.
5. Verify that there are no entries with yellow or red warning symbols next to them. If this is the case, the devices are correctly installed. If this is not the case, follow the instructions in *Remove Improperly Installed Files*.

You have now verified device setup.

OOILIBS Software Troubleshooting

Program Keeps Freezing or Locking Up

Problem

The OOILIBS software keeps freezing or locking up.

Probable Cause

Multiple causes.

Solution

► ***Procedure***

1. Click on the **Reset** button. If the system unfreezes, the problem is solved.
2. Reboot the computer. You must also reset the spectrometer system by disconnecting the USB cable and power from the PC.
3. Verify that the Lamp Sync trigger is being transmitted to the spectrometer.
4. Ensure that the same serial numbers are not assigned twice in the **Select Spectrometer Modules** window.

Appendix A

Specifications

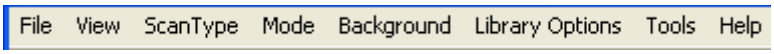
Specification	Value
Spectrometer range:	200-980 nm
Resolution:	0.1 nm (FWHM)
Detection:	CCDs with a combined 14,336 pixels
Frame rate:	10 Hz capability, computer-controlled
Integration time:	2.1 ms; variable in the free-run mode
Trigger delay:	-121 μs to +135 μs in 500 ns steps, computer-controlled
Trigger jitter:	+/-250 ns
Trigger level:	TTL not to exceed 5.5 V
Computer connection:	USB 1.1 (in all computers)
Software:	OOILIBS
Power requirement:	5 volts at <1 amp, power supply included
Input optical fiber:	2-meter, multimode sampling probe with SMA connector and collimating lens
Size:	84HP x 3U Rack Housing with handles (130 mm x 483 mm x 350 mm)
Certification:	CE

Appendix B

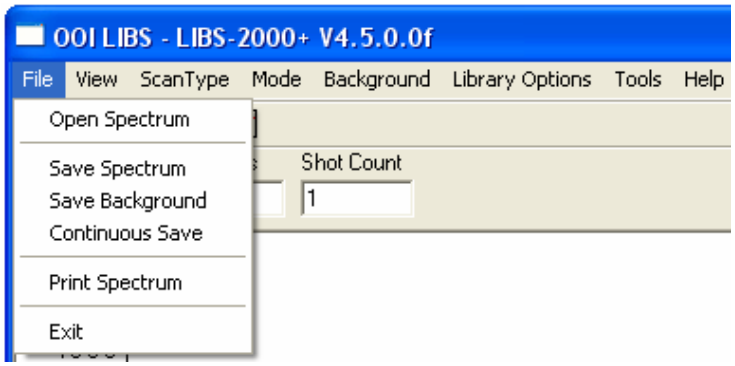
User Interface

Menu Bar

The OOILIBS Menu Bar is located at the top of the OOILIBS screen and features the following options:

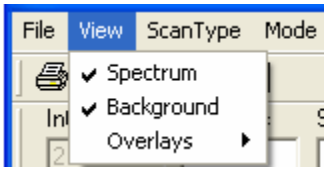


File Menu



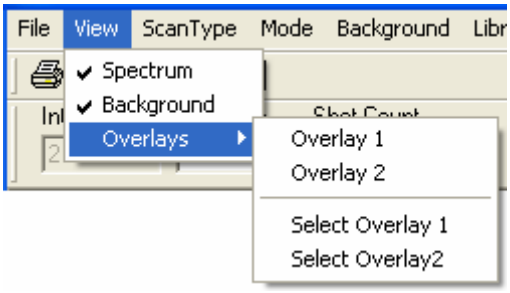
Menu Option	Description
Open Spectrum	Opens a Saved Spectrum file and displays it in the graph. You can analyze this data.
Save Spectrum	Saves a spectrum file (.ols). You can load this file into overlays or opened it directly.
Save Background	Saves a background spectrum. You can use this for background subtraction, but it cannot be loaded for overlays or display.
Continuous Save	Starts Continuous Save. When activated, each scan is saved with a file appended with a incremental file number.
Print Spectrum	Prints the spectrum displayed in the graph window.
Exit	Exits the program.

View Menu



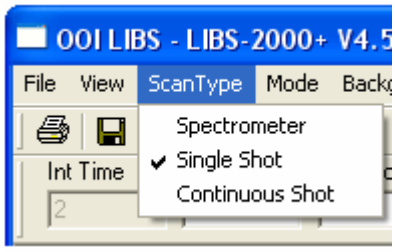
Menu Option	Description
Cursor Info	Displays the Cursor info dialog box. This dialog box lets you customize and record information about the cursor.
Spectrum	Display the Spectrum in the graph window.
Background	Display the background data in the graph window.
Overlays	Brings up the Overlay sub-menu, which displays and loads an overlay.

Overlay Sub-Menu



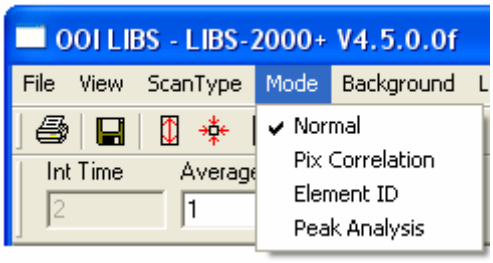
Menu Option	Description
Overlay 1	Display overlay 1
Overlay 2	Display overlay 2
Select Overlay 1	Load an .ols file into Overlay 1.
Select Overlay 2	Load an .ols file into Overlay 2.

ScanType Menu



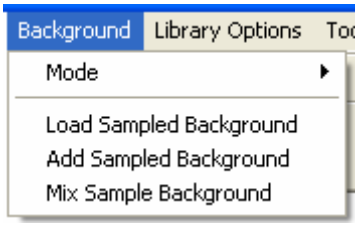
Menu Option	Description
Spectrometer	Selects Spectrometer mode. You can set the integration time in this mode, but laser control is not enabled.
Single Shot	Selects Single Shot mode. This mode controls the laser and allows you to manually fire it.
Continuous Shot	Selects Continuous mode. This mode fires the laser on a interval set in the Setup Options, and the software acquires and analyzes data.

Mode Menu



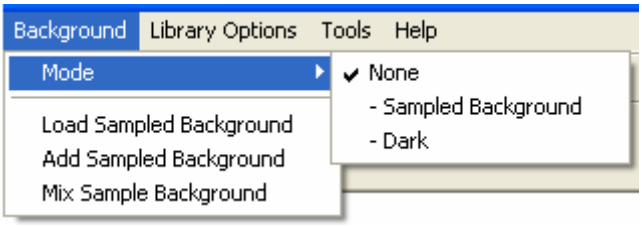
Menu Option	Description
Normal	Data collection only. No analysis is performed.
Pix Correlation	Allows you to correlate against a library and determine the closest match based on pixel information.
Element ID	Attempts to pick out the lines of elements contained in the spectrum.
Peak Analysis	Allows you to get some statistical information on user definable peaks.

Background Menu



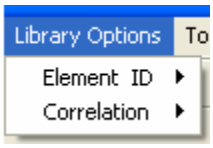
Menu Option	Description
Mode	Allows you to select the type of background subtraction
Load Sampled Background	Loads a background file to be subtracted off in Sampled Background mode.
Add Sampled Background	Adds together a sampled background doing a per point add-on to the background files.
Mix Sample Background	Mixes two background files, retaining the higher counts per point.

Background | Mode Menu



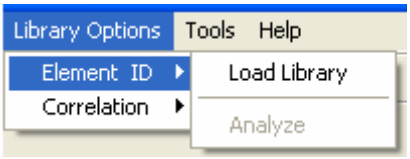
Menu Option	Description
None	No background subtraction.
Sampled Background	Sampled background subtraction loaded using *Background Menu* options.
Dark	Dark subtraction uses the masked pixels of each detector as the background.

Library Options Menu



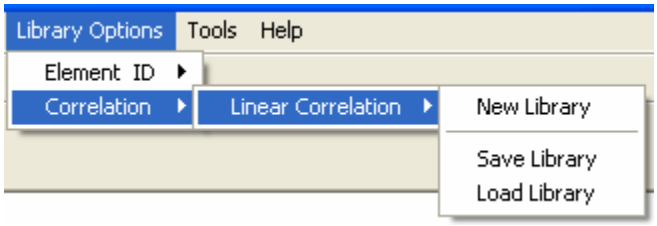
Menu Option	Description
Element ID	Brings up the **Element ID** library menu (see *Library Options | Element ID Menu*.
Correlation	Brings up the **Correlation** library menu (see *Library Options | Correlation Menu*.

Library Options | Element ID Menu



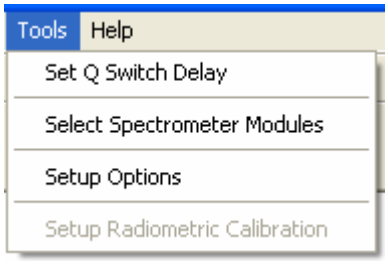
Menu Option	Description
Load Library	Loads an Element ID library.
Analyze	For future use.

Library Options | Correlation Menu



Menu Option	Description
New Library	Creates a new correlation library.
Save Library	Saves the correlation library.
Load Library	Loads a correlation library.

Tools Menu



Menu Option	Description
Set Q Switch Delay	Opens the **Adjust Q Switch** window.
Select Spectrometer Modules	Selects the serial numbers of the spectrometers to be used.
Setup Options	Sets up general options for OOILIBS software.
Setup Radiometric Calibration	Sets up the radiometric calibration options.

Stage Menu

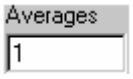
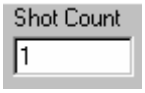
Menu Option	Description
Control	Opens the Sample Chamber stage control window.
Move Stage	Automatically moves the stage during sampling. Only available on the closed loop sample chamber.

Tool Bar

The OOILIBS tool bar, located at the top of the screen, features the following options:

Icon	Description
	Prints the contents of the graph window.
	Saves the contents of the graph window
	Scale the contents of the graph window according to the highest and lowest readings.
	Auto-scales the contents of the graph window.
	Scales the contents of the graph window according to the highest readings.

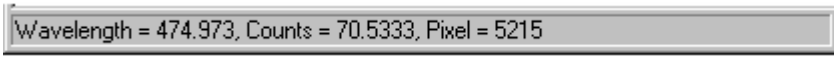
Dialog Bar

Icon	Description
	Displays the integration time (in Spectrometer Mode).
	Displays the averages of the specified number of scans (all modes).
	Displays the number of shots to take and the average (Single and Continuous Shot Modes).
	Allows you to manually take a scan (Single Shot Mode).
	Resets the spectrometer (in the event that a trigger is missed).
	Not used.
	Takes the specified number of cleaning shots. This option is configured in the Setup Options window.

Icon	Description
	Turns the alignment light on or off.

Status Bar

The OOILIBS Status Bar, located at the bottom of the screen, features the following options:

Option	Description
	Displays the wavelength, counts and pixel number of the current cursor location.
	Displays the current Q Switch delay.
	Displays the current Continuous Save File name (when in use).

Graph Window

The OOILIBS Graph Window, located in the center of the screen, features the following options:

- In the main display window, the X axis represents Wavelength and the Y axis represents Counts (or arbitrary intensity, if **Use Radiometric Calibration** is checked).
- Click directly on the graph window to place the cursor at a specific point.
- Double-click on the graph window to reset the zoom ranges.
- Hold the both the SHIFT and left mouse buttons down, then drag and outline a region to zoom in on that region.

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