

# **FOXY System**

## **Fiber Optic Oxygen Sensor System**

# **Operating Manual**

Version 1.61F

**Ocean Optics, Inc.**  
380 Main Street  
Dunedin, FL 34698  
(727) 733-2447  
(727) 733-3962 fax

**For the latest information, consult our web site:  
[www.OceanOptics.com](http://www.OceanOptics.com)**

**Or, e-mail our Technical Service Department:  
[TechSupport@OceanOptics.com](mailto:TechSupport@OceanOptics.com)**



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# Introduction

The FOXY Fiber Optic Sensor System is easy to setup and use. In most cases, your system can be up and running in a few minutes. If you need additional assistance, please refer to the S2000 operating manual, or contact our Technical Services Department. The numbers and addresses are shown on the cover.

The FOXY system consists of several modular components, which together comprise an oxygen sensing system. There are several variations and configurations that will work. Please make sure that you have all of the required components. If you are not sure, call our technical service department. In general, the systems consist of a spectrometer, and oxygen probe with fiber optics, and a blue LED excitation source. Item codes follow:

## Spectrometers:

The S2000-FL is configured for fluorescence in general and is ideal for oxygen sensing. It requires a separate excitation source.

S2000-FL                      S2000 fiber optic spectrometer for fluorescence, grating #3, 360 – 900nm, 200  $\mu$ m slit, L2 lens. \$2000.00

## A/D Products:

The S2000-FL will interface to a desktop computer using one of the following A/D systems: ADC500, ADC1000 or SAD500. The spectrometer can be used with a notebook computer using the serial interface of the SAD500. The SAD500 has a microprocessor which can be used to calculate O<sub>2</sub> levels directly, for easy interface to PLCs and other control equipment:

ADC500                      500 KHz 12 bit ISA bus A/D card. \$499.00

ADC1000                    1 MHz 12 bit ISA bus A/D card. \$599.00

SAD500                      500 KHz microprocessor A/D system in a stand-alone box. The SAD500-S is stacked in the spectrometer box. The SAD500-R is in a 19" rack mount configuration. \$699.00

The best system performance is achieved by the combination of a rack mounted blue LED (R-450) and the spectrometer in a single package called an SF2000. The SF2000 has a master spectrometer and card mounted blue LED in an SD2000 enclosure. The LED uses an external power source but has internal connections for synchronization with the S2000, and for on/off control through the software. An A/D card, oxygen probe, bifurcated fiber assembly and splice bushing are also required (FOXY-2).

SF2000                      S2000 fiber optic spectrometer for fluorescence, grating #3, 360 – 900nm, 200  $\mu$ m slit, L2 lens, with integral R-450 card mounted blue LED pulsed source in dual spectrometer enclosure. \$2499.00

The card mounted Blue LED pulsed source can also be added to our line of rack mounted components. The rack-mounted spectrometers and accessories permit up to 8 spectrometers to be operated from a single A/D board. Full control of R-450 requires a J series or later version of the S2000.

## Oxygen probes:

The FOXY kit can be combined with any suitable spectrometer and A/D card to make a fiber optic sensing system. If you are buying the kit to add to an existing spectrometer, make sure that the spectrometer is set up to monitor low light levels.

FOXY                      Fiber Optic Oxygen Kit for S2000-FL, consisting of one each of FOXY-R probe, LS-450 pulsed blue LED, FOXY600-VIS/NIR cable assembly, 21-02 Splice bushing, and OOIFOXY oxygen sensor software. \$1499.00

FOXY-2                    Fiber Optic Oxygen Kit for SF2000, consisting of one each of FOXY-R probe, FOXY600-VIS/NIR cable assembly, 21-02 Splice bushing, and OOIFOXY oxygen sensor software. \$999.00

**Oxygen sensors:**

FOXY-R	Fiber Optic Oxygen Sensor on 1mm fiber in 1/16" SS ferule. \$499.00
FOXY-AL300	Fiber Optic Oxygen sensor on 300 micron Aluminum jacketed fiber. Requires BIF200-VIS/NIR cable assembly. \$499.00
FOXY-PI600	Fiber Optic Oxygen Sensor on 600 micron Polyimide jacketed fiber. Requires cable assembly. \$499.00
BIF-400-VIS/NIR	
FOXY-GF	Glass fiber membranes for Oxygen, 5/pk. \$50.00
FOXY-RECOV	Re-coating of probes. \$100.00
FOXY-SGS	Glass cover slips for Oxygen, 5/pk. \$200.00

**Blue LEDs:**

LS-450	Blue LED pulsed source with cable for external connection to spectrometer. \$499.00
R-450	Card mounted Blue LED pulsed source for mounting in spectrometer enclosure or 19" rack system. \$499.00

**Other Items:**

FOXY600-VIS/NIR	Bifurcated 600 micron fiber assembly. \$450.00
BIF200-VIS/NIR	Bifurcated 200 micron fiber assembly (for use with FOXY-AL300). \$350.00
BIF400-VIS/NIR	Bifurcated 400 micron fiber assembly (for use with FOXY-PI600). \$400.00
21-02	Splice bushing . \$ 13.00

# Description of System Components

## Oxygen Sensor

Oxygen sensors are available in a variety of custom formats. The standard product, FOXY-R, consists of a 1mm core diameter optical fiber in a 1/16<sup>th</sup> inch O.D. stainless steel tube, beveled at 45 degrees. The distal tip is polished and coated with the oxygen sensing material. The proximal end is finished in a 905 SMA fitting for coupling to the optical cables. The probe is designed to couple to a 600 micron bifurcated fiber using a splice bushing. The FOXY-AL300 is similar, except that the fiber is jacketed with an extremely tough aluminum coating. The result is a tough, small diameter probe with very small bending radius. The FOXY-AL300 should be coupled to a 200 micron bifurcated fiber. The FOXY-PI600 is a 600 micron fiber jacketed with polyimide. It is designed to be coupled to a bifurcated 400 micron fiber. The relative signal strength of the probes scales to their cross sectional area.



## Spectrometer

The spectrometer is an S2000 fiber optic spectrometer optimized for low light level applications. The spectrometer can be used with the oxygen sensor, or for other applications by connecting it to the appropriate sampling optics. For oxygen work, one leg of the bifurcated assembly delivers fluorescence from the probe tip to the spectrometer. The S2000 interfaces to a computer by way of an A/D card. The 25 pin connector in the rear of the unit couples to an ADC500 card in a desktop computer, or to a SAD500 A/D system for connection through the serial port to a notebook computer, desktop PC, PLC or other serial devices.

The 15 pin connector at the rear of the S2000 is for connecting various accessories, such as the LS-450 blue LED. Timing signals and on/off for controlling the LED will be transmitted from the spectrometer to the LED. In the rack mounted devices, such as the R-450, these signals are routed through header pins that connect the 2 boards.

## Blue LED

The Blue LED is specially designed for use with the oxygen sensor. A linear voltage regulator provides constant power to the LED. External power is supplied by a 12 Volt DC power transformer. If you need a 220 volt supply, contact our sales department to order a INT-P (\$20.00). The trigger cable is designed to plug into the 15 pin connector of the S2000. If you purchased an SF2000 or a rack mounted LED, the trigger lines are connected internally.

## **OOIFOXY Software**

The oxygen probe can be used with any software that operates the S2000 (e.g. OOIBASE, OCEANS32, EXCEL). However, OOIFOXY is provided as a user friendly, easy to use package especially designed for the oxygen sensor. You should have a diskette with OOIFOXY installation software in your package. Please check our website periodically to learn about free upgrades and other technical issues related to this software. If you purchased a SAD500, it is possible to have the spectra converted to oxygen values at the microprocessor level, and transmitted through the serial interface to other devices. Call our tech service department for details.

# Installing the System

Installing the system consists of 3 steps:

1. Installing the A/D card in the computer
2. Installing the software in the computer
3. Coupling the optical components

## A /D Card

**ADC500 or ADC1000** – If you familiar with installing computer boards, this will be easy. If you've never done this, you might want to consult our S2000 manual for detailed procedures.

Turn off your computer and disconnect the power cord. Open the computer case and locate an empty ISA slot. You should pick one that is away from the video card. You will need to remove the slot cover from the chassis. Then insert the ADC500 or ADC1000 in the ISA slot, making sure to properly seat the card edge into the connectors. Fasten the card to the chassis with the cover plate screw.

The ADC500 and ADC1000 cards come preset to a base address of 768 (decimal) and IRQ = 7. This will work in most computers. However, if you have another card or device using these settings, you will need to change the base address or IRQ by changing some dip switches. Please refer to Appendix I for details.

Connect the blue interface cable from the ADC500 or ADC1000 to the S2000-FL or SF2000 spectrometer.



## Software

Installing software is easy, just insert the diskette, and run SETUP. The installation program will ask you a few questions, and take care of the rest. If you don't know what to answer, just stick with the default options. OOIFOXY will be installed in your program directory. Just double click on the OOIFOXY selection to start.

## Optical Components

The FOXY probe should be coupled to the common leg of the bifurcated optical assembly. The common leg is identified as the single cable coming from the stainless steel breakout in the middle of the "Y" shaped assembly. Use the SMA splice bushing to couple these pieces together. It is only necessary to make these finger tight to make a good connection.

Connect one of the legs of the assembly to LED, the other goes to the spectrometer. Again, finger tight is sufficient. Both legs are equivalent, so it doesn't matter which one is connected to the spectrometer.

The Blue LED must be connected to the power source, and to the trigger line from the spectrometer. There is an OFF/TRIGGERED/ON switch on the back of the unit. The triggered position is towards the outside of the case, on towards the inside. NOTE: The LED will not turn on in trigger mode unless the software has been activated. Exiting the software will not turn the LED off, but rebooting the computer will. In triggered mode, the intensity will appear to be ½ as bright as the ON mode. Triggered mode is recommended for use with the oxygen sensor.

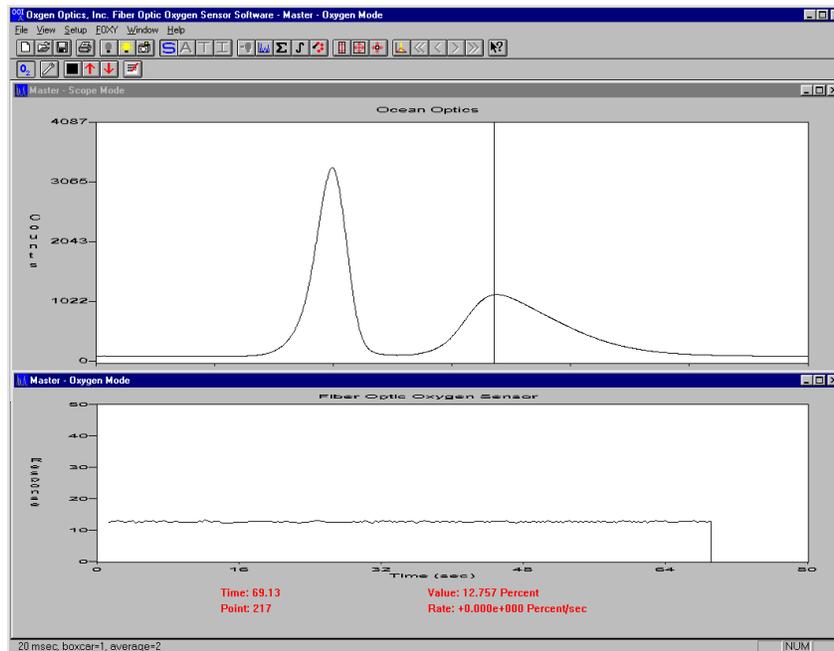
The rack mounted blue LED in the SF2000 has various options set by jumpers on the board. These come preset for the optimum performance with the oxygen probe. However, if you wish to change any of the settings, remove the 2 screws from the back of the SF2000, and slide the spectrometer and R-450 cards out of the box. You can safely run the system out of the box as it is low voltage only. Refer to Appendix II for jumper settings. The settings control 1) manual vs software control of on/off and 2) the pulse frequency of the LED.

# Using the System

## Starting & Setting Parameters

Double click on the OOIFOXY menu selection under PROGRAMS to start the software. Make sure the Blue LED switch is in the ON or TRIGGERED position. You should see blue light coming from the sensor. Shielding the tip from ambient light, you should be able to see a red glow if you look at the tip from the side

At this point you should see a spectrum on the screen consisting of a back reflection of the blue LED in the 450 - 550nm range and a fluorescence peak in the 600 - 615nm range. The exact location of the peaks will vary from unit to unit and should be determined each time a new component is installed. Use the cursor to locate the wavelength of the maximum signal for each peak, and record these in the oxygen parameters dialog box accessed by clicking on the wrench icon.



The magnitude of the peaks depends on the integration period of the detector. You can increase the signal by making the integration period longer, and decrease the signal by making the integration period shorter. Click on the icon with the integral sign to set the integration period. Adjust it until you have the fluorescence peak about half way up the screen (about 2000 counts), and the LED peak anywhere (it does not matter if the LED peak is saturated). NOTE: the signal differs greatly between air and water deployments; install the probe in the test media before adjusting integration period.

The spectra are broad smooth curves. An increase in signal-to-noise can be obtained through smoothing. Click on the  $\Sigma$  icon and set the smoothing to 25 pixels.

The probe should be installed in a suitable sampling compartment. It is critical that ambient light be excluded from the field of view of the probe tip, and that provisions for sampling standard oxygen levels are available. For gases, a flow chamber with connections to  $N_2$ , dry air, and/or  $O_2$  is suggested. For fluids, these gases can be used with glass frits (airstones) and a stirrer to bring the liquid into equilibrium with the calibration gas. As an option, sodium hydrosulfite can be used to strip  $O_2$  from aqueous solutions.

## Storing Reference Values and Dark

**Three (3) values are required to calculate oxygen concentration of a sample:**

1. the dark level of the detector
2. the intensity at a low oxygen level (preferably zero)
3. the intensity at a known high level of oxygen (preferably near the concentration of your samples).

These values are stored in the software by clicking on the appropriate icons:

1. the black box for dark
2. the down arrow for low oxygen
3. the up arrow for high oxygen.



The standard values for the calibration gases are entered into the oxygen configuration dialog box, accessed with icon with the wrench symbol. The wavelengths for the blue LED and oxygen fluorescence as determined from inspection of the spectra should be entered into the appropriate text boxes. All settings are stored in an initialization file so that the software can be exited and re-entered without the necessity of re-calibration.

## Viewing Oxygen Concentration

Once you have stored dark, high and low, you can view the oxygen concentration by clicking on the O<sub>2</sub> icon. A time series graph window appears with text data at the bottom of the graph, and a time series of oxygen values in the plot area. This data is updated in real-time, as fast as the spectrometer acquires data and the computer can redraw the graph. To slow down the acquisition rate, increase the number of scans that are signal averaged, or set a delay between acquisitions in the O<sub>2</sub> configuration box. To signal average click on the Setup | Data Acquisition icon indicated with a blue spectra. If you want to speed up acquisition, decrease the number of scans being averaged, or decrease the integration period.

The oxygen values can be logged to an ASCII data file in 3 ways:

1. Clicking on the log value icon indicated by the pen & paper will write the current value to a standard log file named CH0.log.
2. Setting the Auto log function in the O<sub>2</sub> dialog box to ON will cause every value to be written to the log file.
3. Using File | Export will write the currently display time series to a file of your choice.

# Principle of Operation

## Fluorescence Quenching

The probe consists of an optical fiber coated on the distal end with a thin layer of a hydrophobic sol-gel material. A ruthenium complex is trapped in the sol-gel matrix, effectively immobilized and protected from water. The LED excites the ruthenium complex with ~475nm light. The excited complex fluoresces, emitting energy at ~600nm. If the excited ruthenium complex encounters an oxygen molecule, the excess energy will be transferred to the oxygen molecule in a non-radiative transfer, decreasing the fluorescence signal. The degree to which this process occurs depends on the concentration of oxygen molecules.

## Stern-Volmer Equation & Calibration

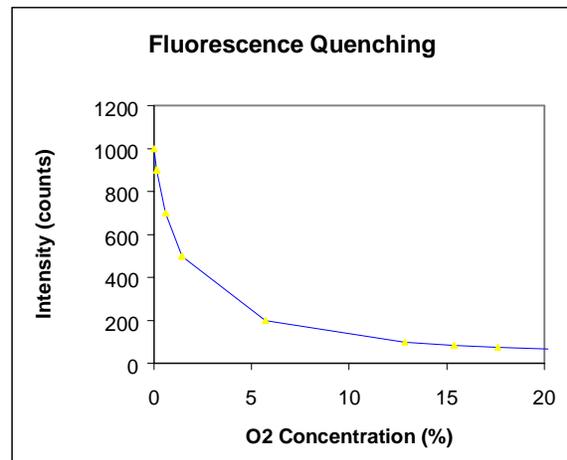
The fluorescence is related quantitatively to the partial pressure of oxygen through the Stern-Volmer equation:

$$\left( \frac{I_0}{I} \right) = 1 + k p_{O_2}$$

$I_0$  is the intensity of fluorescence at zero pressure of oxygen,  $I$  is the intensity of fluorescence at a pressure  $p$  of oxygen, and  $k$  is the Stern-Volmer constant. For a given media, and at a constant total pressure, and temperature, the partial pressure of  $O_2$  is proportional to  $O_2$  concentration.

It is evident from the equation that the sensor will be most sensitive to low levels of oxygen. The photometric signal to noise is roughly proportional to the square root of the signal intensity, and the rate of change of signal intensity with oxygen concentration is greatest at low levels.

The Stern-Volmer constant ( $k$ ) is primarily dependent on the chemical composition of the ruthenium complex. The probes have shown excellent stability over time, and this value should be largely independent of the other parts of the measurement system. However,  $k$  does vary among probes, and is also temperature dependent. All measurements should be made at the same temperature as the calibration experiments.



$I_0$  depends on details of the optical setup: LED power, optical fibers, losses at the probe to fiber coupling, and backscattering from the media. It is important to measure  $I_0$  for each experimental setup. Backscattering in the media can increase the collection efficiency of the probe, increasing the observed fluorescence. It is important to perform calibration procedures in the media of interest for highly scattering substances. For optically clear fluids and gases, this is not necessary.

# Application Tips

## Ambient Light

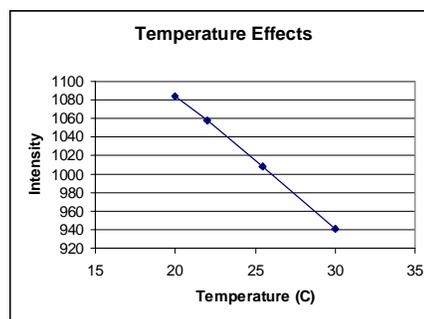
The S2000 is very sensitive, and the oxygen probe will readily detect ambient light. The probe must be shielded from ambient light to obtain reliable data. You can determine if ambient light is entering the probe by turning the blue LED off. The spectra should appear flat, near the bottom of the scale.

## Scattering Media

Fluorescence emissions from the ruthenium complexes propagate in all directions. In clear media, only those emissions propagating towards the fiber within the acceptance angle of the probe are detected. If the probe tip is held near a reflecting surface, or immersed in a highly scattering media, the fluorescence signal will increase. The increase will be proportional for both  $I$  and  $I_0$  in the Stern-Volmer equation, and will not affect the constant. For this reason it is necessary to measure  $I_0$  in the media.

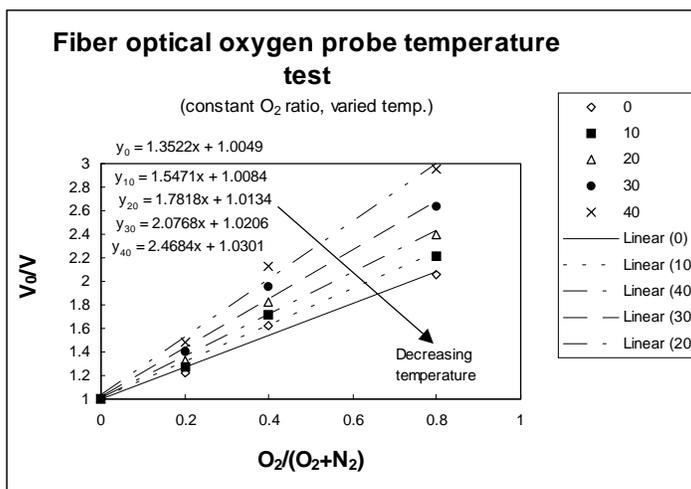
## Temperature

Temperature affects  $k$  and  $I_0$  for each probe, and may have secondary effects on the collection optics. It is recommended that measurements be performed at a constant temperature. The effect of temperature is predictable, and can be used to correct sample data that is collected at a different temperature than the calibration standards.



## Calibration

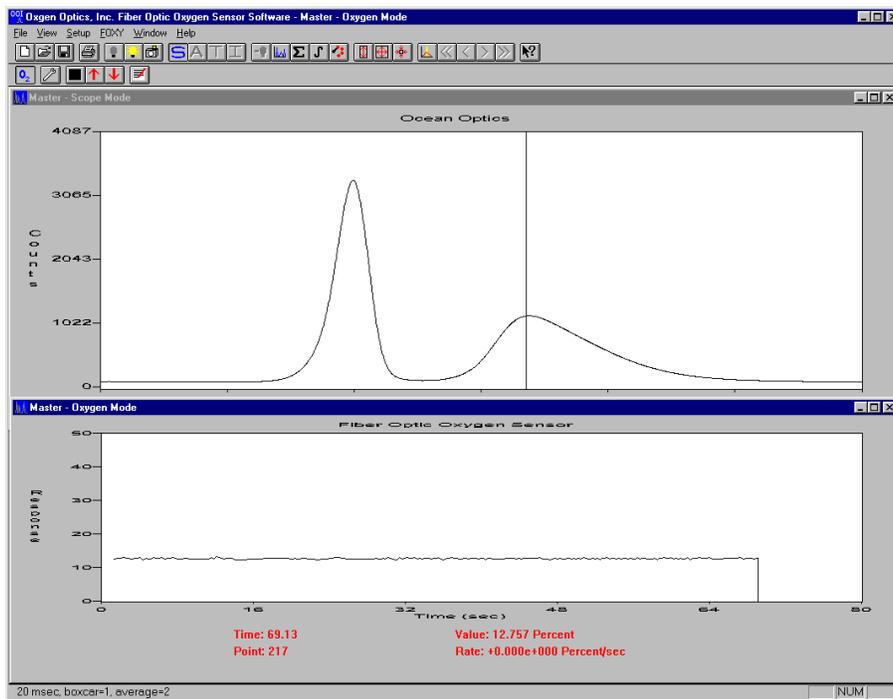
Any two levels of known  $O_2$  concentration or partial pressure can be used to calibrate the system. If you are using the probe in gases,  $N_2$  can be used for the low value (0%) and air (20.9%) or  $O_2$  (100%) for the high value. It may be difficult to prepare standards for liquid media. Sodium hydrosulfite dissolved in aqueous media will consume  $O_2$  rapidly, and can be used to prepare a 0% concentration. Air saturated values for various solvents and salt solutions can be found in textbooks.



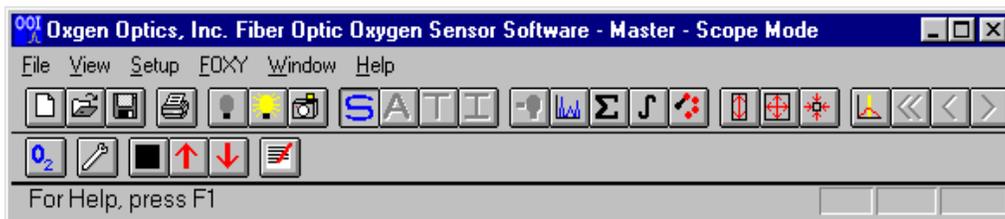
# Software Directions

OOIFOXY will be installed in your PROGRAMS directory. Double click on the entry or icon to start the software.

On startup, a single window will appear showing the SCOPE MODE view of the spectrometer (top panel in the picture above). This graph shows the output from the spectrometer in real-time. If the LED is off, you should see a trace running across the bottom of the screen. If you turn the LED on, you should see a spectra with 2 peaks like the picture above. The lower wavelength peak is back reflection of the blue LED source from the sensor surface. The longer wavelength peak is the red fluorescence from the ruthenium complex. Data windows can be opened and closed, and displayed in tiled or cascaded view. Clicking on a window title bar selects the window for modification by the various tools.



The software consists of all the commands necessary to control the spectrometer, acquire data, convert the data into meaningful numbers, and save the data in files and logs. OOIFOXY is an enhanced version of OOIBASE, which is the general software supplied with all spectrometers.



The software can be used by activating icons and menu items. The top row of icons refer to general spectroscopy functions. The bottom row are related to functions required for use in the oxygen sensing mode. Specific instructions can be found in the HELP file for icon and menu commands. Briefly, the icons for general spectroscopy are:



**Open a new window.** Each window shows data from the spectrometer.

**Open a saved file.** Spectra are stored as binary files.

**Save a file.** Binary files can be read into a window for display.

**Print.** Send the graph in the window to the printer.



**Store Dark.** For general spectroscopy, stores dark spectra

**Store Reference.** For general spectroscopy, stores spectra of 100% transmission or reflection, or blackbody source

**Snapshot Mode.** Turns off real-time mode



**Scope Mode.** Shows data in A/D counts.

**Absorbance.** With a suitable dark & reference, shows absorbance values

**Transmission.** With a suitable dark & reference, show % T or %R

**Irradiance.** With a suitable dark & reference, shows relative energy.



**Subtract Dark Spectra.** Affects display only.

**Configure Data Acquisition.** Set static signal averaging, triggering options, A/D resolution and other parameters.

**Averaging.** Set dynamic signal averaging and spectral smoothing.

**Integration.** Sets detector integration period.

**Channel selector.** For multi-spectrometer systems, sets the spectrometer channel for the current window.



**Y Rescale.** Rescales the current window in the Y axis.

**Set Scale.** Shows dialog box for setting x & y limits.

**Default Scale.** Returns scale to default settings

**Cursor On/Off.** Puts vertical cursor in current window, values reported at bottom of main window.

**Move Cursor.** Left, right, fast & slow.



**O<sub>2</sub>.** Opens a new window in the oxygen time series mode.

**Configure O<sub>2</sub>.** Opens the oxygen configuration screen.

**Store Dark.** Stores the dark values at the fluorescence and reference wavelengths.



**Store High O<sub>2</sub>.** Stores the intensity values at the fluorescence and reference wavelengths for the high O<sub>2</sub> standard.

**Store Low O<sub>2</sub>.** Stores the intensity values at the fluorescence and reference wavelengths for the high O<sub>2</sub> standard.

**Log O<sub>2</sub> Value.** Writes the currently display oxygen value and time value to the general log file, CH0.LOG.

## Optimizing Signal to Noise

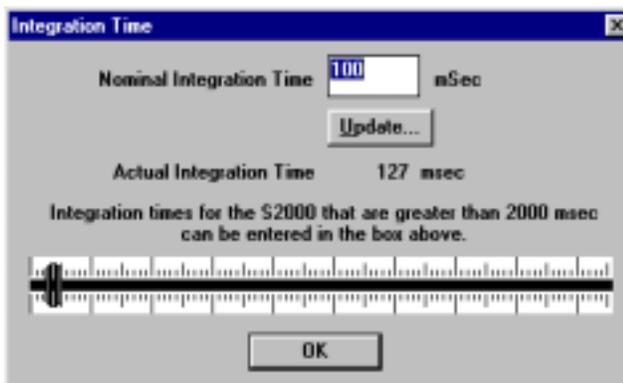
Photometric signal to noise in the oxygen sensor system is limited by the number of photons. Randomness in photon flux yields signal to noise ratios that are approximately equal to the square root of the number of photons sampled. The number of photons sampled can be increased by:

1. increasing the integration period.
2. signal averaging through time.
3. signal averaging across the spectra.

The trade off to options 1 & 2 are the speed of acquiring data. The appropriate setting depends on your application needs, the stability of the oxygen levels in the samples, or your patience in waiting for answers! The trade-off to option number 3 is optical wavelength resolution. As the fluorescence and LED spectra are broad smooth curves, optical resolution is not a concern, and smoothing should be set to the maximum 25 pixels. In addition, the software permits averaging across the whole band. You should set these values in the oxygen configuration dialog box to 100 pixels for the oxygen peak and 50 for the blue LED.

## Setting Integration Period

The integration period for the CCD controls the length of time the detector is exposed to light before being read. It is analogous to the shutter speed in a camera. The ideal setting depends on the intensity of the light being sampled. To adjust the integration period, click on the integration icon, and either enter the period in msec in the text box, or use the slide bar. To see the effects of the change, click on update. You can see the spectra being acquired behind the dialog box. Select a setting that gives a signal that is >75% of full scale, but less than saturation. Any values at or above 4095 counts will be invalid. Remember that the signal at low O<sub>2</sub> concentration is about 40% higher than in air. **NOTE! Set the integration period to factors of 2 only (i.e. 2,4,8,16,32,64,128,256...)** This is to insure a constant number of LED pulses during the integration period.

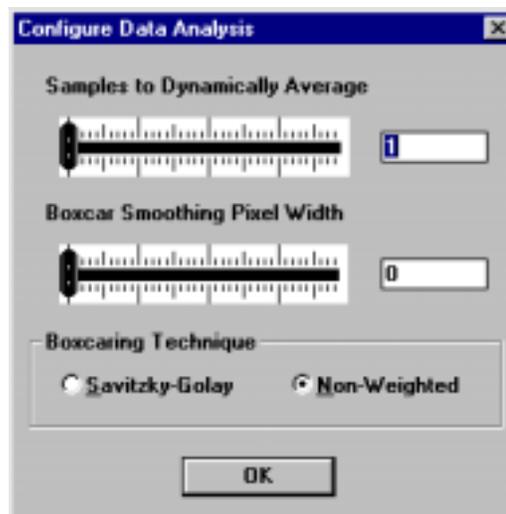


## Setting Signal Averaging

Signal averaging over time can be done in a static mode or a dynamic mode. In static mode, n number of scans are acquired, averaged and sent to the graphics module for. In dynamic mode, the graphics display a running average of n scans. There is no quantitative difference between these modes, only the cosmetics of data presentation are affected.

To set Static Averaging, click on the Configure Data Acquisition icon. Enter the number of scans to be averaged in the text box.

To set dynamic averaging, click on the  $\Sigma$  icon. Enter the number of scans to average in the text box, or use the slide bar.



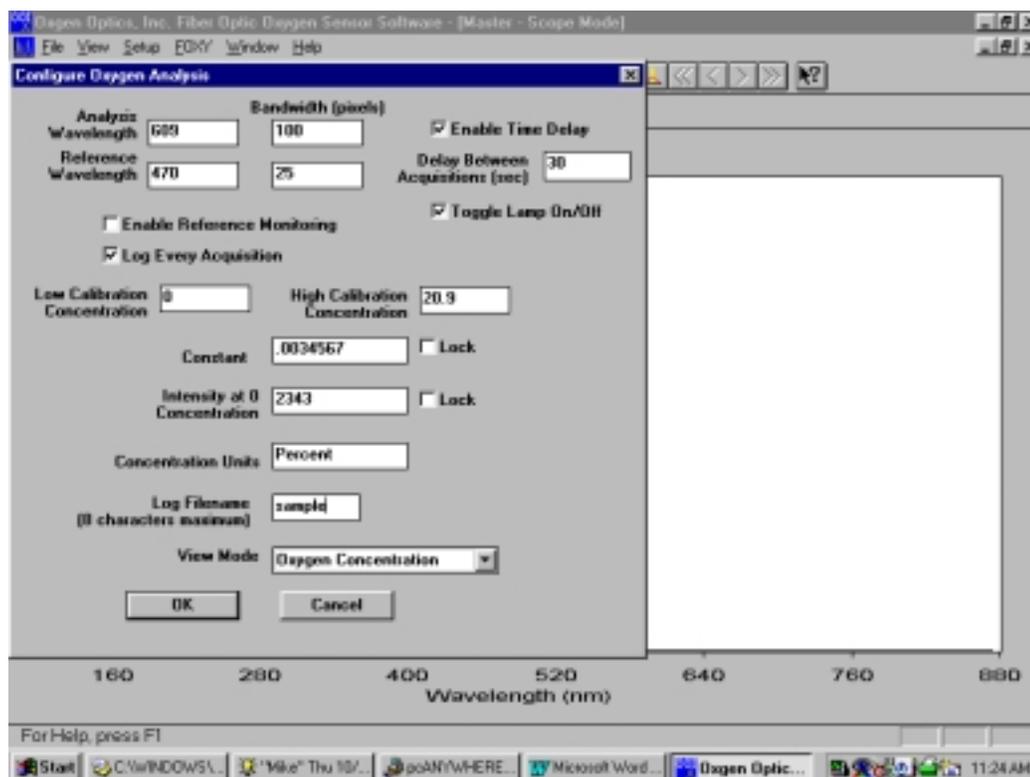
## **Setting Optical Smoothing**

To set optical smoothing, click on the  $\Sigma$  icon. Enter the number of pixels to smooth in the text box, or use the slide bar. You will need to click once to bring the slide bar control to the smoothing function, then click and drag to move the control. Smoothing for oxygen sensors should be set to the maximum of 25 pixels.

## Oxygen Configuration Screen

The oxygen configuration screen is used to set values for the particular oxygen probe being used. All values are written to a file that is read whenever the software is started, allowing the user to exit and re-enter the software without having to recalibrate the sensor.

The **analysis wavelength** is the wavelength of the fluorescence maximum. For the oxygen sensor this lies in the 600 – 615nm range. You should measure the wavelength of the maximum fluorescence signal by using the cursor. Then enter this value in the text box. To improve signal to noise, the fluorescence band can be integrated. Set the half **band- width** in pixels in the text box next to the analysis wavelength. A value approximately equal to half width, half-maximum intensity is appropriate (100 for the oxygen peak and 25 for the blue LED).



The **reference wavelength** is the peak of the blue fluorescence, a point along the shoulder of the Blue LED curve if it is saturated, the second order peak for the blue LED (around 900 nm), or an internal fluorescence standard for future probe products. Use the cursor to determine the wavelength of the reference you have chosen, and also set a bandwidth for integration. This reference value will be used to correct any variations in excitation energy, if you turn on the **Enable Reference Monitoring** Check box.

The spectrometer and LED can run all the time, or the software will turn on the LED, record spectra, turn off the LED and wait. This mode is useful to prevent photo-bleaching of the probe and improve stability. To activate this mode, click the **Toggle Lamp On/OFF** button. If you have an SF2000, the blue LED will turn on only when data is being acquired. To preserve the probe, you wait between readings by entering the value in seconds in the **Delay Between Acquisitions** check box, and also clicking the **Enable Time Delay** check box.

Automated data logging can be turned on and off with **the Log Every Acquisition** check box. When this box is checked, every oxygen and time value are appended to the log file FILENAME.log where the filename comes from the **Log Filename** text box

The values of the oxygen concentration standards are entered into **the Low and High calibration concentration** text boxes. Although zero oxygen level is recommended for the low concentration, any value can be used for the standards, as long as they are sufficiently different. The units for the calibration standards and for the values reported for the samples can be entered into the **Concentration Units** text box. This is just a text string and has no mathematical significance.

The values for the Stern-Volmer **Constant** ( $k$ ) and Intensity **at Zero Oxygen Concentration** ( $I_0$ ) are calculated from the intensities recorded by clicking on the High, Low and Dark icons, and the concentration values for the standards. The results are posted to the text boxes. If you wish to enter these manually you can do so. If the lock values boxes are checked, these values will be set.

The **View** pull down menu offers Absorbance, Concentration, Oxygen Concentration, Scope Mode, Scope Mode – Dark, and Transmission. The Oxygen Concentration mode uses the Stern-Volmer equation and is the correct choice for using the FOXY probe. The other modes are available for non oxygen sensing applications.

## Storing Reference Values

The fluorescence intensities for high and low oxygen concentration standards are stored by clicking on the upward arrow and down arrow icons. The dark value is stored by clicking the black box icon. Old values are overwritten when these icons are clicked. The values are saved in an initialization file, and are read at start-up. It is important that these values be re-measured whenever the analysis wavelength, bandwidth, detector signal averaging, smoothing, and/or integration period are changed.

## Viewing Windows

Data is viewed in a window. New windows are opened by clicking on the blank sheet icon at the top left tool bar. When you open a new window, it will default to the scope mode spectra. This view can be changed to absorbance, transmission, or irradiance spectra, or to a time series. When multiple windows are open, the actions of the icons will apply to the highlighted (selected window) only. Each window has its own set of parameters indicated in the oxygen configuration screen. However, only the values in the selected window will be saved on exiting the program.

## Viewing Time Series

To view the Oxygen time series data, click on the O<sub>2</sub> icon. A time series window will open. The graphic is oxygen concentration (dependent) vs. time (independent). If you have selected a different view mode, data will be displayed as absorbance, transmission, etc. The current values are displayed in red letters under the graph, along with a rate of change value based on the last 2 data points.

The graph can be re-scaled using the standard graphic functions previously described. The cursor can be used to find the values of any point (current or past) on the graph.

As values are added, the graph eventually fills the available x axis space, and then automatically rescales on the x axis.

The time values are calculated from the computer's system clock through the Windows timer functions. It is precise to 1 millisecond.

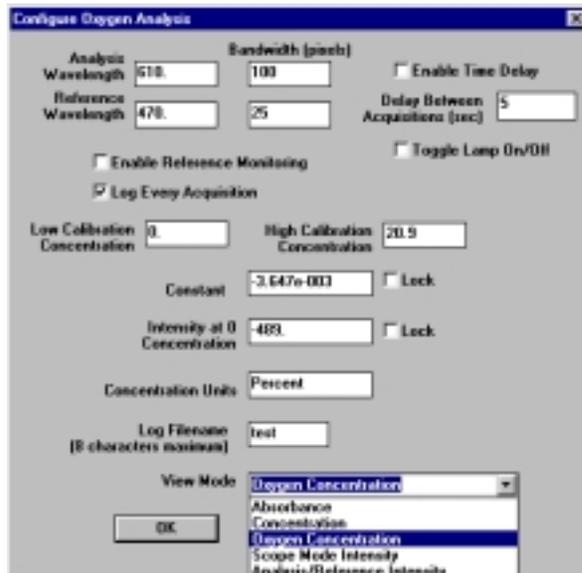
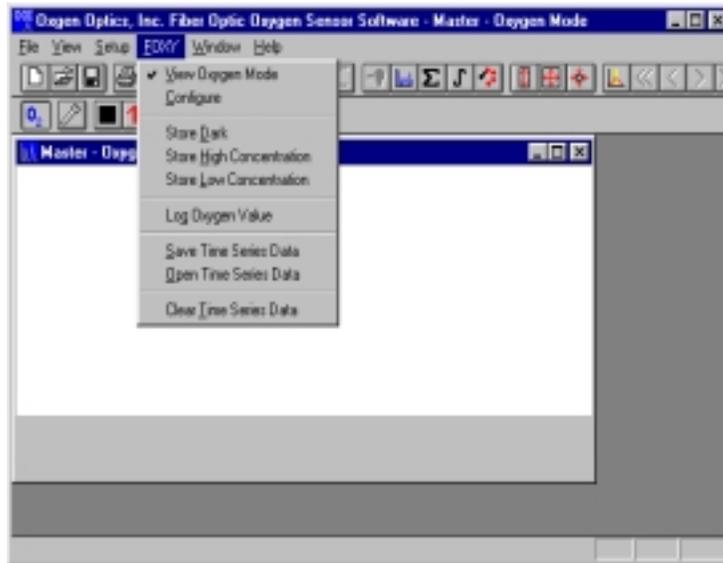
## Saving Oxygen Values

The data in the time series can be logged automatically by activating the log every value checkbox in the O<sub>2</sub> configuration screen. The data will be appended to the file given by FILENAME.log where filename is the character string entered in the text box in the oxygen configuration screen. Data can also be logged on demand by clicking on the log data point icon.

The time series data that is available on screen can be saved all at once by using the Save Time Series Data option in FOXY menu. These time series files can also be viewed in OOIFOXY by using Open Time Series Data.

The time series graph can be reset by choosing Clear Time Series Data. If you open the oxygen parameters screen, and click OK, you will be asked if you would like to reset the times series.

In addition to the Stern-Volmer *Oxygen Concentration* presentation, OOIFOXY can be used to display time series data at the analysis wavelength as *Absorbance*, *Concentration* (Beers Law), *Scope Mode Intensity*, and *Analysis/Reference Intensity* (intensity at analysis wavelength divided by intensity at reference wavelength). These modes are made available for diagnostic purposes, and for using the spectrometer for applications that do not involve an oxygen sensor.



In all cases, the values used for calculating the view are those stored by the Oxygen standard icons. For absorbance, the blank or reference is stored using the up arrow. Dark is stored using the black box icon. For concentration, absorbance is multiplied by the value in the constant text box. This constant should be hand calculated, and entered in the text box. You should also lock the value with the checkbox.

# Appendix I: Useful values for oxygen analysis

## Solubility of Oxygen in Water

$$\ln(X) = a + b/T^* + C \times \ln(T^*)$$

a	-66.7354	X = mole fraction
b	87.4755	T* = T/100 where T is in Kelvin
c	24.4526	

T (C)	T* (T/100K)	pure O2		Air
		Mole Fraction at 1 atmosphere pO2	Weight Fraction (ppm) at 1 atmosphere pO2	Weight Fraction (ppm) at 0.209476 atmospheres pO2
5	2.7815	3.46024E-05	61.46203583	12.87482142
10	2.8315	3.06991E-05	54.52891411	11.42249881
15	2.8815	2.75552E-05	48.94460474	10.25272002
20	2.9315	2.50049E-05	44.41468119	9.303809756
25	2.9815	2.29245E-05	40.71933198	8.529722785
30	3.0315	2.12205E-05	37.69265242	7.895706058
35	3.0815	1.98218E-05	35.20817214	7.375267068
40	3.1315	1.86735E-05	33.16861329	6.948028438

# Appendix II: Changing Base Address & IRQ on the ADC500

The ADC500 is preset to a default base address (768) and IRQ level (7). There may be other devices in your computer which conflict with these settings. Conflicts are manifested by software which hangs up, zeros in spectral data, divide by zero errors or other problems. Diagnosing the source of the conflict is an inexact science, and it is necessary to use a trial & error approach. If you are using Windows 95, click on Start | System | Control Panel, then click on the system icon, click on the device manager tab, click on computer (at the top of the list) and select properties. The used IRQ's and base addresses are listed here.

**Note: You must set both the hardware and the software to change the base address or irq levels.**

To change a setting:

1. Turn off the computer and remove the cover. After grounding yourself to the power supply, unplug the computer.
2. Remove the mounting screw and remove the PC1000 master card.
3. Change the base address or the IRQ level by moving the dip switches as indicated. The base address is set through the bank of 6 dip switches labeled SW1. The IRQ is set through a bank of 4 dip switches labeled SW2.
4. Reinstall the card.
5. Change the software settings to match the hardware settings (see the appropriate software section for instructions).
6. Try running the system.

## Base Address Settings (SW1)

**Example: Default Setting (768 decimal = Hex300 = 0x300)**

	1	2	3	4	5	6
on						
off						

Decimal equivalent	16	32	64	128	256	512
Value as shown					256	512
PC address	A4	A5	A6	A7	A8	A9

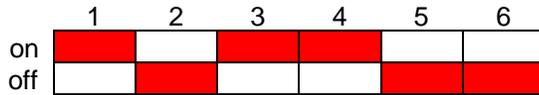
Switches in the OFF position have the decimal values shown. Switches in the ON position have a value of zero. The base address is the sum of the values of the switches. In the above example, switches 5 & 6 are added to give a total of 768. A few of the many combinations are illustrated below.

**Example: (784 decimal = Hex310 = 0x310)**

	1	2	3	4	5	6
on						
off						

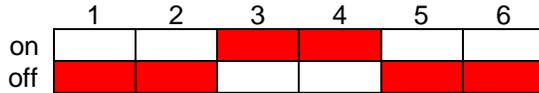
Value as shown	16				256	512
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**Example: (800 decimal = Hex320 = 0x320)**



Value as shown		32			256	512
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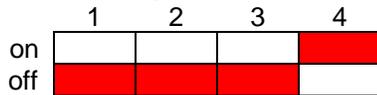
**Example: (816 decimal = Hex330 = 0x330)**



Value as shown	16	32			256	512
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## IRQ Interrupt Level (SW2)

**Example: Default Setting (IRQ = 7)**



IRQ value		3	5	7
Value as shown				7

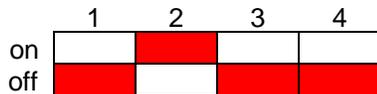
The IRQ level is set using SW2. Set to the ON position only one of the SW2 dip switches. (Note: our service department can modify your PC1000 to operate at a different IRQ level should that become necessary) .

**Example: (IRQ = 5)**



IRQ value		3	5	7
Value as shown			5	

**Example: (IRQ = 3)**



IRQ value		3	5	7
Value as shown		3		

### **Changing Software Settings**

If you changed the hardware switches, you must change the software settings as well.

1. Start the program
2. Select SETUP, CONFIGURE SPECTROMETER. Then choose the appropriate IRQ and/or base address from the dialog box.
3. Exit and Restart the software.

# Appendix III: R-450 Blue LED Light Source

The R-LS-450 Blue LED light source allows the user to utilize all of the built-in features of Ocean Optics S2000 Product line.

## Features

1. Internal 470nm short pass filter (Filter has 50% transmission at 470nm)
2. Pulsed or Continuous (CW) mode operation
3. All features controllable via software.
4. Adjustable focusing SMA connector to maximize light into fiber

## Operating Mode

Three jumpers determine the operating mode of the R-LS-450. These functions are described below:

**JP1 S0 Enable:** If the jumper is present the S0 line of the spectrometer turns the light source on (TTL high) and off (TTL low). This feature is only available with S2000 Rev J or later spectrometers. Defaults to on with revisions prior to J.

**JP3 Remote/Manual Control:** Determines the source of control. A jumper needs to be in either the Remote (software) or Manual.

**JP2 Strobe select:** Determines the LED's pulse frequency at 50% duty cycle. The various frequencies are jumper selectable and are divided down from the Master Clock frequency. If you have an ADC500, it's Master Frequency is 500KHz and thus the "2<sup>10</sup>" position implies this frequency is divided by 1024 (2<sup>10</sup>) or 488Hz. A CW position will turn the source on continuously and the CS position allows for software control of the frequency using the continuous strobe line (available on when using an ADC1000 or PC2000 only).

S1	JP1	JP3	LED Status
off	X	X	Off
CW	out	X	Continuously on
CW	in	Remote	CW mode controlled by software (S0)*
CW	in	Manual	Continuously on
Pulsed	out	X	Pulsing at rate determined by JP
Pulsed	in	Remote	Pulsed mode controlled by software (S0)*
Pulsed	in	Manual	Pulsing at rate determined by JP

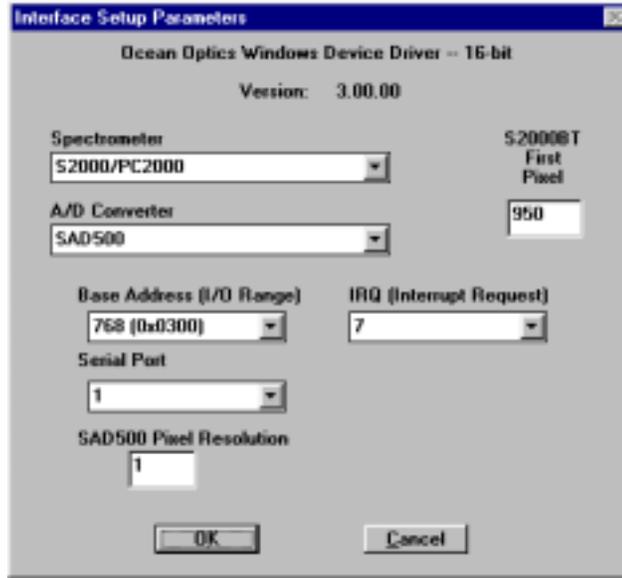
Requires revision J or later S2000 (i.e. J is 3<sup>rd</sup> letter in S2000 serial number)

# Appendix IV: Installation of SAD500

## Hardware Installation

The SAD500 is a microprocessor-controlled Serial Port Interface A/D converter for serial port connection or stand-alone operation. The SAD500 can be used to interface to desktop or portable PCs, PLCs, and other devices that support the RS-232 communication protocol. Interfacing the SAD500 to a desktop or portable PC is simple.

1. If you ordered your SAD500 mounted onto your S2000 spectrometer, simply connect the 6-pin DIN end of the serial cable to the SAD500 and the DB9 end to your PC. Some PCs may require a 9-pin to 25-pin converter (not included). If you ordered your SAD500 in its own housing, attach the 25-pin conductor ribbon cable from the S2000-series spectrometer to the SAD500. Then connect the 6-pin DIN end of the serial cable to the SAD500 and the DB9 end to your PC.
2. For either configuration, note the serial port number (also called COM Port) on the PC to which you are interfacing. (Older PCs may not have numbered ports.)
3. Plug the +12V DC wall transformer into an outlet and connect it to the SAD500.



## Software Installation

The SAD500 requires that you have version 3.00.00 or later of our device driver (OOIDRV16.DLL or OOIDRV32.DLL). You can download the latest version of the driver from our web site at [www.oceanoptics.com](http://www.oceanoptics.com).

### Installing OOIBase (Windows)

1. Insert the OOIBase floppy disk into a floppy drive.
2. Select **Run** and type **(drive):setup**. Click **OK**.
3. Click **OK** at the "Welcome!" dialog box.
4. Select the **Destination Directory**. Choose the default destination or type where you want the software housed. Click **OK**.
5. In the "Make Backups" dialog box, click **YES**.
6. After the software installation is complete, you will go back out to your desktop.
7. Start OOIBase by selecting **Start | Programs | OOIBase V 1.5 | OOIBase V 1.5**.

### The "Interface Setup Parameters" Dialog Box

After selecting OOIBase V 1.5, the "Interface Setup Parameters" dialog box opens. You must specify your hardware configuration in this dialog box.

8. First, choose the S2000/PC2000 option under Spectrometer.
9. Next, choose the SAD500 option under A/D Converter.

10. Under Serial Port, you must specify the same COM port number as the one being used to interface to your SAD500. See the Troubleshooting section for help in determining the COM Port number.
11. The SAD Pixel Resolution parameter specifies that every n<sup>th</sup> pixel of the S2000 is transmitted from the SAD500 to the PC. You can enter resolution values from 1 to 500. Ultimately, your resolution value depends on your experiment. By sacrificing pixel resolution, you gain speed. The transfer of one complete spectra requires ~0.6 seconds when communicating at 57,600 baud rate. If you need your information in <0.6 seconds, increase the pixel resolution. You can always go back to this dialog box by selecting **Setup | Configure Hardware**.
12. For this configuration, only these four parameters apply to your system. Ignore any others and click **OK**.
13. If you do not see the “Interface Setup Parameters” screen when you start OOIBase, exit OOIBase by selecting **File | Exit**. Then select **Start | Run**, and type **C:\windows\ooidrv.ini**. This will open Notepad and allow you to edit the initialization file for our device driver. Find the “Initialized” entry within this file. Make sure this line reads: **Initialized=0**. Save the OOIDRV.INI file and exit Notepad. Restart OOIBase. You should now see the “Interface Setup Parameters” dialog box allowing you to specify your hardware configuration.
14. At this point, OOIBase (or other Ocean Optics software) should be acquiring data from your spectrometer. There should be a dynamic trace responding to light near the bottom of the displayed graph. If your spectrometer is not responding to light, please contact our Technical Support Department.

## Troubleshooting

Occasionally, there will be problems associated with your PC configuration and the software. Here are a few tips to assist you.

- To ensure that the software and hardware are in-synch, exit OOIBase, cycle power on the SAD500 and restart OOIBase.
- In Windows 95 and Windows 98, you can find out your Serial Port number by selecting **Start | Settings | Control Panel**. Then double-click on the **System** icon and select the **Device Manager** tab. Double-click on **Ports (COM & LPT)** and this will display the COM port numbers. Ensure that there is no yellow warning sign next to the COM Port you are attempting to use.
- If the ports on your PC are not labeled and you don't know which COM port you are using for your SAD500, you may have to resort to trial and error. If you choose the wrong serial port number, you will not see a dynamic trace responding to light near the bottom of the displayed graph (see step 14). Instead, you will see a straight line.
- The default baud rate is 57,600. If your computer is not capable of communicating at this speed, select **Start | Run**, and type **C:\windows\ooidrv.ini**. This will open Notepad and allow you to edit the initialization file for our device driver. Find the “SerialPortBaudIndex=5” line and change it to a value your PC supports. Notes just above this line on your screen describe your options. Save the OOIDRV.INI file, exit Notepad and restart OOIBase. (Use of the 115,200 baud rate is prone to errors and not recommended in a multitasking environment.)
- The 16-bit communication library requires approximately 3 seconds to completely close communications with the SAD500, and the 32-bit communications library requires 6 seconds. If you exit OOIBase and try to restart without allowing enough time to transpire, conflicts will occur. The best solution at this point is to restart Windows and then run OOIBase.
- On some computers, users may have to disable any virus protection software to ensure timely and complete transfer of the data.

# Technical Support

For immediate technical assistance, please contact us via e-mail at [TechSupport@OceanOptics.com](mailto:TechSupport@OceanOptics.com). Our application engineers will be glad to assist you.

## Watch for Free Updates!

The OOIFOXY software will be continuously updated and improved. You are entitled to free updates until a completely new version is released. Download the latest version at [www.oceanoptics.com](http://www.oceanoptics.com). See the back of your Software and Resources Library CD for the password.

For more information, please contact Ocean Optics, Inc. via one of the methods below:

Ocean Optics, Inc.  
380 Main Street  
Dunedin, FL 34698  
(727) 733-2447  
(727) 733-3698 (FAX)

[Info@OceanOptics.com](mailto:Info@OceanOptics.com)  
[TechSupport@OceanOptics.com](mailto:TechSupport@OceanOptics.com)  
<http://www.OceanOptics.com>