FOXY Fiber Optic Oxygen Sensor Systems Manual

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Introduction

Ocean Optics -- a full service provider of photonics solutions -- offers the FOXY Fiber Optic Oxygen Sensor system. When connected to our miniature fiber optic spectrometers and compact excitation sources, the FOXY system measures the partial pressure of oxygen in real time. Six different fiber optic fluorescence probes -- ranging from probes for process applications to slender fibers for sampling sediments to needle probes for penetrating vial septa -- provides users with just the right system for their oxygen sensing application.

Our FOXY Sensor systems are helping to usher in a new generation of low-cost, portable chemical-sensing devices. Thanks to innovation in the development of various chemical-sensing complexes -- particularly those with fluorescing properties -- products such as the FOXY Sensor system will continue to provide viable alternatives to traditional chemical-sensing devices such as electrodes. Indeed, the use of optical-sensing methods lessens the reliance on the occasionally electrochemical technologies that have dominated the field of oxygen sensing for many years.

But the chemical-sensing side of FOXY Sensors is only part of the equation. There are two other components of the system that are equally important: the spectrometer and the PC interface. In fact, one of the reasons that a FOXY Sensor can use a fluorescence method is that the spectrometer to which the probe is attached is sensitive enough to detect low light levels. Add a compact LED to excite the probe coating, and you have a very attractive system. Transfer your data to a PC via an analog-to-digital converter, and signal processing becomes as sophisticated as the special software that comes with the system.
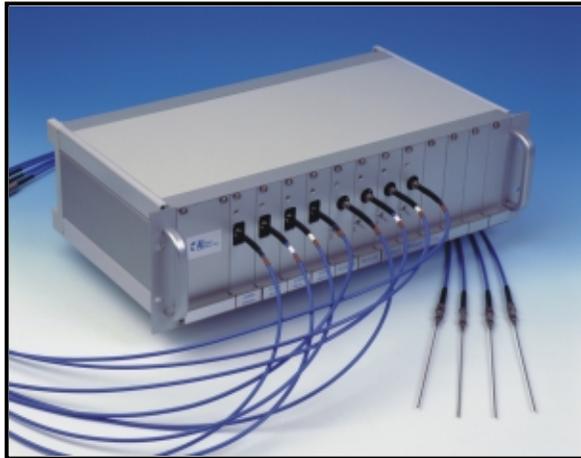
The FOXY Sensor system will change the way you work. Because the probe does not consume oxygen -- it can be in continuous contact with viscous samples such as foods, pharmaceuticals and biologicals -- constant stirring is no longer required. Now that there is an alternative to the oxygen electrode, changing membranes and filling solutions can be avoided. Because there is no membrane, the probe works in organic solvents and does not experience drift. And unlike electrodes, frequent calibrations are unnecessary, so the probe can be deployed for longer times. The FOXY Sensors are not affected by electrical interference or interference caused by pH change, ionic strength, salinity or biofouling. Below is a list of advantages of our oxygen sensing system compared to commercial electrodes.

Key Features of FOXY Sensor Systems	FOXY Systems vs. Commercial Electrodes
FOXY measures both oxygen gas and dissolved oxygen in gases and liquids.	Most electrodes are designed for use in gas *or* liquids, but not both media.
FOXY is immune to environmental changes in pH, salinity and ionic strength.	Polarographic electrodes can be affected by changes in pH, salinity and ionic strength of the environment.
FOXY is immune to interference from moisture, carbon dioxide, methane and other substances.	Electrochemical electrodes are subject to interference from a number of substances and sampling conditions.
FOXY has fast response time -- <1 second for dissolved oxygen and oxygen gas.	Electrodes can have a response time of 1-1.5 *minutes*, depending on temperature.
FOXY has a long life -- more than 1 year.	Electrodes have a typical lifetime of just 3 months.
FOXY does not consume oxygen, allowing for continuous contact with the sample.	Electrodes can consume oxygen of ~0.1 micrograms/hour.
Frequent calibration is unnecessary.	Calibration may be necessary on an hourly basis.
FOXY probe temperature range is -60° C to +120° C.	The temperature range for some electrodes is 0-45° C.

FOXY Sensor systems are the first of many potential optical-sensing devices for chemical analysis. In fact, its development supports the notion that optical-sensing instruments may soon replace traditional methods of chemical sensing for many applications -- a trend with major consequences for the analytical instrumentation market, especially in process control.

Documentation

With your FOXY Fiber Optic Oxygen Sensing system, you are sent important information and documentation regarding your instrument. They include the following:

Packing List

A packing list comes with your order. It is located inside a plastic bag attached to the outside of the shipment box. The invoice is mailed separately. The items listed on your packing slip include all of the components in your order, some of which are items you have specified to be installed into your spectrometer, such as the grating, detector collection lens and slit. The packing list also includes important information such as the shipping and billing addresses as well as components on back order.

Wavelength Calibration Data Sheet and File

Your spectrometer is shipped in a silver-gray anti-static bag. Also inside this bag is a Wavelength Calibration Data Sheet wrapped around a Spectrometer Configuration diskette. The information on the Data Sheet and in the file on the diskette is identical and is unique to your spectrometer. When you install OOISensors Software onto a PC, you will need to enter values from the Wavelength Calibration Data Sheet into the software. Once OOISensors is installed, select **Configure | Spectrometer** from the menu. Then select the **Sensors** tab. Make sure that the values in this dialog box under **Wavelength Calibration Coefficients** are the same as the values on the Wavelength Calibration Data Sheet. Be sure to retain the Data Sheet. (If you have a USB2000-series spectrometer, you will not need to manually enter the Wavelength Calibration Coefficients. The software will retrieve these values directly from a memory chip on the spectrometer.)

Software and Resources Library CD

Your spectrometer order comes with our *Software and Resources Library* CD. It contains all Ocean Optics software and manuals for operating our software, spectrometers and spectroscopic accessories. All manuals and operating instructions on the CD are in Portable Document Format (PDF), which means that you need to have Adobe Acrobat Reader to view them. We have included Adobe Acrobat Reader 4.0 on the CD and we recommend installing it on your PC for the finest viewing quality.

Except for OOIBase32 Spectrometer Operating Software, all Ocean Optics software is password protected. OOISensors Software is free with your FOXY system but is password protected. The password for the software can be found on the back of the *Software and Resources Library* CD jewel case.

Components in your FOXY System

The FOXY Fiber Optic Oxygen Sensor system consists of several modular components, which together comprise a rugged oxygen sensing package. A FOXY sensor consists of a probe with ruthenium complex in a sol-gel substrate on its tip. The sensor is connected to an excitation source and a spectrometer, which interfaces to your PC via an A/D converter. Specifically, each FOXY system requires the following components:

♦ a fiber optic fluorescence probe with proprietary oxygen-sensing thin-film coating on its tip,
♦ a miniature fiber optic spectrometer,
♦ a pulsed blue LED as the excitation source,
♦ a bifurcated optical fiber assembly with splice bushing that connects the probe to the spectrometer and the LED,
♦ an A/D converter that interfaces the spectrometer to your PC, and
♦ OOISensors Software to control the excitation source, process spectra and display and save data.

Ocean Optics' Application Scientists have configured a system that fits your application. Perhaps you have a one-channel system or you have multiple spectrometer channels, probes and LED light sources. The spectrometer you specified might be part of a kit or it might have been custom configured. Perhaps the probe you chose is for penetrating vial septa or for sampling sediments. The A/D converter you selected might install into your PC or connect to your PC via a serial cable. Whatever components you specified, the system operates virtually the same. The following list briefly describes the many different oxygen sensing components available to the user.

Probes

There are seven available oxygen probes. The distal tip of each probe is polished and coated with the oxygen-sensing material. The proximal end of each probe has an SMA 905 fitting for coupling to the optical cables.

FOXY-R   1000-μm core diameter stainless steel optical fiber, 1/16" outer diameter stainless steel tube beveled at 45°, approximately 6" in length, designed to couple to a 600 μm bifurcated fiber and splice bushing

FOXY-AL300   300-μm aluminum jacketed fiber optic probe, 1 m in length, designed to couple to a 200 μm bifurcated fiber and splice bushing

FOXY-PI600   600-μm polyimide coated fiber optic probe, 2 m in length, designed to couple to a 400 μm bifurcated fiber and splice bushing

FOXY-24G   300-μm aluminum jacketed fiber optic probe with 24-gauge needle tip for penetrating vial septa, designed to couple to a 200-μm bifurcated fiber and splice bushing

FOXY-OR125   1000-μm core diameter stainless steel fiber optic probe, 1/8" outer diameter, 2.5" in length, designed to couple to a 600-μm bifurcated fiber and splice bushing (direct replacement for 1/8" diameter oxygen electrodes)

FOXY-OR125G   1000-μm core diameter stainless steel fiber optic probe, 1/8" outer diameter, O-ring groove at tip, 2.5" in length, designed to couple to a 600-μm bifurcated fiber and splice bushing (direct replacement for 1/8" diameter oxygen electrodes)

FOXY-T1000   1000-μm core diameter stainless steel fiber optic probe with screw-on light shield, 1/4" outer diameter, approximately 7" in length, designed to couple to a 600-μm bifurcated fiber and splice bushing

Overcoats

The following silicone overcoats exclude ambient light, improve chemical resistance and eliminate refractive index effects. *A silicone overcoat is required for applications involving liquids or gas-to-liquid activity.*

FOXY-AF   RTV healthcare-grade silicone overcoat for FOXY probes

FOXY-AF-MG   RTV high-strength medical implant-grade silicone overcoat for FOXY probes (provides a thicker and stronger coating than the FOXY-AF)

Temperature Compensating Components

Because FOXY probes are temperature dependent, temperature electrodes can be used in conjunction with FOXY probes to compensate for temperature effects. Below are descriptions of the three temperature probes that Ocean Optics offers:

FOXY-TK1   Omega K-type Thermocouple has 1/8" outer diameter, temperature range of -150° C to 220° C with accuracy of 2.2° C or 0.75% of reading with precision of 1° C (requires FOXY-T-MOD-K module for data acquisition and 10-foot wire)

FOXY-TS1   Omega Thermistor has 1/8" outer diameter, temperature range of 0° C to 100° C with accuracy of 0.1° C with precision of 0.01° C (requires FOXY-T-MOD-1 module for data acquisition)

FOXY-TK-1-W   K-type Wire Thermocouple with exposed end has temperature range of -150° C to 220° C with accuracy of 2.2° C or 0.75% of reading with precision of 1° C (requires FOXY-T-MOD-K module for data acquisition)

Sol-Gel Coated Membranes and Microscope Coverslips and Slides

Our sol-gel oxygen-sensitive film can be applied to any glass substrate, including membranes, microscope coverslips and microscope slides. We also can apply the oxygen-sensitive film to other products, such as cuvettes and micro-well plates. Below is a list of off-the-shelf products that are coated with the sol-gel.

FOXY-GF   Sol-gel coated glass fiber membranes (pack of 5) for testing viability of reactive material; useful in evaluating membrane-holding probes

FOXY-SGS   1" x 1" sol-gel coated, microscope glass coverslips (pack of 5) for qualitative feasibility testing

FOXY-SGS-M   1" x 3" sol-gel coated microscope slide for testing viability of reactive material when used with microscopes

Spectrometers

The spectrometer you selected for your FOXY system is optimized for low light level applications. A bifurcated fiber connects to the spectrometer. One end of the fiber connects to the light source; the other end connects to the sensor. (Some setups have the LS-450 built on top of and wired to the spectrometer.) Below are three popular spectrometers configured for oxygen sensing.

S2000-FL   Comes with Grating #3, wavelength range of 360-900 nm, a 200-μm slit, and an L2 collection lens (LS-450 Blue LED Light Source is separate)

SF2000   Comes with Grating #3, wavelength range of 360-900 nm, a 200-μm slit, and an L2 collection lens (LS-450 Blue LED Light Source is built on top of and wired to the spectrometer)

USB2000-FL   Comes with Grating #3, wavelength range of 360-900 nm, a 200-μm slit, and an L2 collection lens (USB-LS-450 Blue LED Light Source, which snaps onto the front of the spectrometer, is separate)

A/D Converters

All Ocean Optics spectrometers interface to a PC via an A/D converter. Typically, the A/D converter chosen depends on the converter's performance characteristics, the kind of PC to which it will connect, what type of operating system the PC uses, and in what way you want to interface your spectrometer to your PC.

ADC1000   ISA-bus A/D card with 1 MHz sampling frequency, 12-bit, 8-channel single-ended, half-length card fits into a slot in a desktop PC

SAD500   Microprocessor-controlled Serial Port Interface has 500 kHz sampling frequency for interfacing the spectrometer to a desktop or notebook PC (because of its microprocessor, the SAD500 can be connected to a device supporting the RS-232 communications protocol, such as a PLC)

DAQ700   PCMCIA A/D card with 100 kHz sampling frequency for interfacing the spectrometer to a notebook PC; fits into credit-card size slot in notebook PC

USB Connect   For USB2000 spectrometer users, the A/D converter has been installed onto the spectrometer itself and is not a separate component; a USB cable connects the spectrometer to a PC with the Windows 98/2000 operating system

LS-450 Blue LED Light Source

The LS-450 Blue LED Light Source is a compact, low-cost light-emitting diode that produces either pulsed or continuous spectral output at 470 nm -- the blue region -- for fluorescence measurements. The LS-450 Blue LED is specially designed for use with the oxygen sensor.

LS-450   Blue LED Pulsed Light Source with cable for external connection to spectrometer

R-LS-450   Blue LED Pulsed Light Source mounted on top of and wired to the spectrometer

Bifurcated Optical Fiber Assemblies and Splice Bushing

Our bifurcated fiber optic assemblies easily connect to our sensors, light sources and miniature fiber optic spectrometers via SMA terminations and an additional splice bushing. These single-strand optical fibers are silica-core and silica-clad. Standard assemblies are 2 meters in length.

BIF200-VIS/NIR 200-µm bifurcated optical fiber assembly (for use with FOXY-AL300 and FOXY-24G probes)

BIF400-VIS/NIR 400-µm bifurcated optical fiber assembly (for use with FOXY-PI600 probe)

BIF600-VIS/NIR 600-µm bifurcated optical fiber assembly (for use with the FOXY-R, FOXY-OR125, FOXY-OR125G and the FOXY-T1000 probes)

21-02 SMA splice bushing for connecting a FOXY probe to a bifurcated optical fiber assembly

OOISensors Software

OOISensors Software is our next generation of operating software for our FOXY Fiber Optic Oxygen Sensing systems. OOISensors is a 32-bit, advanced acquisition and display program that provides a real-time interface to a variety of signal-processing functions for Windows 95/98/2000/NT users.

Getting Started

The three pages in this section provide *brief* instructions on setting up your system, installing your A/D converter, installing and configuring the software, and connecting sampling optics. If you prefer step-by-step directions for setting up and operating any part of your system, check the Table of Contents to find specific instructions on a component. The steps in this section are as follows:

    Step 1: Interface the A/D Converter to your PC

    Step 2: Install OOISensors Software

    Step 3: Set Up the Sampling Optics

    Step 4: Configure OOISensors Software

    Step 5: Calibrate the System

    Step 6: Take Measurements

A complete FOXY system in one box: temperature regulated spectrometer, LS-450 Blue LED, FOXY-TK1 Thermocouple and a FOXY-R probe

Step 1: Interface the A/D Converter to your PC

An analog-to-digital (A/D) converter is a device that converts a continuously varying (analog) signal, such as voltage, from a monitoring instrument to binary code for use by a computer. An A/D converter is necessary to interface your spectrometer to your PC. (For detailed instructions on A/D converters, see pages 29-40.)

If you are using a USB200 Plug-and-Play Spectrometer
Because the USB2000 has an A/D converter built onto the spectrometer, it does not require an external A/D card. Go to Step 2: Install OOISensors Software.

If your A/D converter is the ADC1000
1. The default settings for our A/D products are a Base Address (or Input/Output Range) of 768 decimal and an IRQ of 7. You will need to match Base Address and IRQ settings on the A/D card to available settings in your computer. First, determine which settings are not being used by other hardware devices.
   ♦ If you have Windows 95/98, go to **Start | Settings | Control Panel**. Double-click the **System** icon. Choose the **Device Manager** tab and double-click on "Computer" at the top of the list of devices. Under **View Resources**, note available settings -- numbers unassigned to hardware. Select the **IRQ** button. Find an available IRQ. Select the **I/O Port** button. Find an available I/O Range (Base Address). Remember that these I/O settings are expressed in hexadecimal and correspond to our Base Address, which is given in decimal, followed by the hexadecimal equivalent in parenthesis.
   ♦ If you have Windows NT, go to **Start | Programs | Administrative Tools (Common) | Windows NT Diagnostics**. Click on the **Resources** tab. Select the **IRQ** button. Find an available IRQ. Select the **I/O Port** button. Find an available I/O Range (Base Address).
   ♦ If you have Windows 2000, **Start | Programs | Accessories | System Tools | System Information**. In the left column, click on **Hardware Resources** and then click on the **I/O** folder. All Input/output Ranges (Base Addresses) being used by your computer appear in the right column. Find an available I/O Range (Base Address). Click on the **IRQs** folder. Find an available IRQ.
2. **Note these available settings.** When you first run OOISensors, you must enter these values in the "Configure Hardware" dialog box.
3. Turn off the computer and take off the computer cover. Ground yourself to the computer chassis or power supply and remove the A/D card from its static-shielded bag.
4. If necessary, change the position of the switches on the A/D board. There is only one bank of switches on the A/D board: the Base Address may be changed via the first 6 switches and the IRQ may be changed via the last 3 switches. (See **Appendix C** on page 68 for switch positions.)
5. Insert the A/D card into an ISA-bus slot and connect the necessary cables from the A/D card to the spectrometer. Make sure the connections are snug and restart your computer.

If your A/D converter is the DAQ-700

1. Install NI-DAQ version 6.7 CD Driver Software -- the device driver library necessary for Windows 95/98/2000 and NT systems to properly use the DAQ-700 on your computer.
2. Insert the DAQ-700 into any available PCMCIA slot.
3. Find the IRQ and Base Address values.
   - ♦ If you have Windows 95/98, select **Start | Settings | Control Panel**. Double-click the **System** icon. Select the **Device Manager** tab. Double-click the hardware group named **Data Acquisition Devices**. Double-click **DAQCard-700**. Click the **Resources** tab. Find the check box next to **Use Automatic Settings**. Clear that check box (deselect it). Now change the settings for either (or both) the **Input/Output Range** or the **Interrupt Request**. To make this change, double-click either **Input/Output Range** or **Interrupt Request**. A dialog box giving the current hardware setting appears. Use the two small arrows to the right side of the **Value** box to change the hardware interface parameters. Choose values that say **No devices are conflicting**. Click **OK**. Click **Yes** at the "Creating a Forced Configuration" message box.
   - ♦ If you have Windows NT, go to **Start | Programs | Administrative Tools (Common) | Windows NT Diagnostics**. Click on the **Resources** tab. Select the **IRQ** button. Find the IRQ that your computer assigned to the A/D converter. Select the **I/O Port** button. Find the I/O Range (Base Address) that your computer assigned to the DAQ-700.
   - ♦ If you have Windows 2000, right click on the **My Computer** icon. Select **Properties** and click on the **Hardware** tab. Click on the **Device Manager** button. Select **Data Acquisition Devices**. Double-click **DAQCard-700**. Click the **Resources** tab. Find the check box next to **Use Automatic Settings**. Clear that check box (deselect it). Now change the settings for either (or both) the **Input/Output Range** or the **Interrupt Request**. To make this change, double-click either **Input/Output Range** or **Interrupt Request**. A dialog box giving the current hardware setting appears. Use the two small arrows to the right side of the **Value** box to change the hardware interface parameters. Choose values that say **No devices are conflicting**. Click **OK**. Click **Yes** at the "Creating a Forced Configuration" message box.
4. **Note these values.** When you first run OOISensors, enter them in the "Configure Hardware" dialog box.

If your A/D converter is the SAD500

If your A/D converter is the SAD500 and is mounted onto the spectrometer, connect the cable from the SAD500 to your PC. If you ordered your SAD500 in its own housing, attach another cable from the spectrometer to the SAD500. Note the serial port number (also called COM Port) on the PC to which you are interfacing. Plug the +12VDC wall transformer into an outlet and connect it to the SAD500.

Step 2: Install OOISensors Software

Before installing OOISensors Software, make sure that no other applications are running.
1. Locate the *Ocean Optics Software and Resources Library* CD. Retain the CD jewel case, as the password for downloading OOISensors is on the back of the jewel case. (During installation, you will have to enter the password.) Insert the CD into your CD-ROM drive. At the opening display window, read the **Before You Begin** section and follow the directions. Select **Install Additional Software**. Choose **Application Software**. Select **OOISensors Software**.
2. At the "Welcome" dialog box, click **Next>**.
3. At the "Destination Location" dialog box, you can choose Browse to pick a destination. Click **Next>**.
4. At the "Backup Replaced Files" dialog box, select either Yes or No. We recommend selecting **Yes**. If you select Yes, you can choose Browse to pick a destination directory. Click **Next>**.
5. Select a Program Manager Group. Click **Next>**. At the "Start Installation" dialog box, click **Next>**.
6. At the "Installation Complete" dialog box, choose **Finish>**. When prompted to do so, restart your computer.

Step 3: Set Up the Sampling Optics

Connect your probe to the bifurcated optical fiber assembly that came with your system. For specific directions on operating the probes, see pages 14-22.
1. Locate the 21-02 SMA Splice Bushing that came with your system. It is a 0.75" screw with 2 female ends.
2. Screw one end of the splice bushing into the SMA 905 connector on the proximal end of your FOXY probe.
3. Locate the bifurcated fiber that came with your system.
4. The bifurcated fiber has a Y design. Connect the common end of the bifurcated fiber to the splice bushing/probe.
5. Connect one arm of the bifurcated fiber to the SMA connector on the spectrometer and connect the other arm to the SMA connector on the LS-450 Blue LED light source. It does not matter which arm of the fiber is connected to the light source or spectrometer.

Step 4: Configure OOISensors Software

After you restart your computer, navigate to the OOISensors icon on your computer and select it. Now that your A/D converter and software have been installed, you need to enter settings in the software. (For details on all of the functions and features of OOISensors, refer to pages 46-64.)

Configure Hardware Dialog Box

Once the software is open, select **Configure | Hardware** from the menu. The parameters in this dialog box are usually set only once -- when OOISensors is first installed and the software first opens. (For detailed instructions on using this dialog box, refer to the page 51.)
1. Select the **Spectrometer Type**. (The S2000-FL, SF2000 and USB2000 are S2000-series spectrometers.)
2. Select the **A/D Converter Type** you are using to interface your spectrometer to your computer. Your choices are the ADC500/PC1000, ADC1000/PC2000, DAQ700, SAD500, Serial USB2000, USB2000 or NONE.
3. Select parameters for your A/D converter:
    ♦   For ADC1000 and DAQ700 users: In **Step1: Interface the A/D Converter to your PC** you were asked to remember an available **Base Address** and **IRQ**. Select these values from the drop down menus.
    ♦   For SAD500 and Serial USB2000 users: Enter your computer's **Serial Port** or COM port number to which the SAD500 is connected. Select the **Baud Rate** or speed at which the SAD500 will operate. Enter a **SAD500 Pixel Resolution**, which specifies that every nth pixel of the spectrometer is transmitted from the SAD500 to the PC. (This option does not appear for Serial USB2000 users.) Enable the **Compressed Data** function to minimize the amount of data transferred over the RS-232 connection.
    ♦   For USB2000 users: Select the **USB2000 Serial Number** for the USB2000 you wish to use.

Configure Spectrometer Dialog Box

Choose **Configure | Spectrometer** from the menu to select the operation parameters for your system. Go through each page of this dialog box to select options for setting sensor and timing parameters and for displaying and logging data. (For detailed information on each page of this dialog box, see pages 51-54.)

Configure Parameters from the Display Window

Several functions are accessed not through the menu but through buttons and taskbars directly on the display window, on the top and to the right of the graph and chart areas. From the display window, you can choose a mode to acquire data, take scans of your sample, store a dark spectrum, configure the cursor, configure the graph, enter data acquisition parameters, and analyze displayed data. For detailed information about the functions in the display window, see pages 47-49.
1. Set the **Integ. Time**. The higher the integration time, the longer the detector "looks" at the incoming photons. If the intensity is too low, increase this value. If too high, decrease the value. Set the integration time to powers of 2 (for example: 4, 8, 16, 32, 64, 128, 256, 512, etc.).
2. Set the **Average** value. Enter a value to implement a sample averaging function.
3. Set the **Boxcar** smoothing value. Enter a value here to implement a technique that averages across spectral data. We recommend setting the boxcar smoothing value to no more that 25 pixels.
4. Click **Scan** to view spectra in graph.

Step 5: Calibrate Your Sensor

In order to make accurate oxygen measurements of your sample, you must first perform a calibration procedure with your FOXY system. Two major factors affect the calibration procedure of your FOXY system.
1. First, decide if you are going to compensate for changes in temperature in your sample.
2. Next, choose the algorithm you wish to use for your calibration procedure. The **Linear (Stern-Volmer)** algorithm requires at least two standards of known oxygen concentration while the **Second Order Polynomial** algorithm requires at least three standard of known oxygen concentration. The Second Order Polynomial algorithm provides more accurate data, especially when working in a broad oxygen concentration range.

Once you have decided on these two issues, perform one of the calibration procedures found on pages 60-64.

Step 6: Take your Measurements

By now you have set up your spectrometer and sampling optics, established your acquisition parameters and calibrated your sensor. Now you are ready to take your measurements.

Theory of Operation

How it Works

FOXY Fiber Optic Oxygen Sensors use the fluorescence of a ruthenium complex in a sol-gel to measure the partial pressure of oxygen:

1. The pulsed blue LED sends light, at ~475 nm, to an optical fiber.
2. The optical fiber carries the light to the FOXY probe. The distal end of the probe tip consists of 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.
3. The light from the LED excites the ruthenium complex at the probe tip.
4. The excited ruthenium complex fluoresces, emitting energy at ~600 nm.
5. If the excited ruthenium complex encounters an oxygen molecule, the excess energy is transferred to the oxygen molecule in a non-radiative transfer, decreasing or quenching the fluorescence signal (see Fluorescence Quenching below). The degree of quenching correlates to the level of oxygen concentration or to oxygen partial pressure in the film, which is in dynamic equilibrium with oxygen in the sample.
6. The energy is collected by the probe and carried through the optical fiber to the spectrometer. The A/D converter converts this analog data to digital data your PC can understand. This data is then displayed in your OOISensors Software.

Fluorescence Quenching

Oxygen as a triplet molecule is able to quench efficiently the fluorescence and phosphorescence of certain luminophores. This effect (first described by Kautsky in 1939) is called "dynamic fluorescence quenching." Collision of an oxygen molecule with a fluorophore in its excited state leads to a non-radiative transfer of energy. The degree of fluorescence quenching relates to the frequency of collisions, and therefore to the concentration, pressure and temperature of the oxygen-containing media.

Calibration

In order to make accurate oxygen measurements of your sample, you must first perform a calibration procedure with your FOXY system. Two major factors affect the calibration procedure of your FOXY system.

1. First, decide if you are going to compensate for changes in temperature in your sample. If you are working with a sample where there are no fluctuations in temperature, you do not need to compensate for temperature.
2. Next, choose the algorithm you wish to use for your calibration procedure. The **Linear (Stern-Volmer)** algorithm requires at least two standards of known oxygen concentration while the **Second Order Polynomial** algorithm requires at least three standard of known oxygen concentration.

Calibration curves are generated from your standards and the algorithms to calculate concentration values for unknown samples. The Second Order Polynomial algorithm provides a better curve fit and therefore more accurate data during oxygen measurements, especially when working in a broad oxygen concentration range.

Linear (Stern-Volmer) Algorithm

The Stern-Volmer algorithm requires at least two standards of known oxygen concentration. The first standard must have 0% oxygen concentration and the last standard must have a concentration in the high end of the concentration range in which you will be working. The fluorescence intensity can be expressed in terms of the Stern-Volmer equation where the fluorescence is related quantitatively to the partial pressure of oxygen:

$$\frac{I_0}{I} = 1 + k\, p_{O2}$$

I_0 is the intensity of fluorescence at zero pressure of oxygen,
I is the intensity of fluorescence at a pressure p of oxygen,
k is the Stern-Volmer constant

For a given media, and at a constant total pressure and temperature, the partial pressure of oxygen is proportional to oxygen mole fraction.

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

If you decide to compensate for temperature, the relationship between the Stern-Volmer values and temperature are defined as:

$$I_0 = a_0 + b_0 * T + c_0 * T^2$$
$$k = a + b * T + c * T^2$$

The *intensity of fluorescence at zero pressure of oxygen (I$_0$)* depends on details of the optical setup: the power of the LED, the optical fibers, loss of light at the probe due to fiber coupling, and backscattering from the sample. It is important to measure the *intensity of fluorescence at zero pressure of oxygen (I$_0$)* for each experimental setup.

It is evident from the equation that the sensor will be most sensitive to low levels of oxygen. Deviations from the Stern-Volmer relationship occur primarily at higher oxygen concentration levels. Using the Second Order Polynomial algorithm when calibrating corrects these deviations.

Second Order Polynomial Algorithm

The Second Order Polynomial algorithm requires at least three standards of known oxygen concentration. The first standard must have 0% oxygen concentration and the last standard must have a concentration in the high end of the concentration range in which you will be working. The Second Order Polynomial algorithm is considered to provide more accurate data because it requires at least three known concentration standards while the Linear (Stern-Volmer) algorithm requires a minimum of two known concentration standards. The Second Order Polynomial algorithm is defined as:

$$\frac{I_0}{I} = 1 + K_1 * [O] + K_2 * [O]^2$$

I_0 is the fluorescence intensity at zero concentration
I is the intensity of fluorescence at a pressure p of oxygen,
K_1 is the first coefficient
K_2 is the second coefficient

If you decide to compensate for temperature, the relationship between the Second Order Polynomial algorithm and temperature are defined as:

$$I_0 = a_0 + b_0 * T + c_0 * T^2$$
$$K_1 = a_1 + b_1 * T + c_1 * T^2$$
$$K_2 = a_2 + b_2 * T + c_2 * T^2$$

Henry's Law

It is possible to calibrate the FOXY system in gas and then use the FOXY system in liquid or vice versa. In theory, your FOXY system detects the partial pressure of oxygen. In order to convert partial pressure to concentration, you can use Henry's Law. When the temperature is constant, the weight of a gas that dissolves in a liquid is proportional to the pressure exerted by the gas on the liquid. Therefore, the pressure of the gas above a solution is proportional to the concentration of the gas in the solution. The concentration (mole %) can be calculated if the absolute pressure is known:

Oxygen mole fraction = oxygen partial pressure / absolute pressure

Since the FOXY system detects partial pressure of oxygen, the response in a gas environment is similar to a liquid environment in equilibrium with gas. Therefore, it is possible to calibrate the FOXY system in gas and then use the system with liquid samples and vice versa if you utilize Henry's Law.

However, Henry's Law does not apply to gases that are extremely soluble in water. The following information illustrates the solubility of oxygen in water at different temperatures.

$$\ln(X) = a + b/T* + c\ln(T*)$$

Temperature range: 0° C - 75° C
X = mole fraction
$T*$ = T/100 in Kelvin
a -66.7354
b 87.4755
c 24.4526

T (C)	T* (T/100K)	Mole Fraction of oxygen in water at 1 atmosphere pO2	Weight Fraction (ppm) at 1 atmosphere pO2 (pure O2)	Weight Fraction (ppm) at 0.209476 atmospheres pO2 (Air)
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

Temperature

Temperature affects the fluorescence decay time, the fluorescence intensity and the collisional frequency of the oxygen molecules with the fluorophore -- and therefore, the diffusion coefficient of oxygen. Temperature also affects the solubility of oxygen in samples. The net effect of temperature fluctuations is seen as a change in the calibration slope. It is best to maintain the sample at a constant (+/-3° C*) temperature. If this is not practical, then you should calibrate your FOXY system by using the temperature compensation features and measuring temperature and oxygen concurrently. To monitor the temperature of the sensing environment and compensate for temperature fluctuations, temperature electrodes can now be used in conjunction with the FOXY probe. (Optional thermistor and K-type thermocouple accessories are available.) OOISensors Software corrects for changes in data due to temperature fluctuations.

* Though Ocean Optics miniature spectrometers are
    extremely sensitive, temperature fluctuations
    +/-3° C cannot be detected by the spectrometer.

Scattering Media

Florescence emissions from the ruthenium complex propagate in all directions. In clear media, only those emissions propagating toward 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 the intensity of the fluorescence at a pressure of oxygen and the intensity of fluorescence at zero pressure of oxygen, but will not affect the Stern-Volmer constant. For this reason, it is necessary to measure the intensity of fluorescence at zero pressure of oxygen in the sample. Also, if you are measuring oxygen in highly scattering media, then the standards you use for your calibration procedure should be in the same media as your sample for the most accurate results.

FOXY Oxygen Sensing Probes

The following general information applies to all of the FOXY probes. For operating and handling procedures and specifications for each probe, see pages 16-21.

Probe construction
The standard FOXY probe has its distal tip polished and coated with the oxygen-sensing material. The active material used for the FOXY probe coating is a sub-micron thin-glass film with an immobilized ruthenium organic complex. The material is applied as a thin film to glass substrates such as optical fibers. The proximal end of the FOXY probe has an SMA 905 termination for coupling to a bifurcated fiber optic assembly.

Accuracy
The accuracy of the probe is based on the algorithm used during the calibration process and the range in which you are working:

♦ 1.0% of full range for 0-20% when calibrating with the Linear (Stern-Volmer) algorithm
♦ 0.1% of full range for 0-20% when calibrating with the Second Order Polynomial algorithm
♦ 1.0% of full range for 0-100% when calibrating with the Second Order Polynomial algorithm

FOXY Probe Options (from top to bottom): FOXY-T1000, FOXY-R, FOXY-PI600, FOXY-AL300, FOXY-24G and FOXY-OR125G

Measurement range
Each FOXY probe will respond to gaseous samples from 0-100% at 1 atmosphere pressure. In water, the probe will respond from 0-10 ppm, which is the saturation level for oxygen in water. In other liquids, the probe responds from 0 to the saturation level for oxygen in that particular liquid.

Sampling chambers
The FOXY 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. 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. It is critical that standards with known oxygen concentration levels are available for use.

Response time
The response time of a FOXY probe is limited by the speed of diffusion of oxygen into the sensor. Our standard thin films are very fast (<1 second) in gases and liquids. In viscous samples, the diffusion through the sample will determine the response rate. The probe will respond quickly in samples such as water, and more slowly in viscous samples such as oils, emulsions and creams. Unlike an electrode, the optical sensor will not consume oxygen. This means that stirring the sample will increase the response rate, but will not affect the final equilibrium reading. Also, optional probe overcoats, applied to exclude ambient light and improve chemical resistance, will slow response time from 20 seconds to as long as 90 seconds, depending on the overcoat.

Environmental conditions
Environmental changes, such as changes in pH, salinity and ionic strength, do not affect FOXY probes.

Chemical compatibility

FOXY probes are not affected by pH change or salinity. They can be used safely with 50% methanol, acids, sodium sulfite, NF_3, hexane, CH_4, acetone vapor, moisture, CO_2 and CO. We recommended not using the probes with strong bases (pH>10), styrene, ethanol, liquid acetone, acetonitrile, HF and BTEX solvents.

Temperature and your FOXY probe

Temperature affects the fluorescence decay time, the fluorescence intensity and the collisional frequency of the oxygen molecules within the fluorophore -- and therefore, the diffusion coefficient of oxygen. Temperature also affects the solubility of oxygen in samples. The net effect of temperature fluctuations is seen as a change in the calibration slope. It is best to maintain the sample at a constant (+/-3° C) temperature. If this is not practical, then you should calibrate your FOXY system by using the temperature compensation features and measuring temperature and oxygen concurrently. To monitor the temperature of the sensing environment and compensate for temperature fluctuations, temperature electrodes can now be used in conjunction with the FOXY probe. OOISensors Software corrects for changes in data due to temperature fluctuations.

Photodegradation

Because the ruthenium may be subject to photodegradation, the total exposure to the excitation source should be minimized. OOISensors Software can control the strobe of the LED so that it illuminates the probe only during a measurement cycle.

Ambient light

Our miniature fiber optic spectrometers are very sensitive, and the oxygen probe will readily detect ambient light. The probe must be shielded from ambient light to obtain reliable data. Install it in a closed vessel, or shield the probe with a dark housing. Our FOXY-T1000 probe has a screw-on cap to block the optical field of view of the fiber, while allowing easy access to the probe tip. Also, an overcoat of silicone can be applied to the probe (at no charge) to help reduce ambient light effects. However, the overcoat can slow the response time of the probe from 20 to 90 seconds.

You can determine if ambient light is entering the probe by turning off the LED. The spectra in OOISensors should appear flat, near the bottom of the scale.

Lifetime

Each FOXY probe is warranted for 1 year. Probes used in benign environments may last for a very long time. However, severe biofouling, physical abrasion and chemical etching of the glass may erode the probes' sensing surface. Cleaning the probe and protecting it from damaging environments will extend its life. After 1 year (or, if necessary, before 1 year), you can send your FOXY probe back to Ocean Optics for re-conditioning and re-coating services (item code FOXY-RECOV).

Specifications

The following specifications pertain to all FOXY probes:

	Dissolved Oxygen in H_2O	Oxygen Gas (at 1 atmosphere)
Dynamic range:	0-40.7 ppm 0-760 mm Hg partial pressure	0-100% (mole percent) 0-760 mm Hg partial pressure
Response time (without overcoat)	< 1 second	< 1 second
Response time (with overcoat):	30-50 seconds	20-30 seconds
Resolution:	0.05 ppm at high O2 0.005 ppm at low concentration	0.1% at high O2 0.01% at low concentration
Stability:	drift <0.02 ppm per day	drift <0.05% per day

FOXY-R Stainless-steel 1/16" OD Fiber Optic Probe

The FOXY-R is a 1000-µm silica core, silica clad fiber encased in a stainless-steel ferrule. The 7" long semi-rugged probe has an outer diameter of 1/16". The FOXY-R was the first probe designed for the FOXY system. The hypodermic needle-sized probe is designed for use with 600-µm bifurcated optical fiber. It has an SMA 905 connector at the proximal end for easy coupling to the bifurcated fiber. The gap between the stainless steel and the silica cladding is filled with epoxy.

Caution!

♦ Avoid using ketones (acetone and alcohols included) with the FOXY-R.
♦ Handle with care. Dropping the probe may cause permanent damage.
♦ Gently remove the plastic cover from the SMA connector before use. Pulling the SMA connector away from the probe when removing the plastic cover could damage the probe.

Cleaning

♦ Sterilize the FOXY-R by autoclave, ETO, e-beam, and/or gamma radiation. If you sterilize the FOXY-R, calibrate the probe afterwards.
♦ You can use detergents to clean the probe. Using detergents to clean the probe does not necessitate calibration.
♦ Avoid cleaning the FOXY-R with ketones (acetone and alcohols included) or organic solvents.

Operation

1. Locate the 21-02 SMA Splice Bushing that came with your system. It is a 0.75" screw with female ends.
2. Screw one end of the splice bushing into the SMA 905 connector on the proximal end of the FOXY-R.
3. Locate the 600-µm bifurcated fiber that must be used with the FOXY-R. The bifurcated fiber has a Y design.
4. Connect the common end (the tail of the Y) of the bifurcated fiber to the splice bushing/probe.
5. Connect one arm of the bifurcated fiber to the SMA connector on the spectrometer and connect the other arm to the SMA connector on the LS-450 Blue LED light source. It does not matter which arm of the fiber is connected to the light source or spectrometer.

Specifications

Fiber core:	1000 µm core silica
Fiber cladding:	silica
Fiber jacketing:	stainless steel
Outer diameter:	1/16"
Length:	7"
Amount of pressure that can be applied:	300 psi
Probe temperature range:	-80° C to +120° C (reflects range of ruthenium complex in the sol-gel matrix)
Connector:	SMA 905
Response time (without overcoat):	<1 second
Compensation:	for temperature only
Probe reconditioning:	yes (FOXY-RECOV @ $100)
Re-calibration:	when probe is replaced or sterilized by autoclave
Probe lifetime:	1 year

FOXY-AL300 Aluminum-jacketed Fiber Optic Probe

The FOXY-AL300 is a 300-µm aluminum jacketed fiber optic probe. The aluminum jacketing, which is FDA approved, is designed for applications where extraordinary environmental performance is required. Aluminum jacketed fibers do not weaken under stress (as ordinary fibers do) and have an extremely high break strength. This extremely flexible and thin probe is 1 meter in length and is designed for use with the BIF200-VIS/NIR 200-µm bifurcated optical fiber assembly.

Caution!

♦ Avoid using ketones (acetone and alcohols included) with the FOXY-AL300.
♦ Handle with care. Dropping the probe may cause permanent damage.
♦ Gently remove the plastic cover from the SMA connector before use. Pulling the SMA connector away from the probe when removing the plastic cover could damage the probe.

Cleaning

♦ Sterilize the FOXY-AL300 by autoclave, ETO, e-beam, and/or gamma radiation. If you sterilize the FOXY-AL300, calibrate the probe afterwards.
♦ Avoid cleaning the FOXY-R with ketones (acetone and alcohols included) or organic solvents.
♦ You can use detergents to clean the probe. Using detergents to clean the probe does not necessitate calibration.

Operation

1. Locate the 21-02 SMA Splice Bushing that came with your system. It is a 0.75" screw with female ends.
2. Screw one end of the splice bushing into the SMA 905 connector on the proximal end of the FOXY-AL300.
3. Locate the 200-µm bifurcated fiber that must be used with the FOXY-AL300. The bifurcated fiber has a Y design.
4. Connect the common end (the tail of the Y) of the bifurcated fiber to the splice bushing/probe.
5. Connect one arm of the bifurcated fiber to the SMA connector on the spectrometer and connect the other arm to the SMA connector on the LS-450 Blue LED light source. It does not matter which arm of the fiber is connected to the light source or spectrometer.

Specifications

Fiber core:	300 µm silica
Fiber cladding:	silica
Fiber jacketing:	aluminum
Outer diameter:	410 to 420 µm
Length:	1 meter
Bending radius:	2 cm
Amount of pressure that can be applied:	300 psi
Probe temperature range:	-80° C to +120° C (reflects range of ruthenium complex in the sol-gel matrix)
Connector:	SMA 905
Response time (without overcoat):	<1 second
Compensation:	for temperature only
Probe reconditioning:	yes (FOXY-RECOV @ $100)
Re-calibration:	when probe is replaced or cleaned by autoclave
Probe lifetime:	1 year

FOXY-PI600 Polyimide coated Fiber Optic Probe

The FOXY-PI600 is a 600-µm polyimide-coated fiber optic probe. The polyimide is a coating designed to operate at temperatures up to 300°C. The polyimide coating allows the sensor to operate in many harsh chemicals and solvents. The FOXY-PI600 is 2 meters in length and is designed for use with the BIF400-VIS/NIR 400-µm bifurcated optical fiber assembly.

Caution!

♦   Avoid using ketones (acetone and alcohols included) with the FOXY-PI600.
♦   Handle with care. Dropping the probe may cause permanent damage.
♦   Gently remove the plastic cover from the SMA connector before use. Pulling the SMA connector away from the probe when removing the plastic cover could damage the probe.
♦   Remove the FOXY-PI600 from its packaging with care.
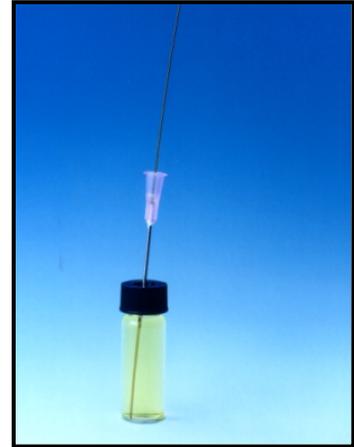
Cleaning

♦   Avoid cleaning the FOXY-R with ketones (acetone and alcohols included) or organic solvents.
♦   Sterilize the FOXY-PI600 by gamma radiation. If you sterilize the FOXY-PI600, you must calibrate the probe afterwards.
♦   You can use detergents to clean the probe. Using detergents to clean the probe does not necessitate calibration.

Operation

1.   Locate the 21-02 SMA Splice Bushing that came with your system. It is a 0.75" screw with female ends.
2.   Screw one end of the splice bushing into the SMA 905 connector on the proximal end of the FOXY-PI600.
3.   Locate the 400-µm bifurcated fiber that must be used with the FOXY-PI600. The bifurcated fiber has a Y design.
4.   Connect the common end (the tail of the Y) of the bifurcated fiber to the splice bushing/probe.
5.   Connect one arm of the bifurcated fiber to the SMA connector on the spectrometer and connect the other arm to the SMA connector on the LS-450 Blue LED light source. It does not matter which arm of the fiber is connected to the light source or spectrometer.

Specifications

Fiber core:	600 µm silica
Fiber coating:	25 µm polyimide
Outer diameter:	~625 µm
Length:	2 meters
Amount of pressure that can be applied:	300 psi
Probe temperature range:	-80° C to +120° C (reflects range of ruthenium complex in the sol-gel matrix)
Connector:	SMA 905
Response time (without overcoat):	<1 second
Compensation:	for temperature only
Probe reconditioning:	yes (FOXY-RECOV @ $100)
Re-calibration:	when probe is replaced or cleaned by autoclave
Probe lifetime:	1 year

FOXY-24G Needle-tipped 24-gauge Fiber Optic Probe

The FOXY-24G is a silica-core, aluminum-jacketed, 1-meter probe with a 24-gauge needle tip at its end for penetrating vial septa. The needle is a 0.022" SST wire soldered into a stainless steel ferrule. The length of the needle tip is 4", while the entire length of the probe is 1 meter. The FOXY-24G is designed for use with the BIF200-VIS/NIR 200-μm bifurcated optical fiber assembly.
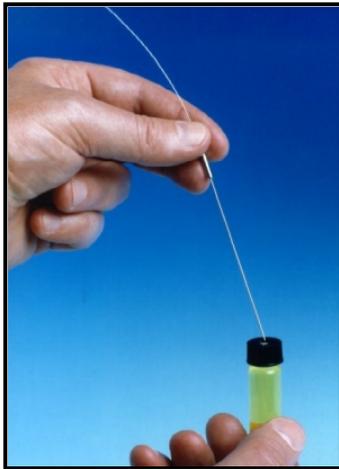
Caution!

- Avoid using ketones (acetone and alcohols included) with the FOXY-24G.
- Handle with care. Dropping the probe may cause permanent damage.
- Gently remove the plastic cover from the SMA connector before use. Pulling the SMA connector away from the probe when removing the plastic cover could damage the probe.

Cleaning

- Sterilize the FOXY-24G by gamma radiation. If you sterilize the FOXY-24G, you must calibrate the probe afterwards.
- You can use detergents to clean the probe. Using detergents to clean the probe does not necessitate calibration.
- Avoid cleaning the FOXY-R with ketones (acetone and alcohols included) or organic solvents.

Operation

1. Locate the 21-02 SMA Splice Bushing that came with your system. It is a 0.75" screw with female ends.
2. Screw one end of the splice bushing into the SMA 905 connector on the proximal end of the FOXY-24G.
3. Locate the 200-μm bifurcated fiber that must be used with the FOXY-24G. The bifurcated fiber has a Y design.
4. Connect the common end (the tail of the Y) of the bifurcated fiber to the splice bushing/probe.
5. Connect one arm of the bifurcated fiber to the SMA connector on the spectrometer and connect the other arm to the SMA connector on the LS-450 Blue LED light source. It does not matter which arm of the fiber is connected to the light source or spectrometer.

Specifications

Fiber core:	300 μm silica
Fiber jacketing:	aluminum
Needle tip:	24-gauge, 0.022" stainless steel wire
Length:	4" for needle tip, 1 meter for entire probe
Amount of pressure that can be applied:	300 psi
Probe temperature range:	-80° C to +120° C (reflects range of ruthenium complex in the sol-gel matrix)
Connector:	SMA 905
Response time (without overcoat):	<1 second
Compensation:	for temperature only
Probe reconditioning:	yes (FOXY-RECOV @ $100)
Re-calibration:	when probe is replaced or cleaned by autoclave
Probe lifetime:	1 year

FOXY-OR125 and FOXY-OR125G O-ring Fiber Optic Probes

The FOXY-OR125 is a silica-core, 1000-µm stainless steel fiber optic probe with a 1/8" outer diameter and an O-ring seal. The FOXY-OR125G is a silica-core, 1000-µm stainless steel fiber optic probe with a 1/8" outer diameter and an O-ring groove at the tip. Both probes are 2.5" in length and are designed for use with a 600-µm bifurcated optical fiber assembly.

Caution!

- ♦ Avoid using ketones (acetone and alcohols included) with the FOXY-OR125 and FOXY-OR125G.
- ♦ Handle with care. Dropping the probe may cause permanent damage.
- ♦ Gently remove the plastic cover from the SMA connector before use. Pulling the SMA connector away from the probe when removing the plastic cover could damage the probe.
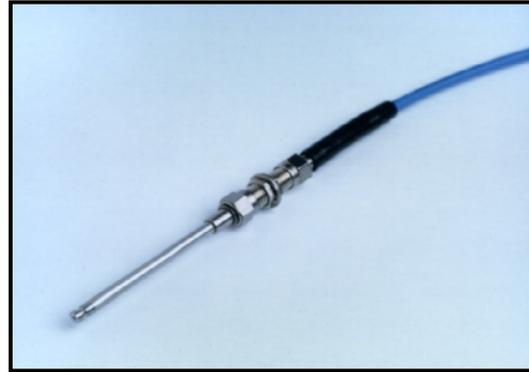
Cleaning

- ♦ Sterilize the FOXY-OR125 and FOXY-OR125G by gamma radiation. If you sterilize the FOXY-OR125 or FOXY-OR125G, you must calibrate the probe afterwards.
- ♦ You can use detergents to clean the probe. Using detergents to clean the probe does not necessitate calibration.
- ♦ Avoid cleaning the FOXY-R with ketones (acetone and alcohols included) or organic solvents.

Operation

1. Locate the 21-02 SMA Splice Bushing that came with your system. It is a 0.75" screw with female ends.
2. Screw one end of the splice bushing into the SMA 905 connector on the proximal end of the FOXY-OR125 or FOXY-OR125G.
3. Locate the 600-µm bifurcated fiber that must be used with the FOXY-OR125 and FOXY-OR125G. The bifurcated fiber has a Y design.
4. Connect the common end (the tail of the Y) of the bifurcated fiber to the splice bushing/probe.
5. Connect one arm of the bifurcated fiber to the SMA connector on the spectrometer and connect the other arm to the SMA connector on the LS-450 Blue LED light source. It does not matter which arm of the fiber is connected to the light source or spectrometer.

Specifications

Fiber core:	1000 µm silica
Fiber cladding:	silica
Fiber jacketing:	stainless steel
Outer diameter:	1/8"
Length:	2.5"
Amount of pressure that can be applied:	300 psi
Probe temperature range:	-80° C to +120° C (reflects range of ruthenium complex in the sol-gel matrix)
Connector:	SMA 905
Response time (without overcoat):	<1 second
Compensation:	for temperature only
Probe reconditioning:	yes (FOXY-RECOV @ $100)
Re-calibration:	when probe is replaced or cleaned by autoclave
Probe lifetime:	1 year

FOXY-T1000 Stainless-steel Fiber Optic Probe with Light Shield

The FOXY-T1000 is a 1000-µm silica core, silica clad fiber encased in a stainless-steel ferrule with a screw-on light shield. The light shield prevents ambient light from entering the probe. The 7" long probe has an outer diameter of 1/4" and is extremely rugged. The probe can withstand pressure up to 3000 psi and temperature up to 100° C. It is designed for use with the 600-µm bifurcated optical fiber assembly.

Caution!

♦ Avoid using ketones (acetone and alcohols included) with the probe.
♦ Handle with care. Dropping the probe may cause permanent damage.
♦ Gently remove the plastic cover from the SMA connector before use. Pulling the SMA connector away from the probe when removing the plastic cover could damage the probe.

Cleaning

♦ Sterilize the FOXY-T1000 by gamma radiation. If you sterilize the FOXY-T1000, you must calibrate the probe afterwards.
♦ Avoid cleaning the FOXY-R with ketones (acetone and alcohols included) or organic solvents.
♦ You can use detergents to clean the probe. Using detergents to clean the probe does not necessitate calibration.

Operation

1. Locate the 21-02 SMA Splice Bushing that came with your system. It is a 0.75" screw with female ends.
2. Screw one end of the splice bushing into the SMA 905 connector on the proximal end of the FOXY-T1000.
3. Locate the 600-µm bifurcated fiber that must be used with the FOXY-T1000. The bifurcated fiber has a Y design.
4. Connect the common end (the tail of the Y) of the bifurcated fiber to the splice bushing/probe.
5. Connect one arm of the bifurcated fiber to the SMA connector on the spectrometer and connect the other arm to the SMA connector on the LS-450 Blue LED light source. It does not matter which arm of the fiber is connected to the light source or spectrometer.
6. To use the light shield, simply screw it onto the end of the FOXY-T1000 (part number FOXY-T1000TIP).

Specifications

Fiber core:	1000 µm silica
Fiber cladding:	silica
Fiber jacketing:	stainless steel
Outer diameter:	1/4"
Length:	7"
Amount of pressure that can be applied:	3000 psi
Probe temperature range:	-80° C to +120° C (reflects range of ruthenium complex in the sol-gel matrix)
Connector:	SMA 905
Response time (without overcoat):	<1 second
Compensation:	for temperature only
Probe reconditioning:	yes (FOXY-RECOV @ $100)
Re-calibration:	when probe is replaced or cleaned by autoclave
Probe lifetime:	1 year

FOXY-AF and FOXY-AF-MG Silicone Overcoats

The FOXY-AF Silicone Overcoat and the FOXY-AF-MG Silicone Medical-grade Overcoat are room temperature vulcanized (RTV) silicone adhesives used as additional coatings for the FOXY probes. Overcoats protect the FOXY probes from ambient light, improve chemical resistance and eliminate refractive index effects of the sensing environment. A silicone overcoat is required for applications involving liquids or gas-to-liquid activity.

FOXY-AF is a multi-surface, healthcare-grade silicone while the FOXY-AF-MG is a high-strength acetoxy, implant-grade silicone. The FOXY-AF-MG provides a thicker and stronger coating than the FOXY-AF. Both overcoats increase the response time of the sensor.

The overcoats are made from a silicone adhesive designed for use in fabricating elastic bonds to silicone, polyester and other substrates. Following cure, the overcoat is of the same chemical composition as other implant-grade silicone elastomers and it contains no solvents or plasticizers. Both overcoats are designed and tested to meet ISO 10993 bio-compatibility test requirements.

Cleaning

Use a 10% hypochlorite detergent for cleaning probes with an overcoat. Using detergents to clean the probe does not necessitate calibration.

Sterilizing

A FOXY probe with either overcoat can be sterilized using ETO, steam, dry heat or gamma radiation. It is the user's responsibility to validate any sterilization method chosen.

Specifications

	FOXY-AF Overcoat	FOXY-AF-MG Overcoat
Response time in oxygen gas (at 1 atmosphere):	20 to 30 seconds	20 to 45 seconds
Response time in dissolved oxygen in H_2O:	30 to 50 seconds	60 to 90 seconds
Coating stability:	poor in long term	very good
Resistance to chemicals (organic solvents):	very good	excellent
Coating hardness:	soft-hard	hard
Tensile strength:	780	
Tear strength:	70 ppi	
Cohesive/adhesive strength:	18 ppi	
Cytotoxicity:	Non-toxic	

FOXY Temperature Control Accessories

Temperature affects the fluorescence decay time, the fluorescence intensity and the collisional frequency of the oxygen molecules with the fluorophore -- and therefore, the diffusion coefficient of oxygen. Temperature also affects the solubility of oxygen in samples. The net effect of temperature fluctuations is seen as a change in the calibration slope. If you cannot maintain the sample at a constant (+/-3° C) temperature, then you should calibrate your FOXY system by using the temperature compensation features and measuring temperature and oxygen concurrently. The FOXY-TS1 Thermistor and the FOXY-TK1 Thermocouple monitor the temperature of the sensing environment and OOISensors Software corrects for changes in data due to temperature fluctuations.

FOXY-TS1 Omega Thermistor

A thermistor, a type of temperature-to-resistance transducer, is able to transduce temperature into a continuous electrical signal. A circuit measures the resistance of the thermistor and provides an output voltage proportional to the temperature. The FOXY-TS1 Thermistor from Omega (model number ON-403-PP) is a stainless-steel tubular electrode probe most often used for liquid immersion. The FOXY-TS1 can monitor temperatures from 0° C to 100° C. It connects to the FOXY-T-MOD-1, an RS-232 module that interfaces the thermistor to your PC.

Application Tips

♦ Immerse the FOXY-TS1 to its cap.
♦ Use detergents to clean the FOXY-TS1.

Operation

1. Connect the FOXY-TS1 to the FOXY-T-MOD-1 RS-232 module. (Rack-mounted systems have the modules installed into the rack box.)
2. Connect the FOXY-T-MOD-1 RS-232 module to your PC. You must have an available serial port on your PC. Note the serial port number (also called COM Port) on the PC to which you are interfacing.
3. Plug the +12VDC wall transformer into an outlet and connect it to the FOXY-TS1.
4. In OOISensors Software, select **Configure | Spectrometer** from the menu. Select the **Sensors** tab. Next to **Temperature Measurement**, select **Omega D5xx1 RS232** for automatic temperature monitoring. Be sure to enable the **Compensate** function (make sure it is checked).
5. Next to **Serial Port**, select the COM Port number on your PC to which the thermistor is connected.
6. The RS-232 module can support up to four thermistors. The RS-232 module has these four ports labeled. Find the port on the module that is connected to the thermistor you are using. Next to **D5xx1**, select between 0 and 3. (If you only have one thermistor, select 0.)
7. Enabling the **Chart** function allows you to view a chart of the temperature values.

Specifications

Length:	5.375"
Outer diameter:	1/8"
Temperature range:	0° C to 100° C
Accuracy	+/-0.1° C
Data acquisition	FOXY-T-MOD-1 RS-232 module
Probe material:	Stainless steel
Type:	2252 Ohm at 25° C

FOXY-TK1 K-type Omega Thermocouple

A thermocouple consists of two dissimilar metals bonded to each other, typically by welding. The bimetallic junction develops a small voltage that varies with temperature. A thermocouple also provides accurate and consistent measurements and operates over a wide temperature range.

The FOXY-TK1 Thermocouple from Omega (model number KMQSS-125-6) is an electrode that can monitor temperatures from -150° C to 220° C. It is smaller and more flexible than the thermistor. The thermocouple must be connected to the FOXY-T-MOD-K, which is an RS-232 module that interfaces the thermocouple to your PC. The FOXY-T-MOD-K can support up to 4 thermocouples. The software can then apply algorithms to the readings to correct for temperature fluctuations.

Application Tips

- ♦ Immerse the FOXY-TK1 to its cap.
- ♦ Use detergents to clean the FOXY-TK1.

Operation

1. Connect the FOXY-TK1 to the 10-foot wire (model number FOXY-T-WIRE) that comes with the thermocouple.
2. Connect the FOXY-TK1 and the wire to the FOXY-T-MOD-K RS-232 module. (Rack-mounted systems have the modules installed into the rack box.)
3. Connect the FOXY-T-MOD-K RS-232 module to your PC. You must have an available serial port on your PC. Note the serial port number (also called COM Port) on the PC to which you are interfacing.
4. Plug the +12VDC wall transformer into an outlet and connect it to the FOXY-TK1.
5. In OOISensors Software, select **Configure | Spectrometer** from the menu. Select the **Sensors** tab. Next to **Temperature Measurement**, select **Omega D5xx1 RS232** for automatic temperature monitoring. Be sure to enable the **Compensate** function (make sure it is checked).
6. Next to **Serial Port**, select the COM Port number on your PC to which the thermocouple is connected.
7. The RS-232 module can support up to four thermocouples. The RS-232 module has these four ports labeled. Find the port on the module that is connected to the thermocouple your are using. Next to **D5xx1**, select between 0 and 3. (If you only have one thermocouple, select 0.)
8. Enabling the **Chart** function allows you to view a chart of the temperature values.

Specifications

Length:	6"
Outer diameter:	1/8"
Temperature range:	-150° C to 220° C
Accuracy:	2.2° C or 0.75% of reading with precision of 1° C
Data acquisition:	FOXY-T-MOD-K RS-232 module
Probe material:	Chomega-Alomega 304 stainless steel
Connector body:	Glass-filled Nylon

Miniature Fiber Optic Spectrometers

In the Beginning

Ocean Optics began in 1989 when Florida university researchers developed a fiber optic pH sensor as part of an instrument designed to study the role of the oceans in global warming. The research team soon formed Ocean Optics, Inc. and their ingenious work earned a Small Business Innovation Research (SBIR) grant from the U.S. Department of Energy. While designing the pH-monitoring instrument, the researchers wanted to incorporate with their sensor a spectrometer small enough to fit onto a buoy and were surprised to discover none existed. So they built their own. In 1992, the founders of Ocean Optics revolutionized the analytical instrumentation market, filled a substantial need in the research community, and changed the science of spectroscopy forever by creating a breakthrough technology: a miniature fiber optic spectrometer nearly a thousand times smaller and ten times less expensive than previous systems.

By April 1992, just thirty days after the successful completion of Phase II of the SBIR grant, Ocean Optics, Inc. introduced the S1000 -- "The World's First Miniature Fiber Optic Spectrometer." With the S1000, applications once deemed too costly or technologically impractical using conventional spectrometers were not only feasible, but practical.
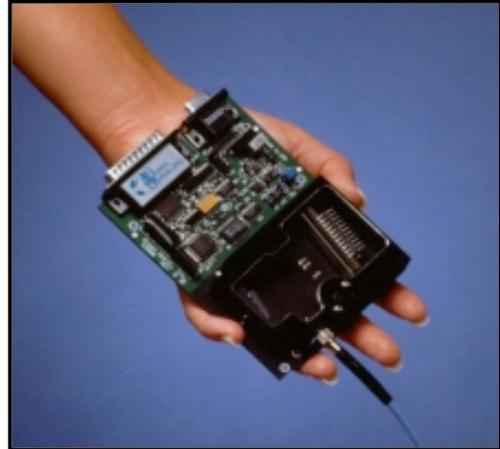
S2000 Miniature Fiber Optic Spectrometer

Our second-generation miniature fiber optic spectrometer, the S2000, couples a low-cost, high-performance 2048-element linear CCD-array detector with an optical bench that's small enough to fit into the palm of your hand. The S2000 accepts light energy transmitted through optical fiber and disperses it via a fixed grating across the detector. The S2000 communicates with a PC via an external analog-to-digital (A/D) converter, which can sometimes be problematic if a PC is connected to several devices. In an effort to fill a need among our users -- hassle-free instrument-to-PC interfacing -- we created a fully plug-and-play spectrometer.

USB2000 Plug-and-Play Fiber Optic Spectrometer

The USB2000 Miniature Fiber Optic Spectrometer is a small-footprint (about the size of a deck of cards), plug-and-play version of our revolutionary S2000 Miniature Fiber Optic Spectrometer. The USB2000 plugs into a USB port of any desktop or notebook PC, eliminating the need for external A/D converters. Wavelength calibration coefficients unique to each spectrometer are programmed into a memory chip right on the USB2000; OOISensors Software simply reads these values from the spectrometer. What's more, the USB2000 does not require an external power supply; it draws its power from the computer.

Performance

Operating performance of the spectrometer varies according to a number of factors, including the spectrometer configuration -- especially the groove density of the grating and the size of the entrance optics -- as well as the application itself. Optical resolution, measured as Full Width Half Maximum (FWHM), of a monochromatic source depends on the groove density (lines/mm) of the grating and the diameter of the entrance optics (optical fiber or slit). For spectrometers used in the FOXY system, the FWHM is ~10 nm. The following performance specifications pertain to the SF2000, S2000-FL and USB2000-FL.

Integration time	3 milliseconds to 60 seconds
Dynamic range	2×10^8
Optical resolution (FWHM)	~10.0 nm
Sensitivity	86 photons/count; 2.9×10^{-17} joule/count; 2.9×10^{-17} watts/count
Signal-to-noise	250:1 single acquisition
Readout noise (single dark spectrum)	3.5 counts RMS, 20 counts peak-to-peak
Stray light	<0.05% at 600 nm; <0.10% at 435 nm

SF2000 Spectrophotometer for Fluorescence

The SF2000 Spectrophotometer for Fluorescence is a low-cost, high-sensitivity spectrometer configured for measuring fluorescence. At the heart of the SF2000 is an S2000 Miniature Fiber Optic Spectrometer (~360-1000 nm), with a 200 μm entrance slit (for optical resolution to ~10.0 nm FWHM) and an L2 Detector Collection Lens for increased light throughput. Unlike the S2000-FL Spectrometer for fluorescence, which is similarly configured, the SF2000 has an integral R-LS-450 Pulsed Blue LED mounted onto the spectrometer. Both share the same housing.

The SF2000 spectrometer has a compact optical bench coupled to a high-sensitivity 2048-element linear CCD-array detector. The spectrometer accepts light energy transmitted through single-strand optical fiber and disperses it via a fixed grating across the CCD array. The SMA 905 connector allows for easy coupling to Ocean Optics' FOXY Oxygen Sensing Probes and other fiber optic accessories.

The SF2000 is available in three platforms. The benchtop version interfaces to a desktop PC via Ocean Optics' ADC1000 ISA-bus A/D card. The portable version interfaces to a notebook PC via National Instruments' DAQCard-700 PCMCIA A/D card. The serial port version interfaces to a desktop or notebook PC via Ocean Optics' SAD500 Serial Port Interface.

Physical Specifications

Physical dimensions (in enclosure)	5.63" x 4.09" x 1.58" LWH (without the LS-450)
Weight	200 g (without the LS-450)

Spectrometer Specifications

Optical bench design	asymmetric crossed Czerny-Turner optical bench
Detector	Sony ILX511 CCD -- 2048-element, linear silicon CCD array
CCD elements	2048 elements @ 12.5 μm x 200 μm per element
CCD well depth	160,000 photons
Gratings	600 lines/mm, set to 360 μm to 1000 μm (blaze wavelength is 1000 μm)
Entrance slit	200 μm width, 1000 μm height
Input fiber connector	SMA 905
Focal length	42 mm (input); 68 mm (output)
L2 collection lens	Improves light collection efficiency ~5x (focuses tall slit images onto short detector pixels)

Absolute Maximum Ratings Specifications

V_{CC}	+ 5.5 VDC
Voltage on any pin	V_{CC} + 0.2 VDC

Power Specifications

Power requirement	130 mA at +5 VDC (master channel); 70 mA at +5 VDC (additional spectrometer channels)
Supply voltage	4.5 – 5.5 V

Environmental Conditions Specifications

Temperature	-30° - +70° C Storage; -10° - +60° C Operation

For S2000-series pin-outs and jumpers, see **Appendix A** on page 65.

S2000-FL Spectrometer for Fluorescence

The S2000-FL Spectrometer for Fluorescence is a low-cost, high-sensitivity spectrometer for fluorescence. Conceived for use with the FOXY Fiber Optic Oxygen Sensor, the S2000-FL is the optimum Ocean Optics spectrometer configuration for looking at fluorescence. The S2000-FL is pre-set to a 360-1000 nm wavelength range, and comes with a 200 μm entrance slit (for optical resolution to ~10.0 nm FWHM) and L2 Detector Collection Lens (for increased light throughput).

The S2000-FL spectrometer has a compact optical bench coupled to a high-sensitivity 2048-element linear CCD-array detector. The spectrometer accepts light energy transmitted through single-strand optical fiber and disperses it via a fixed grating (set for 360-1000 nm) across the CCD array. An SMA 905 connector allows for easy coupling to Ocean Optics' comprehensive line of fiber optic light sources and accessories.

The S2000-FL is available in three platforms. The benchtop version interfaces to a desktop PC via Ocean Optics' ADC1000 ISA-bus A/D card. The portable version interfaces to a notebook PC via National Instruments' DAQCard-700 PCMCIA A/D card. The serial port version interfaces to a desktop or notebook PC via Ocean Optics' SAD500 Serial Port Interface.

Physical Specifications

Physical dimensions (in enclosure)	5.63" x 4.09" x 1.58" LWH
Weight	200 g

Spectrometer Specifications

Optical bench design	asymmetric crossed Czerny-Turner optical bench
Detector	Sony ILX511 CCD -- 2048-element, linear silicon CCD array
CCD elements	2048 elements @ 12.5 μm x 200 μm per element
CCD well depth	160,000 photons
Gratings	600 lines/mm, set to 360 μm to 1000 μm (blaze wavelength is 1000 μm)
Entrance slit	200 μm width, 1000 μm height
Input fiber connector	SMA 905
Focal length	42 mm (input); 68 mm (output)
L2 collection lens	Improves light collection efficiency ~5x (focuses tall slit images onto short detector pixels)

Absolute Maximum Ratings Specifications

V_{CC}	+ 5.5 VDC
Voltage on any pin	V_{CC} + 0.2 VDC

Power Specifications

Power requirement	130 mA at +5 VDC (master channel); 70 mA at +5 VDC (additional spectrometer channels)
Supply voltage	4.5 – 5.5 V

Environmental Conditions Specifications

Temperature	-30° - +70° C Storage; -10° - +60° C Operation

For S2000-series pin-outs and jumpers, see **Appendix A** on page 65.

USB2000-FL Plug-and-Play Fiber Optic Spectrometer

The USB2000-FL Plug-and-Play Fiber Optic Spectrometer is a plug-and-play version of the our S2000 Miniature Fiber Optic Spectrometer. Setting up the USB2000 Spectrometer is easy. The user only has to install the latest version of OOISensors Software onto any desktop or notebook PC with Windows 98/2000 operating system. The PC must be an IBM-compatible with Pentium or better microprocessor and have 32 MB RAM.

Set Up

When you get your USB2000, you must install the OOISensors Software first. Before installing OOISensors, make sure that no other applications are running. During installation, you will have to enter the OOISensors password. You can find it on the back of the *Ocean Optics Software and Resources Library* CD jewel case.
1. Execute **Setup.exe**. At the "Welcome" dialog box, click **Next>**.
2. At the "Destination Location" dialog box, accept the default or choose **Browse** to pick a directory. Click **Next>**.
3. At the "Backup Replaced Files" dialog box, select either **Yes** or **No**. We recommend selecting Yes. If you select Yes, accept the default or choose **Browse** to pick a destination directory. Click **Next>**.
4. Select a Program Manager Group. Click **Next>**. At the "Start Installation" dialog box, click **Next>**.
5. At the "Installation Complete" dialog box, choose **Finish>**.
6. When prompted to do so, **restart your computer**. Do not run OOISensors at this time.

Now you may connect the USB2000 to your PC.
1. Find the USB cable that came with your shipment. Insert the square end of the cable into the side of the USB2000 spectrometer. Insert the other end into a USB port on your PC.
2. If you installed OOISensors correctly, an Add New Hardware Wizard message box appears telling you that the USB2000 has been successfully loaded.

Specifications

Physical Specifications

Physical dimension	3.5" x 2.5" x 1.31" LWH; 89 mm x 64 mm x 34 mm LWH
Weight	0.45 lb. or 200 grams without cable

Spectrometer Specifications

Optical bench design	asymmetric Cross Czerny-Turner optical bench
Detector	Sony ILX511 -- 2048-element, linear silicon CCD array
Gratings	600 lines/mm set to 360 μm to 1000 μm
Entrance slit	width: 200 μm, height: 1000 μm
Input fiber connector	SMA 905
Focal length	42 mm (input), 68 mm (output)
Optional order-sorting filters	long pass plug filters block second order effects, reduce signal intensity
Optional order-sorting coating	single-piece, detector coating for ~ 200-850 nm applications (available with grating #1 and #2 only) blocks second and third order effects
Optional UV detector upgrade	Quartz window at entrance allows transmission of UV light for applications <360 nm
Optional detector collection lens	Improves light-collection efficiency ~5x (lens focuses tall slit images onto short detector pixels)

Absolute Maximum Ratings Specifications

Vcc	8.0V
Voltage (on any pin)	7.0V

Power Specifications

Power requirement	0.5W (100 mA @ 5V)
Supply voltage	3.9V - 8.0V

Environmental Conditions Specifications

|	
Temperature	-30° to +70° C Storage; 10° to +50° C Operation

For USB2000 pin-outs, see **Appendix B** on page 67.

Analog-to-Digital (A/D) Products

This section covers the basic installation instructions for our A/D converters: ADC1000, SAD500 and DAQ700. Because A/D converter installation goes hand-in-hand with software installation, you will find directions for installing OOISensors Software included in this section. The A/D converters we offer are:

♦ ADC1000 ISA-bus A/D Converter is a high-speed, 12-bit, 8-channel, single-ended, half-length card that fits into an ISA slot in a desktop PC and has 1 MHz sampling frequency. It also has the ability to acquire spectral data from multiple channels simultaneously.

♦ SAD500 Serial Port Interface is a 12-bit, 8-channel A/D converter for serial port connection for interfacing to desktop or notebook PCs and has 500 kHz sampling frequency. This microprocessor-controlled A/D converter can be used to interface the spectrometer to desktop or portable PCs, PLCs and other devices that support the RS-232 communication protocol.

♦ DAQ-700 PCMCIA A/D Converter (National Instruments model number DAQCard-700) is a 12-bit, 16-channel, single-ended, 8-channel differential card. The DAQ-700 fits into a credit card-size slot in a notebook PC and has 100 kHz sampling frequency.
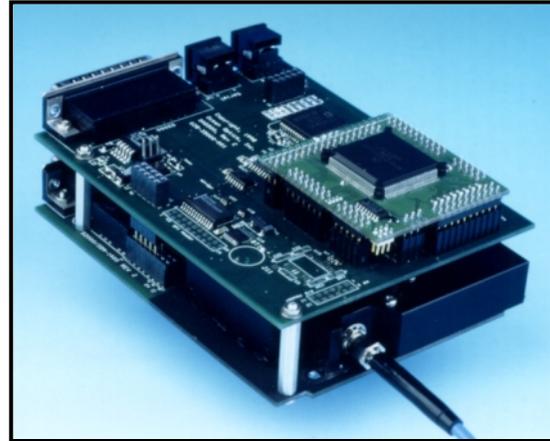
SAD500 Serial Port Interface mounted onto an S2000

ADC1000 ISA-bus A/D converter

♦ The USB2000-FL Plug-and-Play Fiber Optic Spectrometer has an A/D converter installed *onto* the spectrometer itself and requires no external A/D converter. For directions on interfacing your USB2000-FL spectrometer to your PC, see page 28.

Our software includes drivers that support the A/D converters we offer. Other A/D converters can be used with our spectrometers if the following conditions are met:
1. the ADC sampling rate is at least 100 kHz
2. external triggering of the A/D conversions is supported
3. there are a sufficient number of clocks and digital output lines to operate the spectrometer
4. a suitable software driver has been written
5. a suitable cable has been fabricated

If you are using an A/D converter other than the ones offered by Ocean Optics, contact one of our Applications Scientists for timing diagrams, pin-outs and other necessary engineering details.

ADC1000 ISA-bus A/D Converter

The ADC1000 ISA-bus A/D Converter is a 12-bit, 8-channel, single-ended A/D card that connects our spectrometers to desktop PCs. This sturdy combination fits easily into a slot in the PC. The following are directions for installing your ADC1000. Because A/D converter installation goes hand-in-hand with software installation, you will find directions for installing OOISensors Software in this section as well.

Each device in or connected to your computer is assigned specific settings; it's similar to giving each device its own name so that your computer will know what to call and how to recognize the device. In order for your ADC1000 to work as a device in your computer, it has to be assigned a Base Address setting and an IRQ setting. The default settings for each are:

Base Address (I/O Range):	**768 decimal (300 hexadecimal)**
IRQ (Interrupt Request):	**07**

These default values are set on the A/D converter. There are dip switches on the A/D board and their positions determine the values. Most of the time, these default settings will work with your computer. However, if you have many devices installed in your computer, you may have a conflict; other devices may be using these settings. If there is a conflict with another device in your computer, you must change the positions of the switches on the A/D board and change the values in the software.

For the ADC1000, there is only one bank of switches on the A/D board: the Base Address may be changed via the first 6 switches and the IRQ may be changed via the last 3 switches. To first check your computer to see which settings are available, follow the instructions for your Windows operating system.

Windows 95 and Windows 98 Users:
Find Available Base Address and IRQ Settings

1. Go to **Start | Settings | Control Panel** and double-click on the **System** icon.
2. Choose the **Device Manager** tab and double-click on "Computer" at the top of the list.
3. Under **View Resources**, find available settings -- numbers unassigned to hardware. Note these available settings for both the Interrupt request (IRQ) and the Input/output (Base Address). When you first run OOISensors, you must enter these values in the "Configure Hardware" dialog box. (Remember that Input/output settings are expressed in hexadecimal.)
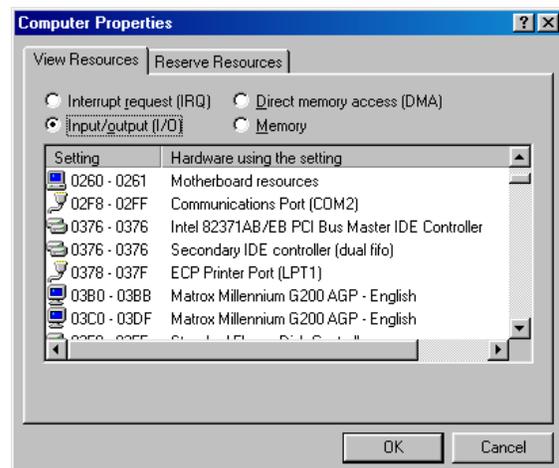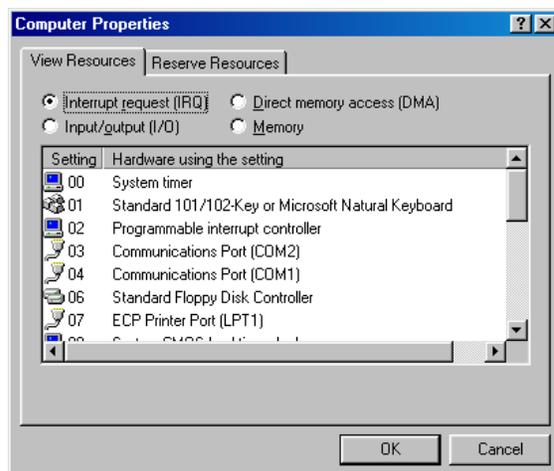
NOTE: For most computers, the default settings work well. In the picture above left, it appears that the Printer occupies IRQ 07, but for most computers, our A/D converters can share the 07 setting with a printer and conflicts will not arise. All computers have multiple Base Address (Input/output) settings from which to choose.

Windows NT Users:
# Find Available Base Address and IRQ Settings

1. Go to **Start | Programs | Administrative Tools (Common) | Windows NT Diagnostics**.
2. In the "Windows NT Diagnostics" dialog box, click on the **Resources** tab.
3. Select the **IRQ** button. Find an available IRQ -- a number unassigned to a device.
4. Select the **I/O Port** button. Find an available I/O Range (Base Address) -- a number or range of numbers unassigned to a device. (The numbers are in hexadecimal.)
5. Note these available settings. When you first run OOISensors, you must enter these values in the "Configure Hardware" dialog box.
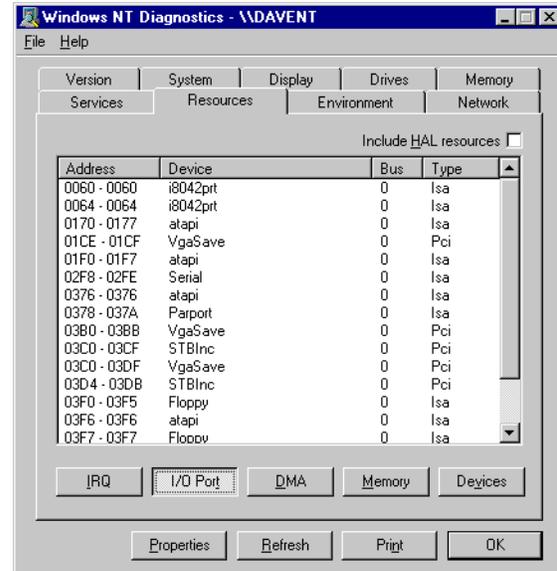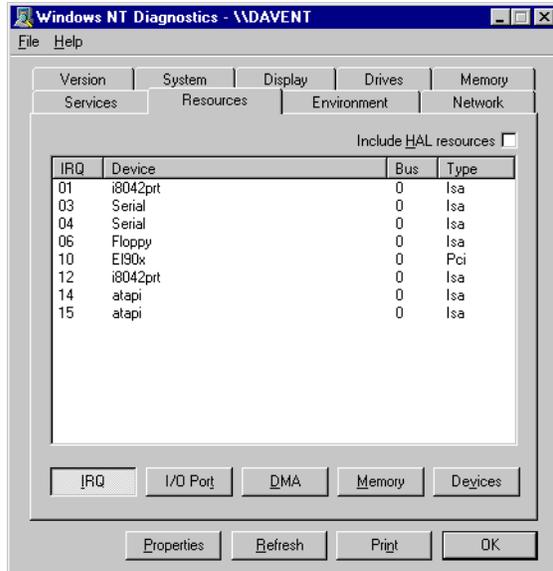
NOTE: With Windows NT, devices cannot share IRQs; each device must be assigned a unique IRQ.

Windows 2000 Users:
Find Available Base Address and IRQ Settings

1. Go to **Start | Programs | Accessories | System Tools | System Information**.
2. In the left column, click on **Hardware Resources**. Several folders under **Hardware Resources** appear.
3. In the left column under **Hardware Resources**, click on the **I/O** folder. All Input/output Ranges (Base Addresses) being used by your computer appear in the right column. Find an available I/O Range (Base Address) -- a range of numbers unassigned to a device. (These numbers are in hexadecimal.)
4. In the left column under **Hardware Resources**, click on the **IRQs** directory. All IRQs being used by your computer appear in the right column. Find an available IRQ -- a number unassigned to a device.
5. Note these available settings. When you first run OOISensors, you must enter these values in the "Configure Hardware" dialog box.
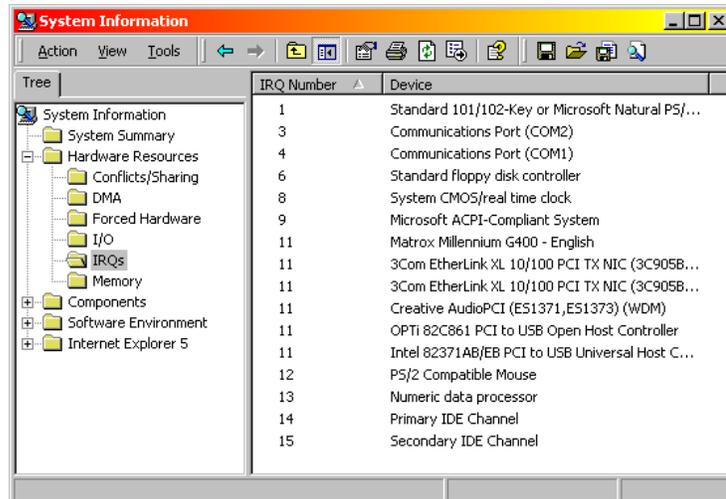
Install the ADC1000

1. Turn off the computer and remove the computer cover.
2. Ground yourself to the computer chassis or power supply and remove the A/D card from its static-shielded bag.
3. If necessary, change the position of the switches on the A/D board. Position the switches to match the available settings you found in the previous section -- numbers not being used by other hardware devices. See **Appendix C** for switch setting positions.
4. Find an open ISA-bus slot and remove the slot protector.
5. Insert the A/D card into an available expansion slot on the motherboard by gently rocking the card into the slot. Make sure the card is fully seated in the motherboard before screwing the tab on the A/D card to the computer. Do not bend the card or move it from side to side once it is seated in the slot.
6. Attach the D37 end of the cable that came with your card and connect the D25 end to the spectrometer. Reinstall the cover.

Install OOISensors

Before installing OOISensors, make sure that no other applications are running. Make sure you have the OOISensors password. During installation, you will have to enter this password. You can find it on the back of the *Ocean Optics Software and Resources Library* CD jewel case.

7. Execute **Setup.exe**.
8. At the "Welcome" dialog box, click **Next>**.
9. At the "Destination Location" dialog box, accept the default or choose **Browse** to pick a directory. Click **Next>**.
10. At the "Backup Replaced Files" dialog box, select either **Yes** or **No**. We recommend selecting Yes. If you select Yes, accept the default or choose **Browse** to pick a destination directory. Click **Next>**.
11. Select a Program Manager Group. Click **Next>**. At the "Start Installation" dialog box, click **Next>**.
12. At the "Installation Complete" dialog box, choose **Finish>**.
13. When prompted to do so, **restart your computer** when the installation is complete.

Run OOISensors

After you restart your computer, navigate to the OOISensors icon and select it. The first time you run OOISensors after installation, you must select settings in the Configure Hardware dialog box.

Configure Hardware Dialog Box

Select **Configure Hardware** from the menu. The parameters in this dialog box are usually set only once -- when OOISensors is first installed and the software first opens.

1. Under **Spectrometer Type**, select S2000/PC2000 (the SF2000, S2000-FL and USB2000-FL are S2000-series spectrometers).
2. Under **A/D Converter Type**, choose ADC1000/PC2000.
3. Under **Base Address**, choose the same setting as the dip switches on the A/D board (and the same available setting you found in your computer).

    Remember that the Input/output Range (Base Address) you selected was expressed in hexadecimal. In this dialog box, the base address is given in decimal, followed by the hexadecimal equivalent in parenthesis. For example, "**768 (0x0300)**" gives the base address as 768 decimal and 300 hexadecimal.

4. Under **IRQ**, choose the same setting as the dip switches on the A/D board (and the same available setting you found in your computer).
5. Only these parameters apply for your setup. Click **OK**.
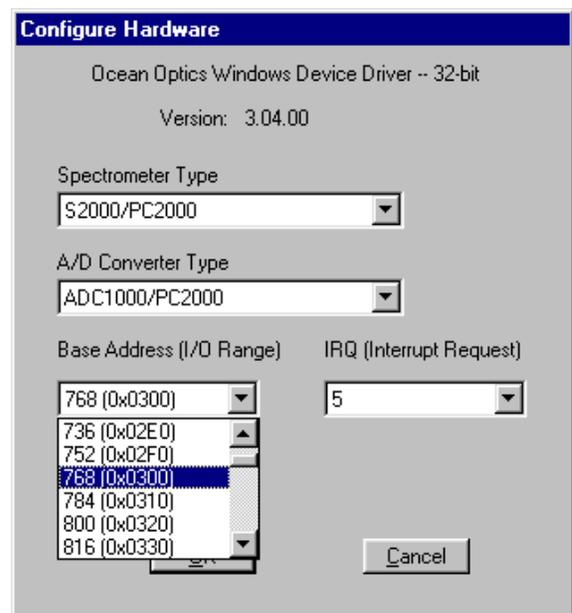
Specifications

Board architecture/design:	half-length ISA-bus card for single slot in desktop PC
Resolution:	12-bit
Sampling frequency:	1 MHz (maximum)
Interface cable:	37-pin connector to A/D card and 25-pin connector to spectrometer
Multiple-channel capability:	up to 8 spectrometer channels for S2000-series spectrometers
Installation parameters:	set dip switch for Base Address (default = 768 decimal, 300 hexadecimal) set dip switch for IRQ (default = 7)
Integration time:	3 milliseconds to 60 seconds with S2000-series spectrometers

SAD500 Serial Port Interface

The SAD500 Serial Port Interface is a microprocessor-controlled 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. The following are directions for setting up your SAD500. Because A/D converter installation goes hand-in-hand with software installation, you will find directions for installing OOISensors Software in this section as well.

Interface the SAD500 to your PC

Interfacing the SAD500 to a desktop or portable PC is simple.
1. If you ordered your SAD500 mounted onto your spectrometer, simply connect the 6-pin DIN end of the serial cable to the SAD500 and the DB9 end to your PC. If you ordered your SAD500 in its own housing, attach the 25-pin conductor ribbon cable from the 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 +12VDC wall transformer into an outlet and connect it to the SAD500.

Install OOISensors

Before installing OOISensors, make sure that no other applications are running. Also, make sure you have the OOISensors password. During installation, you will have to enter this password. You can find it on the back of the *Ocean Optics Software and Resources Library* CD jewel case.
1. Execute **Setup.exe**. At the "Welcome" dialog box, click **Next>**.
2. At the "Destination Location" dialog box, accept the default or choose **Browse** to pick a directory. Click **Next>**.
3. At the "Backup Replaced Files" dialog box, select either **Yes** or **No**. We recommend choosing Yes. If you select Yes, you can choose **Browse** to pick a destination directory. Click **Next>**.
4. Select a Program Manager Group. Click **Next>**. At the "Start Installation" dialog box, click **Next>**.
5. At the "Installation Complete" dialog box, choose **Finish>**. Restart your computer after installation is complete.

Run OOISensors

After restarting your computer, navigate to and select the OOISensors icon. The first time you run OOISensors after installation, select settings in the Configure Hardware dialog box.

Configure Hardware Dialog Box

Select **Configure | Hardware** from the menu. The parameters in this dialog box are usually set only once -- when OOISensors is first installed and the software first runs.
1. Under **Spectrometer Type**, select S2000/PC2000 (the SF2000, S2000-FL and USB2000-FL are S2000-series spectrometers).
2. Under **A/D Converter Type**, choose SAD500.
3. Under **Serial Port**, choose the COM port number your computer is using to interface to your SAD500. See the **Troubleshooting** section to determine the COM Port.
4. Under **Baud Rate**, select the speed at which the SAD500 will operate. (We recommend 115,200 baud.)
5. Under **SAD Pixel Resolution**, enter resolution values from 1 to 500. This value specifies that every nth pixel of the spectrometer is transmitted from the
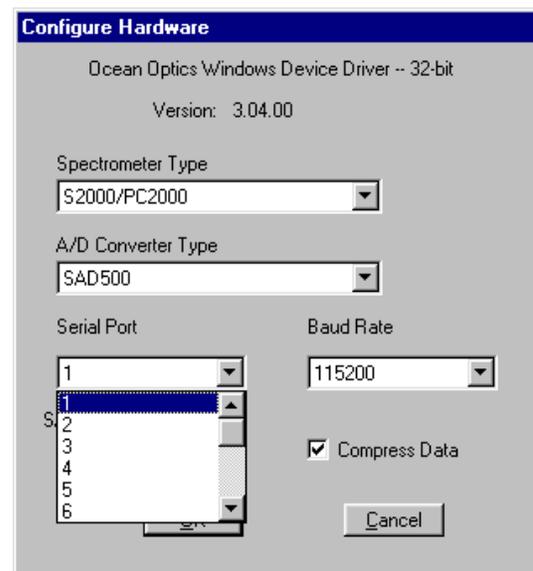
SAD500 to the PC. By sacrificing resolution, you gain speed. The transfer of one complete spectra requires ~0.4 seconds when communicating at 115,200 baud rate. If you need your information in <0.4 seconds, increase the resolution or enable data compression.

6. Enable the **Compress SAD500 Data** function to minimize the amount of data transferred over the RS-232 connection. Transmission of spectral data over the serial port is a relatively slow process. Enabling this function ensures that every scan transmitted by the SAD500 will be compressed, greatly increasing the data transfer speed of the SAD500.

7. For your setup, only these parameters apply to your system. Click **OK**.

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 OOISensors, cycle power on the SAD500, and restart OOISensors.

♦ In Windows 95/98, you can find out your Serial Port (or COM 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)** to display the COM port numbers. Ensure that there is no yellow or red 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. Instead, you will see a straight line at 0 counts.

♦ On some computers, users may have to disable any virus protection software to ensure timely and complete transfer of the data.

Specifications

A/D resolution:	12-bit
A/D sampling frequency:	500 kHz (maximum)
Communication port:	RS-232
Baud rate:	2400-115,200
Input voltage:	10 – 24V
Input current:	130 mA without spectrometer
Interface cable:	6-pin DIN connector to PC, 25-pin connector to spectrometer
Multiple-channel capability:	supports up to 8 spectrometer channels
Spectrometer integration time:	5 milliseconds to 60 seconds (S2000 spectrometers)

DAQ-700 PCMCIA A/D Converter

The DAQ-700 PCMCIA A/D Converter is a 12-bit, 100 kHz A/D card that connects our spectrometers to notebook PCs. This 16-channel single-ended, 8-channel differential card (National Instruments model DAQCard-700) fits into a credit card-size slot in a notebook PC.

Before using your spectrometer, configure your computer to properly detect and use the DAQ-700 and then follow several steps to use it as an interface to your Ocean Optics spectrometer. Because A/D converter installation goes hand-in-hand with software installation, you will find directions for installing OOISensors Software as well.

Install OOISensors

Before installing OOISensors, make sure that no other applications are running. Also, make sure you have the OOISensors password. During installation, you will have to enter this password. You can find it on the back of the *Ocean Optics Software and Resources Library* CD jewel case.
1. Execute **Setup.exe**. At the "Welcome" dialog box, click **Next>**.
2. At the "Destination Location" dialog box, accept the default or choose **Browse**. Click **Next>**.
3. At the "Backup Replaced Files" dialog box, select either **Yes** or **No**. We recommend selecting Yes. If you select Yes, accept the default or choose **Browse** to pick a destination directory. Click **Next>**.
4. Select a Program Manager Group. Click **Next>**. At the "Start Installation" dialog box, click **Next>**.
5. At the "Installation Complete" dialog box, choose **Finish>**. Restart your computer after the installation.
6. Do not run OOISensors at this time. Your computer must be properly configured to use the DAQ-700 before you can use OOISensors.

Install NI-DAQ

Windows 95/98/2000/NT users must install NI-DAQ Driver Software -- the device driver library necessary for Windows 95/98/2000/NT systems to properly use the DAQ-700. The NI-DAQ CD came with your DAQ-700.
1. Insert your NI-DAQ version 6.7 CD into your CD-ROM drive.
2. After you insert your CD, a setup program starts. If the setup program does not automatically start, run the **Setup.exe** program from the CD.
3. The installation program has an option called **Install NI-DAQ**. Select that option.
4. In the "Select Components" dialog box, make sure **NI-DAQ Driver Files (Minimal Install)** is checked. Choose any of the other options you wish to install. Click **Next>**.
5. Accept the default destination directory and the default **Program Group**.
6. In the "Ready to Install" dialog box, click **Next>**. When prompted to do so, **RESTART YOUR COMPUTER**.

Install the DAQ-700

1. After the computer restarts, wait until all disk drive activity stops -- that is, wait until your computer is completely restarted. Connect the spectrometer cable between your DAQ-700 and your spectrometer.
2. Insert the DAQ-700 into any available PCMCIA slot.
3. Windows operating systems will play a sound consisting of two tones of increasing pitch. If you do not hear this sound, and you do have internal speakers in your notebook computer, try turning the speaker volume up and reinserting the DAQ-700. If you still do not hear the "happy" sound, contact our Technical Support Department.
4. To find IRQ and Base Address values, follow the instructions for your Windows operating system.

For Windows 95/98 Users:
Configure the DAQ-700

1. If you hear the "happy" sound, click **Start**, and select **Settings | Control Panel**.
2. Double-click the **System** icon. Select the **Device Manager** tab.
3. In the "Device Manager" dialog box, find the hardware group named **Data Acquisition Devices**. Either double-click the group or select the group and click **Properties**.

4. Under the Data Acquisition Devices group, find the entry for your DAQ-700. Either double-click **DAQCard-700**, or select the entry and click **Properties**.

5. Once you have selected your DAQCard-700 from the Device Manager, click the **Resources** tab. The entries here control the hardware interface to your DAQ-700.
6. In this dialog box, find the check box next to **Use automatic settings**. Clear that check box (deselect it).
7. In the same dialog box, you will see entries for Input/Output Range and Interrupt Request. The Input/Output Range corresponds to the Base Address, and the Interrupt Request corresponds to the IRQ in our software. By deselecting the **Use automatic settings** box in the previous step, you disabled Plug-and-Play for the DAQ-700. But in order to fully disable Plug-and-Play, you must also change the settings for either (or both) the Input/Output Range or the Interrupt Request. To make this change, double-click either **Input/Output Range** or **Interrupt Request**. A dialog box giving the current hardware setting appears. On the right side of the **Value** box are two small arrows: one up and one down. You must use these arrows to change the hardware interface parameters of either the Input/Output Range or the Interrupt Request.

8. While making this change, notice the **Conflict information** area at the bottom. Make sure you choose a value that says **No devices are conflicting**. If it shows a conflict, you must select a different value. After selecting values with no conflicts, click **OK**. You will then see the "Creating a Forced Configuration" message box. Click **Yes**.

Edit Interrupt Request

Enter the interrupt request you would like to set for this device.

You may either enter a specific value and the nearest valid value will be automatically selected, or you may select a value using the up and down arrows.

Value: 10

Conflict information
The setting you have chosen does not conflict with any other devices.

No devices are conflicting.

OK   Cancel

Edit Input/Output Range

Enter the input/output range you would like to set for this device.

You may either enter a specific range and the nearest valid range will be automatically selected, or you may select a range using the up and down arrows.

Value: 0120 - 013F

Conflict information
The setting you have chosen does not conflict with any other devices.

No devices are conflicting.

OK   Cancel

9. Note your values of both the Input/Output Range (Base Address) and the Interrupt Request (IRQ). When you first run OOISensors, you must enter these values in the "Configure Hardware" dialog box.

For Windows NT Users:
Configure the DAQ-700

1. If you hear the "happy" sound, go to **Start | Programs | Administrative Tools (Common) | Windows NT Diagnostics**.
2. In the "Windows NT Diagnostics" dialog box, click on the **Resources** tab.
3. Select the **IRQ** button. Find the IRQ that your computer assigned to the DAQ-700. Note this number.
4. Select the **I/O Port** button. Find the I/O Range (Base Address) that your computer assigned to the DAQ-700. Note this number. (This number is in hexadecimal.)

Windows NT Diagnostics - \\DAVENT
File Help

| Version | System | Display | Drives | Memory |
| Services | Resources | Environment | Network |

Include HAL resources ☐

IRQ	Device	Bus	Type
01	i8042prt	0	Isa
03	Serial	0	Isa
04	Serial	0	Isa
06	Floppy	0	Isa
10	El90x	0	Pci
12	i8042prt	0	Isa
14	atapi	0	Isa
15	atapi	0	Isa

IRQ   I/O Port   DMA   Memory   Devices

Properties   Refresh   Print   OK

Windows NT Diagnostics - \\DAVENT
File Help

| Version | System | Display | Drives | Memory |
| Services | Resources | Environment | Network |

Include HAL resources ☐

Address	Device	Bus	Type
0060 - 0060	i8042prt	0	Isa
0064 - 0064	i8042prt	0	Isa
0170 - 0177	atapi	0	Isa
01CE - 01CF	VgaSave	0	Pci
01F0 - 01F7	atapi	0	Isa
02F8 - 02FE	Serial	0	Isa
0376 - 0376	atapi	0	Isa
0378 - 037A	Parport	0	Isa
03B0 - 03BB	VgaSave	0	Pci
03C0 - 03CF	STBInc	0	Pci
03C0 - 03DF	VgaSave	0	Pci
03D4 - 03DB	STBInc	0	Pci
03F0 - 03F5	Floppy	0	Isa
03F6 - 03F6	atapi	0	Isa
03F7 - 03F7	Floppy	0	Isa

IRQ   I/O Port   DMA   Memory   Devices

Properties   Refresh   Print   OK

For Windows 2000 Users:
Configure the DAQ-700

1. From your desktop, right click on the **My Computer** icon.
2. Select **Properties**. Click on the **Hardware** tab. Then click on the **Device Manager** button.
3. In the "Device Manager" dialog box, find the hardware group named **Data Acquisition Devices**. Either double-click the group or select the group and click **Properties**.
4. Under the Data Acquisition Devices group, find the entry for your DAQ-700. Either double-click **DAQCard-700**, or select the entry and click **Properties**.
5. Once you have selected your DAQCard-700 from the Device Manager, click the **Resources** tab. The entries here control the hardware interface to your DAQ-700.
6. In this dialog box, find the check box next to **Use automatic settings**. Clear that check box (deselect it).
7. In the same dialog box, you will see entries for Input/Output Range and Interrupt Request. The Input/Output Range corresponds to the Base Address, and the Interrupt Request corresponds to the IRQ in our software. By deselecting the **Use automatic settings** box in the previous step, you disabled Plug-and-Play for the DAQ-700. But in order to fully disable Plug-and-Play, you must also change the settings for either (or both) the Input/Output Range or the Interrupt Request. To make this change, double-click either **Input/Output Range** or **Interrupt Request**. A dialog box giving the current hardware setting appears. On the right side of the **Value** box are two small arrows: one up and one down. You must use these arrows to change the hardware interface parameters of either the Input/Output Range or the Interrupt Request.
8. While making this change, notice the **Conflict information** area. Make sure you choose a value that says **No devices are conflicting**. If it shows a conflict, you must select a different value. After selecting values with no conflicts, click **OK**. You will then see the "Creating a Forced Configuration" message box. Click **Yes**.
9. Note your values of both the Input/Output Range (Base Address) and the Interrupt Request (IRQ). When you first run OOISensors, you must enter these values in the "Configure Hardware" dialog box.

Run OOISensors

After you restart your computer, navigate to the OOISensors icon and select it. The first time you run OOISensors after installation, you must select settings in the Configure Hardware dialog box.

Configure Hardware Dialog Box

Select **Configure | Hardware** from the menu. The parameters in this dialog box are usually set only once -- when OOISensors is first installed and the software first opens.

1. Under **Spectrometer Type**, select S2000/PC2000 (the SF2000, S2000-FL and USB2000-FL are S2000-series spectrometers).
2. Under **A/D Converter Type**, choose DAQ700.
3. Choose the same **Base Address** value you selected in previous steps.

   The I/O Range (Base Address) you selected was expressed in hexadecimal. In this dialog box, the Base Address is given in decimal, followed by the hexadecimal equivalent in parenthesis. For example, "**768 (0x0300)**" is 768 decimal, 300 hexadecimal.
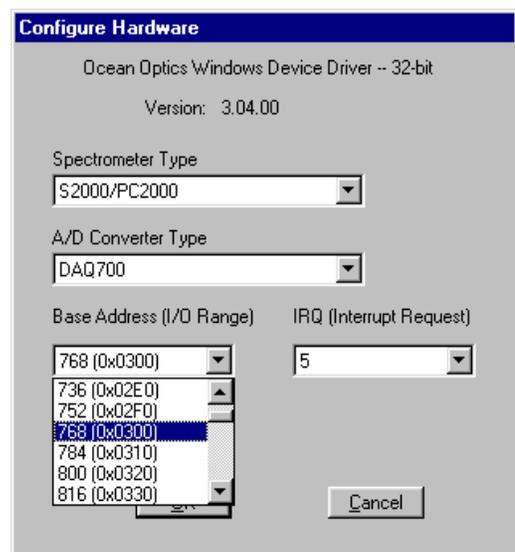
4. Choose the same **IRQ** value you selected previously.
5. For your setup, only these parameters apply to your system. Click **OK**.

Specifications

Type:	PCMCIA Type II
Resolution:	12-bit
Sampling frequency:	100 kHz (maximum)
Channels:	16-channel single-ended; 8-channel differential
Interface cable:	50-pin connector to A/D card; 25-pin connector to spectrometer
Multiple-channel capability:	supports up to 4 spectrometer channels (number of supportable channels is function of electrical current limitations)

Excitation Sources

The LS-450 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. The LS-450 Blue LED pulsed source has a cable for external connection to the spectrometer. The R-LS-450 Blue LED is a card-mounted pulsed source for mounting in a spectrometer enclosure or 19" rack system.

LS-450 Blue LED Pulsed Light Source

The LS-450 Blue LED Pulsed Light Source is a compact, low-cost light-emitting diode that produces pulsed or continuous spectral output at 470 nm -- the blue region -- for high-sensitivity emission fluorescence measurements. The LS-450 excitation source can be combined with other sampling optics for fluorescence applications.

Operation

1. Plug the wall transformer into a standard 110V outlet and into the back of the LS-450.
2. Locate the bifurcated fiber that must be used with the FOXY-24G. The bifurcated fiber has a Y design. Connect one arm of the bifurcated fiber to the SMA connector on the spectrometer and attach the other arm to the SMA connector on the LS-450 Blue LED light source. It does not matter which arm of the fiber is connected to the light source or spectrometer.
3. Locate the Splice Bushing that came with your system. It is a screw with female ends. Connect the common end of the bifurcated fiber to the splice bushing. Attach a FOXY probe to the other end of the splice bushing.

Using the Continuous Mode
1. Turn the switch on the back of the LS-450 to "contin." The continuous mode simply means that the light coming from the LS-450 is continuous.
2. To turn the lamp off, simply change the position of the switch to "off."

Using the Pulsed Mode
1. Plug one end of the DB-15 accessory connector into the back of the LS-450 and the other end into the back of the S2000.
2. Turn the switch on the back of the LS-450 to "pulsed" for pulsed mode of operation.
3. The pulsing of the LS-450 is controlled through the spectrometer. Remove your spectrometer from its housing. Do not tamper with the optical bench. (If you have more than one channel in your system, you may have to disconnect the channels from one another. The master spectrometer is always on the bottom of a multiple channel system.)
4. In the center of the green circuit board, near the optical bench, find Jumper Block 3, labeled JP3. Jumper Block 3 consists of 10 pins. The pins are labeled by rows: /16, /14, /12, /10 and 2. See the following chart for which pins must be jumpered according to how many pulses per second you need for the A/D converter you have interfaced to your S2000. (The default setting from the factory is /16.) For example, if you have an ADC1000 A/D converter, you have four choices for how many pulses per second can come out of your LS-450: 976, 244, 60 and 15. If you select 244 pulses per second, place a jumper over the pins next to the /14 label.

S2000 JP3 Post #	DAQ700 Frequency (Hz)	SAD500 Frequency (Hz)	ADC1000 Frequency (Hz)
/10	98.0	488.0	976.0
/12	24.0	122.0	244.0
/14	6.1	30.0	60.0
/16	1.5	7.6	15.2

5. When using the pulsed flash mode, the user needs to ensure that a constant number of flashes occurs for every integration cycle. To achieve a constant number of flashes per integration cycle, the integration time must be a multiple of that shown in the table below. Integration times are set in the software.

S2000 JP3 setting	Integration time for DAQ700 must be a multiple of	Integration time for SAD500 must be a multiple of	Integration time for ADC1000 must be a multiple of
/10	8 (with a min. value of 24 ms)	4	4
/12	32	8	4
/14	128	32	16
/16	512	128	64

Specifications

Physical dimensions:	9.0 cm x 5.0 cm x 3.2 cm (LWH) 3.5" x 2.0" x 1.25" (LHW)
Spectral ouput:	20 mA total output power = 500 μW typical power into 600 μm fiber = 75 μW (+/-25%) typical power into 200 μm fiber = 6 μW (+/-25%)
Stability (after 2 minutes):	+/-2 counts

R-LS-450 Rack-mount Blue LED Pulsed Light Source

The R-LS-450 Blue LED Pulsed Light Source is a compact, low-cost light-emitting diode that produces pulsed or continuous spectral output at 470 nm -- the blue region -- for high-sensitivity emission fluorescence measurements. The R-LS-450 is the rack mount version of the LS-450. The R-LS-450 can be configured to operate in continuous wave mode through manual operation and through the software. It can also be configured to operate in pulsed mode through manual operation and through the software.

The R-LS-450 is shipped with the following pins jumpered: Jumper over pins in JP1, a jumper over the Manual pins in JP3, and a jumper over the 2^{10} pins in JP2 for the fastest pulse rate available.

Operation with the R-LS-450 Board

You can configure the lamp's performance through a switch and three jumper blocks on the circuit board of the R-LS-450 and, if desired, through one jumper block on the circuit board of the S2000 spectrometer. The following lists the many different choices you have for configuring the R-LS-450 for your application. You need to determine the best mode of operation for your setup and configure your system appropriately.

S1 Switch
The S1 Switch is a three-position switch on the R-LS-450. The switch can be positioned in continuous wave operation, no operation, and pulsed operation.

Jumper Block 1 (JP1)
There is only one set of pins in JP1. If other jumper blocks are configured correctly, a jumper over JP1 allows you to turn the R-LS-450 on and off via the Enable Strobe feature in OOISensors Software and to even control the pulse rate through the Flash Delay feature in OOISensors Software. This feature is only available with an ADC1000 A/D converter and with a "J-series" or later version of the S2000. (To find out if you have a J-series or later S2000, see the third letter in your S2000 serial number.)

Jumper Block 2 (JP2)

There are nine sets of pins in JP2. The number of pulses per second of the R-LS-450 depends on the pins you jumper on JP2. However, the pulses per second are also dependent upon the master frequency of your A/D converter.

♦ A jumper over the CW pins makes the R-LS-450 operate continuously, which means that there is no pulsing of the light source. Other jumper blocks must be configured correctly. However, this configuration is not recommended for use with the FOXY system.

♦ A jumper over the 2^{16}, 2^{15}, 2^{14}, 2^{13}, 2^{12}, 2^{11} and 2^{10} pins controls the pulse rate per second of the R-LS-450, depending on the A/D converter you are using to interface to your S2000. (See table below for pulse rates.)

♦ A jumper over the CS pins allows you to control the pulse rate via the OOISensors Software. (See Using JP3 on the S2000 on the next page for more information.)

Pins on the JP2	Function	DAQ700 Frequency (Hz)	SAD500 Frequency (Hz)	ADC1000 Frequency (Hz)
CW	Continuous Mode	0	0	0
2^{16}	Divide by 2^{16}	1.5	7.6	15.2
2^{15}	Divide by 2^{15}	3.1	15.2	30.4
2^{14}	Divide by 2^{14}	6.1	30.0	60.8
2^{13}	Divide by 2^{13}	12.2	60.8	122.0
2^{12}	Divide by 2^{12}	24.0	122.0	244.0
2^{11}	Divide by 2^{11}	48.0	244.0	488.0
2^{10}	Divide by 2^{10}	98.0	488.0	976.0
CS*	Continuous Strobe	N/A	N/A	Software Controlled

Jumper Block 3 (JP3)

There are two sets of pins in JP3. The jumper position here determines the source of control for the R-LS-450: manual or remote control. A jumper over the Remote pins means that you can control the R-LS-450 through the software (if other jumper blocks are configured correctly).

R-LS-450 Operating Matrix

This matrix will help you configure the jumper blocks on the R-LS-450.

S1 Switch	JP1	JP3	LED Status
Off	No jumper	No jumper	Off
CW	No jumper	No jumper	Continuously on
CW	Jumpered	Jumper Remote pins	Continuous wave mode controlled by software (see *Continuous Wave Mode with the S2000's JP3* for more information)
CW	Jumpered	Jumper Manual pins	Continuously on
Pulsed	No jumper	No jumper	Pulse rate determined by JP2 on the R-LS-450 board (see the JP2 table for pulse rates)
Pulsed	Jumpered	Jumper Remote pins	Pulsed mode controlled by software (see *Pulsed Mode with the S2000's JP3* for more information)
Pulsed	Jumpered	Jumper Manual pins	Pulse rate determined by JP2 on the R-LS-450 board (see the JP2 table for pulse rates)

Using JP3 on the S2000

You can also have functionality of the R-LS-450 by utilizing Jumper Block 3 (JP3) on the S2000 circuit board. The S2000's JP3 allows you to control the R-LS-450 through the OOISensors Software.

Continuous Wave Mode with the S2000's JP3

The Continuous Wave Mode is not recommended for use with the FOXY system. However, if you want to control the turning on and off of the R-LS-450 while it is in continuous wave mode through the Enable Strobe function in the OOISensors Software, only do so if:

♦ The switch is turned to continuous wave mode.
♦ There is a jumper over the pins in JP1 of the R-LS-450.
♦ There is a jumper over the CW pins in JP2 of the R-LS-450.
♦ There is a jumper over the Remote pins in JP3 of the R-LS-450.
♦ There is a jumper over the 2 pins in JP3 of the S2000 board.

Pulsed Mode with the S2000's JP3

Another way you can control the pulses per second of the R-LS-450 is if

♦ The switch is turned to pulsed mode.
♦ There is a jumper over the pins in JP1 of the R-LS-450.
♦ There is a jumper over the CS pins in JP2 of the R-LS-450.
♦ There is a jumper over the over the Remote pins in JP3 of the R-LS-450.
♦ There is a jumper over pins labeled /16, /14, /12, or /10 in JP3 of the S2000, depending on the pulse rate you need. The pulses per second are also dependent upon the frequency of your A/D converter. See the table below for choices.

Pins on the S2000's JP3	DAQ700	SAD500	ADC1000
/16	1.5	7.6	15.2
/14	6.1	30.4	60.8
/12	24.0	122.0	244.0
/10	98.0	488.0	976.0

You can control the pulses per second of the R-LS-450 through the **Flash Delay** function in the OOISensors Software if:

♦ You are using an ADC1000 A/D converter.
♦ The switch is turned to pulsed mode.
♦ There is a jumper over the pins in JP1 on the R-LS-450 board.
♦ There is a jumper over the pins labeled CS in JP2 on the R-LS-450 board.
♦ There is a jumper over the pins labeled Remote in JP3 on the R-LS-450 board.
♦ There is a jumper over the pins labeled 2 in JP3 on the S2000 board.

Setting the Integration Time

When using any of the pulsed modes for the R-LS-450, you need to ensure that a constant number of flashes occurs for every integration cycle. This achieves a continuous and stable signal. The integration time is set in the OOISensors Software. To achieve a constant number of flashes per integration cycle, the integration time must be a multiple of those shown in the following table, according to the A/D converter being used:

Pins on the JP3 (of the S2000)	Integration time for DAQ700 must be multiple of	Integration time for SAD500 must be multiple of	Integration time for ADC1000 must be multiple of
/16	512	128	64
/14	128	32	16
/12	32	8	4
/10	8 (with a min. value of 24 ms)	4	4
2	N/A	N/A	N/A

Bifurcated Optical Fiber Assemblies

Our bifurcated fiber optic assemblies easily connect to our sensors, light sources and miniature fiber optic spectrometers via SMA terminations and an additional splice bushing. These single-strand, multi-mode optical fibers are silica-core and silica-clad. Standard assemblies are 2 meters in length, although custom options include lengths greater than 2 meters. The ends of the fibers are cleaved, epoxied into the connectors, and polished.

Bifurcated assemblies are shaped like a "Y" with a stainless steel breakout located midway from the ends of the fibers. The common end (the tail of the "Y") of a bifurcated assembly has 2 fibers side by side. The common end of a bifurcated fiber can be coupled to a larger diameter probe with a splice bushing The bifurcated fibers used in FOXY systems are:

♦ The BIF200 Bifurcated Fiber consists of 2 separate 200-µm optical fibers in a "Y" configuration. It should be used with the FOXY-AL300 and FOXY-24G probes.
♦ The BIF400 Bifurcated Fiber consists of 2 separate 400-µm optical fibers in a "Y" configuration. It should be used with the FOXY-PI600 probe.
♦ The BIF600 Bifurcated Fiber consists of 2 separate 600-µm optical fibers in a "Y" configuration. It should be used with the FOXY-R, FOXY-OR125, FOXY-OR125G and the FOXY-T1000 probes.

Caution!

♦ Gently remove the plastic cover from the SMA connector before use. Pulling the SMA connector away from the fiber when removing the plastic cover will permanently damage the fiber.
♦ When fibers break, they stop transmitting light. Inspect fibers by eye to determine if light is being transmitted.
♦ Do not coil the fiber too tightly, or bend it at a sharp angle. The maximum sustained bend radius of a 400 µm fiber is 10 cm. Bending the fiber can cause attenuation. To minimize this effect, add extra strain relief to both ends of the fiber.
♦ Do not exceed the temperature specifications for the materials involved: 200°C for the fiber, 100°C for PVC cabling, 100°C for standard epoxy.
♦ Keep connectors and probe tips covered when the fibers are not being used.
♦ Clean ends of the fibers with lens paper and distilled water, alcohol or acetone. Avoid scratching the surface.
♦ Do not immerse fiber ends in caustic materials or other solutions that can damage quartz or aluminum.

Operation

1. Locate the 21-02 SMA Splice Bushing that came with your system. It is a 0.75" screw with female ends.
2. Screw one end of the splice bushing into the SMA 905 connector on the proximal end of the FOXY probe.
3. Connect the common end (the tail of the "Y") of the bifurcated fiber to the splice bushing/probe.
4. Connect one arm of the bifurcated fiber to the SMA connector on the spectrometer and connect the other arm to the SMA connector on the LS-450 Blue LED light source. It does not matter which arm of the fiber is connected to the light source or spectrometer.

Specifications

|	
Connector/termination:	SMA 905
Fiber core:	pure fused silica
Fiber cladding:	doped fused silica
Fiber jacket:	Nylon (temperature range -40° C to 100° C)
Sheathing/cabling:	♦ PVC with Kevlar reinforcement (standard) ♦ PVC Monocoil (optional) ♦ BX flexible metal sleeve (optional)
Mode structure:	step-index multi-mode
Numerical aperture:	0.22
Recommended minimum bend radius:	momentary = 200x the fiber radius; long term = 400x the fiber radius

OOISensors Software

OOISensors Software is our next generation of operating software for our FOXY Fiber Optic Oxygen Sensing systems. OOISensors is a 32-bit, advanced acquisition and display program that provides a real-time interface to a variety of signal-processing functions for Windows 95/98/2000/NT users. With OOISensors, users have the ability to obtain oxygen partial pressure and concentration values, control all system parameters, collect data from up to 8 spectrometer channels simultaneously and display the results in a single spectral window, perform time acquisition experiments and display and correct for temperature fluctuations in the sample.

The most important change from the previous oxygen sensing software, the 16-bit OOIFOXY, is the ability to use the Second Order Polynomial algorithm in the calibration procedure. This algorithm often provides more accurate data than the linear Stern-Volmer algorithm. Also, with OOISensors, you can now monitor temperature. The software corrects the data for any fluctuations in temperature. Another improvement over OOIFOXY is that OOISensors can display up to 8 spectrometer channels in one spectral window, and yet each spectrometer channel can have its own data acquisition parameters.

What's more, a time chart displays the data from all active channels at a specific wavelength over time. During a timed data acquisition procedure, you can enter text for an event into the log file. Enabling the time chart and the data logging function are as easy as clicking on switches next to the graph.
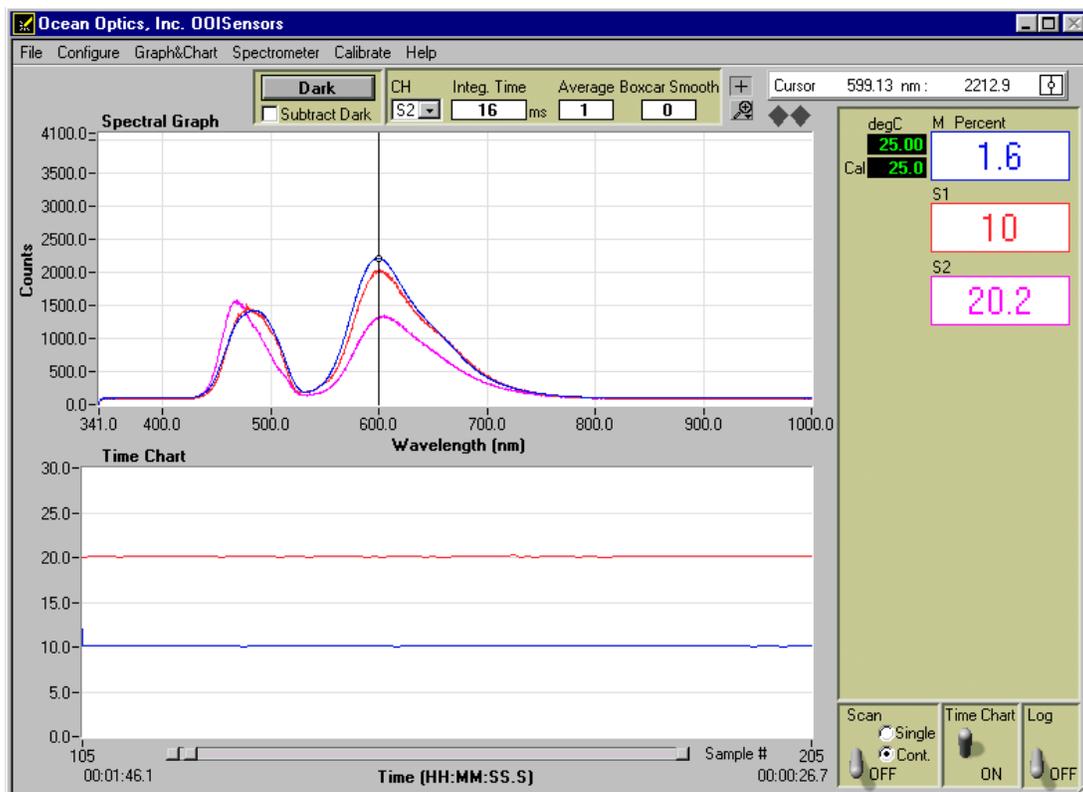
Display Functions

Several functions are accessed not through the menu but through buttons and taskbars directly on the display window, on the top and to the right of the spectral graph and time chart areas. From the display window, you can choose a mode to acquire data, take scans of your sample, store a dark spectrum, configure the cursor, configure the graph, enter data acquisition parameters and analyze data.

Scan Single and Continuous

When in **Single** mode, the Scan function acts as a snapshot. After selecting the Single mode, click the Scan switch to **ON** to take a scan of the sample. The switch stays in the **ON** position until the scan has been completed (the time set in the Integration Time box). The switch then moves to the **OFF** position.
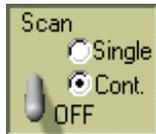
When in **Cont.** (continuous) mode, the Scan function continuously takes as many scans of the sample as needed. After each integration cycle, another scan will immediately begin. Click the switch to **OFF** to discontinue acquiring data.

Store Dark

This function stores the current spectrum as the dark spectrum for all active channels. The dark spectrum is taken with the light path to the sample blocked. Storing a dark spectrum is requisite before the computer can make accurate measurements. This function stores the dark values at the fluorescence and reference wavelengths. If you have configured the spectrometer to control the LS-450 (see pages 41-44), the software can take *automatic* dark scans if you select **Configure | Spectrometer** from the menu, click on the **Sensors** tab and select **Scan dark for every measurement**. When this function is enabled, the LS-450 automatically turns off, and a dark scan is stored, each time you take a sample scan.

Subtract Dark

Selecting this box subtracts the current dark spectrum from the spectra being displayed. This command is useful if you are trying to eliminate from the spectra fixed pattern noise caused by a very long integration time. This function is only for display purposes.

Data Acquisition Parameters

Functions at the top of the display window such as choosing the integration time, averaging and boxcar smoothing values provide you with immediate access to important data acquisition settings.
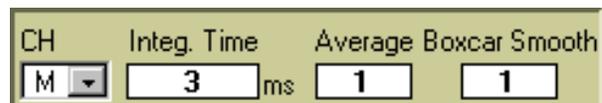
Channel [CH]

To set the data acquisition parameters (such as integration time, averaging and boxcar smoothing) for a specific spectrometer channel, first select the spectrometer channel from the **CH** pull down menu. This pull down menu is not for selecting the spectrometer channels that are active in the display graph; it's only for setting data acquisition values for each channel. (To activate your spectrometer channels and have them displayed, select **Configure | Spectrometer** from the menu and click on the **Sensors** tab. Enable each spectrometer in your system.)

Integration Time

Enter a value to set the integration time in milliseconds for the chosen spectrometer channel. The integration time of the spectrometer is analogous to the shutter speed of a camera. The higher the value specified for the integration time, the longer the detector "looks" at the incoming photons. If your signal intensity is too low, increase this value. If the signal intensity is too high, decrease the value. Adjust the integration time until the fluorescence peak (~600 nm) is about 2000 counts in air or saturated water. The fluorescence peak should not exceed 3500 counts. The intensity of the LED peak (~475 nm) does not affect your measurements. You only need to adjust the integration time if the fluorescence peak is saturating the detector.

Be sure to set the integration time to powers of 2. These numbers (2, 4, 8, 16, 32, 64, 128, 256, 512, etc.) will insure a constant number of LED pulses during the integration time.

Average

Enter a value to implement a sample averaging function that averages the specified number of spectra for the chosen spectrometer channel. The higher the value entered the better the signal-to-noise ratio (S:N). The S:N improves by the square root of the number of scans averaged.

Boxcar Smooth

Enter a value to implement a boxcar smoothing technique that averages across spectral data for the spectrometer channel chosen. This method averages a group of adjacent detector elements. A value of 5, for example, averages each data point with 5 points (or bins) to its left and 5 points to its right. The greater this value, the smoother the data and the higher the signal-to-noise ratio. However, if the value entered is too high, a loss in spectral resolution results. The S:N improves by the square root of the number of pixels averaged. When using the oxygen sensors, we recommend setting the boxcar smoothing value to no more than 25 pixels.

Cursor Functions

In this bar, you can label the cursor, monitor its X and Y values and move the cursor. To the right of the X and Y values of the cursor is a cursor selection button that allows you to choose a cursor style and a point style.

| + | Cursor | 599.13 nm : | 2212.9 | ⬚ |
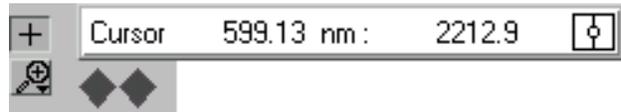
+ Sign

When the **+** is selected, the pointer becomes a crosshair symbol, enabling you to drag the cursor around the graph.

Magnify Symbols

There are several magnify functions from which to choose. The function chosen remains in use until another magnify icon or the crosshair symbol is selected. Clockwise, beginning with the top left symbol, the magnify icons perform the following functions:

1. magnifies a specific area by clicking and dragging a box around the area
2. zooms in on the horizontal scale, but the vertical scale remains the same
3. zooms in on the vertical scale, but the horizontal scale remains the same
4. zooms in approximately one point vertical and horizontal, click once or press continuously
5. zooms out approximately one point vertical and horizontal, click once or press continuously
6. reverts to the last zoom function
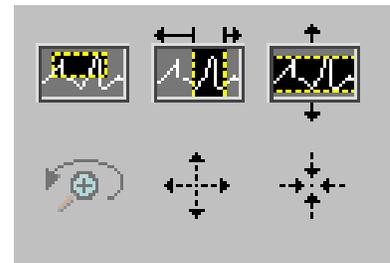
Cursor Diamonds

To move the cursor left or right in small increments in the graph area, click on the left and right cursor diamonds.

Cursor Label

The first box in the configure cursor taskbar allows you to label the cursor.

X and Y Values

The cursor taskbar displays the X value and Y value of the cursor point.

Cursor Properties

To the right of the X and Y values of the cursor is a cursor selection button that allows you to utilize many cursor features such as choosing a cursor style, selecting a point style and finding a color for the cursor trace .

Data Values

The data displayed to the right of the graphs and chart areas provides you with the oxygen values for each spectrometer channel and probe combination. If you are monitoring and correcting for temperature, these values appear in this area as well.
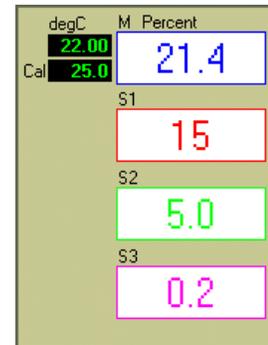
Spectral Graph

The spectral graph area of the display window provides you with real-time spectral scans of your sample. You can change the vertical and/or horizontal scales of the graph by simply clicking on an X and Y endpoint and manually typing in a value. The graph will then resize itself.

Temperature Chart

To display the temperature chart, select **Graph&Chart | View Temperature Chart** from the menu. The Temperature Chart will then take the place of the Spectral Graph. To save the Temperature Chart, select **File | Save Time Chart** from the menu. You will receive two Save prompts, one for the Time Chart and one for the Temperature Chart. By selecting **Graph&Chart | View Temperature Chart** again (deselecting the function), the Spectral Graph will return.

You can also save Temperature Chart data without displaying the chart. By selecting **Configure | Spectrometer** from the menu, clicking on the **Sensors** tab, and enabling the **Chart** function under Temperature Measurement, temperature data is collected, whether or not the Temperature Chart is displayed. Then you can use the save function.

Time Chart

The time chart displays the data from all active channels at a specific wavelength over time. To view the Time Chart, select **Configure | Spectrometer** from the menu and click on the **Display** tab. Make sure that **Spectral Graph & Time Chart** is selected next to **Graph and Chart Display Mode**. To configure a timed data acquisition procedure, select **Configure | Spectrometer** from the menu and click on the **Timing** tab. (For details on configuring a timed acquisition procedure, see page 53.)

Time Chart and Log On/Off Switches

Once you have configured a timed data acquisition procedure, you can start and stop the acquisition by clicking on the **Time Chart** switch. (To set the parameters for a timed data acquisition procedure, select **Configure | Spectrometer** from the menu, click on the **Timing** tab and enter your settings.) Turn on and off saving this data to a log file by clicking on the **Log** switch. (To set parameters for saving timed acquisition data, select **Configure | Spectrometer** from the menu, click on the **Log** tab, select how frequently you want to save data and choose the file name for the log.) Only the last 10,000 scans of a timed data acquisition can be saved in the log file.

File Menu Functions

Save Spectrum

Select **File | Save Spectrum** from the menu to save the current spectrum as a tab-delimited ASCII file. You can then open these files as overlays in the spectral graph or import them into other software programs, such as Microsoft Excel.

Save Time Chart

Select **File | Save Time Chart** from the menu to save the current time chart as a tab-delimited ASCII file. You can then open these files as a static chart or import them into other software programs, such as Microsoft Excel.

Open Spectrum

Select **File | Open Spectrum** from the menu to open a dialog box that allows you to open a previously saved spectrum and to open it as an overlay (a static spectrum) while still acquiring live data.

Open Time Chart

Select **File | Open Time Chart** from the menu to open a dialog box that allows you to choose a previously saved time chart and open it as a static chart.

Page Setup

Select **File | Page Setup** to select printing parameters.

Print Spectrum and Time Chart

Select **File | Print Spectrum** from the menu to print the current display in the Spectral Graph, or select **File | Print Time Chart** from the menu to print the time chart.

Exit

Select **File | Exit** from the menu to quit OOISensors. A message box appears asking you if you are sure you want to exit the software.

Configure Menu Functions

Hardware

The Configure Hardware dialog box sets the hardware parameters for the spectrometer. The parameters in this dialog box are usually set only once -- when OOISensors is first installed. The first time you run OOISensors after installation, you need to select settings in the Configure Hardware dialog box. Select **Configure | Hardware** from the menu. First, select a **Spectrometer Type** (the S2000-FL, SF2000 and USB2000 are S2000-series spectrometers). Next, select an **A/D Converter Type**. Select the A/D converter you are using to interface your spectrometer to your computer. Your choices are the ADC500/PC1000, ADC1000/PC2000, DAQ700, SAD500, Serial USB2000 or USB2000.

Depending on the Spectrometer Type and the A/D Converter Type you chose, other choices must be made:

♦ For ADC1000 and DAQ700 users: Select an available **Base Address (or I/O Range)** and **IRQ (Interrupt Request)** from the drop down menus. See the directions for your A/D converter for details on selecting these values. For ADC1000 users, see pages 30-33. For DAQ700 users, see pages 36-40.

♦ For SAD500 and Serial USB2000 users:

-- Enter your computer's **Serial Port** (or COM Port) number to which the device is connected.

-- Select the **Baud Rate** or speed at which the device will operate.

-- Enter a **SAD500 Pixel Resolution**, which specifies that every nth pixel of the spectrometer is transmitted from the SAD500 to the PC. Enter resolution values from 1 to 500. Your resolution value depends on your experiment. By sacrificing pixel resolution, you gain speed. The transfer of one complete spectra requires ~0.4 seconds when communicating at 115,200 baud rate. If you need your information in <0.4 seconds, increase the resolution or enable data compression. (This option does not appear for Serial USB2000 users.)

-- Enable the **Compress Data** function to minimize the amount of data transferred over the RS-232 connection. Transmission of spectral data over the serial port is a relatively slow process. Enabling this function insures that every scan transmitted will be compressed, greatly increasing the data transfer speed.

♦ For USB2000 users: Select the **USB2000 Serial Number** for the USB2000 you wish to use.
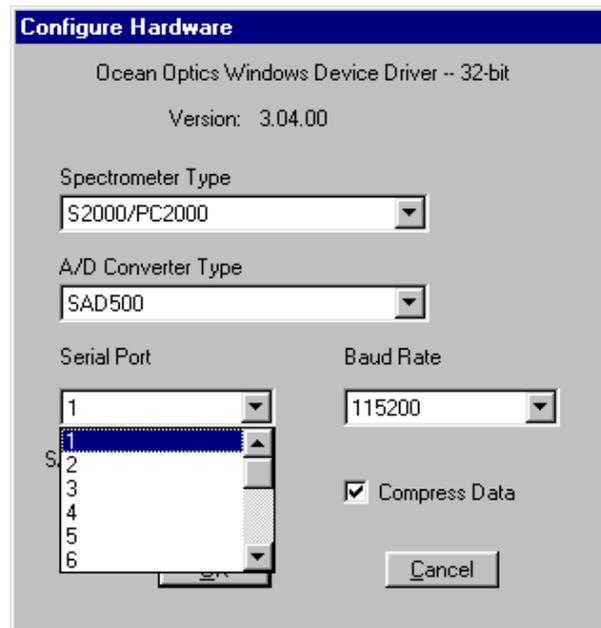
Spectrometer

Choose **Configure | Spectrometer** from the menu. Go through each page of this dialog box to select options for sensing, timing, displaying and logging options.

Sensors Tab

To set the parameters for your sensors, select **Configure | Spectrometer** from the menu and then click on the **Sensors** tab.

♦ **Choose a spectrometer channel to view its sensor parameters.** Set parameters for each spectrometer channel in your system by first selecting a channel. Each spectrometer channel has its own parameters.

♦ **Scan dark for every measurement.** Storing a dark spectrum is requisite before the computer can make accurate measurements. If you have configured the spectrometer to control the LS-450 (see pages 41-44), the software can take *automatic* dark scans if you select **Scan dark for every measurement**. When this function is enabled, the LS-450 automatically turns off, and a dark scan is stored, each time you take a sample scan.

♦ **Channel active.** Select this box to activate the spectrometer channel.

- **Sensor.** Use the pull down menu to select the type of sensor you are using for each spectrometer channel.
- Click on the solid colored box to change the color of the spectral trace that will appear in the display graph.
- **Chart.** Select the type of information you want charted in the Spectral Graph. You can choose to view the spectral graph of the sensor or the intensity at the analysis wavelength.
- **Analysis Wavelength Box.**
  Enter the analysis wavelength. The analysis wavelength should be very close to 600 nm. (When the excited ruthenium complex at the tip of the oxygen probe fluoresces, it typically emits energy at ~600 nm.) In the **Bandwidth [box] pixels** area, select the number of pixels around the analysis wavelength to average.
- **Data Display for Sensor Measurement.** Choose the data display format and precision of the data. Under **Format** select Decimal or Scientific. Under **Precision**, select a value to specify the precision of the oxygen data displayed and saved in files. The maximum is 5.
- **Wavelength Calibration Coefficients.** Check the Wavelength Calibration Data Sheet that came with your system to make sure the values on the Data Sheet and in this dialog box are the same.
- **Pressure Compensation CH.** If you have your own pressure transducer, you can use this feature to monitor and correct for pressure fluctuations in your sample. You can either use a pressure transducer separately from the system or interface it to your sensor system. If you interface a pressure transducer to your sensor system, you must have an available spectrometer channel that is not connected to an oxygen sensor. Use the pull down menu to select how you want to monitor pressure.
- **Temperature Measurement.** If you want to monitor and correct for temperature fluctuations in your sample, select a method from the pull down menu.
  - -- Select **None** if you are not monitoring temperature.
  - -- Select **Manual** if you are monitoring temperature, but you do not want OOISensors Software to read and display the temperature values. The Manual selection means that you must manually type temperature values in the display window. Enable the **Compensate** function if you want the software to correct for temperature fluctuations. Enabling the **Chart** function allows you to view a chart of the temperature values.
  - -- Select **Omega D5xx1 RS232** if you are monitoring temperature and if you want the software to automatically read and display the temperature values. Ocean Optics offers the Omega Thermistor and the Omega Thermocouple for monitoring temperature. The thermistor and thermocouple should already be connected to your PC via an RS-232 module. Next to **Serial Port**, select the COM Port number on your PC to which the thermistor or thermocouple is connected. Because the RS-232 module can support up to four thermistors or thermocouples, it has these four ports labeled. Next to **D5xx1 CH**, select the port to which the thermistor or thermocouple connects to the RS-232 module. (If you only have one thermistor or thermocouple, select 0.) Enable the **Compensate** function if you want the software to correct for temperature fluctuations. Enabling the **Chart** function allows you to view a chart of the temperature values.
- **Enable reference correction.** Enable this function if you want to monitor and correct for any drift or change in the LS-450 Blue LED light source. The LED emits light at ~475 nm. In the **Bandwidth [box] pixels** area, select the number of pixels around the reference wavelength to average.
- **Level alarm.** Enable this feature to set alarm properties. A green indicator appears in the display window if this feature is activated. If the values fall below the alarm parameters, the green indicator turns red. If the values rise above the alarm parameters, the green indicator turns yellow.

Timing Tab

To configure a timed data acquisition procedure, select **Configure | Spectrometer** from the menu and select the **Timing** tab. In this dialog box, you can set the parameters for a timed data acquisition procedure.

♦ **Preset Duration.** Enable this box and enter values to set the length for the entire timed acquisition process. Be sure to enter hours (HH), minutes (MM) and seconds (SS).

♦ **Preset Sampling Interval.** Enable the Preset Sampling Interval box and enter a value to set the frequency of the data collected in a timed acquisition process. Be sure to select hours (HH), minutes (MM) and seconds (SS).

♦ **Flash Delay.** Enter a value to set the delay, in milliseconds, between strobe signals of the LS-450 Blue LED light source. You can only use this feature if you have an ADC1000 A/D converter. (See pages 41-44 for details.)

♦ **External Trigger Mode.** You have two methods of acquiring data. Choose a triggering mode from the pull down menu:

-- In the normal mode (called **No External Trigger**), the spectrometer is continuously scanning, acquiring, and transferring data to your computer, according to parameters set in the software. In this mode, however, there is no way to synchronize the acquisition of data with an external event.

-- To synchronize data acquisition with external events, choose **External Software Trigger**. In this level-triggered mode, the spectrometer is "free running," just as it is in the normal mode. With each trigger, the data collected up to the trigger event is transferred to the software. (See **Appendix D** for details.)

♦ Once you have configured a timed data acquisition procedure, you can start and stop the acquisition by clicking on the **Time Chart** switch on the main display window.
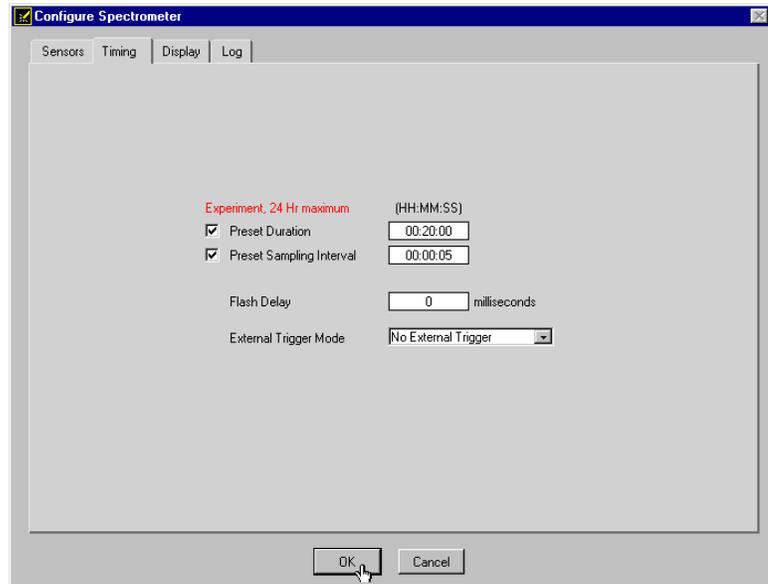
Display Tab

To configure your display window, select **Configure | Spectrometer** from the menu and click on the **Display** tab. In this dialog box, select the graphs and charts to appear in the display window.

♦ **Graph and Chart Display Mode.** Choose the information that appears in the display window. If you choose **Spectral Graph Only**, a spectral graph appears in the display window. If you choose **Spectral Graph & Time Chart**, the spectral graph appears in the top of the display window and the time chart appears in the bottom. (To view a temperature chart, select **Graph&Chart | View Temperature Chart** from the main menu. The temperature chart then replaces the spectral graph.)

♦ **Temperature Units.** Select either **Celsius** or **Fahrenheit** as the temperature units. (The application works in Kelvin, and converts to Celsius or Fahrenheit.)

♦ **Color for overlays.** Select colors for static spectra that open when selecting File | Open Spectrum from the menu. These static spectra are called overlays and you may wish to distinguish overlays from real-time spectra by changing the colors of their traces.
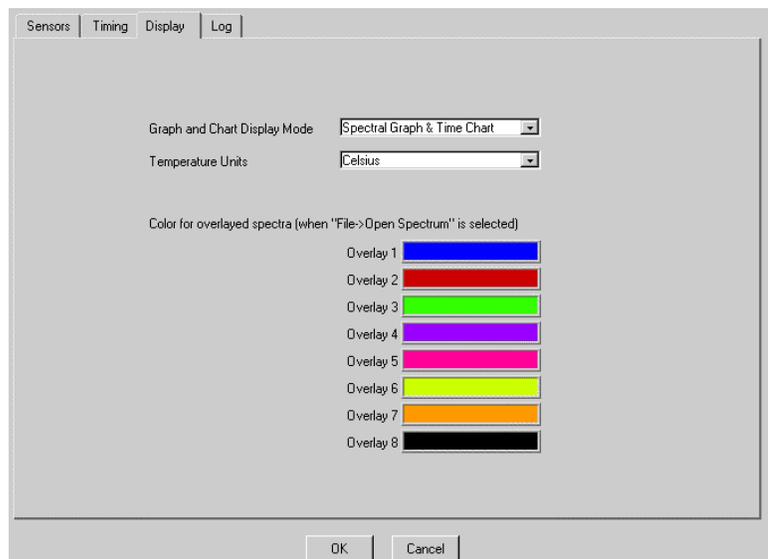
Log Tab

To configure the data logging feature for a timed data acquisition procedure, select **Configure | Spectrometer** from the menu and select the **Log** tab.

♦ **Store to disk every x acquisitions.** Enter a value to set how many scans are stored in RAM before they are saved permanently into a file. The smaller this number, the more frequently data is saved permanently to a file. The larger this number, the less frequently data is saved permanently to a file, but entering a large number enhances the performance of the process.

♦ **Filename and Path.** Name the log file for the timed data acquisition process. Click on the file folder icon to navigate to a designated folder.

♦ **Insert Event in Log File.** If you want to enter text into the log file, you can select **Spectrometer | Insert Event in Log File** from the menu. A dialog box then appears allowing you to enter text. In the log file, this text appears next to the data that was acquired at the time you entered the text.

♦ To turn the logging function on for the time chart, you must select the **Log On/Off Switch** on the main display window.
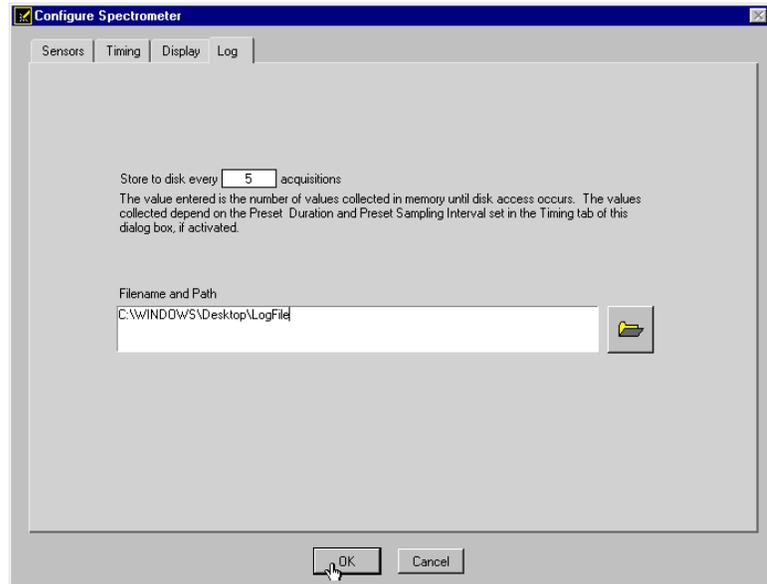
Graph & Chart Menu Functions

Clear Spectrum Graph

Select **Graph&Chart | Clear Spectrum Overlays** from the menu to remove static spectra from the graph.

Clear Time Chart

Select **Graph&Chart | Clear Time Chart** from the menu to clear the time chart traces. A message box then appears, asking if you are sure you want to clear the time chart.

Enable Grid

Select **Graph&Chart | Enable Grid** from the menu to generate a grid in the spectral graph. If you also have the time chart displayed, this function will create a grid in the time chart as well. De-selecting **Enable Grid** from the menu makes the grid disappear.

Autoscale Horizontal (Spectral Graph)

Select **Graph&Chart | Autoscale Horizontal (Spectral Graph)** from the menu to automatically adjust the horizontal scale of a current graph so the entire horizontal spectrum fills the display area.

Autoscale Vertical (Spectral Graph)

Select **Graph&Chart | Autoscale Vertical (Spectral Graph)** from the menu to automatically adjust the vertical scale of a current graph so the entire vertical spectrum fills the display area.

Autoscale Vertical (Time Chart)

Select **Graph&Chart | Autoscale Vertical (Time Chart)** from the menu to automatically adjust the vertical scale of a current time chart so the entire vertical chart fills the display area.

View Temperature Chart

Select **Graph&Chart | View Temperature Chart** from the menu to view temperature data. The temperature chart replaces the spectral chart. To view the spectral graph again, select **Graph&Chart | View Temperature Chart** from the menu and the spectral graph replaces the temperature chart.

Spectrometer Menu Functions

Scan

Select **Spectrometer | Scan** from the menu to take a scan of your sample. When in **Single** mode, the Scan function acts as a snapshot. The button depresses and Stop replaces Scan. The button will stay depressed until the scan has been completed (the time set in the Integration Time box).

When in **Continuous** mode, the Scan button continuously takes as many scans of the sample as needed. After each integration cycle, another scan immediately begins. The button depresses and Stop replaces Scan. Select **Spectrometer | Scan** from the menu or click on the Stop button to halt the scanning process and discontinue acquiring data.

Insert Event in Log File

During a timed data acquisition procedure, you can enter text into the log file by selecting **Spectrometer | Insert Event in Log File**. A dialog box then appears allowing you to enter text. In the log file, this text appears next to the data that was acquired at the time you entered the text. Both the Time Chart and Log switches in the display window should be turned to the On position to use this feature.

Enable Strobe

If you have configured the spectrometer to control the LS-450 (see pages 41-44), selecting this function in the software allows you to enable or disable the triggering of the LS-450 Blue LED light source. The value entered in **Flash Delay** of the **Timing** tab in the **Configure Spectrometer** dialog box sets the delay, in milliseconds, between strobe signals of the LS-450 Blue LED light source.

Calculate Sensor Values with Scan

When you first start OOISensors, the values displayed in the Data Values boxes to the right of the Spectral Graph will appear illogical. These values will continue to appear this way until you have calibrated your system. If you don't want to see these illogical values displayed, deselect **Spectrometer | Calculate Sensor Values with Scan**.

Once you have calibrated your system, this function should always be enabled (or have a check mark in front of it) if you want the oxygen values displayed.

Calibrate Menu Functions

In order to make accurate oxygen measurements of your sample, you must first perform a calibration procedure with your FOXY system. Two major factors affect the calibration procedure of your FOXY system.
1. First, decide if you are going to compensate for changes in temperature in your sample. If you are working with a sample where there are no fluctuations in temperature, you do not need to compensate for temperature. (Though Ocean Optics miniature spectrometers are extremely sensitive, they will not be able to detect temperature fluctuations +/- 3° Celsius.)
2. Next, choose the algorithm you wish to use for you calibration procedure. The **Linear (Stern-Volmer)** algorithm requires at least two standards of known oxygen concentration while the **Second Order Polynomial** algorithm requires at least three standard of known oxygen concentration.

Calibration curves are generated from your standards and the algorithms to calculate concentration values for unknown samples. The Second Order Polynomial algorithm provides a better curve fit and therefore more accurate data during oxygen measurements, especially when you are working in a broad oxygen concentration range.

Linear (Stern-Volmer) Algorithm

The Stern-Volmer algorithm requires at least two standards of known oxygen concentration. The first standard must have 0% oxygen concentration and the last standard must have a concentration in the high end of the concentration range in which you will be working. The fluorescence intensity can be expressed in terms of the Stern-Volmer equation where the fluorescence is related quantitatively to the partial pressure of oxygen:

$$\frac{I_0}{I} = 1 + k\, p_{O2}$$

I_0 is the intensity of fluorescence at zero pressure of oxygen,
I is the intensity of fluorescence at a pressure p of oxygen,
k is the Stern-Volmer constant

For a given media, and at a constant total pressure and temperature, the partial pressure of oxygen is proportional to oxygen mole fraction.

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

If you decide to compensate for temperature, the relationship between the Stern-Volmer values and temperature is defined as:

$$I_0 = a_0 + b_0 * T + c_0 * T^2$$
$$k = a + b * T + c * T^2$$

The *intensity of fluorescence at zero pressure of oxygen (I$_0$)* depends on details of the optical setup: the power of the LED, the optical fibers, loss of light at the probe due to fiber coupling, and backscattering from the sample. It is important to measure the *intensity of fluorescence at zero pressure of oxygen (I$_0$)* for each experimental setup.

It is evident from the equation that the sensor will be most sensitive to low levels of oxygen. Deviations from the Stern-Volmer relationship occur primarily at higher oxygen concentration levels. Using the Second Order Polynomial algorithm when calibrating corrects these deviations.

Second Order Polynomial Algorithm

The Second Order Polynomial algorithm requires at least three standards of known oxygen concentration. The first standard must have 0% oxygen concentration and the last standard must have a concentration in the high end of the concentration range in which you will be working.

The Second Order Polynomial algorithm is considered to provide more accurate because it requires at least three known concentration standards while the Linear (Stern-Volmer) algorithm requires a minimum of two known concentration standards. The Second Order Polynomial algorithm is defined as:

$$\frac{I_0}{I} = 1 + K_1 * [O] + K_2 * [O]^2$$

I_0 is the fluorescence intensity at zero concentration
I is the intensity of fluorescence at a pressure p of oxygen,
K_1 is the first coefficient
K_2 is the second coefficient

If you decide to compensate for temperature, the relationship between the Second Order Polynomial algorithm and temperature is defined as:

$$I_0 = a_0 + b_0 * T + c_0 * T^2$$
$$K_1 = a_1 + b_1 * T + c_1 * T^2$$
$$K_2 = a_2 + b_2 * T + c_2 * T^2$$

Henry's Law

It is possible to calibrate the FOXY system in gas and then use the FOXY system in liquid or vice versa. In theory, your FOXY system detects the partial pressure of oxygen. In order to convert partial pressure to concentration, you can use Henry's Law. When the temperature is constant, the weight of a gas that dissolves in a liquid is proportional to the pressure exerted by the gas on the liquid. Therefore, the pressure of the gas above a solution is proportional to the concentration of the gas in the solution. (However, Henry's Law does not apply to gases that are extremely soluble in water.) The concentration (mole %) can be calculated if the absolute pressure is known:

Oxygen mole fraction = oxygen partial pressure / absolute pressure

Since the FOXY system detects partial pressure of oxygen, the response in a gas environment is similar to a liquid environment in equilibrium with gas. Therefore, it is possible to calibrate the FOXY system in gas and then use the system with liquid samples and vice versa if you utilize Henry's Law.

However, Henry's Law does not apply to gases that are extremely soluble in water. The following information illustrates the solubility of oxygen in water at different temperatures.

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

Temperature range: 0° C - 75° C
X is the mole fraction
T^* is the T/100 in Kelvin
a -66.7354
b 87.4755
c 24.4526

T (C)	T* (T/100K)	Mole Fraction of oxygen in water at 1 atmosphere pO2	Weight Fraction (ppm) at 1 atmosphere pO2 (pure O2)	Weight Fraction (ppm) at 0.209476 atmospheres pO2 (Air)
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

Temperature

Temperature affects the fluorescence decay time, the fluorescence intensity and the collisional frequency of the oxygen molecules with the fluorophore -- and therefore, the diffusion coefficient of oxygen. Temperature also affects the solubility of oxygen in samples. The net effect of temperature fluctuations is seen as a change in the calibration slope. It is best to maintain the sample at a constant (+/-3° C*) temperature. If this is not practical, then you should calibrate your FOXY system by using the temperature compensation features and measuring temperature and oxygen concurrently. To monitor the temperature of the sensing environment and compensate for temperature fluctuations, temperature electrodes can now be used in conjunction with the FOXY probe. (Optional thermistor and K-type thermocouple accessories are available.) OOISensors Software corrects for changes in data due to temperature fluctuations.

* (Though Ocean Optics miniature spectrometers are extremely sensitive, temperature fluctuations +/-3° C cannot be detected by the spectrometer.)

Scattering Media

Fluorescence emissions from the ruthenium complex propagate in all directions. In clear media, only those emissions propagating toward 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 the intensity of the fluorescence at a pressure of oxygen and the intensity of fluorescence at zero pressure of oxygen, but will not affect the Stern-Volmer constant. For this reason, it is necessary to measure the intensity of fluorescence at zero pressure of oxygen in the sample. Also, if you are measuring oxygen in highly scattering media, then the standards you use for your calibration procedure should be in the same media as your sample for the most accurate results.

Samples to Use

♦ If you are using the probe in gases, N_2 can be used for the low value (0%) and either air (20.9%) or O_2 (100%) can be used for the high value.

♦ If you are using the probe in liquid media, it may be difficult to prepare standards. 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.

Calibration Data

Once you have calibrated your sensor system, the calibration data is stored in two files. It is stored in the `OOISensors.cfg` file, which is the application configuration file. The calibration data is called from this binary file each time you use your sensor system and software.

Calibration data is also stored in an ASCII file (or text file) so that you use read the data and even import it into other application programs such as Microsoft Word and Excel. This ASCII file is called `chXFoxy.cal`, where "X" stands for the spectrometer channel ("0" for master spectrometer, "1" for spectrometer channel 1, "2" for spectrometer channel 2 and so on). The `chXFoxy.cal` file is not used by the OOISensors application; it is strictly for analyzing calibration data. (If you have temperature data in this file, temperature will be displayed as Kelvin.)

If you ordered the **Factory Calibration**, you are provided with an additional file that includes data for the Calibration Table in the **Multiple Temperature Calibration** dialog box. The name of the file corresponds to the serial number of the probe. (For more information on Factory Calibrations, see pages 61-62.)

Re-calibration

FOXY probes do need re-calibration from time to time. The following factors necessitate re-calibration:
1. If you use a FOXY probe in a harsh environment that degrades the probe coating.
2. If you expose a FOXY probe to the LED source for long periods of time, causing faster photobleaching of the ruthenium compound.
3. If you re-condition your FOXY probe.
4. If you sterilize your FOXY probe with processes such as autoclave or gamma radiation.

Calibration Procedure:
If you do not want Temperature Compensation

1. Set data acquisition parameters for your calibration procedure, such as integration time, averaging and boxcar smoothing (see pages 47-48 for details).
2. Set the integration time for the entire calibration procedure when the probe is measuring the standard with zero concentration. The fluorescence peak (~600 nm) will be at its maximum at zero concentration. Adjust the integration time so that the fluorescence peak does not exceed 3500 counts. If your signal intensity is too low, increase the integration time. If the signal intensity is too high, decrease the integration time. Set the integration time to powers of 2 (2, 4, 8, 16, 32, 64, 128, 256, 512, etc.) to ensure a constant number of LED pulses during the integration time. (The intensity of the LED peak [~475 nm] does not affect your measurements.)
3. Select **Calibrate | Oxygen, Single Temperature** from the menu.
4. Enter the serial number of the probe in the **S/N** box. Today's date should enter automatically in the **Date** box. The file name and path appears under **Calibration File Path** once you select **File | Save Calibration Chart** and save the chart. At the bottom of the dialog box is a place for you to enter the **Oxygen Concentration Units**. This area is for typing in a label; it does not affect data in any way.
5. Next to **Calibration Type**, select **Multi Point** from the pull down menu.
6. Under **Channel**, select the spectrometer channel to which the sensor you are calibrating is connected.
7. Under **Curve Fitting**, select the kind of algorithm you want to use to calibrate your sensor system: Linear (Stern-Volmer) or Second Order Polynomial. Calibration curves are generated from your standards and the algorithms to calculate concentration values for unknown samples. The Second Order Polynomial algorithm provides a better curve fit and therefore more accurate data during oxygen measurements, especially if you are working in a broad oxygen concentration range.
   - If you choose **Linear (Stern-Volmer)**, you must have at least two standards of known oxygen concentration. The first standard must have 0% oxygen concentration and the last standard must have a concentration in the high end of the concentration range in which you will be working.
   - If you choose **Second Order Polynomial**, you must have at least three standards of known oxygen concentration. The first standard must have 0% oxygen concentration and the last standard must have a concentration in the high end of the concentration range in which you will be working.
8. In the Calibration Table, in the **Standard #** column, enter **1** for your first standard of known oxygen concentration. The first standard should have 0% oxygen concentration, such as can be found in a nitrogen flow or in a solution of sodium hydrosulfite.
9. Under the **Concentration** column, enter **0**.
10. Leave your FOXY probe in the standard for at least 5 minutes to guarantee equilibrium.
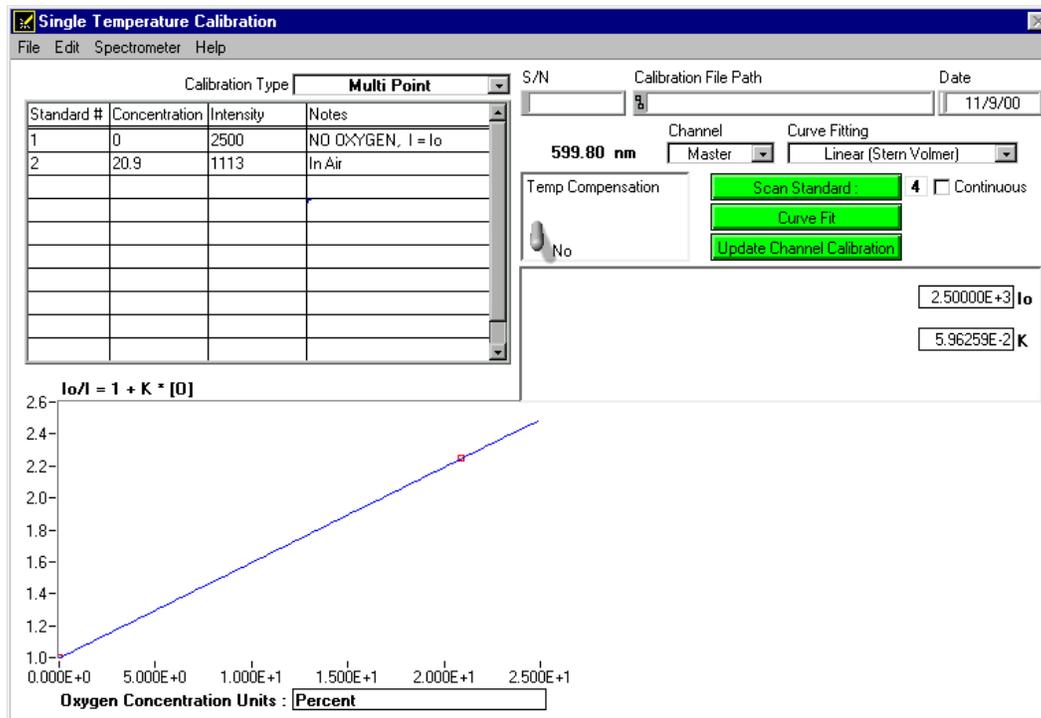
11. Move your cursor to the **Intensity** column.
12. Click the green **Scan Standard** button or select **Spectrometer | Scan Standard** from the menu.
13. Enabling the optional **Continuous** function just to the right of the **Scan Standard** button allows you to receive continuous intensity values of a standard. To use this function, make sure to put a check mark in the **Continuous** box. Click the green **Scan Standard** button, which will then turn into a red **Scanning** button. Watch the values in the **Intensity** column. When there appears to be no changes in this value, select the red **Scanning** button to accept the intensity value.

NOTE: If the probe has an overcoat, then the standards used in the calibration can be of a state of matter different from the sample that you are using. You could switch between gas and liquid and your calibration data will be valid. If the probe does not have an overcoat, standards used in the calibration not only must be of the same state of matter as your sample, but also must have the same refractive index as your sample.

14. In the **Standard #** column, enter 2 for your second standard of known oxygen concentration.
15. Once you have entered the known oxygen concentration of the standard in the **Concentration** column, left your FOXY probe in the standard for at least 5 minutes, and moved the cursor to the **Intensity** column, click the green **Scan Standard** button or select **Spectrometer | Scan Standard** from the menu. The intensity of the standard should then appear in the **Intensity** column.
16. When you have finished entering all available standards with known oxygen concentrations and received their intensity readings, click the green **Curve Fit** button. A graph displaying the results of your calibration procedure appears in the bottom of the dialog box.
17. If the results of the calibration are satisfactory, click the green **Update Channel Calibration** button to save information from this calibration procedure for the specified spectrometer channel into data files. (For more information on these data files, see Calibration Data on page 59.)
18. To save the Calibration Table for future use, select **File | Save Calibration Table** from the menu. To print the entire dialog box, select **File | Print** from the menu. When you have completed the calibration procedure, select **File | Close** from the menu to return to the main display window.

Calibration Procedure:
# If you want to Compensate for Temperature

If you want to compensate for temperature changes, decide if you want to accept the calibration that was performed at Ocean Optics. We perform, for free, a calibration of your FOXY system if you specified the oxygen concentration range and temperature in which you will be working. This process is called **Factory Calibration**. If you want to compensate for temperature but cannot use the Factory Calibration coefficients and tables, see pages 63-64 for directions on your calibration procedure.

Using the Factory Calibration
1. Set data acquisition parameters for your calibration procedure, such as integration time, averaging and boxcar smoothing (see pages 47-48 for details).
2. Set the integration time for the entire calibration procedure when the probe is measuring the standard with zero concentration. The fluorescence peak (~600 nm) will be at its maximum at zero concentration. Adjust the integration time so that the fluorescence peak does not exceed 3500 counts. If your signal intensity is too low, increase the integration time. If the signal intensity is too high, decrease the integration time. Set the integration time to powers of 2 (2, 4, 8, 16, 32, 64, 128, 256, 512, etc.) to ensure a constant number of LED pulses during the integration time. (Do not change the integration time to adjust the intensity of the LED peak [~475 nm]. The intensity of the LED peak does not affect your measurements.)
3. Select **Calibrate | Oxygen, Multiple Temperature** from the menu.
4. If you ordered the **Factory Calibration**, you are provided with an additional file that includes data for the Calibration Table. Select **File | Open Calibration Table** from the menu. The name of the file corresponds to the serial number of the probe that you are calibrating. (To find the serial number of the probe, check the tag attached to the probe.)
5. The Calibration Table should now be populated with oxygen concentration amounts and temperatures.
6. Select the green **Curve Fit** button. Graphs displaying the curves appear in the bottom of the dialog box.
7. If the graphs are satisfactory, click the green **Update Channel Calibration** button to save information from this calibration procedure.
8. Select **File | Close** from the menu to return to the main display window.
9. Select **Calibrate | Oxygen, Single Temperature** from the menu.

10. Enter the serial number of the probe in the **S/N** box. Today's date should enter automatically in the **Date** box. The file name and path appears under **Calibration File Path** once you select **File | Save Calibration Chart** from the menu and save the chart. At the bottom of the dialog box is a place for you to enter the **Oxygen Concentration Units**. This area is for typing in a label; it does not affect data in any way.

11. Next to **Calibration Type**, select **Single Point** from the pull down menu. Single Point calibration is based on the procedure you just completed in the Oxygen, Multiple Temperature dialog box. Because you are using the data from the Oxygen, Multiple Temperature dialog box, you only need one standard of known oxygen concentration to complete your calibration.

12. Under **Channel**, select the spectrometer channel to which the sensor you are calibrating is connected.

13. Under **Curve Fitting**, select the kind of algorithm you want to use to calibrate your sensor system: Linear (Stern-Volmer) or Second Order Polynomial. Calibration curves are generated from your standards and the algorithms to calculate concentration values for unknown samples. The Second Order Polynomial algorithm provides a better curve fit and therefore more accurate data during oxygen measurements, especially if you are working in a broad oxygen concentration range.

14. Enter the known oxygen concentration of your standard under **Concentration**.

15. Under **Temp Compensation**, change the switch to **Yes**. To get the proper temperature reading, select **Spectrometer | Sample Temperature** from the menu in the dialog box or enter the temperature manually.

16. Leave your probe in the standard for ~5 minutes to guarantee equilibrium. Place your cursor in the **Intensity** box and click the **Scan Standard** button.
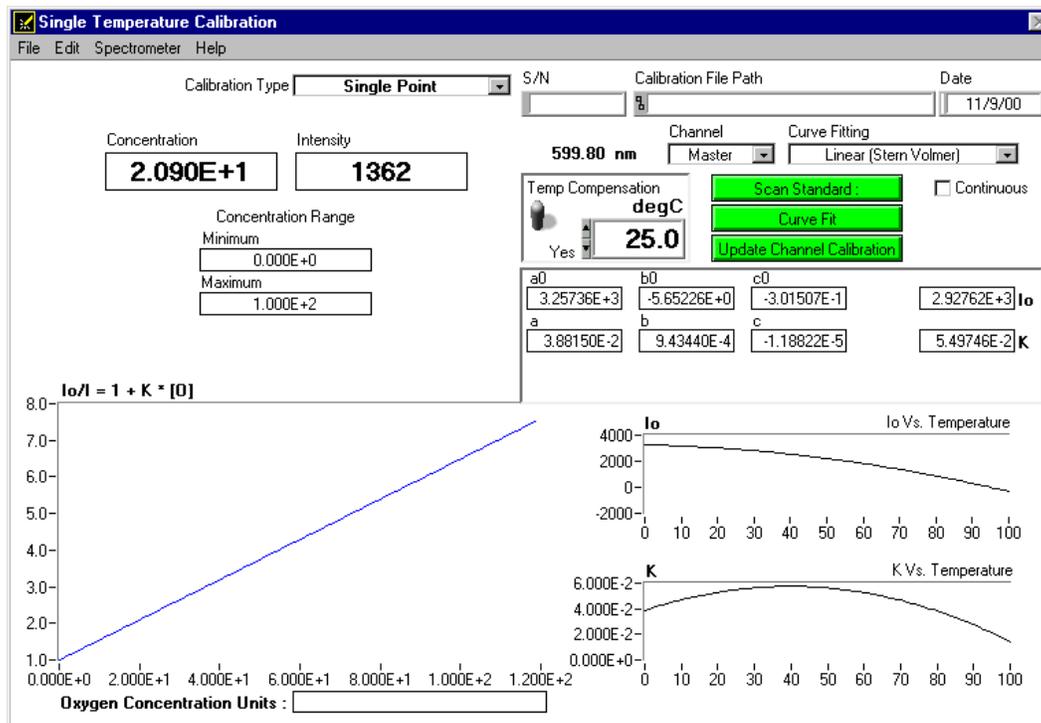
17. Enabling the optional **Continuous** function just to the right of the **Scan Standard** button allows you to receive continuous intensity values of a standard. To use this function, make sure to put a check mark in the **Continuous** box. Click the green **Scan Standard** button, which will then turn into a red **Scanning** button. Watch the values in the **Intensity** box. When there appears to be no changes in this value, select the red **Scanning** button to accept the intensity value.

18. Click the green **Curve Fit** button. A graph displaying the results of your calibration procedure appears in the bottom of the dialog box.

19. If the results of the calibration are satisfactory, click the green **Update Channel Calibration** button to save information from this calibration procedure for the specified spectrometer channel into data files. (For more information on these data files, see Calibration Data on page 59.)

20. To save the Calibration Table for future use, select **File | Save Calibration Table** from the menu. To print the entire dialog box, select **File | Print** from the menu. When you have completed the calibration procedure, select **File | Close** from the menu to return to the main display window.

Not Using the Factory Calibration

1. Set data acquisition parameters for your calibration procedure, such as integration time, averaging and boxcar smoothing (see pages 47-48 for details).

2. Set the integration time for the entire calibration procedure when the probe is measuring the standard with zero concentration. The fluorescence peak (~600 nm) will be at its maximum at zero concentration. Adjust the integration time so that the fluorescence peak does not exceed 3500 counts. If your signal intensity is too low, increase the integration time. If the signal intensity is too high, decrease the integration time. Set the integration time to powers of 2 (2, 4, 8, 16, 32, 64, 128, 256, 512, etc.) to ensure a constant number of LED pulses during the integration time. (The intensity of the LED peak [~475 nm] does not affect your measurements.)

3. Select **Calibrate | Oxygen, Multiple Temperature** from the menu.

4. Enter the serial number of the probe in the **S/N** box. Today's date should enter automatically in the **Date** box. The file name and path appears under **Calibration File Path** once you select **File | Save Calibration Chart** from the menu and save the chart. At the bottom of the dialog box is a place for you to enter the **Oxygen Concentration Units**. This area is for typing in a label; it does not affect data in any way.

5. In the Oxygen Concentration/Temperature Table, enter the concentration values for each standard with known oxygen concentrations in the top row of the table. The first standard should have 0% oxygen concentration, such as can be found in a nitrogen flow or in a solution of sodium hydrosulfite.

6. Leave your FOXY probe in the standard for at least 5 minutes to guarantee equilibrium.

7. Manually enter the temperature of this standard in the second cell of the left column or select **Spectrometer | Sample Temperature** from the menu.
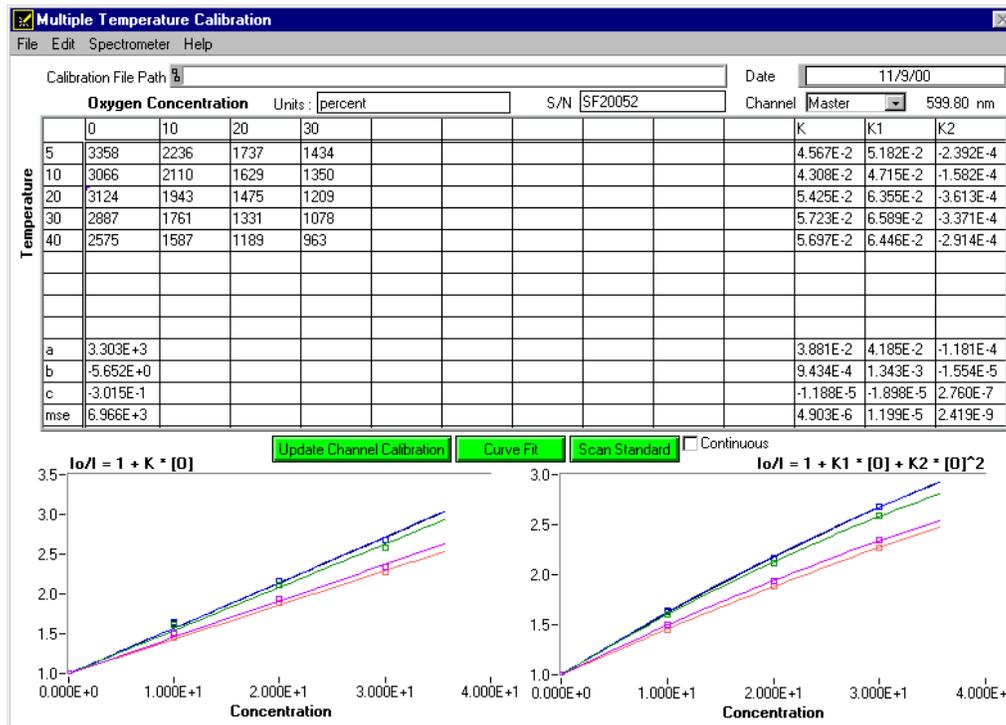
8. Place your cursor under the oxygen concentration of the first standard. Click the green **Scan Standard** button or select **Spectrometer | Scan Standard** from the menu.

9. Enabling the optional **Continuous** function just to the right of the **Scan Standard** button allows you to receive continuous intensity values of a standard. To use this function, make sure a check mark in the **Continuous** box. Click the green **Scan Standard** button, which will then turn into a red **Scanning** button. Watch the values in the **Intensity** column. When there appears to be no changes in this value, select the red **Scanning** button to accept the intensity value.

10. Repeat steps 5 through 9 until you have the number of scans necessary for the algorithm you are going to use to compute your calibration.

11. Select the green **Curve Fit** button. Graphs displaying the curves appear in the bottom of the dialog box.

12. If the results of the calibration are satisfactory, click the green **Update Channel Calibration** button to save information from this calibration procedure for the specified spectrometer channel into data files. (For more information on these data files, see Calibration Data on page 59.)

13. To save the data in the Calibration Table, select **File | Save Calibration Table** from the menu. To print all of the graphs, including ones that are not visible in the dialog box, select **File | Print** from the menu.
14. Select **File | Close** from the menu to return to the main display window.
15. Select **Calibrate | Oxygen, Single Temperature** from the menu.
16. Enter the serial number of the probe in the **S/N** box. Today's date should enter automatically in the **Date** box. The file name and path appears under **Calibration File Path** once you select **File | Save Calibration Chart** from the menu and save the chart. At the bottom of the dialog box is a place for you to enter the **Oxygen Concentration Units**. This area is for typing in a label; it does not affect data in any way.
17. Next to **Calibration Type**, select **Single Point** from the pull down menu. Single point calibration is based on the procedure you just completed in the Oxygen, Multiple Temperature dialog box. Because you are using the data from the Oxygen, Multiple Temperature dialog box, you only need one standard of known oxygen concentration to complete your calibration.
18. Under **Channel**, select the spectrometer channel to which the sensor you are calibrating is connected.
19. Under **Curve Fitting**, select the kind of algorithm you want to use to calibrate your sensor system: Linear (Stern-Volmer) or Second Order Polynomial. Calibration curves are generated from your standards and the algorithms to calculate concentration values for unknown samples. The Second Order Polynomial algorithm provides a better curve fit and therefore more accurate data during oxygen measurements, especially if you are working in a broad oxygen concentration range. In order to use the Second Order Polynomial algorithm, you needed at least three standards of known oxygen concentration when you were scanning standards in the **Oxygen, Multiple Temperature** dialog box.
20. Enter the known oxygen concentration of your standard under **Concentration**.
21. Under **Temp Compensation**, change the switch to **Yes**. To get the proper temperature reading, select **Spectrometer | Sample Temperature** from the menu in the dialog box or enter the temperature manually.
22. Leave your FOXY probe in the standard for at least 5 minutes to guarantee equilibrium. Place you cursor in the **Intensity** box and click on the green **Scan Standard** button.
23. Enabling the optional **Continuous** function just to the right of the **Scan Standard** button allows you to receive continuous intensity values of a standard. To use this function, make sure to put a check mark in the **Continuous** box. Click the green **Scan Standard** button, which will then turn into a red **Scanning** button. Watch the values in the **Intensity** box. When there appears to be no changes in this value, select the red **Scanning** button to accept the intensity value.
24. Click the green **Curve Fit** button. A graph displaying the results of your calibration procedure appears in the bottom of the dialog box.
25. If the results of the calibration are satisfactory, click the green **Update Channel Calibration** button to save information from this calibration procedure for the specified spectrometer channel into data files. (For more information on these data files, see Calibration Data on page 59.)
26. To save the Calibration Table for future use, select **File | Save Calibration Table** from the menu. To print the entire dialog box, select **File | Print** from the menu. When you have completed the calibration procedure, select **File | Close** from the menu to return to the main display window.

Appendix A: S2000-series Pin-outs and Jumpers

The average user would not normally need to know about the interconnect scheme of the S2000, as the cables supplied with all of the units need only be plugged into the matching connectors on the hardware. However, if the need arises to design and fabricate your own cabling system, the following tables supply the necessary information.

J1 (D-25) Interface Cable (connects the S2000 master with the A/D board)

J1 Pin	Function	A/D Pin Connection
1	Analog Channel 0	37
2	Analog Channel 1	36
3	Analog Channel 2	35
4	Analog Channel 3	34
5	Analog Ground	19
6	Reserved	
7	N/C	
8	N/C	
9	Digital Ground	7
10	A/D Trigger	25
11	Master Clock	20
12	Digital Ground	Not in Cable
13	+5VDC	1
14	Analog Channel 4	33
15	Analog Channel 5	32
16	Analog Channel 6	31
17	Analog Channel 7	30
18	Analog Ground	Not in Cable
19	N/C	
20	Continuous Strobe In	8 (or use internal jumpers)
21	External Software Trigger Out (DO3)	5
22	Spectrometer Mode Input S1	4
23	Integration Time Clock In	2
24	Strobe Enable, Spectrometer Mode Input S0	23
25	Enable Read In	3

J2 (D-SUB-15) Accessory Connector

J2 Pin	DB-15 (Female)	Description
1	Single Strobe	TTL output signal used to pulse a strobe that is high at the start of each integration period.
2	Continuous Strobe	TTL output signal used to pulse a strobe that is divided down from Master Clock signal.
3	V_{CC}	The positive supply voltage +5VDC.
4	External Hardware Trigger	TTL trigger signal (rising edge trigger input) used in the External Hardware Trigger mode.
5	External Synchronization Trigger	TTL signal used to define the integration time (time between rising edges) when using the External Synchronization Trigger mode.
6	Channel 7	The analog input for spectrometer slave channel 7.
7	Channel 6	The analog input for spectrometer slave channel 6.
8	D3 or External Software Trigger	Active high TTL input signal used to trigger the acquisition system in the External Software Trigger mode. The input from J1-8 is passed unbuffered to this line.
9	Channel 1	The analog input for spectrometer slave channel 1.
10	GND	Ground (supply voltage return) or case ground.
11	Channel 4	The analog input for spectrometer slave channel 4.
12	Channel 5	The analog input for spectrometer slave channel 5.
13	S0 and S1	TTL inputs used to determine the triggering mode: S1 S0 Mode L X Normal or Continuous Scan L X External Software Trigger H L External Synchronization Trigger H H External Hardware Trigger X = does not matter In the first 2 modes, S0 is also used to enable/disable light sources.
14	Channel 3	The analog input for spectrometer slave channel 3.
15	Channel 2	The analog input for spectrometer slave channel 2.

H1 Header Pins (Analog)

Pin	Description
1	Analog Channel 0
2	Analog Channel 1
3	Analog Channel 2
4	Analog Channel 3
5	Analog Channel 4
6	Ground
7	Reserved
8	Analog Channel 7
9	Analog Channel 6
10	Analog Channel 5

H2 Header Pins (Digital)

Pin	Description
D	N/C
C	A/D Trigger
B	Digital In 3 (D3)
A	S1
1	Ground
2	+5 VDC
3	Phi A/D clock
4	Phi Read Out Gate
5	Reserved
6	Temperature (optional)
7	Read Enable
8	S0
9	Strobe Single flash
10	Strobe Multiple Flash
11	Integration Clock
12	Master Clock

H1 and H2 Header Blocks connect a master spectrometer channel to one or more additional spectrometer channels.

Appendix B: USB2000-series Pin-outs

Listed below is the pin description for the USB2000 Accessory Connector (J2) located on the front vertical wall of the unit. (To order multiple mating connectors, contact Samtec, Inc. for item number IPS1-105-01-S-D. Visit Samtec's web site at www.samtec.com.)

Pin #	Description
1	V_{USB} or $5V_{in}$
2	RS232 Tx
3	RS232 Rx
4	Lamp Enable
5	Continuous Strobe
6	Ground
7	External Trigger In
8	Single Strobe
9	I^2C SCL
10	I^2C SDA

```
10  8  6  4  2
 9  7  5  3  1
```
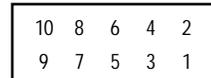
**Diagram of Pins on the
Accessory Connector**

Appendix C: Changing ADC1000 Settings

Base Address Settings for the ADC1000

To change the Base Address settings on the ADC1000, see the bank of switches on the A/D board: The Base Address may be changed via the first 6 switches (the IRQ may be changed via the last 3 switches). 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 default setting, switches 5 and 6 are added to give a total of 768. A few of the many combinations for Base Address settings are below. After you have changed the switches, reinstall the card and change the software settings to match the hardware settings. The red block indicates the position of the switch.

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

Switch #	1	2	3	4	5	6
ON	⬛	⬛	⬛	⬛		
OFF					⬛	⬛

	1	2	3	4	5	6
Decimal equivalent	16	32	64	128	256	512
Value as shown					256	512

Example: 784 decimal = Hex310 = 0x310

Switch #	1	2	3	4	5	6
ON		⬛	⬛	⬛		
OFF	⬛				⬛	⬛

	1	2	3	4	5	6
Value as shown	16				256	512

Example: 800 decimal = Hex320 = 0x320

Switch #	1	2	3	4	5	6
ON	⬛		⬛	⬛		
OFF		⬛			⬛	⬛

	1	2	3	4	5	6
Value as shown		32			256	512

Example: 816 decimal = Hex330 = 0x330

Switch #	1	2	3	4	5	6
ON			⬛	⬛		
OFF	⬛	⬛			⬛	⬛

	1	2	3	4	5	6
Value as shown	16	32			256	512

switch is in the on, upward position = ⬛

Interrupt Request Settings for the ADC1000

To change the IRQ settings on the ADC1000, see the bank of switches on the A/D board: The IRQ may be changed via the last 3 switches. The following matrix defines the different IRQ settings by switch positions 7, 8, and 9. In the default setting, the IRQ is set to 7. Other combinations for IRQ settings are below. After you have changed the switches, reinstall the card and change the software settings to match the hardware settings. The red block indicates the position of the switch.

Interrupt Request 3

Switch #	7	8	9
ON			
OFF	RED	RED	RED

Interrupt Request 4

Switch #	7	8	9
ON	RED		
OFF		RED	RED

Interrupt Request 5

Switch #	7	8	9
ON		RED	
OFF	RED		RED

Interrupt Request 7 (Default Setting)

Switch #	7	8	9
ON	RED	RED	
OFF			RED

Interrupt Request 9

Switch #	7	8	9
ON			RED
OFF	RED	RED	

Interrupt Request 10

Switch #	7	8	9
ON	RED		RED
OFF		RED	

Interrupt Request 11

Switch #	7	8	9
ON		RED	RED
OFF	RED		

switch is in the on, upward position = RED

Appendix D: External Triggering

Our S2000-series spectrometers, when used with OOISensors Software, provide two methods of acquiring data. In the Normal Mode, the spectrometers are "free running." That is, the spectrometer is continuously scanning, acquiring, and transferring data to your computer, according to parameters set in the software. In this mode, however, there is no way to synchronize the scanning, acquiring and transferring of data with an external event.

To synchronize data acquisition with external events, one other mode of acquiring data is available. It involves connecting an external triggering device to the spectrometer and then applying an external trigger to the spectrometer before the software receives the data.

NOTE: In order for you to use the External Software Trigger option, it is imperative that you know the specifications and limitations of your triggering device. The design of your triggering device may prevent you from using the External Software Trigger mode as it is described here.

In this level-triggered mode, the spectrometer is "free running," just as it is in the Normal Mode. The spectrometer is continually scanning and collecting data. With each trigger, the data collected up to the time of the trigger event is transferred to the software. If you continuously apply triggers, such as by holding down the button on an external switch, this mode is equivalent to operating in the Normal Mode.

In the External Software Trigger Mode, you set the integration time in the software. All other acquisition parameters are set in the software as well. The source for the integration clock comes from the A/D converter.

External Software Trigger with the SF-2000 and S2000-FL

1. Supply a line from your triggering device to Pin 3 of the J2 Accessory Connector to provide the positive voltage +5VDC to the spectrometer. (See figure for pin location.) We do not advise using an outside source to supply the voltage, as it is based on a referenced ground and your reference may be different from ours. Using Pin 3 to supply voltage ensures that the spectrometer will receive the appropriate voltage for the trigger event.
2. Supply a line from Pin 8 of the J2 Accessory Connector to your triggering device. (See figure above for pin location.)
3. Set your acquisition parameters, such as integration time, in the software.
4. Select **Configure | Spectrometer** from the menu and select the **Timing** tab. Next to **External Trigger Mode**, select **External Software Trigger** from the pull down menu.
5. Once you select the External Software Trigger Mode, it will appear on your computer that your spectrometer is unresponsive. Instead, it is waiting for the trigger. Activate your triggering device.
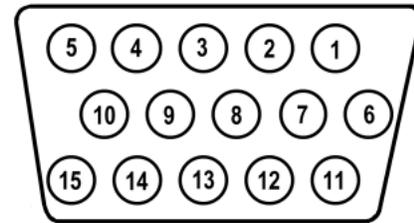
J2 (D-SUB-15) Accessory Connector (female)

External Software Trigger with the USB2000-FL

1. Supply a line from Pin 7 of the Connector to your triggering device. (See figure for pin location.)The triggering device must be connected to Pin 7 of the Accessory Connector. The maximum recommended voltage on Pin 7 is 5.5 V. If your triggering device could exceed this voltage, you must regulate or condition the signal (via transistor buffering, transformer isolation or opto-isolation, for example).
2. Set your acquisition parameters, such as integration time, in the software.
3. Select **Configure | Spectrometer** from the menu and select the **Timing** tab. Next to **External Trigger Mode**, select **External Software Trigger** from the pull down menu.
4. Once you select the External Software Trigger Mode, it will appear on your computer that your spectrometer is unresponsive. Instead, it is waiting for the trigger. Activate your triggering device.


| 10 | 8 | 6 | 4 | 2 |
| 9 | 7 | 5 | 3 | 1 |
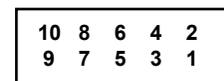
Diagram of Pins on the Accessory Connector

Appendix E: Values for Oxygen Analysis

Solubility of Oxygen in Water

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

Temperature range: 0° C - 75° C
X is the mole fraction
T^* is the T/100 in Kelvin
a -66.7354
b 87.4755
c 24.4526

T (C)	T* (T/100K)	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	9.30380975
25	2.9815	2.29245E-05	40.71933198	8.52972278
30	3.0315	2.12205E-05	37.69265242	7.89570605
35	3.0815	1.98218E-05	35.20817214	7.37526706
40	3.1315	1.86735E-05	33.16861329	6.94802843

Appendix F: Chemical Effects on FOXY Probes

Chemicals that Interfere with FOXY Measurements	Supporting Data Available
Strong Bases pH> 10	Yes
Styrene	Yes
Ethanol	Yes
Liquid acetone	No
Acetonitrile	Yes
HF	No

Benign Chemicals with FOXY Measurements	Supporting Data Available
50% Methanol (overcoat probe results)	Yes
Acids	No
Hexane	Yes
Sodium Sulfite	Yes
SF6 (test slide results)	Yes
NF_3 (test slide results)	Yes