User Guide

WA-1000/WA-1500 Wavemeter®
Laser Wavelength Meters

P/N: 1041650

EXFO

Contents

1. Introduction

This operating manual includes information about WA-1500 and WA-1000 Wavemeter® systems. It covers all the topics necessary to help you operate your system. All sections apply to both models. In Section 8 there are two subsections that describe issues specifically related to the WA-1000 and the WA-1500.

If you just received your WA-1500/WA-1000, refer first to Section 3 for instructions about initial setup. For routine operation, Sections 4 and 5 will be most informative.

Overview

WA-1500 and WA-1000 systems are instruments designed for simple, automatic and accurate wavelength measurement of continuous wave (CW) laser sources. The WA-1500/1000 measure wavelengths by counting interference fringes produced by the input laser radiation in a scanning Michelson interferometer. Simultaneously, the WA-1500/1000 counts fringes from a built-in reference laser, and the wavelength of the input laser is computed from the ratio of the fringe counts.

The accuracy of the measured wavelength is dependent on the knowledge of the reference laser wavelength. The WA-1000 uses a multi-mode HeNe reference laser with an absolute wavelength accurate to within ± 500 MHz or ± 1 part per million. The WA-1500 uses a stabilized single frequency HeNe laser that is calibrated to an accuracy better than ± 50 MHz relative to the Ne^{20} atomic line center. This corresponds to a reference accuracy of ± 0.2 parts per million.

Two methods are provided for introducing laser light into the WA-1500/1000. For laser radiation that is transmitted through fiber-optic cable, the input can be introduced through a fiber-optic connector in the instrument's front panel. Because some laser wavelengths are not easily transmitted by fiber optics, the alternative is to direct the collimated free laser beam into the instrument through a side aperture. A red tracer beam emitted from the side aperture is provided as an alignment aid.

Both the WA-1500 and WA-1000 have microprocessor-based electronics that allow accurate counting and analysis of interference fringes. The microprocessor computation automatically corrects for the refractive index of air, using data from built-in temperature and pressure sensors, and converts the resulting measurement to units of nm, cm^{-1} or GHz. The microprocessor also makes it possible for the WA-1500/1000 to calculate and display the deviation between the measured wavelength and a specified set point, or compute the average of up to 50 measurements.

The WA-1500 and WA-1000 have other features that enhance their use for laboratory automation and laser control applications. A built-in bi-directional RS-232 interface transmits the instrument data to a computer and can be used to remotely control the instrument settings. Sample software is provided to demonstrate this computer interfacing capability. An optional GPIB interface can be added that provides the same flexibility for an IEEE-488 bus.

The WA-1500/1000 also outputs an analog voltage through a rear panel connector. This voltage is proportional to the difference between the measured wavelength and a setpoint programmed by the operator, using either the front panel keypad or a computer interface. The analog output can be used to monitor changes in laser wavelength on a chart recorder, or as feedback to control the laser wavelength directly.

On the rear panel, a **Monitor** port provides access to the interferometer fringe signals and timing signals that govern the wavelength measurement. These signals, displayed on an oscilloscope, are useful for viewing and optimizing the operation of the WA-1500/ 1000 for different input lasers.

Both models operate in three wavelength ranges: VIS (visible), NIR (near infrared) and IR (infrared). Each model includes a photodetector and a beamsplitter that are selected to optimize its operation in the corresponding wavelength range. You can easily convert from one model to another by replacing the beamsplitter and the photodetector.

Applications

The WA-1500/1000 are designed for real-time monitoring of laser wavelength. While the laser is being used in an experiment a small portion of the beam can be split off and directed into the WA-1500/1000 to continuously confirm the laser wavelength. A typical experimental arrangement is shown in Figure 1-1.

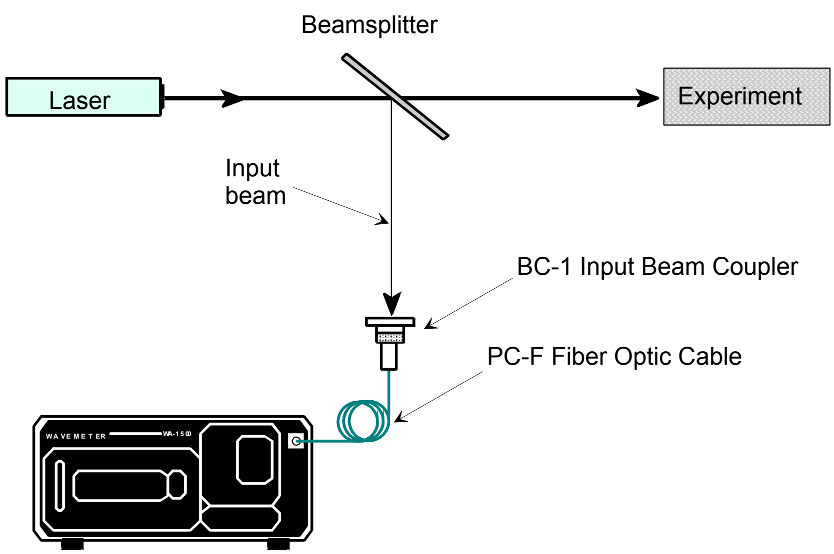


Figure 1-1: Typical WA-1500/1000 experimental arrangement

The application in Figure 1-1 depicts coupling laser light into the WA-1500/1000 through a fiber-optic cable. This coupling method makes it possible to position the WA-1500/1000 in any location leaving space on the optical table for other experimental apparatus.

As an alternative, a collimated laser beam can be directed into the WA-1500/1000 through an aperture on the side. In this case the WA-1500/1000 must be positioned on the optical table and aligned precisely with the input beam. A red tracer beam emitted from the aperture facilitates this alignment.

The WA-1500 and WA-1000 are easily interfaced to a computer for remote operation and wavelength recording through either the standard RS-232 serial interface or optional GPIB (IEEE-488) bus interface. An example of a computer-controlled application is shown in Figure 1-2. The laser wavelength is measured and compared to a set point transmitted to the WA-1500/1000 from the computer. The deviation from that set point is output as an analog voltage to the laser wavelength controller which drives the laser to the set point. The laser wavelength is accurately controlled by programming the set point from the computer.

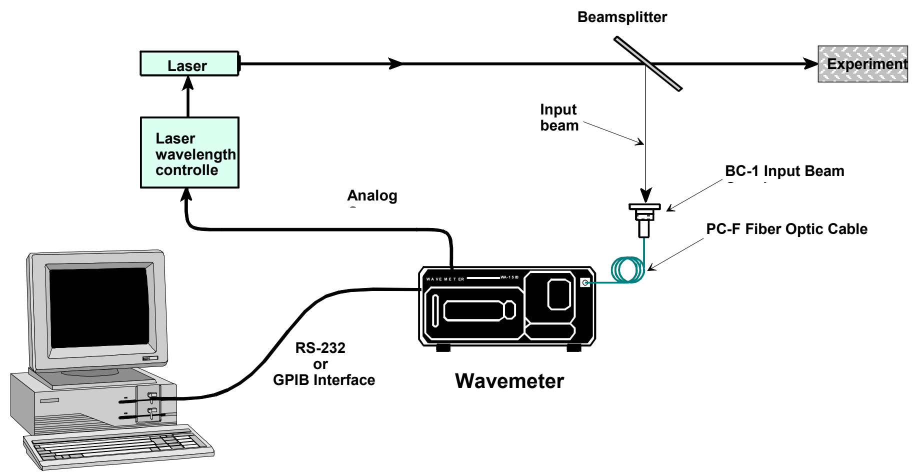


Figure 1-2: Accurate laser wavelength control from a computer

Safety Conventions Used in This Manual

	**WARNING** **Indicates a potentially hazardous situation that, if not avoided, could result in *death or serious injury*. Do not proceed unless you understand and meet the required conditions.**
	**CAUTION** **Indicates a potentially hazardous situation that, if not avoided, may result in *minor or moderate injury*. Do not proceed unless you understand and meet the required conditions.**

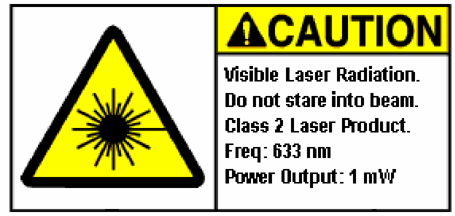
	CAUTION **Indicates a potentially hazardous situation that, if not avoided, may result in *component damage*. Do not proceed unless you understand and meet the required conditions.**
	IMPORTANT **Refers to information about this product that you should not overlook.**

Safety Information

This product has been designed, manufactured and tested in accordance with EC Standard EN61010-1, Safety Requirements for Electronic Measuring Apparatus, and has been supplied in a safe condition. Follow the recommendations in this section to ensure safe operation and to maintain the product in a safe condition.

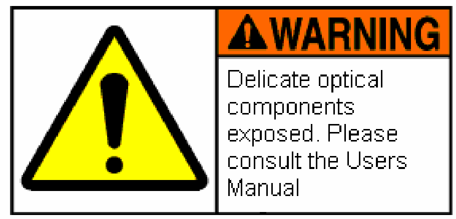
	WARNING **This equipment must be used as specified or the protection provided by the equipment may be compromised. Use this product in the SPECIFIED mode and do not deviate from the written instructions provided.**
	WARNING **Refer servicing to qualified personnel. To prevent electrical shock, do not open or remove the bottom cover of the WA-1500/1000.**
	WARNING **To prevent electrical shock, turn off the power to the unit before cleaning. Use a dry or slightly dampened (with water) cloth to clean the external parts. Do not attempt to clean anything inside the WA-1500/1000.**
	CAUTION **This is a Safety Class 1 product. Plug the main power cord into a socket outlet provided with a protective earth contact. Always use a three-prong AC power cord with this equipment. Failure to ensure adequate grounding may cause instrument damage.**

This label indicates that the WA-1500/1000 contains a laser classified as Class 2 by the IEC 60825-1:2001-08 standard. The wavelength is 633 nm, with a maximum power output of 1 mW.



This label appears on the rear panel. It indicates that removing the bottom cover of the WA-1500/1000 with the power on will expose the user to hazardous voltages from both the mains and the high voltage supply used to control the PZ optical positioners.

This label appears on the base plate under the top cover. It indicates that the delicate optical components exposed at that point can be damaged by improper handling. Refer to the Optical Alignment section of this manual for more information.



CAUTION

ESD-sensitive components exist inside the WA-1500/1000. Do not under any circumstances touch any of the electronic components. Damage not covered under warranty requiring return of the instrument to the factory may result from improper handling.

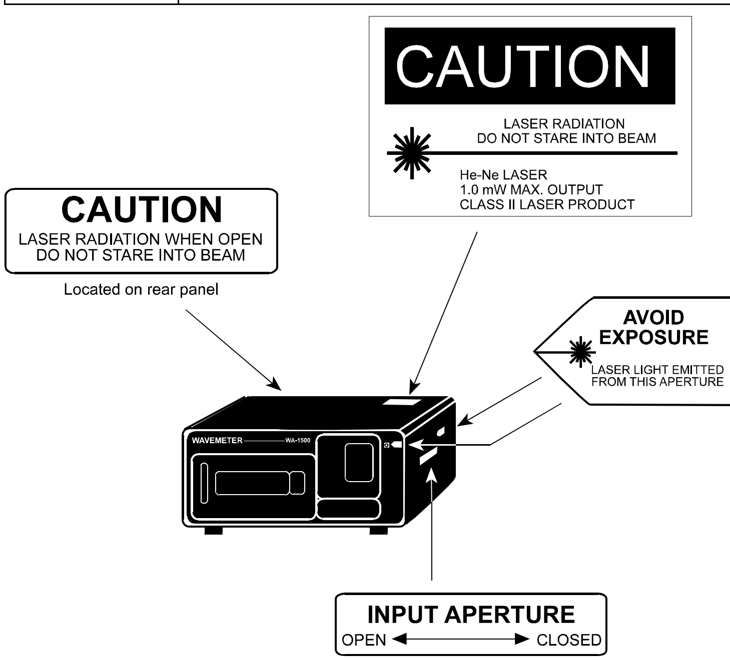


Figure 1-3: WA-1500/1000 labels

2. Initial Setup

This section includes a list of items that you should receive with your shipment and instructions for an initial inspection. Follow the instructions carefully before using your WA-1500/1000 and contact EXFO or your local representative if there are any problems.

Visual Inspection

The WA-1500/1000 is packed in a carton designed to give maximum protection during shipment. If the outside of the shipping carton is damaged, notify your shipping department immediately. They may wish to notify the carrier at this point.

If the external shipping carton is not damaged, carefully remove and identify the components listed below. Contact EXFO or your local representative if any of the components are missing. Save the shipping carton for storage or transportation.

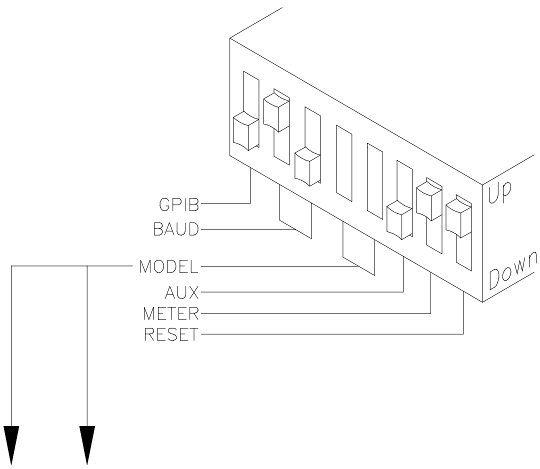
A WA-1000 or WA-1500 system includes the following components:

- WA-1500/1000
- Power cord
- Monitor port mating connector
- Allen wrench set
- Insulated screw driver (WA-1500 only)
- Sample software
- Operating manual

Operational Inspection

This section provides you a brief functional check of your WA-1500/1000. Please perform the following procedure upon receiving the instrument.

1. Place the WA-1500/1000 on a firm horizontal surface (optical bench or laboratory table).
2. Verify that the **Setup** switch on the rear panel is set in the factory configuration as shown in Figure 2-1, depending on the model of your WA-1500/1000. Make sure the **Aux** switch is in the down position.



Model	Position	
VIS	Down	Up
NIR	Up	Down
IR	Up	Up

Figure 2-1: Factory configuration

3. Attach the AC line cord. The WA-1500/1000 uses a universal power supply that works with any line voltage 90-260 VAC, 50/60 Hz. Turn on the power switch and listen for any unusual noises.
4. After a second, the display will blank and then light all LED indicators and numeric display segments, followed by a wavelength or a message display. LEDs should be lit indicating the current selection for **Display**, **Medium**, **Resolution** and **Averaging** as well as the **Auto** or **Manual Input Attenuator**. The **Units** selection LED will be illuminated only if a numerical value for the wavelength or frequency is displayed.
5. The WA-1000 will display a "LO SIG" message.
6. The WA-1500 will display the message "LA OP XX" signifying the laser operation warm-up period is active. The "XX" digits indicate the warm-up time in minutes. After a warm-up period of 5 to 20 minutes, the WA-1500 will display a "LO SIG" message.
7. Test the **Display**, **Medium**, **Resolution** and **Averaging** selections by pressing the appropriate buttons. The selection should toggle between the two LEDs with each button press.
8. Test the Setpoint, Display Res, Analog Res, # Averaged, Temperature, Pressure, Humidity and Remote buttons. When depressed the adjacent led should light and remain illuminated until the button is pressed again.
9. Push the **Setpoint** button again so that the adjacent LED is on. Now the display will show the setpoint value and the corresponding **Units** will be backlit. Check the display cycles between nm, cm^{-1}, and GHz when the **Units** button is pressed.

   You have finished the initial operational inspection; now you are ready to set up for laser wavelength measurements.

Ventilation

CAUTION

The WA-1500/1000 is designed to operate in the specified environmental conditions. This requires proper ventilation. Do not block the rear fan. Do not place the back of the WA-1500/1000 in an enclosed area that limits free air flow.

3. Aligning the Input Laser Beam

Alignment between the WA-1500/1000 and the input laser depends on the type of input chosen, either a free laser beam introduced through the side aperture, or laser light introduced via the fiber-optic coupler. This section describes the alignment procedures for both cases.

Free Laser Beam Input

Both the WA-1500 and WA-1000 have a 2-mm diameter aperture on one side for introduction of a collimated free laser beam. As shown in Figure 3-1, a flip mirror inside the unit directs the beam into the Michelson interferometer. The position of the flip mirror is controlled by a lever just below the input aperture. When the flip mirror is positioned for the free laser beam input, a red tracer beam is emitted from the aperture to facilitate alignment.

CAUTION

The power in the tracer beam is less than 10 microwatts, but do not stare into the beam or view it directly with an optical instrument.

The tracer beam defines the optical path of the internal HeNe reference laser through the Michelson interferometer. For the best measurement accuracy it is imperative that the input laser beam follow exactly the same path. This is easily accomplished as follows:

1. With appropriate mirrors adjust the laser beam to be measured parallel to the optical table at a height of approximately 7.0".
2. Set the WA-1500/1000 in front of the beam about 1 meter from the source and adjust the two feet on the aperture side so that the tracer beam and the input laser beam are accurately superimposed at the WA-1500/1000 aperture. If the tracer beam is not accurately centered coming out of the aperture, refer to *Aligning the Internal Optics* on page 37 to check the internal optical alignment.
3. Adjust the height of the third foot on the WA-1500/1000 and slide it on the table until the tracer beam is directed back along the input laser beam.

IMPORTANT

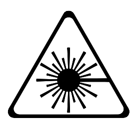
For the specified measurement accuracy, the tracer beam and input laser beam must be precisely collinear over a one-meter path from the WA-1500/1000 input aperture (within 0.5 mm for the WA-1500; within 1.5 mm for the WA-1000).

4. Steps 2 and 3 may have to be repeated to get perfect alignment. Use the lock nuts on the feet to secure the WA-1500/1000 when alignment is complete.

Fiber-Optic Input

For laser radiation that can be transmitted through small core fiber-optic cable, the simplest way to couple light into the WA-1500/1000 is via the front panel fiber-optic connector. The standard connector is an FC style. It is prealigned internally with the Michelson interferometer; no further alignment should be necessary. To use the fiber-optic input:

1. Verify that the flip mirror in Figure 3-1 is in the correct position for the fiber-optic input. When the flip mirror is out of the way the internal HeNe laser light will appear as a divergent red light coming out of the fiber-optic connector. If the red light is not accurately centered coming out of the connector, refer to *Aligning the Internal Optics* on page 37 to check the internal optical alignment.



CAUTION

The power in the tracer beam is less than 10 microwatts, but do not stare into the beam or view it directly with an optical instrument.

2. Attach a fiber-optic cable (such as a EXFO PC-F patch cord) with the mating connector to the front panel of the WA-1500/1000. Make certain that the key on the connector is properly seated. If the fiber-optic connector is well aligned, red light from the WA-1500/1000 reference laser will transmit through the fiber-optic cable. Otherwise refer to *Aligning the Internal Optics* on page 37 to check the internal optical alignment.
3. If the fiber-optic cable is not already coupled to the laser, introduce the laser light to the fiber-optic cable with an appropriate input coupler. The EXFO BC-1 input beam coupler is ideal for this purpose because it produces two weak reflected spots that facilitate alignment. The BC-1 mounts easily in a two-axis optical mount (Figure 3-1). When the reflected spots symmetrically straddle the input beam, the laser light is coupled into the fiber.

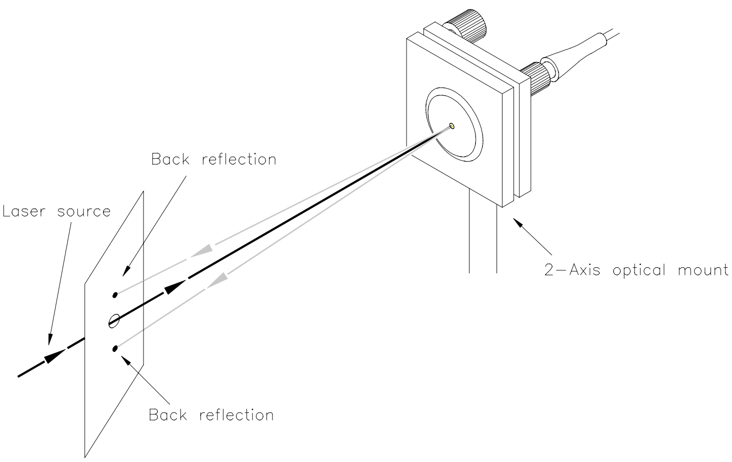


Figure 3-1: Input beam coupler alignment

4. When sufficient light is coupled into the WA-1500/1000 through the fiber-optic cable, the Intensity meter will read in the green region and the WA-1500/1000 will display the wavelength. If this is not the case, refer to *Aligning the Internal Optics* on page 37 for checking the internal alignment of the fiber-optic connector.

4. Operation

The WA-1500 front panel is shown in Figure 4-1. The WA-1000 front panel is identical. The panel controls are divided into two major areas: the display and **System Configuration**. A full description of their operation is covered in this section.

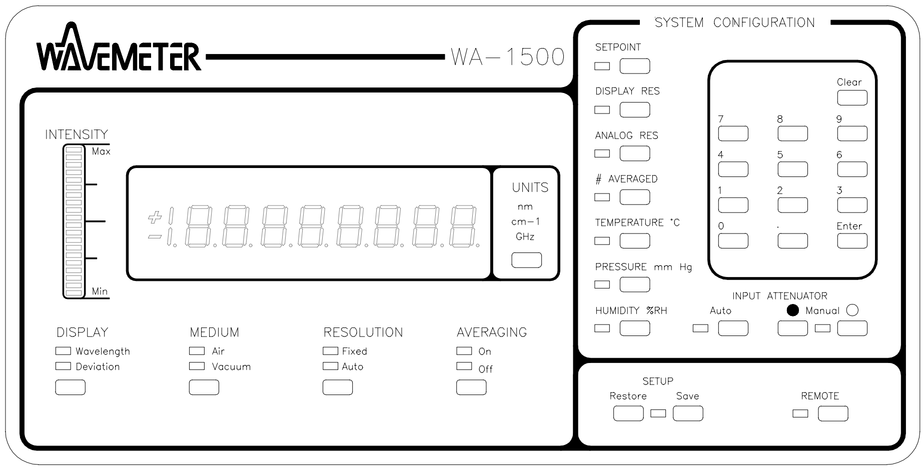


Figure 4-1: WA-1500 front panel

Display

The display includes of a 20-element bar graph intensity meter, an 8½ digit numerical readout and buttons that select the type of measurement displayed. Buttons have associated LEDs that indicate the current selection and alternate choices.

A ± sign flashing on and off to the left of the numerical readout indicates that amplitude or frequency noise on the input laser beam may be introducing some uncertainty in the measurement, and usually will accompany some fluctuation in the reading. If this condition persists, refer to Section 8.

Input Intensity Meter

The **Intensity** bar graph meter shows input laser intensity. When the intensity is zero, the first LED is on (red). As the intensity increases successive LEDs are turned on, first orange and then green, one at a time. The top three segments of the range on the bar graph are orange and red. Above the maximum input level, the top red LED is on.

When the input attenuator is set in **Auto** mode, the intensity should be automatically adjusted to fall in the green region. When the intensity falls below 20% or above 80% of the bar graph range the attenuator will move to increase or decrease the signal. If the attenuator range is exceeded and the meter stays in the red at either end, a **LO SIG** or **HI SIG** message will appear on the display requiring the input laser power to be increased or decreased.

When the input attenuator is in **Manual** mode, the two manual attenuator buttons can be used to open (o) or close (•) the attenuator. In this mode, if the **LO SIG** or **HI SIG** messages appear, the input laser power must be increased or decreased, either by manual operation of the attenuator, or by externally changing the input laser power.

Wavelength / Deviation Mode

The WA-1500/1000 can display the measurement as the absolute **Wavelength** or as the **Deviation** from a setpoint entered by the user. The **Display** button toggles between two LEDs that indicate which mode is active.

In **Wavelength** mode the measurement is displayed in the current units.

In **Deviation** mode, the difference between the measured value and the setpoint is displayed in the current units.

The **Setpoint** button in the **System Configuration** group is used to display the current setpoint. When the setpoint LED is lit, a new setpoint can be entered on the keyboard. After the number is typed, push **Enter** to complete the entry. The setpoint may be entered in any units and will be converted if the **Units** selection is changed. The wavelength range for the setpoint is 200 to 4000 nm.

Medium Selection

The wavelength (or wavenumber) can be displayed based on **Air** or **Vacuum** as the **Medium.** The **Medium** button toggles between two LEDs that indicate whether the value displayed corresponds to air or vacuum.

In vacuum mode the vacuum wavelength of the input laser is displayed. The vacuum value is the most fundamental because it is independent of temperature, pressure and humidity.

In air mode the air wavelength of the input laser is displayed. The air value corresponds to the wavelength measured under the conditions of temperature, pressure and humidity inside the WA-1500/1000. These can be displayed using the **Temperature**, **Pressure** and **Humidity** buttons on the front panel. Temperature and pressure readings are derived from internal sensors. The humidity value must be entered by the operator.

IMPORTANT

Do not change the temperature and pressure readings by typing in new values. This should be done only to recalibrate the sensors as described in Section 8.

Resolution Selection

The resolution is the number of digits displayed. The user can choose between a **Fixed** resolution or **Auto**-resolution. The **Resolution** button toggles between two LEDs that indicate whether fixed or auto-resolution mode is active.

In fixed resolution, the number of digits that will be displayed relative to the decimal point is programmed using the **Display Res** button in the **System Configuration** group. While the Display Res LED is on, type in a decimal point followed by zeros and a 1 in the place of the least significant digit desired in the display. For example, to display four decimal places, type ".0001", then push **Enter** to record the new selection. Changing units will convert the display resolution to similar relative precision in the new units.

In auto-resolution mode the number of digits displayed is governed by the coherence length of the input laser that determines the number of fringes during the measurement window. Insignificant digits to the right of the decimal point are not displayed if the precision of the measurement is reduced because not enough fringes could be counted. If insignificant digits occur before the decimal point, they are replaced by an underscore character "_".

Averaging Mode

The **Averaging** button toggles between two LEDs that indicate whether averaging mode is **On** or **Off**. When average mode is on, the WA-1500/1000 computes and displays a running average of measurements.

The number of measurements averaged is programmed under **System Configuration** using the **# Averaged** button**.** When the # averaged LED is lit, the current number of points in the running average is displayed. Type in a new number between 2 and 50 followed by **Enter** to change the range of the running average.

When averaging is first enabled the average is computed from the total number of samples currently measured, therefore an average is reported immediately. When the number of samples equals the number requested, the oldest measurement is discarded and the newest is added to the set to be averaged. If the Averaging Mode is subsequently turned off the sample set is zeroed along with the average.

Units Selection

The **Units** button cycles through the three choices of display units in succession; either nanometers (nm), wavenumbers (cm^{-1}) or gigahertz (GHz). An LED backlights the abbreviation for the units selected when a measurement is displayed.

Conversion between these units is given by the equations:

$$\nu\ (cm^{-1}) = 1 / \lambda\ (cm)$$

$$\nu\ (GHz) = c / \lambda\ (cm)$$

where ν is the frequency, λ is the wavelength and c is the velocity of light in cm/second. A measurement in nanometers or wavenumbers depends on the medium selected, air or vacuum. Frequency in gigahertz is independent of the medium.

System Configuration

The buttons in the **System Configuration** group allow certain operating parameters of the WA-1500/1000 to be reprogrammed. All buttons outside of the keypad have associated LEDs that define the current button selections.

Setpoint

Setpoint is the fixed wavelength or frequency used to compute the deviation for display, and for the analog output voltage. When the setpoint LED is lit, the setpoint is displayed in the current units. The setpoint can be changed by typing in a new value followed by **Enter**. When the units are changed the setpoint is also converted into the new units.

Display Resolution

The **Display Res** button is used to program the least significant digit (LSD) for the fixed resolution display. When the LED is lit, the display will show a “1” in the position of the LSD in the current units. For example, to display three significant digits after the decimal point, the display resolution code is “.001”.

Type a new code followed by **Enter** to change the display resolution. Valid input is a combination of “0”, “1” and “.”. Range is 0.0001 to 10 nm (0.001 to 100 cm^{-1} or 0.01 to 1000 GHz.). The display will locate the decimal point so that the LSD displayed matches this setting.

Analog Output and Resolution

The **Analog Output** BNC connector on the rear panel produces an analog voltage proportional to the deviation between the measured wavelength and the setpoint wavelength. The same analog output is present whether the display is in wavelength or deviation mode, and independent of the units displayed.

The range of the analog output is ± 5 volts in increments of 2.44 millivolts from a 12-bit DAC (11 bits plus a sign bit). Positive deviation values produce a positive voltage and vice versa. The output voltage may include a fixed voltage offset of a few millivolts that must be corrected by external circuitry.

The resolution of the analog voltage in wavelength units is set in the System Configuration using the **Analog Res** button. When the Analog Res LED is on, a “1” is displayed in the location corresponding to an analog output of approximately 4.9 mV.

Valid input is a combination of “0”, “1” and “.”. The range for setting the analog resolution is 0.0001 to 100 nm.

Based on the numerical value of the Analog Res setting:

Analog Output Voltage = .0049 x (Deviation in nm) / (Analog Res) + Offset

Increment of one least significant digit (LSD), defined by the location of “1” in the analog resolution setting, corresponds to approximately a 4.9 mV change on the analog output voltage.

Averaged

In Averaging mode the number of measurements averaged is set under the System Configuration using the **# Averaged** button. Then the # Averaged LED is on the current number is displayed and can be changed by typing in a new one between 2 and 50, followed by **Enter**.

Temperature and Pressure Sensors

The **Temperature** button displays the temperature in degrees Celsius inside the WA-1500/1000. An LED indicates when the temperature display is on.

IMPORTANT

Do not change the temperature reading by typing in a new value. This should be done only to recalibrate the sensors as described on page 39. If the temperature setting is changed accidentally, press Restore to recover the previous calibration.

If a number is entered from the keypad when the **Temperature** mode is on, the processor recalculates the temperature sensor calibration (a dc offset) and saves that value in place of the old value. Range is 0 to 50 degrees C. The new value must be within range, or it is rejected.

The **Pressure** button displays the barometric pressure in mm Hg inside the WA-1500/1000. An LED indicates when the pressure display is on.

IMPORTANT

Do not change the pressure reading by typing in a new value. This should be done only to recalibrate the sensors as described on page 39. If the pressure setting is changed accidentally, press Restore to recover the previous calibration.

If a number is entered from the keypad when the Pressure mode is on, the processor recalculates the pressure sensor calibration (a dc offset) and saves that value in place of the old value. Range is 635 mm Hg to 900 mm Hg. The new value must be within range or it is rejected.

Humidity Setting

The **Humidity** button displays the percent relative humidity that will be used in calculating the refractive index of air. An LED indicates when the humidity display is on.

The humidity value should be entered by the user, corresponding to the existing laboratory conditions.

Input Attenuator

Inside the WA-1500/1000 there is a motorized variable attenuator capable of reducing the intensity of the input laser beam up to 100 times. Three buttons below the keyboard on the front panel control its operation.

In ***Auto*** mode the attenuator is adjusted automatically in accordance with the intensity displayed on the bar graph intensity meter. When the intensity falls below 20% or above 80% of the bar graph range the attenuator will move to increase or decrease the signal. If the attenuator range is exceeded and the meter stays in the red at either end, a **LO SIG** or **HI SIG** message will appear on the display requiring the input laser power to be increased or decreased externally.

In ***Manual*** mode, the two manual attenuator buttons can be used to open (o) or close (•) the attenuator. In this mode, if the **LO SIG** or **HI SIG** messages appear, the input laser power must be increased or decreased, either by manual operation of the attenuator or by externally changing the input laser power. Each time a button is depressed the attenuator moves a small increment (the size of this increment may be adjusted using R69 on the main circuit board). To move further requires repeated pressing of the button.

Push **Auto** to set the WA-1500/1000 in auto-attenuation mode and the corresponding LED will be lit. Push either manual buttons to switch to manual control of the attenuator and the manual LED will be lit.

IMPORTANT

The WA-1500/1000 should be set in manual attenuator mode when using the intensity bar graph meter to monitor changes in the strength of the input laser signal. Otherwise, in auto-attenuator mode, the input attenuator will counteract those changes.

Saving and Restoring Setup Parameters

The **Save** button under **Setup** is used to save the current front panel setup to non-volatile RAM so that it will be restored automatically on next power-up. The Setup LED blinks momentarily to indicate that the save operation has taken place.

IMPORTANT

The front panel setup is not automatically saved when the power is turned off. Use the setup save button to do this.

The **Restore** button resets the front panel to the setup that was last saved. The Setup LED blinks momentarily to indicate that the restore operation has taken place. Restore is executed automatically on power-up.

Remote Operation

When the WA-1500/1000 is controlled remotely from a computer, the **Remote** button can be used to lock out the response to all other buttons. It also can be useful to prevent accidentally changing the front panel setup.

When the remote LED is lit, all other buttons are locked out. Pressing **Remote** again turns off the front panel lockout.

5. Changing Wavelength Ranges

The WA-1500 and WA-1000 can operate over three overlapping wavelength ranges between 400 and 4000 nanometers. This section provides instructions on how to change the operating wavelength range of your WA-1500/1000.

Converting Between Models

Either the WA-1000 or WA-1500 can be converted easily between models that cover different wavelength ranges. The configurations for each model are listed in Table 5-1.

Table 5-1: Model configurations

Model	**VIS**	**NIR**	**IR**
Wavelength Range (nm)	400-1100	600-1800	1500-4000
Beamsplitter	WA-VIS/BS	WA-NIR/BS	WA-IR/BS
Photodetector	WA-VIS/PD	WA-NIR/PD	WA- IR/PD
Drive Pivot Position			
WA-1000	Middle	Middle	Outer
WA-1500	Outer	Outer	Outer
Model Setup Switches	DN UP	UP DN	UP UP

For most cases, conversion from one model to another involves changing the beamsplitter and detector and resetting the rear panel **Model** switch. Some WA-1000 conversions require that the pivot position for the drive bar connecting the moving retro-reflector assembly to the drive wheel be changed between an inner and outer mounting hole.

Changing the Beamsplitter

The beamsplitter is mounted in a ring that makes it easy to handle and locates it accurately when mounted. The surface of the beamsplitter that is almost flush with the rim of the ring has a soft dielectric reflective coating.

CAUTION

Do not touch the coated surface with your fingers or with any hard material that might scratch or contaminate the coating. Store the beamsplitter carefully, protected from scratches, dirt and humidity.

The beamsplitter is mounted with the coated surface facing the beamsplitter mount and is held in place by three screws as shown in Figure 5-1.

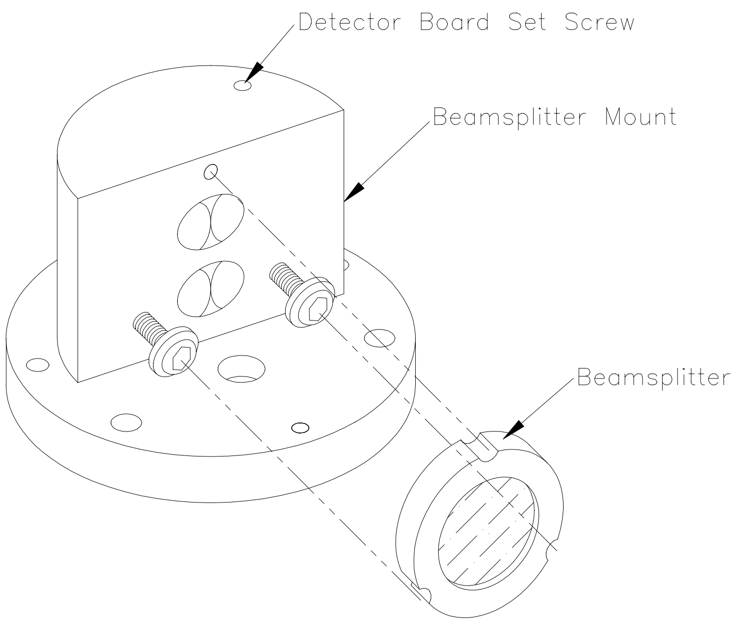


Figure 5-1: Beamsplitter mounting

To remove the existing beamsplitter, loosen the bottom two screws about two turns and remove the top screw. The beamsplitter then can be tilted away from the mounting surface, lifted out and replaced with a new one. When the new beamsplitter is in position, replace the top screw and gently tighten all three screws.

Changing beamsplitters often requires a slight realignment of the interferometer optics. Checking the alignment is recommended whenever a new beamsplitter is mounted (refer to Section 8).

Changing the Photodetector

IMPORTANT

Use antistatic equipment and procedures at all times when handling the detector board and circuitry.

To change the photodetector:

1. Turn off the power to the WA-1500/1000.
2. Disconnect the ribbon cable from the end of the detector board.
3. Loosen the single set screw in the top of the beamsplitter mount shown in Figure 5-1.
4. Carefully slide the detector board straight back until it clears the beamsplitter mount, then lift it up to remove it from the WA-1500/1000.

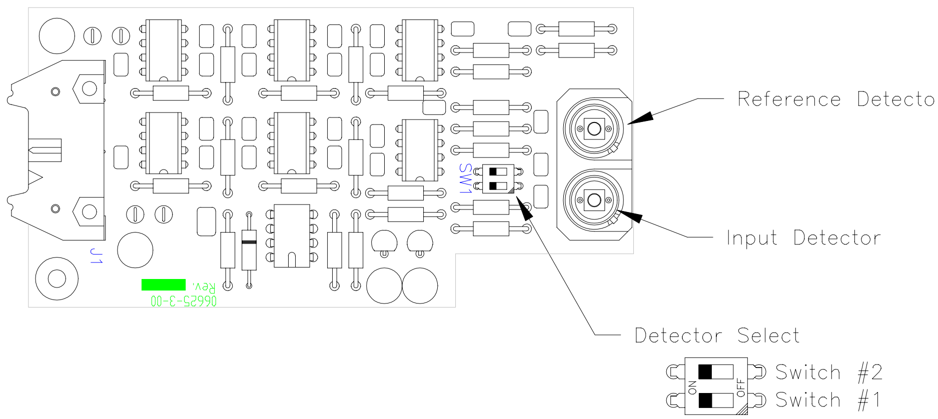


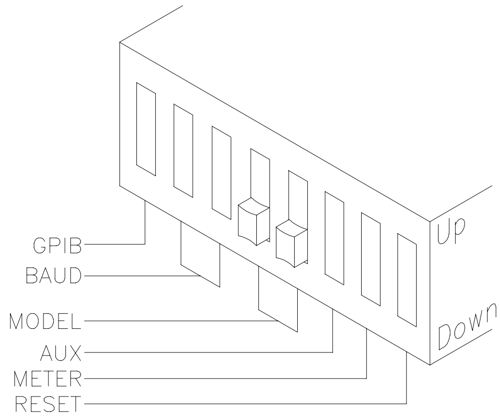
Figure 5-2: Detector board

5. With a small screwdriver or tweezers, carefully remove the input detector (Figure 5-2) from its socket.
6. Replace it with the new detector, making sure to align the tab on the detector case with the notch in the socket.

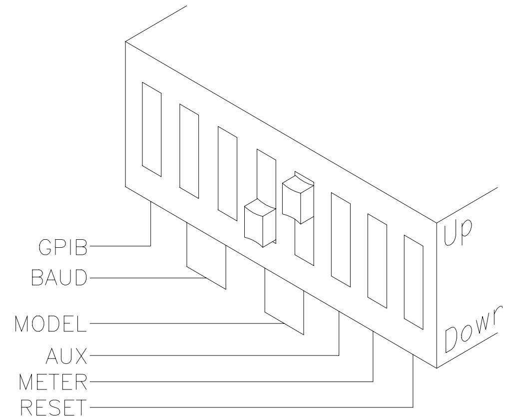
	**IMPORTANT** **The Detector Select switch should be set in the UV/VIS/NIR position or the IR position, depending on which detector is mounted.**
	**CAUTION** **Always make sure the switch is properly set before applying power to the detector board to avoid damage to the detector. Reinstall the detector board by reversing the previous steps.**
	**WARNING** **Be sure to tighten the set screw in the top of the beamsplitter mount because it provides an electrical shield connection between the circuit board and the beamsplitter mount.**

Selecting the Wavelength Range

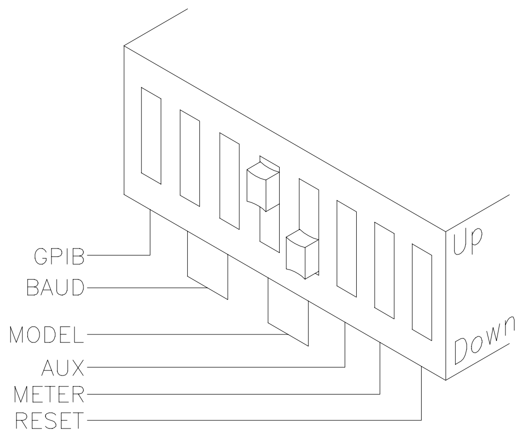
The rear panel **Setup** switch identifies for the microprocessor the current model configuration of the WA-1500/1000. The switch positions for each model are shown in Figure 5-3.



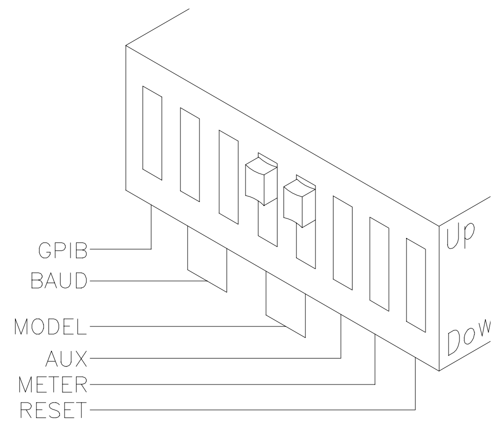
UV



VIS



NIR



IR

Figure 5-3: Setup switch positions for different models

After changing the beamsplitter and photodetector, set the **Model** switch accordingly.

!	**IMPORTANT** **Whenever the Model switch is changed, the WA-1500/1000 must be turned off and powered up again to read the new switch position.**

6. Output Interfacing

The rear panel has several connectors, switches and indicators that allow interfacing the WA-1500/1000 and other devices. These rear panel components are shown in Figure 6-1. The operation of the Monitor, RS-232 and optional GPIB interfaces are discussed in this section.

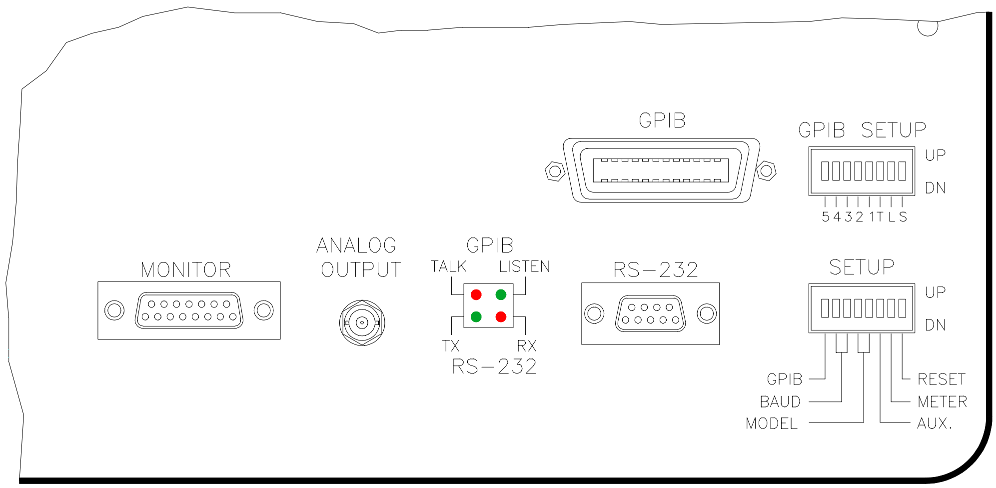


Figure 6-1: Rear panel

Monitor Signals

The **Monitor** connector on the rear panel of the WA-1500/1000 provides a combination of analog and digital signals as well as power for optional accessories. This connector can be used as a general system monitor to observe the fringe signals and measurement timing signals using an oscilloscope.

The signals have the following characteristics:

Analog Signals

Output Voltage	± 7 V maximum
Output Current	100 mA maximum

Digital (TTL) Signals

Output Voltage	V_{OL} = 0.4V max, V_{OH} = 2.4V min
Output Current	I_{OL} = 16 mA max, I_{OH} = -0.4 mA
Output Timing	$t_r \leq 7$ nsec, $t_f \leq 7$ nsec

The Monitor output is a 15-pin, female, D-sub style connector (Figure 6-2), with the pinout shown in Table 6-1.

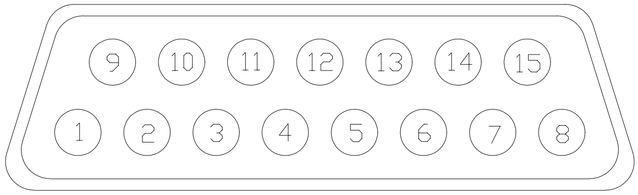


Figure 6-2: Monitor output connector

Table 6-1: The monitor output connector pinout

Pin Number	Signal Name	Signal Type	Description
1	INPUT	Analog	Input laser signal
2	REFERENCE	Analog	Reference laser signal
3	+15VDC	Power	+15 VDC supply
4	-15VDC	Power	-15 VDC supply
5	+5VDC	Power	+5 V supply
6	DGND	-	Digital ground
7	TRIGGER	TTL	Scanning window trigger
8	ZOP	TTL	Zero optical path signal
9	AGND	-	Analog ground
10	AGND	-	Analog ground
11	+15VDC	Power	+15 VDC supply (250 mA fused)
12	-15VDC	Power	-15 VDC supply (250 mA fused)
13	+5VDC	Power	+5 VDC supply (250 mA fused)
14	DGND	-	Digital ground
15	WINDOW	TTL	Scanning window

INPUT Input laser sinusoidal fringe signal.

REFERENCE Reference laser sinusoidal fringe signal.

TRIGGER Trigger is a digital pulse with a duration that defines the maximum measurement interval for the interferometer scan. It goes active (H = active) during the allowed measurement interval.

ZOP ZOP (zero optical path) is a digital pulse derived from the interferometer scanner that produces a low to high transition at the point in the scan where the difference between the two optical paths in the interferometer is zero.

WINDOW The Window digital output is derived from the amplitude of the input laser fringe signal. When the peak-to-peak amplitude of this signal exceeds 1 volt, within the Trigger interval and before or spanning the ZOP transition, the Window is active (H =

active). Depending on the character of the input laser fringes, there may be several Windows during a Trigger, but the first Window period to terminate after the ZOP transition is the only "Valid Window" used for the measurement.

Examples of these signals for different input laser characteristics are shown in Figures A-2, A-3 and A-4.

RS-232 Interface

The WA-1500/1000 has a RS-232 serial communications port on the back panel. To make the RS-232 port operational move the GPIB switch as indicated in Figure 6-3.

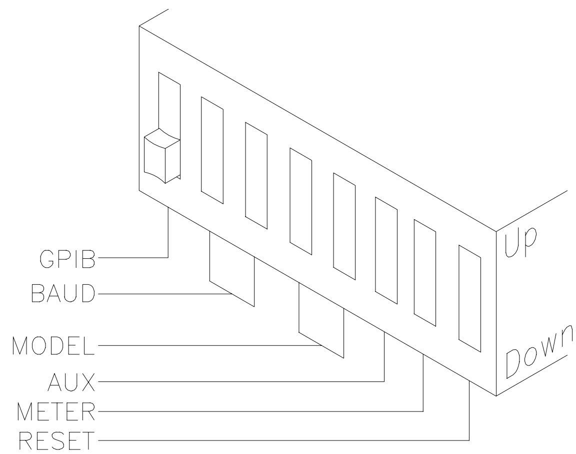
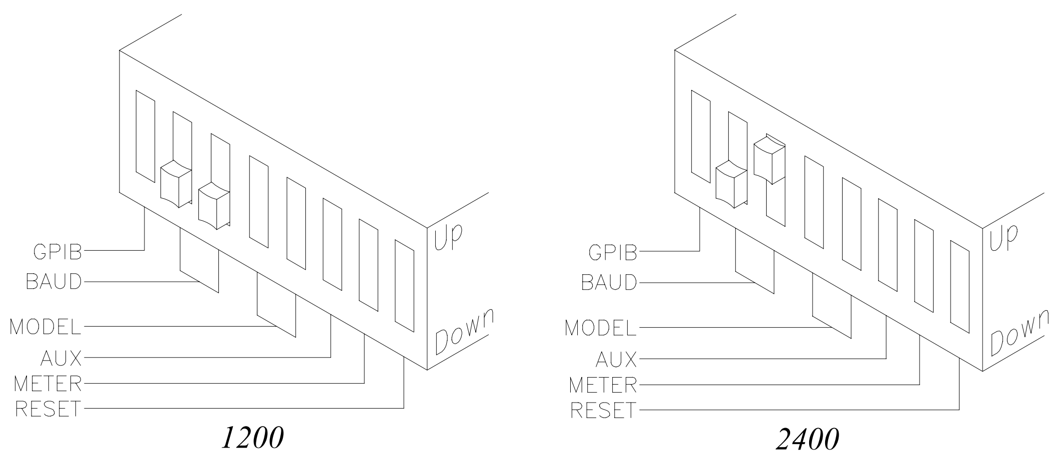


Figure 6-3: GPIB switch in RS-232 position

The serial port baud rate switch is sampled at power-up and selects the operating baud rate. To change the baud rate set the switches appropriately (Figure 6-4) and turn the WA-1500/1000 off. Wait a moment, then turn the power back on.



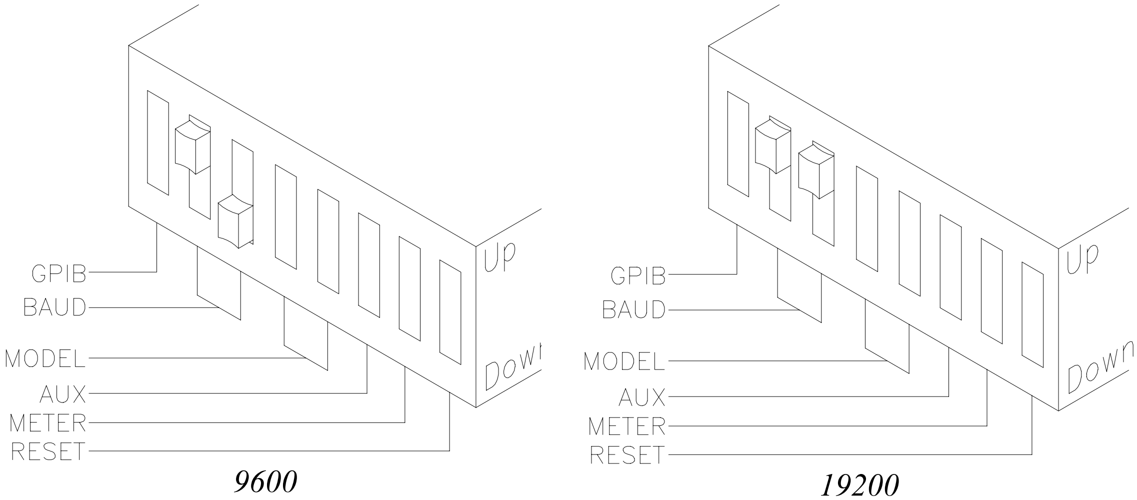


Figure 6-4: RS-232 baud rate settings

The RS-232 port is a nine-pin, female, D-sub style connector (Figure 6-5) with the pinout shown in Table 6-2.

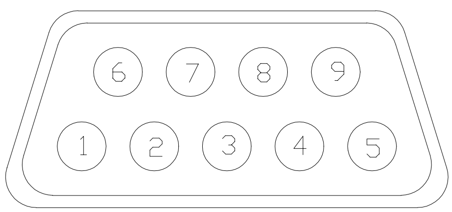


Figure 6-5: RS-232 serial interface connector

Table 6-2: RS-232 connector pinout

Pin Number	Signal Source	Signal Name	Description
1	-	-	N/C
2	WA-1000/1500	TxD	Transmit data
3	User	RxD	Receive data
4	User	DSR	Data set ready
5	-	GND	Signal ground
6	WA-1000/1500	DTR	Data set ready
7	User	CTS	Clear to send
8	WA-1000/1500	RTS	Request to send
9	-	-	N/C

The above pin configuration complements that of the PC/AT. To connect the WA-1500/1000 to a PC/AT, only a serial extension cable, with 1:1 pin correlation is required. To facilitate the connecting of the serial port, the signal descriptions (H=active) and usage is as follows:

TxD - Transmit Data - Data from the WA-1500/1000 is output on this signal pin.

RxD - Receive Data - Data from the user is received on this signal pin.

DSR - Data Set Ready - This input signal must be held active by the user for the WA-1500/1000 to consider the serial port connected to an external device.

GND - Signal Ground - Required for proper RS-232 operation.

DTR - Data Terminal Ready - This output signal is active whenever the WA-1500/1000 is powered and is not in internal reset.

CTS - Clear To Send - An input signal indicates to the WA-1500/1000 when the user device is able to accept additional data.

RTS - Request To Send - The WA-1500/1000 makes this signal active as long as its internal command buffer has room in it. When the internal command buffer is full, the WA-1500/1000 sets RTS inactive.

SHIELD - The connector housing provides connection to the earth ground inside the WA-1500/1000.

For additional information, see *Interface Programming* later in this section.

GPIB Interface Option

The WA-1500/1000 has an optional GPIB communications port on the back panel. If the GPIB option is purchased separately, refer to Appendix D for installation instructions.

To make the GPIB port operational move the GPIB switch, and baud rate switches to the positions as indicated in Figure 6-4.

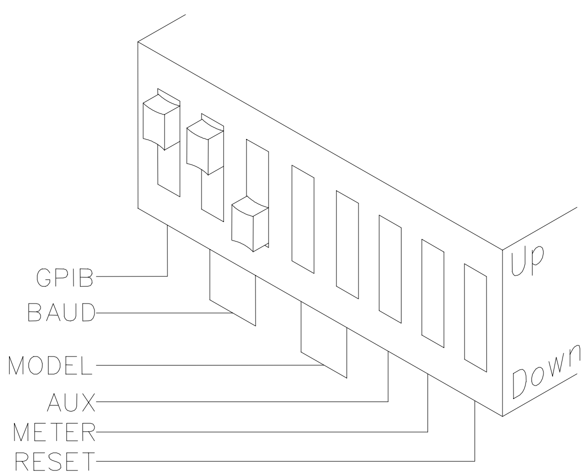


Figure 6-4: GPIB switch and baud rate settings (9600) for GPIB interface

The **GPIB Setup** switches are 16-8-4-2-1 binary-coded decimal (BCD). The five-bit weighted code has the property that the weights are w_5, w_4, w_3, w_2 and w_1, and the code $a_5a_4a_3a_2a_1$ represents a decimal number N, where

$$N = w_5a_5 + w_4a_4 + w_3a_3 + w_2a_2 + w_1a_1$$

The weights are $w_5 = 16$, $w_4 = 8$, $w_3 = 4$, $w_2 = 2$ and $w_1 = 1$. For example, the binary code 0 0100, where 1 represents the switch in the Up position, represents the decimal address

$$N = 16*0 + 8*0 + 4*1 +2*0 + 1*0 = 4$$

The GPIB address 4 is the factory default (Figure 6-5). Switches T, L and S should always be down.

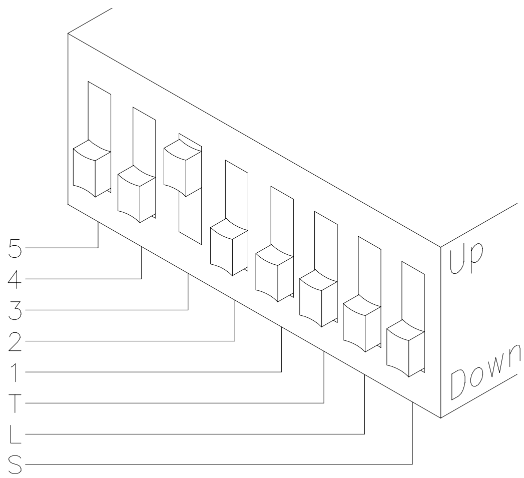


Figure 6-5: GPIB SETUP switch set to GPIB Address 4

The GPIB port uses the standard IEEE-488 connector (Figure 6-6), with the pinout shown in Table 6-3.

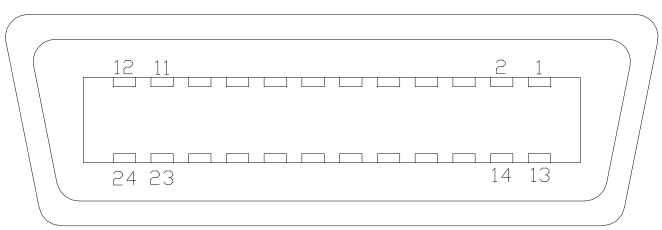


Figure 6-6: GPIB interface connector

Table 6-3: Standard IEEE-488 connector pinout

Pin Number	Signal Name
1	DIO1
2	DIO2
3	DIO3

4	DIO4
5	EOI
6	DAV
7	NRFD
8	NDAC
9	IFC
10	SRQ
11	ATN
12	SHIELD
13	DIO5
14	DIO6
15	DIO7
16	DIO8
17	REN
18	GND (TW W/ DAV)
19	GND (TW W/ NRFD)
20	GND (TW W/ NDAC)
21	GND (TW W/ FC)
22	GND (TW W/ SRQ)
23	GND (TW W/ ATN)
24	SIGNAL GROUND

For additional information, see *Interface Programming* later in this section.

Interface Programming

The following is a discussion of interfacing using the sample program included with the WA-1500/1000 on floppy disk and in Appendix C. The sample program shows how to communicate with the WA-1500/1000 using the RS-232 and GPIB interfaces. It demonstrates bi-directional communication using fixed field ASCII formatted strings. These command strings mimic keys being pressed on the WA-1500/1000 control panel display. The use of command data strings as input is done to reduce the complexity of the communication routines.

There are two types of strings: command (input to the WA-1500/1000) strings and response (output from the WA-1500/1000) strings.

A command string is composed of four characters. Special characters are used as part of the transmission as 'start' and ‘stop' characters. The first character is the '@' character, and must always be the ‘start’ character. The ‘start’ character is followed by the ‘command’ character. Each string is terminated using a carriage return - line feed pair. For example, to change units send the following command string "@\x27\r\n". In this case, the command character is \x27 (hexadecimal 27); the carriage return - line feed pair is represented by \r\n. For a list of the command strings refer to Appendix B.

The WA-1500/1000 powers up in the 'Broadcast' mode. This means that each new wavelength reading is transmitted automatically to the communications port. To switch the WA-1500/1000 to 'Query' mode issue the 'Query' command @\x51\r\n once. In this mode another 'Query' command must be issued for each wavelength reading.

The WA-1500/1000 responds with a 23-character, comma-delimited, fixed-field, formatted string. This string also uses special characters as the 'start' and 'stop' characters. The first character is always a +, - or ~, and the terminating characters are always a CR (0x0D) carriage return and LF (0x0A) line feed pair.

- The first field is an 11 ASCII character field containing the wavelength or status code. If the first character in this field is a + or a -, it indicates the magnitude of the measurement. If the first character in this field is a ~, then the system has detected some noise in the input laser beam that may increase the uncertainty of the measurement (see *Error Messages* in Section 8 for more information).

- The second field is a four hexidecimal character field indicating the state of the display LEDs.

- The third field is a four hexidecimal character field indicating the state of the system LEDs. One can infer the state of the instrument by interpreting the content of the first display field, along with the content of the next two LED fields.

For example a response string may be '+ 632.9911,2A49,0200\r\n'. The first field, '+ 632.9911' are the characters currently being displayed. The next field '2A49' represents the Display LEDs. The '2' indicates that Averaging is Off. The 'A' indicates that Resolution is set to Auto. The '4' indicates that Medium is set to Vacuum. The '9' indicates that the Units selected are Nanometers. The final field '0200' is the state of the System LEDs. The '2' indicates that the Input Attenuator is in the Automatic mode. To interpret the LED fields first take the four-character string and convert to its hexadecimal equivalent; then logically AND this with the appropriate mask. If the result is non-zero then the LED is on, indicating that feature has been selected. For a complete list of the response string masks refer to Appendix B.

A diskette supplied with the WA-1500/1000 provides sample programs written in BASIC and C demonstrating interfacing to the WA-1500/1000 using the RS-232 port and the GPIB port.

Appendix C contains C program segments that demonstrate how to communicate with the WA-1500/1000 via RS-232 and GPIB.

7. Calibrating the Reference Laser

The accuracy of the WA-1500/1000 is directly related to the knowledge of the reference laser wavelength. This section discusses the calibration of the reference laser for the WA-1500 and WA-1000.

WA-1000

The WA-1000 uses a multimode HeNe laser that does not require calibration of the reference laser wavelength for an absolute accuracy of ± 500 MHz (1 part per million).

A built-in power meter can be used to check the "health" of the reference laser by switching the rear panel ***Meter*** switch shown in Figure 7-1. The internal power meter reading is displayed when the switch is in this position.

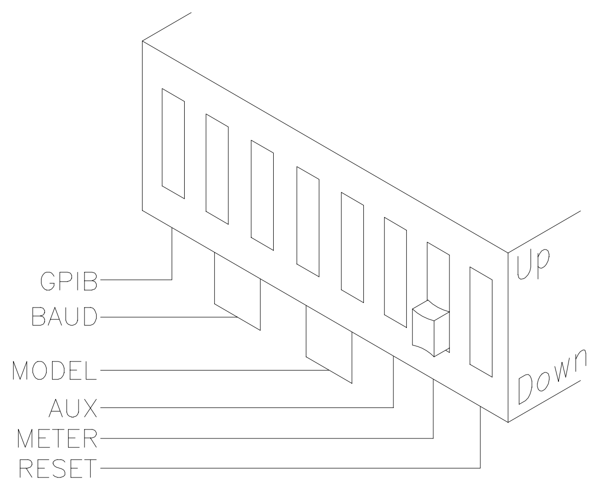


Figure 7-1: Switch position for power meter display

The power meter reading on the display is identified by a "P" followed by the laser power in milliwatts. For example, the display

P 0.81

indicates a laser power of 0.81 milliwatts.

Both models are shipped with a test sheet that identifies the laser power measured at the time of manufacture. Aging of the reference laser therefore can be determined by comparing the current power measurement to the test sheet value.

If the laser power has decreased significantly, slightly loosen the small set screw in the top of the periscope (refer to Figure 8-1) and rotate the reference laser attenuator until the reference signal is approximately 2.5 volts peak-to-peak. The reference signal is measured by attaching an oscilloscope to the Monitor port pin 2.

WA-1500

The WA-1500 uses a single frequency HeNe reference laser that is stabilized to a set position on the gain curve of the Ne^{20} atomic transition. While the laser is warming up, the frequency sweeps through the gain profile and an internal power meter in the WA-1500 monitors the intensity to record the maximum at the line center.

By switching the rear panel Meter switch as shown in Figure 7-1 it is possible to observe the power change during the warm-up period. For the WA-1500 the power meter display will show a “P” followed by the laser output expressed as a percent of maximum and actual power in milliwatts. For example, the display might show:

P 75 0.59

indicating that the power is 75% of maximum and 0.59 milliwatts.

The power relative to the maximum at the center of the HeNe gain curve is directly related to how far the laser frequency is detuned to the short wavelength side of the Ne^{20} atomic line center. Figure 7-2 is a graph of the relative intensity as a function of detuning the laser frequency. By setting the relative intensity at 75% ± 5% the frequency offset is maintained at 490 MHz ± 50 MHz. At this setting, the Reference Laser Vacuum Wavelength = 632.99070 nm.

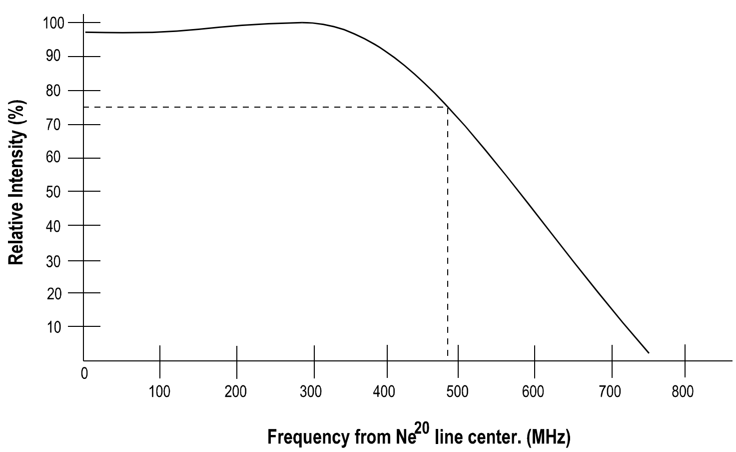


Figure 7-2: Laser intensity as a function of frequency detuning

To verify the calibration of the WA-1500 at any time after warm-up, put the rear panel Meter switch in the position shown in Figure 7-1. The first number after the “P” should be between 70 and 80. If it is not, reset it to 75 by adjusting the trim pot on the side of the reference laser using the insulated screwdriver provided. The trim pot is accessible through a hole in the rear panel of the WA-1500 next to the power cord. This will recalibrate the laser wavelength to the correct value within ± 50 MHz.

8. Error Messages and Servicing

The WA-1500/1000 continually checks the quality of the signal it is analyzing and reports as an error message any unusual conditions that might affect the precision of the measurement. This section includes a list of error messages and what they mean, instructions for alignment of optical components inside the WA-1500/1000, calibration of the temperature and pressure sensors, and replacement of the reference laser.

Error Messages

The first column in the following table lists the messages that may appear on the display. The second column describes the cause of the message. The third column lists suggested actions or solutions.

Error messages that appear during power-up or while changing alignment of the WA-1500/1000 and the input laser may be ignored. When an error message persists, often a slight adjustment by the operator will correct the problem. The following table is designed as a quick reference for what to do.

The error messages are listed in alphanumerical order.

Message	Description	Solution
± appears next to the number on the display.	Instability has been detected in the input laser system that may cause increased uncertainty in the measurement.	Check the input laser for intensity or frequency instability. If the ± persists, check for instability of the laser by viewing the envelope of the input laser signal at the monitor output on the rear panel.
~ appears before the number on the RS-232 or GPIB output.	Instability has been detected in the input laser system that may cause increased uncertainty in the measurement.	Check the input laser for intensity or frequency instability. If the ~ persists, check for instability of the laser by viewing the envelope of the input laser signal at the monitor output on the rear panel.
LA OP XX	WA-1500 only, reference laser warm-up period message.	This message is normal on power up of the WA-1500. The digits XX count minutes of warm-up time. If this time exceeds 60 minutes Error 11 will be displayed. Turning power off and on again will restart the warm-up timer. Check that laser head is connected to the main circuit board at J8. Otherwise, contact EXFO Service.

Message	Description	Solution
LO SIG	Input signal (fringe amplitude) is too low.	The input laser signal observed at the Monitor output must exceed 1.5 volts p-p amplitude. Check input alignment (Section 3). If the input attenuator is in manual mode, decrease the attenuation (page 16). If in auto-attenuate mode, increase the intensity of the input laser beam. If the problem persists check alignment of the internal optics (page 37).
HI SIG	Input signal (fringe amplitude) is too high.	The input laser signal will saturate and distort if it exceeds 14 volts p-p amplitude. If the input attenuator is in manual mode, increase the attenuation (page 16). If in auto-attenuate mode, or the attenuator has been manually set to maximum attenuation, decrease the intensity of the laser beam entering the WA-1500/1000.
Error 10	WA-1500 only, reference laser is over temperature.	The laser stabilization circuit is indicating an over temperature condition. Turn off the WA-1500/1000, wait 15 minutes and power up again. It the problem persists, contact EXFO Service.
Error 11	WA-1500 only, reference laser will not stabilize.	The laser has failed to reach stability in the appropriate amount of time. Contact EXFO Service.
Error 12	Intermittent signal from the reference laser during the measurement window. This may be due to partial misalignment of the WA-1500/1000 internal optics.	Check alignment of internal optics (page 37). Reference laser signal at the Monitor output should exceed 2.0 volts p-p throughout the measurement window.
Error 13	Detector failure or insufficient signal amplitude from the reference laser. This may be due to a decrease in reference laser power or a major misalignment of the internal optics. This error may also indicate the detector board is disconnected.	Check the detector board is connected securely. Check alignment of internal optics (page 37). Rotate the reference laser attenuator on the periscope to obtain more reference laser power. Reference laser signal at the Monitor output should be approximately 3.5 volts p-p throughout the measurement window.
Error 14	WA-1500 reference laser calibration error.	Recalibrate WA-1500 reference laser. Refer to the reference laser calibration (page 31).

Message	Description	Solution
Error 15	Insufficient reference laser intensity measured by the internal power meter	Switch to meter display using the rear panel Meter switch to display the reference laser power in milliwatts (Section 7). Check whether the laser power has degraded. If the power is zero either the laser is dead (no tracer beam) or the meter detector is malfunctioning. Check that the meter detector is plugged into the main circuit board at J4.
Error 22	Input laser power has saturated the detector. In this case the intensity bar graph meter may indicate low signal because of insufficient fringe amplitude when the detector is saturated. This error usually indicates that too much intensity is required to get a good fringe signal because the internal optical alignment is bad.	Reduce the input laser power, either externally or using the input attenuator in manual mode. Check the internal alignment (page 37).
Error 23	Input signal intensity has been briefly interrupted during the measurement window, causing a miscount of the fringes. Often this is caused by high frequency instability of the input laser beam due to optical feedback from reflections. Also, bubbles in the dye jet of a dye laser can cause this error.	Check the input laser intensity for instability. Depending on the characteristics of the instability, this may be observed on the envelope of the input laser signal at the Monitor output, or by studying the laser beam intensity directly with a large bandwidth external detector.
Error 24	This indicates that there are insufficient fringes within the measurement window at the Zero Optical Path (ZOP) point of the interferometer scan. Also, the ZOP detector may not be positioned properly. This error is sometimes triggered by rapid variations in input laser intensity, similar to those that cause Error 23.	If measuring a low coherence laser with a short fringe envelope, adjust the position of the ZOP detector until the ZOP signal rising edge occurs about 0.4 msec after the center of the fringe envelope. Observe the two signals from the Monitor while moving the plate that holds the ZOP detector (page 38).

Message	Description	Solution
Error 30	Interferometer scan motion error. Either the scan assembly is not moving or the scan timing detector is malfunctioning.	Examine the scan assembly for mechanical obstruction, and check that both the ZOP and Trigger detector cables are connected. Check the Monitor output for ZOP and Trigger signals. Both are TTL (+5 volt) pulses greater that 0.1 seconds long occurring twice per scan cycle. Remove the lower cover to check the motor is connected to the main circuit board and the drive belt is in place.
Error 31	Static RAM read/write failure. This error may sometimes occur on power up.	Turn the instrument off, wait a few moments, turn the instrument back on. If the problem persists contact EXFO Service.
Error 32	EEPROM read failure. Problem occurs on power up or when restoring.	Turn the instrument off, wait a few moments, set Reset switch on the rear panel to the DN position, and turn the instrument back on. If error clears turn the instrument off, wait a few moments, set Reset switch back to the UP position and turn on power again. If this fixes the problem, recalibration of the Temperature and Pressure sensors will be required (page 39). If the problem persists contact EXFO Service.
Error 33	EEPROM write failure. Problem occurs while booting or while saving.	Contact EXFO Service.
Error 34	Temperature reading is out of range; range is 1°C to 50°C. A temperature reading of 0°C usually indicates the temperature sensor is not connected or has a broken wire.	Verify ambient temperature reading by pushing the Temperature button. Check the temperature calibration, and recalibrate if necessary (page 39). Remove the bottom cover and check that the temperature sensor is connected to J7 on the main board. If the problem persists contact EXFO Service.
Error 35	Pressure reading is out of range; range is 500 mm Hg to 1000 mm Hg.	Verify ambient pressure reading by pushing the Pressure button. Check the pressure calibration, and recalibrate if necessary (page 39). If the problem persists contact EXFO Service.
Error 37	The wavelength (or frequen-cy) measurement is out of the range for the model setting.	Check the setting on the rear panel Model switch and the specified wavelength range (Section 5).

Message	Description	Solution
Error 41 to Error 48	Fringe division errors. These errors may occur momentarily due to instability of the laser intensity or laser wavelength.	Check input laser for intensity or frequency instability. If the error persists, contact EXFO Service.

Aligning the Internal Optics

The following is a step-by-step description on how to realign the internal optics of either the WA-1000 or WA-1500. Refer to Figure 8-1 for the optical layout and to identify components.

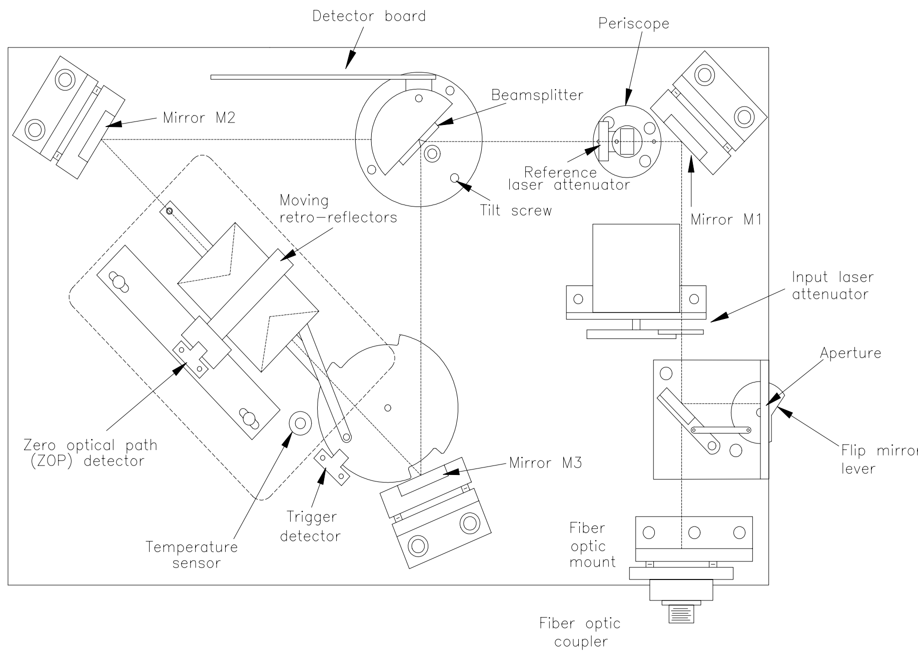


Figure 8-1: Optical layout

IMPORTANT

Adjusting the periscope, fiber-optic coupler and Mirror M1 is likely to affect the WA-1500/1000 accuracy more than the specification. Making other adjustments described here should have a minimal effect on the accuracy. However, you may want to consider a program to systematically verify the accuracy/performance by verifying it with a well-known wavelength. EXFO can perform this service for you.

1. Remove the top cover of the WA-1500/1000 by loosening the three black screws on either side about eight turns and lifting off the cover. Tilt the cover slightly to clear the silver lever under the input aperture.

2. Attach an oscilloscope to the reference laser signal (pin #2) of the Monitor port and ground the oscilloscope to pin #9 or #10. Set the oscilloscope sweep rate to 10 microseconds per division and the vertical display to one volt per division.
3. Check that the beam reflected from the beamsplitter to Mirror M3 is precisely parallel to the base plate. If necessary, tilt the beamsplitter mount using the "tilt" screw in the rim.
4. Fine adjust mirror M3 to obtain the maximum constant amplitude p-p signal while the retro-reflector assembly is moving. The signal will momentarily drop to zero when the retro-reflector assembly reverses direction. The large screw with a spring washer on the mirror mount may have to be loosened slightly to enable adjustment. If so, retighten it carefully after the adjustment is done.

Setting the Zero Optical Path Location

For broad bandwidth laser sources with low coherence, the length of the fringe envelope is reduced as shown in Figure A-3. The short fringe envelope is centered on the position in the scan where the difference in the optical path length in the two arms of the interferometer is zero. This zero optical path (ZOP) point is identified by the ZOP detector shown in Figure 8-1.

For narrow bandwidth lasers with high coherence, the ZOP detector position is not critical. To measure the wavelength of broad bandwidth lasers it may be necessary to optimize the location of the ZOP detector.

Resetting the ZOP detector position requires input from a broad linewidth laser (see Figure A-3) while observing certain signals from the Monitor output connector (Table 6-1) on a dual-channel oscilloscope.

Trigger the oscilloscope on the Trigger signal, and display the Input fringe signal and the ZOP signal. Compare the timing of the rising edge of the ZOP signal and the center of the fringe envelope from the input laser signal. If necessary, adjust the ZOP detector position by loosening the screws in both ends of the silver plate supporting the ZOP detector and sliding it slightly in either direction until the ZOP rising transition occurs about 0.4 msec after the center of the fringe envelope.

Carefully secure the plate again while maintaining this position.

Recalibration of Temperature and Pressure Sensors

The temperature and pressure sensors are semiconductor devices that have known dependence on changes in air temperature and barometric pressure, but must be individually calibrated for the correct absolute values. This calibration is done at the factory before shipment and the offset, programmed into the WA-1500/1000 at that time, is recorded on the test sheet supplied. If this factory calibration is destroyed, it can be easily reset from the WA-1500/1000 keypad. A complete recalibration of the sensors requires comparison with an accurate thermometer and barometer.

To reset the factory sensor calibration:

1. Erase the existing calibration offsets by moving the **Reset** switch on the rear panel to the Down position.
2. Turn the WA-1500/1000 power switch off for a few seconds and then on again. Now both of the sensor calibration offsets equal zero. Move the **Reset** switch back to the Up position.
3. Push the Temperature button on the front panel to read the temperature. Then add the temperature sensor calibration offset value specified on the factory test sheet to this reading and type in the new value followed by **Enter**. This resets the factory calibration of the Temperature sensor.
4. Push the Pressure button and add the pressure sensor calibration offset value specified on the factory test sheet to the reading. Type in the new value followed by **Enter** to reset the factory calibration of the Pressure sensor.
5. Press **Save** to store this calibration in non-volatile memory.

IMPORTANT

The WA-1500 reference laser peak power is erased during the reset operation. After reset, turn the WA-1500 off for five minutes to let the laser repeat part of its power up cycle and recover its calibration.

To recalibrate the Temperature sensor:

1. Remove the top cover of the WA-1500/1000 and the small inner cover that protects the moving retro-reflectors and the temperature sensor.
2. Turn on the WA-1500/1000.
3. Position a thermometer with its bulb touching or close to the top of the temperature sensor.
4. After allowing sufficient time for the thermometer to come to equilibrium, read the temperature.
5. Push **Temperature** and type in the thermometer temperature reading followed by **Enter**.
6. Press **Save** to store the calibration.
7. Replace the WA-1500/1000 covers.

To recalibrate the Pressure sensor:

1. Turn on the WA-1500/1000 and allow 10 minutes for the circuitry to warm up.
2. Determine the existing barometric pressure using an accurate barometer.
3. Push **Pressure** and type in the new barometric pressure followed by **Enter**.
4. Press **Save** to store the calibration.

9. Specifications

Absolute accuracy	± 2 x 10-7 (WA-1500)
	± 1 x 10^{-6} (WA-1000)
	± 4 x 10^{-7} (WA-1500IR)[1]
	± 2 x 10^{-6} (WA-1000IR)[2]
Resolution @ 1000 nm	± 0.0001 nm (WA-1500)
	± 0.001 nm (WA-1000)
Display	Absolute wavelength or deviation from a setpoint
Display units	nm, cm^{-1} or GHz, air or vacuum
Display resolution	Automatic or user selected
Dynamic intensity range	400:1 (with input attenuation)
Input attenuator	Automatic, 0-2 OD
Input aperture	2 mm
Input beam height	7.0" (± .3" adjustable)
Analog output	± 5 V, user-selected resolution
RS232 interface	Yes
GPIB interface	Optional
Power requirements	90-260 VAC, 50/60 Hz
	.2 A @ 240 VAC
	.4 A @ 120 VAC
Fuse	2A, 250 V, time-delay
Weight	25 lbs
Dimensions (including feet)	11.5" D × 15.3" L × 8.0" H
Wavelength range	
VIS	400-1100 nm
NIR	600-1800 nm
IR	1500-4000 nm
Free input beam	
VIS	Yes
NIR	Yes
IR	Yes
Fiber-optic input	
VIS	Yes

[1] At wavelengths from 1.8 to 3.0 µm, the absolute accuracy is ± 3 x 10^{-7} and at wavelengths from 3.0 to 4.0 µm, the absolute accuracy is ± 1 x 10^{-7}

[2] At wavelengths longer than 3.0 µm, the absolute accuracy is ± 1 x 10^{-6}

NIR	Yes
IR	No
Sensitivity[3]	
VIS	20 μW
NIR	20 μW
IR	1.0 mW

IMPORTANT

Sensitivity defines the optical input power required over most of the wavelength range. More power may be necessary at either end of the range, depending on the photodetector.

Measurement rate	**WA-1500**	**WA-1000**
VIS	1.0 Hz	4.0 Hz
NIR	1.0 Hz	4.0 Hz
IR	.75 Hz	2.5 Hz

[3] At wavelengths longer than 450 nm, an optical input power of 100 μW should be sufficient

Appendix A. Theory of Operation

This section reviews the theory behind wavelength measurement as it applies to the WA-1500 and WA-1000. It also discusses the factors that influence the accuracy of the measurement.

Operating Principles

A variety of techniques have been devised to determine the wavelength of lasers. Interferometric techniques have proven to be the most practical, precise and reliable for wavelength measurement instrumentation.

The WA-1500 and WA-1000 use a Michelson interferometer to generate sinusoidal interference fringes from the input radiation. The optical layout is shown schematically in Figure A-1.

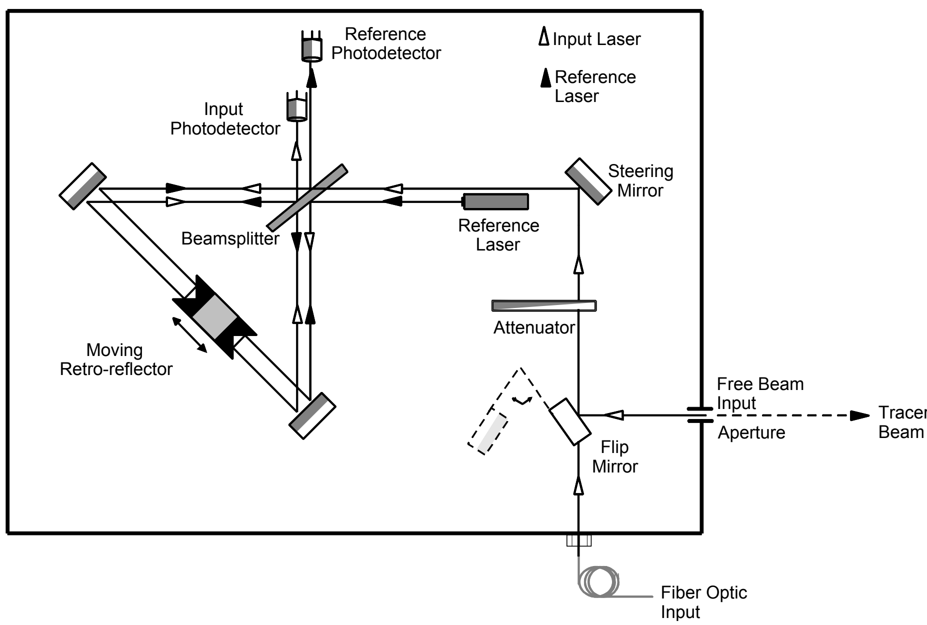
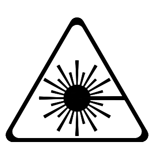


Figure A-1: Optical schematic

	**WARNING** **The WA-1500/1000 optical head contains a HeNe laser that is rated as a Class II laser product. The intensity of the laser beam exposed by removing the top cover is less than 10 microwatts directed through the internal apertures. However, do not stare directly into the beam or view it with an optical instrument.**

The input laser beam, identified by the open arrows, enters the WA-1500/1000 through either a fiber-optic connector on the front panel or an aperture on the side panel. The position of the flip mirror determines which input is in use. After passing through an attenuator, the beam is reflected from a steering mirror that directs the input laser beam into the Michelson interferometer. At the beamsplitter, the input beam is divided into two beams that follow separate optical paths. These two beams reflect off opposite ends of the moving retro-reflector assembly and return to the beamsplitter. The intensity reaching the input photodetector depends on the relative lengths of the two paths that govern whether constructive or destructive interference occurs at the beamsplitter. As the retro-reflectors move back and forth the detected intensity varies sinusoidally.

If the retro-reflector assembly moves a distance **d**, the number of fringes produced is given by the equation:

$$m\lambda = 4 n_{\lambda} d \qquad \text{equation A.1}$$

where: **m** is the number of fringes generated by the input laser

λ is the wavelength of input laser beam

$\mathbf{n}_{\lambda}$ is the refractive index of air at the wavelength λ.

The above equation can be used to determine the wavelength of the laser radiation in vacuum by measuring **d** very accurately while counting the number of fringes **m**, and substituting the refractive index of air.

The accuracy of such a measurement is limited to the precision in the measurement of **d** and our knowledge of $\mathbf{n}_{\lambda}$. To determine **d** for high accuracy measurements, a reference HeNe laser with an accurately known wavelength is built into the WA-1500/1000. The reference laser beam is directed along exactly the same path as the input laser through the Michelson interferometer, but in the opposite direction so it can be detected on a separate reference photodetector. The reference laser beam path is identified by the solid arrows in Figure A-1. For the reference laser beam, we can write the equation:

$$m_o \lambda_o = 4 n_o d \qquad \text{equation A.2}$$

Combining equationsA.1 and A.2 gives:

$$\lambda = \left[{m_o}/{m} \right] \left[{n_{\lambda}}/{n_o} \right] \lambda_o \qquad \text{equation A.3}$$

Therefore, the wavelength of the input laser beam is equal to the ratio of the number of fringes recorded for each laser multiplied by a refractive index correction and the wavelength of the reference laser beam.

The accuracy of the wavelength measurement depends on the terms in the equation A.3:

- $\mathbf{m_0} / \mathbf{m}$ - this ratio is calculated from the number of fringes generated for each laser over the distance scanned by the retro-reflector assembly. If the fringes are accurately subdivided, the numerator and denominator do not have to be integers.

- **n_λ / n_o** - this ratio accounts for the difference in optical distances traveled by two laser beams with different wavelengths. Such a dispersion correction is necessary to determine the wavelength relative to vacuum. It is dependent on the temperature, pressure and humidity of the air inside the interferometer.
- λ_o - the reference laser vacuum wavelength. Its absolute accuracy is fundamental to the accuracy of the measurement.

Once light is properly directed into the WA-1500/1000, either through the fiber-optic connector or as a free laser beam, the rest of the operation is automatic. A motorized internal attenuator adjusts the intensity input to the Michelson interferometer to a suitable level. This input level is indicated on the front panel bar graph intensity meter. When the intensity falls into the proper range, the WA-1500/1000 displays the wavelength or frequency according to the units selected by the operator.

Buttons on the front panel enable the operator to display the wavelength or frequency measurement in a variety of ways:

- **Units** of the measurement can be either nanometers (nm), wavenumbers (cm^{-1}) or gigahertz (GHz).
- **Deviation** of the measured value from a setpoint entered by the operator on the front panel keypad. The **Analog Output** on the rear panel is proportional to this value.
- **Medium** selection of either vacuum or air. The air wavelength is the vacuum wavelength divided by the refractive index of air at the temperature, pressure and humidity inside the WA-1500/1000.
- **Resolution** of the display can be fixed at a certain number of decimal places or automatically set by the WA-1500/1000 to the most significant accuracy based on the number of fringes counted in the input laser signal.
- **Averaging** measurements can reduce the fluctuation in the displayed value. Using the keypad, the WA-1500/1000 can be programmed to display a running average of the last two to 50 successive measurements.

Accuracy

Fundamentally, the accuracy of the WA-1500/1000 depends on the absolute accuracy of the reference laser, but several other factors can affect the accuracy of the measured wavelength:

- **Fringe counting resolution:** Computing a wavelength with high accuracy requires that the precision in the numerator and denominator of the count ratio (**m_o/m**) is statistically sufficient. For the count ratio to have high precision the number of fringes counted must be large or the fringes must be accurately subdivided. The WA-1500 and WA-1000 use a specially designed counter circuitry to divide the interferometer fringes more than one hundred times. This design ensures that the counting statistics are always much higher than the number of fringes.

- **Dispersion in the Refractive Index of Air:** The vacuum wavelength of the input radiation is computed from the vacuum wavelength of the reference laser by correcting for the dispersion ($\mathbf{n_\lambda/n_o}$) in the refractive index of air. In the WA-1500 and WA-1000, the dispersion correction for temperature and pressure is calculated from the revised Edlén equation from Birch and Downs (*Metrologia*, 30, 155 (1993). If the temperature, pressure and humidity of the air are known, these calculations have an accuracy of better than five parts in 10^8 at wavelengths between 230 and 1700 nm. Matsumoto (*Metrologia* 18, 49 (1982)) also has determined that Edlén's formula for the refractive index of dry air is valid in the three-micron wavelength region to within 1.2 parts in 10^8.

  The temperature and pressure are measured inside the WA-1500/1000 and a correction factor is applied when computing the wavelength. Correction for humidity is included based on the relative humidity value entered on the WA-1500/1000 front panel keypad.

  For reference, the error in parts per million (ppm) introduced by errors in the temperature, pressure or humidity is given by the formula:

  $$\Delta(\mathbf{n_\lambda/n_o}) = A(\lambda) \times \Delta T + B(\lambda) \times \Delta P + C(\lambda) \times \Delta H \text{ ppm} \qquad \text{equation A.4}$$

  where: ΔT is the temperature error in °C

  ΔP is the barometric pressure error in mm Hg

  ΔH is the relative humidity error expressed as a fraction between 0 and 1.

  The coefficients A(λ), B(λ), and C(λ) depend on wavelength as shown in Table A-1.

Table A-1: Wavelength dependence of A(λ), B(λ) and C(λ) coefficients

Wavelength (nm)	A	B	C
200	-0.146	0.0615	0.211
300	-0.0457	0.0195	0.0808
400	-0.0189	0.00806	0.0352
500	-0.00738	0.00316	0.0141
600	-0.00137	0.000586	0.00265
700	0.00219	-0.00094	-0.00427
800	0.00447	-0.00192	-0.00875
900	0.00602	-0.00258	-0.0118
1000	0.00712	-0.00306	-0.014
1100	0.00793	-0.00341	-0.0157
1200	0.00855	-0.00367	-0.0169
1300	0.00902	-0.00388	-0.0179
1400	0.0094	-0.00404	-0.0186
1500	0.00971	-0.00417	-0.0192
1600	0.00996	-0.00428	-0.0197

1700	0.0102	-0.00437	-0.0202
1800	0.0103	-0.00444	-0.0205
1900	0.0105	-0.0045	-0.0208
2000	0.0106	-0.00456	-0.0211
2100	0.0107	-0.0046	-0.0213
2200	0.0108	-0.00464	-0.0215

From Table A-1, the dispersion is most sensitive to the accuracy of the temperature, pressure and humidity at ultraviolet wavelengths. Equation A.4 shows that, at 200 nm wavelength, to maintain an accuracy in $\Delta(n_\lambda/n_o)$ on the order of 0.2 ppm requires an accuracy in temperature of ± 0.7 °C, an accuracy in pressure of ± 2 mm Hg and an accuracy in relative humidity of ± 50 %. At wavelengths above 400 nm the accuracy of the wavelength measurement is much less sensitive to the accuracy of the temperature, pressure and humidity.

- **Alignment:** An accurate measurement depends on the reference laser beam and the input laser beam passing along exactly the same path through the Michelson interferometer. For this reason the reference laser is emitted as a red tracer beam from the WA-1500/1000 aperture. If the tracer beam and input laser beam are collinear over a one meter path outside of the WA-1500/1000, within 0.5 mm for the WA-1500 or within 1.5 mm for the WA-1000, the alignment error will be within the specified accuracy. The fiber-optic input connector is prealigned to ensure that the alignment error is less than one part in 10^7.
- **Diffraction:** If an aperture anywhere along the laser beam path is made small, diffraction will change the direction of the light passing through the Michelson interferometer, possibly causing an additional error. No small apertures are incorporated in the WA-1500 and WA-1000 that would introduce diffraction errors greater than one part in 10^7 for any of the wavelength ranges.
- **Coherence:** In order to achieve a high accuracy wavelength measurement, the band-width of the laser radiation must be narrow. This is because the generation of inter-ference fringes by a Michelson interferometer is dependent upon the coherence length:

$$L_c = (2\pi\ \Delta\nu)^{-1}$$

which is inversely proportional to the bandwidth ($\Delta\nu$) in cm^{-1}.

A narrow bandwidth laser, with a coherence length greater than a few centimeters, generates a sufficient number of interference fringes to achieve the highest accuracy. If the laser bandwidth is increased, resulting in a shorter coherence length, the number of fringes that can be counted is reduced.

A low coherence laser source may have a broad linewidth or operate simultaneously on two or more closely spaced lines. Three examples of Michelson interferometer fringe patterns for different laser spectra are depicted in Figures A-2, A-3 and A-4.

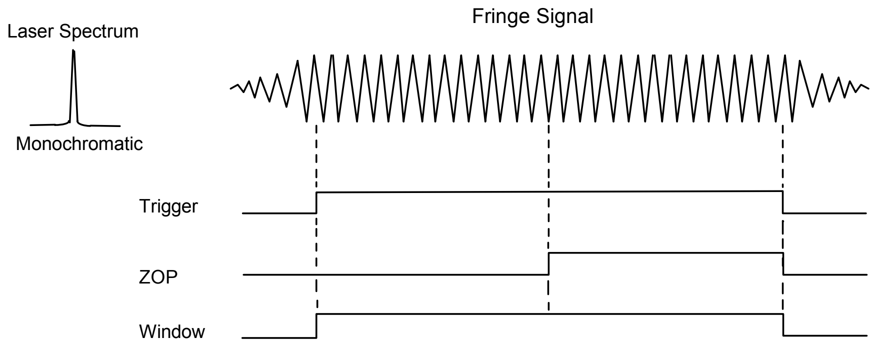


Figure A-2: Fringe signal and measurement window for a monochromatic input laser with a narrow linewidth

The WA-1500/1000 has a **Monitor** port on the rear panel where signals like these corresponding to the actual input laser can be observed on an oscilloscope.

In these figures, the digital logic signals labeled Trigger, ZOP (zero optical path) and Window below each fringe pattern identify the timing and extent of each measurement interval. These five-volt logic signals also can be observed at the **Monitor** port. Trigger defines the largest measurement range possible for the particular model. The rising transition of the ZOP signal defines the point in the scan where the two arms of the interferometer are exactly equal in optical path length. The envelope of the fringe pattern always exhibits maximum amplitude at the ZOP point, independent of the linewidth or mode structure. Window is a signal that identifies where the envelope of the fringe signal exceeds approximately 1-volt p-p amplitude. After a Window occurs that includes the ZOP point, no further Windows will be generated. When multiple Windows occur (Figure 2-4), only one "Valid Window" that includes the ZOP point is used in the measurement.

Narrow linewidth lasers produce fringes throughout the entire Trigger interval (Figure A-2). In this case, the Window interval is the maximum length allowed by the Trigger interval, and the highest precision measurement is made.

When the laser linewidth is broad (Figure A-3), the envelope of the fringes does not extend as far as the Trigger interval on either side of the ZOP point. The Window interval is shortened to include only the number of fringes with sufficient amplitude to be reliably counted and the precision of the measurement is reduced accordingly.

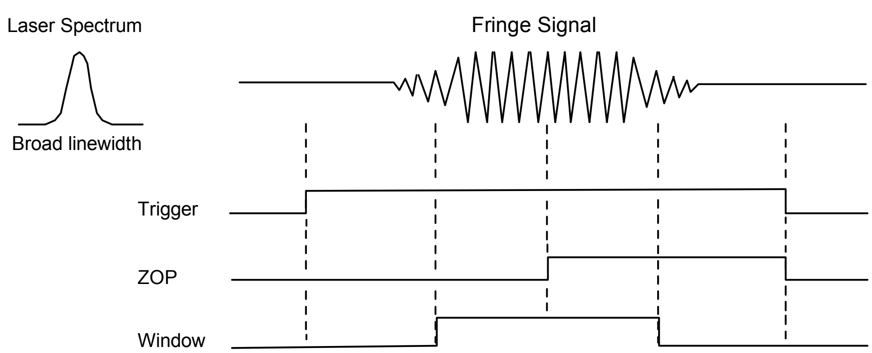


Figure A-3: Fringe signal and measurement window for a broad linewidth input laser

Figure A-4 shows an example of a bi-modal laser with two strong spectral lines. This laser produces a fringe pattern that exhibits beating between the two laser frequencies. Since the fringe amplitude goes to zero on either side of the ZOP, only the center fringe envelope can be used. Prior to the valid Window surrounding the ZOP point, other windows may occur but these are ignored for measurement purposes.

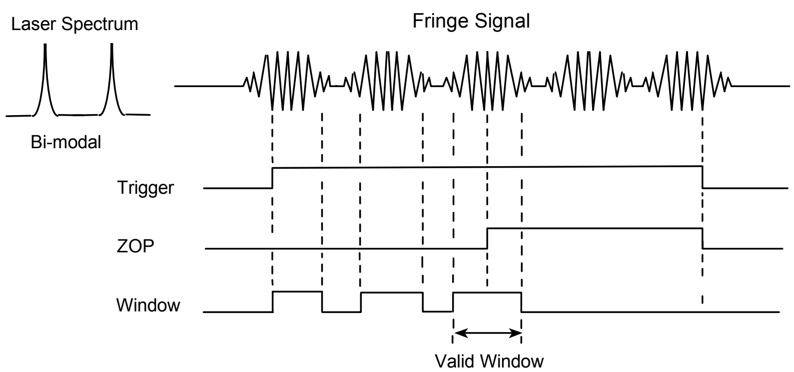


Figure A-4: Fringe signal and measurement window for a bi-modal input laser

When the number of fringes is reduced by increased bandwidth or lack of coherence in the laser source, the accuracy of the wavelength measurement also is reduced. Typically, an increased bandwidth limits the accuracy of measurement to about 10% of the laser bandwidth for a single broad line as in Figure A-3, or to 10% of the mode separation in a multi-mode laser spectrum as in Figure A-4. When a laser has a complex mode structure, the measurement precision will be about 10% of the effective bandwidth and the wavelength reported will correspond to the intensity-weighted average of the spectral distribution.

The WA-1500 and WA-1000 have an auto-resolution feature that automatically adjusts the precision of the wavelength or frequency measurement according to the laser band-width. Insignificant digits after the decimal point are eliminated. If insignificant digits occur ahead of the decimal point they are replaced by the "_" character on the display. The reduction in resolution and number of digits displayed is demonstrated in Table A-2.

Table A-2: Auto-resolution as a function of laser bandwidth

Laser Bandwidth ($\Delta\nu$)	Coherence Length (L_C)	Auto-resolution Display
$\Delta\nu \leq 1.5$ GHz (WA-1500 only)	> 32 mm	0.0001 nm
$\Delta\nu \leq 15$ GHz	> 3.2 mm	0.001 nm
$\Delta\nu \leq 150$ GHz	> 0.32 mm	0.01 nm
$\Delta\nu \leq 1.5$ THz	> 0.032 mm	0.1 nm
$\Delta\nu \leq 15$ THz	>0.0032 mm	1.0 nm

The WA-1500/1000 also can be operated in Fixed Resolution mode where the number of digits displayed is set by the operator. However, the accuracy of the measurement is still limited to approximately the same resolution as specified in Table A-2.

Appendix B. Software Interface Commands and Masks

The WA-1500 and WA-1000 accept two types of commands: “Hard” commands - those that have an equivalent on the physical display/control panel and “soft” commands - those that have no equivalent.

There are four “soft” commands: Broadcast, Query, Deviation On and Deviation Off. Broadcast and Deviation On are the power on defaults.

The WA-1500/1000 powers up in the ‘Broadcast’ mode. This means that each new wavelength reading is transmitted automatically to the communications port. To switch the WA-1500/1000 to ‘Query’ mode issue the ‘Query’ command @\x51\r\n once. In this mode another ‘Query’ command must be issued for each wavelength reading.

Deviation Off sets the Analog Output voltage to zero, whereas Deviation On outputs a voltage proportional to the difference between the current reading and the setpoint.

To communicate with the instrument simply send the command string via RS-232 or GPIB, then parse the response string.

Soft Command	String
Broadcast	@\x42\r\n
Deviation on	@\x44\r\n
Query	@\x51\r\n
Deviation off	@\x55\r\n

Front Panel Button or Hard Command	String
0	@\x00\r\n
1	@\x01\r\n
2	@\x02\r\n
3	@\x03\r\n
4	@\x04\r\n
5	@\x05\r\n
6	@\x06\r\n
7	@\x07\r\n
8	@\x08\r\n
9	@\x09\r\n
Clear	@\x0A\r\n
.	@\x0B\r\n
Enter	@\x0C\r\n
Remote	@\x0D\r\n

Front Panel Button or Hard Command	String
Save	@\x0E\r\n
Reset	@\x0F\r\n
Manual Deattenuate	@\x10\r\n
Manual Attenuate	@\x11\r\n
Auto Attenuate	@\x13\r\n
Humidity	@\x20\r\n
Pressure	@\x21\r\n
Temperature	@\x22\r\n
# Averaged	@\x23\r\n
Analog Res	@\x24\r\n
Display Res	@\x25\r\n
Setpoint	@\x26\r\n
Units	@\x27\r\n
Display	@\x28\r\n
Medium	@\x29\r\n
Resolution	@\x2A\r\n
Averaging	@\x2B\r\n

Each hexadecimal mask in the table below can be logically combined with the Display LED field in the response string to determine if that the associated condition is indicated or not.

LED	Mask
UNITS - nm	0x0009
UNITS - cm^{-1}	0x0012
UNITS - GHz	0x0024
DISPLAY - Wavelength	0x0040
DISPLAY - Deviation	0x0080
MEDIUM - Air	0x0100
MEDIUM - Vacuum	0x0200
RESOLUTION - Fixed	0x0400
RESOLUTION - Auto	0x0800
AVERAGING - On	0x1000
AVERAGING - Off	0x2000

Each hexadecimal mask in the table below can be logically combined with the System LED field in the response string to determine if that the associated condition is indicated or not.

LED	Mask
DISPLAY RES	0x0001
SETPOINT	0x0002
# AVERAGED	0x0004
ANALOG RES	0x0008
PRESSURE	0x0010
TEMPERATURE	0x0020
HUMIDITY	0x0040
SETUP Restore/Save	0x0080
REMOTE	0x0100
INPUT ATTENUATOR Auto	0x0200
INPUT ATTENUATOR Manual	0x0400

Appendix C. Sample Programs

Communication by the RS-232 Interface

The following C program segments demonstrate how to communicate with the WA-1000 or WA-1500 via RS-232.

```
// filename - query.c
// Rev.A

#include <bios.h>
#include <conio.h>
#include <ctype.h>
#include <stdio.h>
#include <string.h>

// misc defines
#define COM1         0
#define XMIT_MASK    0x0610
#define CHAR_MASK    0x00FF
#define STATUS_MASK  0xFF00
#define TIMEDOUT     0x8000
#define ESC          0x1B
#define CR           0x0D
#define LF           0x0A

// rs232 buffer
char cRS232Buffer[32];

// example command
char cUnitsCmd[] = "@\x27\r\n";

// misc vars
short i;
short nComStatus;

unsigned nChar = 0x0;
unsigned nKeyCode = 0x0;

// misc routines
short sendcommand(char *);

void main(int argc, char *argv[]) {

   // init RS232 port COM1, 2400 baud, 8 data bits, no
parity, 1 stop bit
   _bios_serialcom(_COM_INIT, COM1,
      _COM_2400|_COM_CHR8|_COM_NOPARITY|_COM_STOP1);

   // loop until the Esc key is pressed
```

```
   do {
      switch(_toupper(nKeyCode)) {
         case 'U':
            nComStatus = sendcommand(cUnitsCmd);
            break;

         default:
            break;
         }

   // continue reading rs232 while !keystroke
      while (!kbhit()) {
   // read rs232
         i = 0;
         cRS232Buffer[0] = '\0';
         while((nChar = _bios_serialcom(_COM_RECEIVE, COM1,
0)) != LF
            && !(nChar&STATUS_MASK)) {
            cRS232Buffer[i++] = (char)(nChar&CHAR_MASK);
            }

   // if no error print string
         if(!(nChar&STATUS_MASK)) {
            printf("%s\n", cRS232Buffer);
            }
         }

      nKeyCode = _getch();

      } while (nKeyCode != ESC);

   }


// sends command string out serial port
short sendcommand(char *pString) {
short n;
short nStringLen;
short nComStatus;

   nStringLen = (short)strlen(pString);
   for(n = 0; n < nStringLen; n++) {
      while ((short)_bios_serialcom(_COM_STATUS, COM1,
0)&XMIT_MASK != 0);
      nComStatus = (short)_bios_serialcom(_COM_SEND, COM1,
(unsigned)pString[n]);
      }

   return(nComStatus);
   }
```

Communication by the GPIB Interface

The following C program segments demonstrate how to communicate with the WA-1000 or WA-1500 via GPIB.

```
// filename - query.c
// Rev.A

// MS-DOS

#include <conio.h>
#include <dos.h>
#include <stdio.h>
#include <string.h>
#include "\at-gpib\c\decl.h"

#define HIWORD(l)  ((unsigned int)((((unsigned long)(l)) >>
16) & 0xFFFF))
#define LOWORD(l)  ((unsigned int)(unsigned long)(l))

// example commands
char cQueryCmd[] = "@\x51\r\n";
char cUnitsCmd[] = "@\x27\r\n";

// misc vars
char cGPIBBuffer[32];

int nBoardID;
int nDeviceID;

union _REGS callregs, returnregs;

// misc funcs
void pause(int);
void Status(char *);


void main(int argc, char *argv[]) {

   // locate & initialize the GPIB board
   nBoardID = ibfind("GPIB0");
   Status("Get board ID...");

   ibsic(nBoardID);
   Status("Make board CIC...");

   // locate & initialize the GPIB device
   nDeviceID = ibfind("DEV4");
   Status("Get device ID...");

   ibclr(nDeviceID);
   Status("Reset device & bus...");

   // loop until the key is pressed
   while (!kbhit()) {
```

```
       if(!(ibsta & ERR)) {
          ibwrt(nDeviceID, (char *)cQueryCmd,
strlen(cQueryCmd));
          pause(25);
          Status("Querying...");

          if(!(ibsta & ERR)) {
             ibrd(nDeviceID, cGPIBBuffer, 23);
             Status("Reading...");
             printf(cGPIBBuffer);
             }
          }

       if(!(ibsta & ERR)) {
          ibwrt(nDeviceID, (char *)cUnitsCmd,
strlen(cUnitsCmd));
          pause(25);
          Status("Changing units...");
          }

       if(ibsta & ERR) {
          ibclr(nDeviceID);
          pause(25);
          }
       }
    }


// reports gpib status & err
void Status(char * message) {
   strcat(message, '\0');

   printf("%s\nIBSTA=0x%04X <", message, ibsta);
   if(ibsta & ERR) printf(" ERR");
   if(ibsta & TIMO) printf(" TIMO");
   if(ibsta & END) printf(" END");
   if(ibsta & SRQI) printf(" SRQI");
   if(ibsta & RQS) printf(" RQS");
   if(ibsta & CMPL) printf(" CMPL");
   if(ibsta & LOK) printf(" LOK");
   if(ibsta & REM) printf(" REM");
   if(ibsta & CIC) printf(" CIC");
   if(ibsta & ATN) printf(" ATN");
   if(ibsta & TACS) printf(" TACS");
   if(ibsta & LACS) printf(" LACS");
   if(ibsta & DTAS) printf(" DTAS");
   if(ibsta & DCAS) printf(" DCAS");

   printf( " >  ");

   if(ibsta & ERR) {
      printf("IBERR=0x%04X", iberr);
      if(iberr == EDVR) printf(" EDVR <DOS Error>");
      if(iberr == ECIC) printf(" ECIC <Not CIC>");
      if(iberr == ENOL) printf(" ENOL <No Listener>");
```

```
        if(iberr == EADR) printf(" EADR <Address error>");
        if(iberr == EARG) printf(" EARG <Invalid argument>");
        if(iberr == ESAC) printf(" ESAC <Not Sys Ctrlr>");
        if(iberr == EABO) printf(" EABO <Op. aborted>");
        if(iberr == ENEB) printf(" ENEB <No GPIB board>");
        if(iberr == EOIP) printf(" EOIP <Async I/O in prg>");
        if(iberr == ECAP) printf(" ECAP <No capability>");
        if(iberr == EFSO) printf(" EFSO <File sys. error>");
        if(iberr == EBUS) printf(" EBUS <Command error>");
        if(iberr == ESTB) printf(" ESTB <Status byte lost>");
        if(iberr == ESRQ) printf(" ESRQ <SRQ stuck on>");
        if(iberr == ETAB) printf(" ETAB <Table Overflow>");
        }
   printf("\n");
}


//suspend processes for howmany milliseconds
void pause(int howmany){
   callregs.h.ah = 0x86;
   callregs.x.cx = HIWORD(1000 * (long)howmany);
   callregs.x.dx = LOWORD(1000 * (long)howmany);
   _int86(0x15, &callregs, &returnregs);
}
```

Appendix D. Installing the GPIB Board

The GPIB interface board is a field-installable interface option. The following procedure is for installing the GPIB circuit board and cables in the WA-1000 and WA-1500. Before starting, take a moment to take proper ESD (electrostatic discharge) precautions, prepare an adequate work area and review the instructions.

1. Turn off the WA-1500/1000.
2. Disconnect the power cable and any other cabling, e.g. Monitor, Analog Out, RS-232, etc.
3. Remove the top cover.
4. Turn the WA-1500/1000 over.
5. Remove the feet.
6. Remove the bottom cover.
7. Remove the BNC nut from the back panel.
8. Disconnect the following cables from the main (CPU) board:
   a. Display board cable from J12
   b. Trigger and ZOP detector cable from J11
   c. Power cable from PW1
   d. Attenuator motor cable from J10
   e. Scan motor cable from J9
   f. Laser Stability sensor cable from J8 (WA-1500 only)
   g. Temperature sensor cable from J7
   h. Power meter cable from J4
   i. Detector cable from J5
9. Remove the four standoffs from the CPU board.
10. Remove the six screws securing the CPU board to the base plate standoffs.
11. Remove the CPU board by first tilting the side nearest the front panel up, then lift and slide out.
12. Remove the GPIB cover plate from the back panel, then remove the standoff from the base plate.
13. Using the hex screws, attach the GPIB switch/cable assembly to the back panel. Discard the washers. Replace the standoff.
14. Check that the switches on the GPIB cable/switch PCB are in the positions shown in Figure 6-4.

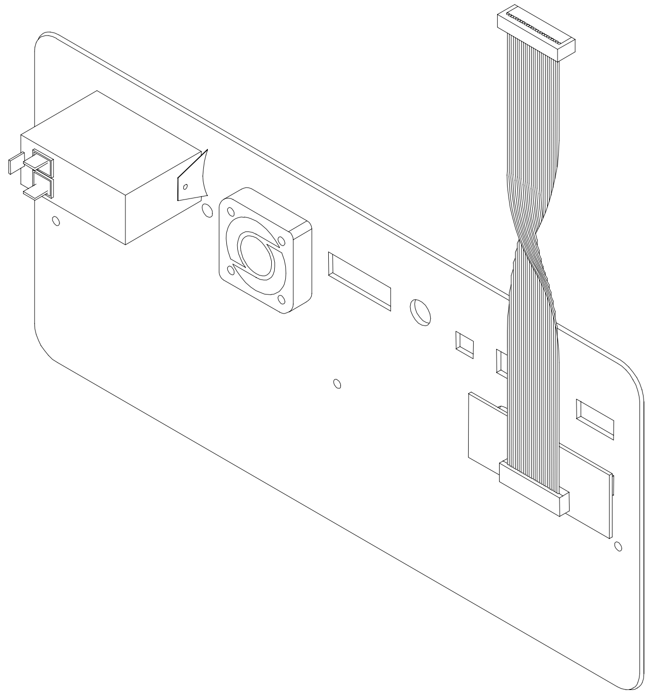


Figure D-1: GPIB switch/cable assembly mounting

15. Put a single twist in the cable half way between the PCB and the connector (Figure D-1), then drape the cable over the front panel.
16. Slide the CPU board back into position.
17. Reconnect the following CPU cables:
    a. Display board cable to J12
    b. Trigger and ZOP detector cable to J11
    c. Power cable to PW1
    d. Attenuator motor cable to J10
    e. Scan motor cable to J9
    f. Laser Stability sensor cable to J8 (WA-1500 only)
    g. Temperature sensor cable to J7
    h. Power meter cable to J4
    i. Detector cable to J5
18. Reinstall the BNC nut.
19. Replace the CPU board mounting screws.
20. Remove the four screws from the CPU board standoffs and set them aside.
21. Replace the standoffs in preparation for mounting the GPIB board.
22. Mount the GPIB board on the standoffs, component side up, as shown in Figure D-2. Connectors J1 and J2 face towards the front of unit.

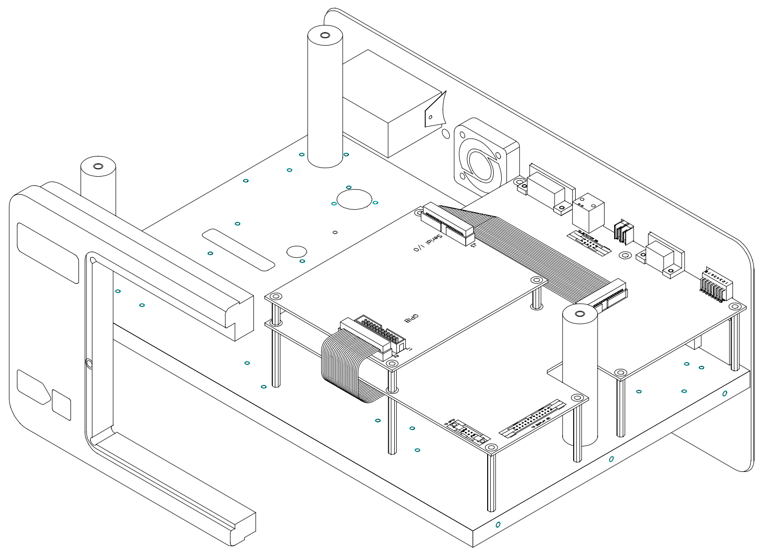


Figure D-2: WA-1500/1000 with GPIB option installed

23. Replace the screws and lock washers, including the cable clamp.
24. Insert the 26-pin connector from the GPIB switch/cable assembly in GPIB board J2 socket.
25. Connect cable #06745-3 from the GPIB board J3 socket to the CPU board J6 socket.
26. Connect the GPIB power cable to the P6 header on the regulator PCB where the header is labeled GPIB.
27. Replace the bottom cover.
28. Replace the feet.
29. Turn the WA-1500/1000 right side up.
30. Replace the top cover.
31. Set the SETUP switch labeled GPIB to the up position.
32. Power up the WA-1500/1000.
33. Test the GPIB interface.

Warranty

WA-1500 and WA-1000 WAVEMETER® systems are warranted against defects in material and workmanship for a period of one year after date of delivery. Optical components are warranted for 90 days. During the warranty period, EXFO will repair, or at its option, replace parts that prove to be defective when the instrument is returned prepaid to EXFO. Before returning an instrument always call EXFO for return authorization. The warranty will not apply if the instrument has been damaged by accident, misuse, or as a result of modification by persons other than EXFO personnel.

It is important to call EXFO or your local sales representative in advance of returning a unit, for a Return Authorization Number (RA#). This will ensure the prompt handling of the repair, as well as provide important tracking information.

The liability of EXFO (except as to title) arising out of supplying of said product, or its use, whether under the foregoing warranty, a claim of negligence, or otherwise, shall not in any case exceed the cost of correcting defects in the products as herein provided. Upon expiration of the warranty period specified herein, all liability shall terminate. The foregoing shall constitute the sole remedy of the buyer. In no event shall the seller be liable for consequential or special damages.

Index

Declaration of Conformity

Manufacturer's Name: EXFO Burleigh Products Group

Manufacturer's Address: 7647 Main Street Fishers
Victor, NY 14564
USA

declares this product:

Product Name: Wavemeter

Model Number(s): WA-1000, WA-1500

in accordance with the following Directives:

89/336/ECC The Electromagnetic Compatibility Directive
and its amended directives

73/23/ECC The Low Voltage Directive
and its amended directives

conforms to the following standards:

Safety: EN-61010-1:2001

EMC: EN 61000-6-3:2001 – Emissions
EN-55022 Class A
EN 61000-3-2 – Harmonics
EN 61000-3-3 – Voltage Fluctuation & Flicker
EN 61000-6-1:2001 & EN 61326:1997/A2:2001 - Immunity
EN 61000-4-2: ESD Immunity
EN 61000-4-3: RFI Immunity
EN 61000-4-4: Fast Transient Immunity
EN 61000-4-5: Surge Immunity
EN 61000-4-6: Conducted RF Immunity
EN-61000-4-11: Dips & Interruptions

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WA-1000/WA-1500
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