

S E R I E S

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**DIODE-PUMPED
NON-PLANAR
RING LASER**

**USERS
MANUAL**

REV DATE: 3/28/97

LIGHTWAVE[®]
ELECTRONICS

PREFACE

Thank you for purchasing this Lightwave Electronics' product. We are confident this product will serve you well. Any comments you have concerning our product or your application are encouraged. Please feel free to call, Fax or E-mail us at:

Sales: 1.888.LIGHTWAVE (544-4892)
Service: 1.888.LWESERV (593-7378)
Operator: (650) 962-0755
FAX: (650) 962-1661
E-mail: Sales@lwecorp.com
Service@lwecorp.com
Internet: <http://www.lwecorp.com>

This manual should be comprehensive and easy to understand. However, should you be uncertain about how to do something, or the consequences of doing something, feel free to contact Lightwave. We'll be glad to answer any questions you may have. Also, if you have any comments on improving this manual, we would appreciate hearing from you.

A BRIEF OVERVIEW OF LIGHTWAVE ELECTRONICS

Lightwave Electronics was established in late 1984 to engage in various opportunities within the laser and electro-optical markets. Since its inception, Lightwave has actively designed, manufactured, and marketed laser-diode-pumped laser products and systems for end-users and original equipment manufacturers (OEMs). Applications include fiber-optic and free-space communications, fiber-optic sensing, semiconductor processing, and basic research and development. Lightwave also performs government and commercial contract research.

Through the years, Lightwave has established a substantial catalogue of diode-pumped, solid-state laser products that include CW, CW single-frequency, Q-switched, and mode-locked lasers. Lasers are available in a number of wavelengths, currently ranging from 0.5 μm to 2 μm , depending on the model. In addition, Lightwave has developed several laser accessories. Lightwave is committed to cultivating new technologies that will lead to additional future products.

PATENTS

This product is manufactured under one or more of the following U.S. patents:

4455657, 4578793, 4731787, 4734912, 4739507, 4749842, 4752931, 4764933, 4797896, 4809291, 4827485, 4829532, 4909612, 4947402, 4998255, 5027361, 5076678, 5103457, 5130995, 5226051, 5237584, 5299222, 5329539, 5420878 and/or 5546222.

Additional patents pending.

WARRANTY

Lightwave Electronics Corporation ("Lightwave") warrants products of its manufacture against defective materials and workmanship for a period of one (1) year from the date of installation by the purchaser or, if shorter, for a period of thirteen (13) months from the date of shipment to the purchaser. The liability of Lightwave under this warranty is limited, at Lightwave's option, solely to repair or replacement with equivalent products, or an appropriate credit adjustment not to exceed the sales price to the purchaser, provided that

- (a) Lightwave is notified in writing by the purchaser within the warranty period promptly upon discovery of defects,
- (b) the purchaser has obtained a Return Materials Authorization Number ("RMA") from Lightwave, which RMA Lightwave agrees to provide the purchaser promptly upon request,
- (c) the defective products are returned to Lightwave, in the original packing material or alternate material approved by Lightwave, with transportation charges prepaid by the purchaser, and
- (d) Lightwave's examination of such products discloses to its satisfaction that defects were not caused by **optical feedback, backpulse, negligence, misuse, improper installation, accident, or unauthorized repair or alteration.**

The original warranty period of any product which has been repaired or replaced by Lightwave shall not thereby be extended.

THE FOREGOING WARRANTY IS PROVIDED EXPRESSLY IN LIEU OF AND LIGHTWAVE HEREBY DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR OF FITNESS FOR A PARTICULAR PURPOSE, AND OF ALL OTHER OBLIGATIONS OR LIABILITIES ON LIGHTWAVE'S PART, AND LIGHTWAVE NEITHER ASSUMES NOR AUTHORIZES ANY OTHER PERSON TO ASSUME FOR LIGHTWAVE ANY OTHER LIABILITIES.

The foregoing warranty is only valid for Lightwave products sold in the United States. For products sold outside of the United States, please refer to the local authorized Lightwave distributor for applicable warranty terms and conditions.

LIMITATION OF LIABILITY

The remedies set forth above constitute the sole and exclusive remedies against Lightwave for the furnishing of nonconforming or defective products. In no event, including if the products are nonconforming, defective, delayed, or not delivered, shall Lightwave be liable for any special, contingent, indirect, or consequential damages, even if Lightwave has been advised of the possibility of such damages, whether under a contract, tort, property, or other legal theory. Such damages for which Lightwave is not responsible include, but are not limited to, personal injury, property damage, anticipated profits, labor expended, delays, and loss of use.

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SECTION 1: BEFORE STARTING

1.1 UNPACKING AND INSPECTION

Upon receipt of the unit, inspect the shipping carton for gross external damage. Unpack the unit and inspect for internal damage. If any damage is found, immediately notify the shipper and Lightwave Electronics.

Retain the shipping carton and packing material. If the Series 126 laser should ever need repair, the specially designed carton will ensure safe shipment of the unit to Lightwave Electronics.

1.2 PRODUCT OVERVIEW

Lightwave Electronics' Series 126 products are single-axial-mode, continuous-wave output Nd:YAG laser.

Each laser produces narrow linewidth, frequency-stable, single-axial-mode output. Diode pumping is incorporated for reliability, compactness and efficiency. At the heart of the Series 126 laser is a patented (US patent 4579793) monolithic, traveling-wave ring resonator, referred to as the NPRO (Non-Planar Ring Oscillator). The NPRO ensures stable, single-frequency operation over a wide range of operating conditions. The Series 126 is designed for OEM and individual user applications. It differs slightly from typical lasers in that the laser head can be operated stand-alone or with an optional Lightwave Electronics power supply.

Laser Head

Typically a laser system consists of a head, which contains the optics and optical pump to produce laser light, and a separate power supply, which provides the drive voltages and other inputs to operate the laser head. However, the Series 126 laser head incorporates many of the electronics, in addition to the resonator, optics and optical pump.

Within the laser head is a hermetically-sealed package (gold box) which contains the solid-state diode laser and NPRO. Other components within the gold box include beam shaping and turning optics and a photodiode used to monitor the laser output from the NPRO.

Also within the laser head, but external to the gold box, are electronics which provide the appropriate drivers for the diode current, the diode thermo-electric cooler (TEC), crystal TEC and other controls. As a result, the Series 126 can be driven directly with the proper DC voltage inputs. If the user wishes to use standard wall plug AC voltage, this can be accommodated by using an optional Lightwave Electronics power supply.

A mechanical drawing of the laser head is given in Appendix I, and the performance specifications are summarized in Appendix II.

Optional Lightwave Electronics Power Supply

As mentioned, the Series 126 can be driven either with DC voltages or with an optional Lightwave power supply. Two different Lightwave Power Supplies are available: the Model 125/126 and the Model A125/126. Both models convert standard wall plug AC voltages (90 to 250 VAC, 50 to 60 Hz) into usable DC voltages for the laser head. The Model 125/126 is microprocessor-based and allows for easy access to, and control of, many laser functions. The Model A125/126 is analog-based, and provides a low cost alternative, while sacrificing some of the convenience of the Model 125/126. See Sections 3 and 4 for additional information.

Optional Diagnostic Accessory

An optional Diagnostic Accessory is available for easy monitoring of laser control parameters. Section 5 describes the functions of the Diagnostic Accessory.

1.3 LASER SAFETY

1.3.1 Explanation of Terms

The cautions and warnings used throughout this manual are explained below. Always read and heed this information. It is basic to the safe and proper operation of the system.

WARNING: Hazardous to persons. An action or circumstance which may potentially cause personal injury or loss of life. Mechanical damage may also result.

CAUTION: Hazardous to persons or equipment. To disregard the caution may cause mechanical damage, however it is not likely to cause serious injury or death.

1.3.2 Safety Summary

With the exception of Models 126-1064-500 and Model 126-1064-700, Series 126 diode-pumped ring lasers are Class IIIb lasers as defined by the Federal Register 21 CFR 1040.10 Laser Safety Standard. The models 126-1064-500 and 126-1064-700 are defined as class IV lasers by the aforementioned standards. The Standard requires that certain performance features and laser safety labels be provided on the product. Black and white reproductions of the warning labels are shown in this section.

The Series 126 is defined as a laser product since it is designed to be incorporated into an OEM system and requires the user to supply various DC power levels. However, if the Series 126 is mated with an optional Lightwave power supply it will function as a laser system. If configured in such a manner, the power supply and laser head have combined safety features which would be in compliance with the Standard. See Sections 3 or 4 for more information regarding the optional Lightwave Power Supplies.

The American National Standards Institute publishes a laser safety standard for users entitled American National Standard for the Safe Use of Lasers (ANSI Z136.1). Lightwave Electronics recommends that laser users obtain and follow the procedures described in this ANSI user standard. Copies may be obtained from:

American National Standards Institute Inc.
1430 Broadway
New York, NY 10018

or

Laser Institute of America
12524 Research Parkway
Orlando, FL 32826

WARNING: Exposure to laser radiation can be harmful. All apertures which can emit laser energy in excess of levels which are considered safe, or areas of the instrument to which exposure to laser radiation can occur due to disassembly, are identified with the appropriate labels shown in this section. Take extreme care when working in areas where these labels are placed.

WARNING: Provide protective eyewear suitable for the laser's emission wavelength. The laser's emission wavelength is indicated in nanometers (nm) by the second number in the model number. For example, a Model 126-1319-250 emits at a wavelength of 1319 nm.

WARNING: Use of controls or adjustments or performance of procedures other than those specified in this manual may result in hazardous radiation exposure.

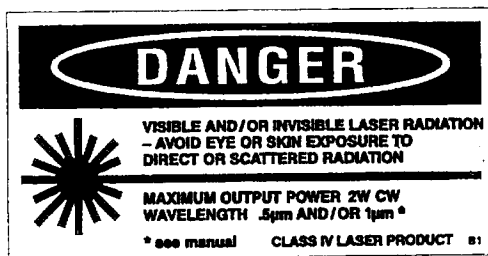
1.3.3 Laser Emission Levels

The maximum laser power emission level for Series 126 lasers is 2W. This emission may be at a wavelength of 1 μm, 1.3 μm, or 2.0 μm.

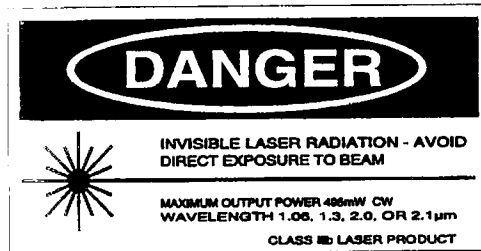
This power level represents a maximum and the user should not expect the laser to emit at this power level. The minimum specified power level is derived from the third number in the model number. The second number indicates the wavelength, in nm. For example, a Model 126-1319-250 will emit at least 250 mW of power at a nominal wavelength of 1319 nm.

1.3.4 Labels

Reproductions of the labels on the Series 126 laser head are given below in Figure 1-1.



For higher power lasers (≥ 500 mW).

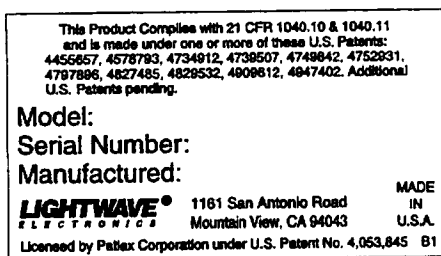


For lower power lasers (< 500 mW).

Warning Label - Located on top of the Laser Head



Aperture Label- Located on top of the laser head, pointing towards the output beam.



Certification Label- Located on side of the laser head. Includes Serial Number, Model Number, Manufactured Date, Manufacturers Name and Address. This label is also found on the rear panel of the optional power supply.

Reproductions not to scale

Figure 1-1: Reproductions of Labels

1.3.5 Laser Head Safety Features

Lightwave's Series 126 incorporates several safety features to minimize the chances of harm as a result of exposure to laser emission. These features are described below, and their locations are given in Figure 1-2.

Power On Indicator

The Power On Indicator is located on the front of the laser head and it is lit whenever there is power to the laser head. This light will be on even if laser emission is suppressed.

Standby (Lase) Pin

Pin #7 on the rear connector allows the user to turn the laser off/on with a +5 V signal. This can be used in an interlock circuit to automatically turn the laser off. For more details see Section 2.3.2.

Aperture Shutter

The aperture shutter is operated manually. To open the aperture and allow laser radiation to exit from the aperture, the shutter needs to be slid out. With the shutter closed, an orange dot will be visible across the aperture.

NOTE: If the Series 126 is not used in conjunction with a Lightwave power supply, the user may need to provide additional safety features to comply with Federal Register 21 CFR 1040.10. Typical additional features include a user-supplied key switch, safety interlock, and an additional emission indicator. **If the Series 126 is to be resold in a system incorporating it, the system seller must ensure the entire system complies with Federal Register 21 CFR 1040.10.** For additional information regarding compliance, contact Lightwave Electronics or the Center for Devices and Radiological Health.

1.3.6 Power Supply Safety Features

Additional safety features exist on the optional Lightwave Power Supplies, and these are described below. Locations of these features are given in Figures 1-3 and 1-4.

Key Switch

Turning the key switch to the ON position supplies power to the laser head. When the laser is connected to a Lightwave power supply, the laser cannot emit radiation unless the key is turned to the ON position. The key cannot be removed if the switch is in the ON position. Simply turning the key switch to the ON position does not necessarily imply the laser is emitting radiation, since the laser may be in the Standby Mode. Furthermore, when the key switch is initially turned to the ON position, the laser will complete its warm-up sequence in the Standby Mode.

Power On Indicator

The Power On Indicator is an LED located on the front panel of the power supply. This will glow yellow when the key switch is turned to the ON position. It does not necessarily indicate the laser is emitting radiation, as explained above.

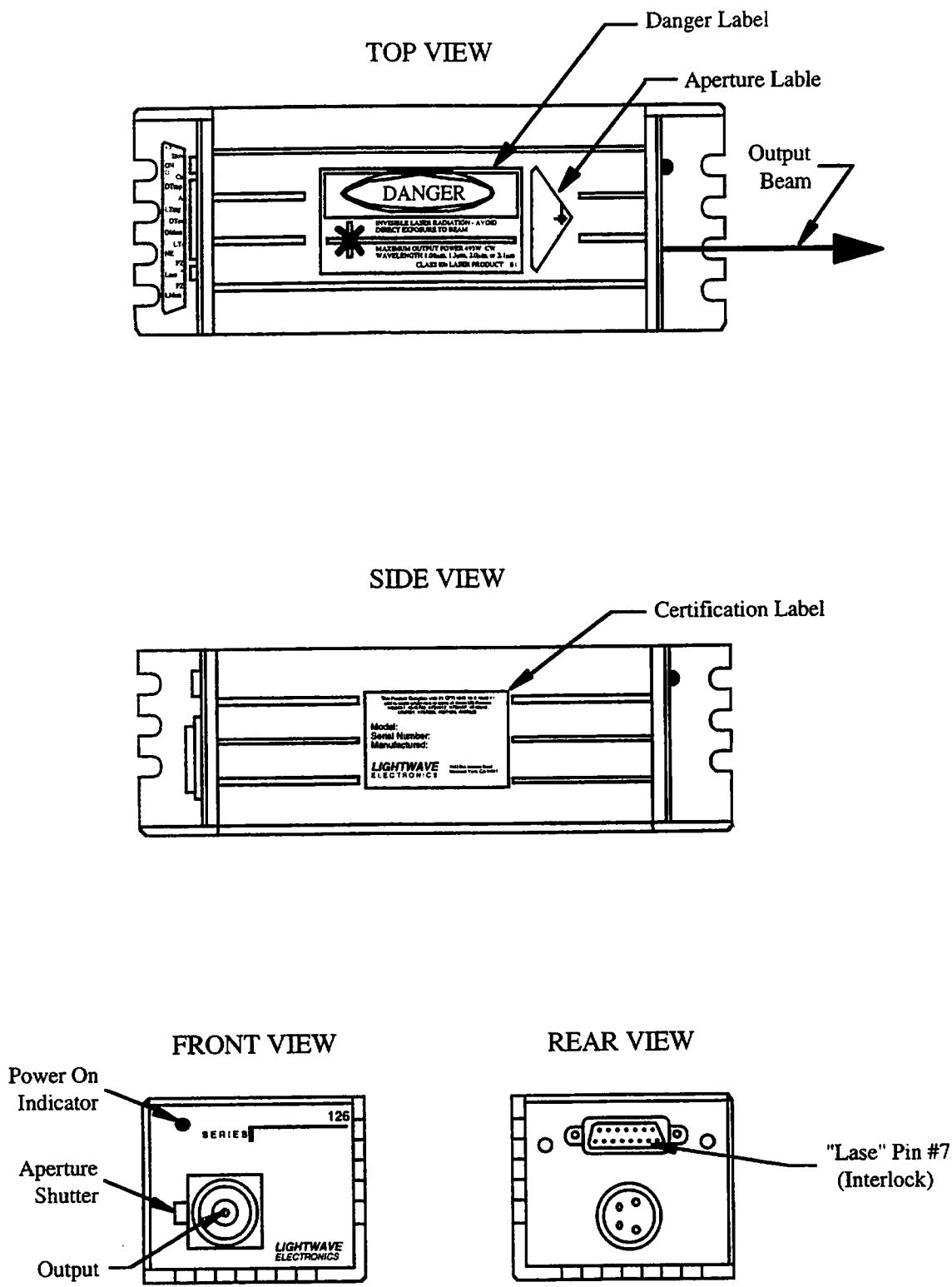


Figure 1-2: Safety Feature and Label Locations

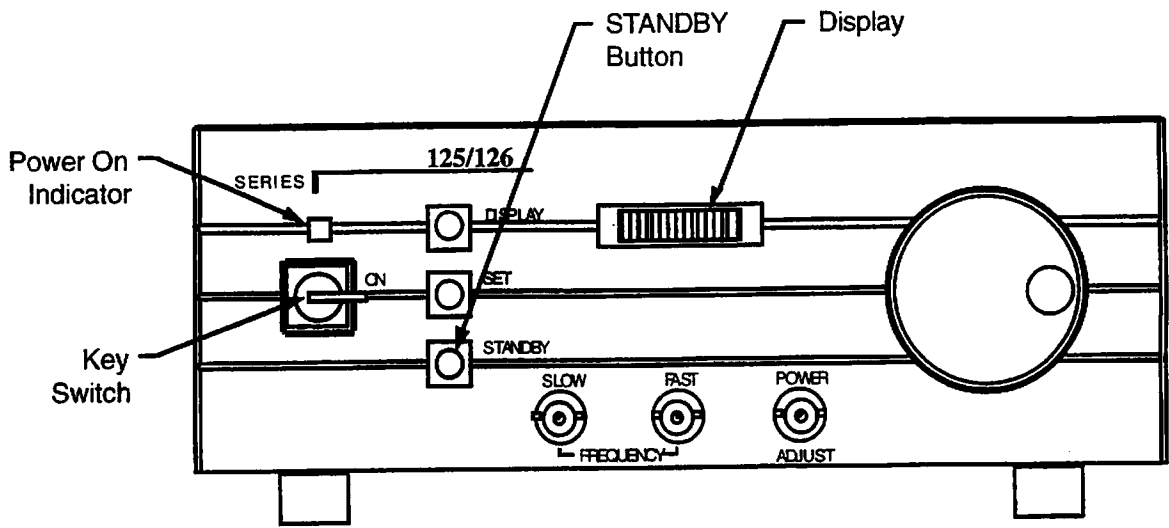


Figure 1-3: Model 125/126 Power Supply Safety Features

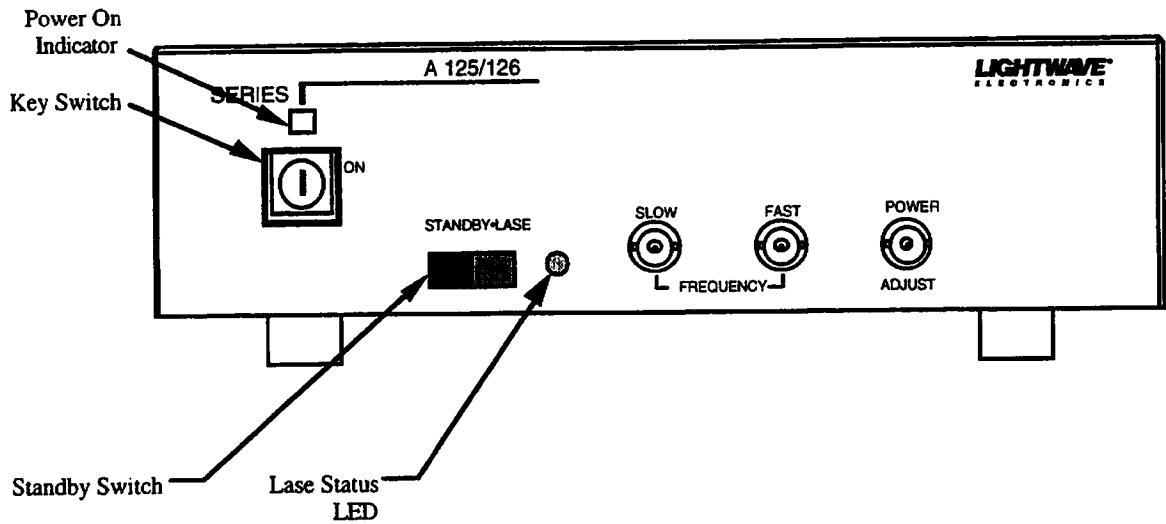


Figure 1-4: Model A125/126 Power Supply Safety Features

STANDBY Button/Standby Switch

The Model 125/126 incorporates a STANDBY button, while the Model A125/126 incorporates a Standby Switch. This button or switch acts as an electrical attenuator which turns off the diode laser when toggled. For the Model 125/126, the display will read "STANDBY" when the diode current is turned off, while the Lase Status LED will be off when the Standby Switch is in the "Standby" position.

More information on the Standby mode of the Model 125/126 can be found in Section 3.2.2, while operation of the Standby Switch and Lase Status LED of the Model A125/126 is described in greater detail in Section 4.2.2.

Safety Interlock

A safety interlock is provided for both Lightwave Power Supplies. The interlock is located on the rear of the Power Supplies (see Figures 3-1 and 4-1), and allows the user to externally disable the laser for safety purposes. An example would be configuring the laser such that the interlock opens/closes when a door is opened/closed. The safety interlock is shipped with an "enable" jumper plug installed. See Section 3.1.5 for additional information on the Model 125/126 interlock, and Section 4.1.5 for additional information on the Model A125/126 interlock.

SECTION 2: LASER HEAD SET-UP AND OPERATION

If the Series 126 laser head is to be powered by a user-supplied power supply all of Section 2 should be read and understood. If the laser is to be used with Lightwave's Model 125/126 Microprocessor-based Power Supply or Model A125/126 Analog Power Supply, read Sections 2.1 and 2.2 below and then proceed directly to Section 3 or 4, respectively.

2.1 MOUNTING

The two main requirements for proper mounting are: 1) good heat removal, and 2) stress-free attachment on a clean flat surface.

2.1.1 Heat Removal

The laser will not function properly without adequate cooling. Both flanged surfaces of the laser head will dissipate heat, as discussed below.

The wider flanged surface must dissipate the most heat. The diode laser and diode laser cooler typically generate ≈ 20 W of heat to be dissipated through this surface. In the worst case, ≈ 50 W will be generated. Consequently, this surface typically is used for mounting the laser head to allow for conduction cooling.

The narrower flanged surface dissipates heat from the power transistors inside the laser head. This surface typically will dissipate ≈ 10 W of heat, with a worst case being ≈ 20 W. For most cases natural convection is sufficient for dissipating this heat. If this is not sufficient, an optional finned heat sink for this surface is available from Lightwave Electronics at no charge.

An aluminum or copper mounting surface normally provides sufficient conduction to cool the wider flanged surface. An optical table does not provide sufficient conduction since steel is not a good conductor; however, it may be possible to mount the narrower flanged surface to an optical table and have a fan cool the wider flanged surface.

A good thermal junction between the head and the mounting surface can be made in several ways. Lightwave's general recommendation is to provide flat, clean, thermally conductive surfaces in full contact. If this is not possible or sufficient, insert a 25 μm to 50 μm thick gasket made of compliant indium foil between the surfaces to improve heat transfer. Indium foil is expensive, so this solution generally is not desirable unless a problem with heat flow has been demonstrated. Alternatively, coating the surfaces with a thin layer of thermally conductive grease (such as Dow Corning 340) may also improve heat transfer. However, thermally conductive grease is messy, and a less desirable alternative. Generally, if the laser base is more than 3° C warmer than the heat sink adjoining the laser base, the thermal connection should be inspected and improved.

The laser is designed with an internal interlock to shut the laser off if the laser head temperature rises above 60° C. Performance may degrade before shutdown occurs. If the laser does shut itself off, it should recover once the temperature of the head drops below 60° C.

2.1.2 Stress-Free Mount

Attach the laser head snugly to your flat heat sink base using the bolt holes provided or a clamp on the extending part of the base. The provided nylon washers should be used between the head of the bolts and the laser base to prevent galling the surface of the laser, and to help prevent over-stressing the laser head. The cover of the laser head should not be clamped in compression or tension, be bent, or subjected to heat sources.

2.2 DC POWER CONNECTIONS

Assuming the laser head will not be operated with a Lightwave power supply, the following directions should be followed. If the optional Model 125/126 Power Supply or Model A125/126 Power Supply is to be used, the user should skip to Sections 3 or 4, respectively, and Sections 2.2, 2.3, and 2.4 may be ignored.

Power is supplied to the laser through the round four pin connector shown in Figure 2-1. Note that it is acceptable for pins #2 and #3 to be hooked together.

WARNING: The laser will emit radiation once power is supplied to these four pins unless the laser head is used in conjunction with a Lightwave power supply or the Lase pin on the Control Connector is used to place the laser in Standby Mode.

CAUTION: While the laser head is well protected against ESD and improper voltage levels, Lightwave recommends that the DC power supply be turned off while connecting or disconnecting the laser.

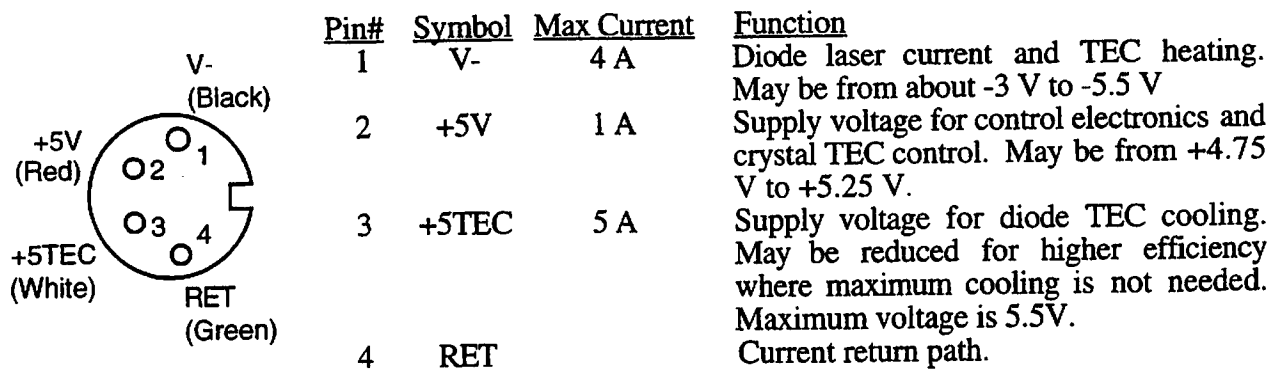


Figure 2-1: Power Connector

The laser comes with a mating connector attached to a 6-foot cable with four separate banana plugs at the other end of the cable. These banana plugs can be plugged into a DC power supply. The color of the banana plug indicates the corresponding voltage pin. These colors are given in parentheses in Figure 2-1.

In the event the mating connector is misplaced, it is a Neutrik NC4FX-B connector, available from Newark Electronics and other suppliers. It may also be ordered from Lightwave. Neutrik may be contacted directly at:

Neutrik USA
195 Lehigh Ave.
Lakewood, NJ 08701
(908) 901-9488

2.2.1 Simplest Method for Connecting DC Power

The Series 126 is designed to be powered most simply by a pair of 5 Volt power supplies, one wired to supply negative current and the other to supply positive current. Five volt power supplies are widely available and inexpensive. Two identical supplies wired as shown in Figure 2-2 will be adequate for most laboratory uses of the Series 126.

The supply shown on the left in Figure 2-2 provides positive current, and the one on the right provides negative current. Since virtually all commercially-available power supplies have both outputs "floating," there is no need to use a "negative" supply for the V^- voltage. The shared *RET* line need not be grounded. If the optional 15 pin control cable is used (see Section 2.3), then it is better not to ground the *RET* line, and to ground only the *Gnd* line of the 15 pin connector. Doing this forces all power supply return currents to stay in the *RET* line, and avoids voltage offsets that could reduce the stability and accuracy of the control lines.

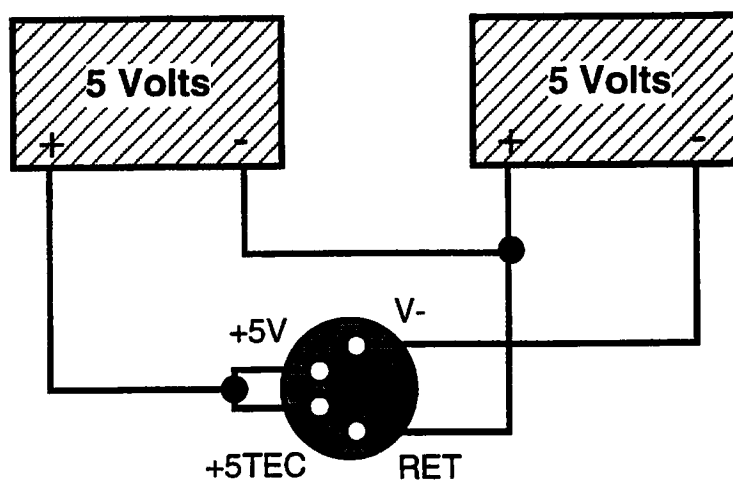


Figure 2-2: DC Power Connection Using Two Identical 5 volt DC Supplies

2.2.2 Methods for Minimizing Power Consumption

The use of a pair of 5 volt supplies is not optimal from the point of view of energy efficiency. The power consumption of the Series 126 can be reduced by over 50% by using voltages which are lower than 5 volts. In applications where power is limited, or where heat dissipation is a problem, it may be worthwhile to choose power supplies at less convenient but more efficient voltages. To first approximation, when it is assumed that the laser works with a fixed heat sink temperature, this reduction in power consumption is simply proportional to voltage, since the power-consuming components of the laser act as constant-current devices. A more complete analysis will show that power consumption falls faster than voltage, since the reduced heat dissipation results in a cooler heat sink, and thus reduced temperature-control currents.

Reducing the negative supply

The simplest way to save power is by using a supply for V^- with a reduced voltage, as shown in Figure 2-3. All Series 126 lasers will show no reduction in output and no reduction in current draw as the negative voltage, V^- , is changed from -5 Volts into the range from -2 to -3 Volts. The Model 126 is guaranteed to operate with -3 Volts supplied; some units may operate at as low as -2 Volts, especially if the cable from the power supply to the laser is short. Since current is constant, power consumption is simply proportional to voltage. The negative supply voltage of the Series 126 can be set by adjusting the voltage toward zero until there is a reduction in power or an increase in noise, and then backing off from that point by about 0.2 Volts to provide a comfortable margin.

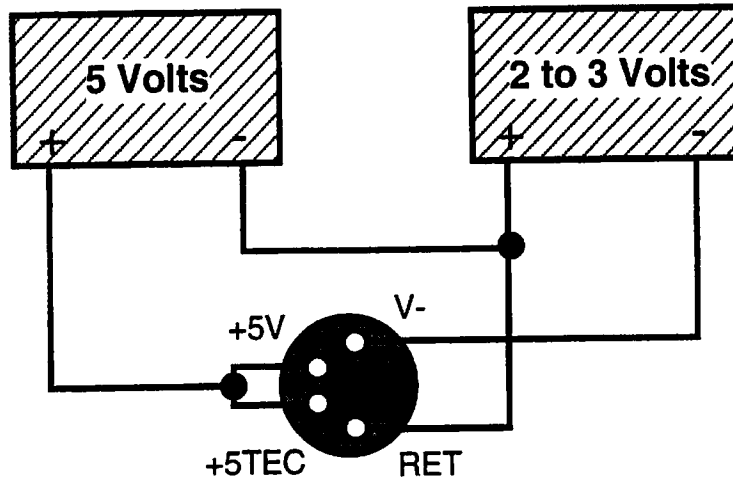


Figure 2-3: Low Power Consumption Configuration: Reduced Voltage to V^- input

Splitting the positive supply

Part of the positive 5 volt supply output is used for the laser control circuitry, but the great majority of the current goes to the thermo-electric cooler (TEC) which cools the diode laser. Figure 2-4 shows a Series 126 using two positive supplies. One supply, connected to the +5V input, has a 1 Ampere capacity. The other supply, connected to the +5TEC input, has a reduced and/or variable voltage. The voltage and current demanded from this supply will depend on the temperature of the laser's heat sink, with a higher temperature requiring higher voltage and current. A 5 Volt, 6 Ampere supply will be adequate in all cases. In most cases, a smaller supply will be adequate.

The minimum voltage and current needed for proper operation can be found as follows. Operate the Series 126 with the heat sink at the highest heat sink temperature expected to ever occur. Use a 5 Volt fixed-voltage supply for the +5V input. For the +5TEC input use a laboratory power supply with adjustable voltage and current limits. Initially operate the supply with the voltage limit set at 5 Volts and the current limit turned all the way up. Turn the laser on and let the current find a stable operating point, which should take a minute or less. At this point, turn the current limit down slowly, until the voltage from the supply drops below +5 Volts. This drop will be quite abrupt.

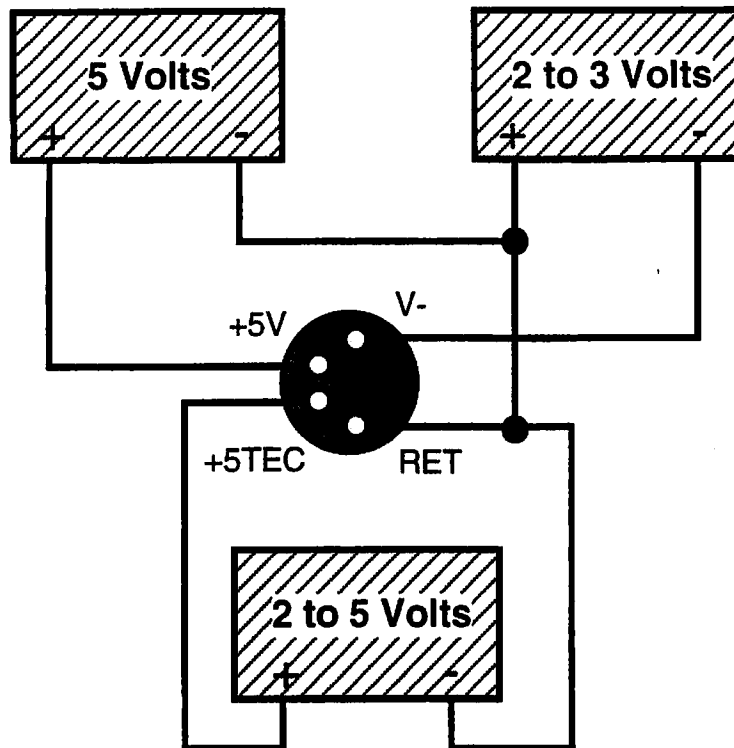


Figure 2-4: Low Power Consumption Configuration: Dual Positive Voltage Supplies

The output of the laser should remain constant, despite the drop in voltage. Note the current level and the voltage level just after the point where the voltage has dropped. This current and voltage will be the highest that your unit needs. Power consumption from the +5TEC input will be reduced by at least the ratio between the voltage you set and 5 Volts.

More complex approaches to maximizing power efficiency are possible. One approach is to use the DTmp output of the 126 as a sense line in a control circuit, and controlling +5TEC to stay just slightly hotter in temperature than the factory-set level. The internal temperature-control circuitry of the 126 will thus have a minimum voltage drop. Another approach would be to set +5TEC at a fixed amount above the DTec output line of the 126. A voltage difference of 1 Volt would be adequate to always keep the internal circuitry in regulation, while keeping dissipation low. Even lower differences would probably be adequate, although it would be best to experiment, keeping in mind that the voltage difference between the +5TEC power input and the DTec level will be greatest when the current drawn is greatest.

2.3 LASER CONTROL AND DIAGNOSTICS

Access to laser features is provided through a 15 pin subminiature-D female connector on the rear of the laser head. The user should attach a 15 pin subminiature-D connector with 4-40 thread female screwlocks (similar to AMP series HDE, HDF, or HDP connectors) to access these pins. This connector is not supplied, but should be easy to purchase. The pin-out for this connector is shown in Figure 2-5. Unless noted, all input and output impedances are 10 k Ω .

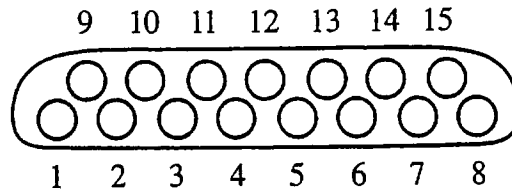


Figure 2-5: Laser Control Connector

<u>Pin #</u>	<u>Symbol</u>	<u>Function</u>
1	+5V	Output for test purposes
2	GND	Ground signal
3	DTmp	Indicator of Diode Temperature
4	LTmp	Measured Crystal Temperature, 10° C/volt
5	DMon	Diode Monitor, relative voltage only (<i>on selected units only</i>)
6	NE	Noise Reduction Control, +5V or open for active, low for off
7	Lase	Bi-directional control and status line for laser
8	LMon	Laser Monitor, relative voltage only
9	Slow	Thermal control of laser frequency. ±10 V
10	Cur	Diode current monitor, 1 V/A
11	Adj	Diode current adjust, +2% to -10% of maximum current
12	DTec	Diode TEC voltage
13	LTec	Laser TEC voltage
14	PZ+	Piezo positive lead
15	PZ-	Piezo negative lead

Inputs (control pins) are in bold

2.3.1 Ground Reference

Pin #2 (labeled **GND**) should be connected to ground to ensure the other voltage readings on the Control Connector are calibrated. If this pin is not grounded, the other voltage readings may include an unknown offset voltage.

CAUTION: The **GND** pin should not be part of the current flow which powers the laser head. It is intended to serve as a reference signal. When incorporating this into a system, treat this as an analog ground

The **GND** pin on the Control Connector and the **RET** pin on the Power Connector are connected inside the laser head. For proper operation of diagnostics and controls, no external connection between **RET** and **GND** should be made. In general, it is preferable to let the **RET** line float, and to connect only the **GND** pin to other ground lines.

2.3.2 Standby Mode/Laser Status

The **Lase** pin (pin #7) is a bi-directional pin which: allows the user to put the laser into a Standby Mode condition, or indicates the laser's current status.

As a control line, the laser can be turned off by pulling this pin low with a TTL signal or a switch to ground. Since the temperature control circuits will remain running, warm-up will be very quick. Turning the laser off using this pin is known as placing the laser in Standby Mode since operation will resume quickly. While in Standby Mode the emission indicator LED will flash at 1 Hz. After releasing the **Lase** signal, the laser will resume operation in about 2 seconds.

The **Lase** pin may be used as an interlock, allowing the user to provide an external disable for safety purposes. An example would be configuring the laser such that the **Lase** pin voltage goes to 0 V when a door is opened.

As a status line the **Lase** pin indicates:

1. **Laser On.** The voltage will be approximately 4.3 V with a 1 k Ω source impedance.
2. **15 Second Power-Up Delay.** The signal will alternate between 0 V and 5 V at a 1 Hz rate, with a 10 k Ω source impedance.
3. **Fault.** A laser head temperature, diode temperature, or voltage level fault causes the **Lase** pin to alternate between 0 V and 5 V at a 5 Hz rate with a 10 k Ω output impedance. After a temperature fault condition is removed, there will be a 15 second power-on delay.

2.3.3 Broad Frequency Tuning

Voltage applied to the SLOW FREQUENCY BNC tunes the laser resonator by heating or cooling the laser crystal. Tuning primarily is due to the change in the index of refraction. This allows for a large tuning range, with a relatively slow time constant (approximately 1 to 10 seconds). The input impedance across this connector is 10 k Ω . The tuning coefficient over the continuous tuning range is +3.8 GHz/V for 1319 nm lasers and +5.0 GHz/V for 1064 nm lasers. Averaged to include the effect of mode hops, the average tuning coefficient is approximately +1.6 GHz/V for either wavelength. The maximum design-case voltage is ± 10 V. See Section 6.3.3 for additional information on frequency tuning. The absolute optical frequency tuning due to a positive applied voltage will be positive.

If the frequency is modulated at a rate of greater than ≈ 1 Hz, the response characteristics of the output to the input signal are complex due to the interaction of thermal loading on the crystal and the control electronics. However, the behavior may be approximated by considering the system to have two dominant time constants. Also, thermal propagation delays add phase shift as the input modulation rate increases.

2.3.4 Fast Frequency Tuning

Fast frequency tuning is accomplished by applying a voltage to pins #14 (**PZ+**) and #15 (**PZ-**). The voltage difference between pins #14 and #15 determines the voltage applied to a piezo mounted on the crystal resonator. This voltage difference contracts a piezoelectric element (piezo) bonded to the laser crystal. This results in a strain sufficient to vary the frequency.

The tuning coefficient varies from laser to laser, but will be >1 MHz/Volt. For a specific laser, the tuning coefficient is given on the laser's Customer Data Sheet. The absolute optical frequency tuning due to a positive applied voltage will be positive. The piezo acts as a capacitor with a capacitance of less than 10,000 pF. A voltage applied across these pins directly drives the piezo without any intermediate electronics.

For relatively low modulation rates (less than 10 kHz), the laser frequency will be tunable over at least 30 MHz. At higher modulation rates, such large modulation depths may result in severe amplitude noise. For small modulation depths the laser may be modulated at rates up to 30 kHz. At frequency modulation rates above 30 kHz the piezo will still operate; however, the tuning coefficient becomes non-linear. For applications in which the laser will modulate at a fixed high modulation rate, and not vary, this may not present a problem.

See Section 6.3.3 for additional information on frequency tuning.

CAUTION: The piezo element generates heat when operated and, in the extreme, this can lead to laser damage. Specifically, applying an RF signal will damage the laser. A signal of ± 50 V at a modulation rate of 100 kHz represents a safe extreme for piezo operation. If the user would like to operate at higher voltages or higher modulation rates than this, the user should consult Lightwave.

2.3.5 Noise Reduction

Pin #6 (NE) can be used to turn off the noise reduction electronics. With this line open or when >3.8 V is applied, the noise reduction electronics will be active. When pulled low by a TTL signal or a switch to ground, the noise reduction electronics will be turned off. See Section 6.5 for additional information on the noise reduction electronics.

2.3.6 Output Power Adjustment

Small adjustments in the laser current may be made by applying +2 V to -10 V to pin #11 (Adj). Positive voltages will increase the diode current above the nominal setting, while negative voltages will decrease it. Voltages outside this range are ignored.

If the power is to be modulated at a frequency above 1 Hz, Lightwave recommends the noise reduction electronics be disabled. This is because the noise reduction electronics "fight" to maintain a certain power level while the signal is asking for a change. For more information regarding this, contact Lightwave.

2.3.7 Diagnostics

The remaining pins on the Control Connector are used for diagnostics.

<u>Pin#</u>	<u>Symbol</u>	<u>Description</u>
1	+5V	Do <u>not</u> use this pin to power the laser. It is provided to examine the status of the supply voltage or to supply limited current for test equipment.
3	DTmp	This voltage provides information on the diode temperature. It reads +5 V at a temperature of 10° C and -5 V at a temperature of 35° C. This is provided as a diagnostic only, as there is no user adjustment of diode temperature.
4	LTmp	This voltage indicates the measured crystal temperature, at 10° C per volt.
5	DMon	This is an uncalibrated negative voltage used to monitor the power of the diode laser pump. <i>This feature is available on certain units, usually by special request only.</i>
8	LMon	This pin provides an uncalibrated indication of the laser's power.
10	Cur	The diode current monitor pin indicates the diode current, at 1 amp per volt.
12	DTec	This pin indicates the voltage applied to the diode TEC. A positive voltage indicates cooling while a negative voltage means the TEC is heating. This voltage should never exceed +4.5 V or -2.5 V.
13	LTec	An indication of the voltage applied to the laser crystal TEC is provided on this pin. A positive voltage indicates cooling while a negative voltage means the TEC is heating. This voltage should not exceed +3.9 V or -2.5 V.

2.4 ADDITIONAL ADJUSTMENTS

Figure 2-6 depicts the rear panel of the Series 126 laser head. In addition to the Power and Control Connectors, there exists a potentiometer for adjusting the nominal laser crystal temperature and a potentiometer for adjusting the diode current.

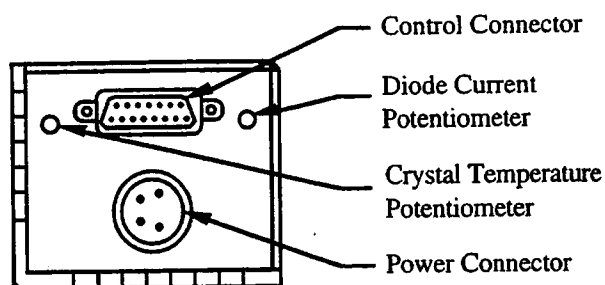


Figure 2-6: Laser Head Potentiometers

2.4.1 Default Crystal Temperature

The default crystal temperature is set at the factory to be centered along a continuously tunable laser frequency region. Upon shipment, the default crystal temperature will be around 40°-50° C. The crystal temperature can be tuned $\pm 15^\circ$ C from this nominal temperature by applying a voltage to pin #9, as discussed in Section 2.3.3.

If the user would like the default temperature to be different from the factory set temperature, it is possible to change the default crystal temperature by adjusting this 10 turn potentiometer. At the warm extreme, the default crystal temperature can be set to 60° C, while at the cold extreme it may be set to 30° C. Cooling the crystal temperature results in increasing the laser frequency. To decrease the crystal temperature and increase the frequency, the Crystal Temperature Potentiometer should be turned clockwise.

2.4.2 Nominal Diode Current

The power out of the laser can be decreased by turning the 10 turn Diode Current Potentiometer counter-clockwise. The laser is shipped with this set at full current and fully clockwise. In the fully counter-clockwise state, the diode current will be 0 amps. The Nd:YAG laser will turn off after only a few counter-clockwise turns, since it will no longer have enough diode pump light to reach the lasing threshold.

If the laser current is reduced significantly, the noise reduction electronics may not function properly, and may increase noise. This is not harmful to the laser, but will impact performance. The noise reduction electronics may be disabled as described in Section 2.3.5.

If the "Adj" is implemented through the Control Connector (see Section 2.3.6, Pin #11), the diode current will be adjusted from the nominal diode current.

SECTION 3: MODEL 125/126 MICROPROCESSOR-BASED POWER SUPPLY

Available as an option, the Model 125/126 Microprocessor-based Power Supply with alphanumeric display provides the user simple access to and control of many of the laser functions.

3.1 POWER SUPPLY SET UP

The laser head should be set up, as discussed in Section 2.1 and the power supply set up as described below. An illustration of the rear panel is shown in Fig. 3-1.

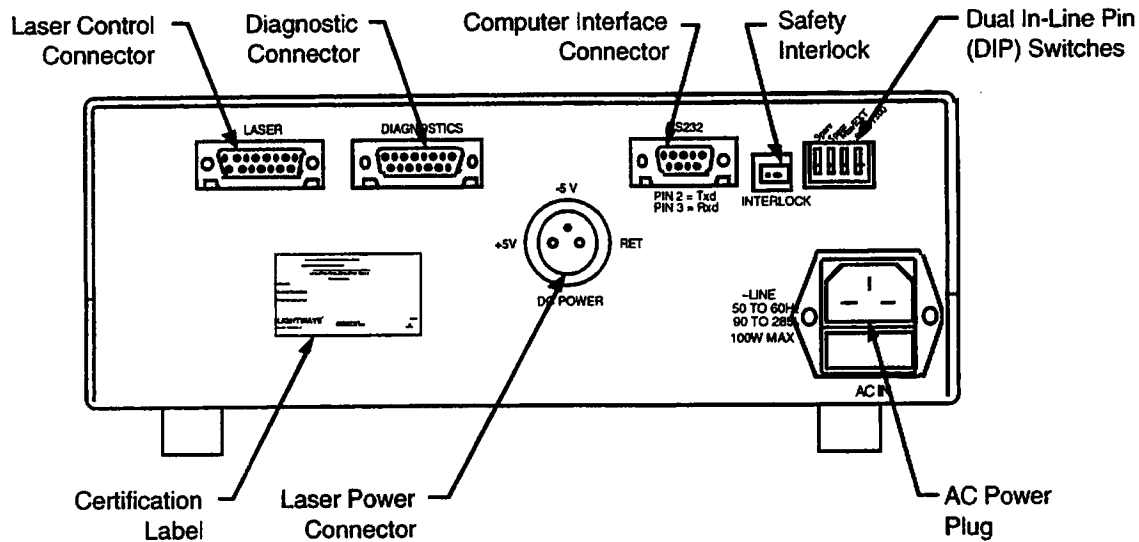


Figure 3-1: Model 125/126 Power Supply Rear Panel

3.1.1 AC Power Connection

Plug the power supply into an appropriate wall outlet. This should be done prior to connecting the laser head to the power supply.

Power input to the Model 125/126 can be any AC voltage 90 to 250 volts, 50 to 60 cycles. The AC power supply automatically identifies the line voltage and configures itself appropriately, so no voltage selection or jumpering is necessary. For 120 volt operation a 1.5 amp slow-blow fuse should be used. For 240 volts substitute a 0.75 amp slow-blow fuse.

3.1.2 Laser Power Connection

Connect the power supply to the Series 126 laser head with Lightwave Cable #4-1301, which is supplied with the power supply. This Power Cable will route the necessary DC voltages to the laser head.

3.1.3 Laser Control Connection

Connect the power supply's Control Connector to the laser head's Control Connector with Lightwave Cable #4-1008. This Control Cable provides signals for all control and diagnostic signals going to and from the laser head.

Note that the head may be safely operated with just the DC power cable connected. Under these conditions the features of the Model 125/126 Power Supply (except STANDBY) will not be of use.

The power supply and laser head may be operated without the Control Cable. In this case the missing cable is sensed and while in Standby Mode does not supply power to the diode laser. When the STANDBY button is pressed, the power supply exams the state of the Diode TEC voltage and if out of range responds with the message:

L	A	S	E	R		O	N
---	---	---	---	---	--	---	---

Pressing the DISPLAY button prompts the user with the message:

C	A	B	L	E		?	
---	---	---	---	---	--	---	--

Pressing DISPLAY will then show the last display function used. If there is no cable the functions will cause no action in the head.

3.1.4 Diagnostic Connection

The Diagnostic Connector is used to connect the Diagnostic Accessory to the laser head, using the power supply as an intermediary. For more information on the Diagnostic Accessory, see Section 5.

3.1.5 Safety Interlock

The safety interlock comes with an "enable" jumper installed which shorts the circuit, thus allowing the laser to operate. However, the jumper may be removed and the safety interlock used to externally disable the laser for safety purposes. An example would be configuring the laser such that the interlock opens/closes when a door is opened/closed.

To utilize the interlock feature, remove the interlock plug and then connect the switch (or relay) contacts across the input. Internally, a "sense" circuit has a 10 k Ω pull-up resistor to +5 V. If the interlock circuit is open, or the input voltage exceeds 2.5 V, the laser will be disabled, and the display will read:

I	L	C	K	O	P	E	N
---	---	---	---	---	---	---	---

Once the circuit is shorted ("enabled") the display will read "STANDBY". Operation is resumed when the STANDBY button is pushed. If the Power-Up option has been implemented, once the interlock circuit is shorted, operation will resume immediately and the display will reflect this.

3.1.6 Power Up Option

For lasers which are not Class IV (<500 mW), the power supply may be reconfigured by the user to power up or return from an interlock condition to the lase mode. Access to the inside of the power supply is achieved by removing the four button head screws which attach the cover. To implement the Power-Up option, jumper pins 1 and 2 of J8 located to the right of IC U17 on the printed circuit board.

Note: Do not implement the power up option for models 126-1064-500 or 126-1064-700. These are Class IV laser products. As a result, implementing the power up option, violates safety standards established by the Center for Devices and Radiological Health, U.S. Department of Health and Human Services. This is because a manual reset is necessary for Class IV products.

3.2 BASIC OPERATION

With the Series 126 laser head set-up and all connections properly made, the laser can be controlled entirely from the front panel of the Model 125/126 Power Supply. Figure 3-2, below, labels the various features of the Model 125/126 Power Supply.

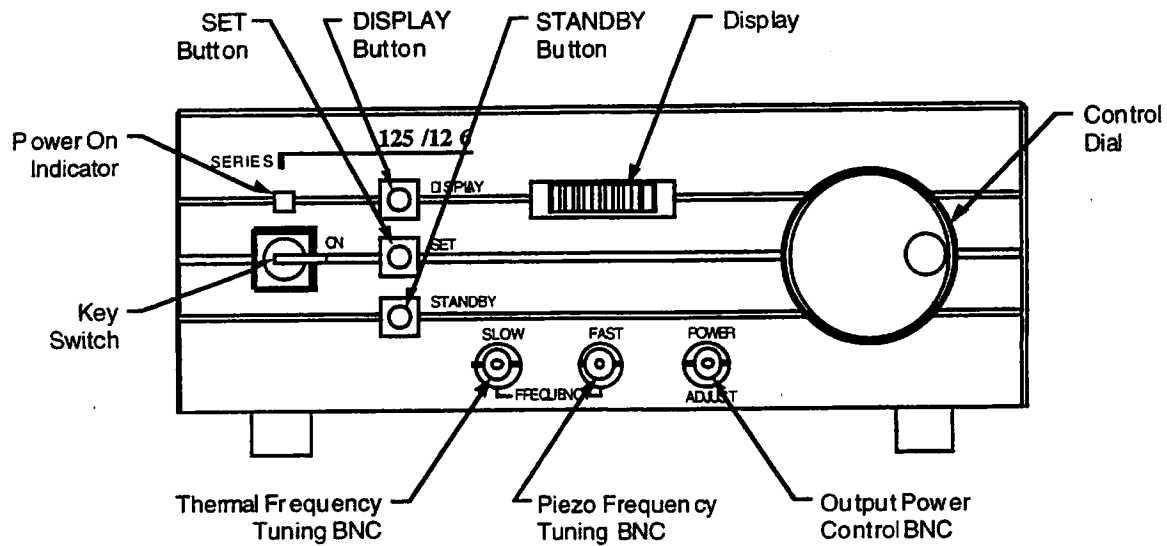


Figure 3-2: Model 125/126 Power Supply Front Panel

3.2.1 Turning the Laser On

Prior to turning the laser on, ensure that personnel in the vicinity have proper protective eyewear and that the beam path will be well contained. See Section 1.3 for details.

Turning the key 1/4 turn clockwise provides power to the laser head and power supply. Illumination of the Power-On Indicator above the key switch indicates that power is available to the laser head. The key may be removed only while it is in the "OFF" position.

Upon power-up there is a 10 second safety time-out. During this time, diagnostics are performed to insure proper operation of the laser. The display reads:

Display Message
 "LWE 126"
 "STANDBY"

Time Message is on
 2 seconds
 Until STANDBY button is pushed

During the turn-on period, pressing any button will show the release date of the software. Successive button presses can be used to bypass the turn-on delays.

3.2.2 Standby Mode

In the Standby Mode the diode laser is off, but the temperature control circuits are active. The display reads "STANDBY". Pressing the STANDBY button toggles the laser in and out of Standby Mode. When toggling out of the Standby Mode, the display will show whatever was last displayed before entering the Standby Mode.

If the laser is to be used several times in the course of a day, it is recommended that the laser be put in the Standby Mode rather than turning the laser off. This will eliminate the need to allow the laser to reach thermal equilibrium each time the laser is turned on, while still extending diode lifetime.

3.2.3 Display Ranges

Pressing the DISPLAY button changes the nature of the information displayed. Two display ranges are available: Minimum and Extended. The desired display range is selected by a DIP switch on the rear of the power supply. The laser is shipped from the factory in the Minimum Display Range. The information available for each display range is given below.

Minimum Display Range
Target Crystal Temperature
Laser Power
Power Adjustment

Extended Display Range
Target Crystal Temperature
Laser Power
Power Adjustment
Diode Current Monitor
Diode Power Monitor
Noise Reduction Control
Diode laser Control
Display Brightness
Diode Temperature
Diode TEC Voltage
Measured Crystal Temperature
Laser TEC Voltage

3.2.4 Parameter Adjustment

SET Button

Depending on the display range selected, the SET button is used to clear, preset, or save displayed values. It is also used to select among the available system configuration options.

Control Dial

This dial adjusts laser operating parameters, especially the laser's frequency (crystal temperature). Often the Control Dial is used in conjunction with the SET button. The speed at which parameters change is dependent on the velocity of the control dial. Quickly spinning the control dial will cause parameter values to change substantially, even if only a few turns occur. Slowly turning the control dial results in small changes to parameter values. This allows for both fine resolution and convenient coverage of the entire range.

3.2.5 Slow Frequency Tuning BNC

Voltage applied to the SLOW FREQUENCY BNC tunes the laser resonator by heating or cooling the laser crystal. Tuning primarily is due to the change in the index of refraction. This allows for a large tuning range, with a relatively slow time constant (approximately 1-10 seconds). The input impedance across this connector is 10 k Ω . The absolute optical frequency tuning due to a positive applied voltage will be positive.

The tuning coefficient between mode hops (continuous tuning coefficient) will be approximately +3.8 GHz/Volt for 1319 nm lasers and +5.0 GHz/Volt for 1064 nm lasers. The tuning coefficient, as averaged across mode hops, is approximately +1.6 GHz/Volt for either wavelength. The maximum signal that should be applied is ± 10 V. Additional information on thermal tuning and mode hops is found in Section 6.3.3.

If the frequency is modulated at a rate of greater than ≈ 1 Hz, the response characteristics of the output to the input signal are complex due to the interaction of thermal loading on the crystal and the control electronics. However, the behavior may be approximated by considering the system to have two dominant time constants. Also, thermal propagation delays add phase shift as the input modulation rate increases.

3.2.6 Fast Frequency Tuning BNC

[This feature is not available on the 2013 nm laser (Series 126-2013)]

Voltage applied to the FAST FREQUENCY BNC contracts a piezoelectric element (piezo) bonded to the laser crystal. This voltage results in a strain sufficient to vary the frequency. The tuning coefficient varies from laser to laser, but will be at least 1 MHz/Volt. For a specific laser, the tuning coefficient is given on the laser's Customer Data Sheet. The piezo acts as a capacitor with a capacitance of less than 10,000 pF. A voltage applied to this BNC directly drives the piezo without any intermediate electronics.

The response characteristics of the laser to inputs at the FAST FREQUENCY BNC are complex due to mechanical resonances of the laser crystal. For relatively low modulation rates (less than 10 kHz), the laser frequency will be tunable over at least 30 MHz. At higher modulation rates, such large modulation depths may result in severe amplitude noise. For small modulation depths the laser may be modulated at rates up to 30 kHz. At frequency modulation rates above 30 kHz the piezo will still operate; however, the tuning coefficient becomes non-linear. For applications in which the laser will modulate at a fixed high modulation rate, and not vary, this may not present a problem.

CAUTION: The piezo element generates heat when operated and, in the extreme, this can lead to laser damage. A signal of ± 50 V at a modulation rate of 100 kHz represents a safe extreme for piezo operation. If the user would like to operate at higher voltages or higher modulation rates than this, the user should consult Lightwave.

3.2.7 Output Power Control BNC

A positive voltage applied to the POWER ADJUST BNC will increase the laser output by increasing the diode drive current by 10 to 15% depending on its factory setting. The resulting increase in light out will be some what higher. Up to +10 V may be applied to this 10 k Ω input although only +2 volts will have an effect.

A negative voltage will reduce the laser output by reducing the diode drive current. Applying a -10 V signal may turn the laser completely off, although this is not guaranteed and the POWER ADJUST BNC should not be used as an interlock.

If the power is to be modulated at frequencies above 1 Hz, Lightwave recommends the noise reduction electronics be disabled. This is because the noise reduction electronics will "fight" to maintain a certain power level while the signal is asking for the power level to change. For more information regarding modulation, contact Lightwave Electronics.

3.3 MINIMUM DISPLAY RANGE

While in the active state, the display will show a selected function. By using the DISPLAY button, the user can sequentially select the various display functions. These functions are:

3.3.1 Target Crystal Temperature

The format is:

T	+	X	X.	X	X	X	∧
---	---	---	----	---	---	---	---

The Control Dial changes the laser crystal's temperature set point. If the Control Dial is turned very slowly (1/4 turn in 10 seconds), the temperature will change in 0.0005 degree steps. At a rotation rate of 2 rev/sec, the temperature will change approximately 0.3 degree per revolution.

After a significant change in the requested temperature, the tracking indicator will show that a change in the actual temperature is occurring. An up arrow will indicate that the temperature is going up, while the down arrow means that it is going down. Because of the difference in resolution of the setting and the reading of the temperature, small changes in the set point will not activate the tracking indicator.

For 1319 nm lasers the continuous tuning coefficient is about -2.4 GHz/°C. It is approximately - 3.1 GHz/°C for 1064 nm lasers. The tuning coefficient averaged across mode hops is approximately - 1 GHz/°C for both 1319 nm and 1064 nm lasers.

It should be noted that the displayed number does not represent the measured temperature of the crystal, rather a calculated value based on the center frequency entered in the temperature center calibration. The number will be accurate assuming there is no external input to the SLOW FREQUENCY BNC. If there is such an input, the BNC input will generate an offset which will not be accommodated on the display.

With the crystal temperature displayed, pressing the SET button will reset the crystal temperature to the factory-set default temperature. This temperature has been selected to be in the center of a laser mode range to insure good lasing operation. See Section 2.4.1 for information on changing the factory-set temperature (default crystal temperature).

3.3.2 Laser Power

The format is:

P	w	r	X	X	X	m	W
---	---	---	---	---	---	---	---

Laser power is shown in milliwatts as detected by a photomonitor in the head. The Control Dial may be used to adjust the power level. This change is made by changing the voltage on the adjust line to the laser head. The voltage on the front panel BNC will also change. If a voltage is applied to the front panel adjust, the applied voltage will override the internally generated adjust signal.

Pressing the SET button will cause the adjust voltage to go to zero and return the power to its default level.

Pressing the SET button again will activate a calibration mode which allows the user to calibrate the display against a power meter. During calibration the display will show:

C	A	L	X	X	X	m	W
---	---	---	---	---	---	---	---

The Control Dial is used to match the display value to the desired value.

Pressing the SET button will cause recalculation and saving of the new power scale factor.

If the new value is not desired, press DISPLAY or STANDBY to cancel function.

3.3.3 Power Adjustment

The format is:

A	d	j		±	X	X	
---	---	---	--	---	---	---	--

The laser is shipped, and generally will perform best, with the Power Adjust set to zero offset ("ADJ 0"). The power can be increased by turning the Control Dial clockwise, or decreased by turning it counter-clockwise. In the fully clockwise position the display will read "ADJ +10", while it will read "ADJ -50" in the fully counter-clockwise position.

Pressing the SET button will return the power to its default level ("ADJ 0").

Changing the Power Adjustment setting will vary the voltage on the POWER ADJUST BNC. If a voltage is applied to the POWER ADJUST BNC, this applied voltage will override the internally generated Power Adjustment signal.

The Power Adjustment setting is retained when the laser is turned off and will be used when the laser is turned on at a later time.

NOTE: The Power Adjustment setting will affect the lifetime of the diode laser. The more negative the value, the longer the anticipated lifetime of the diode.

3.4 EXTENDED DISPLAY RANGE

If the Display range DIP switch on the rear panel is set to the extended display range, the following additional functions can be shown on the display by successive presses of the button:

3.4.1 Diode Current Monitor

The format is:

D	C		X	X	X	∧	A
---	---	--	---	---	---	---	---

This display shows the DC current to the diode laser as read by an active current monitor in the laser head. The Control Dial may be used to adjust the diode current level. This change is similar to adjusting the Power Adjustment setting. Pressing the SET button will return the current to its nominal (factory ship) level.

Since the Diode Current Monitor is an active reading, it will accurately reflect changes to the diode current made by altering the Power Adjustment setting or by applying a voltage to the POWER ADJUST BNC on the power supply's front panel.

To change the nominal (factory set) value of the diode current, see Section 2.4.2.

3.4.2 Diode Power Monitor

[This feature is available on some units, usually by special request only.]

The format is:

D	P	M	-	X	X	X	V
---	---	---	---	---	---	---	---

This display monitors the output of the diode laser. The reading indicates the voltage on the diode's internal photomonitor and is not calibrated to the diode's actual power. Thus, this information is useful as a relative gauge of diode power.

The Control Dial and SET Button have no function in this display.

3.4.3 Noise Reduction Control

The format is:

N	E	O	N	/	o	f	f
---	---	---	---	---	---	---	---

The noise reduction electronics may be turned ON or OFF by pressing the SET button. Capital letters indicate the current state.

Pressing the SET button changes the state and stores the new state. If the laser is turned off or placed in the Standby Mode, the power supply will remember the current state and return to this state when turned back on or brought out of the Standby Mode.

The Control Dial has no function in this display.

See Section 6.5 for additional information regarding the noise reduction electronics.

3.4.4 Diode laser Control

The format is:

L	D	O	N	/	o	f	f
---	---	---	---	---	---	---	---

This function allows the diode laser to be turned off, similar to the Standby Mode, but also allows the user to toggle through the display range. (In Standby Mode the display will read "STANDBY" or given system configuration options, as described in Section 3.5.) Pressing the SET button changes the selected state. If the laser is turned off or placed in Standby Mode with the Diode laser Control set to OFF ("LDon/OFF"), the diode laser will be turned back on ("LDON/off") when the laser is turned back on or brought out of Standby Mode.

The Control Dial has no function in this display.

3.4.5 Display Brightness

The format is:

D	i	s	p	l	a	y	X
---	---	---	---	---	---	---	---

The brightness of the display is indicated by a number from 0 to 7 corresponding with minimum to maximum brightness. The factory set value is 5. Turning the Control Dial will change the brightness of the display. Pressing the SET button will save the displayed value.

The value "0" will turn the display off completely, for applications requiring less light. This value is saved as "1" if the laser is turned off so that the display can be read upon power up.

3.4.6 Diode Temperature

The format is:

D	T		X	X	X	°	C
---	---	--	---	---	---	---	---

The Diode Temperature is displayed. This is an informational display only, as this parameter is set at the factory and stored in the laser head.

The Control Dial and SET button have no function in this display.

3.4.7 Diode TEC Voltage

The format is:

D	T	E	C	±	X	X	V
---	---	---	---	---	---	---	---

The Diode TEC (Thermo Electric Cooler) voltage is displayed. This is an informational display only, as this voltage is controlled by electronics in the head. This voltage is positive when the diode is being cooled and negative if heated. The maximum voltage is about 4 volts. In typical operation, this voltage would go up to the maximum for several seconds after turn on and then back down to a lower level depending on laser type and ambient temperature.

The Control Dial and SET Button have no function in this display.

3.4.8 Measured Crystal Temperature

The format is:

L	T		X	X	X	°	C
---	---	--	---	---	---	---	---

The Measured Crystal Temperature is an informational display which shows the measured value of the crystal temperature. It cannot be altered directly with the Control Dial or SET button, although altering the Target Crystal Temperature (Section 3.3.1) set point will change the Measured Crystal Temperature value. This number may correspond to the Target Crystal Temperature set point, but may be different if a voltage is applied to the SLOW FREQUENCY BNC on the power supply's front panel. In this case, the Measured Crystal Temperature reading is accurate since the Target Crystal Temperature is only a set point, and not a monitor. The Measured Crystal Temperature also may vary from the Target Crystal Temperature set point if it is not calibrated, as discussed in Section 3.5.2.

3.4.9 Laser Crystal TEC Voltage

The format is:

L	T	E	C	±	X	X	V
---	---	---	---	---	---	---	---

The laser crystal TEC (Thermo Electric Cooler) voltage is an informational display only, as this voltage is controlled by electronics in the head. The voltage is positive when the laser crystal is cooled and negative when heated. The maximum voltage is about 4 volts. In typical operation this value will be around zero volts, depending on the laser type and the crystal temperature setting.

3.5 SYSTEM CONFIGURATION OPTIONS

Two options for configuring the operation of the laser system are available from the front panel. These options are selected by pressing the DISPLAY button while the display reads "STANDBY". Listed below, they will be sequentially selected when the DISPLAY button is pressed.

1. Wide/Normal Laser Crystal Temperature Display
2. Crystal Temperature Center Calibration.

If the DISPLAY button or SET button is not pushed again within 4 seconds the display will return to "STANDBY".

3.5.1 Temperature Range Select

The format is:

N	O	R	M	/	w	i	d
---	---	---	---	---	---	---	---

Standard Series 126 lasers have a 30° C crystal temperature range; however, a special wide-tuning model is available with a 60° C range. This display configures the power supply to correctly model the Target Crystal Temperature set point as having either the standard range or the wide-tuning range. Pressing the SET button will change the selected state. Note that this does not change the actual range of the laser crystal's temperature, only the display's range.

The Control Dial has no function in this display.

3.5.2 Center Temperature Calibration

The format is:

C	+	X	X.	X	X	X	X
---	---	---	----	---	---	---	---

The Target Crystal Temperature reading ("T+XX.XXX^") is determined by reading the encoder on the Control Dial to generate an offset from a specified Center Temperature. The above display indicates this Center Temperature. This display is for information only and turning the Control Dial will have no effect on the display.

Pressing the SET button once will zero the internally generated offset voltage and the display will change to show the monitored temperature of the laser crystal as:

C	A	L	X	X.	X	°	C
---	---	---	---	----	---	---	---

Pressing the SET button a second time will calibrate the Center Temperature value to be equivalent to the displayed "CAL" temperature. It is best to wait a few moments before pressing the SET button the second time to allow the crystal temperature to stabilize.

This calibration function is designed for use when the Crystal Temperature Potentiometer on the laser head is adjusted or the power supply is switched to a different head.

Note that if the SET button is pressed at least once, when the laser is brought out of the Standby Mode the Target Crystal Temperature will be set to the Center Temperature.

3.6 OTHER MESSAGES

3.6.1 LASE Head Status

The format is:

H	D		S	T	D	B	Y
---	---	--	---	---	---	---	---

If the power supply senses that the "LASE" signal (see Section 2.3.2) is held low when the power supply comes out of Standby Mode, it will display the above message. This condition could be caused by another control device holding the "LASE" line low or possibly by a failure in the head.

Pressing the DISPLAY button will show the last display function used.

3.6.2 Heat Temperature Fault

The format is:

H	D		F	A	U	L	T
---	---	--	---	---	---	---	---

If the laser head or diode laser become too hot, the head will generate a fault condition and display the above message. If the laser is in the Standby Mode at the time the laser or diode becomes too hot, the above message will be displayed when the laser is brought out of Standby Mode.

Pressing the DISPLAY button will show the last display function used if the error condition goes away. If the temperature is not reduced, the error message will remain.

3.7 RS-232 OPERATION

These instructions apply to software dated Apr 28, 1995 and later, for the Model 125/126 microprocessor-controlled laser power supply.

3.7.1 Introduction: Laser Serial Interface

When a Series 126 laser head is combined with a Model 125/126 power supply, it is possible to communicate with this laser system through RS-232 protocol. (This is possible only with the 125/126 microprocessor-controlled power supply, not with the A 12512/6 analog power supply). The RS-232 serial interface provides the user with the ability to monitor and control the laser electronically. This feature is useful in many applications, including:

1. Operating the laser from a computer or terminal.
2. Incorporating the laser into an automated system.
3. Local and remote fault diagnosis.
4. In manufacturing, to assist in calibration.

This communication is achieved via connection to the 9-pin D-connector on the rear panel of the power supply. This connector has the same pin-out as an "IBM-compatible" personal computer.

Hardware and Software Required

In addition to the Lightwave Series 126 laser head, and the 125/126 power supply, the following are required:

1. Computer, for instance an IBM-compatible or Apple Macintosh PC.
OR
"Dumb" computer terminal (or PC emulating a terminal).
2. Pair of modems and phone line, if remote operation is required.
3. Appropriate serial cable to connect the computer, terminal or modem to the 9-pin connector on the rear of the 125/126 power supply.
4. Software to enable RS-232 communication between the computer or terminal and the laser system.

Hardware Configuration

The overall layout of the setup is shown in fig. 1. The 126 laser head must be connected to the 125/126 power supply using the supplied umbilical and DC power cables, as for stand-alone operation of the laser. The 9-pin female RS-232 connector on the rear of the power supply needs to be connected to a serial port of a terminal, host computer, or modem. This port usually has a 9- or 25-pin "D" connector; on a terminal the connector is usually labeled "Modem", on a PC it is labeled "Serial Port".

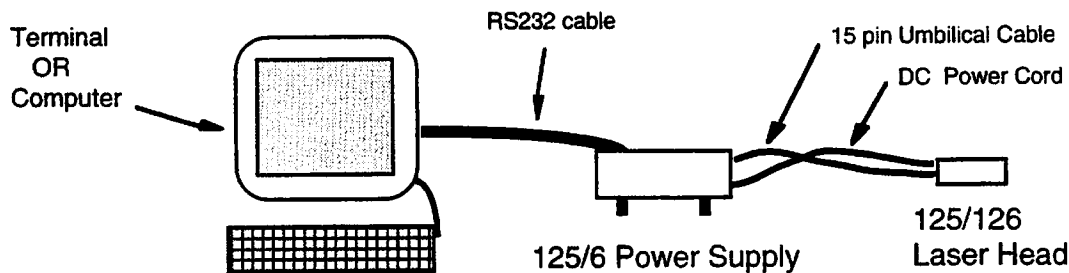


Figure 3-3: Serial port cabling when using the laser with a terminal or computer.

The functions of the pins, at the power supply, are:

2	/RxD	Received Data (into the Model 125/126)
3	/TxD	Transmitted Data (from the Model 125/126)
5	/Gnd	Ground
7	/RTS	Request To Send (Not Implemented)
8	/CTS	Clear To Send (Not Implemented)

The serial communications cable required depends on what device the laser system is connected to. For connecting the laser system to a terminal or computer the cable must provide the connections shown in Fig. 2. For connecting to a modem, the cable is similar, but pins 2 and 3 at the power supply connect directly to pins 2 and 3 respectively at the modem, i.e. the pin 2 and 3 wires are not crossed in this case.

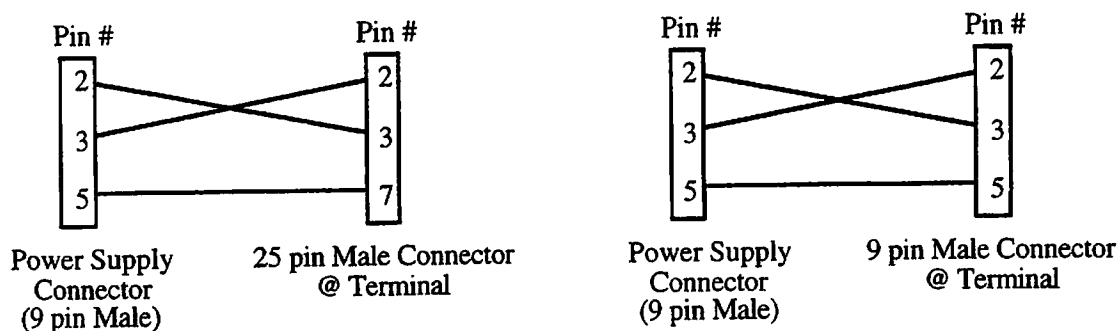


Figure 3-4: Serial port cabling when using the laser with a terminal or computer.

Communication Settings

The following settings are needed for proper communication:

Baud Rate:	9600 or 1200 (can be set on power supply)
Parity:	None
Data Bits:	8
Stop Bits:	1
Duplex:	Full

The baud rate of the laser is set using the Baud Rate DIP switch (see Section 3.1 of the manual). For operation with a terminal or host computer, 9600 is the recommended baud rate. With a modem, 1200 is recommended. The Baud Rate DIP switch is read by the internal microprocessor only upon power-up. Therefore, the unit must be turned off and then on again to change the baud rate.

3.7.2 Operating modes

There are two different ways to monitor and control the Series 126 laser system. The first is Screen Status and Control which provides direct visual feedback of the laser parameters and simple control from a terminal. The second is Remote Computer Control which provides a means to interact with the laser system from a computer program.

Screen Status and Control from a Terminal

This approach provides a screen display of the Series 126 laser operating parameters. The screen control commands are executed from a terminal (or a personal computer (PC) running terminal emulation software) that is connected to the Model 125/126 power supply.

The power supply sends information in a format that is compatible with a Lear Siegler ADM-3A or Televideo 912 terminal. Any terminal that can be set to emulate one of these terminals can be used. A PC can also be used, in which case software is required to emulate the appropriate terminal. The software "Crosstalk Communicator" and "Procomm Plus" have been demonstrated to work at Lightwave. In "Procomm Plus" the terminal emulation selected should be the Lear Siegler ADM-3A. In "Crosstalk Communicator" the correct selection is the Televideo 912.

The 9-pin female RS-232 connector on the rear of the power supply needs to be connected to what is usually a 25-pin connector on the terminal or PC. On the terminal the connector is usually labeled "Modem". On a PC it is labeled "Serial Port".

Typing an "S" on the keyboard initiates on-screen display of the laser parameters. These parameters will appear on the right side of the terminal screen. The screen will be updated every 2 seconds after sending an "S" to the power supply. Screen control and updates are terminated by entering an "ESC" character on the keyboard. Screen Control mode is automatically disabled if a command in the computer interface format is received. These commands are described in detail below. They may be typed by hand from a terminal for transmission to the laser system, for instance for testing purposes

Frequency Tuning: One of the most common operations users perform is changing the laser crystal temperature to tune the laser frequency. There is a simple way to perform this operation: Simply send a "+" or "-" to the laser through the RS-232 port. Each "+" or "-" changes the crystal temperature by the smallest increment or decrement. This simple control method may be used both from a terminal or from a computer program. Upon receiving one of these commands, the display will change to show the temperature.

Remote Computer Control

Control of selected parameters of the Series 126 laser by a computer program may be accomplished via sending commands to the RS-232 port on the Model 125/126 power supply. This requires that the user write or have available a program that can transmit specific ASCII strings to the RS-232 interface. These ASCII commands are described below.

3.7.3 RS-232 Commands

The general protocol for Lightwave lasers consists of sending an ASCII "command string" with the following format:

Escape lead-in char, command code, parameter, optional data, End of String.

The Series 126 will not send strings except in response to commands.

Command Notes:

- (1) There are two types of command: one that does not require data, and one that does require data.
- (2) Each command string has a fixed length. Decimal points are implied by position. Leading zeroes are required.
- (3) If a command string of the wrong length is received, a NAK (15 hex), without LF CR, is the Series 126's reply.
- (4) An ESC starts a new command string. If an ESC is received before a command string has been completed, that command is aborted, and "? LF CR" is sent by the Series 126.
- (5) CR (Carriage Return) and LF (Line Feed) may be used interchangeably.

e.g. the 126 receives ESC 0 1 0 ESC 0 4 0 LF CR. The 2nd ESC aborts the first command, causes a "?" to be sent, and starts a new command. On a terminal, the reply would look something like

? 126 28 APR 95

Command String Format:

Byte	
0	ESC
1	LASER Number (Must be "0" at present; reserved for future use)
2	Command
3	Parameter
[4]	MSB Command Specific Data (Most Significant Byte)
[.]	Next MSB
[.]	
[.]	LSB data (Least Significant Byte)
Last-1	EOS 1 (End Of String byte 1. LF, [0Ah in hex or Control J] default.)
Last	EOS 2 (End Of String byte 2. CR, [0Dh in hex or Control M] default.)

Command. No Data required

Byte 0	ESC
Byte 1	LASER Number
Byte 2	Command
Byte 3	Parameter
Byte 4	LF
Byte 5	CR

Command, four digits data required

Byte 0	ESC
Byte 1	LASER Number
Byte 2	Command
Byte 3	Parameter
Byte 4	MSB data (ASCII, in HEX)
Byte 5	next MSB data
Byte 6	next MSB data
Byte 7	LSB data
Byte 8	LF
Byte 9	CR

Byte 1: LASER Number:

NOTE: Currently the software is able to address only one laser system, so this parameter must be set to 0.

0	1st LASER (LASER 0)	(ASCII 0, 30h)
1	2nd LASER (LASER 1)	(1, 31h)
n	nth . . .	

Byte 2: Command:

0	Increment Parameter	(ASCII 0, 30h)
1	Decrement Parameter	(1, 31h)
2	Turn Parameter on	(2, 32h)
3	Turn Parameter off	(3, 33h)
4	Read Parameters Current Value	(4, 34h)
5	Read Parameters Default Value	(5, 35h)
6	Set Default to Current Value	(6, 36h)
7	Set Parameter to Default	(7, 37h)
8	Start Parameter Procedure	(8, 38h)
9	Write Data to Parameter	(9, 39h)

Byte 3: Parameter:

NOTE: The first ten are common to all LWE Models. Model Specific Parameters follow.

Universal Parameters:

0	Model Number & Software Date	(ASCII 0, 30h)	
1	LW and Head Number	(1, 31h)	Not used.
2	Chassis Serial Number	(2, 32h)	
3	Hours Since Service	(3, 33h)	Not used.
4	Total Hours	(4, 34h)	Not used.
5	End Of String (EOS) Characters	(5, 35h)	
6	Diode On/Off (Standby)	(6, 36h)	
7	LASER Power	(7, 37h)	
8	Interlock	(8, 38h)	
9	Fault Status	(9, 39h)	

Lightwave Electronics Series 126 Laser Specific Parameters:

A	Diode Current Adjust	(ASCII A, 41h)
C	Diode Power Setting	(C, 43h)
D	LASER Temperature Setting	(D, 44h)

A summary of the commands and parameters is given in the following table:
In the table, a "✓" indicates that this operation is valid.

Command:	incr	decr	On	Off	Rd	Def	St D	S2D	Strt	Writ
Command Code:	0	1	2	3	4	5	6	7	8	9
Parameter:										
0 Model ID					✓					
1 Head #										
2 Chassis #					✓					
3 Serv Hours										
4 Total Hours										
5 EOS Char										
6 Laser On			✓	✓	✓					
7 Laser Pwr					✓					
8 Interlock					✓					
9 PS Status					✓					
A Diode Cur Ad	✓	✓			✓			✓		
C Diode Pwr					✓					
D Laser Temp					✓			✓		✓

Note on Diode Cur Adj: Because the displayed resolution is less than the output resolution, only every second or third increment or decrement will be seen as a change on the display.

Here are sample commands to the power supply:

	<u>Command</u>			<u>Function for 126</u>	<u>Example</u>	<u>Response Format</u>
	L	C	P D			
	N	C	MD			
esc	0	4	0	LF CR	Read Model # & Date	125 20 APR 95 125 dd MMM yy
esc	0	4	2	LF CR	Chassis Serial Number	01099 nnnnn
esc	0	9	5 00	LF CR	Set End Of String Chars	OK OK
esc	0	7	5	LF CR	Set EOS Chars to Default	OK OK
esc	0	2	6	LF CR	Diode On (Leave Standby)	DIODE ON DIODE ON
esc	0	3	6	LF CR	Diode Off (Standby)	DIODE OFF DIODE ON
esc	0	4	7	LF CR	Read LASER Power	Pwr 85 mW Pwr nn mW
esc	0	4	8	LF CR	Read Safety Interlock Status "status" = OPEN or CLOSED	ILOCK OPEN ILOCK status
esc	0	4	9	LF CR	Read Power Supply Status	0 * see below
esc	0	0	A	LF CR	Increment Diode Current Adj	ADJ -35 ADJ +/- nn
esc	0	4	A	LF CR	Read Diode Current Adj	ADJ -35 ADJ +/- nn
esc	0	7	D	LF CR	Set Temp to Center of Range	38.0000 nn.nnnn
esc	0	4	D	LF CR	Read Laser temperature	56.7765 nn.nnnn

LN = Laser Number
CC = Command Code
PM = Parameter
DD = Data

<u>* Status Response:</u>	<u>Meaning:</u>
No Fault	No Faults Detected
ILCKOPEN	BRH Interlock is Open
LASER ON	Laser on, diagnostic cable is not connected
CABLE ?	Diagnostic cable is not connected
HD STDBY	The head is in Standby
HD FAULT	The head is reporting a fault

Laser Temperature Write

This command may be used often, so a detailed description of it follows:

The data sent to the Series 126 will be in the range from 0 to 65,535 in an ASCII hexadecimal format (OFFFHH). This data is exactly the value used by the 16 bit D/A converter that controls the temperature offset from the head center setpoint. This data will be translated for display purposes to the target temperature, added to the lowest temperature of the range and will return the converted data as a response on the RS-232 port.

As an example lets say we want to set the laser crystal temperature to 10 °C above a center temperature of 40 °C on a normal temperature range Series 125/6 which has a temperature range of 25 to 55 °C. Thus the value of the number to send would be

$$\left(\frac{(10+40) - 25}{55 - 25} \right) * 65535 = 54613$$

Converting this to hexadecimal gives a value to send of: D555

The sequence

Byte 0	ESC	ESC
Byte 1	Laser #	0
Byte 2	Command	9
Byte 3	Parameter	D
Byte 4	MSB data	D
Byte 5	next MSB data	5
Byte 6	next MSB data	5
Byte 7	LSB data	5
Byte 8	LF	LF (a Control J on a terminal)
Byte 9	CR	CR (a Control M on a terminal)

sent to the power supply will set the temperature to 50.000 (if the center temperature was 40) and change the display to reflect that. After receiving this command, the power supply will respond with the sequence:

5 0 . 0 0 0 3 LF CR

Possible Problems

Symptom: The terminal or PC looks like it's not getting anything at all

- Possible Cause: Pins 2 and 3 are switched on one end of the cable. Check and change if needed.
- Possible Cause: On the PC, the wrong serial port has been selected in the communication software. Check and change if needed.
- Possible Cause: In older power supplies, capacitor C12 on the power supply microprocessor board is the wrong value. It should be 0.001 μ F, but may be 0.1 μ F. If in doubt, remove this capacitor (for instance by bending back and forth until the wires break off) – the power supply runs fine without this component present.

Symptom: The terminal or PC is receiving information, but it looks like gibberish.

- Possible Cause: The baud rate is incorrect. Check the baud rate and other settings on the terminal or PC. Check the baud rate setting of the laser power supply (see Section 3.4.1). If you change this switch turn the supply on and off to register the change.
- Possible Cause: Your terminal or emulation program is not operating as a fully functional ADM-3A or Televideo 912 terminal.

If you have problems with an IBM compatible try these possible solutions:

- (1) Using a different COM port.
- (2) At the DOS prompt for 9600 baud on COM 1, type:
mode com1:96,8,n,2,r
- (3) Using a "Null Modem" cable or adapter to swap pins 2 & 3.
- (4) Disable any loading of mouse software in autoexec.bat and config.sys before rebooting.
- (5) If you are running multitasking software (MS Windows), give your task exclusive or high priority use of communications.

SECTION 4: MODEL A125/126 ANALOG POWER SUPPLY

Available as an option, the Series A125/126 Analog Power Supply provides an inexpensive method of powering Series 126 lasers for laboratory applications. The power supply converts a 90 to 250 VAC (50 Hz or 60 Hz) input voltage into +5 V and -4 V necessary for laser operation. It also provides features which simplify controlling the laser.

4.1 POWER SUPPLY SET UP

The laser head should be set up, as discussed in Section 2.1 and the power supply set up as described below. An illustration of the rear panel is shown in Fig. 4-1.

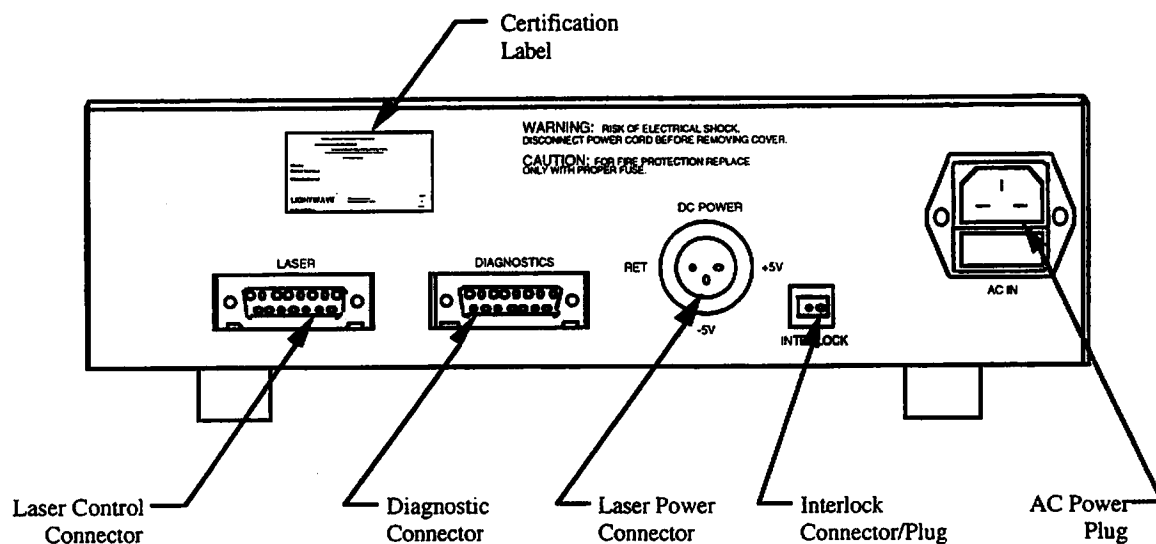


Figure 4-1: A125/126 Power Supply Rear Panel

4.1.1 AC Power Connection

Plug the power supply into an appropriate wall outlet. This should be done prior to connecting the laser head to the power supply.

Power input to the Model A125/126 can be any AC voltage 90 to 250 volts, 50 to 60 cycles. The AC power supply automatically identifies the line voltage and configures itself appropriately, so no voltage selection or jumpering is necessary. For 120 volt operation a 1.5 amp slow-blow fuse should be used. For 240 volts substitute a 0.75 amp slow-blow fuse.

4.1.2 Laser Power Connection

Connect the power supply to the Series 126 laser head with Lightwave Cable #4-1301, which is supplied with the power supply. This Power Cable will provide power to the laser head.

4.1.3 Laser Control Connection

Connect the power supply's Control Connector to the laser head's Control Connector with Lightwave Cable #4-1008. This Control Cable provides signals for all control and diagnostic signals going to and from the laser head.

Note that the head may be safely operated with just the DC power cable connected. Under these conditions the features of the Model A125/126 Power Supply (except STANDBY) will not be of use.

4.1.4 Diagnostic Connection

The Diagnostic Connection is used to connect the Diagnostic Accessory to the laser head, using the power supply as an intermediary. For more information on the Diagnostic Accessory, see Section 5.

4.1.5 Safety Interlock

The safety interlock allows the user to externally disable the laser for safety purposes. An example would be configuring the laser such that the interlock opens/closes when a door is opened/closed. The safety interlock is shipped with an "enable" jumper installed.

To utilize the interlock feature, remove the interlock plug and then connect the switch (or relay) contacts across the input. Internally, a "sense" circuit has a 10 k Ω pull-up resistor to +5 V. If the interlock circuit is open, or the input voltage exceeds 2.5 V, the laser will be disabled. Once the circuit is closed, the laser will return to Standby Mode. Operation is resumed by toggling the Standby Switch.

4.1.6 Power-Up Option

For lasers which are not Class IV (< 500 mW), the power supply may be reconfigured by the user to power up or return from an interlock condition to the mode indicated by the Standby Switch (i.e. the laser does not automatically power-up in Standby Mode). Access to the inside of the power supply is achieved by removing the four button head screws which attach the cover. To implement the Power-Up option, solder a jumper across pins 1 and 2 of JOPT.

Note: Do not implement the power up option for models 126-1064-500 or 126-1064-750. These are class IV laser products. As a result, implementing the power up option violates safety standards established by the Center for Devices and Radiological Health, U.S. Department of Health and Human Services. This is because a manual reset is required for Class IV products.

4.2 BASIC OPERATION

With the Series 126 laser head set-up and all connections properly made, the laser can be controlled entirely from the front panel of the Model A125/126 Power Supply. Figure 4-2, below, labels the various features of the Model A125/126 Power Supply.

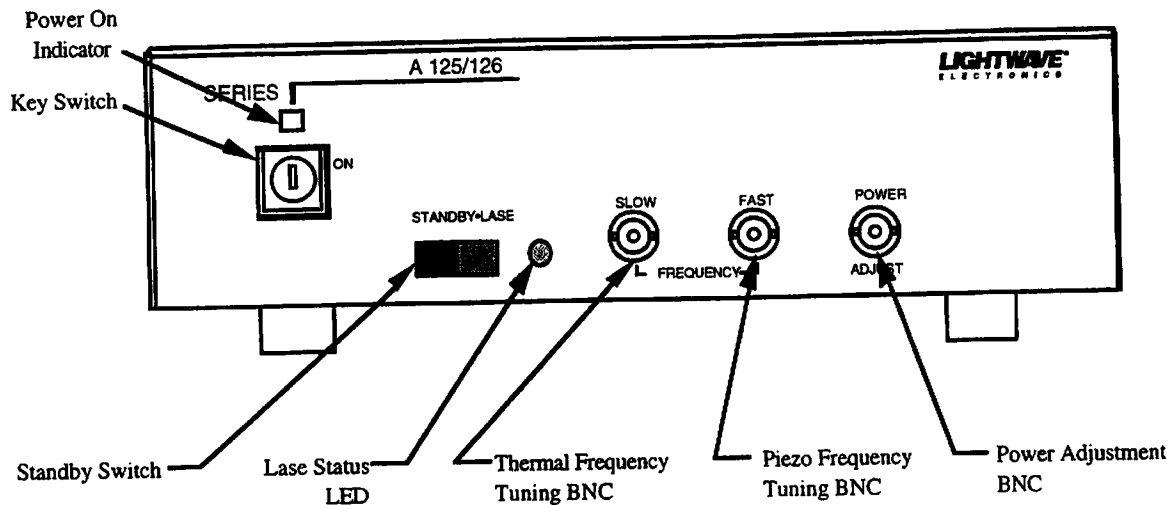


Figure 4-2: Model A125/126 Power Supply Front Panel

4.2.1 Turning the Laser On

Prior to turning the laser on, ensure that personnel in the vicinity have proper protective eyewear and that the beam path will be well contained. See Section 1.3 for details.

Turning the key 1/4 turn clockwise provides power to the laser head and power supply. Illumination of the Power-On Indicator above the key switch indicates that power is available to the laser head. When the key switch is initially turned to the ON position, the laser will complete its warm-up in Standby Mode.

Note that having the key switch in the ON position does not ensure the laser is emitting radiation, since the laser may be in Standby Mode or the shutter's cover may be closed.

4.2.2 Standby Mode

With the Standby Switch in the left position, the laser is in Standby Mode and the LED to the right of the switch is off. Flipping the Switch to the right will initiate lasing two seconds later (unless the LASE pin is held low, see Section 2.3.2). The Lase Status LED will turn on.

If the key switch has just been turned to the ON position or if the interlock has been closed after being open, the laser will return to Standby Mode even though the switch is in the LASE position. The Standby Switch must be cycled to STANDBY and back to LASE to enable lasing.

The Standby Switch will be operative with or without the Control Cable to the laser head's Control Connector. If the cable is not in place the V- voltage to the head will be disabled on the Power Connector when placed in Standby Mode. If the umbilical to the Diagnostic Connector is sensed, the Lase pin will be used to place the head in Standby Mode.

4.2.3 Lase Status LED

This LED indicates the condition of the laser as follows:

1. LED is continuously on. The laser is operating.
2. LED is off. The power supply or another device is pulling the Lase pin low on the Control Cable. This condition will occur after power-up or after closing an open interlock. This LED also will be off if the key switch is in the OFF position, in which case the Power On Indicator will also be off.
3. LED is blinking at a 1 Hz rate. The laser head is in a 15 second time-out or there is +5 V fault. If the +5 V line on the Power Cable is below 4.5 V, the laser will not turn on.
4. LED is blinking at a 5 Hz rate. This indicates a head temperature fault. Check the heat sinking of the laser head.

4.2.4 Slow Frequency Tuning

Voltage applied to the SLOW FREQUENCY BNC tunes the laser resonator by heating or cooling the laser crystal. Tuning primarily is due to the change in the index of refraction. This allows for a large tuning range, with a relatively slow time constant (approximately 1 to 10 seconds). The input impedance across this connector is 10 k Ω .

The tuning coefficient between mode hops (continuous tuning coefficient) will be approximately +3.8 GHz/Volt for 1319 nm lasers and +5.0 GHz/Volt for 1064 nm lasers. The tuning coefficient, as averaged across mode hops, is approximately +1.6 GHz/Volt for either wavelength. The maximum signal that should be applied is ± 10 V.

If the frequency is modulated at a rate of greater than ≈ 1 Hz, the response characteristics of the output to the input signal are complex due to the interaction of thermal loading on the crystal and the control electronics. However, the behavior may be approximated by considering the system to have two dominant time constants. Also, thermal propagation delays add phase shift as the input modulation rate increases. Additional information on thermal tuning is found in Section 6.3.3.

4.2.5 Fast Frequency Tuning

[This feature is not available on the 2013 nm laser (Series 126-2013)]

Fast frequency tuning of the Series 126 is performed by applying a voltage to the FAST BNC on the power supply's front panel. This voltage expands or contracts a piezo which is bonded to the laser crystal. This strain is sufficient to vary the laser's frequency. This feature acts the same as the PZ+ and PZ- pins on the Diagnostic Connector, as described in Section 2.3.

The tuning coefficient varies from laser to laser, but will be >1 MHz/Volt. For a specific laser, the tuning coefficient is given on the laser's Customer Data Sheet. The piezo acts as a capacitor with a capacitance of less than 10,000 pF. A voltage applied to the FAST FREQUENCY BNC directly drives the piezo without any intermediate electronics.

For relatively low modulation rates (less than 10 kHz), the laser frequency will be tunable over at least 30 MHz. At higher modulation rates, such large modulation depths may result in severe amplitude noise. For small modulation depths the laser may be modulated at rates up to 30 kHz. At frequency modulation rates above 30 kHz the piezo will still operate; however, the tuning coefficient becomes non-linear. For applications in which the laser will modulate at a fixed high modulation rate, and not vary, this should not present a problem.

When the piezo is not being used, electrical pick-up at the FAST FREQUENCY BNC may result in small, but observable, fluctuations of the laser. Either a short-circuit or a 50 Ω BNC terminator placed on the BNC should eliminate the problem of electrical pick-up.

CAUTION: The piezo element generates heat when operated and, in the extreme, this can lead to laser damage. Specifically, applying an RF signal will damage the laser. A signal of ± 50 V at a modulation rate of 100 kHz represents a safe extreme for piezo operation. If the user would like to operate at higher voltages or higher modulation rates than this, the user should consult Lightwave.

4.2.6 Power Adjustment

A positive voltage applied to the POWER ADJUST BNC will increase the laser output by increasing the diode drive current by 10 to 15% depending on its factory setting. The resulting increase in light out will be some what higher. Up to +10 V may be applied to this 10 k Ω input although only about +2 volts will have an effect.

A negative voltage will reduce the laser output by reducing the diode drive current. Applying a -10 V signal may turn the laser completely off although this is not guaranteed and the POWER ADJUST BNC should not be used as an interlock.

If the power is to be modulated, Lightwave recommends the noise reduction electronics be disabled. This is because the noise reduction electronics will "fight" to maintain a certain power level while the signal is asking for the power level to change. For more information regarding modulation, contact Lightwave Electronics.

SECTION 5: DIAGNOSTIC ACCESSORY

The optional Diagnostic Accessory is a useful tool for observing laser parameters and operation. The Diagnostic Accessory can display laser parameters, control functions in the laser, or be used as a digital voltmeter. A 15 pin male-to-male umbilical cable (#4-1008) is included.

A sketch of the Diagnostic Accessory is given in Figure 5-1.

5.1 CONFIGURATIONS

The Diagnostic Accessory may be used alone or in conjunction with a Lightwave-supplied power supply.

Used alone

Plug one end of a 15 pin cable into the laser head's Control Connector and the other end into either Diagnostic Connector on the Diagnostic Accessory. The other Diagnostic Connector may be used as a pass-through for user control signals. The Diagnostic Connectors are wired together such that either may be cabled to the head. While any 15 pin cable may be used, the Lightwave-supplied cable (#4-1008) is recommended since it incorporates shielded coaxial cable for the piezo signals.

Used in conjunction with a Lightwave Electronics' Power Supply

The Diagnostic Accessory may be plugged into the Diagnostic Connector on the rear of either the Model 125/126 or A125/126 Power Supply instead of directly into the laser head. An umbilical cable should also connect the power supply's Control Connector to the laser head's Control Connector. All signals are passed directly from the laser head through the power supply to the Diagnostic Accessory.

As when the Diagnostic Accessory is used alone, either 15 pin connector on the Diagnostic Accessory may be used, and the other 15 pin connector may be used for supplying control signals.

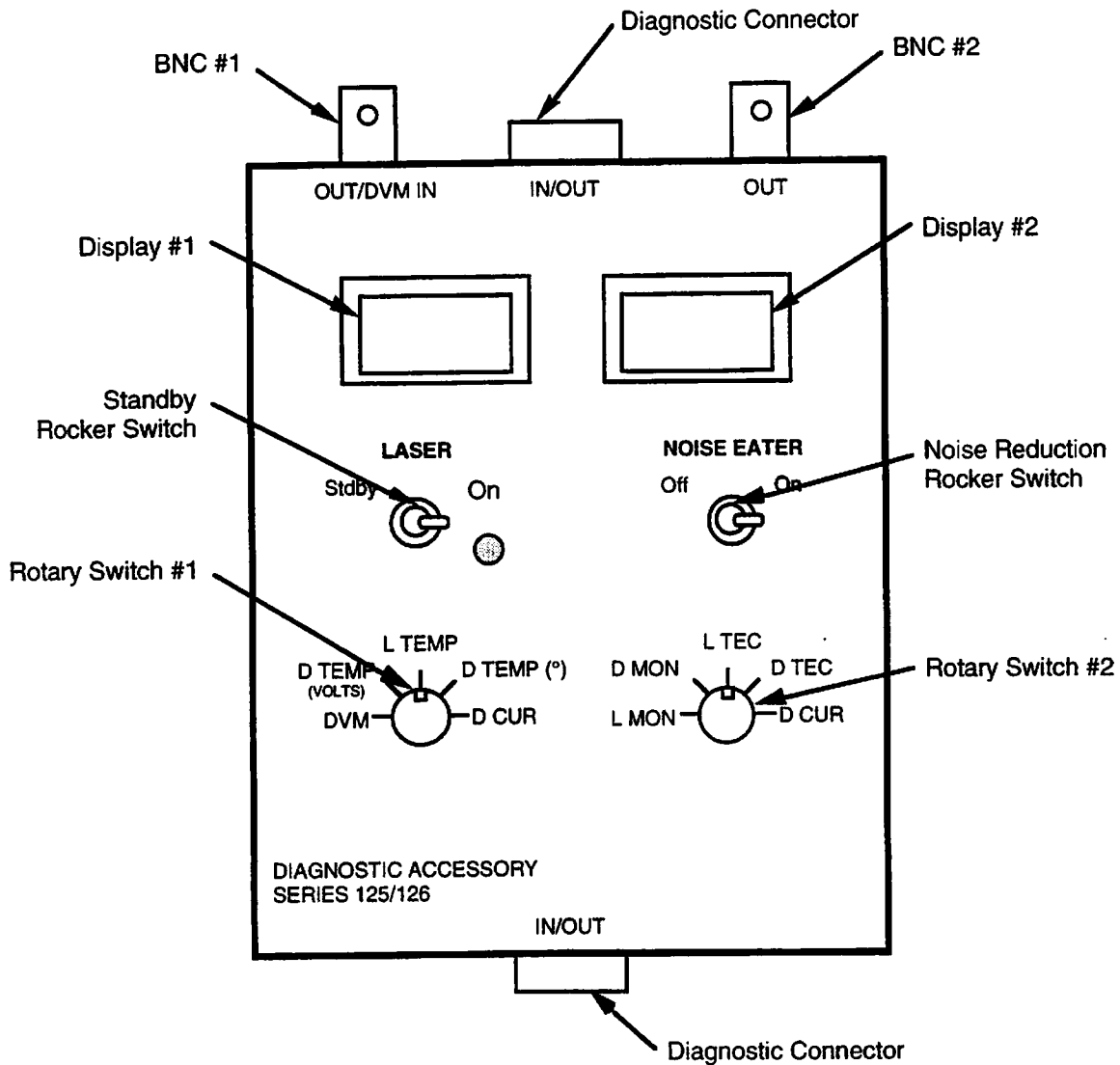


Figure 5-1: Diagnostic Accessory

5.2 OPERATION

Operation of the Diagnostic Accessory is fairly straightforward and described below.

Standby Rocker Switch

The Standby Rocker Switch controls current going to the diode. In the "ON" position current flows through the diode and the laser will emit radiation. In the "STDBY" position (Standby Mode) current to the diode is shunted, thus inhibiting emission.

If the Diagnostic Accessory is connected to a Lightwave power supply, both the Standby Switch on the Diagnostic Accessory or the Standby Button/Switch on the power supply will put the laser into Standby Mode. Only the Standby Button/Switch on the Lightwave power supply can initiate emission immediately after the laser is turned on or returns from an interlock condition.

Noise Reduction Rocker Switch

Toggling the Noise Reduction Rocker Switch to the "OFF" position will disable the noise reduction electronics. See Section 2.3.5, and/or Section 6.5 for additional information.

Diagnostics

Changing the position of a rotary switch will alter the display directly above the switch so the display shows the value of the parameter indicated by the switch. The corresponding BNC connectors provide output voltages which correspond to the parameters indicated by the rotary switches. The BNC voltages will mimic the voltages given on the displays.

- DVM** If Rotary Switch #1 is set to the "DVM" position the Diagnostic Accessory will function as a digital voltmeter. A voltage supplied to BNC #1 ("Out/DVM In") will be shown on Display #1.
- D TEMP (VOLTS)** This voltage provides raw information on the diode temperature. It reads +5 V at a temperature of 10° C and -5 V at a temperature of 35° C.
- L TEMP** This voltage indicates the measured crystal temperature, at 10° C per volt.
- D TEMP (°)** This value represents the temperature of the diode laser. The value is obtained by converting the D TEMP (volts) value into ° C.
- D CUR** This voltage indicates the diode current, at 1 amp per volt.
- D MON** This is an uncalibrated negative voltage used to monitor the power of the diode laser pump. (*On selected units only*)
- L MON** This setting provides an uncalibrated indication of the laser's power.
- L TEC** An indication of the voltage applied to the laser crystal TEC is provided with this setting. A positive voltage indicates cooling while a negative voltage means the TEC is heating. This voltage should not exceed +3.9 V or -2.5 V.
- D TEC** This setting indicates the voltage applied to the diode TEC. A positive voltage indicates cooling while a negative voltage means the TEC is heating. This voltage should never exceed +4.5 V or -2.5 V.

SECTION 6: THEORY OF OPERATION

6.1 TECHNICAL BASICS

6.1.1 Solid-State Lasers

Solid-state lasers contain a lasing medium which consists of light-emitting atoms fixed in a crystalline or glassy material. The light emitting atoms are referred to as the dopant, and the material they are embedded in is referred to as the host. Typically, the dopant accounts for about one percent of the total material. Examples of hosts materials are YAG (Yttrium Aluminum Garnet), YLF (Yttrium Lithium Fluoride) and Glass. Examples of dopants are Neodymium and Holmium. Generally, solid state lasers can emit light continuously (CW), in short powerful pulses (Q-switched), or in a continuous high repetition rate train of very short pulses (mode-locked).

6.1.2 History and Overview of Diode Pumping

Solid-state lasers have traditionally "pumped" their laser crystals with devices such as linear flashlamps or discharge arc lamps. Since its demonstration in 1962, the semiconductor diode laser has been widely seen as an important pumping alternative to flashlamps. It was not until the 1980s, however, that the technology of diode lasers as pump sources in solid state lasers reached commercialization. Diode pumping is now incorporated in continuous wave, Q-switched, and mode-locked lasers.

6.1.3 Advantages of Diode Pumping Over Lamp Pumping

In conventional flashlamp pumped lasers, over 90% of the flashlamp output is unused because it lies outside the absorption bands of the crystal. This highly inefficient coupling leads to heat stressing of components and diminished performance. On the other hand, diode laser pumping is extremely efficient due to the ability of diodes to be wavelength tuned to overlap their emission with a strong absorption band of the gain media. This allows nearly all of the pump light to be utilized. See Figure 6-1. The result is a solid-state laser which is compact, reliable, and long lived.

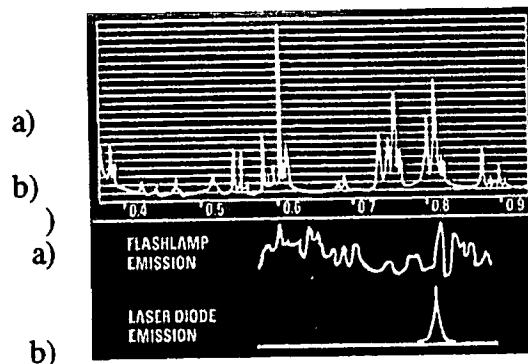


Figure 6-1: Nd:YAG Absorption and Pump Source Emission

Nd:YAG absorbs energy in a number of discrete bands as shown in a). In b) a flashlamp emits in a broad continuous band and the diode laser emits in a single discrete output. By temperature tuning, the diode laser output will overlap one of the discrete absorptions of the crystal laser for efficient coupling. On the other hand, much of the broad flashlamp output cannot be absorbed by the laser crystal and must be dissipated as heat.

6.2 SERIES 126 CRYSTAL RESONATOR

The monolithic, non-planar, ring resonator used in the Series 126 is often referred to in literature and this manual as a NPRO (Non-Planar Ring Oscillator). (Another common acronym for this resonator design is MISER, which stands for Monolithic, Isolated, Single-frequency, End-pumped Ring.) Features of this resonator are described below, and a schematic of a typical NPRO is given in Figure 6-2.

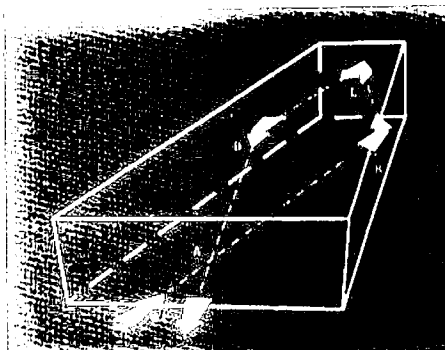


Figure 6-2: NPRO crystal design

6.2.1 Crystal Gain Media and Coatings

Most Series 126 lasers use Nd:YAG as the gain medium. This material typically is known for providing gain at 1064 nm; however, it also produces significant gain at a wavelength of 1319 nm. The Series 126 Nd:YAG NPRO may be coated so that it emits at a wavelength of 1064 or 1319 nm. In order to generate 2 μm output, NPRO's fabricated from Thulium:YAG are used in the Series 126-2013 laser. Other gain materials and wavelengths may be available; please contact Lightwave Electronics for more information.

6.2.2 Standing Wave Resonators vs. Ring Resonators

The standing wave pattern present in linear resonators does not completely saturate the gain medium. Wherever the field intensity is low, a region of low saturation (or higher gain) remains. This "spatial hole burning" decreases the degree of coupling between the various oscillating modes. This in turn leads to weak cross-saturation and allows additional longitudinal modes to oscillate simultaneously. Combined with the broad gain profile of the Nd:YAG medium, this effect leads to the multimode operation usually present in standing wave resonator lasers.

The Series 126 avoids the problem of spatial hole burning by using a unidirectional ring configuration which removes the effects of spatial hole burning. In the absence of spatial hole burning, and in the presence of the homogeneous broadening of Nd:YAG gain medium, the modes of the laser compete strongly for gain. This strong mode coupling leads to strong cross saturation, and a single dominant mode oscillating above threshold. Hence the ring configuration of the Series 126 promotes single longitudinal mode operation. The direction of oscillation is set by designing an optical diode into the optical resonator. In the case of the Series 126, this optical diode is obtained by applying a magnetic field to the crystal, and by using the polarization properties of the non-planar resonator configuration to increase the gain in one direction. This method provides the Series 126 with a single, unidirectional mode.

6.2.3 Monolithic Resonator Design

The stability of the Series 126 is obtained through its monolithic design. The mirrors of the laser cavity are the polished surfaces of the crystal. High mirror reflectivity is achieved through the use of either total internal reflection or through the application of optically reflective coatings to the surface of the crystal. The Series 126 achieves an even greater degree of stability since the pump source of the laser is a diode laser with stable output power.

The monolithic design, a stable diode laser pump, and non-planar geometry, coupled with the magnetic field applied on the crystal, provides the Series 126 with true unidirectional operation. The non-planar beam path within the crystal allows for a very compact design since only a few components are required.

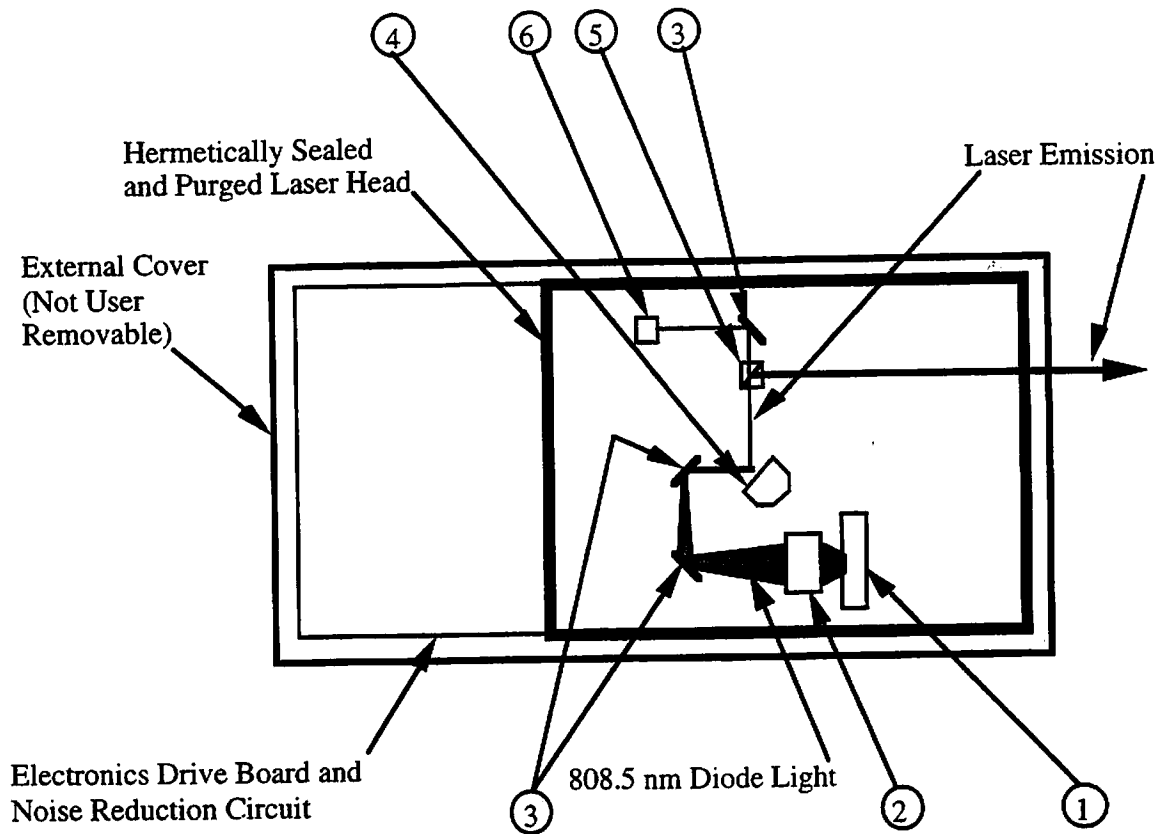
6.3 LASER HEAD LAYOUT

The optical layout of the Series 126 laser head is shown in Figure 6-3 on the following page and explained below.

6.3.1 Diode and Diode TEC

The diode laser is carefully selected at the time of manufacture for a wavelength that will give near optimal absorption for the doped - YAG gain medium. Gallium:aluminum:arsenide (GaAlAs) diode lasers are used to pump the laser medium, and their wavelength is a function of the aluminum content in the active region.

For example, a highly efficient absorption wavelength for Nd:YAG can be found at approximately 808.5 nm. Several other absorption wavelengths for Nd:YAG exist, but 808.5 nm is particularly attractive because diodes are available with outputs in this wavelength region. While diode manufacturers can control diode wavelength to within a tolerance of several nanometers, this is not sufficient for optimal absorption. Fortunately, the wavelength of the diode is also temperature dependent, increasing about 0.3 nm/ $\Delta^{\circ}\text{C}$. Thus, by increasing a diode's temperature a 805 nm diode can be brought to 808.5 nm, while cooling an 810 nm diode can bring it to 808.5 nm. For several reasons, it is more desirable to cool the diodes; the most important reason being that diode lifetime is improved. This fine tuning is done by cooling the diode with a thermo-electric cooler (TEC) under the diode package. To keep the diode precisely tuned to the absorption of the laser gain material the diode temperature is held constant using electronic feedback control.



Top View of Series 126 Laser Head

Laser Head Optical Components

1. Laser Diode Pump Assembly with Thermoelectric Cooler for Wavelength Tuning
2. Focusing Optic
3. Turning Mirror
4. Laser Crystal Resonator (NPRO) mounted on Thermoelectric Cooler for Thermal Frequency Tuning.
5. Beam Splitter
6. Photodiode used for Amplitude Noise Reduction

Figure 6-3: Optical Layout

6.3.2 Focusing Optics and Turning Mirrors

Output from the diode laser is manipulated through a series of imaging optics to be properly focused into the laser crystal. The diode facet is a single linear (rectangular) stripe with the divergences of the two axes being different. To obtain efficient pumping of the gain media, the light from the diode must be manipulated such that as it closely matches the mode volume of the crystal. This essentially involves fairly tightly focusing the diode light in a uniform pattern into the crystal. Series 126 lasers direct light into the laser gain medium through one end (end-pumping), as opposed to pumping through a side (side-pumping). An end-pumping geometry such as this is very efficient and leads to TEM₀₀ operation.

6.3.3 Laser Crystal and Frequency Tuning

The resonator of the Series 126 is a single crystal as explained in Section 6.2. Tuning of the wavelength of the laser is accomplished in two ways: heating of the laser crystal and inducing strain in the crystal with a piezo element.

By applying a voltage to a thermoelectric cooler (TEC) under the laser crystal the temperature of the crystal can be varied. Two primary effects of heating the crystal occur: the crystal physically expands and the index of refraction of the crystal increases. The crystal expansion leads to a physically longer cavity length, which slightly decreases the frequency of the laser. The increase in the index of refraction also makes the optical cavity length appear longer, and this leads to a further decrease in the output frequency. This allows for a tuning range over tens of gigahertz with a relatively slow time constant (approximately 1 to 10 seconds).

As it is tuned, a laser's frequency will vary in a fairly linearly manner until it reaches a mode hop. Where a mode hop occurs the frequency of the laser will jump back slightly. Tuning will then proceed in the same direction. This is schematically illustrated in Figure 6-4. The continuous tuning coefficient is approximately $-2.4 \text{ GHz}/^\circ\text{C}$ (1319 nm) or $-3.1 \text{ GHz}/^\circ\text{C}$ (1064 nm). The interval between mode hops is $>7 \text{ GHz}$ and the average tuning coefficient across mode hops is approximately $-1 \text{ GHz}/^\circ\text{C}$.

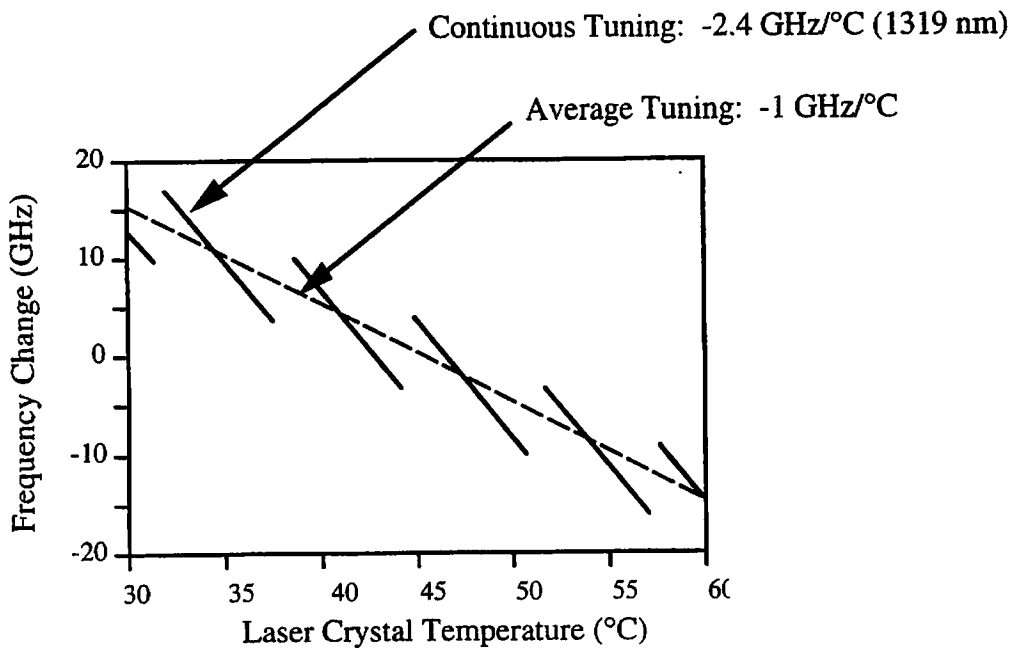


Figure 6-4: Typical Frequency Tuning Characteristics of a Model 126-1319-250

The single-frequency output of the laser can be quickly tuned over several megahertz by applying a voltage to an optional piezoelectric element bonded onto the crystal. Voltage applied to this element contracts or expands the laser crystal. This strains the crystal sufficiently to vary the frequency by tens of MHz at rates up to 30 kHz. The tuning coefficient is specified to be >1 MHz per volt and is given for each individual laser on the Customer Test Result Sheet. The piezo can operate at frequencies greater than 30 kHz; however, the tuning coefficient can vary fairly substantially above 30 kHz. The strain in the crystal also may slightly modify the laser output power. A positive applied voltage always leads to a positive absolute optical frequency change.

6.3.4 Photodiode

A photodiode is incorporated downstream of the NPRO and the electrical output from this photodiode would be used to monitor the laser's power and control the diode current.

The photodiode also is used to eliminate the relaxation oscillation and reduce relative intensity frequency noise. This is discussed further in Section 6.5.

6.4 DRIVE ELECTRONICS

A functional block diagram of the electronics for the Series 126 system is shown in Figure 6-5.

The major components in the laser head which require electrical power are the diode, the diode thermoelectric cooler (TEC), and the crystal resonator TEC. The drive currents for these components are supplied by drivers built into the printed circuit board (PCB) within the laser head. These component drivers require DC voltages which are supplied by the user or the optional Series 125/126 Power Supply.

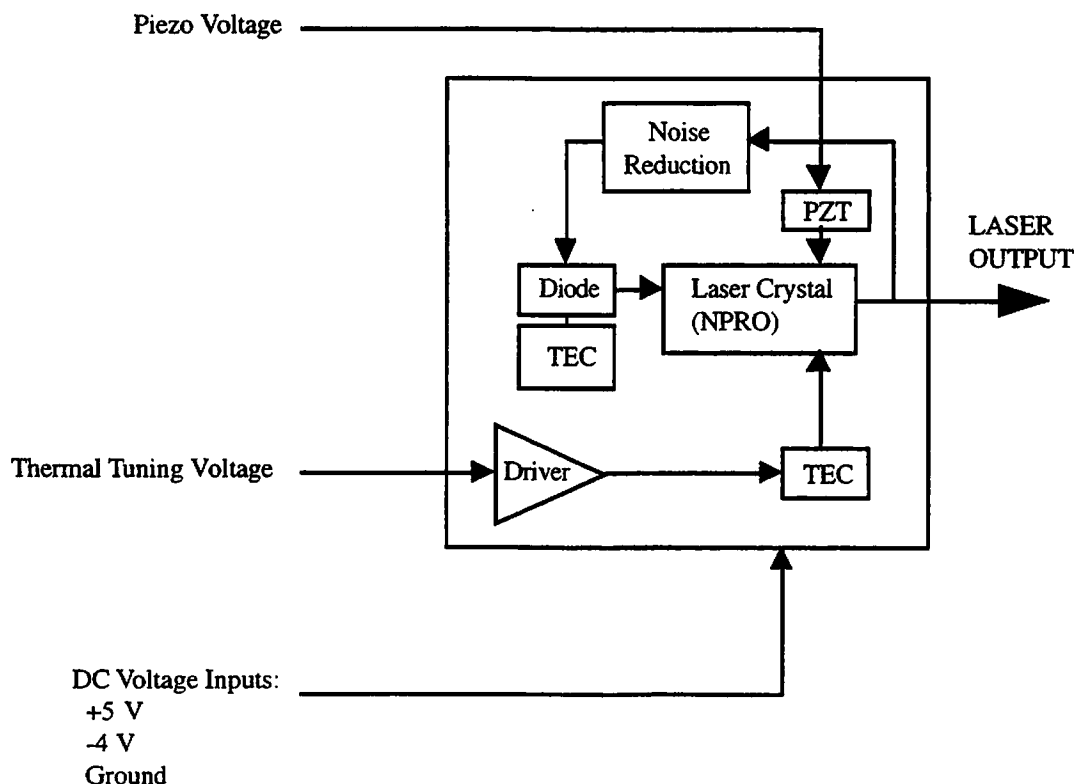


Figure 6-5: Electrical Functional Block Diagram

6.5 RELATIVE INTENSITY NOISE AND NOISE REDUCTION

Each Series 126 employs an amplitude noise reduction system which reduces both the rms and relative intensity noise (RIN) of the laser. RIN is a measure of the spectral distribution of the noise content of the laser. The rms noise is the amplitude modulation (AM) noise content measured and integrated over a certain frequency range (5 Hz to 1 MHz for the Series 126).

A typical plot of RIN for the Series 126 is shown in Figure 6-6. The noise reduction electronics can be turned on or off by altering voltage on pin #6 of the Diagnostic Connector.

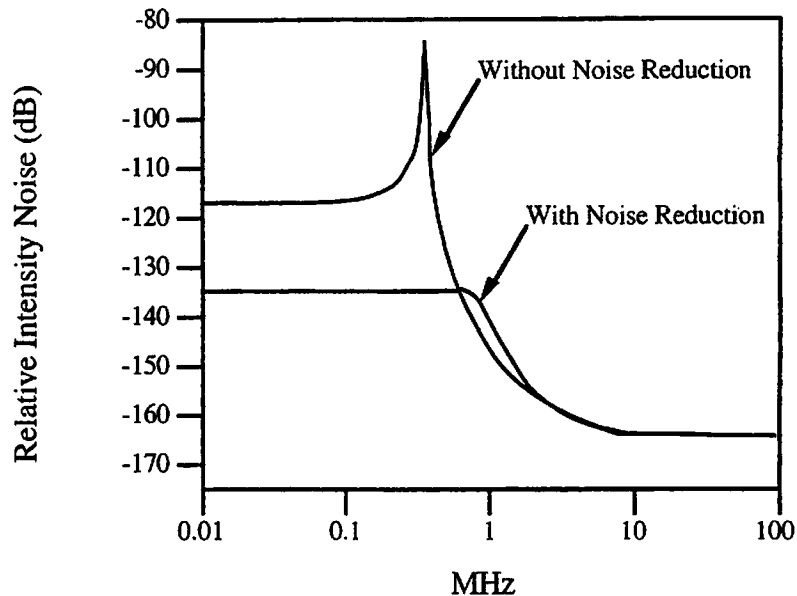


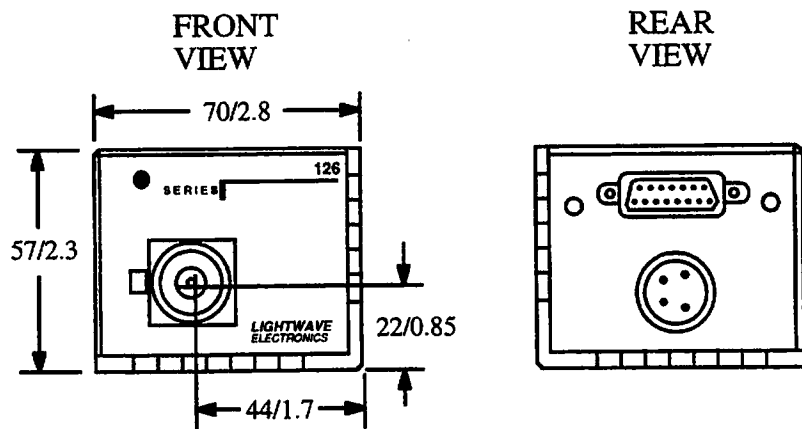
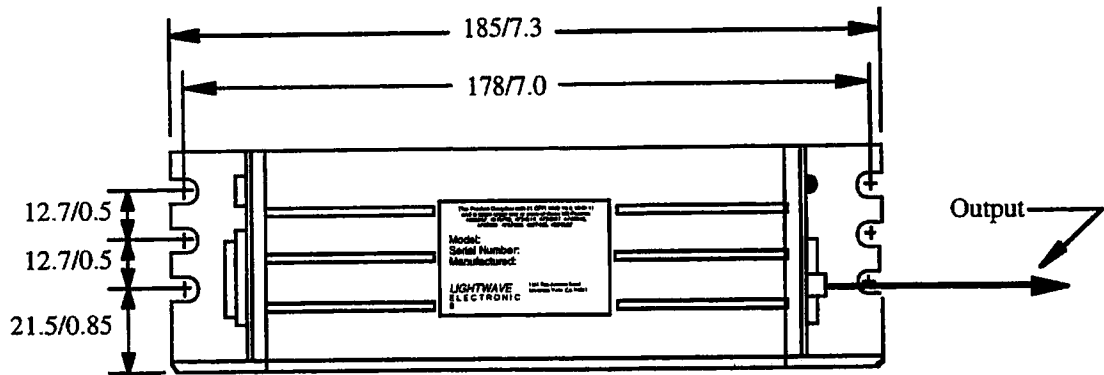
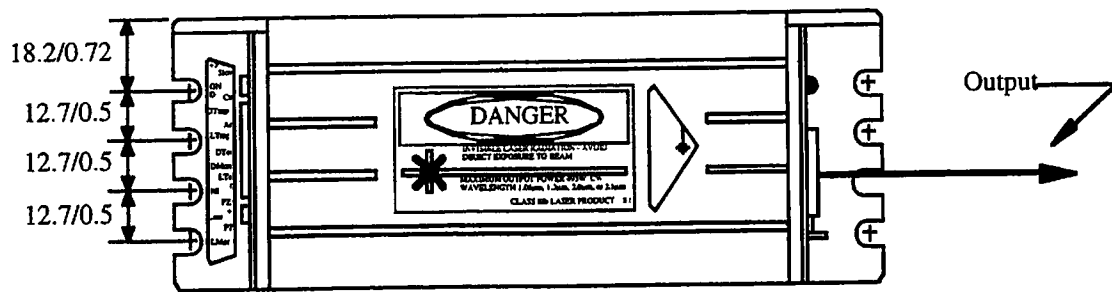
Figure 6-6: Typical Relative Intensity Noise (RIN) Spectrum

6.6 CONCLUSION

The Series 126 is a narrow-linewidth, single-longitudinal-mode source of radiation at 1319 nm or 1064 nm. The patented monolithic, non-planar ring oscillator ensures stable, single-mode output, while the diode pump reduces power inefficiencies and ensures a long-lived product. The frequency of the output can be tuned thermally over a broad range or can be modulated quickly over a smaller range. The package for the Series 126 has been kept compact and robust. A built-in noise reduction circuit virtually eliminates the relaxation oscillation and leads to a very low intensity noise. For applications such as the optical transmission of wide bandwidth analog communication signals, elimination of the relaxation oscillation is particularly useful since it simplifies system design.

APPENDICES

APPENDIX I: OUTLINE DRAWINGS



All dimensions are in mm/inches

Figure A1-1: Laser Head Mechanical Drawings

APPENDIX II: SPECIFICATIONS

Specifications	<u>126-1064-XXX</u>	<u>126-1319-XXX</u>	<u>126-2013-040</u>
<u>Output Beam</u>			
Wavelength	1064 nm	1319 nm	2013 ± 2 nm
CW Power ⁽³⁾	700, 500, 100, 200 mW	350, 250, 100 mW	40 mW
Spatial Mode	TEM _∞		
Longitudinal Mode	Single Frequency		
Amplitude Noise (10Hz to 10MHz)	< 0.1% rms	< 0.05 %	< 0.2% rms
Warm-up Time	< 1 minute		
Linewidth, over 1 msc.	< 5 kHz		
Coherence Length, calculated	> 1000m		< 10 kHz
Frequency Jitter	< 200 kHz/sec		> 500 m
Frequency Drift, at constant temperature	< 50 MHz/hour		
Thermal Tuning Range, continuous	10 GHz		
Thermal Tuning Range, total	30 GHz		
Thermal Tuning Rate	1 GHz/sec		
Piezo Tuning Range +15 V	30 MHz		None
Piezo Response Bandwidth, small signal	> 30 kHz		None
Polarization, linear	> 300:1, vertical		> 100:1, vertical
Waist Location, from shutter housing	5 cm outside laser		
Waist Diameter, 1/e ² , vertical	0.35 mm	0.38 mm	1.31 mm
horizontal	0.46 mm	0.50 mm	1.71 mm
Beam Divergence, full angle, vertical	3.9 mRad	4.4 mRad	1.9 mRad
horizontal	3.0 mRad	3.4 mRad	1.5 mRad
<u>Input & Ambient Requirements</u>			
DC Voltage/Current, max. load ⁽⁴⁾	+ 5 V/6 A, - 5 V/4 A		
Operating Ambient Temperature	10 to 45 °		
Relative Humidity, non-condensing	10 to 90 %		
<u>Size and Weight</u>			
Laser Head, wxhxh	7 x 6 x 19 cm		
Mass	0.9 kg		
<u>Series 125/126 Power Supply</u>			
Voltage, AC	90 V to 250 V~, 50Hz to 60 Hz		
Electrical Power Consumption ⁽⁵⁾	20 W Typical, 50 W Maximum		

Notes:

1. Specifications subject to change without notice.
2. The Series 126 laser is manufactured under one or more of the following US patents: 4578793, 4455657, 4734912, 4749842, and/or 4797896.
3. The last three digits of the model number specify the minimum output power. For example, a Series 126-1319-350 will produce an output beam with at least 350 mW. The power is specified for crystal temperature between 20 °C to 50 °C.
4. Assuming adequate heat sinking and 25 °C ambient. Typically much less, especially for lower power units.
5. Excess heat is dissipated in the baseplate of the laser head which requires adequate heat sinking for proper operation (see section 2.1.1).

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