

# *Explorer OEM*

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## Diode-Pumped, Q-Switched, Ultraviolet Laser System

### *User's Manual*

This laser product is intended to be sold to a manufacturer of OEM products for use as a component (or replacement thereof) in those products. As such, this product is exempt from performance standards of *United States Code of Federal Regulations*, Title 21, Chapter 1 – Food and Drug Administration, Department of Health and Human Services, Subchapter J – Parts 1040.10 (a), (1) or (2).



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## Preface

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This manual contains information for safely installing, operating and servicing your *Explorer* diode-pumped, Q-switched, frequency-tripled laser system. The system consists of an *Explorer* laser head and an *L-Series* power supply.

Chapter 1, “Introduction,” contains a brief description of the *Explorer* laser systems.

Chapter 2, “Laser Safety,” contains essential information for the safe use of these products. The *Explorer* is a Class IIIB laser and, as such, emits laser radiation that can permanently damage eyes and skin. This section contains information about these hazards and offers suggestions on how to safeguard against them. To minimize the risk of injury or expensive repairs, be sure to read this chapter—then carefully follow these instructions.

Chapter 3, “Laser Description,” contains a more detailed description of the *Explorer* laser systems and concludes with system specifications and outline drawings.

Chapter 4, “Controls, Indicators and Connections,” describes these three *Explorer* system components. Chapter 5 provides procedures for installing the laser and they refer to the component descriptions in Chapter 4.

Chapter 6, “Using the L-Win Software,” provides instructions for using the custom graphic user interface to operate the *Explorer* laser as a stand-alone system. This chapter also provides further descriptions of the extended *Explorer* models and some general considerations regarding laser output. A listing of the commands available through the *L-Win* interface is provided in Appendix A.

Chapter 7, “Commands and Signals,” provides detailed instructions for using serial commands and analog signals to control the laser. This chapter provides examples of different ways of configuring the laser output. A complete listing of the serial command language is provided in Appendix B.

Chapter 8, “Maintenance and Service,” is intended as a guide for routine maintenance, as well as for troubleshooting the laser to identify the source of possible problems. *Do not attempt repairs yourself while the system is still under warranty.* Instead, report all problems to Spectra-Physics for warranty repair. This chapter concludes with a list of world-wide Spectra-Physics service centers you can call if you need help. Should you experience any problems with any equipment purchased from Spectra-Physics, or if you are in need of technical information or support, contact Spectra-Physics.

Appendix A and Appendix B are references for the commands available through the *L-Win* interface and the serial command language, respectively. Appendix C lists all of the possible status codes returned via system queries.

Appendix D contains a short section on laser theory regarding the Nd:YLF crystal and the harmonic generation scheme used in the *Explorer*, as well as a brief description of some of the basic physics common to all lasers.

This product has been tested and found to conform to the provisions of Directive 73/23/EEC, the low-voltage directive governing product safety, and the provisions of EMC Directive 89/336/EEC for electromagnetic compatibility. Refer to the “CE Declaration of Conformity” statement in Chapter 2, “Laser Safety,” for a complete list of test specifications.

Every effort has been made to ensure that the information in this manual is accurate. All information in this document is subject to change without notice.

Spectra-Physics makes no representation or warranty, either express or implied, with respect to this document. In no event will Spectra-Physics be liable for any direct, indirect, special, incidental or consequential damages resulting from any defects in this documentation.

Finally, if you encounter any difficulty with the content or style of this manual, or encounter problems with the laser itself, please let us know. The last page of this manual is a form to aid in bringing such problems to our attention.

Thank you for your purchase of Spectra-Physics instruments.

# CE Environmental Specifications

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## CE Electrical Equipment Requirements

For information regarding the equipment needed to provide the electrical service listed in Table 3-2, please refer to specification EN-309, “Plug, Outlet and Socket Couplers for Industrial Uses,” listed in the official *Journal of the European Communities*.

## Environmental Specifications

The *Explorer* system is designed for indoor use. The environmental conditions under which the laser system will function are:

### Operating specifications:

Altitude	0 to 3000 m
Temperature	18°C to 35°C
Max. Baseplate Temperature	40°C
Relative humidity	< 80%, non-condensing
Mains supply voltage	not to exceed $\pm 10\%$ of the nominal voltage
Insulation category	II
Pollution degree	2

### Non-operating specifications:

Altitude	0 to 12000 m
Temperature	0 – 60°C
Maximum relative humidity	< 90%, non-condensing

## FCC Regulations

This equipment has been tested and found to comply with the limits for a Class A digital device pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference, in which case the user will be required to correct the interference at his own expense.

Modifications to the laser system not expressly approved by Spectra-Physics could void your right to operate the equipment.



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# Warning Conventions

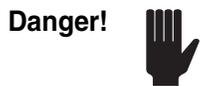
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The following warnings are used throughout this manual to draw your attention to situations or procedures that require extra attention. They warn of hazards to your health, damage to equipment, sensitive procedures, and exceptional circumstances. All messages are set apart by a thin line above and below the text as shown here.

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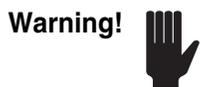
Laser radiation is present.



Condition or action may present a hazard to personal safety.



Condition or action may present an electrical hazard to personal safety.



Condition or action may cause damage to equipment.



Action may cause electrostatic discharge and cause damage to equipment.



Condition or action may cause poor performance or error.



Text describes exceptional circumstances or makes a special reference.



Do not touch.



Appropriate laser safety eyewear should be worn during this operation.



Refer to the manual before operating or using this device.

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## Standard Units

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The following units, abbreviations, and prefixes are used in this Spectra-Physics manual:

Quantity	Unit	Abbreviation
mass	kilogram	kg
length	meter	m
time	second	s
frequency	hertz	Hz
force	newton	N
energy	joule	J
power	watt	W
electric current	ampere	A
electric charge	coulomb	C
electric potential	volt	V
resistance	ohm	$\Omega$
inductance	henry	H
magnetic flux	weber	Wb
magnetic flux density	tesla	T
luminous intensity	candela	cd
temperature	Celsius	C
pressure	pascal	Pa
capacitance	farad	F
angle	radian	rad

Prefixes								
tera	$(10^{12})$	T	deci	$(10^{-1})$	d	nano	$(10^{-9})$	n
giga	$(10^9)$	G	centi	$(10^{-2})$	c	pico	$(10^{-12})$	p
mega	$(10^6)$	M	mill	$(10^{-3})$	m	femto	$(10^{-15})$	f
kilo	$(10^3)$	k	micro	$(10^{-6})$	$\mu$	atto	$(10^{-18})$	a



## Abbreviations

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The following is a list of abbreviations used in this manual:

ac	alternating current
AOM	acousto-optic modulator
APM	active pulse mode locking
AR	anti-reflection
CDRH	Center of Devices and Radiological Health
CPM	colliding pulse mode locking
CW	continuous wave
dc	direct current
E/O	electro-optic
fs	femtosecond or $10^{-15}$ second
HR	high reflector
IR	infrared
OC	output coupler
ps	picosecond or $10^{-12}$ second
RF	radio frequency
SCFH	standard cubic feet per hour
SPM	self phase modulation
TEM	transverse electromagnetic mode
UV	ultraviolet
VPA	variable power attenuator
$\lambda$	wavelength



# Unpacking and Inspection

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## Unpacking the Laser

Your *Explorer* laser was packed with great care, and its container was inspected prior to shipment—it left Spectra-Physics in good condition. Upon receiving your system, immediately inspect the outside of the shipping containers. If there is any major damage (holes in the containers, crushing, etc.), insist that a representative of the carrier be present when you unpack the contents.

**Keep the shipping container.** If you file a damage claim, you may need it to demonstrate that the damage occurred as a result of shipping. If you need to return the system for service at a later date, the specially designed container assures adequate protection.

## System Components

Two components comprise an *Explorer* laser system:

- *Explorer* laser head
- *L-Series* power supply

If ordered, an optional custom heatsink with fan and/or a wall-plug auto-ranging AC-DC converter will also be included with the shipment. Verify that all components are present. The laser system is shipped in a single container.

The power supply weighs approximately 0.9 kg (about 2 lb). The laser head weighs approximately 1.2 kg (about 2.6 lb). Both can be handled easily by one person.

## Accessory Kit

Included with the laser system is this manual, a packing slip listing all the parts shipped, and an accessory kit containing the following items (Spectra-Physics part numbers are given in parentheses):

- (1) laser head cable 1, 15-pin (PS-L08-Head1)
- (1) laser head cable 2, 26-pin (PS-L08-Head2)
- (1) jumper plug for the ANALOG IN connector
- (2) keys for the *L-Series* power supply





**Figure 1-1: The *Explorer* System**

Spectra-Physics *Explorer* systems are solid-state, Q-switched lasers that produce ultraviolet pulses at adjustable repetition rates up to 5 kHz. The *Explorer* laser is designed for applications where high pulse energy, low cost-of-ownership and ease of integration are essential.

This OEM laser provides stable pulse energy through the entire range of its operating repetition rate, as well as precise triggering or gating in response to user-provided signals. Changing the *Explorer* pulse energy or pulse repetition rate has very little impact on the laser beam parameters.

An *Explorer* system consists of the *Explorer* laser head and an *L-Series* power supply (Figure 1-1). Two versions of the *Explorer* OEM laser are available—the standard system that produces pulse energies up to 60  $\mu\text{J}$ , and a high-power system with pulse energies up to 120  $\mu\text{J}$ . In addition, both versions are available as “extended” models that provide advanced control of the timing of the output pulses.

All versions of the *Explorer* offer a variety of methods to control laser output: the choice of internal or external triggering or gating capability, a unique trigger output that is highly coincident with the laser pulses (“Opto-Sync”), and an internal pulse energy monitor that can measure the energy of individual pulses. In addition, the extended models provide Burst Mode and First Pulse Suppression (a description of the extended models capabilities is provided in Chapter 3.)

Explorer Model	Pulse Energy	Burst and FPS Control
Explorer -349-060-1KS	60 $\mu$ J	no
Explorer -349-060-1KE	60 $\mu$ J	yes
Explorer -349-120-1KS	120 $\mu$ J	no
Explorer -349-120-1KE	120 $\mu$ J	yes

Some of the advantages of the *Explorer* laser are:

- Actively Q-switched
- Variable repetition rate
- Variable pulse energy
- Excellent mode quality
- High peak power
- Superior pulse-to-pulse stability
- Reliable, rugged design
- Low jitter

## The *Explorer* Laser Head

The *Explorer* laser system was specifically designed for applications requiring a Q-switched ultraviolet beam with an adjustable repetition rate and with good mode quality in a cost-effective package. *Explorer* is a rugged, sealed unit designed for simple hands-free operation. The laser head is air-cooled or cooled by conduction through a heat sink.

All optical components are contained in the laser head itself. These include the Nd:YLF laser crystal, the diode laser pump source, and the nonlinear crystals that convert the fundamental infrared light into the 349 nm output beam. The nonlinear crystals are temperature controlled to maintain the phase-matching condition for efficient nonlinear optical conversion. The laser head also contains the Q-switch and its RF driver.

The two versions of the *Explorer* system use diode laser modules that have different pump powers. Both diode laser modules are typically operated at a derated power level in order to ensure extended lifetime.

Note



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The diode laser module is often referred to simply as the “diode” in the context of this manual, e.g., “the diode current.”

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## The *L-Series* Power Supply

The *L-Series* power supply provides the low-voltage, high-amperage drive current necessary to power the diode laser in the laser head. In addition, the power supply parallel interface attaches to the laser and provides monitor and control functions.

The power supply requires a single 24 Vdc, 3 A power source. Like the laser head, the power supply requires no water or external cooling connections. The *L-Series* power supply complies with the requirements of the European Union for safety, noise, and regulation of hazardous component materials. See Chapter 2 for certification details.

## System Control

As a component in a master system, the *Explorer* is designed to be controlled via serial commands and queries and/or analog signals provided by the host system. The host connects to the *L-Series* through the power supply serial port. The analog/TTL control signals can either be used alone or in combination with the serial commands. Combining the two methods provides the greatest control over the laser output. Both analog and serial controls are fully described in Chapter 7.

Custom *L-Win* control software for a Windows®-based personal computer is provided to operate the laser as a stand-alone device, for example when installing or servicing the unit. Operating the *Explorer* using the *L-Win* software is described in Chapter 6.

## Patents

*Explorer* systems are manufactured under one or more of the following patents:

4,653,056	4,979,176	5,577,060	5,999,544
4,656,635	5,018,152	5,579,422	6,185,235
4,665,529	5,080,706	5,608,742	6,504,858
4,701,929	5,127,068	5,638,397	6,697,390
4,723,257	5,155,631	5,651,020	6,816,536
4,761,786	5,410,559	5,745,519	6,822,978
4,872,177	5,412,683	5,801,403	6,890,474
4,894,839	5,436,990	5,812,583	
4,913,533	5,504,762	5,835,513	
4,977,566	5,561,547	5,907,570	RE: 34,192

*Windows* is a registered trademarks of the Microsoft Corporation.





Note



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The Spectra-Physics *Explorer* lasers are *Class IIIb—High-Power Lasers* whose beams are, by definition, safety and fire hazards. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage. *Because the ultraviolet beam at 349 nm is invisible, it is especially dangerous.* Residual light at 1047 nm, 806 nm and 524 nm wavelengths might also be present.

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This product is an OEM laser system. As such, it does not conform to the safety specifications and performance standards required of a Class IIIb laser as defined by the Center for Devices and Radiological Health (CDRH), 21 CFR 1040.

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## Precautions For The Safe Operation of Class IIIb High Power Lasers

- Wear protective eyewear at all times; selection depends on the wavelength and intensity of the radiation, the conditions of use and the visual function required. Protective eyewear is available from suppliers listed in the *Laser Focus World*, *Lasers and Optronics*, and *Photonics Spectra* buyer's guides. Consult the ANSI and ACGIH standards listed at the end of this section for guidance.
- Maintain a high ambient light level in the laser operation area so the eye's pupil remains constricted, reducing the possibility of damage.
- Avoid looking at the output beam; even diffuse reflections are hazardous.
- Avoid blocking the output beam or its reflections with any part of the body.
- Establish a controlled access area for laser operation. Limit access to personnel trained in the principles of laser safety.
- Enclose beam paths wherever possible.
- Post prominent warning signs near the laser operating area (Figure 2-1).
- Install the laser so that the beam is either above or below eye level.

- Set up shields to prevent any unnecessary specular reflections or beams from escaping the laser operation area.
- Set up a beam dump to capture the laser beam and prevent accidental exposure (Figure 2-2).



Figure 2-1: These standard safety warning labels are appropriate for use as entry warning signs (EN 60825-1, ANSI Z136.1 Section 4.7).

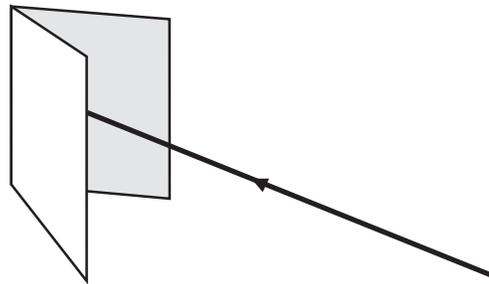


Figure 2-2: Folded Metal Beam Target



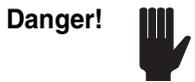
Caution!



---

Use of controls or adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.

---



Danger!



---

Operating this laser without due regard for these precautions or in a manner that does not comply with recommended procedures may be dangerous. At all times during installation, maintenance or service of your laser, avoid unnecessary exposure to laser or collateral radiation\* that exceeds the accessible emission limits listed in “Performance Standards for Laser Products,” *United States Code of Federal Regulations*, 21CFR1040.10(d).

---

Follow the instructions contained in this manual to ensure proper installation and safe operation of your laser.

\* Any electronic product radiation, except laser radiation, emitted by a laser product as a result of or necessary for the operation of a laser incorporated into that product.

# Safety Devices

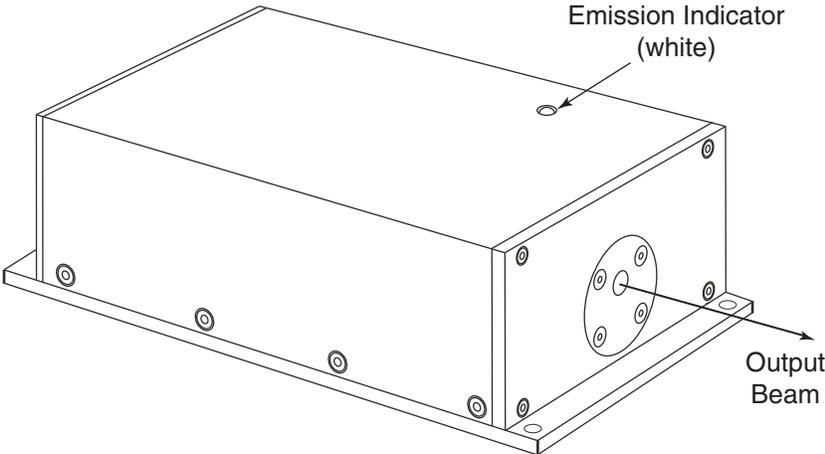


Figure 2-3: Laser Head Emission Indicator

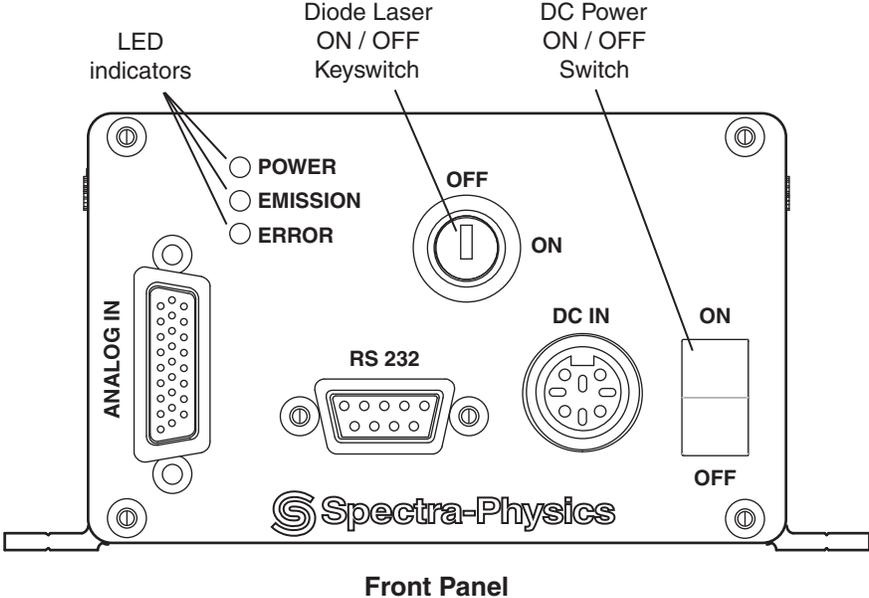


Figure 2-4: Power Supply Safety Devices

## **Emission and Power Indicators**

The system provides the following emission and power indicators:

- A white EMISSION indicator illuminates on top of the laser head (Figure 2-3) 3 seconds before actual emission occurs.
- A blue EMISSION indicator illuminates on the power supply front panel (Figure 2-4) 3 seconds before actual emission occurs.
- A yellow POWER indicator illuminates on the power supply front panel (Figure 2-4) when the DC power switch is turned on.
- If the *Explorer* is operated using the *L-Win* software, an indicator on the *L-Win* main screen turns green when the DC power rocker switch is set to ON, the diode laser keyswitch is set to ON, and the proper ON commands have been issued by the software. This *L-Win* indicator illuminates 3 seconds before actual emission occurs.
- Pin 9 of the ANALOG IN connector or the relay formed by pins 6 and 7 of the DC IN power connector can be used to control an external emission indicator. See Chapter 4 for more information.

## **Shutter**

The *Explorer OEM* laser is intended exclusively for use as a component in a master system. As such, it provides *no internal shutter*.

## **Diode Laser ON/OFF Keyswitch**

The keyswitch on the front panel of the power supply (Figure 2-4) provides power to the diode laser when it is turned on, and prevents unauthorized use of the laser when it is turned off and the key is removed. Placing this switch in the ON position enables the laser to be turned on via serial commands or analog signals.

## **DC Power ON/OFF Switch**

The ON/OFF switch on the front panel of the power supply (Figure 2-4) provides electrical power to the laser system when in the ON position.

## **Safety Interlocks**

### **External Interlock**

Pins 7 and 8 of the ANALOG IN connector can be used in a relay circuit to terminate laser emission when a safety switch that spans an access point, such as an entry panel, is opened unexpectedly. See Chapter 7 for the requirements of a circuit used for this purpose.

### **Cover Safety Interlocks**

The *Explorer* lasers are OEM systems that are designed to be integrated into a master system that itself complies with regulatory requirements. As such, the laser head and power supply do not have cover safety interlocks. The laser head and power supply covers are not to be opened by the user. The *Explorer* laser is not to be operated with the covers removed.

## Maximum Emission Levels

The following are the maximum emission levels possible for the *Explorer* laser. Use this information for selecting appropriate laser safety eyewear and implementing appropriate safety procedures. These values do not imply actual system power or specifications.

Laser light at 1047 nm, 806 nm and 524 nm wavelengths is generated in the production of the ultraviolet emission. These wavelengths are substantially confined to the inside of the laser head.

**Table 2-1: Maximum Emission Levels from Laser Head**

Emission Wavelength	Max Power, Max Pulse Energy Min Pulse Duration
Laser Output: 349 nm	500 mW, 0.5 mJ, 1-10 ns
Doubled Fundamental: 523 nm	< 1 mW
Diode Laser Emission: 805 nm	< 1 mW
Fundamental Beam: 1047 nm	< 1 mW

## System with a User-Provided Control Device

When the *Explorer OEM* laser system is controlled by a device provided by the user or by software written by the user, the following criteria must be met in order to comply with recognized safety agency requirements:

- **A keyswitch**—must be employed that limits access to the laser and prevents it from being turned on. It can be a real key lock, a removable computer disk, a password that limits access to computer control software, or a similar “key” implementation. The laser must only operate when the “key” is present and in the “on” position.
- **An emission indicator**—must be used to indicate that laser energy is present or can be accessed. It can be a “power-on” lamp, a computer display that flashes a statement to this effect, or an indicator on the control equipment for this purpose. It need not be marked as an emission indicator so long as its function is obvious. Its presence is required on any control panel that affects laser output.

## CE Radiation Control Drawings

Refer to "CE Warning Labels" on page 2-7.

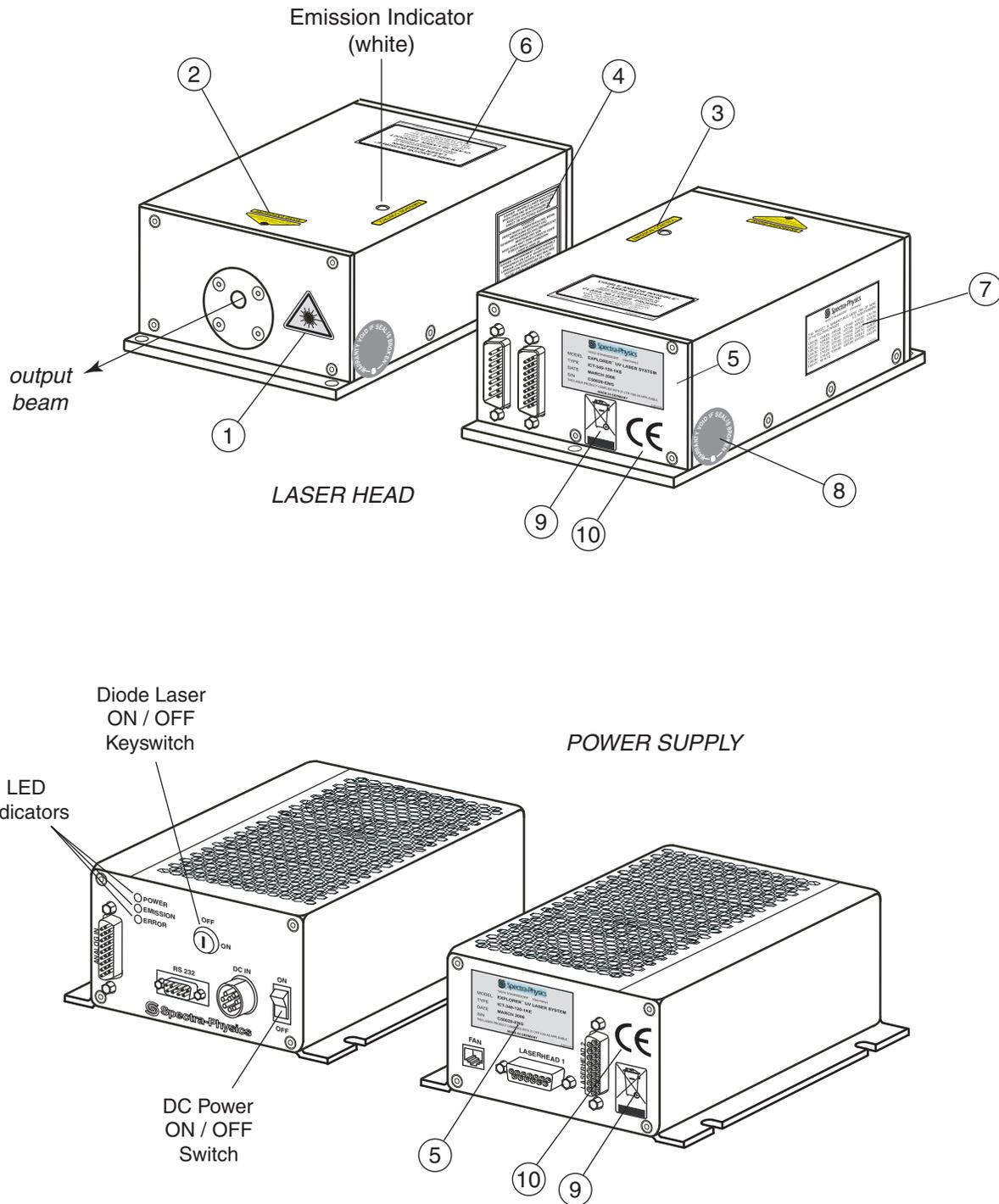


Figure 2-5: Explorer OEM Radiation Control Drawing

## CE Warning Labels



Aperture Symbol Label (1)



Aperture Warning Label (2)



Emission Indicator Label (3)



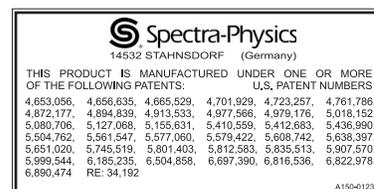
Invisible Radiation Danger Label (4)



Serial Label, Laser Head and Power Supply (5)



Class 3B CE Warning Label (6)



Patent Label (7)



Warranty Seal (8)



WEEE Label (9)



CE Approval Label (10)

Figure 2-6: Explorer OEM CE Warning Labels

**Label Translations**

For safety, the following translations are provided for non-English speaking personnel. The number in parentheses in the first column corresponds to the label number listed on the previous page.

**Table 2-2: Label Translations**

Label No.	French	German	Spanish	Dutch
Aperture Warning Label (2)	Ouverture Laser – Exposition Dangereuse – Un rayonnement laser visible et/ou invisible est émis par cette ouverture.	Austritt von sichtbarer und unsichtbarer Laserstrahlung! Bestrahlung vermeiden!	Por esta abertura se emite radiación láser visible e invisible; evite la exposición.	Vanuit dit apertuur wordt zichtbare en onzichtbare laserstraling geëmitteerd! Vermijd blootstelling!
Emission Indicator Label (3)	Commande d'émission	Emissionskontrolle	Control de la emisión	Controle van emissie
Class 3B CE Warning Label (6)	Rayonnement laser visible et/ou invisible. Exposition dangereuse de l'oeil ou de la peau au rayonnement direct ou diffus. Laser de classe 3B.	Sichtbare und/oder unsichtbare Laserstrahlung. Bestrahlung von Auge oder Haut durch direkte oder Streustrahlung vermeiden. Laser Klasse 3B.	Radiación láser visible y/o invisible. Evitar la exposición directa ó dispersa sobre la piel o los ojos. Producto Láser Clase 3B.	Zichtbare en/of onzichtbare* laserstraling. Vermijd blootstelling aan ogen of huid door directe of gereflecteerd straling. Klasse 3B laser produkt.
	EN60825-1:2001 349 nm, 523 nm, 805 nm, 1047 nm	EN60825-1:2001 349 nm, 523 nm, 805 nm, 1047 nm	EN60825-1:2001 349 nm, 523 nm, 805 nm, 1047 nm	EN60825-1:2001 349 nm, 523 nm, 805 nm, 1047 nm
	Puissance maximum moyenne de 500 mW	Mittlere maximale Leistung 500 mW	Potencia máxima promedio 500 mW	Maximaal uittredend vermogen 500 mW
	Energie maximum par impulsion 0,5 mJ	Maximale Pulsenergie 0,5 mJ	Energía máxima del pulso 0,5 mJ	Maximaal pulsenergie 0,5 mJ
	Durée d'impulsion 1–10ns	Pulsdauer 1–10ns	Duración de pulso 1–10ns	Pulsduur 1–10ns

## Waste Electrical and Electronic Equipment (WEEE) Recycling Label

To Our Customers in the European Union:

As the volume of electronics goods placed into commerce continues to grow, the European Union is taking measures to regulate the production and disposal of waste from electrical and electronic equipment. Toward that end, the European Parliament has issued directives instructing European Union member states to adopt legislation concerning the reduction, recovery, re-use and recycling of waste electrical and electronic equipment.

The directive addressing the reduction, recovery, re-use and recycling of waste electrical and electronic equipment is referred to as WEEE. In accordance with this directive, the accompanying product has been marked with the WEEE symbol. See Label 9 in Figure 2-6.

The main purpose of the symbol is to designate that at the end of its useful life, the accompanying product should not be disposed of as normal municipal waste, but should instead be transported to a collection facility that will ensure the proper recovery and recycling of the product's components. The symbol also signifies that this product was placed on the market after 13 August, 2005. At this time, regulations for the disposal of waste electrical and electronic equipment vary within the member states of the European Union. Please contact a Newport / Spectra-Physics representative for information concerning the proper disposal of this product.

## CE Declaration of Conformity

We,

Spectra-Physics  
1335 Terra Bella Avenue  
Mountain View, CA. 94043  
United States of America

declare under our sole responsibility that the following products:

### **Explorer Q-Switched Ultraviolet Lasers**

manufactured after June 30, 2006,

meet the intent of “EMC Directive 89/336/EEC (2004/C 98/05) for Electromagnetic Compatibility.” Compliance was demonstrated to the following specifications as listed in the official *Journal of the European Communities*:

#### **89/336/EEC: 2004/C 98/05, EMC Directive**

**EN61000-3-2 : 2000+A2:2005:** Electromagnetic Compatibility (EMC)—Limits for harmonic current emissions (equipment input current up to and including 16 A per phase).

**EN61000-3-3 : 1995+A1:2001:** Electromagnetic Compatibility (EMC)—Limitation of voltage changes, voltage fluctuation and flicker.

**EN61000-6-2 : 2001:** Electromagnetic Compatibility (EMC)—Immunity for industrial environments.

**EN 61000-6-4 : 2001:** Electromagnetic Compatibility (EMC)—Emission standard for industrial environments.

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards.



Bruce Craig  
Vice President  
Spectra-Physics  
A Division of Newport Corporation  
October 26, 2006

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## Sources for Additional Information

### *Laser Safety Standards*

*Safe Use of Lasers* (Z136.1)

American National Standards Institute (ANSI)

11 West 42<sup>nd</sup> Street

New York, NY 10036

Tel: (212) 642-4900

Occupational Safety and Health Administration (Publication 8.1-7)

U. S. Department of Labor

200 Constitution Avenue N. W., Room N3647

Washington, DC 20210

Tel: (202) 693-1999

Internet: [www.osha.gov](http://www.osha.gov)

*A Guide for Control of Laser Hazards*, 4th Edition, Publication #0165

American Conference of Governmental and

Industrial Hygienists (ACGIH)

1330 Kemper Meadow Drive

Cincinnati, OH 45240

Tel: (513) 742-2020

Internet: [www.acgih.org/home.htm](http://www.acgih.org/home.htm)

Laser Institute of America

13501 Ingenuity Drive, Suite 128

Orlando, FL 32826

Tel: (800) 345-2737

Internet: [www.laserinstitute.org](http://www.laserinstitute.org)

Compliance Engineering

Canon Communications LLC

11444 W. Olympic Boulevard

Los Angeles, CA 90064

Tel: (310) 445-4200

International Electrotechnical Commission

*Journal of the European Communities*

EN 60825-1 Safety of Laser Products — Part 1: Equipment classification,  
requirements and user's guide

Tel: +41 22-919-0211 Fax: +41 22-919-0300

Internet: [www.iec.ch](http://www.iec.ch)

Cenelec

35, Rue de Stassartstraat

B-1050 Brussels, Belgium

Tel: +32 2 519 68 71

Internet: [www.cenelec.org](http://www.cenelec.org)

Document Center, Inc.

111 Industrial Road, Suite 9

Belmont, CA 94002

Tel: (650) 591-7600

Internet: [www.document-center.com](http://www.document-center.com)

## ***Equipment and Training***

### *Laser Safety Guide*

Laser Institute of America  
13501 Ingenuity Drive, Suite 128  
Orlando, FL 32826  
Tel: (800) 34LASER  
Internet: [www.laserinstitute.org](http://www.laserinstitute.org)

### *Laser Focus World Buyer's Guide*

Laser Focus World  
Pennwell Publishing  
98 Spit Rock Road  
Nashua, NH 03062  
Tel: (603) 891-0123  
Internet: [lfw.pennnet.com/home.cfm](http://lfw.pennnet.com/home.cfm)

### *Photonics Spectra Buyer's Guide*

Photonics Spectra  
Laurin Publications  
Berkshire Common  
PO Box 4949  
Pittsfield, MA 01202-4949  
Tel: (413) 499-0514  
Internet: [www.photonics.com](http://www.photonics.com)

An *Explorer* laser system consists of an *Explorer* laser head and an *L-Series* power supply. The following sections briefly describe the design of the laser head and power supply. Controls and connections are described in Chapter 4, “Controls, Indicators and Connections,” and the methods of operating the laser are described in Chapter 6 and Chapter 7.

**Note**

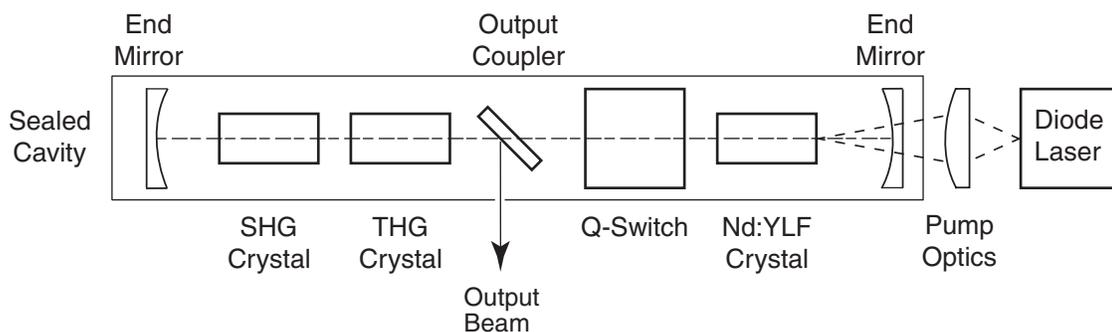
Appendix D provides an introduction to the physical principals that underlie the design of the *Explorer* laser, including pumping the laser with diode laser energy, choosing crystalline materials, using nonlinear optics, and using an acousto-optic modulator as a Q-switch.

## The Explorer Laser Head

### Overview

The *Explorer* laser head is designed for maximum reliability with minimum complexity. No adjustments to the laser head are needed for normal operation. In addition to the optical components (see Figure 3-1), the laser head contains microprocessors and memory for storing system parameters (for example, the last operating settings). These parameters are up-loaded to the *L-Series* power supply when the system is turned on.

The *Explorer* laser head integrates several key components, including a newly developed fiber-coupled, single-emitter, pump laser diode, as well as the 40 MHz Q-switch driver. An integrated UV detector is used to measure the energy of individual pulses and to provide timing signals for synchronizing laboratory equipment to the pulsed output.



**Figure 3-1: Optical Design of the *Explorer* Laser Head**

## **Optical Design**

The 806 nm output of the single-emitter diode laser inside the laser head is coupled into the Nd:YLF crystal by means of a fiber optic cable. The diode laser itself is incorporated in a module that is mounted directly on a temperature-regulated cold plate to stabilize its output wavelength. The *Explorer* software allows the diode laser current and temperature to be adjusted when necessary.

The output of the fiber is coupled into a beam-shaping telescope that focuses the pump light into the laser crystal. The Nd:YLF laser crystal absorbs the 806 nm pump light and is energized to produce a laser beam that is of much higher quality than the pump laser light, but at a significantly longer wavelength (1047 nm). The energy of this output is concentrated into a series of intense pulses by the acousto-optic Q-switch. These intense pulses are much more efficient at producing the shorter wavelengths obtained through nonlinear optical conversion.

## **Frequency Doubling and Tripling**

The *Explorer* ultraviolet output (349 nm) is obtained by frequency tripling the fundamental Nd:YLF laser output (1047 nm). This wavelength conversion is accomplished using two separate nonlinear optical crystals of lithium triborate (LBO). A portion of the fundamental beam is first doubled to 524 nm in the “SHG” LBO crystal, then this frequency-doubled light is mixed again with the fundamental wavelength in the “THG” crystal to produce the final ultraviolet output beam. The LBO crystals must be heated and temperature-stabilized to maintain good conversion efficiency. The *Explorer* software provides the ability to adjust the temperatures of these crystals when necessary.

The nonlinear wavelength conversion takes place entirely inside the laser head. A specially coated mirror directs the ultraviolet light out of the laser cavity while reflecting the green and infrared wavelengths; the laser emits neither the fundamental nor the frequency-doubled light (refer to Table 3-1 on page 3-9 for specifications regarding leakage output).

## **Pulse Energy Monitor**

A small fraction of the output of the laser is reflected into a detector (not shown in Figure 3-1). This detector generates several signals that are processed by the microprocessor, including the calculation of the energy of each pulse. The analog value of the pulse energy is stored by a sample and hold circuit that provides this output value until the next pulse is measured. The calculation of the single pulse energy is available either from the RS-232 interface or the ANALOG IN port on the *L-Series* power supply.

The pulse energy monitor is an integral part of the *Explorer's* advanced control features. These include the OptoSync output, as well as the Burst mode and FPS features available on the extended models. Burst mode, FPS, and OptoSync are described in more detail later in this chapter. Information about using these features is provided in Chapters 6 and 7, which describe how to operate the *Explorer*.

## **Replaceable Output Window**

A problem common to all laser systems that emit ultraviolet light is the degrading effects caused by these high energy ultraviolet photons on the optical components within the system. The output window on the *Explorer* laser head is designed to be replaced in the field as needed to ensure the transmission and delivery of the full pulse energy output of the laser to the target. Refer to the procedure in Chapter 8, “Maintenance and Service,” for instructions on when and how to change the window.

## **Laser Head Thermal Management**

Thermal management of the *Explorer* laser head is key to achieving proper system performance, including cold-start performance. At normal ambient operating temperature (25°C), the *Explorer* laser head generates about 25 W of heat. This generated heat must be dissipated by the heatsink to which the laser head is mounted.

Spectra-Physics offers an optional custom heatsink that includes a fan for use with the *Explorer* OEM laser head (contact your Spectra-Physics representative for more information). The auxiliary fan attached to the heatsink is controlled through the *L-Series* power supply. A temperature sensor located inside the laser cavity continuously measures the laser head temperature, and its feedback is part of an active servo-loop that is used to set the fan RPM.

## **The L-Series Power Supply**

The *L-Series* power supply provides the drive current for all of the active components inside of the laser head, including the TECs, the diode laser, the Q-switch driver, the microprocessors and non-volatile memory. It also provides the communication and control interface for the user.

The air-cooled power supply is capable of supplying up to 8 A of diode laser drive current, and it requires a 24 ±2 Vdc, 3 A electrical source. A small fan ensures proper cooling inside the supply. The rugged *L-Series* design ensures reliable operation even in harsh environments. Spectra-Physics offers an optional wall-plug, auto-ranging, AC-DC converter for use with the *Explorer* laser. Contact your Spectra-Physics representative for more information.

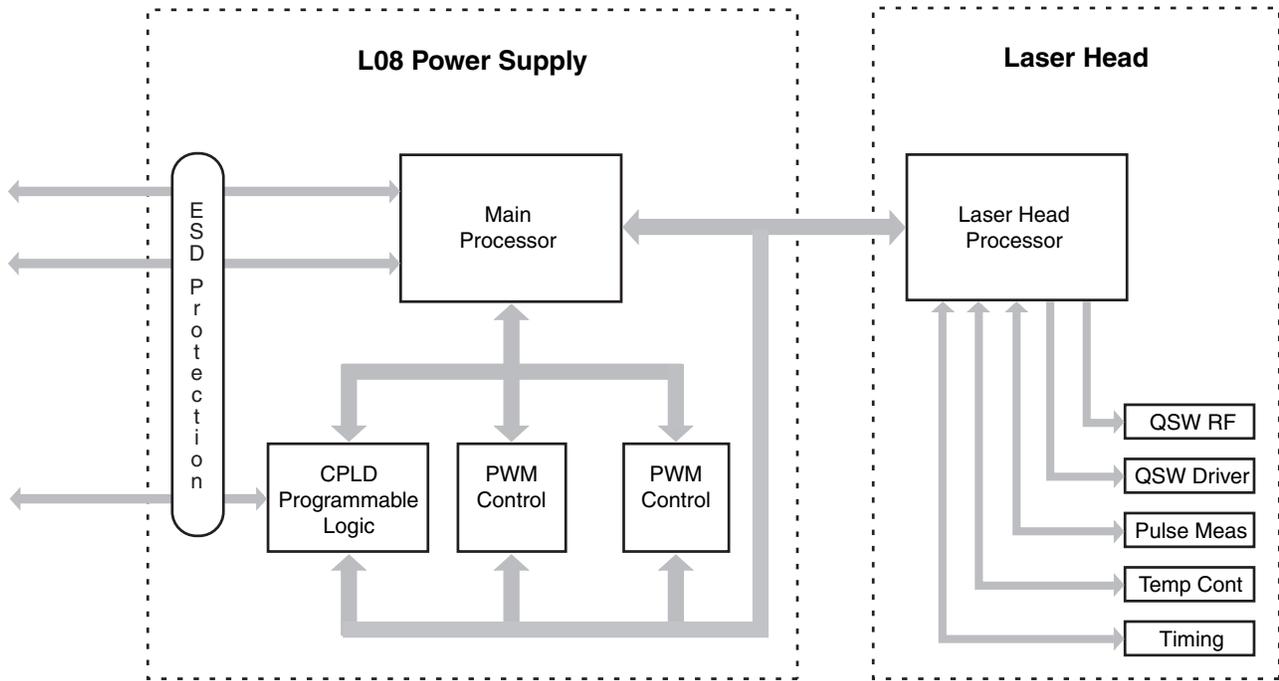
The *L-Series* power supply has been certified in its manufacture to comply with the requirements of the RoHS Directive (the Restriction of Hazardous Substances) of the European Union.

## **System Control**

As a component in a master system, the *Explorer* is controlled using the serial language or analog signals (or a combination of both). The ports for the serial and analog interfaces are located on the power supply. The most common methods of operating the laser are described in Chapter 6 and Chapter 7. The *Explorer* can also be operated as a stand-alone system using the custom *L-Win* software provided with the laser.

**System Control Hardware**

Figure 3-2 shows the location of the main logic components in the laser head and the *L-Series* power supply.



**Figure 3-2: Explorer System Control Hardware**

The microprocessor inside the *L-Series* power supply controls the power supply and communication with the laser head. The laser head has its own microprocessor for control of laser head functions, such as maintaining the harmonic crystal temperature and the diode laser current.

The versatility of the *L-Series* results in part from the use of a CPLD (Complex Programmable Logic Device). By setting operating registers through software commands, a variety of triggering schemes can be used without the need for changes to the hardware. Precise timing is realized by locking incoming signals to the microprocessor clock and using counters and registers to minimize jitter.

**Note**



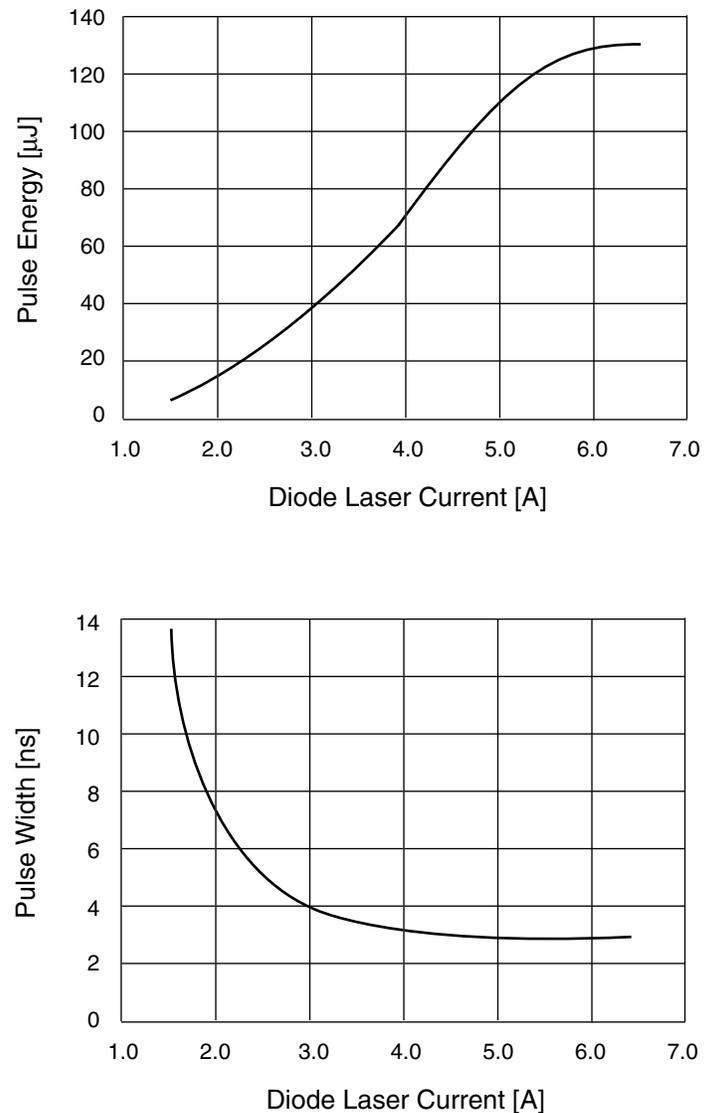
All *L-Series* power supply inputs are protected from ESD.

Laser operational settings are stored in non-volatile memory inside the laser head. In case of a sudden power outage, the power supply saves important system parameters in this non-volatile memory, ensuring that all important system parameters are secure. The laser head permanent memory contains unit-specific identification information and parameters such as the maximum diode laser current and operating temperature. The contents of permanent memory cannot be changed in the field.

## Laser Performance

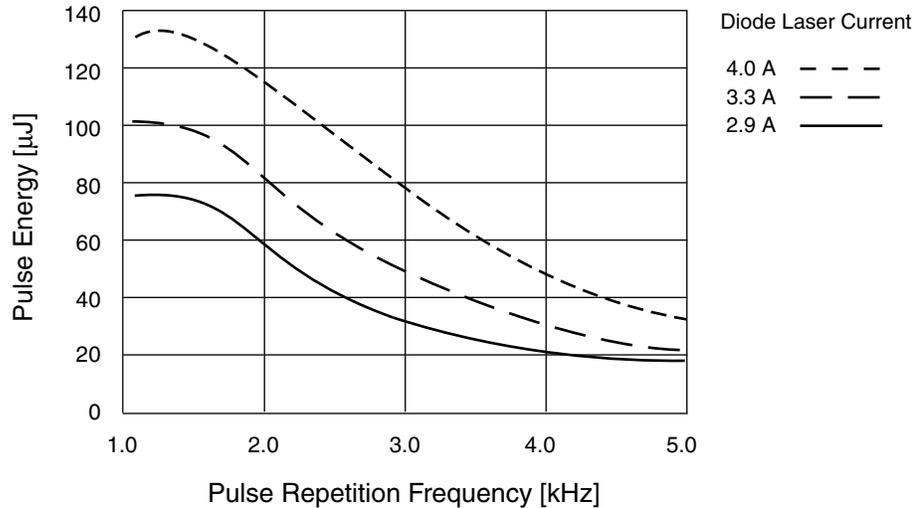
The energy of individual pulses increases in a fairly linear manner as the diode current is increased. The duration of the pulses decreases sharply as the pulse energy is increased, which is typical of any pulsed laser. (The duration of pulses is commonly measured at their full width at half maximum or FWHM). This pulse narrowing effect levels off when a minimum pulse duration is achieved at about 50% of the maximum pulse energy.

The graphs in Figure 3-3 show the typical results of these effects.



**Figure 3-3: Variation of Energy and Pulse Width vs. Current**

At a given diode laser pump current, the individual pulse energy itself will decrease as the repetition rate is increased. The lower the diode laser pump current (i.e., the lower the average output power), the less pronounced this effect will be.



**Figure 3-4: Pulse Energy vs. Pulse Repetition Rate**

### OptoSync Output

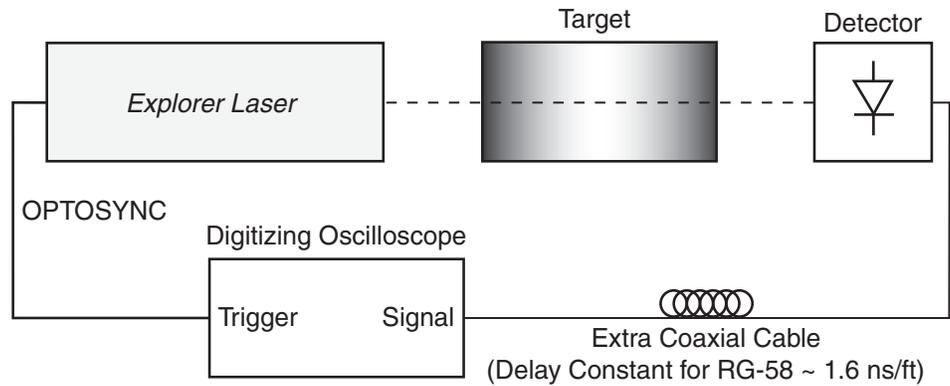
The OptoSync output provides a TTL level signal that is in high coincidence with the production of individual pulses. The jitter between the peak of the laser pulse and the corresponding OptoSync pulse is specified as  $< \pm 0.5$  ns. The OptoSync trigger is provided on pin 14 of the ANALOG IN connector on the *L-Series* power supply.

OptoSync triggering *follows* the laser pulse by about 45 ns. For some applications, this OptoSync delay is unimportant. Other applications may lend themselves to data collection techniques that compensate for this delay.

Some digital data collection instruments, such as digitizing oscilloscopes, include a “pre-triggering” feature that can be useful in this regard. In this case, data is stored until the arrival of the trigger pulse that initiated the event, and marks the temporal relationship of the two.

It can also prove useful to place a delay line between the detected signal and the digitizer so that the OptoSync signal can “catch up” to the detected pulse. This is illustrated in Figure 3-5. Here, an extra length of coaxial cable has been inserted between the optical detector and the oscilloscope. As an example, an extra 48 feet of coaxial cable between the detector and the oscilloscope produces an additional delay of approximately 70 ns, placing the detected pulse beyond the leading edge of the OptoSync signal.

The OptoSync output, as well as the output trigger signal derived from the Q-switch trigger input, are made available on various pins of the ANALOG IN connector on the front of the *L-Series* power supply. Refer to Chapter 7 for more details about using these trigger outputs.



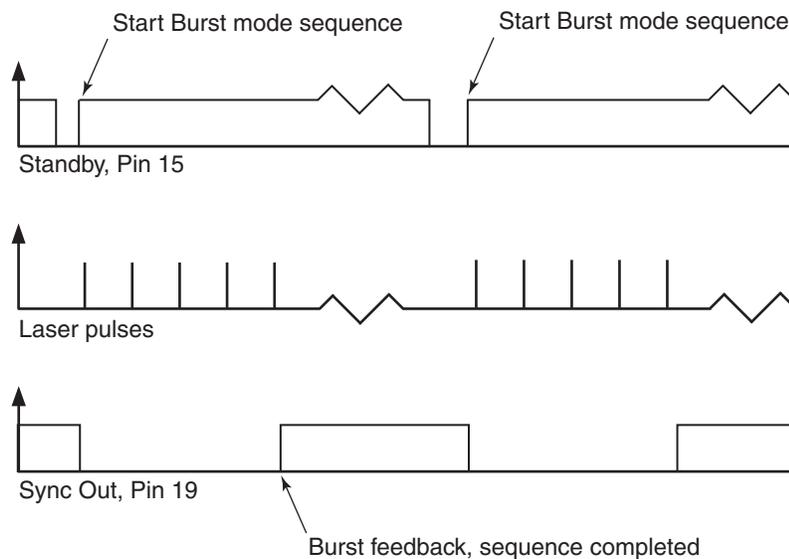
**Figure 3-5: Example of Delay Compensation Using Coaxial Cable**

**Extended Control Features**

The two extended models of the Explorer system, the Explorer-349-060-IKE and the Explorer-349-120-IKE, have all the features of the corresponding standard models, plus Burst mode and First Pulse Suppression (FPS) capability. These features provide the user with advanced control of the pulsed output of the laser.

**Burst Mode**

Burst mode allows the user to select a desired number of laser pulses to be grouped together as a single packet. The number of pulses allowed in a burst is between 1 and 4095. Burst sequences can be controlled via software commands or TTL signals. The Explorer system also produces feedback signals for monitoring the status of individual burst sequences. Figure 3-6 shows an example of Burst mode timing.



**Figure 3-6: Burst Mode Timing Example**

Burst mode is especially useful in MALDI applications. To produce a sufficient number of ions for each measurement, multiple laser shots are fired onto a MALDI plate. The *Explorer* Burst mode feature significantly reduces external hardware and software algorithm requirements for MALDI and simplifies laser integration into the system.

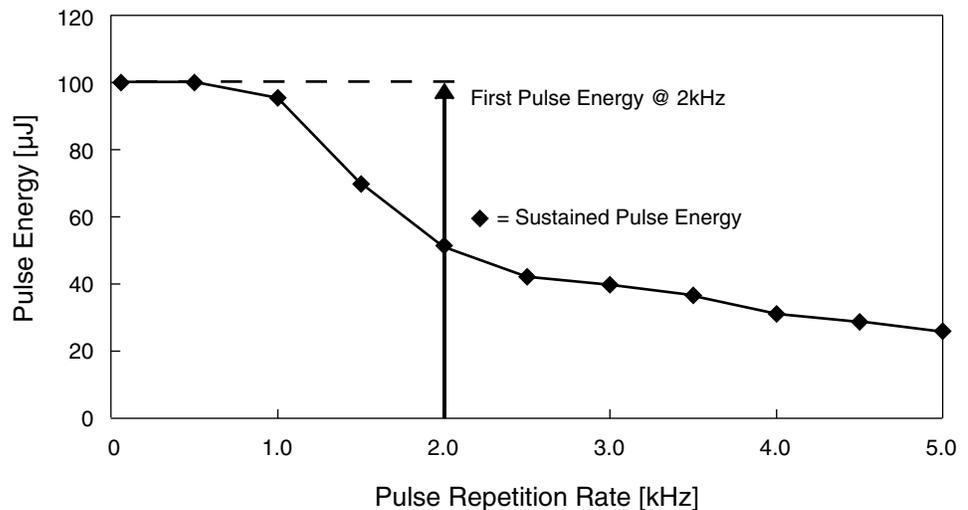
Refer to Chapters 6 and 7 for examples of implementing Burst mode.

**First Pulse Suppression**

The First Pulse Suppression (FPS) feature is important for users who must operate at pulse repetition rates of 1.5 kHz or higher. Figure 3-7 shows the typical relationship between pulse energy and pulse repetition rate at constant pump power. Around 2 kHz, the laser produces a “giant” first pulse that has roughly twice the energy of subsequent pulses. While desirable in some applications, this anomalous first pulse energy is often a problem.

The first pulse anomaly can be avoided by using the FPS feature. FPS allows the user to adjust the initial pulses in a train to have approximately the same energy as the ensuing pulses. FPS reduces the pump energy for the first pulse in a train by reducing the time allowed for light to circulate within the laser resonator before the first pulse is emitted.

Refer to Chapters 6 and 7 for examples of how to implement FPS.



**Figure 3-7: The First Pulse Effect at High Repetition Rates (2 kHz)**

## Specifications

Environmental specifications for operating and non-operating conditions are listed in “Environmental Specifications” on page v.

**Table 3-1: Explorer Performance Specifications<sup>1</sup>**

<b>General Characteristics</b>	
Wavelength	349 nm
Repetition Rate	Single shot to 5 kHz
Pulse Width (FWHM) at nominal pulse energy	< 5 ns
Nominal Pulse Energy	60 $\mu$ J or 120 $\mu$ J
Leakage Power	
All wavelengths combined, CW	< 0.5 mW
524 nm @ 1 kHz	< 60 nJ
1047 nm @ 1 kHz	< 60 nJ
<b>Beam Characteristics</b>	
Spatial Mode	TEM <sub>00</sub>
M <sup>2</sup>	< 1.3
Polarization (vertical)	> 100:1
Beam Diameter <sup>2</sup>	0.15 mm $\pm$ 10%
Waist Location (relative to laser beam exit aperture)	-60 mm to -80 mm (i.e., inside the laser head)
Beam Divergence (1/e <sup>2</sup> , full angle)	< 3.5 mrad
Beam Roundness	< 1.2
Astigmatism	< 0.2
Optical Axis Height	25.4 mm
Beam Position	< $\pm$ 0.1 mm
Beam Angle	< $\pm$ 0.5 mrad
<b>Stability</b>	
Pulse-to-Pulse Energy Stability <sup>3</sup>	< 3%
Long Term Power Stability (non-cumulative)	< $\pm$ 2% / 1 hr ( $\pm$ 1°C)
Warm-up Time <sup>4</sup>	< 5 min
Jitter	
Laser Pulse to OptoSync	< $\pm$ 0.5 ns peak-to-peak

<sup>1</sup> Due to our continuous product improvement program, specifications may change without notice.

All specifications pertain to 1 kHz pulse repetition rate unless otherwise noted.

<sup>2</sup> Specified at the beam waist with beam diameter at 1/e<sup>2</sup> points.

<sup>3</sup> 1 sigma variation, absolute value.

<sup>4</sup> Cold start to > 95% of full power.

**Table 3-2: Electrical and Cooling Specifications**

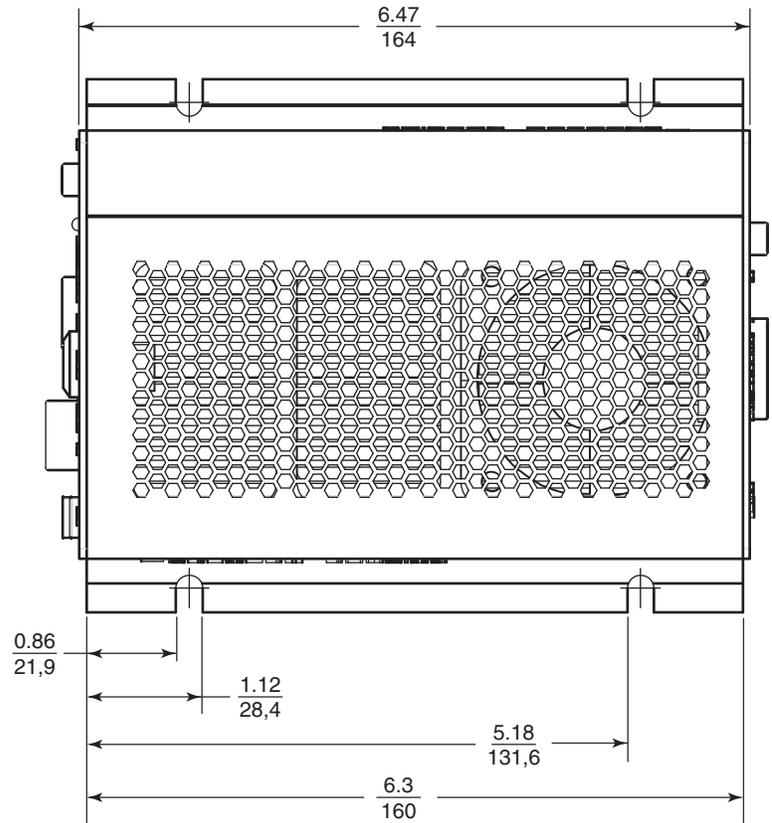
Operating Voltage	24 Vdc $\pm$ 2 V
Power Consumption	
Typical	< 50 W @ 25°C
Maximum	< 75 W
Maximum Inrush Current	< 4 A
Cooling	
<i>L-Series</i> power supply	Air-cooled
Explorer Laser head	Air- and conduction-cooled

**Table 3-3: Dimensions and Weight**

<b>Explorer Laser Head</b>	
Size (L x W x H)	165 x 95 x 54 mm (6.50 x 3.74 x 2.13 in.)
Weight (typical)	1.2 kg (2.64 lb)
<b>L08 Power Supply</b>	
Size (L x W x H)	164 x 130 x 65 mm (6.46 x 5.12 x 2.56 in.)
Weight (typical)	0.9 kg (2.0 lb)
Laser Head Cable Lengths <sup>1</sup>	2.0 m (6 ft)

<sup>1</sup> These lengths are approximate.





All Measurements In:

inches  
mm

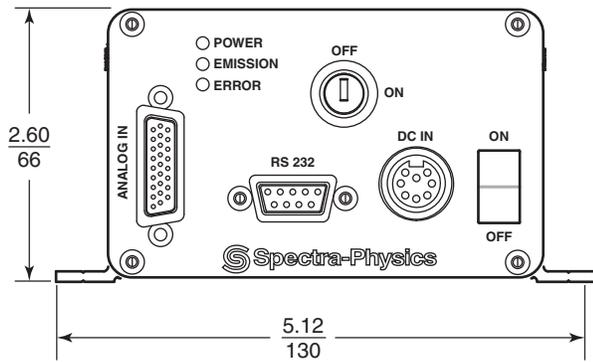


Figure 3-9: Outline Drawing, L-Series Power Supply

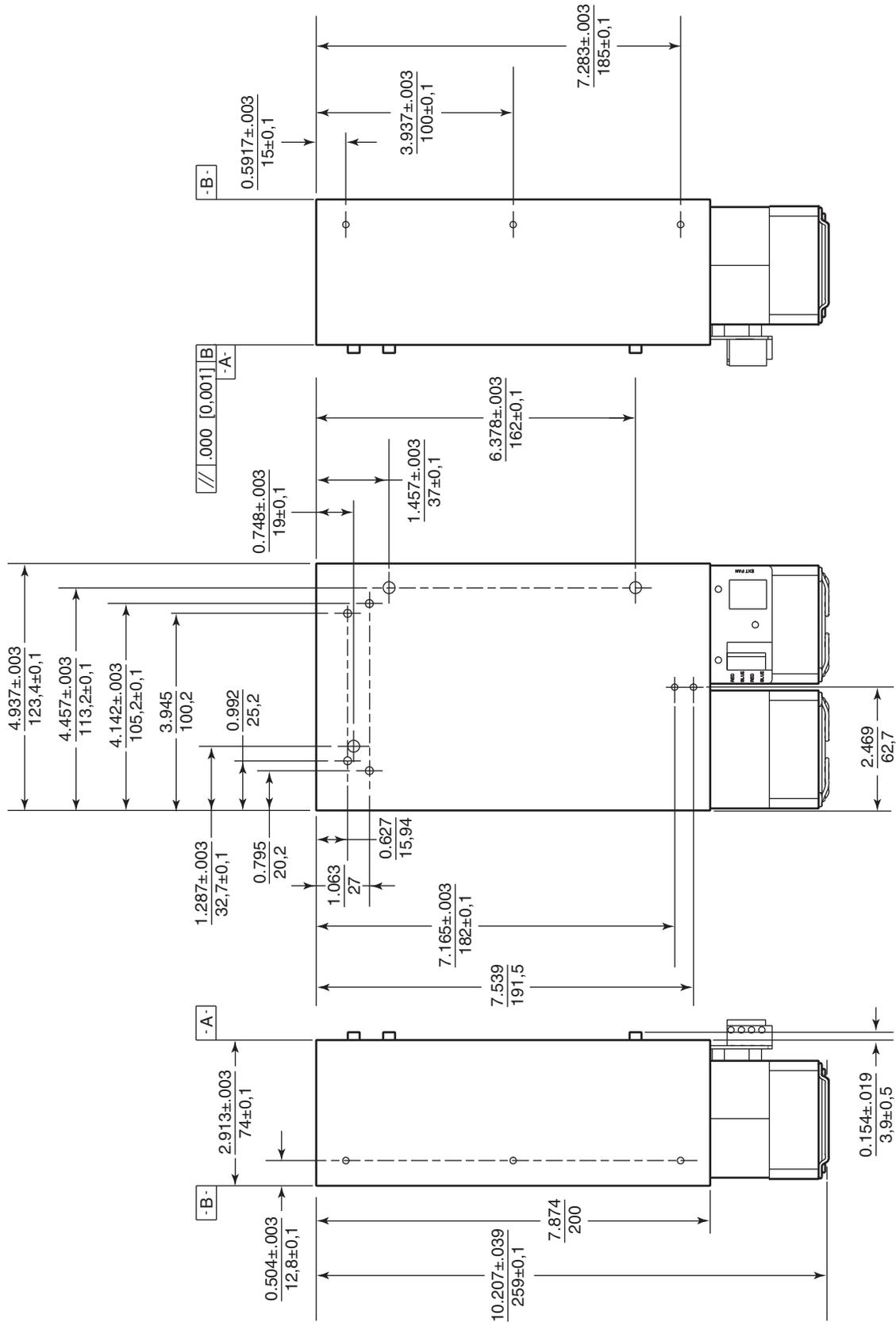


Figure 3-10: Outline Drawing, Heatsink Assembly

### Interlock Block Diagram

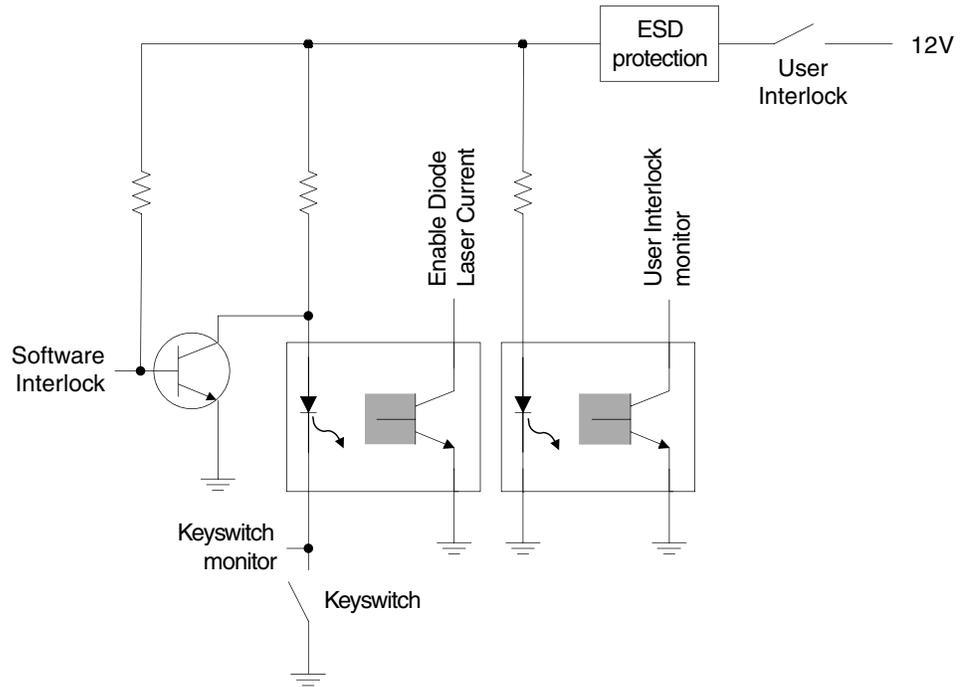


Figure 3-11: Interlock Safety Block Diagram

This section describes the user controls, indicators and connections of the *Explorer OEM* laser head and power supply. Connector types are also listed. For the functional description of the ANALOG IN connector, refer to the detailed descriptions in Table 7-1.

For control of the system using either the *L-Win* software or serial commands and analog signals via the RS-232 and ANALOG IN connectors, refer to the operating procedures described in Chapters 6 and 7, respectively.

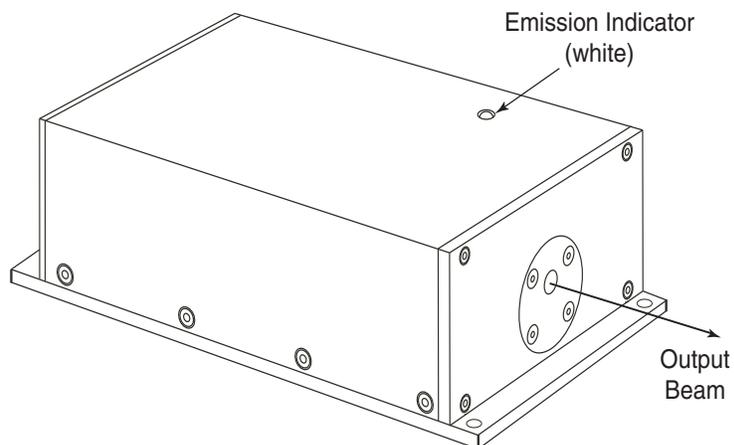
## The Explorer Laser Head

### Controls

There are no controls on the *Explorer OEM* laser head itself—no adjustment is required. The laser is controlled through the *L-Series* power supply. Note that there is no shutter on the *Explorer OEM* laser head. The laser head is designed for integration into a master system that possess the required safety features.

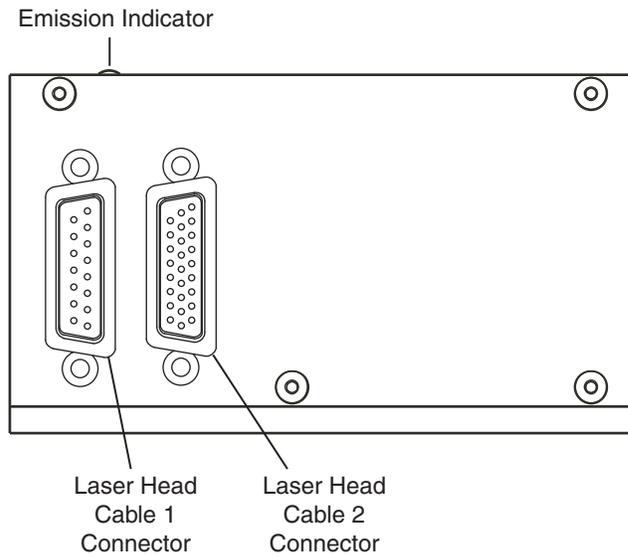
### Indicators

**Emission indicator** (white)—turns on when an ON command is issued, indicating that laser emission may be present. The indicator remains on during laser emission and turns off when current to the diode laser is terminated.



**Figure 4-1: *Explorer OEM* Laser Head Emission Indicator**

## Connections



**Figure 4-2: Explorer OEM Laser Head Rear Panel Connections**

**Laser Head Cable 1 connector** (15-pin, D-sub, male)—provides connection for the control cable from the LASERHEAD 1 connector on the back of the *L-Series* power supply. It provides the diode laser drive current and the currents for the TECs (thermoelectric coolers) for the optical components in the laser head.

**Laser Head Cable 2 connector** (26-pin, D-sub HD, male)—provides connection for the control cable from the LASERHEAD 2 connector on the back of the *L-Series* power supply, which provides monitoring and control functions for the laser head.

## The L-Series Power Supply

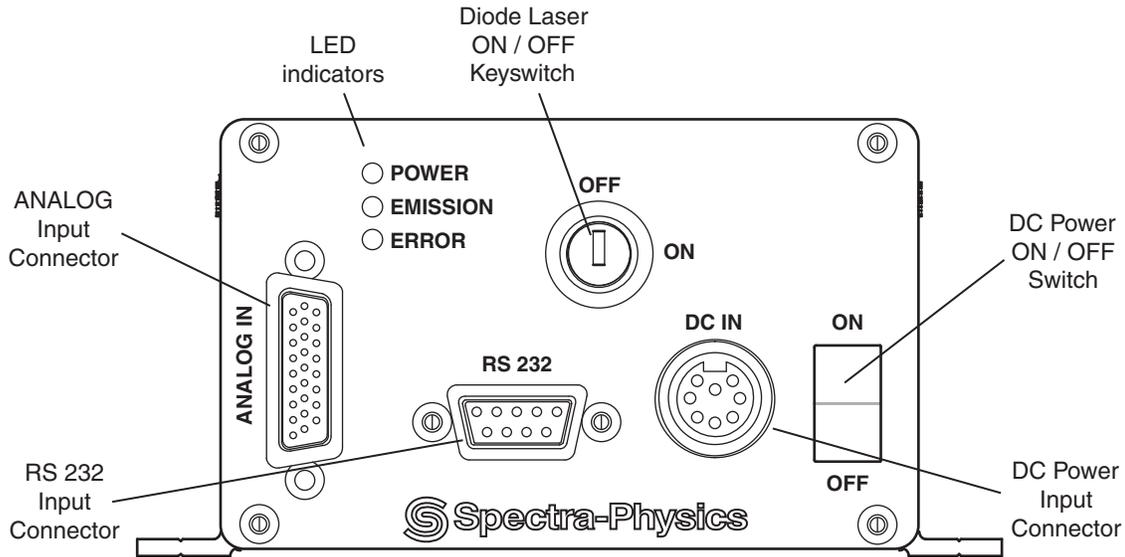


Figure 4-3: Power Supply, Front Panel

### Front Panel Controls

**DC power ON/OFF switch**—provides DC power to the laser head when set to the ON position. When the laser is installed in its final configuration, leave this switch in the ON position for remote control of the laser.

When this switch is turned on, the red ERROR LED turns on and remains on during the power supply warm-up sequence, about 5 minutes from a cold start.

While the ERROR LED is on, the *Explorer OEM* laser cannot produce laser light. This safety feature prevents possible damage to the internal optical components that might result if intense intracavity laser light is produced before the laser components have achieved proper operating temperature. Once the ERROR LED turns off, the laser can be turned on.

**Diode laser ON/OFF keyswitch**—provides power to the diode laser in the laser head when it is set to the ON position. For safety, when the system is not installed in a master system and is not in use, turn off the keyswitch and remove the key to prevent unauthorized use of the laser.

The function of this switch depends upon the software laser mode setting. Placing this switch in the ON position allows the laser to be turned on via serial commands or analog signals. When the laser is installed in its final configuration, leave this switch in the ON position so that the laser can be remotely controlled.

### Front Panel Indicators

**POWER indicator** (yellow)—turns on when the power rocker switch is turned on, indicating that DC power is being supplied to the laser head.

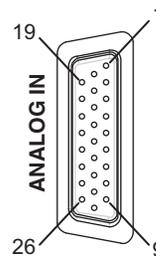
**EMISSION indicator** (blue)—illuminates to indicate that laser emission is present or imminent when the diode laser keyswitch is turned on and an appropriate serial command or analog signal is provided.

**ERROR indicator** (red)—turns on when the software has detected an error condition. It is also normal for this indicator to remain on for about 5 minutes during the warm-up sequence when the laser is turned on from a cold start condition.

### Front Panel Connections

**ANALOG IN connector** (26-pin, D-sub, HD, male)—provides attachment for a control cable to an analog control device. Refer to Table 7-1 for a complete description of these pins, and to Chapter 7, “Operating with Commands and Signals,” for instructions on how to use this connector to control advanced features of the *Explorer OEM* laser.

The female mating connector is TYCO/AMP 1658682-1 (housing, RoHS-compliant), using pins TYCO/AMP 1658686-1 (crimp socket, RoHS-compliant).



**Figure 4-4: ANALOG IN Connector**

**Note**



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In order for the system to operate, pins 7 and 8 must be shorted together, either directly (as when using the supplied shorting jumper) or through a user-supplied, normally-closed interlock switch.

---

**Warning!**



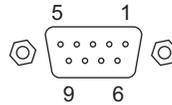
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This connector is identical to the LASERHEAD 2 connector on the back of the laser head! Interchanging the cables to these connectors may cause damage to the laser!

---

Among its many functions, this connector can be used to provide an interlock to turn off laser emission in the event that a safety switch is opened unexpectedly. This connector also provides a status output that can be used to drive an emission indicator.

**RS-232 input connector** (9-pin, D-sub, female)—provides attachment for a serial cable from a control device, such as a personal computer. Refer to Table 4-1 for a complete description of these pins, and to Chapter 6 or Chapter 7 for instructions on how to control the laser using this connector.



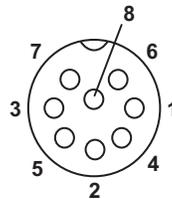
**Figure 4-5: The 9-Pin RS-232 Port Connector**

**Table 4-1: IBM-PC/AT Serial Port Pinout**

RS-232-C Signal Name	Computer or Terminal			L-Series	
	Signal	Pin No. (25-Pin)	Pin No. (9-Pin)	Pin No.	Signal
<i>Transmit Data</i>	TXD	2	3	3	RXD
<i>Receive Data</i>	RXD	3	2	2	TXD
<i>Signal Ground</i>		7	5	5	
<i>Protective Ground</i>		1	SHELL	SHELL	

**DC IN power connector** (8-pin, high-current connector, female)—provides attachment for the cable from the  $24 \pm 2$  Vdc, 3 A electrical source with a current ripple of  $< 100$  mV rms. The DC IN power connector is an 8-pin DIN 45326 socket. Table 4-2 describes the pins of this interface.

Pins 6 and 7 of this connector form a floating relay that can be used to control an external emission indicator. The relay switch is closed when emission is on.

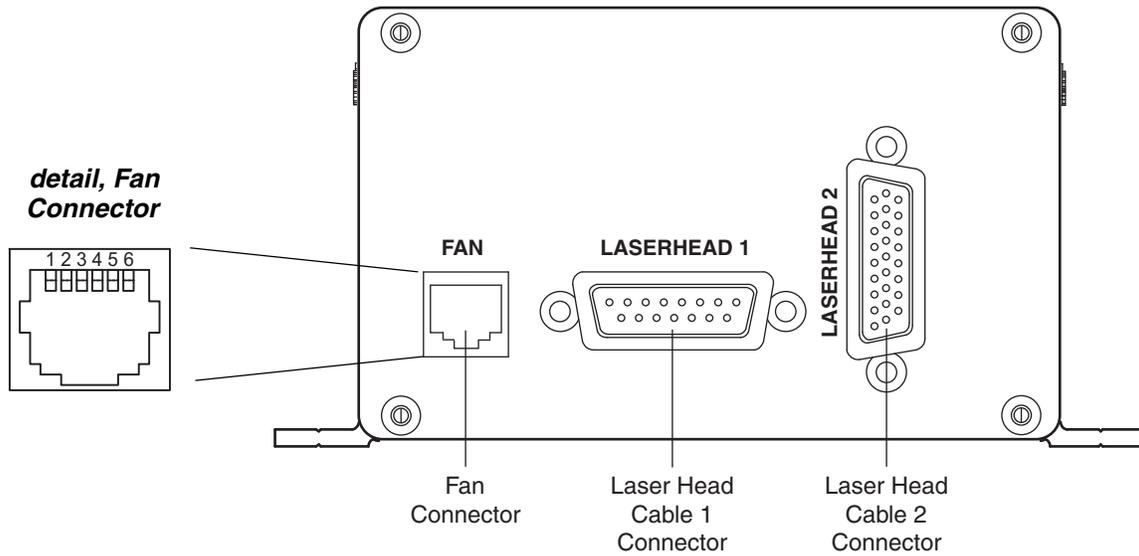


**Figure 4-6: DC IN Power Connector**

**Table 4-2: DC IN Power Connector Pinout**

Pin	Signal
1, 2, 4	Return
3, 5, 8	+24 Vdc
6	Emission relay (max 48 Vdc, 1 A)
7	Emission relay return

**Rear Panel Connections**



**Figure 4-7: Power Supply, Rear Panel**

**FAN connector** (6-pin RJ12)—provides variable DC power for an auxiliary cooling fan. The fan voltage is dependant on the thermal load generated by the *Explorer OEM* laser head. The FAN connector is a Western-Modular socket. It provides up to 250 mA at 13 Vdc. Table 4-3 describes the pins of this connector.

**Table 4-3: FAN Connector Pinout**

Pins	Signals
1, 2, 3	+Fan out
4, 5, 6	Fan return

**LASERHEAD 1 connector** (15-pin, D-sub, female)—provides attachment for the control cable to the laser head Laser Head Cable 1, male, 15-pin connector. This connector provides the diode laser drive current and the drive current for the TECs used by some optical components in the laser head.

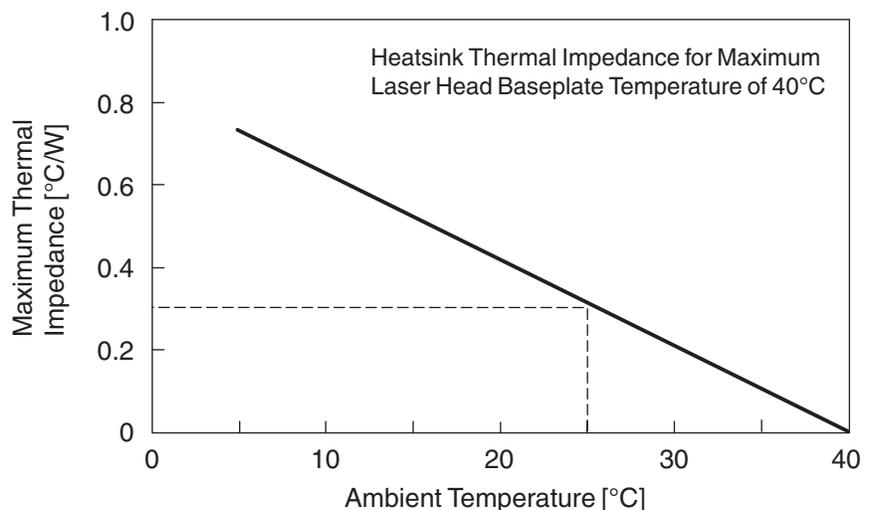
**LASERHEAD 2 connector** (26-pin, D-sub HD, female)—provides attachment for the control cable to the laser head Laser Head Cable 2, male, 26-pin connector. This connector provides monitoring and control signals to and from the laser head.

## Thermal Management

Proper heat conduction is essential to allow the *Explorer OEM* laser to perform according to specifications. Determine the heat removal capacity of your heatsink mounting before installing the laser head.

At a normal operating temperature of 25°C, the laser head produces about 25 W of waste heat; at the maximum specified operating temperature of 40°C, the heat load that must be removed is about 50 W. The laser head should be mounted on a heatsink capable of maintaining its baseplate temperature below 40°C and greater than 18°C.

Cooler ambient temperatures makes it easier to dissipate waste heat through the baseplate. Refer to Figure 5-1 for the thermal impedance required for the heatsink. The heatsink surface must be flat to 0.050 mm or better if no heat-conducting material is used (such as a silicone thermal pad).



**Figure 5-1: Laser Head Heatsink Thermal Impedance Requirement**

Spectra-Physics offers an optional heatsink with an auxiliary fan that can be attached to the laser head and is controlled through the *L-Series* power supply. Refer to the fan connector description provided in Chapter 4 for details. A temperature sensor located inside the laser head continuously measures the laser head temperature and provides feedback for controlling fan RPM.

When active, the servo loop maintains a constant laser head temperature at a value set using serial commands. The default laser head temperature is 35°C, i.e., the lower the environmental temperature is, the lower the fan speed will be. Temperature settings below ambient will result in the fan operating at constant (maximum) speed.

As soon as the head temperature exceeds 40°C (typical), Error Code 39 “Warning Overtemp Laser Head” is issued, but the laser will continue operating normally. However, exceeding 45°C will cause an emergency shut-off, whereby the laser is immediately placed into Sleep mode. Sleep mode can be exited and the laser restarted once the head temperature gets below 40°C (typical) again. For other temperature limits, please refer to Chapter 7.

Alternatively, the thermal servo loop can be deactivated via serial command and the fan speed set by the user. This allows the heatsink to be controlled by the operator through the *L-Series* power supply interface.

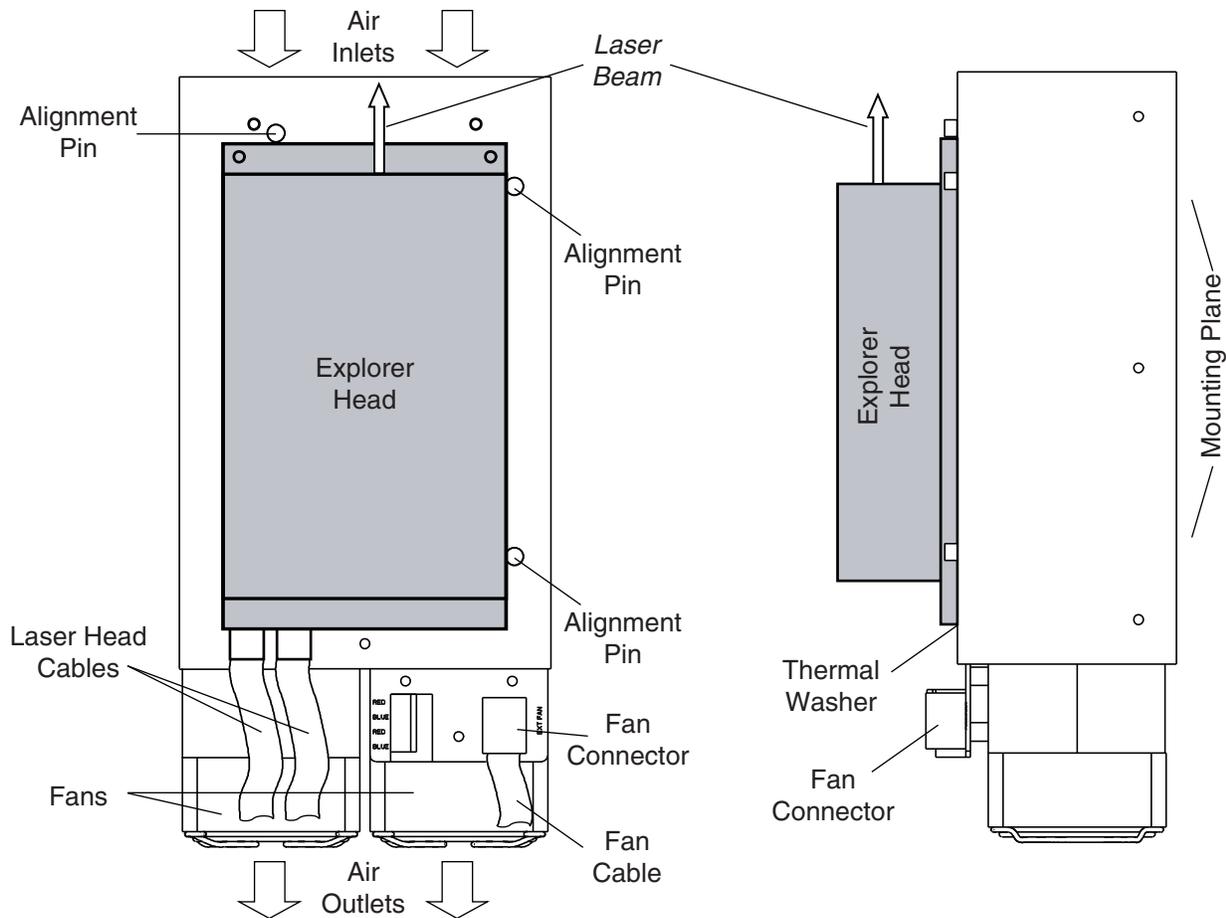


Figure 5-2: Air Flow through the Spectra-Physics Heatsink

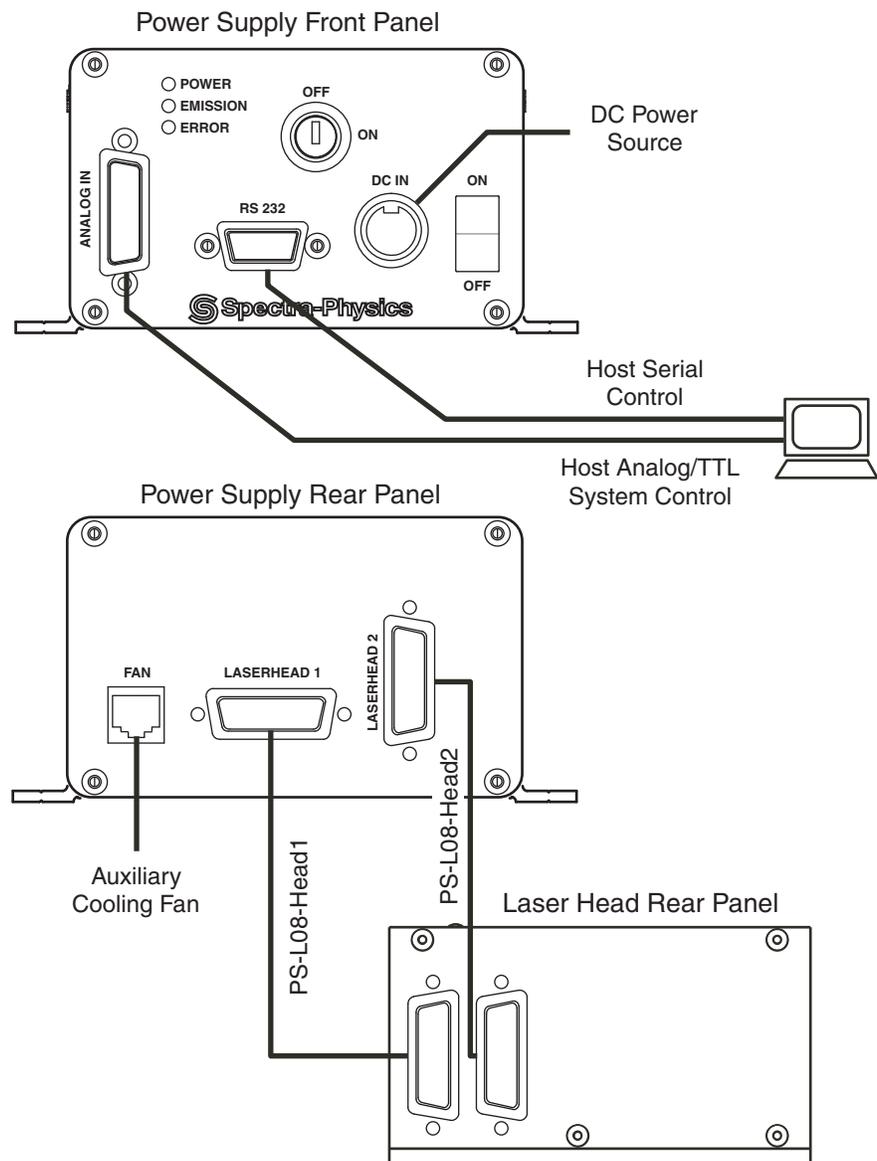
## Mounting the Hardware

Following standard practice, mount the laser head on a suitable heatsink as described in the preceding section. Use three 8-32 bolts or three M4 bolts and washers to mount the laser head. Refer to “Outline Drawings” on page 3-11 for dimensions and hole locations.

Using the slots shown in Figure 3-9, mount the power supply to a suitable surface using four 14-20 or M6 bolts and washers.

## Connecting the System

Refer to the Interconnect Drawing (Figure 5-3) to connect the *Explorer OEM* laser system components.



**Figure 5-3: System Interconnect Drawing**

1. Attach the Laser Head 1 control cable (PS-L08-Head1) between the LASERHEAD 1 connector on the power supply and the Laser Head Cable 1 connector on the laser head.
2. Attach the Laser Head 2 control cable (PS-L08-Head2) between the LASERHEAD 2 connector on the power supply and the Laser Head Cable 2 connector on the laser head.
3. Attach a 2-wire or 4-wire cord (suitable for 3 A) between the DC IN connector on the power supply and the DC power source. We recommend using 2 pins of the +24 Vdc line and 2 pins of the return line to lighten the current load. Refer to the description of the DC IN connector provided in Chapter 4 for pin descriptions.

Make sure that the required voltage of 22–26 Vdc and 3 A are available at the DC IN connector. Furthermore, the off-load voltage of the DC source cannot exceed 30 Volts.

Recall that pins 6 and 7 form a relay that can be used to turn on an emission indicator when the laser is on. This relay is rated for a maximum 48 Vdc and 1 A.

4. It is recommended that the control circuitry provided for a user-supplied fan be used to maintain the proper heatsink temperature. Refer to the description of the FAN connector in Chapter 4 for details about using this option.
5. Attach a standard 9-pin serial cable (male/female, do not use a null modem cable!) between the RS-232 connector on the front of the power supply and the serial port on your computer. Note the computer port number. Refer to Table 4-1 on page 4-5 for a functional description of this connector.
6. If analog signals are to be used to control the laser, attach an analog control cable (not provided) between the analog port of your host controller and the ANALOG IN connector on the power supply. Refer to Table 7-1 for a functional description of each pin.

**Note**



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Note that pins 7 and 8 must be shorted together in order for the laser to operate. A shorting jumper plug is provided for this purpose in case the ANALOG IN connector is not used. These pins can be used in a circuit to shut the laser off if an emergency switch is opened unexpectedly. Pin 7 provides up to 100 mA at 12 Vdc.

Note also that pin 9 of this connector can be used to control an emission indicator. Chapter 7 provides a circuit example for this function.

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### **Laser Alignment**

No alignment is necessary for the *Explorer OEM* laser head; there are no controls to adjust nor optics to align.

## Initial Turn On/Turn Off Using the *L-Win* Software



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Spectra-Physics *Explorer OEM* lasers are *Class IIIB—High-Power Lasers* whose beams are, by definition, safety and fire hazards. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage. *The 349 nm ultraviolet output emitted from the laser head is invisible and is therefore especially dangerous!* Residual light at other wavelengths might also be present. Please read all of Chapter 2, “Laser Safety,” before turning on the *Explorer OEM* laser for the first time.

---

When operated as a stand-alone system, before it is installed in a master system for example, the *Explorer OEM* laser can be conveniently controlled using the *L-Win* software provided.

Chapter 6 provides instructions for operating the *Explorer OEM* laser using the *L-Win* software, including instructions for monitoring performance, changing the output power, and controlling the pulsed output. Appendix A contains a complete description of each of the *L-Win* GUI displays.

### Installing the *L-Win* Software

The *L-Win* software is provided on a CD-ROM shipped in the accessory kit with the system.

1. Insert the CD into the computer that is to be used to control the system. Use Windows Explorer or My Computer to find the CD drive, then double-click the file “setup.exe” to start the installation.
2. Follow the on-screen instructions to complete the software installation. This procedure installs the *L-Win* software and the *LabView* runtime libraries (version 6.1) onto the computer hard drive.
3. If you have never used programs based on *Labview* on this computer, you may also have to install the *VISA* runtime environment. If the *VISA* runtime environment is not installed, you will not be able to select a serial port, and the serial port communication will not work. *VISA* provides a common software interface layer between *Labview* controls and hardware interfaces like serial port or GPIB.
  - a. Double-click the file “visa260runtime.exe” to start the installation.
  - b. Follow the instructions to complete the software installation. Select the complete installation. If you prefer custom installation, you will need at least the **Serial** runtime support.

After installation, a new program group will be present in your Windows Start menu as Spectra-Physics Laser Control -> L-Win.

The next sections describe how to set up communications between the computer and the laser system, and how to start the laser for the first time.

### Setting Up Initial L-Win Communications

1. Turn on the power supply.
2. Start the *L-Win* control software using your Windows Start menu.
3. The software will automatically search for the COM port to which the *L-Series* power supply is connected. (Alternatively, you can select the port manually. To do this, refer to Appendix A for a description of the Tools menu under the Settings tab.)

### Turn On

1. Turn on the *L-Series* power supply DC switch. The POWER indicator on the power supply will illuminate. Wait for the system to finish its initialization and warm-up sequence, which takes about five minutes. During this time, the red ERROR indicator on the power supply remains on. When it turns off, the laser is ready to operate.
2. Turn on the diode laser ON/OFF keyswitch.
3. From the *L-Win* Main menu, select the Power Control tab.

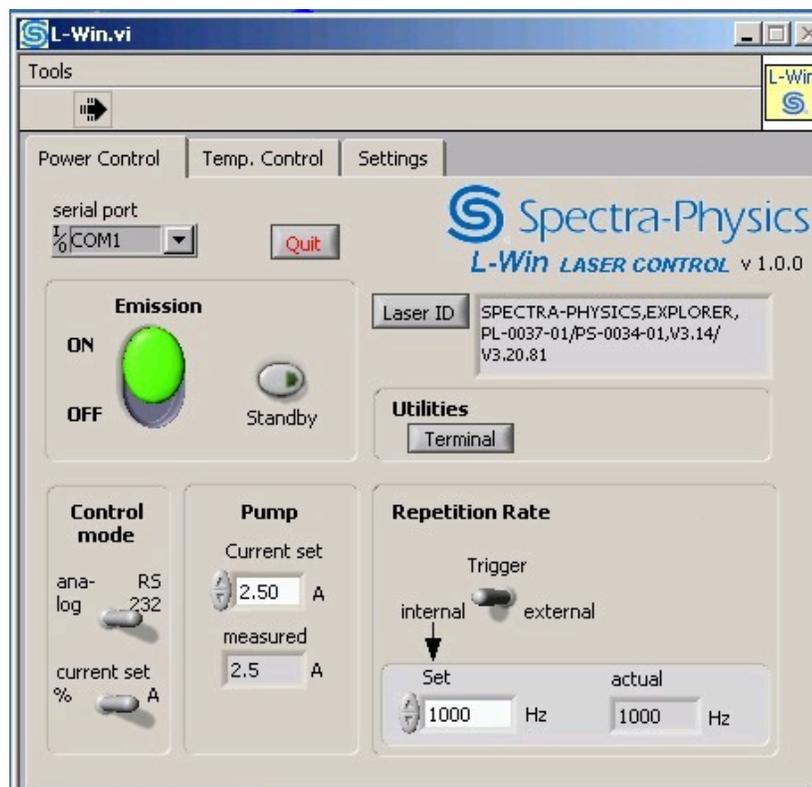


Figure 5-4: The *L-Win* Power Control Display

4. On the *L-Win* Power Control display, Control Mode should be set to RS 232 and Current set to A (for “Amps”). Set the Repetition Rate: Trigger toggle switch to internal.

5. Verify that the laser beam is terminated properly. For example, point it into a beam block or power meter.
6. The laser starts either at the pre-stored factory settings or the user-stored pre-set values.
7. Click on the Emission control to turn on the laser. The blue EMISSION lamp on the power supply and the white indicator on the laser head will illuminate, indicating that the laser is capable of producing laser light.
8. The *Explorer OEM* laser head will begin emitting UV pulses after a 3-second safety delay. Allow the laser to warm up and achieve stable output.
9. The *Explorer* system comes with a data sheet that details the performance of the laser before it left the factory. Verify that the laser performs at or close to the listed values by adjusting the current and repetition rate to match the listed settings. Use a calibrated detector certified for use at 349 nm pulsed output in the kHz range to measure output power.

## Turn Off

If you expect to use the laser again in a short while, use the short-term procedure to leave the crystal ovens turned on in the laser head (and, thus, reduce the warm-up time). Otherwise, use the “long-term” procedure.

### Short-term

1. On the *L-Win* Power Control display, click on the Emission control to turn off the laser.
2. Leave the keyswitch and the DC Power switch on the power supply in the on position.

### Long-term

1. On the Power Control display, click on the Emission control to turn off the laser.
2. Turn off the keyswitch and the DC Power switch on the power supply.
3. Exit the *L-Win* program and turn off the computer.





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Spectra-Physics *Explorer OEM* lasers are *Class IIIb—High Power Lasers* whose beams are, by definition, safety and fire hazards. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage. *The 349 nm ultraviolet output emitted from the laser head is invisible and is, therefore, especially dangerous!* Residual light at other wavelengths might also be present. Read Chapter 2, “Laser Safety,” in its entirety before turning on the *Explorer* system.

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*L-Win* is a LabView<sup>1</sup>-based graphical user interface (GUI) that provides a simple, direct method of controlling the *Explorer OEM* laser as a stand-alone system from a personal computer, for example during installation or service.

This chapter provides instructions for using *L-Win* to control the most commonly used features of the laser. For a complete description of each of the *L-Win* screens, refer to Appendix A, “*L-Win* GUI Reference.”

For instructions on operating the *Explorer* system using serial commands or analog signals, see Chapter 7, “Operating with Commands and Signals.”

**Note**

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The procedures in this chapter assume that the *Explorer OEM* laser has been installed according to the instructions in Chapter 5 and that:

- the laser has been installed with proper attention to heat removal,
- the laser head, power supply, and computer have been properly connected and DC power is being supplied to the power supply,
- the interlock relay and emission circuits, if installed, have been properly wired, or the interlock jumper plug has been correctly installed,
- the *L-Win* software is installed and functioning,
- the power supply DC power has been turned on, the keyswitch is on, and the laser is warmed to operating temperature.

If you are uncertain about the status of the laser, return to Chapter 5 and verify that it has been installed correctly and that *L-Win* is operating.

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<sup>1</sup>Labview is a trademark of National Instruments Inc.

## Basic Operating Control

### Turning the Laser On and Off

This procedure assumes that the laser is already at operating temperature (a warm-start condition). If this is not the case, follow the procedure listed at the end of Chapter 5 for starting the laser as it was done at the time of installation (a cold-start condition). If not already active, enable the Power Control display by clicking on the Power Control tab near the menu bar.

See “Setting the Auto-On Mode” on page 6-5 for a description of the interaction of the keyswitch on the *L-Series* power supply with the functionality of the software.

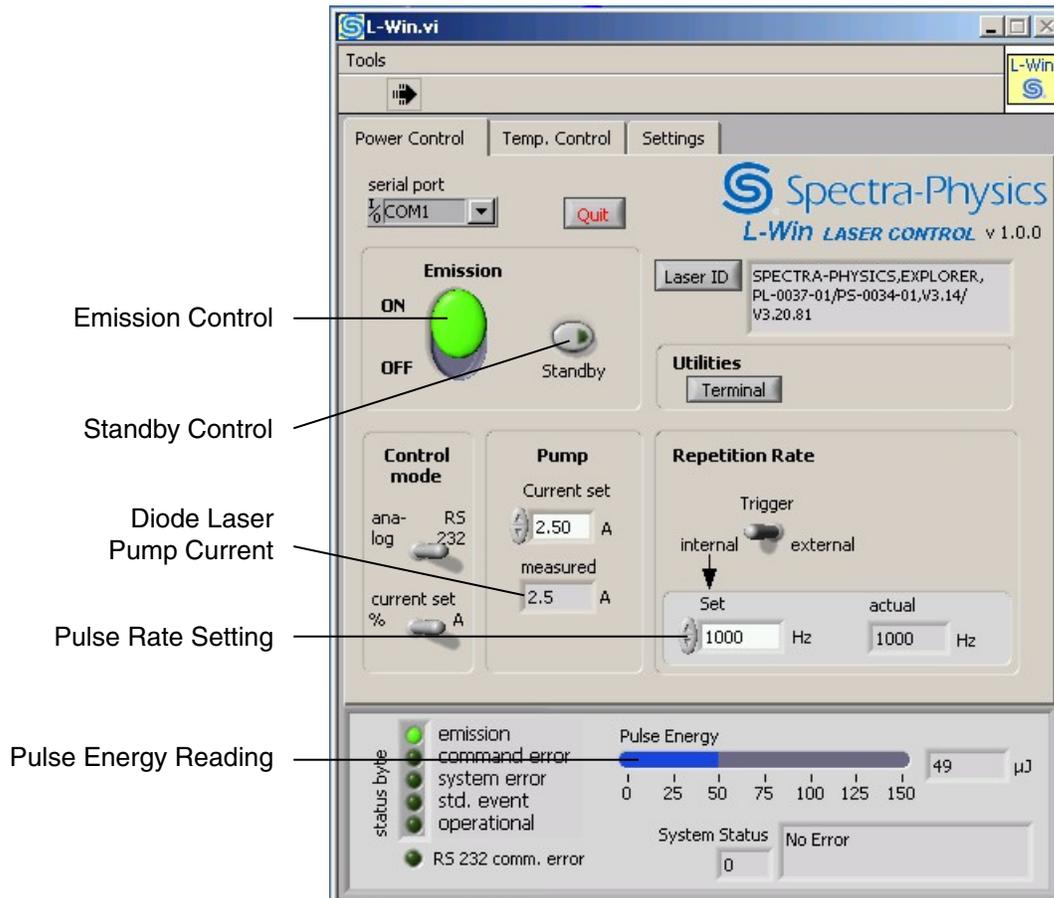


Figure 6-1: The *L-Win* Main Display

To start the laser, click on the Emission switch. The laser head emission indicator turns on immediately, and a pulsed UV beam at the displayed pulse repetition rate is emitted after a 3-second safety delay (assuming the laser is triggered internally.)

To turn the laser off, click on the Emission switch again. The switch will turn gray.

---

**Note**

If the Control mode toggle switch on this display is set to Analog for external control, the ANALOG control switches on this display are disabled. Keep the toggle switch set to RS-232 to operate the laser using the *L-Win* controls.

---

### ***Adjusting the Pulse Energy***

To change the pulses energy (or the average energy of the laser beam), adjust the diode laser current. The current can be changed by clicking on the up/down arrows to the left of the Current Set field, or a value can be typed directly into the text field. Note that the current can also be varied as a percentage of the maximum pre-set current limit. This is enabled by setting the Current Set toggle switch to “%.” The display will then switch from “Amps” to a percentage.

---

**Note**

Changing the pump current can affect other aspects of the laser performance. Refer to “Important Notes on Controlling the Explorer Output” on page 6-15 for more information.

---

The energy of individual pulses can be read from the pulse monitor on the status panel at the bottom of the Main display (Figure 6-1). The status panel readings are updated every second.

### ***Changing the Pulse Repetition Rate***

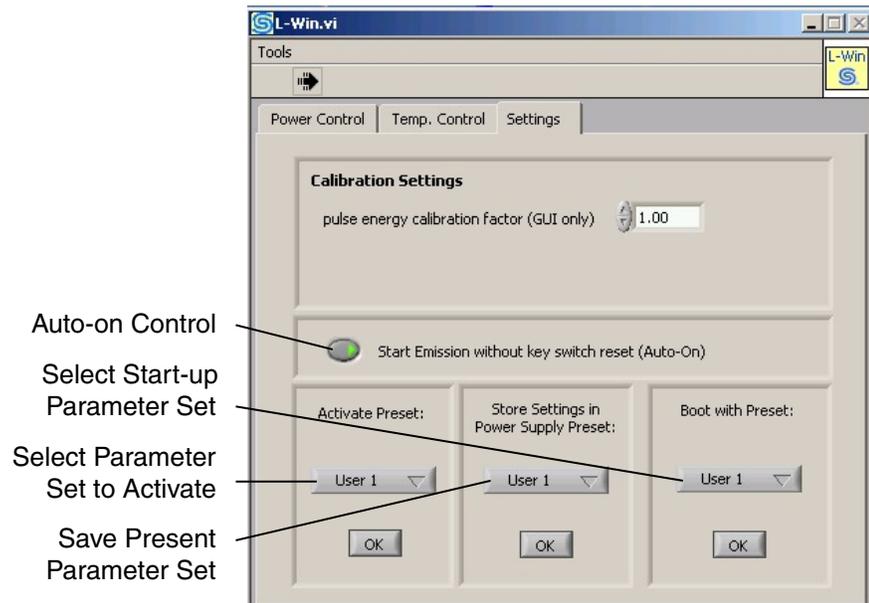
To change the pulse repetition frequency, click on the up/down arrows to the left of the Set field of the Repetition Rate section of the display, or type a value directly into the text field.

Using *L-Win*, the repetition rate can be varied from 1 Hz to 5 kHz. Note that external triggering is also available (see Chapter 7, “Operating with Commands and Signals,” for more information).

### ***Setting the Laser to Standby***

Clicking on the Standby button sets the diode laser to standby current, which is below the threshold for *Explorer* lasing. This extends diode laser lifetime when the laser is inactive, but it keeps the laser at operating temperature for immediate use. Clicking this button again will return the system to normal operation. This button turns yellow when Standby mode is active.

## Saving and Using Pre-Set Operating Parameters



**Figure 6-2: Settings Tab—Selecting Operating Parameters**

**Note**



Pre-sets can only be stored or activated when laser emission is off.

The Settings tab presents the display shown in Figure 6-2, which is used to enable laser operation using a stored set of parameters, either saved by the user or pre-set at the factory. To save the current operating parameters, select either User 1 or User 2 in the Store Preset section of the display, then click on OK to save.

To use a saved set of operating parameters, select either User 1 or User 2 in the Activate Preset section of the display. Factory 1 and Factory 2 are also available. (These factory parameter sets cannot be changed by the user.) Click on OK to operate the laser using the selected set of parameters.

Select a parameter set from the Boot with Preset section and click on OK to designate the parameter set to activate the next time the system is booted.

## Setting the Auto-On Mode

The Settings display may also be used to activate the Auto-On feature. Auto-On mode overrides the need to turn the keyswitch off and on when using *L-Win*. Click on the button labeled Start Emission without key switch reset to enable Auto-On.

Warning!



---

Over-riding the keyswitch does **not** comply with CDRH regulations.

With Auto-On enabled and the keyswitch in the ON position, the laser may only be turned off or on using software commands.

---

## Monitoring and Adjusting Performance

The performance of the laser can be monitored from the Energy Statistics display, and the performance can be optimized concurrently on the Main display. Access the Energy Statistics display from Tools on the menu bar by selecting Pulse Noise Measurement from the drop-down menu (see Figure 6-3 and Figure 6-4 on the following page).

The Energy Statistics display monitors performance in terms of pulse-to-pulse stability by displaying the pulse energy distribution in a histogram as well as other statistical graphical representations. Concurrently, laser performance can be adjusted using the *L-Win* Main window to change parameters such as diode laser current and pulse repetition rate.

Online Histogram activates/deactivates the data collection, calculation and histogram display. While this function is active, the indicator illuminates and the displays are automatically updated. Histo. Intervals sets the resolution of the histogram display in number of intervals to be used. Statistics calc every x measurements sets the update interval for calculating statistics, in number of measurements. The number of pulses sampled is shown by the # pulses selection.

The data fields display the max value and min value for the energy values of the sampled pulses, as well as their mean, rms value, and sigma in % values. The Clear button clears all data fields.

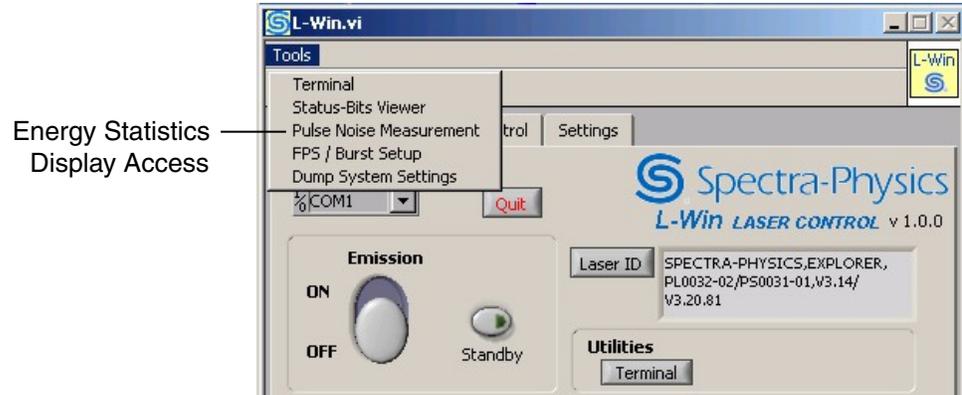


Figure 6-3: Tools Menu—Accessing the Energy Statistics Display

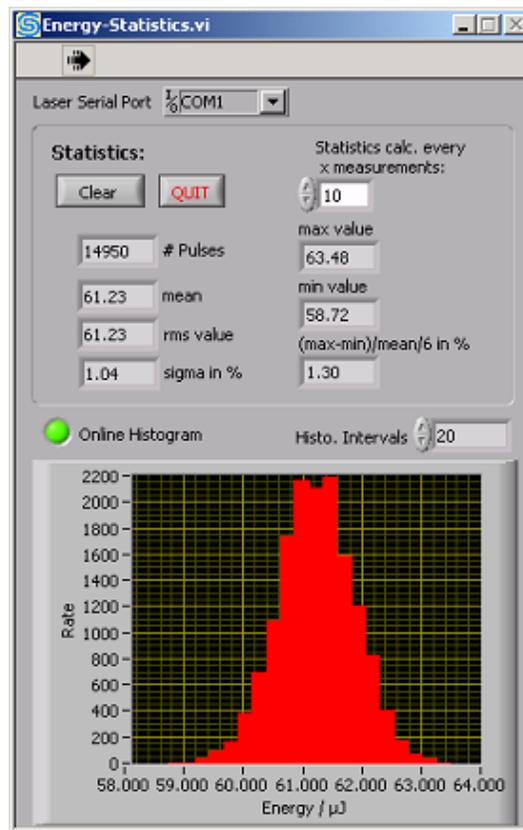
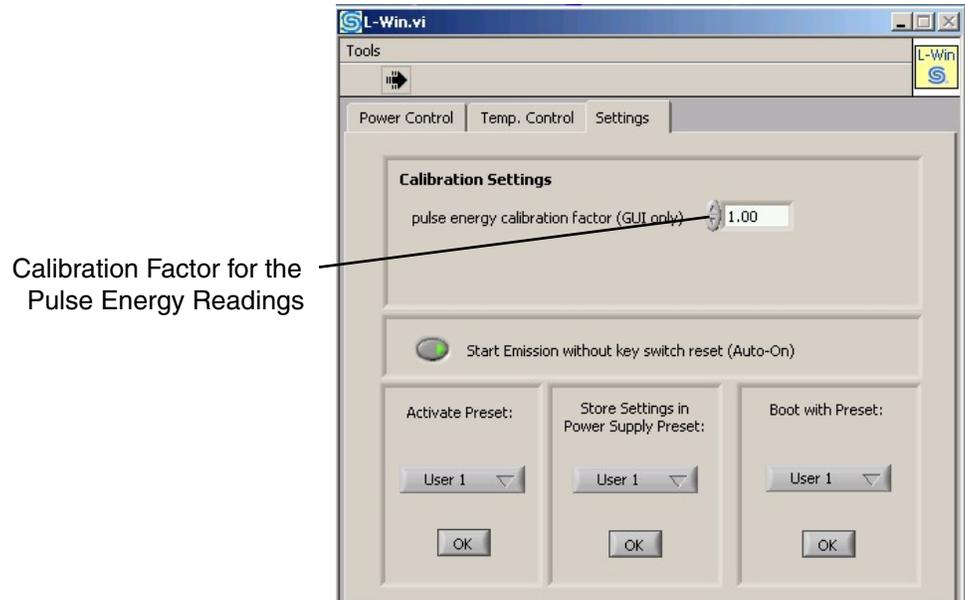


Figure 6-4: Energy Statistics Display

## System Settings

### Calibrating the Pulse Energy Monitor Readings

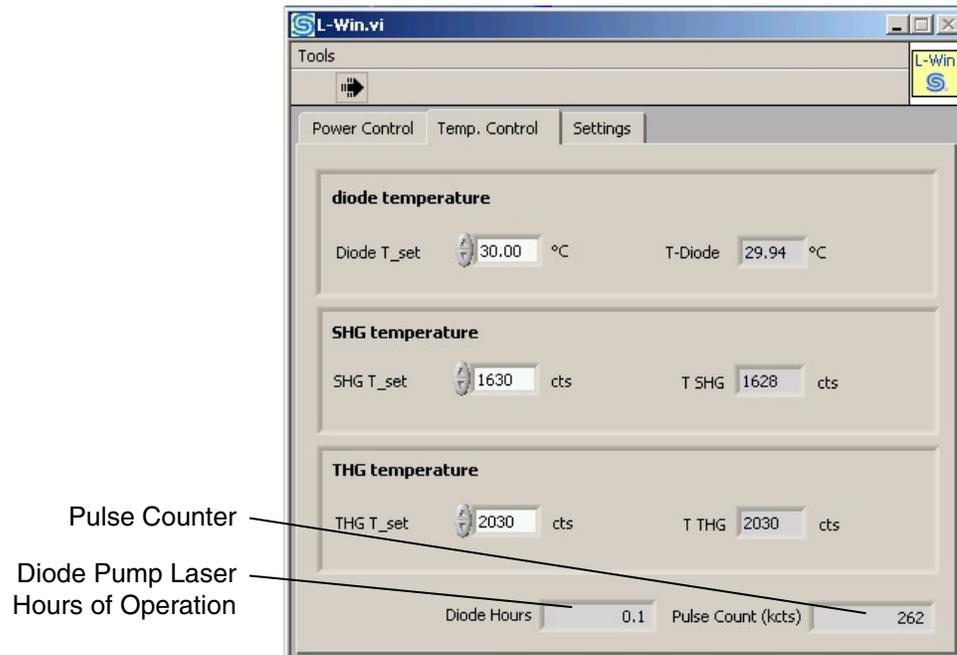


**Figure 6-5: Settings Tab—Calibration Factor**

The Pulse energy calibration factor available under the Settings tab enables a calibration factor for the internal pulse energy monitor readings. A value of 1 shows the unchanged pulse energy values (as reported by the *Explorer OEM* laser) on the *L-Win* displays.

This factor can be changed to correct the displayed values to correspond with an external energy meter. This calibration only adjusts the *L-Win* display readings. It does not calibrate the values reported by the pulse energy monitor itself.

### Tracking Operating Hours

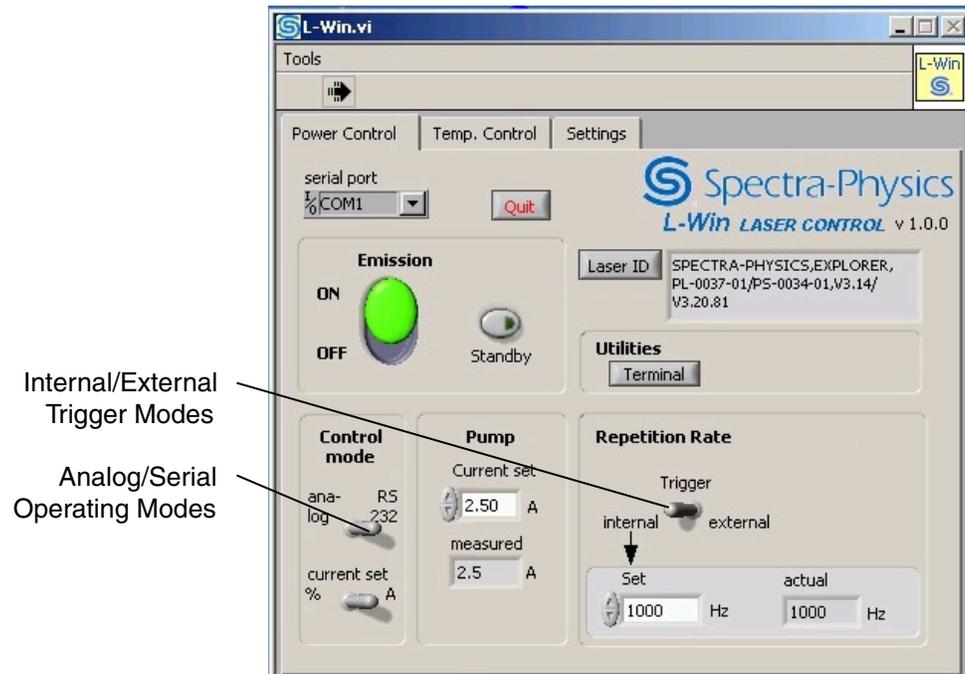


**Figure 6-6: Tracking Operating Hours**

The Diode Hours field shown on the Temp. Control display tracks the total number of hours the diode pump laser has been operated. This information is also useful in monitoring the lifetime of the nonlinear crystals in the laser head.

The field Pulse Count (kcts) displays the total number of pulses, in thousands of pulses, that the laser has emitted during its lifetime. The pulse counter is set to “0” prior to shipment.

## Selecting Analog Control



**Figure 6-7: Selecting Analog Control or the Q-Switch Trigger Source**

Setting the analog/RS 232 toggle switch to analog in the Control Mode section under the Power Control tab allows the laser to be controlled by analog voltages applied at the 26-pin ANALOG IN connector. While in this mode, the controls for emission on/off and diode current are disabled on the *L-Win* displays. Refer to Chapter 7 for information about operating the laser using analog signals.

When Control Mode is set to RS 232, the laser can be controlled via the *L-Win* displays and, likewise, through serial commands. Again, refer to Chapter 7 for information about operating the laser using the RS-232 serial commands. Also refer to Appendix B for a detailed description of the RS-232 commands.

## Changing the Q-Switch Trigger Source

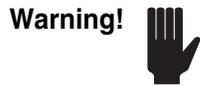
To use an external trigger source instead of the *Explorer* internal Q-switch trigger, set the Repetition Rate Trigger mode to external. The external trigger signal is input through the ANALOG IN connector of the *L-Series* power supply. Refer to Chapter 7 for information about operating the laser using analog signals.

When Control Mode is set to analog, the *L-Win* controls for emission on/off and diode current are disabled.

## Component Temperature Adjustment

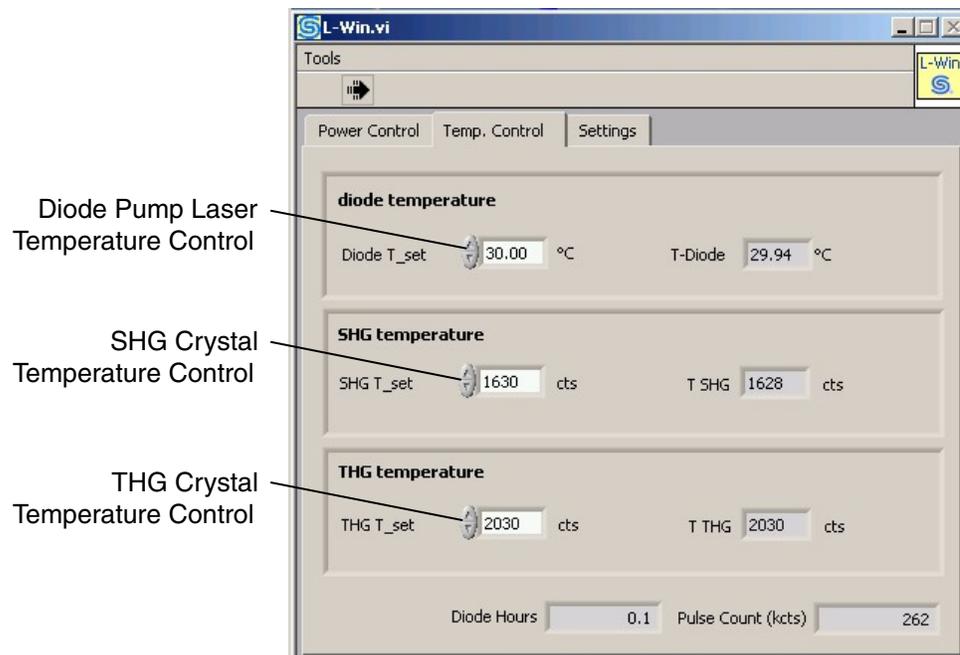
The diode pump laser and the harmonic crystals in the laser head all depend strongly on operation at their correct temperatures in order to function properly. The temperatures of these components are controlled and stabilized using monitoring and feedback loops.

The Temp. Control display provides controls for the pump diode and the second and third harmonic crystals (SHG and THG). The temperatures are set in °C for the diode laser, and in counts for the crystals.



The *Explorer OEM* laser has been designed so that under normal operating conditions it is not necessary to change the original factory setpoint temperatures for the diode laser and nonlinear crystals. Do not change the temperatures of these components unless instructed to do so by an authorized Spectra-Physics service representative.

### Setting the Diode Pump Laser Temperature



**Figure 6-8: Temperature Control Display**

If instructed to change the diode laser temperature, before making any changes, record the present values for operating current and temperature, as well as the other laser parameters (output power, etc.), in the event you need to return the system to these values later. To maintain the diode laser wavelength at its optimum value of 805.6 nm, make small adjustments to the diode laser temperature, then wait to see the effect the change has on the UV pulse energy.

Set the desired temperature of the pump diode using the Diode T\_set controls. The T-Diode field displays the measured temperature in °C.

If the initial operating parameters are lost, restore the original temperature setpoints by activating the preset “Factory 1.”

### **Setting the SHG and THG Temperatures**

Before making any changes to the crystal temperatures, record the starting values for the temperature settings.

When adjusting the temperatures for maximum UV pulse energy, change the value for the THG crystal in maximum increments of 10 counts, then allow the laser output to stabilize before making further changes. Continue making small changes to the THG crystal temperature until a maximum pulse energy output has been achieved.

Next, change the SHG crystal setting, again by small increments, waiting for the laser output to stabilize before making further changes.

After a maximum value has been achieved by adjusting the SHG crystal, return to the THG adjustment. Note the new starting values of the crystal temperature settings, then see if making small changes to the THG temperature results in any further improvement in pulse energy. If it improves, make further small changes to the SHG crystal temperature as well.

When the optimum output has been achieved, log the new temperatures along with the current and energy readings.



**Caution!**



If the SHG and/or THG temperature setpoints are changed too rapidly, *Explorer* emission will be automatically switched off to prevent optical damage to the laser components. The laser will remain off until the SHG and/or THG temperatures have reached a stable operating condition.

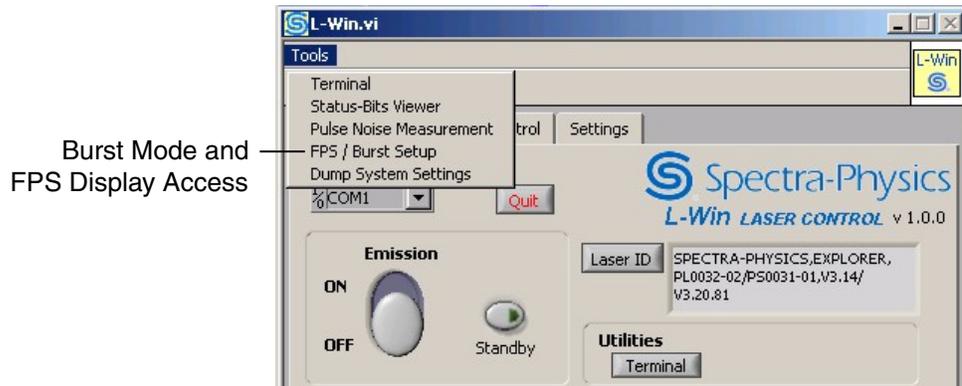
Return to the Main display to allow laser emission to resume.

---

## Features of the Extended Models

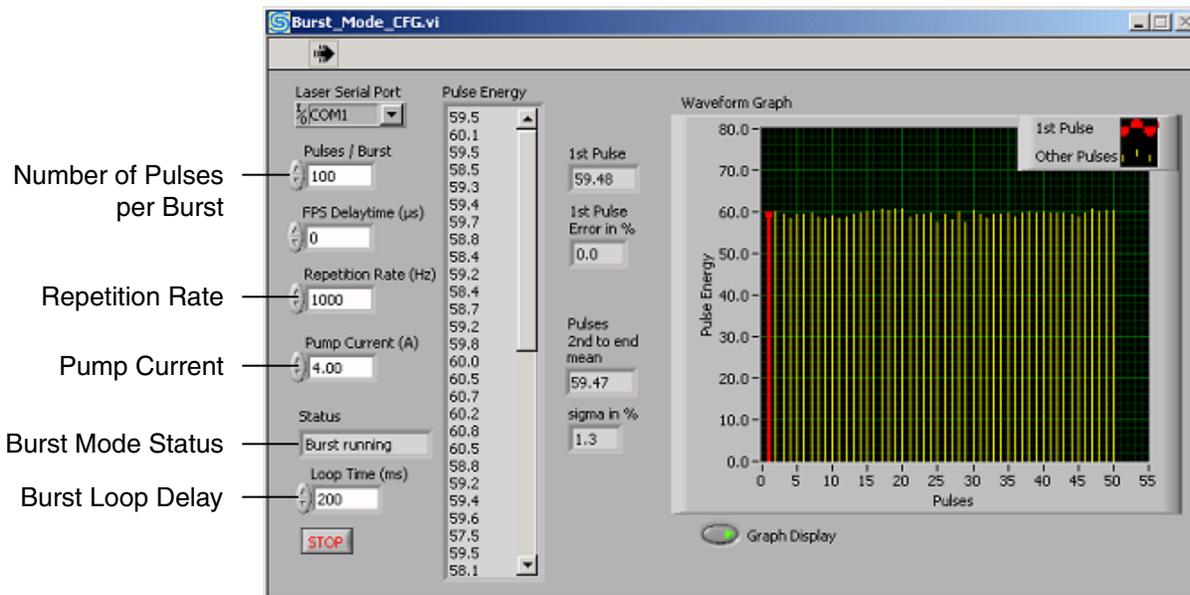
### Burst Control

The two extended models of the *Explorer OEM* laser allow pulses to be grouped in packets that are separated by periods with no laser output. This method of operating the laser is called Burst mode. To set up Burst mode, select FPS/Burst Setup from the Tools menu as shown in Figure 6-9.



**Figure 6-9: Tools Menu**

The Burst mode display will appear as shown in Figure 6-10.



**Figure 6-10: Burst Mode and FPS Display**

Note that current and pulse repetition frequency can be changed using this screen. Set the laser to operate at the energy level and frequency desired for pulses that will comprise a burst.

To establish Burst mode operation:

1. Set the number of pulses to be contained in a single burst using the Pulses/Burst field.

This setting, together with the repetition rate, will determine how long the burst will last. The example shown in Figure 6-10 has 100 pulses (at 1 kHz) per burst, so a burst will span 100 milliseconds.

2. Use the Loop Time field to set, in milliseconds, how often a burst will be emitted. Setting the delay to 200 ms as shown in Figure 6-10 will result in an interval of 200 ms between bursts. (Note that Loop Time is a parameter only in *L-Win*, and is not supported by *Explorer* firmware itself.)

For Burst mode to be effective, the duration of a burst must not overlap the loop time, or no delay will occur between bursts (i.e., pulsed emission will be continuous).

The STOP button quits the Burst mode application. Status shows its present status.

**Note**



If the Burst mode application is exited with a non-zero value set in the Pulses/Burst field, no laser light will be emitted until a new burst command is issued either by serial command or analog signal.

Setting Pulses/Burst to “0” disables the Burst mode application.

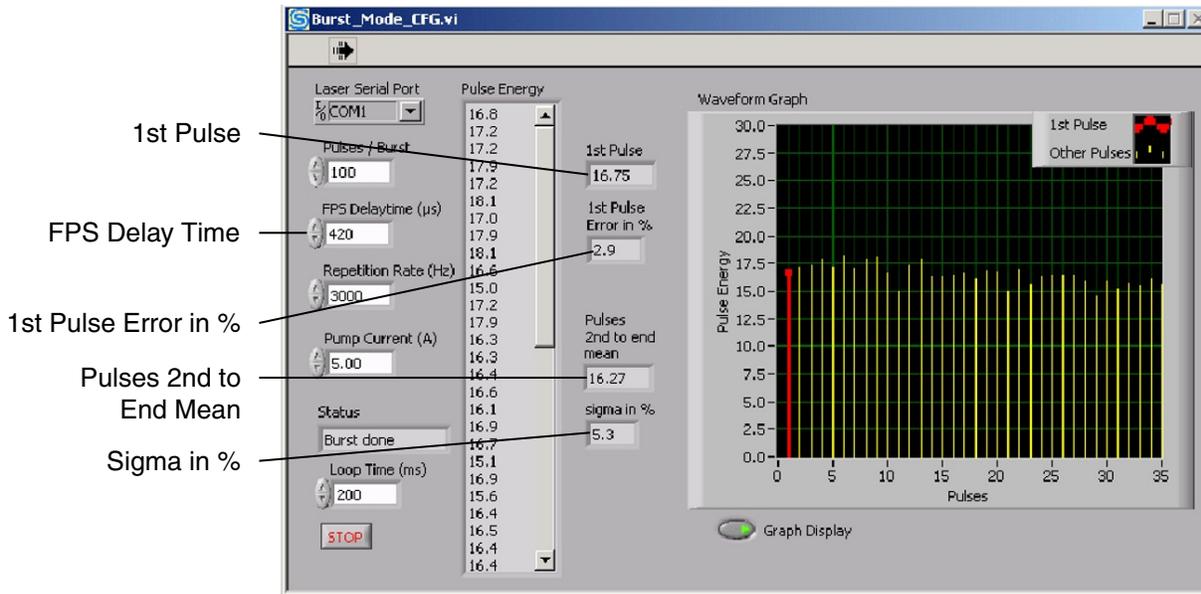
**FPS Operation**

First Pulse Suppression (FPS) is an important feature for operating the laser in Burst mode at repetition rates above 1.5 kHz. Without FPS, the first pulse of a burst of high repetition rate pulses will be a “giant” pulse with an energy much larger than the subsequent pulses. With FPS, the first pulse energy can be reduced so that all pulses in a sequence have approximately the same energy. See “First Pulse Suppression” on page 3-8 for a further description of the first pulse effect.

Useful operating modes of the *Explorer OEM* laser using FPS at pulse repetition frequencies greater than 2 kHz are “FPS with Gating” and “FPS with Burst mode.” Refer to the section “Advanced Control of the Pulsed Output” on page 7-23 for more information.

For convenience, both the current and the pulse repetition frequency can be changed using the FPS and Burst mode display (Figure 6-11).

To use FPS, set the FPS Delay Time parameter (in  $\mu\text{sec}$ ) so that the first pulse has approximately the same energy as subsequent pulses in a burst. The recommended starting value of the FPS delay time is the inverse of the applied pulse repetition frequency. For example, if the PRF is 2 kHz, the recommended FPS starting value is 500  $\mu\text{s}$ . Iterate the FPS delay time around this starting value to minimize the difference between the first pulse energy and the energy of subsequent pulses in the chain.



**Figure 6-11: FPS and Burst Mode Display**

The energy of the first pulse can be compared to the remaining pulses using the red bar shown in the waveform graph. Also, the First Pulse Error field displays the discrepancy (as a percentage) between the energy of the first pulse and the mean energy of the remaining burst pulses. Adjust the FPS Delay Time value until the First Pulse Error is close to 0%.

This display provides additional pulse energy monitoring as well. The First Pulse field displays the energy of the first pulse of the burst. The Pulse energy field displays the energy of each pulse in a burst, chronologically. The Pulses 2nd to end mean field displays the calculated average energy of all pulses in a burst except the first. And the sigma in % field displays the calculated standard deviation of the energy of all pulses in the burst (excluding the first pulse).

The Waveform Graph display shows one vertical bar for each pulse in a burst, showing its energy in relation to other pulses. Use the Graph Display button to display or close the waveform graph.

## Important Notes on Controlling the Explorer Output

The *Explorer OEM* laser output power is controlled by changing the diode laser current. Diode current can be varied as needed, but the maximum allowed diode laser current is pre-set at the factory.

There is no lower diode current limit. However no laser light will be emitted if the diode current is lowered below the laser threshold. If the diode current is lowered close to the laser threshold, unstable operation might result.

Changes to the diode current will change the temperature of the diode laser and, hence, the wavelength of its emission. Failure to maintain the diode emission wavelength at the proper wavelength can actually cause a decrease in ultraviolet power when diode current is increased.

### A Cautionary Note on Changing Power

*Explorer* systems are specified and tested for the highest power they can reliably output. The laser must not be operated at power levels higher than this tested level (refer to the Ship Report included with the system).



Caution!



---

Over-driving the system can cause spatial mode degradation and Q-switch hold-off problems, and can shorten the diode laser lifetime.

---

Output power levels may be reduced if the application requires lower power. Since diode laser lifetime is strongly a function of current, reducing this current can extend the lifetime of the diode laser. However, reducing pump power might impact other performance parameters of the laser output. For example, it is common for pulsed, solid-state lasers to change pulse width when the pump power changes. Decreasing pump power will lower optical gain and result in a broadening of the pulse width. This might also result in higher pulse-to-pulse instability.

### Working with the Diode Laser Current Limit

To ensure long system lifetime, the *Explorer OEM* laser head achieves specified output power using a level of pump power that is lower than the maximum rating of the pump diode laser. To protect the diode laser, a current limit is imposed that prevents an over-driven situation that could damage the diode laser or even the *Explorer* itself. When new, the diode laser module achieves its rated output power using a fraction of the current required at its end of life. Higher drive current is necessary later in the diode life in order for the laser to achieve its specified output power.





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Spectra-Physics *Explorer OEM* lasers are *Class IIIb—High-Power Lasers* whose beams are, by definition, safety and fire hazards. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage. *The 349 nm ultraviolet output emitted from the laser head is invisible and is, therefore, especially dangerous!* Residual light at other wavelengths might also be present. Read Chapter 2, “Laser Safety,” in its entirety before turning on the *Explorer* system.

---

The *Explorer OEM* laser must be started initially using either the serial commands outlined in this chapter or the *L-Win* software described in Chapter 6. Once the *Explorer* system is turned on, it can also be controlled using signals applied to the ANALOG interface on the power supply or through a combination of serial commands and analog signals. Maximum control of laser output is provided by combining the flexibility of serial commands with the speed of analog signals.

**Note**

---

The procedures in this chapter assume that the *Explorer OEM* laser has been installed according to the instructions in Chapter 5. This means that:

- the laser was installed with proper attention to heat removal,
- the laser head, power supply and computer were properly connected, and that DC power is supplied to the power supply,
- the interlock relay and emission circuits, if installed, are properly wired or the jumper plug is installed,
- the power supply DC power has been turned on, the keyswitch is on, and the laser is warmed up to operating temperature.

If you are uncertain about the status of the laser, return to Chapter 5 and verify that it has been installed correctly.

---

Appendix B lists all of the serial commands and analog signals available to the user. This chapter provides instructions and examples on how to use some of these commands and signals to control laser output.

## Serial Communication

### ***Connection and Parameters***

The *Explorer* serial connection is the RS 232 port on the front of the power supply. Refer to Table 4-1 on page 4-5 for a functional description of this connector.

#### **Communications Parameters**

4,800 – 57,600 baud  
No parity  
8 data bits  
1 stop bit  
Hardware handshake: none  
Enable: echo local typed characters.

### ***Serial Command/Query Language***

The user can issue commands and create programs for operating the *Explorer OEM* laser system using the serial command/query language. The latest version can always be obtained from Spectra-Physics.

The command terminator is a carriage return, “<CR>”

All queries and commands reply with a carriage return and line feed, “<CR><LF>.” Commands are not case-sensitive.

### ***Serial Communication through the L-Win GUI***

Once installed in the host system, a user-written program run on the system host computer can be used to operate the *Explorer*, possibly in combination with analog command signals. Serial commands can also be entered manually through the RS 232 port using a terminal emulation program.

The *L-Win* software provides a convenient method of executing serial commands. (Refer to Chapter 5, “Installation,” for instructions on installing and starting *L-Win*). From the *L-Win* Main display, select Tools from the menu bar, then Terminal from the pull-down list of options that appears. This will activate a display that can be used to type in serial commands manually.

## Basic Serial Operating Control

Note



Refer to “Important Notes on Controlling the Explorer Output” near the end of Chapter 6 before making significant changes to the operation of the *Explorer*.

### Remote and Local Control

Before the laser can be operated using serial commands, on/off control must be transferred to the RS 232 serial port. Use the following command to transfer control for remote operation (i.e., using serial commands):

MODE:REMOTE 1 puts the system in remote mode where the system is controlled via the serial port.

MODE:REMOTE 0 puts the system in local (analog) mode where the system can be switched on by turning the *L-Series* diode laser keyswitch to the ON position and signals can be provided to the ANALOG interface.

Use the following query to determine if the laser is in remote or local mode:

MODE:REMOTE?

Response n = 1 the system is in computer (remote) mode.

Response n = 0 the system is in analog (local) mode.

### Turning the Laser On and Off

If the DC power switch and the keyswitch on the L-Series power supply are both on and control has been transferred to remote operation, the laser is turned on by entering:

ON

Emission will begin after a safety delay of 3 seconds. The emission indicators on the laser system will turn on immediately.

OFF causes laser emission to stop immediately and turns off the emission indicators.

### The Watchdog Timer

The laser has a watchdog timer that, if enabled, turns off the laser if it does not receive a communication from the host computer within a user-specified interval. The default setting for the watchdog timer is OFF. Set the watchdog timer interval using the following command:

WDOG <n> where <n> = interval time from 0 to 110 seconds

To query the status of the watchdog timer, enter

WDOG? where the return value is the interval time in seconds

WDOG 0 turns off the watchdog timer.

### ***Adjusting the Pulse Energy***

To read the actual pulse energy (in  $\mu\text{J}$ ), use the query:

READ:PENER?

To change pulse energy, adjust the diode laser current using the following command:

DIODE1:CURR <f> where <f> is a decimal value for the current in Amps.

Example:

DIODE1:CURR 4.5

READ:DIODE1:CURR? returns the actual value of the diode current.

DIODE1:CURR? returns the value last commanded.

The current can also be set as a percentage of its maximum allowed value using the following command:

PCUR <f> where <f> is a decimal value for the percent of maximum current.

### ***Changing the Pulse Repetition Rate***

The QSW:PRF command changes the pulse repetition frequency (PRF). For example, to set the pulsed output to 1 kHz, enter the command:

QSW:PRF 1000

To return the present value of the PRF, enter the query:

QSW:PRF?

### ***Changing the Q-Switch Trigger Source***

The QSW:PRF command is also used to set the Q-switch trigger input to an external source that is supplied to the ANALOG IN connector on the *L-Series* power supply. Details for using an external trigger source are provide later in this chapter in “The Analog Interface.” To change to an external Q-switch trigger source, enter the command:

QSW:PRF 0

### ***Setting the Laser to Standby Modes***

There are three Standby modes for the *Explorer OEM* laser: Standby, Ready, and Sleep. The modes differ in the time required for the laser to return to operation from each mode.

#### **Standby Mode**

Standby mode lowers the current of the diode laser below the threshold for laser output but keeps the diode laser in a state of readiness. All other *Explorer* components are maintained at operating temperature. To enter Standby mode, enter the command:

MODE:STBY 1



### Tracking Operating Hours

To monitor laser head hours of operation, which is useful in tracking the lifetime of the diode laser and harmonic crystals, enter the query:

```
READ:HEAD:HOURL?
```

Example:

```
READ:HEAD:HOURL?
```

```
456.2HrsHd
```

### Saving and Using Operating Parameters

As a short-cut to activate a desired state of laser operation, the *Explorer* system allows the use of stored sets of parameters that are either saved by the user or pre-set at the factory. The parameters can either be loaded automatically at boot-up or activated after operation has begun. The system can save two sets of user-specified operating parameters.

There are 11 parameters that comprise a complete set for the standard *Explorer* and 14 parameters for an extended model. The parameter set is listed in Table 7-2.

To save the current operating parameters, enter the following command:

```
CONFIG:PARSET:STOR <n> where <n> specifies User Set 1 or 2
```

In addition to the two sets of user-defined parameters, the *Explorer* system comes with two sets of factory commands. To use one of these saved factory sets, enter the following command:

```
CONFIG:PARSET:LOAD <n> where <n> specifies one of the following parameter sets:
```

n = 1: user set #1

n = 2: user set #2

n = 3: factory set #1

n = 4: factory set #2

To return which set of parameters is presently active, enter the query:

```
CONFIG:PARSET:ACT? where 1, 2, 3, or 4 is returned, corresponding to the parameter sets listed above.
```

To designate which parameter set is to activate the next time the system is booted, enter the command:

```
CONFIG:PARSET:BOOT <n> where 1, 2, 3, or 4 is returned, corresponding to the parameter sets listed above.
```

To find out which set of parameters will be activated the next time the system is booted, enter the query:

```
CONFIG:PARSET:BOOT? where 1, 2, 3, or 4 is returned, corresponding to the parameter sets listed above
```

## Setting the Auto-On Mode

Auto-On mode overrides the need for a keyswitch reset (i.e., turning the keyswitch off then back on) to turn the system on using serial commands. This is the normal mode for operating the laser using remote control. To enable Auto-On Mode, enter the command:

```
CONT:AUTOON 1
```

To disable Auto-On mode, enter the command:

```
CONT:AUTOON 0
```

To return the status of Auto-On mode, enter the query:

```
CONT:AUTOON?
```

Warning!




---

Over-riding the keyswitch does **not** comply with CDRH regulations.

With Auto-On enabled and the keyswitch in the ON position, the laser can only be turned on or off using software commands.

---

## Laser System Settings

### Configuring Analog Control

Serial commands can be used to configure and monitor the individual pins of the ANALOG IN connector. Refer to “The Analog Interface” later in this chapter for information regarding the function of the ANALOG IN connector. The serial commands and queries act on an 8-bit Analog Port Status Byte where each bit corresponds to a particular laser function controlled by an analog signal.

If a bit in the Analog Port Status Byte is set to “1,” the corresponding analog signal is either set to “high” (for a command) or is read as “high” (in response to a query).

More detailed information, including tables of the Analog Port Status Byte and the polarity of the analog port, can be found in Appendix B.

The query STAT:APORT:SIGNAL? is used to read the status of a function available through the analog interface. If this query returns “64,” for example, it means, if bit 5 is active high, the laser is in Standby mode.

To set the polarity of an individual pin to active high or active low, enter the command CONFIG:APORT. The command CONFIG:APORT 96, for example, places a “1” in bit positions 5 and 6, corresponding to Standby and Go functions, which are set to active high.

The query CONFIG:APORT? returns the setting of an individual pin. If a “96” was returned, for example, it means that there are 1’s in bits 5 and 6, so those functions (Standby mode and Go) will be activated when the pins for them are pulled high.

### ***Setting the Output Trigger Source***

The *Explorer* provides an output trigger signal to synchronize measurement equipment to the optical pulses. The trigger output is provided on pin 19 of the ANALOG IN connector on the *L-Series* power supply. This output trigger can be configured to be either the trigger for the Q-switch signal, or the result from firing the Q-switch.

To set pin 19 to provide the trigger signal *after* the Q-switch fires, enter the command:

```
CONFIG:APORT:SYNC 1
```

To set pin 19 to provide the trigger for the Q-switch, enter the command:

```
CONFIG:APORT:SYNC 0
```

Refer to the description of pin 19 in “Trigger Output” on page 7-20 for specifications of these timing signals. (Note that the *Explorer* also provides the OptoSync output signal. Refer to Chapter 3 for more information about OptoSync.)

### **Component Temperature Adjustment**

The diode pump laser and the harmonic crystals in the laser head all depend strongly on operating at the correct temperature in order to function properly. These components are actively cooled or heated using monitoring and feedback loops. The laser system also provides the ability to actively control an optional fan to cool the laser head mounting baseplate.

#### ***Controlling the Laser Head Temperature***

To read the temperature of the laser head in °C, enter the query:

```
READ:HEAD:BAS:TEMP?
```

To read the temperature setting for the laser head fan in °C, enter the query:

```
HEAD:FANCONT:TEMP?
```

To set the temperature of the laser head in °C, enter the command:

```
HEAD:FANCONT:TEMP <f> where <f> is a decimal number:  $24.0 \leq f \leq 40.0$ 
```

Example:

```
HEAD:FANCONT:TEMP 33.5
```

#### ***Setting the Diode Pump Laser Temperature***

The laser diode operating temperature is specified between 18–35°C. If the temperature is properly stabilized, the measured value is constant in a range of  $\pm 0.05^\circ\text{C}$ .

To read the temperature of the diode laser in °C, enter the query:

```
READ:DIODE1:TEMP?
```

To read the temperature setting for the diode laser in °C, enter the query:

```
DIODE1:TEMP?
```

To set the temperature of the diode laser in °C, enter the command:

DIODE1:TEMP <f> where <f> is a decimal number:  $17.0 \leq f \leq 43.0$

Example:

DIODE1:TEMP 29.2

### ***Setting the SHG and THG Temperatures***

Temperatures are set in counts between 100 and 4000 for the SHG and THG crystals.

Use the query READ:SHG.TEMP? or READ:THG.TEMP? to read the temperature of the SHG or THG crystal in counts.

Example:

CONT:SHG:TEMP?  
1649

Use the command CONT:SHG:TEMP <n> or CONT:THG:TEMP <n> to set the temperature of the SHG or THG crystal in counts.

Example:

CONT:SHG:TEMP 1650

Use the query CONT:SHG.TEMP? or CONT:THG.TEMP? to read the last commanded temperature for the SHG or THG crystal in counts.

Example:

CONT:SHG:TEMP?  
1650

## System Temperature Management

The *Explorer* system continuously monitors component temperature during operation. If an over-temperature condition is detected for the laser head or the power supply, the system will perform a safety shut-down by entering Sleep mode in order to prevent any damage. Before the shut-down condition is reached, however, warning codes are issued and the system continues to operate normally.

The temperature conditions of the laser system may be checked using the serial commands or the Status Viewer display of *L-Win*.

The heatsink temperature can be checked with the READ:HEAD:BAS:TEMP? query.

**Table 7-1: System Response to Over Temperature Conditions**

Component	Temperature*	Action
Heatsink	<18°C	Issue message: WARNING UNDERTEMP HEATSINK Laser remains fully operational
Heatsink	>40°C	Issue message: WARNING OVERTEMP LASERHEAD Laser remains fully operational
Heatsink	>45°C	Safety shutdown (Sleep mode is activated) Clear message: WARNING OVERTEMP LASERHEAD Issue message: ERROR LASER HEAD OVERTEMPERATURE
Heatsink	unit returns to <40°C	Clear message: ERROR OVERTEMP LASERHEAD User may exit Sleep mode
Power supply	>50°C	Issue message: WARNING OVERTEMP POWERSUPPLY Laser remains fully operational
Power supply	>60°C	Safety shutdown (Sleep mode is activated) Clear message: WARNING OVERTEMP POWERSUPPLY Issue message: ERROR POWERSUPPLY OVERTEMPERATURE
Power supply	unit returns to < 50 °C	Clear message: ERROR OVERTEMP POWERSUPPLY User may exit Sleep mode

\* all temperatures listed are typical values

## Features of the Extended Models

Two extended *Explorer OEM* laser models provide Burst mode and FPS operation in addition to all of the standard operating features.

### **Burst Control**

Burst mode can only be initiated using serial commands. Actual bursts can also be started using analog signals provided to the ANALOG IN port.

The BURST command causes the *Explorer OEM* laser to emit one burst of pulses.

The number of pulses in a burst, up to 4000, is set using the command BURST:CNTS <n>.

To return the number of pulses that will be contained in the next burst (when issued), use the query BURST:CNTS?. If the return value for this query is “0,” Burst mode is disabled.

The command BURST:CNTS 0 disables Burst mode and returns the laser to normal output.

The following is an example of how to execute a burst output. Laser emission is assumed to be off. Note: if the laser was booted using pre-set parameters or is already operating at the desired energy level and pulse repetition rate, the first 3 commands should be skipped.

---

MODE:REMOTE 1	Place the laser in computer control.
QSW:PRF 1000	Set the pulse repetition rate (In this example, 1000 Hz)
DIODE1:CURR 3.0	Set the pulse energy
BURST:CNT 100	Select the number of pulses in the burst (In this example, 100 pulses).
ON	Emission is activated (3-sec safety delay) No pulses are emitted, laser emission is at idle.
BURST	Emit a burst of 100 pulses.
BURST	Emit a second burst of 100 pulses.
BURST:CNTS 0	Exit Burst mode and return to normal operation.

---

The *Explorer OEM* laser allows the trigger output, which is available for synchronizing equipment to the laser output, to be extended for the duration of the burst.

BURST:SYNC 1 extends the trigger output for the burst duration.

BURST:SYNC 0 causes the trigger output to have its normal duration.

BURST:SYNC? returns the status of this “synchronize-over-burst” setting.

## ***FPS Operation***

The first pulse of a burst will become anomalously large when the repetition rate of the pulses exceeds 1.5 kHz. (This effect is discussed in more detail in Chapter 3 and also in Chapter 6.) To reduce the energy in the first pulse, use the First Pulse Suppression (FPS) commands and queries described below.

The query READ:PENER:HIST? is useful for determining the level of the first pulse energy. It returns the energy values of the first 50 pulses, in counts, after the ON, BURST, or READ:PENER:HIST? commands have been sent to the software control interface. (A returned value of “0” means the laser has not emitted pulse in this session.)

As an example, a return might look like:

```
955 772 781 776 ..... 776 778 773
```

Based on this example, the FPS delay time should be set to reduce the first pulse from a value, in counts, of about 950 to about 750.

To optimize laser performance using the FPS feature, the recommended start value is the inverse of the applied pulse repetition frequency. For example, if the PRF is 2 kHz, the recommended FPS starting value is 500  $\mu$ s.

FPS:DELAY <n> sets the FPS delay time, where is <n> an integer value in  $\mu$ sec up to 65535.

Example:

```
FPS:DELAY 500
```

```
FPS:DELAY? reads the value of the FPS delay time.
```

```
FPS:DELAY 0 exits FPS mode.
```

When an external trigger is used for the Q-switch, FPS mode must be enabled separately as well. Refer to Appendix B for details.

## ***Random Pulsing Mode***

This mode allows an externally triggered variable pulse rate to maintain constant pulse energy. Once Random Pulsing is activated, each external trigger pulse generates one laser output pulse.

Random pulsing can only be used in FPS mode and only if external triggering is selected.

MODE:RAND 1 activates Random Pulsing; MODE:RAND 0 deactivates Random Pulsing, and leaves the standard FPS mode active.

## User Parameter Sets

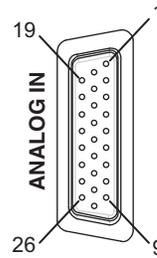
Defining and implementing user parameter sets was described in the section “Saving and Using Operating Parameters” on page 7-6. Each of the operating parameters in a complete set have been discussed in the preceding sections.

The parameters in Table 7-2 comprise a user parameter set. Two different sets can be defined and stored as “User Set 1” and “User Set 2.”

**Table 7-2: User Parameters**

<b>Parameter Description</b>	<b>Command to Modify Parameter</b>
Pulse repetition frequency	QSW:PRF <n>
Diode current	DIOD1:CURR <f> or PCUR <f>
Operation modes	
Auto-On feature	CONT:AUTOON <n>
Computer/Analog Mode	MODE:RMT <n>
Sync Mode after Q-switch	CONFIG:APORT:SYNC <n>
Polarity of analog port signals	CONFIG:APORT:POLAR <n>
Pulses per burst	BURST:CNTS <n>
Sync pulse spanned over burst	BURST:SYNC <n>
Delay time for first pulse suppression	FPS:DELAY <n>
SHG temperature	CONT:SHG:TEMP <n>
THG temperature	CONT:THG:TEMP <n>
Diode temperature	CONT:DIOD1:TEMP <n>
Alert time for software watchdog	WDOG <n>

## The Analog Interface



**Figure 7-1: The 26-Socket ANALOG IN Connector**

The *L-Series* 26-pin D-sub ANALOG IN port is used to control the laser system via user-supplied DC voltages and/or TTL-level signals.



In order for the system to operate, pins 7 and 8 must be shorted together, either directly (using the supplied shorting jumper plug) or through a user-supplied, normally-closed interlock switch.

The analog interface accommodates a variety of control modes and timing requirements and is used in conjunction with serial commands executed through the RS 232 interface. This interface provides the following controls:

- laser on/off
- Standby mode
- diode laser current set
- safety interlock
- emission output
- ready and fault indicators
- UV pulse energy monitor
- Q-switch trigger
- pulse gating
- synchronous output trigger signals

To use this analog interface, communication must first be established with the *Explorer* using either the *L-Win* software or through serial commands. Analog control is then enabled by setting the ANALOG toggle switch on the *L-Win* Main display, or by executing the serial command `MODE:REMOTE 0`.

A functional description of the pins of the analog interface is given in Table 7-3 below. “Configuring Analog Control” describes how the functions of some of the pins can be set to a different polarity; the descriptions in Table 7-3 are given in their default states. Table 7-3 is followed by examples of using the analog interface to perform some of the more common laser operations.

**Table 7-3: Analog Port Description**

Pin	Type	Description	Function
1	Output, Analog	Pulse Energy	UV pulse energy monitor Scale: 0 – 4 V (2 V corresponds to nominal pulse energy) (0–60 $\mu$ J or 120 $\mu$ J, respectively) Tolerance: +5%/–10% Maximum load: 2 k $\Omega$ Validity: < 25 $\mu$ s after optical pulse to next trigger
2	Input, Analog	I_EXT	External diode current control Active if ILD_SOURCE (Pin 18) is pulled low (high) <sup>1</sup> Scale: 0 – 4 V 0%–100% of diode current limit
3	N/A		
4	N/A		
5	N/A		
6	N/A		
7	Output, Power	USR_ILK	+12 V line with 470 $\Omega$ source impedance. Must be shorted to Pin 8 by a floating contact to complete the interlock return circuit.
8	Input, Power	USR_ILK_RTN	Must be shorted to Pin 7 by a floating contact to complete the interlock return circuit. Typical current is 10 mA. The floating contact resistance must be <100 $\Omega$ (see Note)
9	Output, Digital	EMISSION(L)	Open-Collector (OC) line, pulls low when laser emission is active, TTL level (see Figure 7-3).
10	Input, Digital	EXT_DIODE_ON	Internal pull-up <sup>2</sup> . Pull and keep low (high) <sup>3</sup> to trigger the diode laser on. Release high (low) <sup>3</sup> to shut laser emission off. Disabled in remote (computer) mode!
11	Output, Digital	READY	Open-Collector (OC) line, pulls low when the laser is operational, TTL level (see Figure 7-3).
12	N/A		
13	Output, Digital	ILK_FAULT	Open-Collector (OC) line, pulls low when the laser interlock is open, TTL level (see Figure 7-3).
14	Output, Digital	PULSE_MONITOR OPTO_SYNC	Pulls low (high) <sup>1</sup> when an optical pulse has been detected. May not appear at <5% maximum specified pulse energy. Source: HCT gate (5 V), 50 $\Omega$ series resistor. A 50 $\Omega$ cable is recommended in order to maintain the waveform. 50 $\Omega$ termination is not necessary. Delay wrt. optical pulse: 45 ns typical Jitter wrt. optical pulse: 1 ns typical
15	Input, Digital	STANDBY	Internal pull-up <sup>2</sup> . Pull low (high) <sup>3</sup> to force the laser diode into standby current level, e.g., it blanks UV laser output. Timing: 2nd order lag: Delay time (50%): 5 $\mu$ s (typ.) Rise time: 5 $\mu$ s (+20%–80%, typ.)

**Table 7-3: Analog Port Description**

Pin	Type	Description	Function
16	N/A		
17	Input, Digital	EXT_GATE	Internal pull-up. <sup>2</sup> Pull low (high) <sup>3</sup> to gate the pulse trigger (blanks UV laser output).
18	Input, Digital	ILD_SOURCE	Internal pull-up. <sup>2</sup> Pull low (high) <sup>3</sup> to switch to an external current control (use I_EXT pin to set the diode current).
19	Output, Digital	SYNC_OUT	TTL-level pulse <sup>1</sup> that is synchronous with the gating of the Q-switch (see Figure 7-5 for timing). Source: HCT gate (5 V), 50 Ω series resistor. A 50 Ω cable is recommended in order to maintain the waveform. 50 Ω termination is not necessary.
20	N/A		<i>Do not connect!</i>
21	Input, Digital	EXT_TRIG	Internal pull-up. <sup>2</sup> Generates a single Q-switch pulse, <sup>1</sup> TTL-level. Software must be set to external triggering mode (QSW:PRF 0) to enable this pin.
22	Analog reference	AGND	Ground for Pins 1 and 2.
23	N/A		
24	Digital reference	DGND	Ground for Pins 6, 9, 10, 11, 13, 14, 15, 16, 17, 19, 21.
25	N/A		<i>Do not connect!</i>
26	Reference	EARTH	PS chassis ground. Low impedance DC-path to supply return (power interface).

<sup>1</sup> The default polarity is “falling edge” (high/low), may be changed to “rising edge” (low/high), using the serial command `CONFIG:APORT:POLAR <n>`

<sup>2</sup> Internal pull-up 10.9 kΩ to +5 V (default) or internal pull-down 8.2 kΩ to GND, depending on user-commanded polarity configuration (`CONFIG:APORT:POLAR <n>`). TTL levels apply.

<sup>3</sup> The default active level is low, by may be changed to active high using the serial command `CONFIG: APORT: POLAR <n.`

The configuration and the status of the pins of the analog interface are set and queried using the serial language. This is accomplished by modifying or querying two bytes that encode some of the functions of the ANALOG IN connector pins: The Analog Port Polarity Configuration byte and the Analog Port Status byte. Refer to “Configuring Analog Control” on page 7-7 for more information about using these bytes.

Tables of these two bytes are provided at the end of Appendix B.



### ***Adjusting the Pulse Energy Using Analog Signals***

Pin 2 of the ANALOG IN port can be used to adjust the diode laser current set point using analog signals. The maximum diode current is set at the factory. A signal voltage of 4.095 V corresponds to 100% of the maximum diode current (which is returned by READ:DIODE1:MAXCURRENT?).

To activate the analog diode laser control, pin 18 of the ANALOG IN port must be pulled low prior to enabling laser emission on pin 10. During emission, the status of the selected mode of operation cannot be changed.

Pin 1 of the ANALOG IN port provides a calibrated feedback signal from the UV detector that is integrated into the laser head. To ensure proper functionality over the full operating range, an output signal of 2 volts on pin 1 corresponds to the nominal laser pulse energy of either 60 or 120  $\mu\text{J}$ , depending on the *Explorer* model. The output signal gets latched through a sample and hold circuit and is refreshed prior to each new laser pulse, thus providing single-pulse energy measurement capability.

### ***External Q-Switch Triggering***

By default the *Explorer* laser is set to internal triggering. To switch from internal to external triggering, send the serial command QSW:PRF 0. This command enables pin 21 of the ANALOG IN port. Once this command has been sent, no emission will occur until a TTL signal is provided on pin 21 to trigger the laser.

The external trigger signal should be applied to pin 21 as a TTL level falling edge input (default setting, see Appendix B and Table B-4) from single-shot to 5 kHz. See Figure 7-2 for an example of a circuit that can be used to supply the trigger signal.

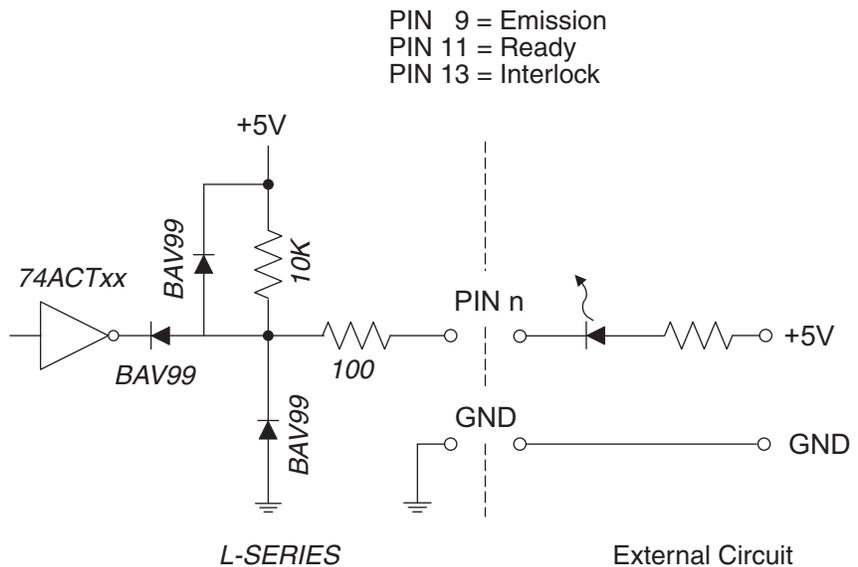
### ***Setting the Laser to Standby***

To place the *Explorer* in Standby mode, force pin 15 low (default setting, see Appendix B and Table B-4). See Figure 7-2 for an example of a circuit that can be used to control this function.

## Monitoring Laser Status

### Using the Indicator Outputs

An example of a simple circuit used to turn one of the *Explorer* analog interface indicators on and off is shown in Figure 7-3. This circuit works for the indicators available on pin 9 (EMISSION indicator), pin 11 (READY indicator), and pin 13 (INTERLOCK active indicator). When the condition corresponding to the pin output is active, the internal transistor connected to the pin will turn on. The LED shown in the figure will then turn on, indicating that the laser condition is active (e.g., pin 9, the *Explorer* is emitting UV pulses).



**Figure 7-3: Laser Indicator Circuit Example**

Note that pin 24 is the reference ground pin of the ANALOG IN connector for use with pins 9, 11 and 13.

### Pulse Energy Monitor

The measured pulse energy can be read out using pin 1 on the ANALOG IN connector (referenced to pin 22). The output signal is calibrated to provide a signal of 2 volts at the nominal pulse energy at either 60 or 120  $\mu\text{J}$ . The resolution of the output signal is 12-bit, which corresponds to a maximum signal of 4.095 V. The measured values gets refreshed approximately 25  $\mu\text{s}$  after the laser pulse is emitted. The measured value is valid until the next pulse is measured.

An example of a simple circuit used to monitor the pulse energy is shown in Figure 7-4 below.

Note that pin 22 is the ground pin of the ANALOG IN connector for pin 1.

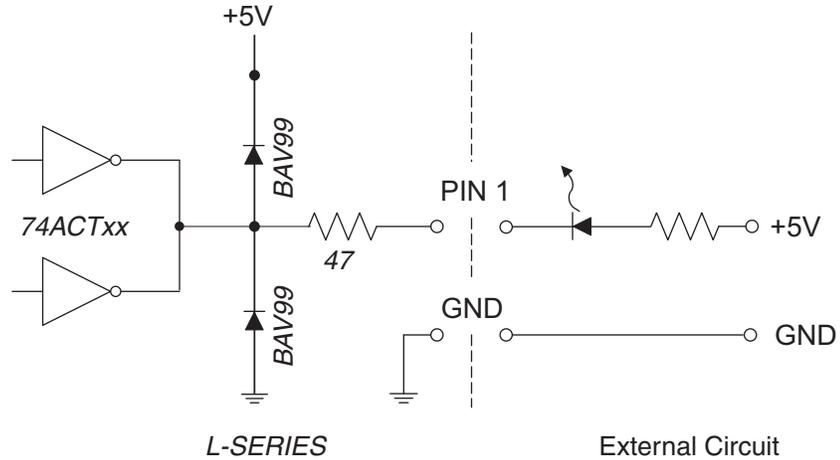


Figure 7-4: Pulse Energy Monitor Circuit Example

### Trigger Output

Pin 19 provides a trigger pulse that can be used to synchronize measurement equipment to the pulsed laser output. There are two options to choose from:

Option 1: *External Sync Out* on pin 19 provides a trigger output signal 900 ns after an *External Trigger* signal on pin 21 occurs.

Option 2: *External Sync Out* on pin 19 provides a trigger output signal that is synchronized to the internal Q-Switch trigger.

The pin 19 output configuration is set using the command CONFIG: APORT:SYNC as described in “Setting the Output Trigger Source” on page 7-8.

The timing and jitter of the trigger signals is shown in Figure 7-5.

### OptoSync

The OptoSync output on pin 14 of the ANALOG IN connector (referenced to pin 24) provides a trigger signal for measurement equipment with very low jitter ( $<\pm 0.5$  ns). Figure 7-5 shows a timing chart. OptoSync triggering follows the laser pulse by about 30 ns. More information about OptoSync is provided in Chapter 3.

The OptoSync output typically will not appear whenever the pulse energy falls below about 5% of specified power.



*Explorer pulse energy may be at levels that can cause serious skin or eye damage even when below the threshold for OptoSync output. Do not use the OptoSync trigger as a laser safety emission indicator!*

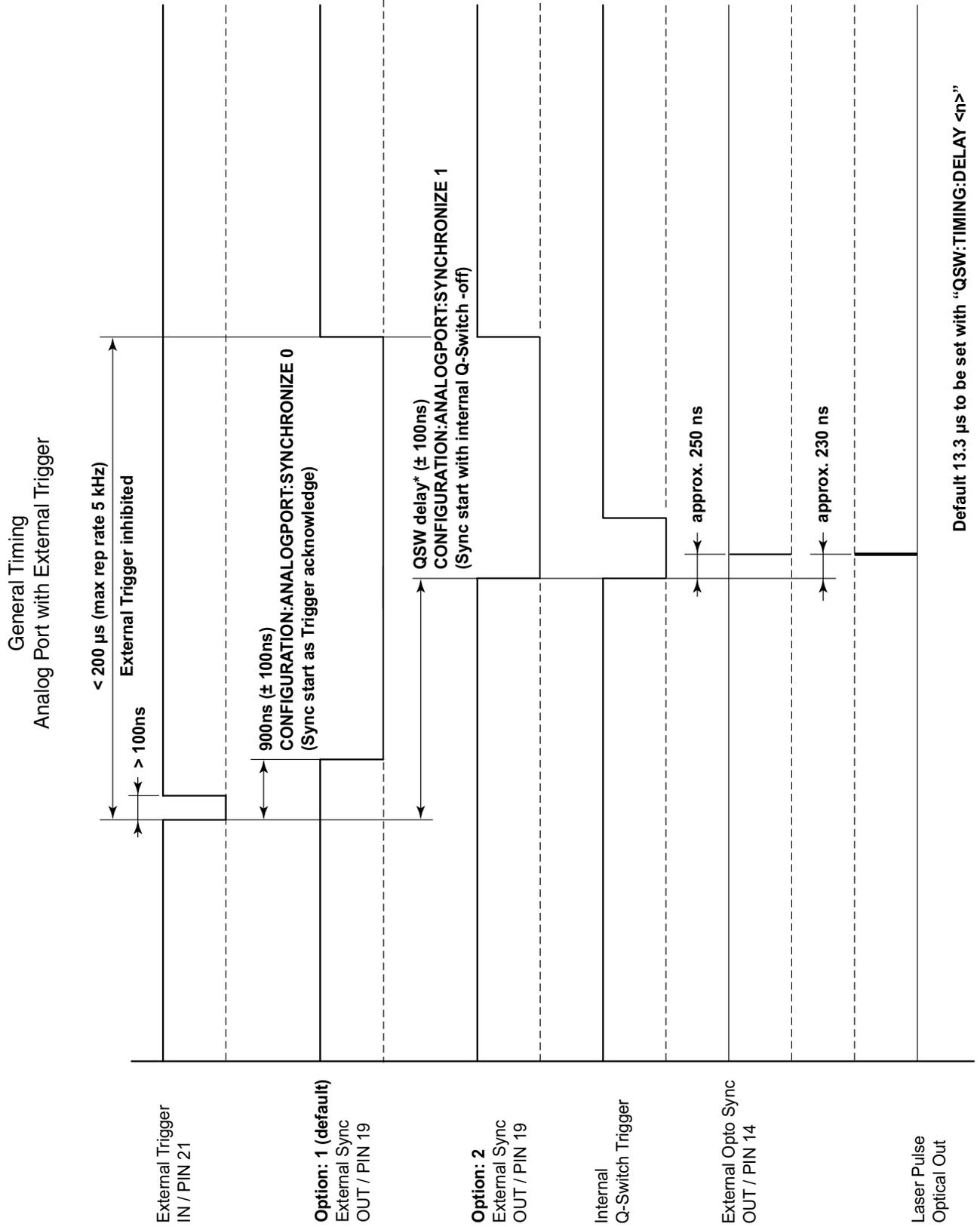


Figure 7-5: Explorer Trigger Timing

## Basic Operating Methods

This section describes two simple methods of operating the laser using analog signals. These methods are used to introduce the more sophisticated methods described later in this chapter.

Table 7-4 summarizes the two operating methods.

**Table 7-4: Operating Mode Summary**

<b>Method A: Internal pulse trigger, external gating</b>	
Advantage	Safe, fast gating; no UV output power during off time
Disadvantage	Additional user-supplied circuitry required to synchronized gating
Main commands	QSW:PRF <n>, n = repetition rate
Pin(s) used	17
<b>Method B: External pulse trigger, external gating</b>	
Advantage	Easy set up; no UV output power during off time; fast repetition rate changes; optional synchronization
Disadvantage	
Main commands	QSW:PRF 0 external trigger mode
Pin(s) used	21, 17 (Pin 17 only enables or disables Q-Switch trigger. It has no impact on internal timing.)

### **Method A**

Method A gates the laser output on and off using an external gating TTL level signal applied to pin 17. The Q-switch repetition rate is set internally using the serial command QSW:PRF <n>.

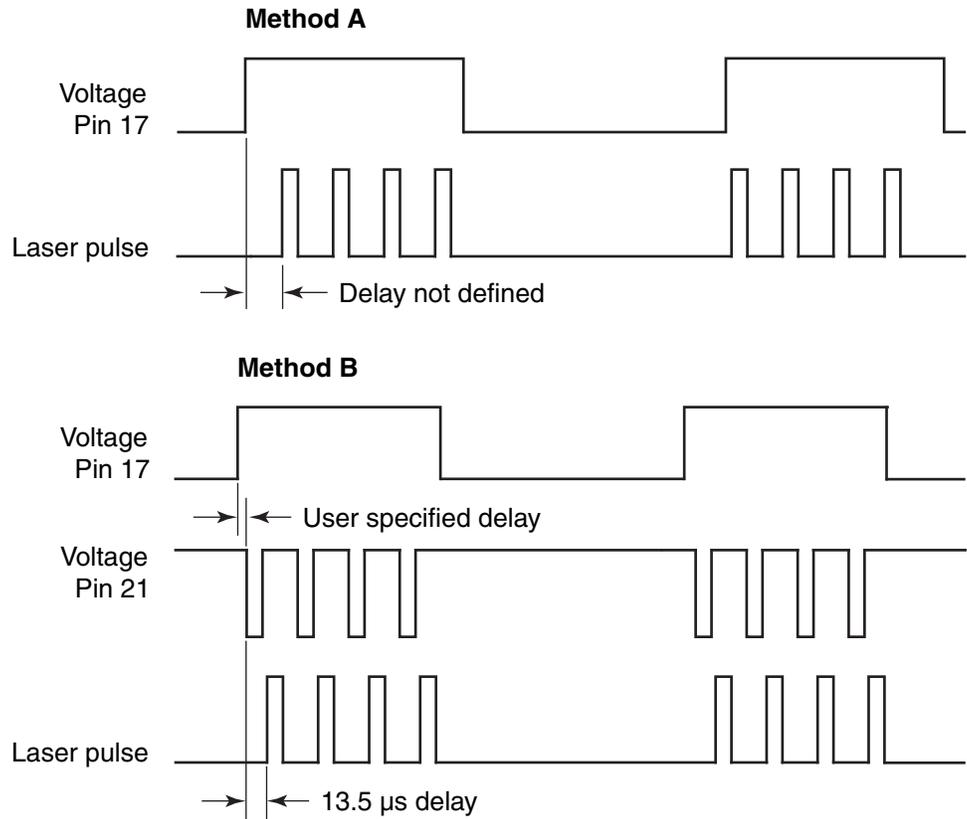
Note that in this example the gate signal and the Q-switch signals have no fixed timing with respect to each other, i.e., the pulse-to-pulse time can vary between the gate open command and the first Q-switch signal. To keep the timing between gate open and the first Q-switch signal constant, use Method B.

### **Method B**

This method is the same as Method A, except that the Q-switch is triggered by TTL signals applied to pin 21. Another option is to use the Q-Switch signal that is available on pin 19 to synchronize laser pulses with the gating signal on pin 17. Using the Q-switch trigger as the output trigger allows laser pulses to be synchronized with the gating signal, which is applied in the same fashion as in Method A (to pin 17).

Note that pin 19 can be configured so that it supplies the Q-switch trigger input (rather than a signal derived from the Q-switch itself) as the output trigger signal.

A timing diagram for Methods A and B is shown in Figure 7-6.



**Figure 7-6: Timing Diagrams for Methods A and B**

## Advanced Control of the Pulsed Output

Figure 7-6 and Figure 7-7 illustrate the timing relationships using either Standby (pin 15) or Gate (pin 17) to control internal triggering. Figure 7-6 shows operation using FPS but not Burst mode, while Figure 7-7 shows operation using both FPS and Burst.

### Gating

The laser output pulses can be shut off by pulling low the voltage available on pin 17. Figure 7-2 shows an example circuit.

The External Gate must provide at least 1  $\mu$ s prior to the estimated start of the optical pulse until at least 1  $\mu$ s after the estimated end of the optical pulse.

To synchronize the External Gate with the External Sync Out, refer to Option 1 in Figure 7-7.

### Burst Output

Burst Mode timing is illustrated in Figure 7-7 on page 7-25.

## ***Random Pulsing***

This mode allows for an externally triggered variable pulse rate that maintains constant pulse energy. Random Pulsing can only be used in FPS mode. The serial command `MODE: RAND 1` activates Random Pulsing; `MODE: RAND 0` deactivates Random pulsing, and leaves standard FPS mode active.

Once Random Pulsing is active, each external trigger pulse will generate one laser output pulse. Pulse energy is dependent on the set laser diode current and FPS delay value. The value for FPS delay is set as described in “FPS Operation” on page 7-12.

The upper limit of the FPS delay is 2000  $\mu\text{s}$ . Setting the FPS-delay to 0 is not permitted in Random Pulsing mode.

The minimum repetition time is given by  $T_{rep} = FPS\ delay + 25\ \mu\text{s}$ . Trigger pulses sent before a cycle is completed will be ignored.

*Sync Out* falling edge (pin 19) appears prior to an optical pulse. The delay time is typically 6.8  $\mu\text{s}$ .

The basic timing relationships are shown in Figure 7-8 on page 7-26.

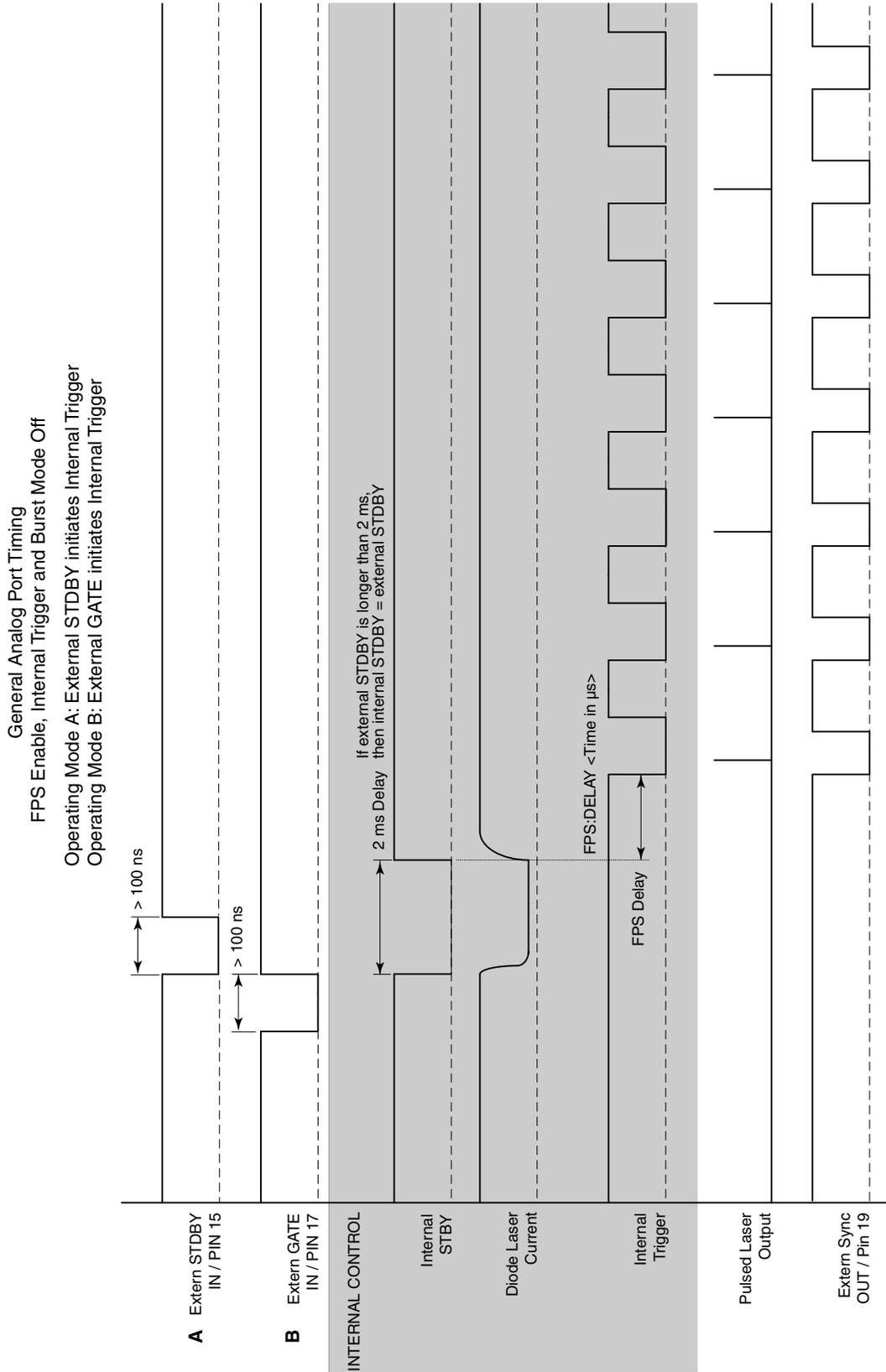


Figure 7-7: External Triggering with FPS and without Burst

General Analog Port Timing  
 FPS Enable, Internal Trigger and Burst Mode On  
 Operating Mode A: External STDBY initiates Internal Trigger  
 Operating Mode B: External GATE initiates Internal Trigger

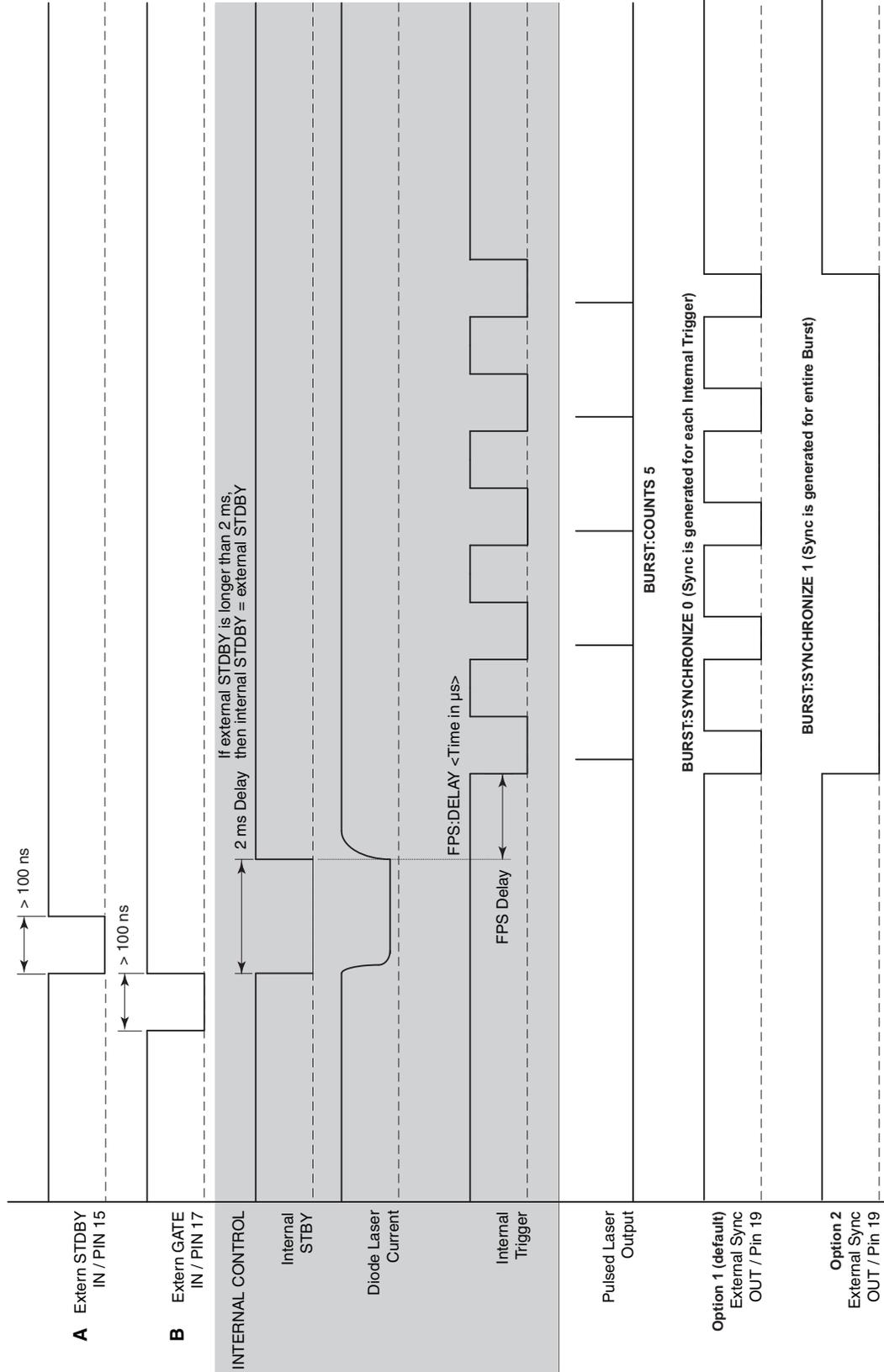


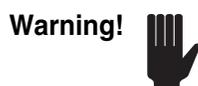
Figure 7-8: External Triggering with FPS or Burst



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*Explorer* is a *Class IIIb—High-Power Laser* whose beam is a safety hazard. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage. Always wear proper eye protection for 1047 nm, 806 nm, 524 nm and 349 nm when working with the laser, and follow the safety precautions in Chapter 2, “Laser Safety.”

---



---

Never open the *Explorer* laser head. To retain a clean intracavity environment, all components have been cleaned to stringent standards prior to assembly in a clean room and have been permanently aligned at the factory. Removing the laser cover will compromise the cleanliness of the intracavity space and void the warranty. There are no user-serviceable parts inside the laser head—replacement of the diode pump laser or the nonlinear crystals must be performed by a technician authorized by Spectra-Physics to service the *Explorer* system.

---

## Troubleshooting

Any error that occurs will cause the ERROR indicator on the *L-Series* power supply to illuminate. This troubleshooting guide is intended to assist you in identifying some of the problems that might arise while using the laser. Use the list of symptoms and potential problems on the following pages to troubleshoot the laser system. Procedures for performing the corrective actions for the symptoms listed in the service tables below are provided in the section following the tables.

Note



---

If a problem with the *Explorer* laser cannot be resolved after using this basic troubleshooting section, contact your Spectra-Physics service representative for further assistance. Contact information for service centers is provided at the end of this chapter.

---

**Symptom: No laser beam**

---

<b>Possible Causes</b>	<b>Corrective Action</b>
No ON signal applied to the power supply	Review instructions for operating the laser in Chapters 6 and 7.
Improper power supply DC voltage	Verify input voltage is 24 Vdc $\pm$ 2 V.
Loose cable connector	Check that all cables are securely connected.
Burst Mode active - no Burst Mode signal	Either deactivate Burst Mode or supply proper Burst Mode signal.
Standby or Gate signal active on Analog Port	Remove Standby or Gate signal from the ANALOG port.

---

**Symptom: Low power**

---

<b>Possible Causes</b>	<b>Corrective Action</b>
Laser is not warmed up	Allow the laser to warm up for at least 5 minutes.
Dirty output window	Clean the laser head output window.
Laser head temperature is outside the operating range	Verify that the laser head baseplate is properly heatsinked.
Reflected laser light is destabilizing the laser	Ensure that light reflected from any external optical elements does not reflect back through the window of the laser head.
Nonlinear crystals require temperature optimization	Refer to the section “Setting the SHG and THG Temperatures” in Chapter 6 or Chapter 7.
Diode pump laser has reached its end of life	Contact your Spectra-Physics service representative.

---

**Symptom: High optical noise**

---

<b>Possible Causes</b>	<b>Corrective Action</b>
Laser head temperature is outside operating range	Verify that the laser head baseplate is properly heatsinked.
External noise source exists	Check that there are no strong electromagnetic noise sources near the laser.
Laser is operating close to threshold (significantly below specified values)	Increase diode laser pump current.

---

**Symptom: Bad transverse mode**

---

<b>Possible Causes</b>	<b>Corrective Action</b>
Laser is not warmed up	Allow the laser to warm up for at least 5 minutes.
Output window is dirty	Clean the laser head output window.
Laser head temperature is outside the operating range	Verify that the laser head baseplate is properly heatsinked.
Nonlinear crystals require temperature optimization	Refer to the section “Setting the SHG and THG Temperatures” in Chapter 6 or Chapter 7.
Nonlinear crystals have reached end of life	Contact your Spectra-Physics service representative.

---

**Symptom: Output power is unstable**

Possible Causes	Corrective Action
Loose cable connector	Verify that all cables are securely connected.
Laser is not warmed up	Allow the laser to warm up for at least 5 minutes.
Laser head temperature is outside the operating range	Verify that the laser head baseplate is properly heatsinked.
Nonlinear crystals require temperature optimization	Refer to the section “Setting the SHG and THG Temperatures” in either Chapter 6 or Chapter 7 as appropriate.

**Corrective Procedures*****The L-Series Power Supply***

From time to time, check the air grills for dust build-up and, when necessary, vacuum out the dust.

**Caution!**

Do not blow the dust out with compressed air because this may simply force it into the power supply where it cannot be removed.

This is the only maintenance required for the power supply.

***Changing the Output Window*****Danger!**

Laser Radiation

Before changing the output window, the laser must be off and the *keyswitch removed* in order to prevent the laser from being turned on accidentally during the procedure.

If a significant amount of scattered UV light appears around the laser beam, the most likely cause is a contaminated output window. If this is the case, the output window must be removed from the laser head for cleaning. Never try to clean the output window when it is mounted on the laser. There is a second (inner) window behind the replacable window that permanently seals the laser cavity. Solvents used for cleaning the outer window while it is on the laser might contaminate the inner window and thus destroy the laser. Always remove the outer window for inspection or cleaning.

Note that the inner window cannot be cleaned. Do not allow any dust or other contaminants to enter the space between the windows.

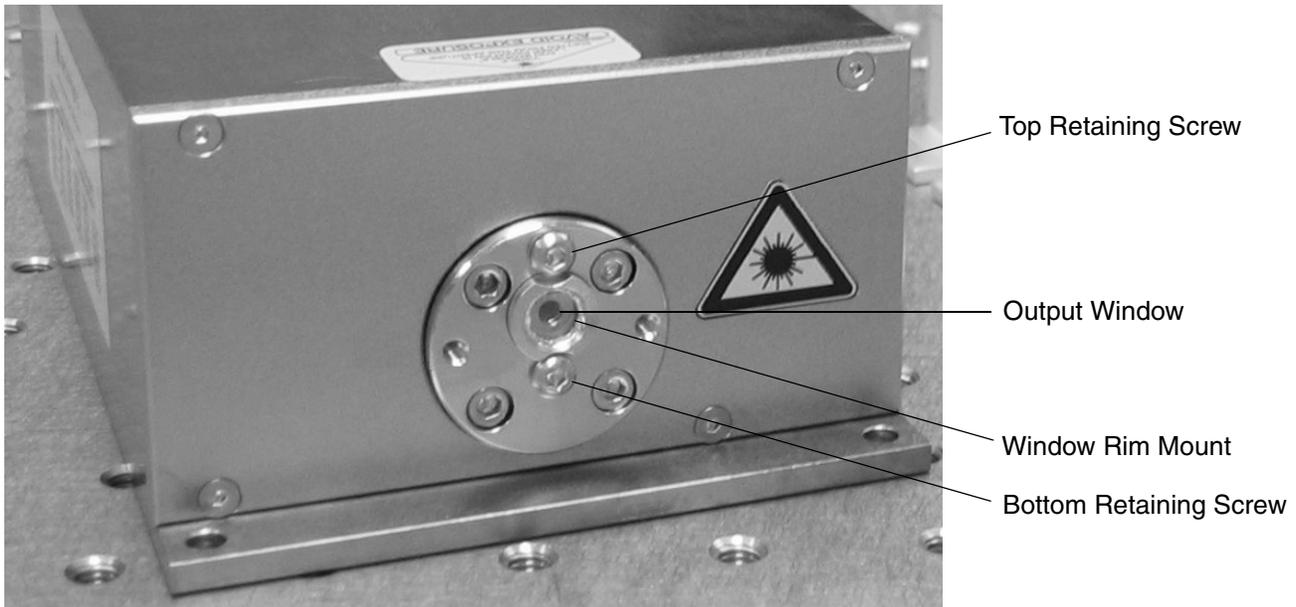


Observe the following when changing the output window:

- The output window should only be removed in a clean, dust free environment. All tools, parts and solvents should be gathered first to minimize the time the window must be removed from the laser.
  - Always wear clean room gloves when exchanging or handling the output window. Never touch the window, even with gloves on; handle the window assembly only by its rim mount.
- 

**Tools required**

- gloves
- 2 mm Allen key
- tweezers



**Figure 8-1: Output Window Assembly**

**Procedure**

1. Loosen the top retaining screw while carefully pressing against the rim mount to hold the window assembly in place (Figure 8-2). Do not remove the screw completely.



**Figure 8-2: Loosen the top retaining screw.**

2. While still holding the rim mount, carefully loosen the bottom screw until the window assembly is completely free (Figure 8-3).



**Figure 8-3: Loosen the bottom retaining screw.**

Do not remove either retaining screw completely. Reassembling the window is much easier if the screws (at least the bottom screw) remain in place.

- 3 The window assembly can now be removed using tweezers (Figure 8-4). Alternatively, the window assembly can be removed using gloved fingers by handling the rim mount—*remember, never touch the window itself!*



**Figure 8-4: Remove the window assembly.**

4. Inspect the window surface and clean it if necessary, following standard practice for ultraviolet optics (feel free to consult Spectra-Physics regarding these procedures). If necessary, replace the window assembly with a new assembly.
5. Carefully place the window in the holder and, while holding the window in position, tighten the bottom retaining screw until the screwhead gently touches the window mount (Figure 8-5). Make sure that the screwhead fits into the clearance in the mount.



**Figure 8-5: Replace the window assembly.**

6. Tighten the top retaining screw until the screw head touches the mount. Carefully tighten both screws using the minimum torque needed to secure the assembly.

## Service Training Programs

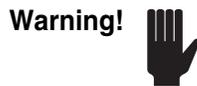
The *Explorer* OEM diode-pumped, Q-switched, ultraviolet laser is designed for hands-off operation. This laser system does not require daily alignment nor routine cleaning of cavity optics. With the exception of the laser output window, servicing components is generally limited to replacing either the entire power supply or laser head.

*Unauthorized* repair will void the warranty. Spectra-Physics offers Service Training Programs to train personnel in the diagnosis of problems and repair of the power supply. These training programs are tailored to suit the needs of the customer and can be conducted on site or at our factory. For more information or to schedule a training program, contact your sales representative.

For information concerning the repair of your unit by Spectra-Physics, please call your local service representative. A list of world-wide service sites is included at the end of this chapter. Before calling, however, note the serial numbers of the laser and power supply.

## Replacement Parts

The following is a list of parts that can be purchased to replace broken, worn out or misplaced components.



The replacement of internal *Explorer* system components must only be performed by personnel trained in these specific procedures by Spectra-Physics. Do not order a field replaceable unit or attempt to replace an internal system component without first receiving proper training.

**Table 8-1: Field Replaceable Units**

Description	Part Number
Output window, customer exchangeable	Explorer-349-OW
Cable – Laser head cable 1, 15-pin	PS-L08-Head1
Cable – Laser head cable 2, 26-pin	PS-L08-Head2
60 $\mu$ J Explorer UV DPSS Laser Head, Standard Model	ICT-349-060-1KS
60 $\mu$ J Explorer UV DPSS Laser Head, Extended Model	ICT-349-060-1KE
120 $\mu$ J Explorer UV DPSS Laser Head, Standard Model	ICT-349-120-1KS
120 $\mu$ J Explorer UV DPSS Laser Head, Extended Model	ICT-349-120-1KE
L-Series Power Supply, 8A, Standard Model	PS-L08-1KS
L-Series Power Supply, 8A, Extended Model	PS-L08-1KE

## Customer Service

At Spectra-Physics, we take great pride in the reliability of our products. Considerable emphasis has been placed on controlled manufacturing methods and quality control throughout the manufacturing process. Nevertheless, even the finest precision instruments will need occasional service. We feel our instruments have excellent service records compared to competitive products, and we hope to demonstrate, in the long run, that we provide excellent service to our customers in two ways: first by providing the best equipment for the money, and second, by offering service facilities that get your instrument repaired and back to you as soon as possible.

Spectra-Physics maintains major service centers in the United States, Europe and Japan. Additionally, there are field service offices in major United States cities. When calling for service inside the United States, dial our toll free number: **1 (800) 456-2552**. To phone for service in other countries, refer to “Service Centers” on page 8-10.

Order replacement parts directly from Spectra-Physics. For ordering or shipping instructions, or for assistance of any kind, contact your nearest sales office or service center. You will need your instrument model and serial numbers available when you call. Service data or shipping instructions will be promptly supplied.

To order optional items or other system components, or for general sales assistance, dial **1 (800) SPL-LASER** in the United States, or **1 (650) 961-2550** from anywhere else.

## Warranty

This warranty supplements the warranty contained in the specific sales order. In the event of a conflict between documents, the terms and conditions of the sales order shall prevail.

Unless otherwise specified, all parts and assemblies manufactured by Spectra-Physics are unconditionally warranted to be free of defects in workmanship and materials for a period of one year following delivery of the equipment to the F.O.B. point.

Liability under this warranty is limited to repairing, replacing or giving credit for the purchase price of any equipment that proves defective during the warranty period, provided prior authorization for such return has been given by an authorized representative of Spectra-Physics. Spectra-Physics will provide, at its expense, all parts and labor and one-way return shipping of the defective part or instrument (if required). In-warranty repaired or replaced equipment is warranted only for the remaining portion of the original warranty period applicable to the repaired or replaced equipment.

This warranty does not apply to any instrument or component not manufactured by Spectra-Physics. When products manufactured by others are included in Spectra-Physics equipment, the original manufacturer's warranty is extended to Spectra-Physics customers. When products manufactured by others are used in conjunction with Spectra-Physics equipment, this warranty is extended only to the equipment manufactured by Spectra-Physics.

This warranty also does not apply to equipment or components that, upon inspection by Spectra-Physics, discloses to be defective or unworkable due to abuse, mishandling, misuse, alteration, negligence, improper installation, unauthorized modification, damage in transit, or other causes beyond the control of Spectra-Physics.

This warranty is in lieu of all other warranties, expressed or implied, and does not cover incidental or consequential loss.

The above warranty is valid for units purchased and used in the United States only. Products shipped outside the United States are subject to a warranty surcharge.

### ***Notice***

This laser product is intended to be sold to a manufacturer of electronic products for use as a component (or replacement thereof) in such electronic products. As such, this product is exempt from DHHS performance standards for laser products in accordance with paragraph 1040.10(a)(1) or (2).

### ***Return of the Instrument for Repair***

Contact your nearest Spectra-Physics field sales office, service center or local distributor for shipping instructions or an on-site service appointment. You are responsible for one-way shipment of the defective part or instrument to Spectra-Physics.

We encourage you to use the original packing boxes to secure instruments during shipment. If shipping boxes have been lost or destroyed, we recommend that you order new ones. We can return instruments only in Spectra-Physics containers.

## Service Centers

### Belgium

Telephone: 0800 11257  
Fax: 0800 11302

### France

Telephone: 0810 007 615  
Fax: 0810 062 611

### Germany and Export Countries

Spectra-Physics GmbH  
Guerickeweg 7  
D-64291 Darmstadt  
Telephone: (49) 06151 708-0  
Fax: (49) 06151 79102

### Japan (East)

Spectra-Physics KK  
East Regional Office  
Daiwa-Nakameguro Building  
4-6-1 Nakameguro  
Meguro-ku, Tokyo 153-0061  
Telephone: (81) 3-3794-5511  
Fax: (81) 3-3794-5510

### Japan (West)

Spectra-Physics KK  
West Regional Office  
Nishi-honmachi Solar Building  
3-1-43 Nishi-honmachi  
Nishi-ku, Osaka 550-0005  
Telephone: (81) 6-4390-6770  
Fax: (81) 6-4390-2760

### The Netherlands

Telephone: 0900 555 5678  
Fax: 0900 555 5679

### People's Republic of China

Spectra-Physics China  
Beijing Office  
8 Nan San Jie, Zhong Guan Cun  
P.O. Box 603  
Beijing 100080  
P. R. China  
Telephone: (86) 10-6254-7746  
Fax: (86) 10-6255-6373

*And all European and Middle Eastern countries not included on this list.*

**Switzerland**

Telephone: 0842 202 203  
Fax: 0842 202 204

**Taiwan R.O.C.**

Newport Taiwan  
2F, No. 188, Nanjing E. Road  
Sec. 5 Taipei 105  
Taiwan, R.O.C.  
Telephone: (886) 2 -2769-9796  
Fax: (886) 2-2769-9638

**United Kingdom**

Telephone: (44) 1442-258100

**United States and Export Countries**

Spectra-Physics  
1330 Terra Bella Avenue  
Mountain View, CA 94043  
Telephone: (800) 456-2552 (Service) or  
(800) SPL-LASER (Sales) or  
(800) 775-5273 (Sales) or  
(650) 961-2550 (Operator)  
Fax: (650) 964-3584  
e-mail: service@spectra-physics.com  
sales@spectra-physics.com  
Internet: www.newport.com/lasers

*And all non-European or Middle Eastern countries not included on this list.*



This appendix contains a screen-by-screen reference for the *L-Win* software. For a description of some common operating procedures for the *Explorer* laser using the *L-Win* interface, refer to Chapter 6.

## L-Win Main Screen

The *L-Win* Main screen consists of:

- Menu bar (Tools menu)
- Control section (Power Control, Temp. Control and Settings tabs)
- Status panel

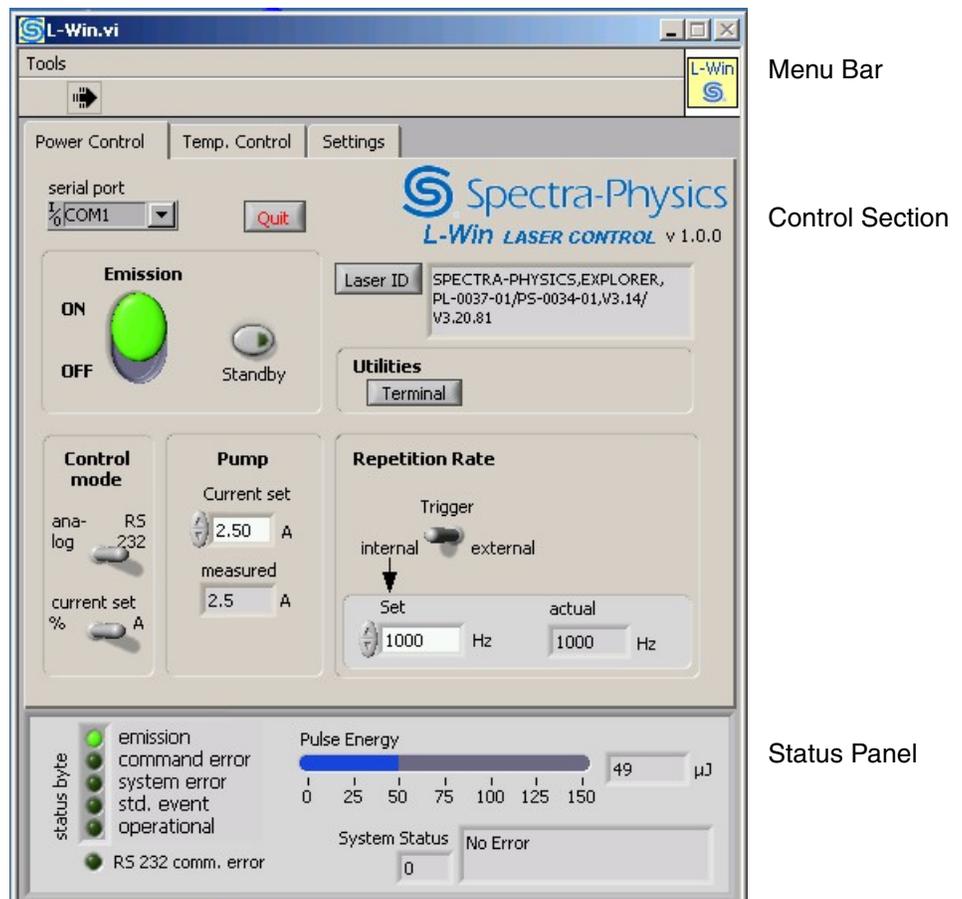
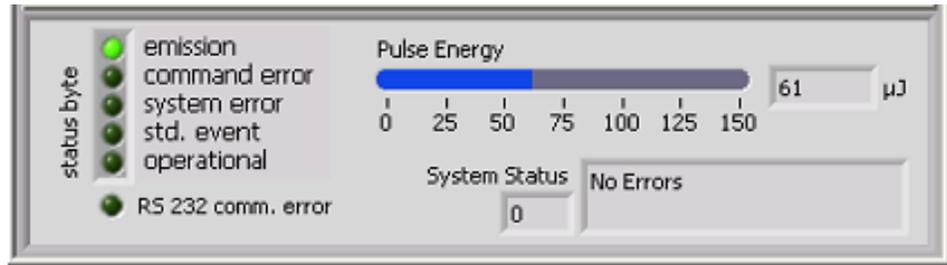


Figure A-1: *L-Win* Main Screen

## Status Panel



**Figure A-2: Status Panel**

The Status Panel displays system status information. The display is updated once per second.

**Status byte indicators**—display bits of the system status byte. (This byte can be also be read with the \*STB? serial query. Refer to Table C-1 on page C-1 for a description.)

**Emission indicator**—illuminates when laser emission is present.

**Command error indicator**—illuminates when a command fault is detected, such as an unknown command or invalid parameter.

**System error indicator**—illuminates when a system fault is detected, such as a temperature fault.

**Std. event indicator**—illuminates if a standard event occurs (e.g., interlock active, system boot, watchdog tripped, etc.)

**Operational indicator**—illuminates if certain operational conditions are fulfilled (e.g., Standby, Burst mode)

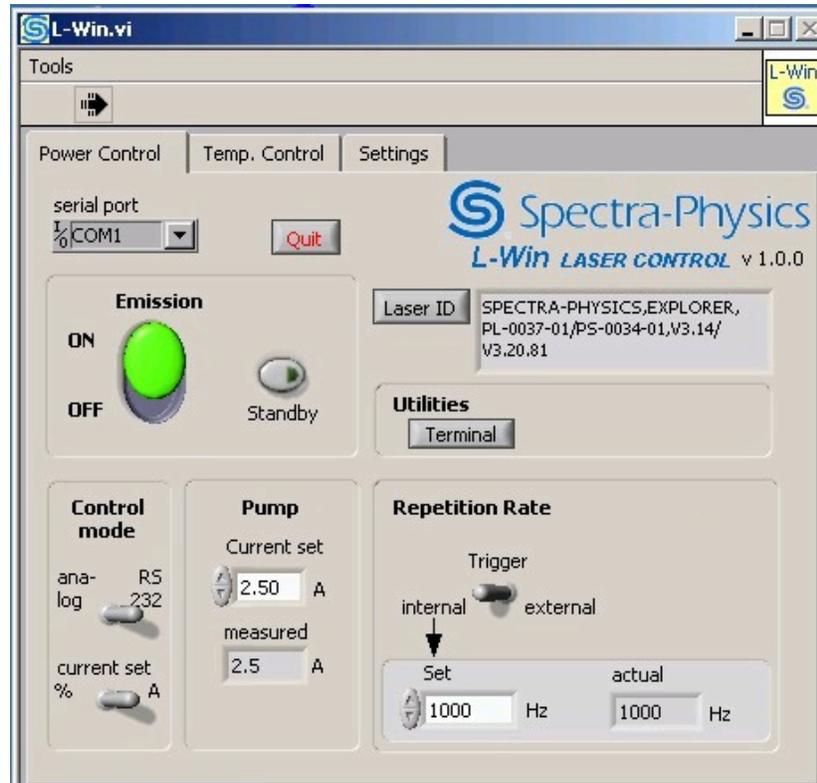
**RS 232 comm. error display**—illuminates when an error is detected on the RS 232 communication link (caused, for example, by a missing RS 232 cable or a switched off power supply).

**Pulse Energy bar and number field**—displays the internally measured pulse energy in  $\mu\text{J}$ .

**System Status numeric and text fields**—display the system error status code and description. The displays are updated once per second. Refer to Table C-3 on page C-7 for status codes.

## Control Section

### Power Control Tab



**Figure A-3: Power Control Tab**

The Power Control tab contains fields for controlling system functions. The display is updated once per second.

**Laser ID field**—displays the laser identification string (serial query \*IDN?), which is available after initialization.

**Serial Port field**—provides a pull-down menu for manually selecting the serial port of the control computer to which the *L-Series* power supply is connected. Alternatively, if the FIND feature is active, the software will search all existing serial ports for an *L-Series* power supply.

**Quit button**—exits the program. All program settings (serial port, calibration settings) are stored in the file “L-Win.ini” in the program directory.

**Emission ON/OFF control**—provides a switch to turn the laser on and off. ON turns the laser on and the Emission indicator turns green if no error is present. Actual emission will occur after a 3-second safety delay. OFF turns the laser off immediately.

**Standby button**—sets the diode laser to standby current (which is below the threshold for lasing) and illuminates the indicator (it turns

yellow). Clicking this button again will return to normal operation, and the indicator will turn off.

**Control mode: analog/RS 232 control**—selects the control mode. When set to Analog, the repetition rate and pump diode current are controlled via the 26-pin ANALOG port. In Program mode, the controls for on/off, diode current and repetition rate are disabled. When set to RS 232, those parameters are controlled by serial commands.

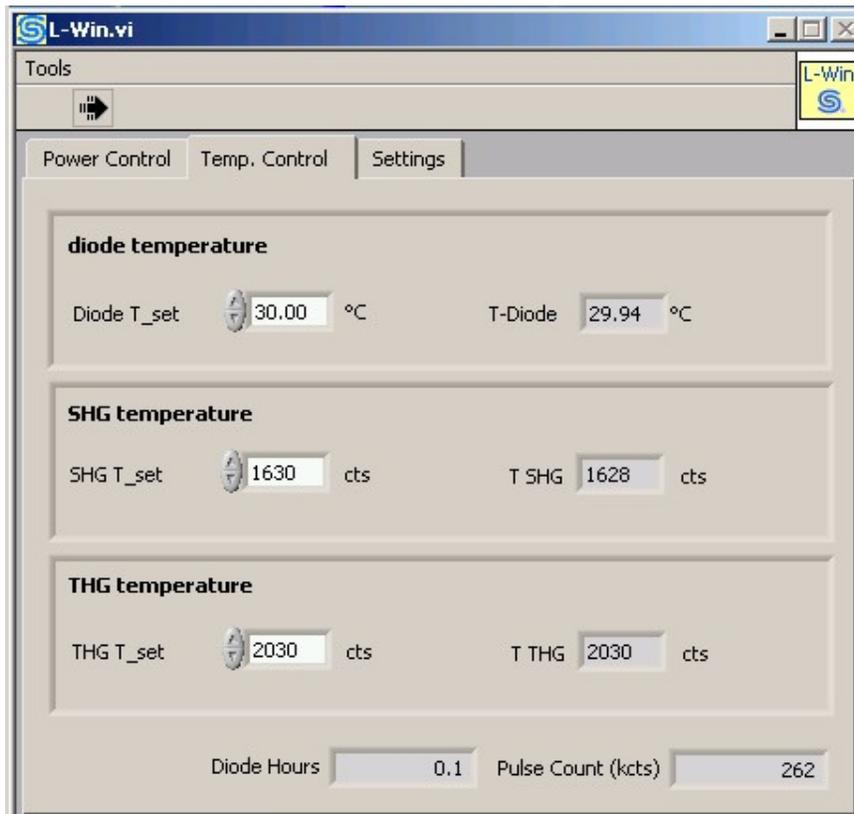
**Control mode: Current set %/A control**—determines whether the pump current is set and displayed in Amperes or as a percentage of the maximum current setting.

**Pump Current fields**—provide a means to set the diode laser current and display the measured current. Both values are displayed either in Amperes or in percent of the maximum current drive setting, depending on Current set switch setting. Current can be set by using the up/down arrows or by typing in the desired value in the window.

**Repetition Rate: Trigger control**—sets the Q-switch trigger mode to internal or external (TTL-low on pin 21 of the ANALOG port).

**Repetition Rate: Set/Actual fields**—provides control to set the pulse repetition frequency and display the measured frequency when Internal Trigger mode is selected.

## Temperature Control Tab



**Figure A-4: Temperature Control Tab**

The Temperature Control tab provides controls for setting the temperature of the pump diode and the second and third harmonic generator crystals (SHG and THG). The temperatures are set in °C for the diode laser, and in “counts” for the SHG and THG. If the temperatures are properly stabilized the measured values are constant in a range of  $\pm 0.05^{\circ}\text{C}$  and  $\pm 3$  counts, respectively.

When adjusting the temperatures for maximum UV pulse energy, change the set values in maximum increments of 10 counts, and allow the temperatures to stabilize for a few seconds after each increment.

**Diode temperature fields**—provide a means to set the desired temperature of the pump diode and display the measured temperature (in °C).

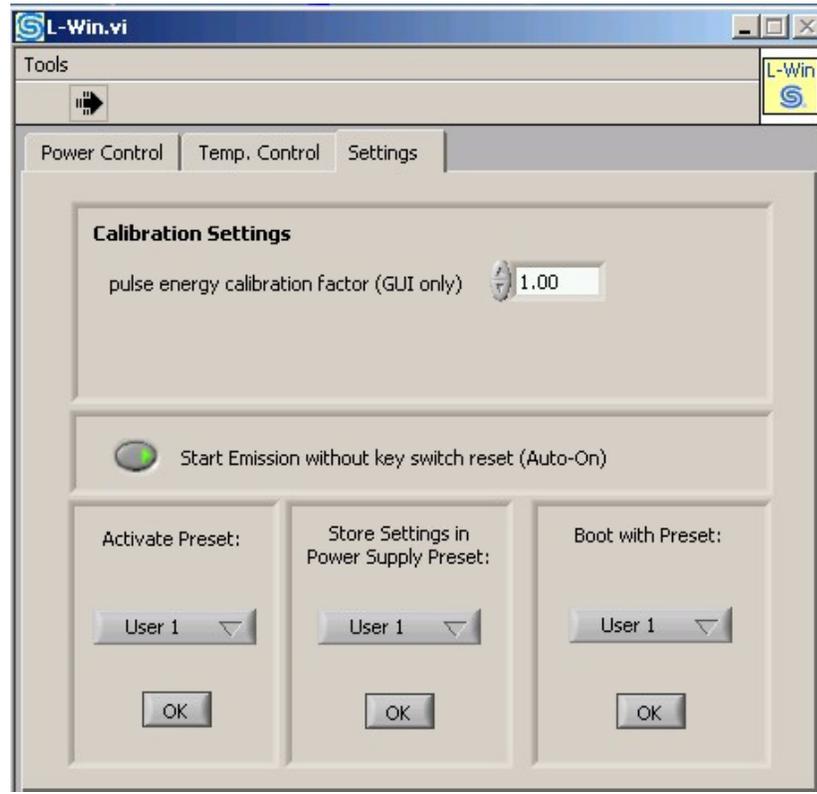
**SHG temperature fields**—provide a means to set the desired temperature of the second harmonic crystal and display the measured temperature (in “counts”).

**THG temperature fields**—provide a means to set the desired temperature of the third harmonic crystal and display the measured temperature (in “counts”).

**Diode Hours field**—displays the total number of hours the diode pump laser has been operated.

**Pulse Count (kcts) field**—displays total number of pulses the laser has emitted in its lifetime in units of thousands of pulses.

## Settings Tab



**Figure A-5: Settings Tab**

The Settings tab has controls for setting, storing and loading system parameter sets, called “presets,” that are defined by the user or at the factory. This tab also allows the calibration display factor to be set, and the Auto-On mode to be enabled/disabled.

**Pulse energy calibration factor field**—sets a correction factor for the measured pulse energy display in the Status Panel (see Figure A-2 on page A-2). With a value of 1, the display shows the unchanged pulse energy values delivered by the power supply in response to the query READ:PENER?. The calibration factor can be changed to correct the displayed values to correspond to your external energy meter.

This factor is used only for the GUI display. It is not stored in the power supply.

**Auto-On button**—enables or disables the Auto-On mode, which overrides the need for a keyswitch reset (turning the keyswitch off and on) to turn the system on with a serial command.

**Note**



Note that overriding the keyswitch reset does NOT comply with CDRH regulations.

**Preset controls**—provide a means to store, activate and boot the system with a predefined parameter set. In each panel, click the menu but-

ton to select the desired parameter set (Factory 1, Factory 2, User 1 or User 2), then click **OK** to execute the function. The factory sets are fixed, but the user sets can be changed and stored again.

**Activate Preset**—loads the specified parameter set from memory and activates it.

**Store Preset**—stores the current actual system values as the specified parameter set (User 1 or User 2).

**Boot with Preset**—designates the parameter set that will be activated next time the system is booted.

## Note



Activating a preset and storing the actual parameters as a preset are only possible when emission is turned off.

## Menu Bar

### Tools Menu



**Figure A-6: Tools Menu**

The Tools pull-down menu provides the following functions:

**Terminal**—starts a session and opens a window for a terminal emulation program that can be used to communicate with the laser system via serial commands. Refer to “Serial Communication” on page 7-2 for a complete list of commands and queries.

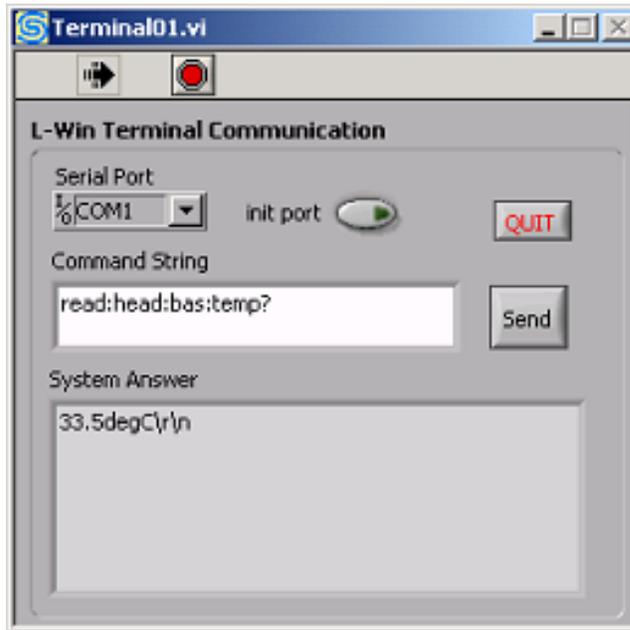
**Status-Bits Viewer**—provides tools for troubleshooting the system by displaying various status and error bits of the system components.

**Pulse Noise Measurement**—displays performance statistics, such as pulse-to-pulse stability.

**FPS/Burst Setup**—allows adjustment and performance monitoring of the first pulse suppression and Burst mode settings.

**Dump System Settings**—stores a snapshot of all relevant settings of the *Explorer* system in an external file. This information can be used for troubleshooting the system by Spectra-Physics service engineers.

**Terminal Window**



**Figure A-7: Terminal Window**

The Terminal window can be used to communicate with the laser system via serial commands. Refer to Appendix B for a complete list of serial commands, queries and responses.

The termination characters “\r” (carriage return) and “\n” (new line) shown in the **System Answer** box correspond to “<CR>” and “<LF>” respectively in “Serial Communication” on page 7-2.

The *L-Win* Main screen remains active while the Terminal window is active. The Main screen is continually updated to reflect any new settings or conditions that result from serial commands in the Terminal window.

**Serial Port field**—provides a pull-down menu for manually selecting the serial port of the control computer to which the power supply is connected. Alternatively, if the FIND feature is active, the software will search all existing serial ports for a power supply.

**init port button**—initializes communication with the power supply. The indicator is illuminated while the link is active.

**QUIT button**—exits the terminal emulation program, closes the window and deactivates the serial communication link.

**Command String field**—allows entry of serial commands.

**Send button**—sends the entered command or query to the power supply.

**System Answer field**—displays the system response to the sent command or query.

## Status Bits Viewer

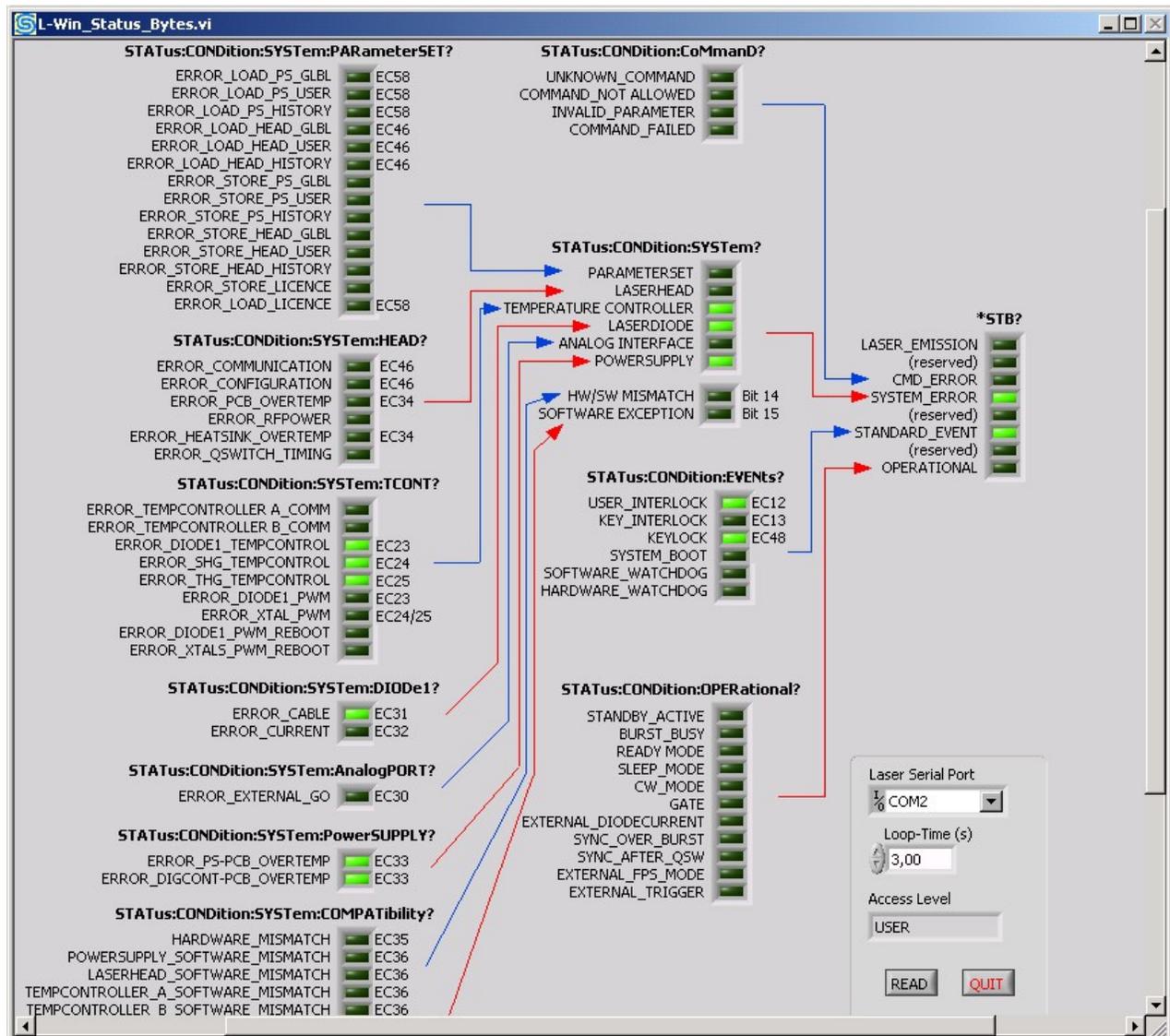


Figure A-8: Status and Error Display

The Status and Error screen displays all condition flags in a tree structure, with the system status byte at the root. Active conditions are illuminated. Individual conditions can be checked by branching from right to left to pinpoint the cause of an error. Above each group of elements is shown the serial command to retrieve the corresponding information.

**Laser Serial Port field**—provides a pull-down menu for selecting the serial port to be used for communicating with the system.

**Loop Time field**—sets the time interval to be used for automatic status inquiries. Values of around 2000 milliseconds (2 sec) are typical.

**Access Level field**—displays the active access security level.

**READ button**—issues a new query and updates the indicators.

**QUIT button**—closes the window.

### FPS and Burst Control Window

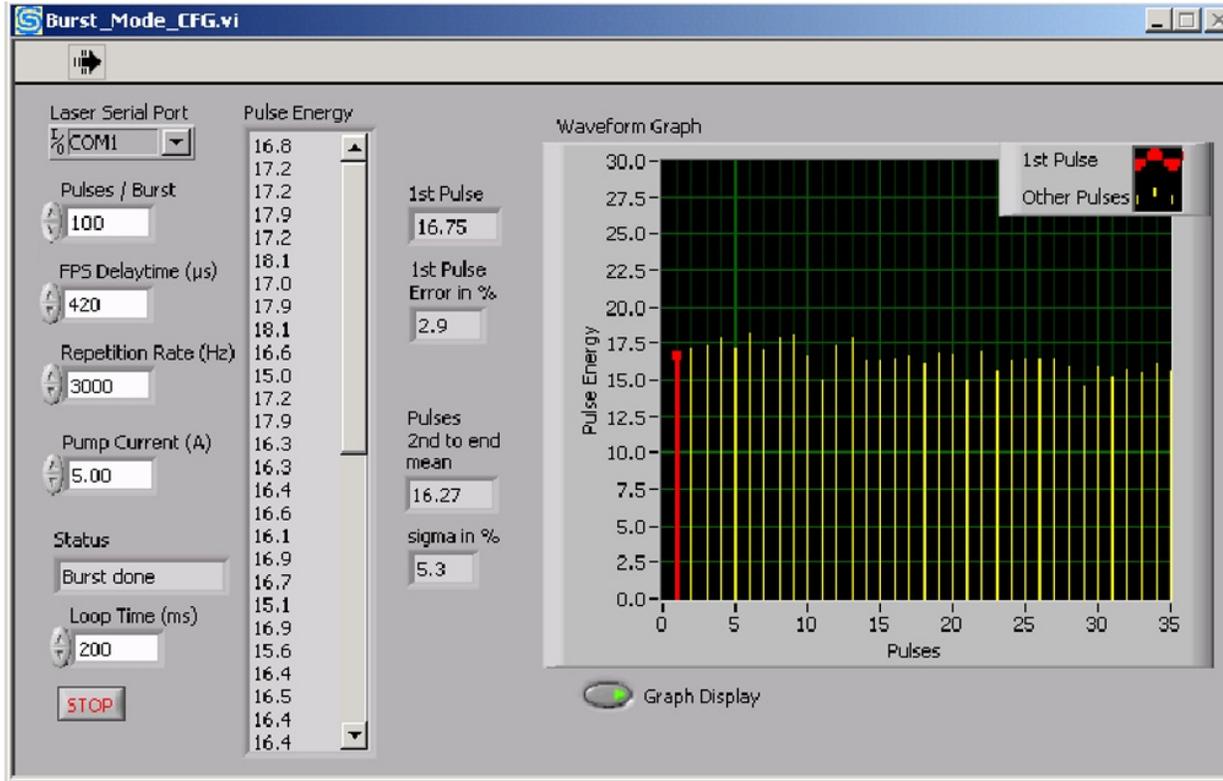


Figure A-9: FPS and Burst Control Window

The FPS and Burst Control window is used to adjust the First Pulse Suppression parameter FPS Delay Time in such a way that the first pulse has approximately the same energy as subsequent pulses.

**Laser Serial Port field**—provides a pull-down menu for selecting the serial port to be used for the communication link with the laser.

**Pulses/Burst field**—sets the number of pulses per burst.

**FPS Delay Time field**—sets the FPS delay interval (in μsec). This value can be varied until either the red bar (which represents the first pulse in the Waveform Graph) is approximately the same height as the other bars, or the First Pulse Error is about 0%.

**Repetition Rate field**—sets the pulse frequency repetition rate (in Hz).

**Pump Current field**—sets the current of the diode pump laser (in Amps).

**Status field**—displays Burst mode status.

**Loop Time field**—sets the time interval for how often a *BURST* command is automatically executed (in milliseconds). For example, setting the interval to 200 ms will cause five *BURST* commands to be issued per second.

**STOP button**—closes the window.

**Pulse energy field**—displays the energy of each pulse in a burst, chronologically.

**1st Pulse field**—displays the energy of the first pulse of the burst.

**1st Pulse Error in % field**—displays the discrepancy, as a percentage, between the first pulse's energy and the mean energy of the other pulses.

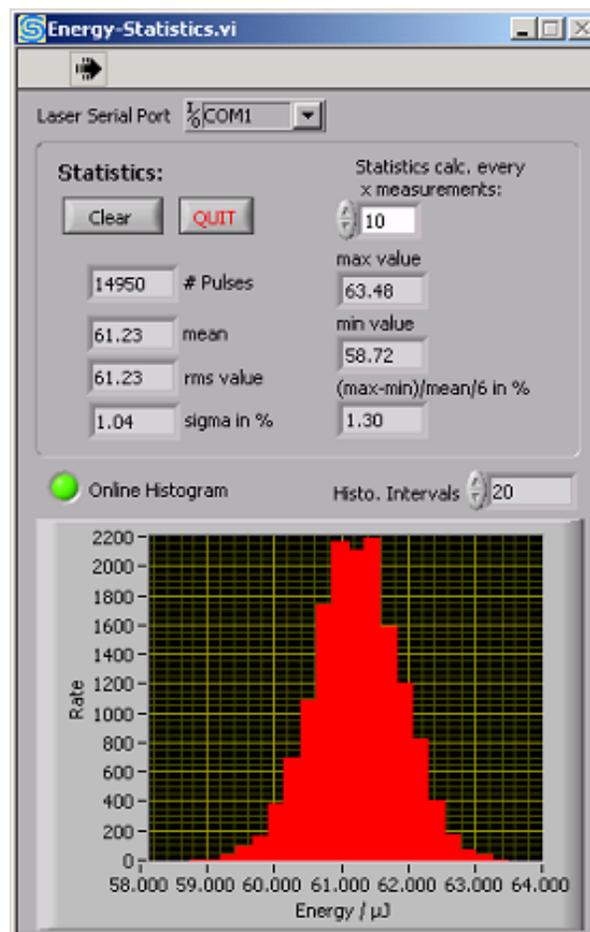
**Pulses 2nd to end mean field**—displays the calculated mean energy of all pulses except the first.

**sigma in % field**—value of the standard deviation of all pulses, excluding the first.

**Waveform Graph display**—shows one vertical bar for each pulse in a burst, showing its energy in relation to other pulses.

**Graph Display button**—turns the graphical pulse display on and off.

### *Pulse Noise View*



**Figure A-10: Pulse Noise View**

The Pulse Noise window can be used to monitor performance in terms of pulse-to-pulse stability, by monitoring the pulse energies and displaying their distribution in a histogram with other statistical data.

Concurrently, the *L-Win* Main window can be used to improve performance by adjusting operational parameters such as diode laser current and repetition rate.

**Laser Serial Port field**—provides a pull-down menu for selecting the serial port to be used for the communication link with the laser.

**Clear button**—clears all data fields.

**QUIT button**—closes the window.

**# pulses field**—displays the number of pulses sampled.

**mean field**—displays the calculated mean energy of sampled pulses.

**rms value field**—displays the “root-mean-square” value of the sampled values, excluding the first.

**sigma in % field**—displays the value of the standard deviation of all pulses, excluding the first.

**Statistics calc every x measurements control**—sets the update interval for calculating statistics (in number of measurements).

**max value field**—displays the highest measured energy value of the sampled pulses.

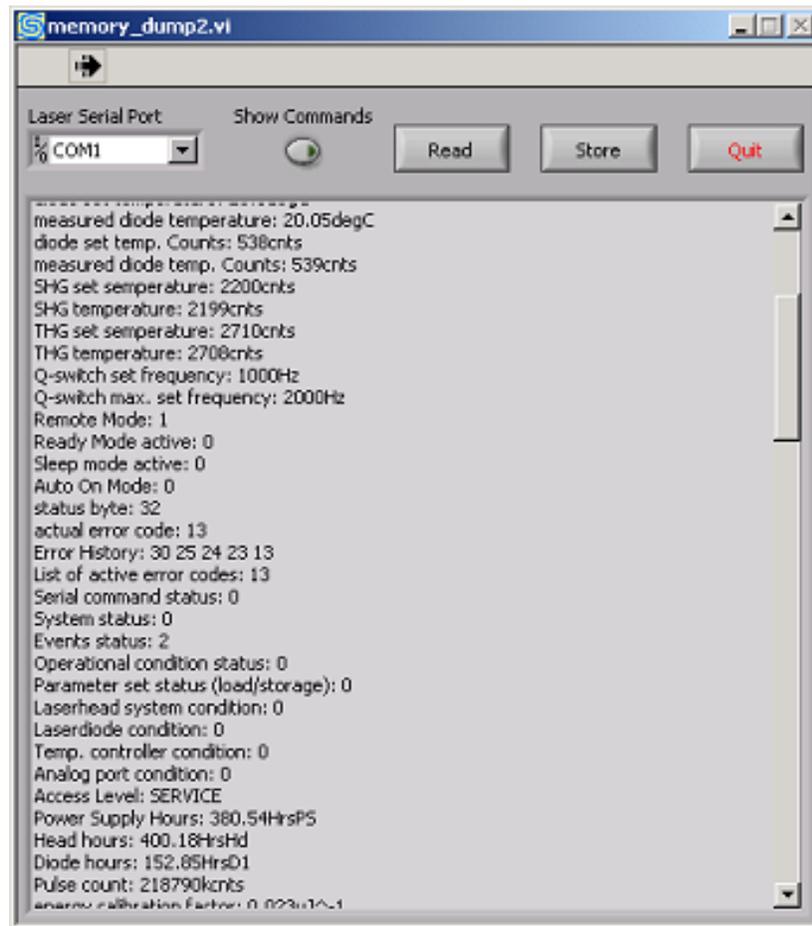
**min value field**—displays the lowest measured energy value of the sampled pulses.

**(max-mean)/mean/6 in % field**—displays the value in percent of the difference between the largest pulse and the smallest, divided by six times the average pulse level. The first pulse is excluded from this calculation.

**Online Histogram control**—activates/deactivates the data collection, calculation and histogram display. While this function is active, the indicator illuminates and the displays are automatically updated.

**Histo. Intervals control**—sets the resolution of the histogram display (in number of intervals to be used).

## System Settings Summary



**Figure A-11: System Settings Summary**

The System Settings Summary screen retrieves the values of all configuration and history parameters by automatically sending the relevant query commands to the laser system, and displays the system responses. The mouse and scroll bar can be used to browse the list.

**Laser Serial Port field**— provides a pull-down menu for selecting the serial port to be used for the communication link with the laser.

**Show Commands button**—turns the command/query display on and off.

**Read button**—retrieves the current list of parameters and settings.

**Store button**—prompts the user for a path and file name, and stores a copy of the list to that file.

**Quit button**—closes the window.

### Note



If the laser is turned on while the Read button is being pressed, the laser will shut off. This behavior is designed to insure that the read captures all parameters.



Serial commands and queries can be used to create programs to allow the master system computer to operate the *Explorer* laser.

Each command is acknowledged by a Carriage Return/Line Feed <CR> <LF> if the default setting of CR = 1 is used. This feature can be disabled by setting CR = 0.

If a command is not successfully executed (unknown command, command not allowed or invalid parameter), the system responds with a question mark “?”.

Commands are not case-sensitive.

This section contains the following tables:

- Table B-1: Serial Commands and Queries (grouped by function), on page B-2
- Table B-2: Serial Commands and Queries (in alphabetical order), on page B-18
- Table B-3: Status / Error Reporting Commands, on page B-32
- Table B-4: Analog Port Polarity Configuration Bits, on page B-33
- Table B-5: Analog Port Status Bits, on page B-33
- Table B-6: User Parameters, on page B-34

**Table B-1: Serial Commands and Queries (grouped by function)**

**System Identification and General Setup**

\*IDN?

This command returns the product identification string.

Return is a four comma-separated field:

manufacturer, model, serial number (laser head/power supply), firmware version (laser head/power supply)

If the laser head controller is not communicating with the power supply controller, the laser head firmware version is replaced by "-999"

**Examples**

Typical response:

SPECTRA-PHYSICS,EXPLORER,PL-0332-02/PS-0129-01,V3.14/V3.20.81<CR><LF>

If the laser head communication fails:

SPECTRA-PHYSICS,EXPLORER,XXXXXXXX/PS-0129-01,-999/V3.20.81<CR><LF>

MODE:REMOTE <n>  
MODE:REMOTE?

Enables(n = 1) or disables(n = 0) the computer (remote) mode.

The computer mode is required to switch the laser on or off via the RS232 serial port.

**Examples:**

→MODE:REMOTE 1<CR>

places the system in computer mode (the laser system is switched on by sending the ON command while the power supply key switch is in the ON position)

→MODE:REMOTE 0<CR>

places the system in local (analog) mode (the laser system is switched on by turning the key switch to the ON position or by processing the EXTERNAL\_DIODE\_ON line of the analog interface)

←MODE:REMOTE?<CR>

queries the setting for the remote mode

CONT:AUTOON <n>  
CONT:AUTOON?

This command sets the Auto-On feature of the laser system.

n = 1 enables auto-on mode: The ON command starts laser emission without a keyswitch reset (turning the key OFF and ON).

n = 0: disables auto-on mode. After the system is booted or after a critical error, a keyswitch reset (turning the key OFF and ON) is necessary to start laser emission with the ON command.

SYST:COMM:SER:BAUD <n>  
SYST:COMM:SER:BAUD?

This command sets the communication speed (baud rate) between the Explorer embedded controller and a customer control computer.

Range n = 4800, 9600, 14400, 19200, 28800, 38400, 57600 bps (bits per second)

Note: At startup the system uses the last baud rate that was in effect.

Examples:

```
→SYST:COMM:SER:BAUD 14400<CR>
    sets the actual baud rate to 14,400 bps
→SYST:COMM:SER:BAUD? <CR>
←14400bps<CR><LF>
```

WDOG <n>  
WDOG?

This command sets the software watchdog alert time, in seconds.

Unit: sec

Range <n>:

- n = 0 – 110
- n = 0 disables the watchdog timer (default)

This is the watchdog timer for RS-232 communication between the embedded computer in the laser system and the host computer. If the *Explorer* has not received commands from the customer's computer within the specified time, the laser will turn off.

Values of 3 to 10 seconds would be typical.

Examples:

```
→WDOG 10<CR>
←<CR><LF>
    The alert time is set to 10 seconds
```

```
→WDOG 0<CR>
←><CR><LF>
    The software watchdog is disabled
```

```
→WDOG?<CR>
←0sec<CR><LF>
    The software watchdog is disabled
```

**Laser Operation Commands**

These commands are executed only if the laser system has been put into computer (REMOTE) mode (with the command MODE:REMOTE 1 or using the GUI).

ON

Turn the diode laser on

Note: the laser emission starts after a security delay of 3 seconds (the emission lamp is switched on immediately)

OFF

Turn the diode laser off

```
MODE:STBY <n>
MODE:STBY?
```

This command enables/disables the standby mode for the diode laser (Refer to “Setting the Laser to Standby Modes” on page 7-4 for a description of standby mode).

Range <n>:

- n = 1: enable standby mode
- n = 0: disable standby mode and turn laser on again (if previously switched on)

### Diode Current Commands and Queries

```
DIODE1:CURRE <f>
DIODE1:CURRE?
```

This command sets the diode laser current, in Amps  
<f> current in Amps

0 < f < maximum diode laser current value (i.e. the value returned by DIODE1:MAXC?)

Note: Commands with values outside the range are rejected

Unit: A1

Examples:

```
→DIODE1:CURRE 4.5<CR>
←<CR><LF>
```

The diode current is set to 4.5 amps

```
→DIODE1:CURRE?<CR>
←4.5A1<CR><LF>
```

```
READ:DIODE1:CURRE?
```

This command reads the actual diode laser current, in Amps

Unit: A1

Example:

```
→READ:DIODE1:CURRE?<CR>
←4.5A1<CR><LF>
```

```
PCURRE <f>
PCURRE?
```

This command sets the diode laser current as a percentage of the maximum current limit.

<f> current in percent of value returned by DIODE1:MAXC?

Unit: %1

Examples:

```
→PCURRE 34.6<CR>
←<CR><LF>
```

```
→PCURRE?<CR>
←34.6%1<CR><LF>
```

**DIODE1:STANDBYC?**

This command reads the diode laser standby current, in Amps  
Unit: A1.

Example:

```
→DIODE1:STANDBYC?<CR>
←0.5A1<CR><LF>
```

**DIODE1:MAXC?**

This command returns the diode laser current limit, in Amps. The diode current limit is set at the factory.

Example:

```
→DIODE1:MAXC?<CR>
←5.5A1<CR><LF>
```

**Diode and Crystal Temperature Control**

```
CONT:SHG:TEMP <n>
CONT:SHG:TEMP?
```

This command sets the SHG temperature, in counts  
100 ≤ n ≤ 4000  
Unit: cnts

Examples:

```
→CONT:SHG:TEMP 1650<CR>
←<CR><LF>
→CONT:SHG:TEMP?<CR>
←1650cnts<CR><LF>
```

**READ:SHG:TEMP?**

This command reads the measured SHG temperature, in counts  
Unit: cnts

Example:

```
→READ:SHG:TEMP?<CR>
←1649cnts<CR><LF>
```

```
CONT:THG:TEMP <n>
CONT:THG:TEMP?
```

This command sets the THG temperature, in counts  
100 ≤ n ≤ 4000  
Unit: cnts

Examples:

```
→CONT:THG:TEMP 2988<CR>
←<CR><LF>
→CONT:SHG:TEMP?<CR>
←2988cnts<CR><LF>
```

READ:THG:TEMP?

This command reads the measured THG temperature, in counts  
Unit: cnts

Example:  
→READ:SHG:TEMP?<CR>  
←2989cnts<CR><LF>

DIODE1:TEMP <f>  
DIODE1:TEMP?

This command sets the diode laser temperature, in degrees C  
18.0 ≤ f ≤ 38.0  
Unit: degC

Examples:  
→DIODE1:TEMP 29.2<CR>  
←<CR><LF>  
→DIODE1:TEMP?<CR>  
←29.2degC<CR><LF>

READ:DIODE1:TEMP?

This command reads the actual laser diode temperature, in degrees C  
Unit: degC

Example:  
→READ:DIODE1:TEMP?<CR>  
←29.2degC<CR><LF>

### **Q-Switch Repetition Rate Commands and Queries**

QSW:PRF <n>  
QSW:PRF?

This command sets the Q-switch repetition frequency, in Hertz.

0 ≤ n ≤ maximum pulse repetition frequency (i.e. the value returned by QSW:PRF:MAX?)  
n=0 is disables internal pulse triggering and allows external triggering.  
Unit: Hz

Note: If the laser is operated in Random Pulsing Mode (MODE:RAND <n>, n = 1), the command to enable internal triggering mode (QSW:PRF <n>, 1 ≤ n ≤ prf limit) is rejected.

Examples:  
→QSW:PRF 1000<CR> (Set the pulse frequency to 1000 Hz.)  
←<CR><LF>  
→QSW:PRF?<CR>  
←1000Hz<CR><LF>  
→QSW:PRF 0<CR> (Set the system to external triggering mode.)  
←<CR><LF>

```
QSW:PRF:MAX?
```

This command reads the maximum pulse repetition frequency.  
Unit: Hz

Examples:  
→QSW:PRF:MAX?<CR>  
←5000Hz<CR><LF>

```
QSW:TIMG:DELAY <n>
QSW:TIMG:DELAY?
```

This command sets the delay time between the trigger signal and the optical pulse. The delay time is entered in units of 49.16 nsec added to a starting value of 3 µsec (head clock rate is 20.34 MHz).  
Unit: cycl  
Range: 0 – 3500 corresponding to 3 µsec to 175 µsec

Note: This command is rejected in Random Pulsing Mode.

Example:  
→QSW:TIMG:DELAY 250<CR> (Set delay time to 15.3 µsec.)  
←<CR><LF>  
QSW:TIMG:DELAY ?<CR>  
250cycl<CR><LF>

### Pulse Counts and Operating Hours

```
READ:QSW:CNTS?
```

This command reads the pulse counter, in Kilocounts  
Unit: kcnts

Examples:  
→READ:QSW.CNTS?<CR>  
←34121kcnts<CR><LF> (The system has issued 34,121,000 pulses.)

```
READ:HEAD:HOURL?
```

This command reads the laser head hours. Laser head hours are incremented every 6 minutes (0.1 hour) that power is supplied to the laser head.  
Unit: HrsHd

Example:  
→READ:HEAD:HOURL?<CR>  
←456.2HrsHd<CR><LF> (The laser head has been supplied with power for 456.2 hours.)

```
READ:PSUPPLY:HOURL?
```

This command reads the power supply hours. Power supply hours are incremented every 6 minutes (0.1 hour) that power is supplied to the power supply.  
Unit: HrsPS

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---

Example:

```
→READ:PSUPPLY:HOURL?<CR>
```

```
←478.7HrsPS<CR><LF> (The power supply has been supplied with power for 478.7 hours.)
```

```
READ:DIODE1:HOURL?
```

This command reads the diode laser operating hours. Diode laser operating hours are incremented every 6 minutes (0.1 hour) that the diode laser is turned on (emission mode) or in standby mode.

Unit: HrsD1

Example:

```
→READ:DIODE1:HOURL?<CR>
```

```
←234.8HrsD1<CR><LF> (The diode laser has been operated for 234.8 hours.)
```

### Analog Interface Commands and Queries

```
CONFIG:APORT:POLAR <n>  
CONFIG:APORT:POLAR?
```

This command sets the polarity of the analog interface lines (refer to Table B-4)

Range <n>: 0 - 255

Individual bit position = 1: line is high active (rising edge)

Individual bit position = 0: line is low active (falling edge) (default)

Examples:

```
→CONFIG:APORT 96<CR> (Set polarity of pins EXTERNAL_DIODE_ON and STANDBY to high-active.)
```

```
←<CR><LF>
```

```
→CONFIG:APORT? <CR>
```

```
←96<CR><LF>
```

```
STAT:APORT:SIGNAL?
```

This command reads the status of the analog interface pins. Use this command to query the activity level of the individual signals applied to the analog port (refer to Table B-5).

Individual bit position = 1: signal on pin is active

Individual bit position = 0: signal on pin is not active

Example:

```
→STAT:APORT:SIGNAL?<CR>
```

```
←64<CR><LF> (Standby line is active)
```

```
CONFIG:APORT:SYNC <n>
```

This command sets the generation mode of the SYNC signal

n = 1: SYNC is started after Q-switch signal

n = 0: SYNC is started after trigger signal

The SYNC mode status can be queried using the STAT:COND:OPER? command.

Example:

```
→CONFIG:APORT:SYNC 1<CR> (SYNC signal will be generated after the Q-switch signal.)
←<CR><LF>
```

## Pulse Energy Queries

```
READ:PENER?
```

This command reads the actual pulse energy, in  $\mu\text{J}$ .  
Unit:  $\mu\text{J}$

Example:

```
→READ:PENER?<CR>
←56 $\mu\text{J}$ <CR><LF>
```

```
READ:PENER:HIST?
```

This command reads the energy values of the first 50 pulses after switching on or after the last read-out of the pulse history. The values are given in ADC counts (0 – 1023) and are separated by blanks. Pulse energy in  $\mu\text{J}$  may be calculated by multiplication with the calibration factor (output of query PENER:CALF?).

This command can be used to adjust the delay time for first-pulse-suppression mode (FPS:DELAY <n>).

Examples :

```
→READ:PENER:HIST?<CR>
←455 772 781 776 ... 776 778 773<CR><LF>
```

```
→READ:PENER:HIST?<CR>
0<CR><LF> (No pulses have been emitted yet.)
```

```
PENER:CALF??
```

This command reads the calibration factor which is used to convert the pulse energy ADC counts (0 – 1023) to the displayed microjoule values. The calibration factor is set at the factory.  
Unit:  $\mu\text{J}^{-1}$

Example:

```
→PENER:CALF?<CR>
←0.5234 $\mu\text{J}^{-1}$ <CR><LF>
```

```
PENER:REFVOLT:CNTS <n>
PENER:REFVOLT:CNTS?
```

This command modifies the reference voltage of the pulse energy ADC. It may be used to re-calibrate the displayed pulse energy to match the values read at the user's energy meter. Higher reference voltage counts result in lower pulse energy values.

Range <n>: 200 - 1023

Unit: cnts

Examples:

```
→PENER:REFVOLT:CNTS 456<CR>
←<CR><LF>
→PENER:REFVOLT:CNTS?<CR>
```

←456cnts<CR><LF>

## Data Administration Commands and Queries

CONFIG:PARSET:STOR <n>

This command stores actual parameters as parameter set #<n>.

Range <n>:

- n = 1: user parameter set #1
- n = 2: user parameter set #2

Example:

→CONFIG:PARSET:STOR 1<CR>  
←<CR><LF>

Refer to Table B-6: User Parameters, on page B-32.

CONFIG:PARSET:LOAD <n>

This command loads parameter set #<n>.

Range <n>:

- n = 1: user parameter set #1
- n = 2: user parameter set #2
- n = 3: factory settings #1
- n = 4: factory settings #2

Example:

→CONFIG:PARSET:LOAD 1<CR>  
←<CR><LF>

Refer to Table B-6: User Parameters, on page B-32.

CONFIG:PARSET:ACT?

This command reads the active parameter set number.

Range <n>: 1 –4

- n = 1: user parameter set #1
- n = 2: user parameter set #2
- n = 3: factory settings #1
- n = 4: factory settings #2

Example:

→CONFIG:PARSET:ACT?<CR>  
←1<CR><LF>

Refer to Table B-6: User Parameters, on page B-32.

CONFIG:PARSET:BOOT <n>  
CONFIG:PARSET:BOOT?

This command designates the number of the parameter set to be loaded at next startup.

Range <n>: 1 –4

- n = 1: user parameter set #1

n = 2: user parameter set #2  
 n = 3: factory settings #1  
 n = 4: factory settings #2

Examples:

```
→CONFIG:PARSET:BOOT 1<CR>
←<CR><LF>
→CONFIG:PARSET:BOOT?<CR>
←1<CR><LF>
```

Refer to Table B-6: User Parameters, on page B-32.

## Status and Error Reporting

### READ:FAULT?

This command reads the error code (refer to Table C-3 on page C-7).

0 means there are no errors.

Example:

```
→READ:FAULT?<CR>
←12<CR><LF>
    User interlock is activated
```

### READ:FAULT:LIST?

This command reads a string of up to 16 status codes which are currently active (refer to Table C-3 on page C-7). Entries are separated by blanks.

0 means there are no errors.

Example:

```
→READ:FAULT:LIST?<CR>
←12 23 24 25<CR><LF>
```

### READ:FAULT:HIST?

This command reads the history buffer, which consists of up to 16 status codes activated after the most recent startup (refer to Table C-3 on page C-7). Entries are separated by blanks.

Example:

```
→READ:FAULT:HIST?<CR>
←0 12 24 13 12 23 24 25 12<CR><LF>
```

### \*STB?

This command reads the system status byte (refer to Table C-1 on page C-1).

Example:

```
→*STB?<CR>
←1<CR><LF>
    Laser emission is present
```

### STAT:COND:CMD?

This command reads the status of the last command (refer to Table C-2 on page C-2).

Example:

```
→STAT:COND:CMD?<CR>
```

```
←0<CR><LF>
```

Last command was successfully completed.

### STAT:COND:SYST?

This command reads the system status (refer to Table B-5 on page B-20).

Example:

```
→STAT:COND:SYST?<CR>
```

```
←2<CR><LF>
```

There is a laser head fault.

### STAT:COND:SYST:PARSET?

This command reads data administration status (refer to Table C-2 on page C-2).

Example:

```
→STAT:COND:SYST:PARSET?<CR>
```

```
←16<CR><LF>
```

An error occurred while loading the user parameter set.

### STAT:COND:SYST:PSUPPLY?

This command reads power supply status (refer to Table C-2 on page C-2).

Example:

```
→STAT:COND:SYST:PSUPPLY?<CR>
```

```
←1<CR><LF>
```

There is an overtemp condition on the power supply board.

### STAT:COND:SYST:HEAD?

This command reads laser head status (refer to Table C-2 on page C-2).

Example:

```
→STAT:COND:SYST:HEAD?<CR>
```

```
←1<CR><LF>
```

There was a communication error with the laser head.

### STAT:COND:SYST:DIODE1?

This command reads diode laser status (refer to Table C-2 on page C-2).

Example:

```
→STAT:COND:SYST:DIODE1?<CR>
```

```
←2<CR><LF>
```

Laser diode current control error

---

**STAT:COND:SYST:TCONT?**

This command reads temperature controller status (refer to Table C-2 on page C-2).

Example:

```
→STAT:COND:SYST:TCONT?<CR>
```

```
←32<CR><LF>
```

PWM controller for laser diode temperature failed.

**STAT:COND:SYST:APORT?**

This command reads analog interface status (refer to Table C-2 on page C-2).

Example:

```
→STAT:COND:SYST:APORT?<CR>
```

```
←1<CR><LF>
```

Missing EXTERNAL\_DIODE\_ON signal

**STAT:COND:EVEN?**

This command reads system events status (refer to Table C-2 on page C-2).

Example:

```
→STAT:COND:EVEN?<CR>
```

```
←4<CR><LF>
```

Keyswitch is in OFF position.

**STAT:COND:OPER?**

This command reads system operational status (refer to Table C-2 on page C-2).

Example:

```
→STAT:COND:OPER?<CR>
```

```
←4<CR><LF>
```

System is in READY mode.

## Power Saving Modes

**MODE:READY <n>**
**MODE:READY?**

This command activates/deactivates READY mode.

In READY mode, the Q-switch is switched off, the TECs for controlling the temperatures of the harmonic crystals and diode laser are left on.

Range <n>: n=1 : READY mode on

n=0 : READY mode off

Note: in READY mode, all commands besides status queries are rejected!

Example:

```
→MODE:READY 1<CR> (Activate READY mode..)
```

```
←<CR><LF>
```

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---

```
→MODE:READY?<CR>
←1<CR><LF>
```

```
MODE:SLEEP <n>
MODE:SLEEP?
```

This command activates/deactivates SLEEP mode.  
(in SLEEP mode, both the Q-switch and the TECs are off , for xtal/diode temperature control.)  
Range <n>:     n=1: SLEEP mode on  
              n=0: SLEEP mode off

Note: in SLEEP mode, all commands besides status queries are rejected!

Example:  
→MODE:SLEEP 1<CR> (Activate SLEEP mode.)  
←<CR><LF>  
→MODE:SLEEP?<CR>  
1<CR><LF>

### Laser Head Temperature Control

```
READ:HEAD:BAS:TEMP?
```

This command reads the temperature of the laser head base plate, in degrees C.  
Unit: deg C

Example:  
→READ:HEAD:BAS:TEMP? <CR>  
←34.5degC<CR><LF>

```
HEAD:FANCONT:MODE <n>
HEAD:FANCONT:MODE?
```

This command sets the operation mode of a connected fan: control mode (base plate temperature is regulated to the adjusted set point, refer to command HEAD:FANCONT:TEMP <f>) or drive mode (constant, but adjustable voltage).

Range <n>:  
    n = 1: control mode  
    n = 0: drive mode (default)

Example:  
→HEAD:FANCONT:MODE 1<CR>  
←<CR><LF>  
→HEAD:FANCONT:MODE?<CR>  
←1<CR><LF>

```
HEAD:FANCONT:TEMP <f>
HEAD:FANCONT:TEMP?
```

This command sets the temperature set point for the fan control (the setting has no effect if no fan is connected).  
Unit: deg C

Range <f>:  
18.0 deg C <= f <= 34.0 deg C

Note: The command is rejected if the fan operation mode is set to “drive mode”

Example:  
→HEAD:FANCONT:TEMP 33.5<CR>  
←<CR><LF>  
→HEAD:FANCONT:TEMP?<CR>  
←33.5degC<CR><LF>

HEAD:FANCONT:PVOLT <f> HEAD:FANCONT:PVOLT?
---

This command sets the fan voltage in percent of the maximum voltage of 13 V, if the fan operation mode is set to drive mode.

Note: The command is rejected if the fan operation mode is put into “control mode”.

Unit: %

Range <f>: 0 – 100 %

Example:  
→HEAD:FANCONT:PVOLT 50.0<CR>  
←<CR><LF>  
    The fan voltage is set to 50% (6.5 Volt)  
→HEAD:FANCONT:PVOLT?<CR>  
←50%<CR><LF>

### First Pulse Suppression (FPS) Commands and Queries

FPS:DELAY <n> FPS:DELAY?
-----------------------------

This command sets the FPS delay time to <n> μsec.

Unit: μsec

Range <n>:

0 <= n <= 2000

n = 0 disables FPS

Examples:  
→FPS:DELAY 678<CR>  
←<CR><LF>  
    Set FPS delay is 678 μsec.  
→FPS:DELAY?<CR>  
←678usec<CR><LF>  
  
→FPS:DELAY 0<CR>  
←<CR><LF>  
    Disable FPS

## Burst Mode Commands and Queries

```
BURST:CNTS <n>
BURST:CNTS?
```

This command sets the number of pulses issued at next BURST command, using the currently active pulse repetition rate.

Unit: cnts

Range <n>:

0 ≤ n ≤ 4000

n = 0 disables burst mode

Examples:

```
→BURST:CNTS 100<CR>
```

```
←<CR><LF>
```

Set burst count to 100 counts

```
→BURST:CNTS?<CR>
```

```
←100cnts<CR><LF>
```

```
→BURST:CNTS 0<CR>
```

```
←<CR><LF>
```

Burst mode is disabled.

```
BURST:SYNC <n>
BURST:SYNC?
```

This command sets synchronize-over-burst mode.

Range <n>:

n = 1: span sync pulse over burst duration

n = 0: sync pulse will have standard duration

Examples:

```
→BURST:SYNC 1<CR>
```

```
←<CR><LF>
```

Span sync pulse over burst duration.

```
→BURST:SYNC?<CR>
```

```
←1<CR><LF>
```

```
BURST
```

This command performs a burst of the specified pulse count.

Note: The command is executed only if the laser system is put into computer (REMOTE) mode and the laser diode is ON.

Example of how to perform a burst:

1. Set system in remote mode:

```
MODE:REMOTE 1<CR>
```

2. Select the desired pulse count per burst (e.g.100):

```
BURST:CNTS 100 <CR>
```

3. Switch laser on: ON<CR>

4. Launch a burst: BURST>CR>

5. Launch next burst: BURST<CR>

## Random Pulsing Mode Command and Query

```
MODE:RAND <n>  
MODE:RAND?
```

This command enables/disables random pulsing mode: in this mode every external trigger pulse generates 1 optical pulse of constant pulse energy (if the FPS delay time is properly adjusted).

If the FPS mode is not activated (i.e. FPS delay time = 0  $\mu$ sec), this command is rejected.

n = 1: Random pulsing mode is enabled

n = 0: Random pulsing mode is disabled

Note: Random Pulsing Mode may only be enabled if the system is in external triggering mode.

Examples:

```
→MODE:RAND 1<CR>
```

```
←<CR><LF>
```

```
→MODE:RAND?<CR>
```

```
←1<CR><LF>
```

If FPS mode is disabled:

```
→MODE:RAND 1<CR>
```

```
←?<CR><LF>
```

**Table B-2: Serial Commands and Queries (listed alphabetically)**

**BURST**

This command performs a burst of the specified pulse count. The command is executed only if the laser system is set in computer (REMOTE) mode and the diode laser is ON.

Example of how to perform a burst:

1. Set system in remote mode:  
MODE:REMOTE 1<CR>
2. Select the desired pulse count per burst (e.g.100):  
BURST:CNTS 100 <CR>
3. Switch laser on: ON<CR>
4. Launch a burst: BURST>CR>
5. Launch next burst: BURST<CR>

**BURST:CNTS <n>  
BURST:CNTS?**

This command sets the number of pulses issued at next BURST command, using the currently active pulse repetition rate.

Unit: cnts

Range <n>: 0 <= n <= 4000  
n = 0 disables Burst Mode

Examples:

→BURST:CNTS 100<CR> (Set burst count to 100 counts.)  
←<CR><LF>

→BURST:CNTS?<CR>  
←100cnts<CR><LF>

→BURST:CNTS 0<CR> (Disable Burst Mode.)  
←<CR><LF>

**BURST:SYNC <n>  
BURST:SYNC?**

This command sets synchronize-over-burst mode.

Range <n>: n = 1: span sync pulse over burst duration  
n = 0: sync pulse will have standard duration

Examples:

→BURST:SYNC 1<CR> (Span sync pulse over burst duration.)  
←<CR><LF>

→BURST:SYNC?<CR>  
←1<CR><LF>

```
CONFIG:APOINT:POLAR <n>
CONFIG:APOINT:POLAR?
```

This command sets the polarity of the analog interface lines (refer to Table B-4).  
Range <n>: 0 – 255

Individual bit position = 1: line is high-active (rising edge)  
Individual bit position = 0: line is low-active (falling edge) (default)

Examples:

```
→CONFIG:APOINT 96<CR> (Set polarity of pins EXTERNAL_DIODE_ON and STANDBY to high-active.)
←<CR><LF>
```

```
→CONFIG:APOINT? <CR>
←96<CR><LF>
```

```
CONFIG:APOINT:SYNC <n>
```

This command sets the generation mode of the SYNC signal. The SYNC mode status can be queried using the STAT:COND:OPER? command.

n = 1: SYNC is started after Q-switch signal  
n = 0: SYNC is started after trigger signal

Example:

```
→CONFIG:APOINT:SYNC 1<CR> (Generate the SYNC signal after the Q-switch signal.)
←<CR><LF>
```

```
CONFIG:PARSET:ACT?
```

This command reads the active parameter set number (refer to Table B-6: User Parameters).  
Range <n>: 1 – 4

n = 1: user parameter set #1  
n = 2: user parameter set #2  
n = 3: factory settings #1  
n = 4: factory settings #2

Example:

```
→CONFIG:PARSET:ACT?<CR>
←1<CR><LF>
```

```
CONFIG:PARSET:BOOT <n>
CONFIG:PARSET:BOOT?
```

This command designates the parameter set, indicated by number, to be loaded at next startup (refer to Table B-6: User Parameters).

Range <n>: n = 1: user parameter set #1  
n = 2: user parameter set #2  
n = 3: factory settings #1  
n = 4: factory settings #2

Examples:

```
→CONFIG:PARSET:BOOT 1<CR>
←<CR><LF>
```

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→CONFIG:PARSET:BOOT?<CR>  
←1<CR><LF>

CONFIG:PARSET:LOAD <n>

This command loads parameter set #<n> (refer to Table B-6: User Parameters).

Range <n>:     n = 1: user parameter set #1  
                  n = 2: user parameter set #2  
                  n = 3: factory settings #1  
                  n = 4: factory settings #2

Example:

→CONFIG:PARSET:LOAD 1<CR>  
←<CR><LF>

CONFIG:PARSET:STOR <n>

This command stores actual parameters as parameter set #<n> (refer to Table B-6: User Parameters).

Range <n>:     n = 1: user parameter set #1  
                  n = 2: user parameter set #2

Example:

→CONFIG:PARSET:STOR 1<CR>  
←<CR><LF>

CONT:AUTOON <n>  
CONT:AUTOON?

This command sets the auto-on feature of the laser system.

n = 1: enables auto-on mode: The ON command starts laser emission **without** a keyswitch reset (turning the key OFF and ON).  
n = 0: disables auto-on mode. After the system is booted or after a critical error, a keyswitch reset (turning the key OFF and ON) is necessary to start laser emission with the ON command.

CONT:SHG:TEMP <n>  
CONT:SHG:TEMP?

This command sets the SHG temperature, in counts.

100 ≤ n ≤ 4000  
Unit: cnts

Examples:

→CONT:SHG:TEMP 1650<CR>  
←<CR><LF>

→CONT:SHG:TEMP?<CR>  
←1650cnts<CR><LF>

CONT:THG:TEMP <n>  
CONT:THG:TEMP?

This command sets the THG temperature, in counts.

100 ≤ n ≤ 4000  
Unit: cnts

Examples:

```
→CONT:THG:TEMP 2988<CR>
←<CR><LF>
```

```
→CONT:THG:TEMP?<CR>
←2988cnts<CR><LF>
```

```
DIODE1:CURRE <f>
DIODE1:CURRE?
```

This command sets the diode laser current, in Amps.

0 < f < maximum diode laser current value, in Amps (i.e. the value returned by DIODE1:MAXC?). Commands with values outside the range are rejected.

Examples:

```
→DIODE1:CURRE 4.5<CR>           (Set the diode laser current to 4.5 Amps.)
←<CR><LF>
```

```
→DIODE1:CURRE?<CR>
←4.5A1<CR><LF>                 (The diode laser current has been set to 4.5 Amps.)
```

```
DIODE1:MAXC?
```

This command returns the diode laser current limit, in Amps.

Example:

```
→DIODE1:MAXC?<CR>
←5.5A1<CR><LF>
```

```
DIODE1:STANDBYC?
```

This command reads the diode laser standby current, in Amps.

Example:

```
→DIODE1:STANDBYC?<CR>
←0.5A1<CR><LF>
```

```
DIODE1:TEMP <f>
DIODE1:TEMP?
```

This command sets the diode laser temperature, in degrees C.

18.0 ≤ f ≤ 38.0

Unit: degC

Examples:

```
→DIODE1:TEMP 29.2<CR>
←<CR><LF>
```

```
→DIODE1:TEMP?<CR>
←29.2degC<CR><LF>
```

```
FPS:DELAY <n>
FPS:DELAY?
```

This command sets the FPS delay time to <n> μsec.

Unit: μsec

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Range <n>:    0 <= n <= 2000  
                  n = 0 disables FPS

Examples:

```
→FPS:DELAY 678<CR>    (Set FPS delay is 678 µsec.)  
←<CR><LF>
```

```
→FPS:DELAY?<CR>  
←678usec<CR><LF>
```

```
→FPS:DELAY 0<CR>                    (Disable FPS.)  
←<CR><LF>
```

HEAD:FANCONT:MODE <n>  
HEAD:FANCONT:MODE?

This command sets the operation mode of a connected fan to: control mode, in which base plate temperature is regulated to the adjusted set point (refer to command HEAD:FANCONT:TEMP <f>); or drive mode, which provides constant but adjustable voltage.

Range <n>:    n = 1: control mode  
                  n = 0: drive mode (default)

Examples:

```
→HEAD:FANCONT:MODE 1<CR>  
←<CR><LF>
```

```
→HEAD:FANCONT:MODE?<CR>  
←1<CR><LF>
```

HEAD:FANCONT:PVOLT <f>  
HEAD:FANCONT:PVOLT?

This command sets the fan voltage in percent of the maximum voltage of 13 V, if the fan operation mode is set to drive mode. The command is rejected if the fan operation mode is set to control mode.

Unit: %

Range <f>:    0 – 100 %

Examples:

```
→HEAD:FANCONT:PVOLT 50.0<CR>                    (Set the fan voltage to 50%, i.e., 6.5 Volt.)  
←<CR><LF>
```

```
→HEAD:FANCONT:PVOLT?<CR>  
←50%<CR><LF>
```

HEAD:FANCONT:TEMP <f>  
HEAD:FANCONT:TEMP?

This command sets the temperature set point for the fan control (the setting has no effect if no fan is connected). The command is rejected if the fan operation mode is set to drive mode.

Unit: deg C

Range <f>:    18.0 deg C <= f <= 34.0 deg C

Examples:

```
→HEAD:FANCONT:TEMP 33.5<CR>  
←<CR><LF>
```

```
→HEAD:FANCONT:TEMP?<CR>
←33.5degC<CR><LF>
```

```
*IDN?
```

This command returns the product identification string

Return is a four comma-separated field:

Manufacturer, model, serial number (laser head/power supply), firmware version (laser head/power supply).

If the laser head controller is not communicating with the power supply controller, the laser head firmware version is replaced by “-999”

Examples:

Typical response:

```
SPECTRA-PHYSICS,EXPLORER,PL-0332-02/PS-0129-01,V3.14/V3.20.81<CR><LF>
```

If the laser head communication fails:

```
SPECTRA-PHYSICS,EXPLORER,XXXXXXXX/PS-0129-01,-999/V3.20.81<CR><LF>
```

```
MODE:RAND <n>
MODE:RAND?
```

This command enables/disables random pulsing mode: in this mode every external trigger pulse generates 1 optical pulse of constant pulse energy (if the FPS delay time is properly adjusted).

If the FPS mode is not activated (i.e., FPS delay time = 0 µsec), this command is rejected.

n = 1: Random pulsing mode is enabled

n = 0: Random pulsing mode is disabled

Note: Random Pulsing Mode may only be enabled if the system is in external triggering mode.

Examples:

```
→MODE:RAND 1<CR>
```

```
←<CR><LF>
```

```
→MODE:RAND?<CR>
```

```
←1<CR><LF>
```

If FPS mode is disabled:

```
→MODE:RAND 1<CR>
```

```
←?<CR><LF>
```

```
MODE:READY <n>
MODE:READY?
```

This command activates/deactivates READY mode. In READY mode, the Q-switch is turned off; the TECs for controlling the temperatures of the harmonic crystals and diode laser are left on.

Range <n>: n = 1 : READY mode on

n = 0 : READY mode off

Note: in READY mode, all commands besides status queries are rejected.

Examples:

```
→MODE:READY 1<CR> (Activate READY mode.)
```

```
←<CR><LF>
```

```
→MODE:READY?<CR>
```

```
←1<CR><LF>
```

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```
MODE:REMOTE <n>
MODE:REMOTE?
```

This command enables (n = 1) or disables (n = 0) computer (remote) mode. Computer mode must be enabled to turn the laser on or off via the RS232 serial port.

Examples:

```
→MODE:REMOTE 1<CR>
    places the system in computer mode turned on by sending the ON command while the power supply key switch
    is in the ON position)
→MODE:REMOTE 0<CR>
    places the system in local (analog) mode (the laser system is switched on by turning the key switch to the ON
    position or by processing the EXTERNAL_DIODE_ON line of the analog interface)
→MODE:REMOTE?<CR>
    queries the setting for the remote mode.
```

```
MODE:SLEEP <n>
MODE:SLEEP?
```

This command activates/deactivates SLEEP mode. In SLEEP mode, the Q-switch and the TECs for controlling the temperatures of the harmonic crystals and diode laser are turned off.

Range <n>:     n = 1: SLEEP mode on  
              n = 0: SLEEP mode off

Note: in SLEEP mode, all commands besides status queries are rejected.

Examples:

```
→MODE:SLEEP 1<CR> (Activate SLEEP mode.)
←<CR><LF>

→MODE:SLEEP?<CR>
1<CR><LF>
```

```
MODE:STBY <n>
MODE:STBY?
```

This command enables/disables the standby mode for the diode laser (Refer to “Setting the Laser to Standby Modes” in Chapter 7 for a description of standby mode).

Range <n>:  
    n = 1: enable standby mode  
    n = 0: disable standby mode and turn laser on again (if previously switched on)

```
OFF
```

This command turns the diode laser off.

```
ON
```

This command turns the diode laser on. The *Explorer* laser emission starts after a security delay of 3 seconds (the emission indicator turns on immediately).

```
PCUR <f>
PCUR?
```

This command sets the diode laser current as a percentage of the maximum current limit.  
<f> current in percent of value returned by DIODE1:MAXC?

Unit: %1

Examples:

```
→PCUR 34.6<CR>
←<CR><LF>
```

```
→PCUR?<CR>
←34.6%1<CR><LF>
```

```
PENER:CALF??
```

This command reads the calibration factor which is used to convert the pulse energy ADC counts (0 – 1023) to the displayed microjoule values. The calibration factor is set at the factory.

Unit:  $\mu\text{J}^{-1}$

Example:

```
→PENER:CALF?<CR>
←0.5234 $\mu\text{J}^{-1}$ <CR><LF>
```

```
PENER:REFVOLT:CNTS <n>
PENER:REFVOLT:CNTS?
```

This command modifies the reference voltage of the pulse energy ADC. It may be used to re-calibrate the displayed pulse energy to match the values read at the user's energy meter. Higher reference voltage counts result in lower pulse energy values.

Range <n>: 200 – 1023

Unit: cnts

Examples:

```
→PENER:REFVOLT:CNTS 456<CR>
←<CR><LF>
→PENER:REFVOLT:CNTS?<CR>
←456cnts<CR><LF>
```

```
QSW:PRF <n>
QSW:PRF?
```

This command sets the Q-switch repetition frequency, in Hertz.

$0 \leq n \leq$  maximum pulse repetition frequency (i.e. the value returned by QSW:PRF:MAX?).

$n = 0$  disables internal pulse triggering and allows external triggering.

Unit: Hz

Note: If the laser is operated in Random Pulsing Mode (MODE:RAND <n>,  $n = 1$ ), the command to enable internal triggering mode (QSW:PRF <n>,  $1 \leq n \leq$  prf limit) is rejected.

Examples:

```
→QSW:PRF 1000<CR>          (Set the pulse frequency to 1000 Hz.)
←<CR><LF>
```

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```
→QSW:PRF?<CR>
←1000Hz<CR><LF>
```

```
→QSW:PRF 0<CR>          (Set the system to external triggering mode.)
←<CR><LF>
```

QSW:PRF:MAX?

This command reads the maximum pulse repetition frequency.  
Unit: Hz

Examples:  
→QSW:PRF:MAX?<CR>  
←5000Hz<CR><LF>

QSW:TIMG:DELAY <n>  
QSW:TIMG:DELAY?

This command sets the delay time between the trigger signal and the optical pulse. The delay time is entered in units of 49.16 nsec added to a starting value of 3  $\mu$ sec (head clock rate is 20.34 MHz).

Unit: cycles

Range: 0 – 3500 corresponding to 3  $\mu$ sec to 175  $\mu$ sec

Note: This command is rejected in Random Pulsing Mode.

Example:  
→QSW:TIMG:DELAY 250<CR> (Set delay time to 15.3  $\mu$ sec.)  
←<CR><LF>  
QSW:TIMG:DELAY ?<CR>  
250cycl<CR><LF>

READ:DIODE1:CURR?

This command reads the actual diode laser current, in Amps.  
Unit: A1

Example:  
→READ:DIODE1:CURR?<CR>  
←4.5A1<CR><LF> (The diode laser current is 4.5 amps.)

READ:DIODE1:HOUR?

This command reads the diode laser operating hours. Diode laser operating hours are incremented every 6 minutes (0.1 hour) that the diode laser is turned on (emission mode) or in standby mode.

Example:  
→READ:DIODE1:HOUR?<CR>  
←234.8HrsD1<CR><LF> (The diode laser has been operated for 234.8 hours.)

READ:DIODE1:TEMP?

This command reads the actual laser diode temperature, in degrees C.  
Unit: deg C

Example:  
→READ:DIODE1:TEMP?<CR>  
←29.2degC<CR><LF>

**READ:FAULT?**

This command reads the fault code (refer to Table C-3).  
0 means there are no errors.

Example:

```
→READ:FAULT?<CR>
←12<CR><LF> (The user interlock has been activated.)
```

**READ:FAULT:HIST?**

This command reads the history buffer, which consists of up to 16 status codes activated after the most recent startup (refer to Table C-3). Entries are separated by blanks.

Example:

```
→READ:FAULT:HIST?<CR>
←0 12 24 13 12 23 24 25 12<CR><LF>
```

**READ:FAULT:LIST?**

This command reads a string of up to 16 status codes which are currently active. Entries are separated by blanks (refer to Table C-3).  
0 means there are no errors.

Example:

```
→READ:FAULT:LIST?<CR>
←12 23 24 25<CR><LF>
```

**READ:HEAD:BAS:TEMP?**

This command reads the temperature of the laser head base plate, in degrees C.  
Unit: deg C

Example:

```
→READ:HEAD:BAS:TEMP? <CR>
←34.5degC<CR><LF>
```

**READ:HEAD:HOURL?**

This command reads the laser head hours. Laser head hours are incremented every 6 minutes (0.1 hour) that power is supplied to the laser head.  
Unit: HrsHd

Example:

```
→READ:HEAD:HOURL?<CR>
←456.2HrsHd<CR><LF> (The laser head has been supplied with power for 456.2 hours.)
```

**READ:PENER?**

This command reads the actual pulse energy, in  $\mu\text{J}$ .  
Unit:  $\mu\text{J}$

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Example:

```
→READ:PENER?<CR>
←56uJ<CR><LF>
```

### READ:PENER:HIST?

This command reads the energy values of the first 50 pulses after switching on or after the last read-out of the pulse history. The values are given in ADC counts (0 – 1023) and are separated by blanks. Pulse energy in  $\mu\text{J}$  may be calculated by multiplication with the calibration factor (output of query PENER:CALF?).

Examples :

```
→READ:PENER:HIST?<CR>
←455 772 781 776 ... 776 778 773<CR><LF>
```

```
→READ:PENER:HIST?<CR>
←0<CR><LF> (No pulses have been emitted yet.)
```

### READ:PSUPPLY:HOURL?

This command reads the power supply hours. Power supply hours are incremented every 6 minutes (0.1 hour) that power is supplied to the power supply.

Unit: HrsPS

Example:

```
→READ:PSUPPLY:HOURL?<CR>
←478.7HrsPS<CR><LF> (The power supply has been supplied with power for 478.7 hours.)
```

### READ:QSW:CNTS?

This command reads the pulse counter, in Kilocounts.

Unit: kcnts

Examples:

```
→READ:QSW.CNTS?<CR>
←34121kcnts<CR><LF> (The system has issued 34,121,000 pulses.)
```

### READ:SHG:TEMP?

This command reads the measured SHG temperature, in counts.

Unit: cnts

Example:

```
→READ:SHG:TEMP?<CR>
←1649cnts<CR><LF>
```

### READ:THG:TEMP?

This command reads the measured THG temperature, in counts.

Unit: cnts

Example:

```
→READ:SHG:TEMP?<CR>
←2989cnts<CR><LF>
```

**STAT:APORT:SIGNAL?**

This command reads the status of the analog interface pins. Use this command to query the activity level of the individual signals applied to the analog port (refer to Table B-5).

Individual bit position = 1: signal on pin is active  
 Individual bit position = 0: signal on pin is not active

Example:

```
→STAT:APORT:SIGNAL?<CR>
←64<CR><LF>          (Standby line is active.)
```

**STAT:COND:CMD?**

This command reads the status of the last command (refer to Table C-2).

Example:

```
→STAT:COND:CMD?<CR>
←0<CR><LF>          (The last command was successfully completed.)
```

**STAT:COND:EVEN?**

This command reads system events status (refer to Table C-2).

Example:

```
→STAT:COND:EVEN?<CR>
←4<CR><LF>          (Keyswitch is in OFF position.)
```

**STAT:COND:OPER?**

This command reads system operational status (refer to Table C-2).

Example:

```
→STAT:COND:OPER?<CR>
←4<CR><LF>          (System is in READY mode.)
```

**STAT:COND:SYST?**

This command reads the system status (refer to Table C-2).

Example:

```
→STAT:COND:SYST?<CR>
←2<CR><LF>          (There is a laser head fault.)
```

**STAT:COND:SYST:APORT?**

This command reads analog interface status (refer to Table C-2).

Example:

```
→STAT:COND:SYST:APORT?<CR>
←1<CR><LF>          (Missing EXTERNAL_DIODE_ON signal.)
```

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STAT:COND:SYST:DIODE1?

This command reads diode laser status (refer to Table C-2).

Example:

```
→STAT:COND:SYST:DIODE1?<CR>
←2<CR><LF>          (Diode laser current control error.)
```

STAT:COND:SYST:HEAD?

This command reads laser head status (refer to Table C-2).

Example:

```
→STAT:COND:SYST:HEAD?<CR>
←1<CR><LF>          (There was a communication error with the laser head.)
```

STAT:COND:SYST:PARSET?

This command reads data administration status (refer to Table C-2).

Example:

```
→STAT:COND:SYST:PARSET?<CR>
←16<CR><LF>         (An error occurred while loading the user parameter set.)
```

STAT:COND:SYST:PSUPPLY?

This command reads power supply status (refer to Table C-2).

Example:

```
→STAT:COND:SYST:PSUPPLY?<CR>
←1<CR><LF>          (There is an overtemp condition on the power supply board.)
```

STAT:COND:SYST:TCONT?

This command reads temperature controller status (refer to Table C-2).

Example:

```
→STAT:COND:SYST:TCONT?<CR>
←32<CR><LF>         (PWM controller for diode laser temperature failed.)
```

\*STB?

This command reads the system status byte (refer to Table C-1).

Example:

```
→*STB?<CR>
←1<CR><LF>          (Laser emission is present.)
```

SYST:COMM:SER:BAUD <n>  
SYST:COMM:SER:BAUD?

This command sets the communication speed (baud rate) between the Explorer embedded controller and a customer control computer.

Range n = 4800, 9600, 14400, 19200, 28800, 38400, 57600 bps (bits per second).

Note: At startup the system uses the last baud rate that was in effect.

Examples:

→SYST:COMM:SER:BAUD 14400<CR> (Set the actual baud rate to 14,400 bps.)

→SYST:COMM:SER:BAUD? <CR>

←14400bps<CR><LF>

WDOG <n>

WDOG?

This command sets the software watchdog alert time, in seconds. This is the watchdog timer for RS-232 communication between the embedded computer in the laser system and the host computer. If the *Explorer* has not received commands from the customer's computer within the specified time, the laser will turn off.

Unit: sec

Range <n>: n = 0 – 110

n = 0 disables the watchdog timer (default)

Values of 3 to 10 seconds would be typical.

Examples:

→WDOG 10<CR> (Set the alert time to 10 seconds.)

←<CR><LF>

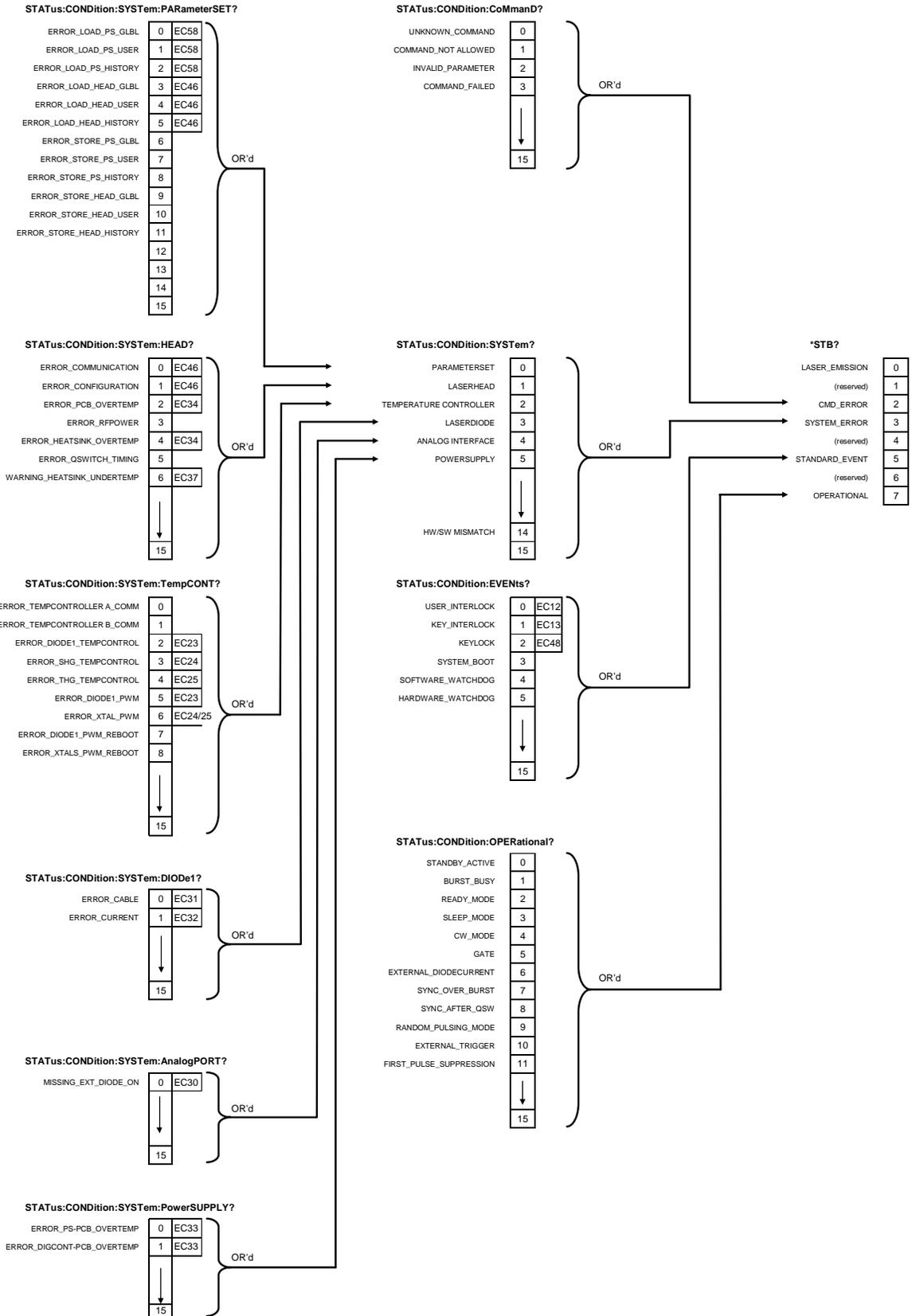
→WDOG 0<CR> (Disable the software watchdog.)

←<CR><LF>

→WDOG?<CR>

←0sec<CR><LF> (The software watchdog has been disabled.)

Table B-3: Status / Error Reporting Commands



**Table B-4: Analog Port Polarity Configuration Bits**

Bit	Description / Signal	Default Setting *
0	Sync out	Low-active (falling edge)
1	Pulse monitor	Low-active (falling edge)
2	External trigger	Low-active (falling edge)
3	External gate	Low-active
4	(reserved)	N/A
5	External standby	Low-active
6	External diode on	Low-active (falling edge)
7	(reserved)	N/A
8	External diode current source	Low-active

\* Polarity/active level can be changed using the serial command: CONFIG:APORT:POLAR <n>

**Examples:**

To set the polarity of the “External trigger” pin to “rising edge” while keeping all other polarities to defaults, the command to change the polarity is CONFIG:APORT:POLAR 4 (bit  $2 \pm 2^2$ ).

To set both the polarity of the “External trigger” pin and of the “External Gate” pin to “rising edge” while keeping all other polarities to defaults, the command to change the polarity is CONFIG:APORT:POLAR 12 (bit  $2 + \text{bit } 3 \pm 2^2 + 2^3 = 4 + 8 = 12$ ).

**Table B-5: Analog Port Status Bits**

Bit	Description	Bit is high ...
0	External diode current source	if pin 18 (ILD_SOURCE ) is active*
1	(reserved)	N/A
2	External trigger	if pin 21 (EXT_TRIG) is active*
3	External gate	if pin 17 (EXT_GATE) is active*
4	(reserved)	N/A
5	External standby	if pin 15 (STANDBY) is active*
6	External diode on	if pin 10 (EXT_DIODE_ON) is active*
7	(reserved)	N/A

\* Active low or high depends on ANALOG port polarity configuration

**Table B-6: User Parameters**

The parameters in this table comprise a user parameter set. Two different sets can be defined and stored as “User Set #1” and “User Set #2.”

<b>Parameter Description</b>	<b>Command to Modify Parameter</b>
Pulse repetition frequency	QSW:PRF <n>
Diode current	DIOD1:CURR <f> or PCUR <f>
Operation modes	
Auto-on feature	CONT:AUTOON <n>
Computer/Analog mode	MODE:RMT <n>
Sync mode after Q-switch	CONFIG:APORT:SYNC <n>
Random Pulsing Mode	MODE:RANDOM <n>
Polarity of analog port signals	CONFIG:APORT:POLAR <n>
Pulses per burst*	BURST:CNTS <n>
Sync pulse spanned over burst*	BURST:SYNC <n>
Delay time for first pulse suppression*	FPS:DELAY <n>
Delay time between trigger signal and optical pulse*	QSW:TIMG:DELAY <n>
SHG temperature	CONT:SHG:TEMP <n>
THG temperature	CONT:THG:TEMP <n>
Diode temperature	CONT:DIOD1:TEMP <f>
Alert time for software watchdog	WDOG <n>

\* extended models only

This appendix contains the following tables:

- Table C-1: System Status Byte, on page C-1
- Table C-2: Operating Status and Error Bits, on page C-2
- Table C-3: Fault Codes, on page C-7
- Table C-4: Non-Critical Fault Codes, on page C-7

The query \*STB? returns an 8-bit byte that yields the following information about the system status.

**Table C-1: System Status Byte**

Bit	Description	Bit is activated ...
0	Laser emission	if the diode laser is on or is in Standby Mode.
1	(reserved)	N/A
2	Command error	if a serial command could not be executed correctly.
3	System error	if a system error is present. (e.g., temperature control, configuration)
4	(reserved)	N/A
5	Event summary	if one or more events have taken place. (e.g., interlocks, system boot, software watchdog)
6	(reserved)	N/A
7	Operational	if one or more system conditions are enabled. (e.g., Standby, external triggering mode, Burst Mode)

**Table C-2: Operating Status and Error Bits**

Bit Active	Description	Condition	Action Required
<b>Serial Commands Register (Query STAT:COND:CMD?)</b>			
0	UNKNOWN_CMD	Unknown command	Use allowed command from list.
1	CMD_NOT_ALLOWED	Command is not allowed, e.g., <i>BURST</i> when Burst mode is not activated.	Prepare system to accept the command.
2	INVALID_PAR	Command was sent using invalid parameter(s): e.g., <i>DIOD1:CURRENT 10.3</i> when the maximum diode current is set to 5.0 A.	Make sure valid parameters are used.
3	CMD_FAILED	A communication error with the laser head or an internal bus error occurred.	Check the cables to the laser head. If the problem persists, contact Spectra-Physics service.
<b>System Condition Register (Query STAT:COND:SYST?)</b>			
0	PAR_SET	There is a problem with the configuration set(s) (communication error, invalid check-sums).	Retrieve detailed information by querying the individual configuration set conditions.
1	LASER_HEAD	There is a problem with the laser head (communication error, temperature, etc.).	Retrieve detailed information to pinpoint the cause of the problem.
2	TEMP_CONTROLLER	Temperature controller failure (crystals and/or diode laser)	Query temperature controller conditions.
3	LASER_DIODE	There is a problem with the diode laser (e.g., cable, current control).	Query diode laser conditions.
4	ANALOG_INTERFACE	There is a problem with the analog port pins.	Query analog port conditions.
5	POWER_SUPPLY	There is a problem with the power supply.	Query power supply conditions.
14	HARDWARE_SOFTWARE_MISMATCH	The updated software does not match the hardware found.	Contact Spectra-Physics service
<b>System Events Condition Register (Query STAT:COND:EVENT?)</b>			
0	USER_INTERLOCK	The user interlock is activated.	Check the cause of the activated interlock. Reset the keyswitch (if Auto-On mode is disabled).
1	KEY_INTERLOCK	The keyswitch is OFF.	Turn keyswitch to ON position.
2	KEY_LOCK	A keyswitch reset is necessary (this condition can only occur if Auto-On mode is disabled).	Reset the keyswitch (turn the key to the OFF position and then to the ON position again).
3	SYSTEM_BOOT	Notification: the laser system has been booted.	No action is required by the user (the bit is cleared automatically after a reading).

Table C-2: Operating Status and Error Bits

Bit Active	Description	Condition	Action Required
4	SOFTWARE_WATCHDOG	The software watchdog for communication between the laser system and the host computer is tripped.	Check the serial communication between your PC software and the power supply. Lengthen the watchdog alert time or disable the software watchdog.
5	HARDWARE_WATCHDOG	The system has rebooted because the hardware watchdog was activated.	Contact Spectra-Physics service
<b>System Operational Condition Register (Query STAT:COND:OPER?)</b>			
0	STANDBY	Standby mode is active (was activated by software or by an external analog signal).	No action is required.
1	BURST_BUSY	Burst mode is activated and a burst is being carried out.	No action is required. (Check this bit before sending a new BURST command).
2	READY_MODE	Ready mode is activated (the Q-switch is turned off). All serial commands besides status queries will be rejected.	To re-enable normal operation, use the <i>MODE:READY 0</i> command.
3	SLEEP_MODE	Sleep mode is activated (the Q-switch and TECs are switched off). All serial commands besides status queries will be rejected.	To re-enable normal operation, use the <i>MODE:SLEEP 0</i> command.
5	GATE	The Gate signal is being applied to the analog port.	No action is required.
6	EXT_DIODE_CURRENT	External diode current control is activated (pin 18 of the analog port).	Apply a voltage of 0–2 V to pin 2 of the ANALOG port in order to adjust the diode current.
7	SYNC_OVER_BURST	The SYNC pulse duration is extended to include the whole burst sequence.	No action is required.
8	SYNC_AFTER_QSWITCH	The SYNC pulse generation mode is set to “After Q-Switch.”	No action is required.
9	RANDOM_PULSING_MODE	Random pulsing mode is activated	No action is required.
10	EXTERNAL_TRIGGER	External triggering mode is activated.	Apply a suitable trigger signal to pin 21 of the analog port.
11	FIRST_PULSE_SUPPRESSION	FPS mode is activated	No action is required.

**Table C-2: Operating Status and Error Bits**

Bit Active	Description	Condition	Action Required
<b>System Condition “Parameter Set” Register (Query STAT:COND:SYST:PARSET?)</b>			
0	ERROR_LOAD_PS_GLBL	An error occurred while retrieving global data from the power supply EEPROM.	Contact Spectra-Physics service
1	ERROR_LOAD_PS_USER	An error occurred while retrieving the actual user parameter set from the power supply EEPROM.	Contact Spectra-Physics service
2	ERROR_LOAD_PS_HISTORY	An error occurred when retrieving (from the EEPROM) the (accumulated) seconds that the power supply has been supplied with power.	Contact Spectra-Physics service
3	ERROR_LOAD_HEAD_GLBL	An error occurred when retrieving the laser head global data from the laser head EEPROM.	Check the cable connection between the power supply and laser head. Contact Spectra-Physics service
4	ERROR_LOAD_HEAD_USER	An error occurred when retrieving the actual user parameter set of the laser head from the laser head EEPROM.	Check the cable connection between the power supply and laser head. Contact Spectra-Physics service
5	ERROR_LOAD_HEAD_HISTORY	An error occurred while retrieving the diode laser operating hours and the pulse counts from the laser head EEPROM.	Check the cable connection between the power supply and laser head. Contact Spectra-Physics service
6	ERROR_STORE_LOAD_PS_GLBL	An error occurred while storing global data to the power supply EEPROM.	Contact Spectra-Physics service
7	ERROR_STORE_PS_USER	An error occurred while storing the actual user parameter set to the power supply EEPROM.	Contact Spectra-Physics service
8	ERROR_STORE_PS_HISTORY	An error occurred while storing the power supply switch-on time to the power supply EEPROM.	Contact Spectra-Physics service
9	ERROR_STORE_HEAD_GLBL	An error occurred while storing the laser head global data to the laser head EEPROM.	Check the cable connection between the power supply and laser head. Contact Spectra-Physics service
10	ERROR_STORE_HEAD_USER	An error occurred while storing the actual user parameter set to the laser head EEPROM.	Check the cable connection between the power supply and laser head. Contact Spectra-Physics service
11	ERROR_STORE_HEAD_HISTORY	An error occurred while storing the diode laser operating hours and the pulse counts to the laser head EEPROM.	Check the cable connection between the power supply and laser head. Contact Spectra-Physics service

**Table C-2: Operating Status and Error Bits**

Bit Active	Description	Condition	Action Required
<b>System Condition “HEAD” Register (Query STAT:COND:SYST:HEAD?)</b>			
0	ERROR_COMMUNICATION	An error occurred while communicating with the laser head.	Check the cable connection between the power supply and laser head. Contact Spectra-Physics service
1	ERROR_CONFIGURATION	An error occurred while retrieving or updating the configuration parameters of the laser head.	Check the cable connection between the power supply and laser head. Contact Spectra-Physics service
2	ERROR_PCB_OVERTEMPERATURE	The laser was turned off because the maximum printed-circuit board temperature was exceeded.	Make sure the laser head is properly heatsinked. If the problem persists, contact Spectra-Physics service
4	ERROR_HEATSINK_OVERTEMPERATURE	The laser was turned off because the maximum heatsink temperature was exceeded.	Make sure the laser head is properly heatsinked.
5	ERROR_QSWITCH_TIMING	Invalid Q-switch timing parameters (not lasing!)	Contact Spectra-Physics service
<b>System Condition “POWER SUPPLY” Register (Query STAT:COND:SYST:PSUPPLY?)</b>			
0	ERROR_PS_PCB_OVERTEMP	The laser was turned off because the maximum temperature of the main PCB was exceeded.	Contact Spectra-Physics service
1	ERROR_DIGCONT_PCB_OVERTEMP	The laser was turned off because the maximum temperature of the digital controller PCB was exceeded.	Contact Spectra-Physics service
<b>System Condition “TEMPERATURE CONTROLLER” Register (Query STAT:COND:SYST:TCONT?)</b>			
0	ERROR_TEMPCONTROLLER_A_COMM	An error occurred while communicating with the temperature controller responsible for the SHG/THG control.	Reboot the system. If the problem persists, contact Spectra-Physics service.
1	ERROR_TEMPCONTROLLER_B_COMM	An error occurred while communicating with the temperature controller responsible for the diode laser control.	Reboot the system. If the problem persists, contact Spectra-Physics service.
2	ERROR_DIODE1_TEMPCONTROL	The setpoint temperature for the diode laser cannot be adjusted by the control loop.	Contact Spectra-Physics service
3	ERROR_SHG_TEMPCONTROL	The setpoint temperature for the SHG crystal cannot be adjusted by the control loop.	Contact Spectra-Physics service
4	ERROR_THG_TEMPCONTROL	The setpoint temperature for the THG crystal cannot be adjusted by the control loop.	Contact Spectra-Physics service

**Table C-2: Operating Status and Error Bits**

<b>Bit Active</b>	<b>Description</b>	<b>Condition</b>	<b>Action Required</b>
5	ERROR_DIODE1_PWM	The temperature control loop for the diode laser is operating at its limit.	Contact Spectra-Physics service
6	ERROR_XTALS_PWM	The temperature control loop for the SHG/THG crystals is operating at its limit.	Contact Spectra-Physics service
7	ERROR_DIODE1_PWM_REBOOT	A diode temperature controller reboot procedure took place.	If the problem persists, contact Spectra-Physics service.
8	ERROR_XTALS_PWM_REBOOT	A crystal temperature controller reboot procedure took place.	If the problem persists, contact Spectra-Physics service.
<b>System Condition “ANALOG PORT” Register (Query STAT:COND:SYST:APOINT?)</b>			
0	MISSING_EXT_DIODE_ON	The laser is in Analog mode. To start laser emission, a signal must be applied to pin 10 of the ANALOG port.	Apply an appropriate signal to pin 10.
<b>System Condition “DIODE” Register (Query STAT:COND:SYST:DIODE1?)</b>			
0	ERROR_CABLE	The laser head cable is not correctly connected.	Check the cable connection between the power supply and laser head. If the problem persist, contact Spectra-Physics service.
1	ERROR_CURRENT	The diode current driver control loop is at its limit.	Contact Spectra-Physics service

**Table C-3: Fault Codes**

<b>Code</b>	<b>Description</b>
0	No Errors Present
12	User Interlock Open
13	Keyswitch Interlock Open
23	Error Diode Laser Temperature
24	Error SHG Temperature
25	Error THG Temperature
31	Error Diode Laser Cable
32	Error Diode Laser Current Control
33	Power Supply Overtemperature
34	Laser Head Overtemperature
35	Error Hardware Mismatch
36	Error Software Mismatch
46	Laser Head EEPROM Malfunction
48	Error Keyswitch Reset Required (Turn the keyswitch OFF then back ON again)
58	Bad Configuration (Power supply EEPROM error)

**Table C-4: Non-Critical Fault Codes**

<b>Code</b>	<b>Description</b>
30	Missing External Diode On Signal
37	Warning Undertemp Heatsink
38	Warning Overtemp Power Supply
39	Warning Overtemp Laser Head



## Emission and Absorption of Light

*Laser* is an acronym derived from Light Amplification by Stimulated Emission of Radiation. Thermal radiators, such as the sun, emit light in all directions, the individual photons having no definite relationship with one another. But because the laser is an oscillating amplifier of light, and because its output comprises photons that are identical in phase and direction, it is unique among light sources. Its output beam is singularly directional, monochromatic, and coherent.

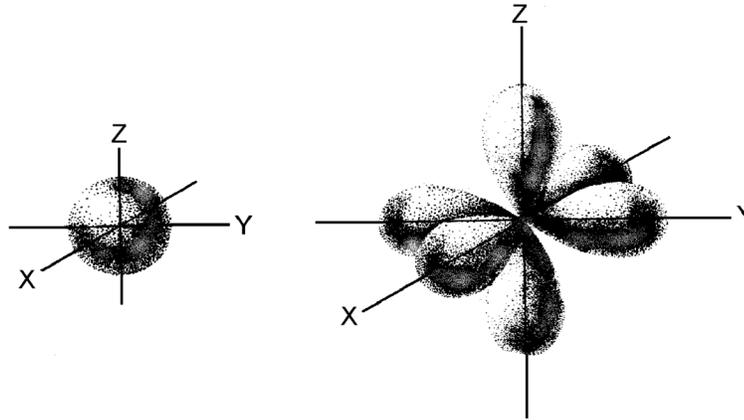
Radiant emission and absorption take place within the atomic or molecular structure of materials. The contemporary model of atomic structure describes an electrically neutral system composed of a nucleus with one or more electrons bound to it. Each electron occupies a distinct orbital that represents the probability of finding the electron at a given position relative to the nucleus. Each orbital has a characteristic shape that is defined by the radial and angular dependence of that probability, e.g., all *s* orbitals are spherically symmetrical, and all *p* orbitals surround the *x*, *y*, and *z* axes of the nucleus in a double-lobed configuration (Figure D-1). The energy of an electron is determined by the orbital that it occupies, and the over-all energy of an atom—its energy level—depends on the distribution of its electrons throughout the available orbitals. Each atom has an array of energy levels: the level with the lowest possible energy is called the ground state, and higher energy levels are called excited states. If an atom is in its ground state, it will stay there until it is excited by external forces.

Movement from one energy level to another—a transition—happens when the atom either absorbs or emits energy. Upward transitions can be caused by collision with a free electron or an excited atom, and transitions in both directions can occur as a result of interaction with a photon of light. Consider a transition from a lower level whose energy content is  $E_1$  to a higher one with energy  $E_2$ . It will only occur if the energy of the incident photon matches the energy difference between levels, i.e.,

$$h\nu = E_2 - E_1 \quad [1]$$

where  $h$  is Planck's constant, and  $\nu$  is the frequency of the photon.

*“Light” will be used to describe the portion of the electromagnetic spectrum from far infrared to ultraviolet.*



**Figure D-1: Electrons occupy distinct orbitals that are defined as the probability of finding an electron at a given position. The shape of the orbital is determined by the radial and angular dependence of this probability.**

Likewise, when an atom excited to  $E_2$  decays to  $E_1$ , it loses energy equal to  $E_2 - E_1$ . The atom may decay spontaneously, emitting a photon with energy  $h\nu$  and frequency

$$\nu = \frac{E_2 - E_1}{h} \quad [2]$$

Spontaneous decay can also occur without emission of a photon, the lost energy taking another form, e.g., transfer of kinetic energy by collision with another atom. An atom excited to  $E_2$  can also be stimulated to decay to  $E_1$  by interacting with a photon of frequency  $\nu$ , emitting energy in the form of a pair of photons that are identical to the incident one in phase, frequency, and direction. This is known as stimulated emission. By contrast, spontaneous emission produces photons that have no directional or phase relationship with one another.

A laser is designed to use absorption and both spontaneous and stimulated emission to create conditions favorable to light amplification. The following paragraphs describe these conditions.

## Population Inversion

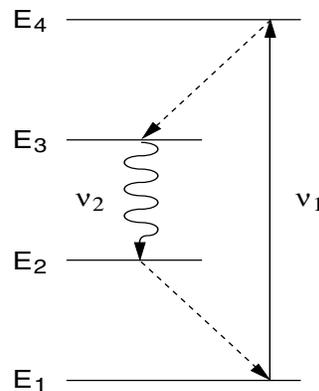
The net absorption at a given frequency is the difference between the rates of emission and absorption at that frequency. It can be shown that the rate of excitation from  $E_1$  to  $E_2$  is proportional to both the number of atoms in the lower level ( $N_1$ ) and the transition probability. Similarly, the rate of stimulated emission is proportional to the population of the upper level ( $N_2$ ) and the transition probability. Moreover, the transition probability depends on the flux of the incident wave and a characteristic of the transition called its “cross section.” The absorption coefficient depends only on the difference between the populations involved,  $N_1$  and  $N_2$ , and the flux of the incident wave.

When a material is at thermal equilibrium, there exists a Boltzmann distribution of its atoms over the array of available energy levels with most atoms in the ground state. Since the rate of absorption of all frequencies exceeds that of emission, the absorption coefficient at any frequency is positive.

If enough light of frequency  $\nu$  is supplied, the populations can be shifted until  $N_1 = N_2$ . Under these conditions the rates of absorption and stimulated emission are equal, and the absorption coefficient at frequency  $\nu$  is zero. If the transition scheme is limited to two energy levels, it is impossible to drive the populations involved beyond equality; that is,  $N_2$  can never exceed  $N_1$  because every upward transition is matched by one in the opposite direction.

However, if three or more energy levels are employed, and if their relationship satisfies certain requirements described below, additional excitation can create a population inversion where  $N_2 > N_1$ .

A model four-level laser transition scheme is depicted in Figure D-2. A photon of frequency  $\nu_1$  excites—or “pumps”—an atom from  $E_1$  to  $E_4$ . If the  $E_4$  to  $E_3$  transition probability is greater than that of  $E_4$  to  $E_1$ , and if the lifetime of an atom at  $E_4$  is short, the atom will decay almost immediately to  $E_3$ . If  $E_3$  is metastable, i.e., atoms that occupy it have a relatively long lifetime, the population will grow rapidly as excited atoms cascade from above. The  $E_3$  atom will eventually decay to  $E_2$ , emitting a photon of frequency  $\nu_2$ . Finally, if  $E_2$  is unstable, its atoms will rapidly return to the ground state,  $E_1$ , keeping the population of  $E_2$  small and reducing the rate of absorption of  $\nu_2$ . In this way the population of  $E_3$  is kept large and that of  $E_2$  remains low, thus establishing a population inversion between  $E_3$  and  $E_2$ . Under these conditions, the absorption coefficient at  $\nu_2$  becomes negative. Light is amplified as it passes through the material, which is now called an “active medium.” The greater the population inversion, the greater the gain.



**Figure D-2: Typical Four-level Transition Scheme**

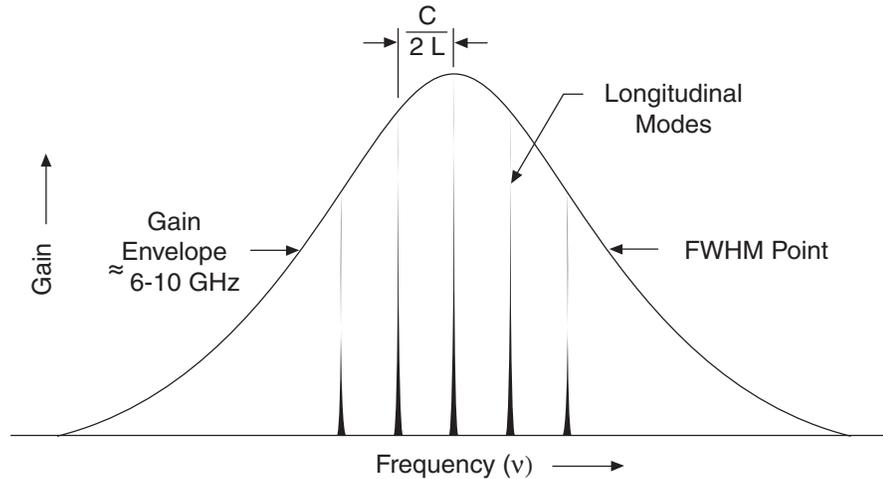
A four-level scheme has a distinct advantage over three-level systems, where  $E_1$  is both the origin of the pumping transition and the terminus of the lasing transition. Over half of the atoms must be pumped from  $E_1$  before an inversion is established in the three-level system.

## Resonant Optical Cavity

To sustain lasing action, the gain medium must be placed in an optical cavity. The latter can be defined by two mirrors which provide feedback to the active medium, i.e., photons emitted parallel to the cavity axis are reflected back into the cavity to interact with other excited states. Stimulated emission produces two photons of equal energy, phase, and direction from each interaction. The two photons become four, four become eight, and the numbers continue to increase geometrically until an equilibrium between excitation and emission is reached.

The laser oscillates within a narrow range of frequencies around the transition frequency. The width of the frequency distribution, the “linewidth,” and its amplitude depend on the gain medium, its temperature, and the magnitude of the population inversion.

Line width is determined by plotting gain as a function of frequency and measuring the width of the curve where the gain has fallen to one half maximum (“full width at half maximum,” or FWHM, Figure D-3).



**Figure D-3: Frequency Distribution of Longitudinal Modes for a Single Line**

The output of the laser is discontinuous within this line profile. A standing wave propagates within the optical cavity, and any frequency that satisfies the resonance condition

$$\nu_m = \frac{mc}{2L} \quad [3]$$

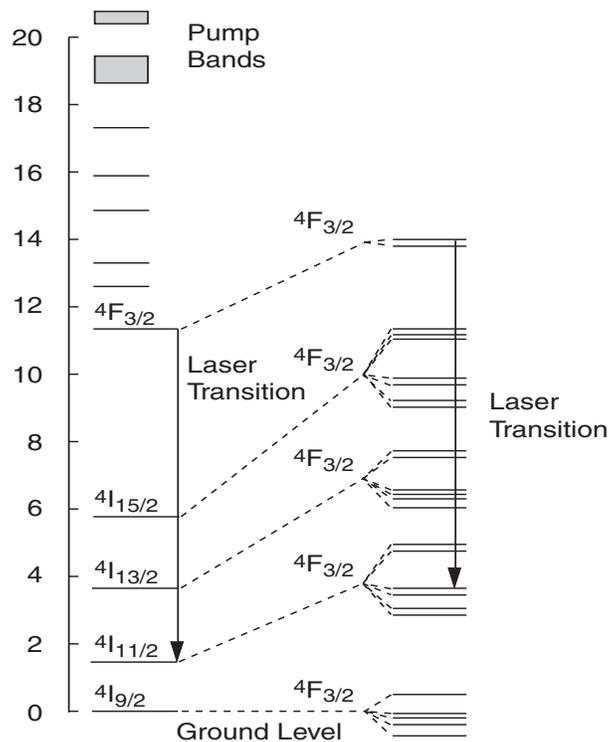
will oscillate, where  $\nu_m$  is the frequency,  $c$  is the speed of light,  $L$  is the optical cavity length, and  $m$  is an integer. Thus, the output of a given line is a set of discrete frequencies, called “longitudinal modes,” that are spaced such that

$$\Delta\nu = \frac{c}{2L} \quad [4]$$

## Nd<sup>3+</sup> as a Laser Medium

In commercial laser designs, the source of excitation energy for the gain medium is usually optical or electrical. The output of one laser can be used to pump another, e.g., a Ti:sapphire laser can be pumped by an argon ion laser or a diode laser can be used to pump a solid state laser. The *Explorer* uses the output from a diode laser to pump Nd<sup>3+</sup> ions doped in a yttrium crystalline matrix (yttrium lithium fluoride, or Nd:YLF).

The properties of neodymium-doped crystals, such as Nd:YLF, are the most widely studied of all solid-state laser media. The four-level Nd<sup>3+</sup> ion scheme is shown in Figure D-4. The active medium is triply ionized neodymium which has principle absorption bands in the red and near infrared. Following some non-optical interaction, excited electrons quickly drop from one of the pump bands into the <sup>4</sup>F<sub>3/2</sub> level, the upper level of the lasing transition. They remain for a comparatively long time (540 μs for Nd:YLF) until stimulated to emit a photon.



**Figure D-4: Energy Level Scheme for the Nd<sup>3+</sup> Ion**

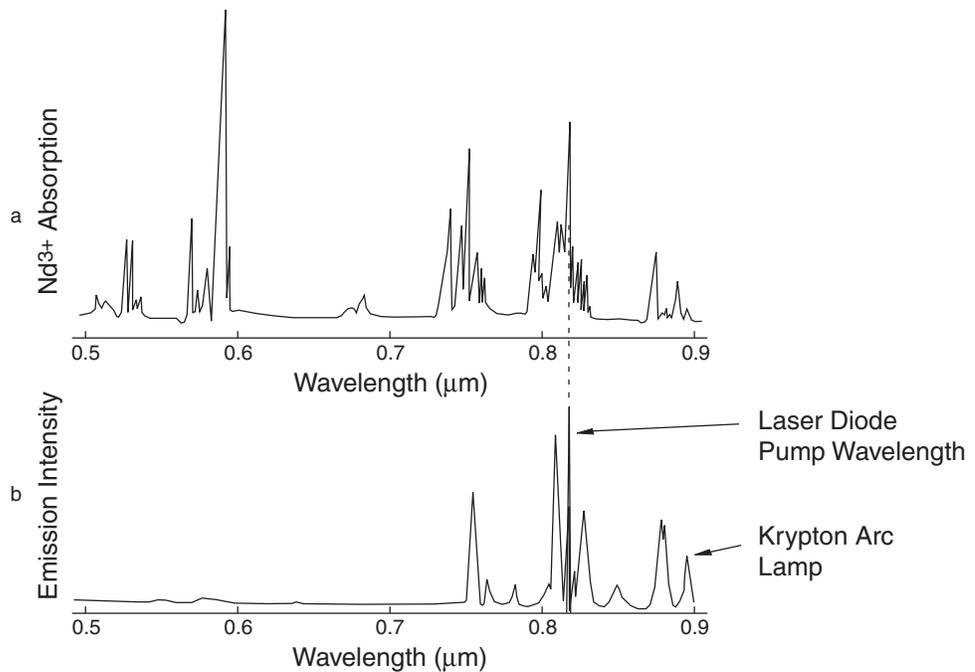
The transition to a lower laser state produces an infrared photon. Because electrons then quickly relax to the ground state, the lower laser state population remains low, making it easy to build a population inversion. The likelihood of stimulated emission for this transition is high, so it takes relatively few photons of the correct wavelength, which are always randomly available, to start the process. There are several competing transitions from the same upper state to the different lower states, resulting in several wavelengths possibly being produced. Wavelength-selective optics are used to limit emission from the laser crystal to the desired wavelength.

Nd:YLF possesses several benefits as a high power, solid state laser material. Its low thermal lensing enables high power operation without the loss of beam quality. Its high thermal conductivity allows for the efficient extraction of heat from the crystal. Its natural birefringence avoids the depolarization problems of isotropic crystals like Nd:YAG which can cause difficulties for harmonic generation. The long upper-state laser lifetime (540  $\mu$ s) of Nd:YLF provides ample energy storage for Q-switching.

While Nd:YLF produces laser emission at several wavelengths, the make strong line at 1047 nm allows frequency tripling to the short ultraviolet at 337 nm.

### Diode-Pumped Laser Design

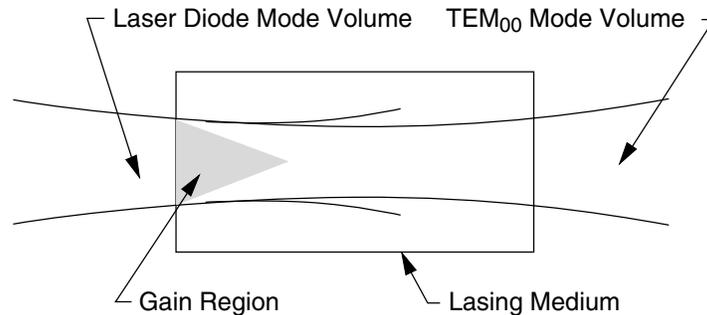
A diode laser combines high brightness, high efficiency, monochromaticity and compact size in an ideal source for pumping solid-state lasers. Figure D-5 shows the emission spectra of a diode laser compared to a krypton arc lamp, and compares that with the absorption spectra of the Nd<sup>3+</sup> ion. The near-perfect overlap of the diode laser output with the absorption band ensures that the pump light is efficiently coupled into the laser crystal. It also reduces thermal loading since any pump light *not* coupled into the medium is ultimately removed as heat.



**Figure D-5: Nd<sup>3+</sup> absorption spectra (a) compared to emission of a Krypton Arc Lamp and a Diode Laser Pump (b).**

One of the key elements in optimizing the efficiency of a solid-state laser is maximizing the overlap of the regions of the active medium excited by the pumping source and the active medium occupied by the laser mode. Maximizing this overlap is called mode matching, and in most applications, TEM<sub>00</sub> is the laser mode that is most desired. A longitudinal pumping geometry provides this optimal mode-matching.

Longitudinal pumping allows the diode laser output to be focused on a volume in the active medium that best matches the radius of the  $TEM_{00}$  mode. In general, the  $TEM_{00}$  mode is focused small as possible to maximize efficiency. Figure D-6 illustrates a mode-matching design of this type.



**Figure D-6: Mode Matching**

For higher output power levels, a larger diode laser having a larger emission region is necessary. The diameter of the  $TEM_{00}$  mode volume must also be expanded to effectively mode-match the volume of the extended diode laser emission region.

Spectra-Physics has developed an efficient method of coupling the output of the diode laser into the laser crystal, where a fiber-optic feeds the diode laser output into a telescopic combination of lenses that optimizes the pump beam for proper mode matching.

## Harmonic Generation

When an intense laser beam strikes a transparent crystal, a new beam may be produced at an integer multiple of the frequency of the incident light (that is, a new beam is produced at a color different from but mathematically related to the color of the input beam). This nonlinear optical effect is referred to both as frequency conversion and as harmonic generation. It is commonly employed to change the infrared output of solid-state lasers into a visible or ultraviolet beam.

Efficient harmonic generation requires power densities not typically available from a CW laser. Since it is the instantaneous power of the fundamental beam that determines how much of the input is converted to the harmonic wavelength, higher conversion efficiency can be achieved by concentrating the laser energy into pulses using techniques such as Q-switching.

Frequency conversion requires that the fundamental and the harmonic light be “phase-matched.” That is, the fundamental and the harmonic waves must remain in phase with each other inside the nonlinear crystal. However since the two wavelengths are substantially different, the fundamental and harmonic beams will experience dispersive effects resulting from different values for the index of refraction in the crystal.

This “wavelength dispersion” will cause the two beams to be quickly *out of phase* in the crystal unless special techniques are employed. These tech-

niques rely on the natural birefringence of the crystals used for frequency conversion. Such crystals possess different refractive indices for different polarization states of the incident light.

Using frequency doubling as an example, the crystal is oriented so that it produces a frequency-doubled beam with a polarization orthogonal to that of the fundamental beam. The doubled beam is the “extraordinary ray,” which has a refractive index that depends on the path it takes through the crystal. The crystal can then be rotated into a position where the refractive indices for the fundamental and the frequency-doubled beams are the same.

So-called “non-critical phase matching” relies on the temperature dependence, rather than the angular dependence, of the refractive index of the extraordinary ray. The crystal is heated to a point where the refractive index for the extraordinary ray equals the index for the ordinary ray. Thus the fundamental and harmonic wavelengths remain in phase. As the name implies, non-critical phase matching is much less sensitive to the alignment of the crystal.

Lithium triborate (LBO) is a nonlinear optical crystal characterized by a relatively high optical damage threshold, a good nonlinear optical coefficient and excellent material properties. The optical qualities of an LBO crystal allow for non-critical phase matching, and its large acceptance angle results in high-efficiency frequency conversion. The crystal is heated and temperature-stabilized to maintain good efficiency.

Second harmonic generation, or frequency doubling, is a nonlinear optical effect that takes place when a large fraction of the intense fundamental beam is converted within a crystal or other nonlinear material to light at half the wavelength (double the frequency). This new light retains the coherent properties of the incident beam but has twice its frequency; for *Explorer* systems, the 1047 nm fundamental infrared beam produced by the Nd:YLF crystal is converted to a new green beam at 524 nm. This green beam is an intermediate stage for producing the ultraviolet output, and it remains confined within the laser head.

The ultraviolet output is the third harmonic of the fundamental, generated by mixing the infrared beam again with the second harmonic beam in a second nonlinear crystal. Nonlinear frequency conversion then results in a new beam in the ultraviolet at 349 nm. (Note: Frequency tripling the fundamental beam to the ultraviolet directly using a single crystal is inefficient due to symmetry considerations that are part of the physics of using nonlinear optical crystals.)

## Acousto-Optic Modulation and Q-Switching

An acousto-optic modulator (AOM) is a block of fused silica that acts as an optical phase grating when vibrated by an ultrasonic wave. The photoelastic effect describes how the strain field produced in the material by the ultrasonic wave changes the optical index of refraction in the block. A standing wave of ultrasound will result in an optical grating that has a period and amplitude set by the acoustic (ultrasonic) wavelength.

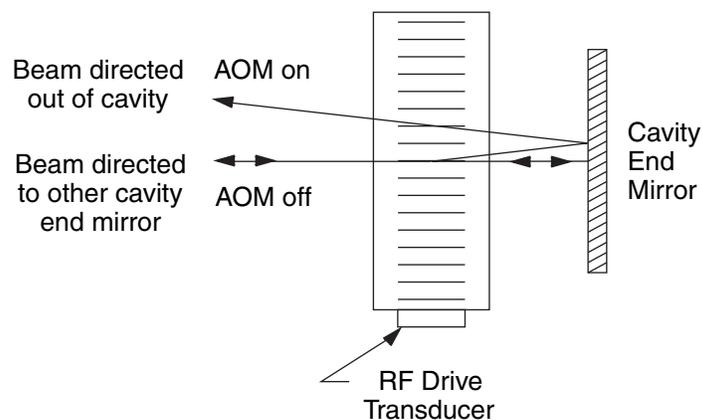
When a light beam is incident upon this grating, a portion of its intensity is diffracted out of the beam. Placing the AOM inside a laser cavity produces a type of light switch that can either allow laser action to proceed, or extinguish laser activity.

By choosing beam parameters properly, any laser beam that attempts to circulate within the resonator experiences a diffraction loss that is sufficient to prevent lasing (i.e., there is no circulating beam). The otherwise low-loss (“high Q”) design of the resonator has been switched to a high-loss (“low Q”) condition.

With no circulating laser light available to pass through the laser gain medium, the pump energy boosts the gain to a much higher level than would otherwise be present. A long lifetime for the upper-state laser level is beneficial to the Q-switch process.

The ultrasonic wave is impressed on the AOM by a piezo-electric transducer. Switching off the driving voltage to the transducer returns the AOM to its passive state of high optical transmission, and the laser resonator is returned to its high Q state. The internal beam is no longer deflected, but instead is amplified by the high gain now available in the laser rod, and a powerful “Q-switched” laser pulse is emitted.

Voltage is then re-applied to the AOM transducer, which again spoils the cavity Q and allows the gain to rebuild to a high level. This process is repeated at the frequency at which pulsed laser output is desired, taking into consideration the characteristics of the laser. The result is a concentration of the otherwise continuous laser beam into pulses of extremely high peak power.

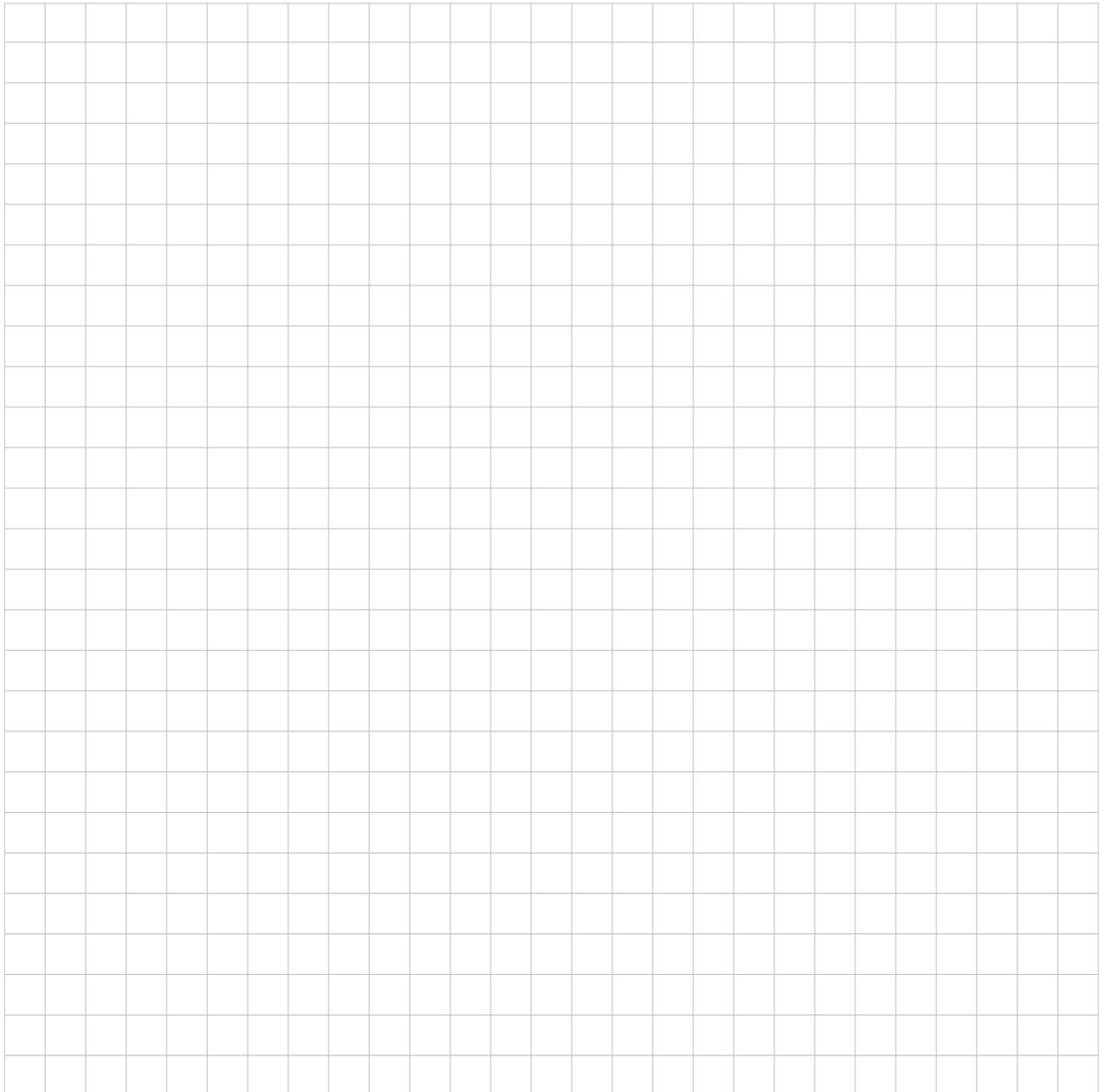


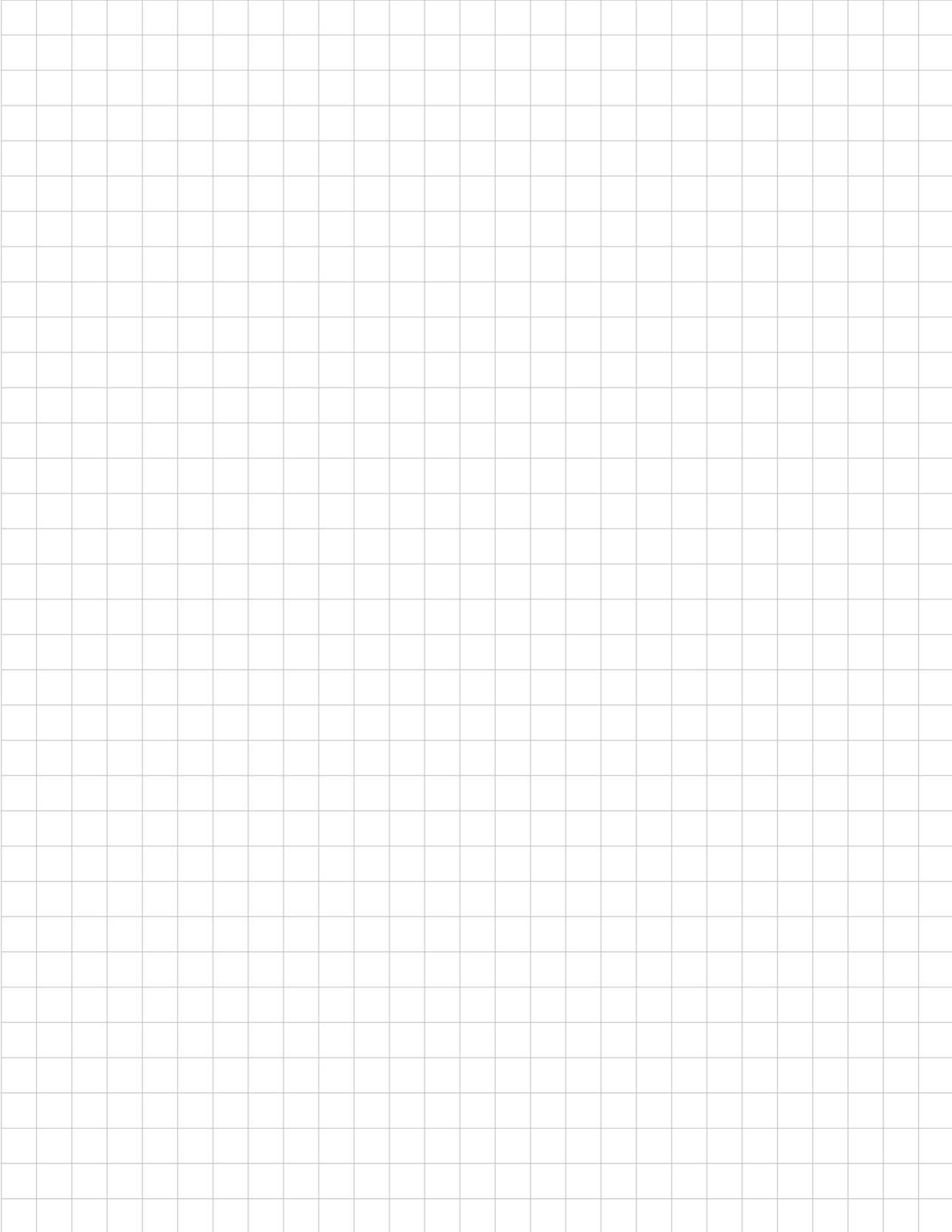
**Figure D-7: An Intracavity Acousto-Optic Modulator**

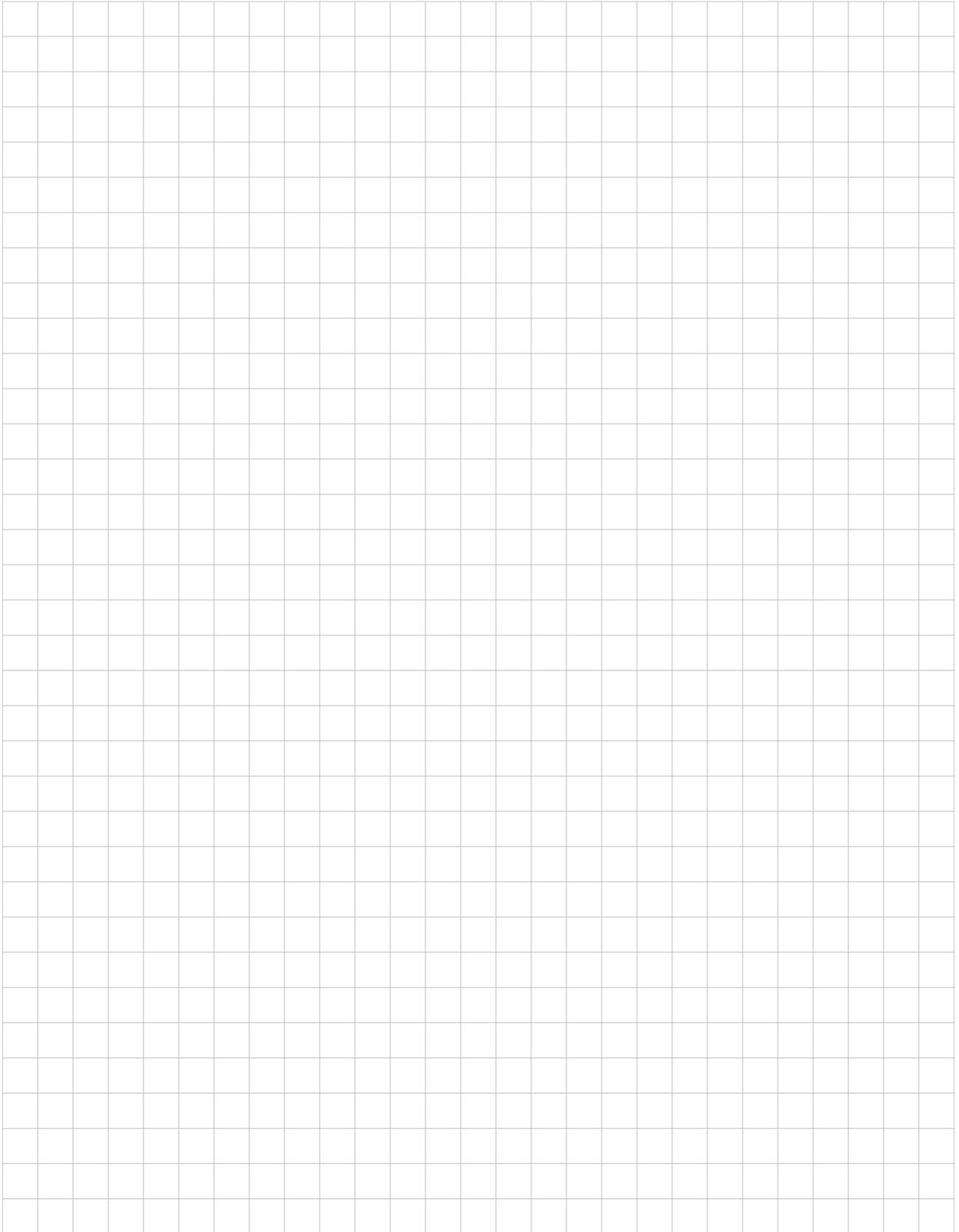


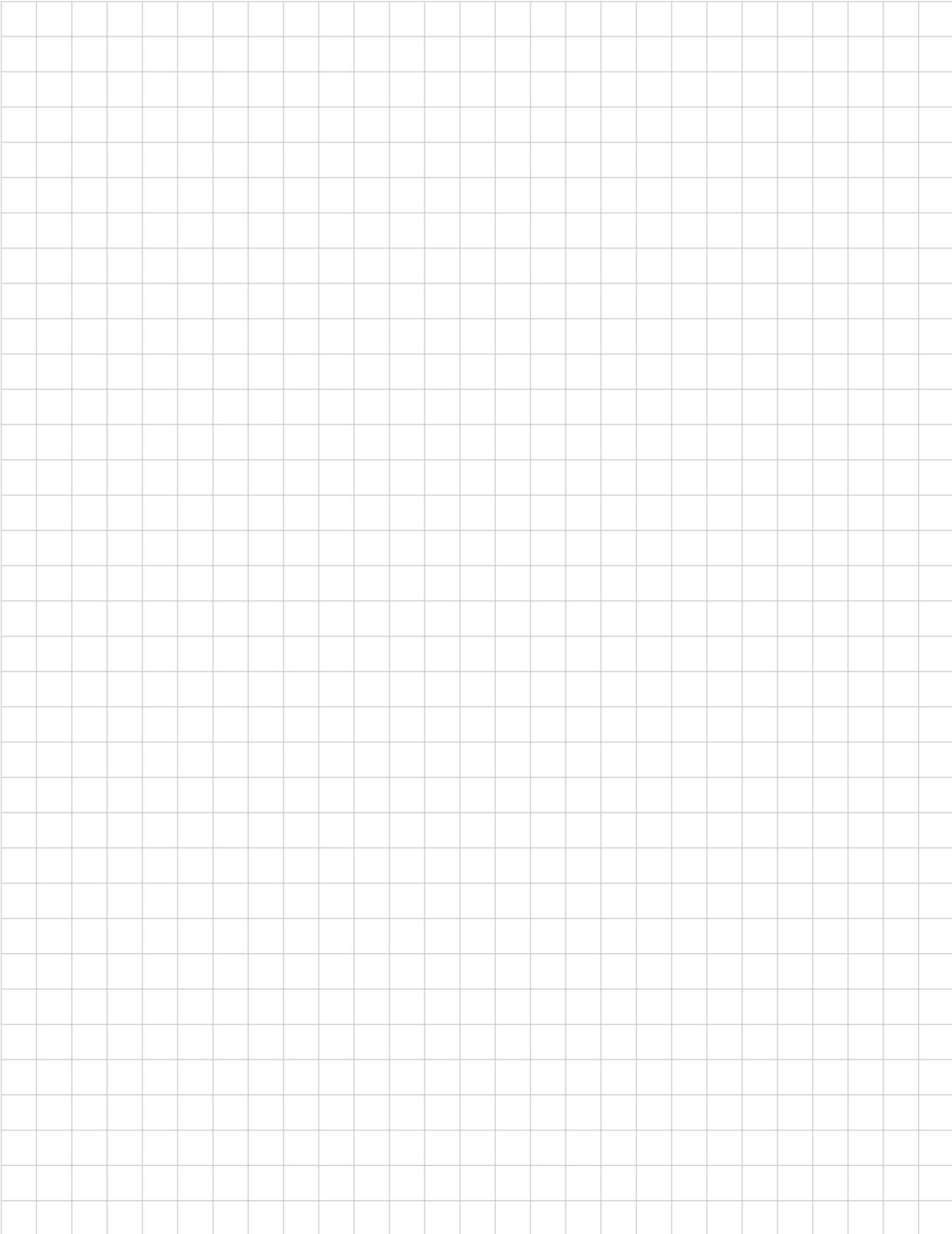
# Notes

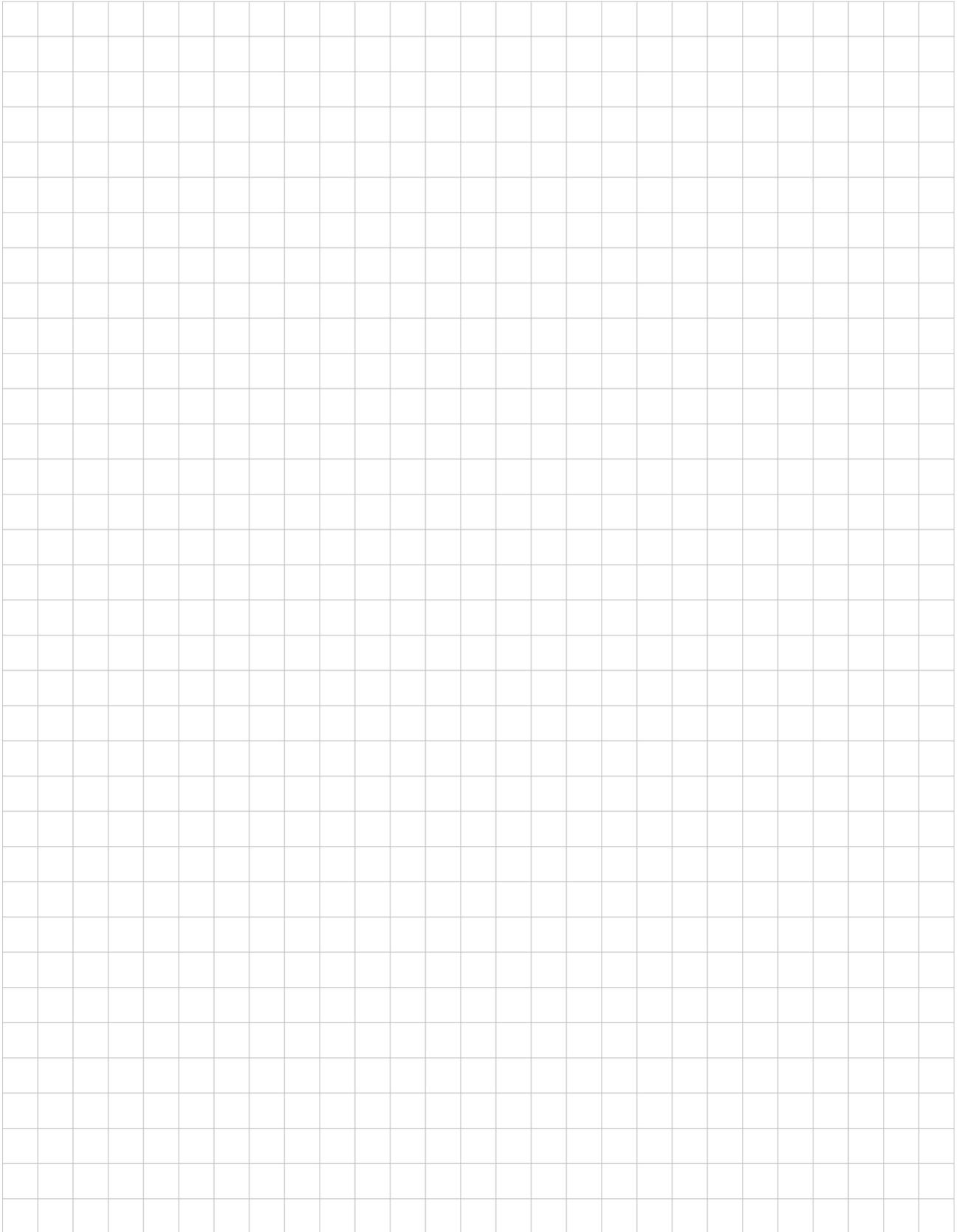
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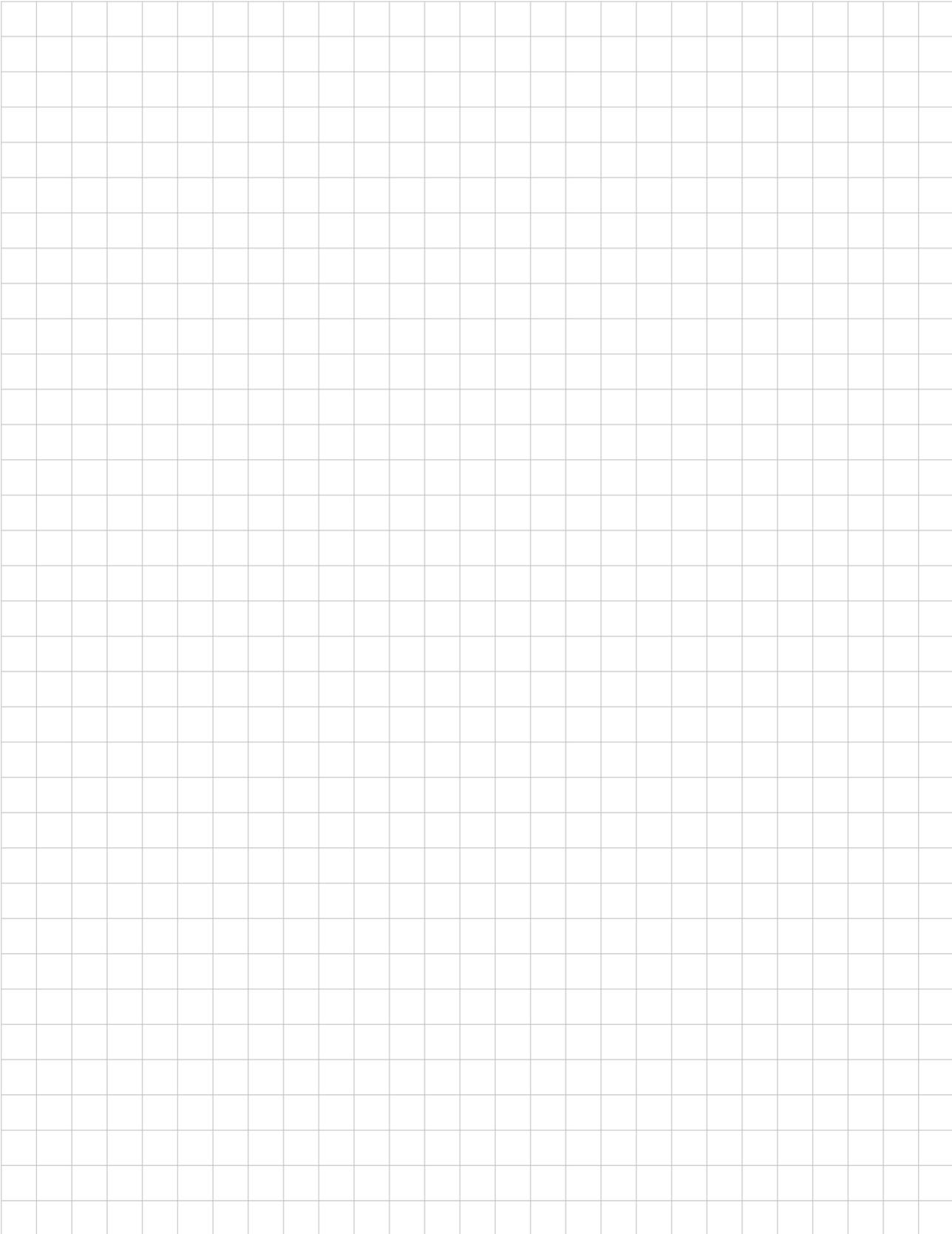












# Report Form for Problems and Solutions

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We have provided this form to encourage you to tell us about any difficulties you have experienced in using your Spectra-Physics instrument or its manual—problems that did not require a formal call or letter to our service department, but that you feel should be remedied. We are always interested in improving our products and manuals, and we appreciate all suggestions.

Thank you.

**From:**

Name \_\_\_\_\_

Company or Institution \_\_\_\_\_

Department \_\_\_\_\_

Address \_\_\_\_\_

Instrument Model Number \_\_\_\_\_ Serial Number \_\_\_\_\_

**Problem:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Suggested Solution(s):** \_\_\_\_\_

\_\_\_\_\_

**Mail To:**

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1330 Terra Bella Avenue, M/S 15-50  
Post Office Box 7013  
Mountain View, CA 94039-7013  
U.S.A.

E-mail: [sales@spectra-physics.com](mailto:sales@spectra-physics.com)  
[www.newport.com/lasers](http://www.newport.com/lasers)

**FAX to:**

Attention: Quality Manager  
(650) 961-7101

